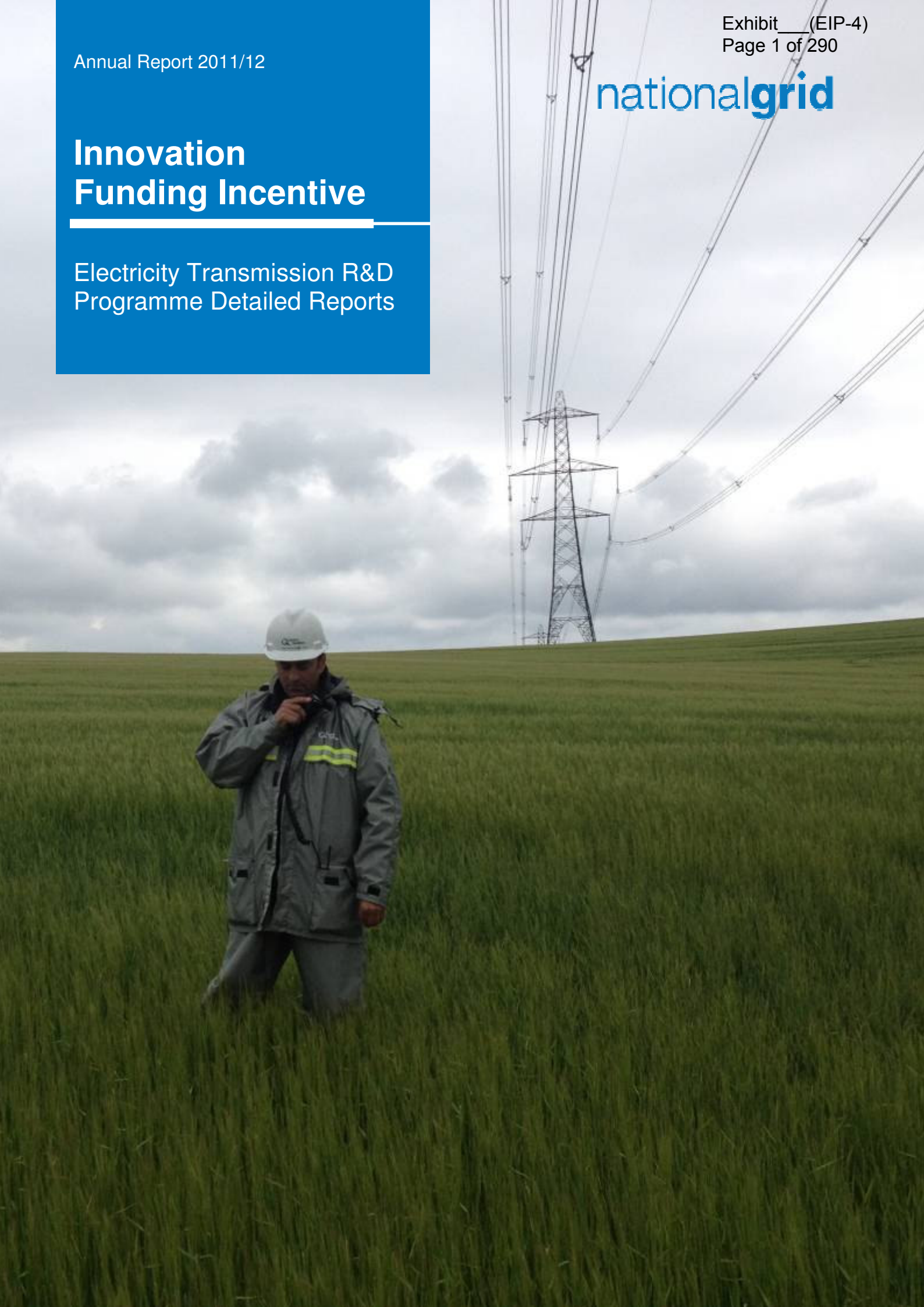
Annual Report 2011/12

Innovation Funding Incentive

Electricity Transmission R&D Programme Detailed Reports



National Grid Electricity Transmission R&D Programme Detailed Report

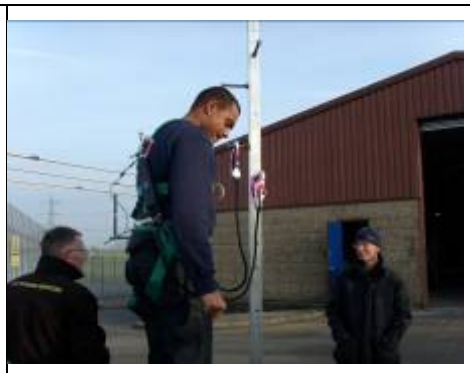
During the financial year, 2011/2012 National Grid Electricity Transmission utilised 99.9% of the Innovation Funding Incentive across a number of programme areas. These programme areas have been reclassified to match National Grids Innovation submission for RIIO the associated projects are indexed below with a detailed progress reports.
Rescind
The report has been structured to mimic the profiling article in the front section of this report.

Contents

Safety

Safe Working Practices

Project title	**Microshock PPE Development**			
Project Engineer	Martin Wilson			
Description of project	The project will aim to further develop the initial work that has been completed by Yasir Ahmed into the microshocks received by linesmen. This project will progress the initial studies to produce a harness and lanyard system that will reduce to an acceptable level or totally remove the microshocks that linesmen experience whilst climbing OHL towers with live adjacent circuits.			
Expenditure for financial year	Internal £8k External £6k **Total £14k**	**Expenditure in previous (IFI) financial years**	Internal £20k External £68k **Total £88k**	
Total project costs (collaborative + external + [company])	£108k	**Projected 2012/13 costs for National Grid**	£0k	
Technological area and/or issue addressed by project	Health and Safety			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		6	-1	7
Expected benefits of project	To produce a harness and lanyard system that will reduce to an acceptable level or totally remove the microshocks that linesmen experience whilst climbing OHL towers with live adjacent circuits. Therefore improving the working environment.			
Expected timescale of project	3 years	**Duration of benefit once achieved**	On going	
Probability of success	75%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£57k	
Potential for achieving expected benefits	Work completed to date would indicate there is a good chance of the expected benefits will be achieved.			

Project progress [Year to End of March 2012]	 2009 – 2010 The theoretical work previously completed has been progressed into physical equipment. A number of controlled trials measuring the effectiveness of the equipment have been completed. To date trials have consistently seen voltages drop from 2.5kv to 200v thus removing microshocks. The final production models for field trials are programmed to be available by end of May 2010. Field trials are then to be completed to enable the effectiveness of the equipment in the work environment to be documented. 2010 – 2011 The field trials were commenced in May 2010. A set of 3 controlled trial days were completed with mixed success due to the conditions on the days. Following these trials a more extensive set of trials were commenced which supplied the equipment to approx 10 OHL teams to use for a period of approximately 6 months. The initial feedback from these trials appears to be positive. A trial closure meeting planned for end of March was cancelled due to the IA issues at that time. The trial closure meeting is now planned for the 20th July at which point the feedback from the trial will be received. Following this meeting a review of the feedback will be completed and will allow the effectiveness of the equipment to be evaluated. 2011 – 2012 Trials where concluded and the feedback received was mainly positive. Results were reviewed by OHL Delivery managers who decided to make the equipment available to order by MDE teams once the harness system becomes available in the Market. UMIP (University of Manchester Intellectual Property) have engaged with P&P and Total Access to agree on the best way the commercial relationship goes forward as the “Microshocks” system consist of the harness (P&P) and lanyard (Total Access). P&P have managed to produce a final version of the harness. However, Total Access yet to perform a number of tests to comply with CE marking standards before the lanyard becomes commercially available. National Grid received a quote for the remaining tests and will shortly instruct Total Access to complete the tests.
Collaborative partners	
R&D provider	Total Access UK, Pammenter & Petrie, The University of Manchester Intellectual Property Limited (UMIP)

Project title	**Development of probabilistic risk assessment procedure for earthing systems**
Project Engineer	Dongsheng Guo
Description of project	Previous involvement with international earthing committees has resulted in the recognition and acceptance of a probabilistic risk based approach to earthing system design and assessment. The confidence gained from National Grid to support this approach was as a direct result of previous research that reviewed local fault levels and fault clearance times against site earth potential rise seen under fault conditions. This project should account for any benefit from supportable historic clearance protection times and actual system fault current magnitudes. Such detail will allow a more precise risk assessment and a relaxation away from worst-case scenarios. In order to gain most benefit from these previous research findings, the future research will focus on four main areas; Effect of fault current level on probabilistic risk assessment around substations. An interface between the National Grid simplified GB transmission system model, implemented on Power Factory, and the probabilistic earthing risk assessment software developed at Cardiff University (CRAFTS) will be developed. This facility will allow the engineer to assess the level of risk at particular problem sites, by quantifying the effect of fault current variation on risk level. This will require procedures to be developed that compute fault current data for given locations taking into account generation ranking order and load level over an annual cycle. CDEGS earthing software interface: Investigating the probabilistic risk for exported potentials and hot zones. Currently, hot zones and exported potentials prediction using CDEGS software provides National Grid with useful information for assessing impact on third parties. The research in this area will enhance this information by also including the associated risk level corresponding to the hot zones and exported potentials mapped for a given substation location. Application of recently updated CENELEC/IEC standards to the developed Cardiff probabilistic software (CRAFTS) The developed Cardiff software (CRAFTS) uses BS7354 as a working standard. Recent developments in UK and Europe have resulted in a new set of standards that will be shortly adopted as UK standards in the form of British Standard European Norms (BSENs). These will be, therefore, adopted by National Grid and other ENA members. It is proposed to adapt the CRAFTS software to include the new standard recommendations which include, inter alia, the revised safety limit threshold values. Investigation of variability of probabilistic risk at different locations within a substation.

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<tr><td></td><td colspan="4"> 

This research will assess whether the currently-used approach of checking the safety voltages at the corner of the substations is the most appropriate method. It is expected that the corners of the substations will have higher probability of higher safety voltage levels compared with other locations in the substations. On the other hand, the presence probability at the corners of the substation is expected to be lower than at the other key-frequented locations within the substation.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £8k
External £113k
Total £121k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £3
External £85
Total £88k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£254k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£45k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The project addresses the issue of safety and risk assessment of earthing systems. It uses a probabilistic risk assessment approach to quantify the risk involved at large substations. The model developed in this project takes into account the detailed configuration of the earthing system and the surrounding area, and it uses historical fault data. The model can be adapted to any set of standard specification and perform the risk assessment accordingly. A friendly software routing is being developed and tested to help engineers implement the model on practical substations.

This will allow aligning practice against recently published safety voltage thresholds and deliver a software tool that will help a) manage National Grid’s risk responsibilities from voltages seen on earth mats within substations under fault conditions and b) manage exported potentials.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>-1</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The four areas above will lead to significant financial benefits due to avoided remedial work on substation earthing systems that would have previously been identified as being of high risk. In 2008 alone three sites were identified where remedial work was not required thus saving between £50k and £100k per site. This procedure will ensure that savings such as this continue to be made routinely in the future.</td></tr>
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Expected timescale of project	3 years	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£154k
Potential for achieving expected benefits	Based upon Cardiff universities previous research in this area, and with the change of standards at IEC/CENELEC levels that recognise Risk Assessments within earthing design and earthing assessments, the likelihood of success is extremely positive. The research assistant is in post and available for use on this project.		
Project progress [Year to End of March 2012]	Over the last year, the software CRAFTS has been updated to include the findings of the original R&D project and changes in the standards at IEC/CENELEC. To date success has been seen in; Building an interface between the Cardiff Risk Assessment for Transmission Systems (CRAFTS) software and the CDEGS earthing analysis software and implement a fault clearance time database. Building a steady-state model of the 400kV/275kV UK transmission system in 'NEPLAN' power system design software and calculate the variation in fault current magnitude and its effect on prediction of individual risk. Undertaking limited case studies with CRAFTS using data provided by National Grid and Scottish Power.		
Collaborative partners			
R&D provider	Cardiff University		

Project title	**High Level Indoor Isolator Access**		
Project Engineer	Dave Turnill		
Description of project	A standardisation of safe working practice and adoption of an interim solution utilising approved methods of accessing both fixed and moving contacts of high level indoor isolators for maintenance activities. An interim solution will reduce the level of exposure to the danger from working at height with the development of a bespoke access podium which can be readily manoeuvred around the existing safe working area. A final solution will remove and replace the current inadequate fixed handrail system and working floor area which has very restrictive access. The final implementation will be an engineering solution that will necessitate that staff maintain safety distances. The solution will have to be a readily applied interlocked safety barrier. When the safety barrier is not in use it can be retracted/withdrawn/removed/lowered to be outside safety distances prior to it being returned to service. It will further reduce the level of exposure of MDE staff to the dangers of working at height. It is envisaged the interim solution will be adopted in the short term and can be developed and finalised in the next 12 months. The long term objective of a final solution to negate the requirement for the interim solutions will take possibly up to 10 year to implement due to system constraints and the restricted access which this allows MDE		
Expenditure for financial year	Internal £14k External £22k **Total £36K**	**Expenditure in previous (IFI) financial years**	Internal £4 External £6 **Total £9**
Total project costs (collaborative + external + [company])	£59k	**Projected 2012/13 costs for National Grid**	£13k
Technological area and/or issue addressed by project	Within National Grid we have 10 substations on the system which are of an indoor design with both main and reserve busbar isolators located above the circuit breakers on the second floor Photo 1. Historically MDE staff has maintained the rotating centre post isolators which have 6 fixed contacts and 6 moving contacts either by accessing from a ladder or climbing the insulator stack with the assistance of a pole strap. These practices have now been outlawed due to legislation changes and policy changes but no replacement method of accessing the equipment to carry out maintenance has been highlighted or developed to allow MDE staff to continue maintaining the asset However in the original design all the 9 insulator stacks were not located within the safe working and hand railed area see photo2 below. The picture is of a Main Bar isolator and it can be seen that both fixed contacts are outside the safe working area. The photograph was taken at Ferrybridge which was the scene of a major incident in the early 1990's. A MDE fitter was accessing the moving contact to carry out maintenance from a ladder stood up against the moving arm of the isolator. Unfortunately the isolator arm moved away and as a consequence he		

<table>
<tr><td></td><td colspan="4">fell on the breaker floor some 8m below severely injuring himself.

Also a near miss at Lister Drive in October 2010 was logged after a hand rail gave way no one was injured but the potential of an incident remain very high.

  

It is proposed to extend the safe working area to encompass all 9 stacks which make up the isolator.

This will however necessities the need to develop a bespoke hand rail mechanism. In Photo 1 there is a need to maintain the physical separation between the MBB Isolator on the right and the RBB isolator on the left.

At this point the hand rail will be required to be a bespoke engineered solution for the following reasons.

1. Maintain the safety distance when in service.
2. Maintain the physical separation between bays.
3. Not interfere with access or reduce the access capability to the adjacent bay
4. Provide adequate fall protection when applied and in position
5. Provide interlocking with isolations and earthing so it cannot be returned to service with the hand rail in its deployed position.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>-4</td><td>13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">This project will provide a package of solutions and systems which are user friendly, very effective and will ensure our MDE maintenance staff have the best working environment to eliminate their exposure to the dangers of working at height. The final removal of this health, safety and restricted access issue will have other benefits such as cost savings gained from none use of scaffold, tower hire and platform hire, it will reduce the amount of time taken to set up and complete the maintenance.
.
It is worth noting that the current annual costs of scaffolding, tower and platform hire will cease once the safe working area and hand rail has been extended to encompass all 9 isolator stacks.</td></tr>
<tr><td>Expected timescale of project</td><td>3 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
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<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£27k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="3">Interim Solution
Having provisionally investigated the interim solution it appears there is nothing on the open market that suitably fulfils our requirements for an access podium to allow ready access to the 9 stacks This project will utilise modern materials to enable a lightweight platform to be designed and manufactured which would be suitable for accessing to the top of the RCP Isolator tower. Initial investigations indicate a very high chance of success with this project.
Final Solutions.
Having provisionally investigated the final solution it appears there is nothing on the open market that suitably fulfils our requirements. There would however be extensive development in guaranteeing the final solution is both suitable and appropriate to MDE’s needs. Initial investigations indicate a high chance of success with this project.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="3">Interim Solution
Bratts Ladders have developed a bespoke podium for accessing the isolator fixed and moving contacts. This has been trialled in the field and following further recommendations resulting form the field trials the design has now been once more modified. The Podiums are currently awaiting suitable outages so they can be field trialled once more.
Final Solution.
Following a successful stage 1 of the Development Plan which was to bring the work area up to current working at height standards. This then led into Stage 2 which was to design, manufacture and install both a collapsible and tilting hand railing systems.
Tilting Collapsible
  
Stage 2 was completed and both systems were installed at Ferrybridge. The installation proved very successful and both the Tilting and Collapsible Hand Railings designed provided a robust and suitable solution. However the complexity of the installation phase was grossly underestimated and as a direct result the installation costs of both systems proved far more expensive than estimated. This has had a knock on effect whereby the unit price of each solution has risen to a level where it has become financially unviable for this solution to be pursued any further unless significant costs can be removed from the manufacturing and installation process.
This development solution will now be parked until a suitable alternative solution can be developed. It is now proposed that the team investigates other ideas in an attempt to provide a more cost effective solution.
The first idea to be investigated will be the concept of installing fully insulated hand railing which will attach to the top of the existing structure and remain</td></tr>
</table>

	permanently in situ. We do however, as a group, need to keep pushing this project in order to come up with a suitable solution which will make the work areas where the isolators reside conform to the requirements of working at height legislation **Interim Solution** Bratts Ladders have provided suitable drawings for a prototype to be built. Preliminary drawings proved unsuitable and were returned with comments. After protracted delays the drawings were accepted. A prototype podium has been built and inspected at Bratts Ladders but it was recommended that further modifications would be required to the Securing/locking device before it will be sent for field trials **Final Solutions.** Retractable Handrail: A meeting is to be set up with Ferrybridge, Precision Engineering and Parkway to discuss access to a spare bay with a view to setting up a test bay area. The Stage 1 Bay Refurbishment at Ferrybridge is now complete. The handrails and flooring have now been replaced. This has been done to provide a safe working area during the construction phase of the retractable handrails We are now awaiting site meeting with Precision Engineering prior to the start of Stage 2. **Before** **During**   **After** 
Collaborative partners	
R&D provider	Planet Platforms, Bratts Ladders, Parkway Sheetmetal

Project title	**Fixed Maintenance Earth (FME) - Development of Handling Techniques and Tools**		
Project Engineer	Dave Turnill		
Description of project	This project has several objectives relating to three issues surrounding the continued use of FMEs by National Grid staff. These are: • To implement and standardise the Manual Handling and Working at Height technique to transport/transfer FMEs from ground level onto high level working gantries. • To further develop a FME Access Platform for FME Maintenance • To further develop an Extended Hand Railing for FME Maintenance. All 3 key objectives are an effort to reduce the manual handling and working at height requirements for MDE substation staff to complete required safety switching & maintenance activities in a manner which will not place unnecessary stresses on their bodies and thus reduce occupational health issues.		
Expenditure for financial year	Internal £11k External £2k **Total £13k**	**Expenditure in previous (IFI) financial years**	Internal £4K External £7k **Total £11k**
Total project costs (collaborative + external + [company])	£24K	**Projected 2012/13 costs for National Grid**	£0K
Technological area and/or issue addressed by project	Historically the Reyrolle FME has always been considered the most onerous and difficult type of Fixed Maintenance Earth to apply. This is due mainly to their inherent design, manual handling and working at height issues surrounding the application of FMEs. The FME is a 3 section portable earthing arm weighing 45kg in total, with 1 set of 3 primary earths being made up of 9 sections in total. Many National Grid substations were designed and constructed in an era where health and safety considerations for maintenance staff were less of a concern than they are today. As a result the location of earthing points can be up to 10m above ground level and the ability to apply and maintain FMEs safely in these conditions is extremely restricted. One of the major issues is transporting the FME sections from ground to the required height before application. Historically the methods utilised to perform this task vary from area to area, most of which no longer conform to current legislation. Some sites have tried to utilise the MEWPs available from Nationwide to lift using home made attachments with limited success. Nationwide now have in their extended range the facility to provide a Sky Rak Boom, though this will require a bespoke fitting to suit our needs specifically. It is intended that this technique will be further developed and trialled to suit National Grid requirements.		

Sky RAK Boom

FME Access Platform

FME Extended Handrail

Another major issue is the maintenance of FMEs at height. This has previously involved utilising a step ladder while already at height. The development and trialling of an access platform and extended handrail system as picture above should reduce the inherent risk of these maintenance activities.

Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		9	-6	15
Expected benefits of project	This project will provide a system which is user friendly, very effective and will ensure we give our MDE maintenance persons the best working environment to eliminate the risk to their health. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries we cause to our staff undertaking their routine duties cannot be underestimated.			
Expected timescale of project	2 year		**Duration of benefit once achieved**	5 year
Probability of success	60%		**Project NPV = (PV benefits – PV costs) x probability of success**	-£20k

Potential for achieving expected benefits	The likelihood of success; Although there is currently nothing on the open market which will fulfil our requirements it is envisaged that there is a high possibility of success with this project if we work in partnership with Nationwide It is expected that the basic design FME Sky Rak Boom lifting device rolled into the provision of single Nationwide MEWP, hence it is also expected that this project will have a high possibility of success. A prototype Access platform and hand rail has been constructed therefore making a MKII model incorporating comments and engineering developments. This would see the project move towards a successful conclusion.
Project progress [Year to End of March 2012]	April 2012 This project has proven very difficult to implement due to the complexity of the solution required on all parts of the project We have however had some success with the SkyRakBoom which has been trialled and is very close to sanction for use with lifting the FMEs. Therefore items 1 & 2 (above) look to be drawing to a successful conclusion. However project 3. a prototype Access Platform and Hand Rail has proved more troublesome with no success due to the limitations imposed on us by the working area and working at height which was underestimated in the original submission. Several prototypes have been designed but implementation on site has been unsuccessful. We are now revisiting the basics with a view to moving the project forward by utilising all that has been successful and redesigning out those which have not. Following meetings at Pentir with ENI, Safety, MDE and Delivery Support Development Engineers in conjunction with The Millward Partnership, it has been confirmed that the original design is unsuitable and an agreed proposal is to be explored with a view to engineering out the short falls of the original design. If we are to achieve our goals this project will have to extended and a Change Control will be submitted. March 2011 - Nationwide FME SkyRak Boom Unfortunately this project has stalled to Nationwide's lack of input into coming up with a prototype design. March 2011 - Prototype Access Platform slow progress has been made on this project due to Bratts Ladders lack of input in producing conceptual drawings. Though we are now awaiting a trial at Wylfa of a MKI prototype staging with integral handrails. MKII Prototype 

	MKI Prototype   The original platform and external handrail concept was not considered a viable option due to the very poor condition of handrails at other substations in the country. It was therefore decide to go for a platform with integral handrails.
Collaborative partners	
R&D provider	Millward Partnership Nationwide Platforms, Bratts Ladders Parkway Sheetmetal.

Project title	**JW420 - developing improved maintenance tools and techniques**		
Project Engineer	Dave Turnill		
Description of project	The aim of this project is to provide as safe a working environment as possible for maintenance activities carried out on JW420 Bulk Oil circuit breakers. The aim is to ensure the improved maintenance tools and techniques are used across MDE by further developing solutions and techniques that have been partially developed and used locally in the past. These include developing the following: • 2 light weight access benches • A light weight rear access working platform connecting the 2 benches to allow 3 side access to the primary contacts • A temporary 1kg step arrangement to allow access to the top damper plug • Temporary flooring for Basic Maintenance • Temporary platforms for major maintenance • Turbulator Manual Handling Device. • Primary contact closing gag.		
Expenditure for financial year	Internal £9k External £3k **Total £13k**	**Expenditure in previous (IFI) financial years**	Internal £6 External £15 **Total £21**
Total project costs (collaborative + external + [company])	£33k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	The JW420 Bulk Oil Circuit Breaker is likely to see a number of years of further service beyond its original design life due to its Anticipated Asset Life being increased from 45 to 55 years by Asset Policy. There are currently 130 JW420 circuit breakers installed on the system. The JW420 design was originally installed in the 1960s and as such was not designed with modern health and safety requirements in mind. If National Grid intends to maximise the life of these assets then ensuring that they can be maintained in the safest way possible is paramount. There are several issues relating to JW420 maintenance that will be addressed by this project. They are detailed below: **JW420 Tank Temporary Flooring Assembly and Working Access Platforms** There are a number of maintenance activities that utilise the installation of a temporary access/flooring within the tanks of the JW 420/421 Bulk Oil Circuit Breakers. Once the CB tanks are emptied of oil then access within the contact tank is required to: Fit the slow closing damper plug which is located in the top of the tank on the mechanism approx 3m from floor level Carry out internal bushing oil samples. The sample point is located in the top of the tank on the mechanism approx 3m from floor level		

Carry out maintenance to the main CB contacts and assembly.

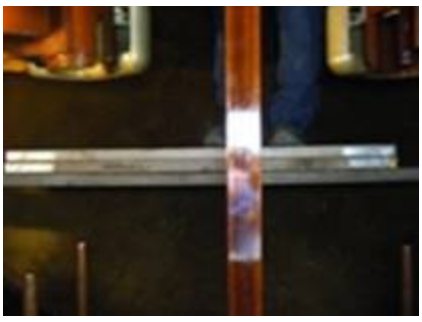
The benches currently being utilised were built and supplied on the original build back in the 1960's. Each bench weighs approx 15kg and each tank takes 2 benches. Each bench has to be manually handled through the 600mm port hole on the side of the tank which can be seen below. This is currently the only bespoke aid supplied to give a working platform within. Each area then devises its own solution to access in to top of the tank to fit the damper plug, many of which are not best practice. Due to the environment within the tank all surfaces are coated in a film of oil and therefore very slippery. In the last picture one team have devised temporary flooring in an effort to reduce risk of a slip hazard.

JW 420 Bulk Oil CB Tanks

600mm Entrance Port hole showing primary contact

Temporary Work Bench showing Flooring

Temporary Access Platform



JW420 Turbulator Handling Device

In the early 90s during extensive system disturbances the JW420 OCB's at Brinsworth cleared many faults. As a consequence all breakers were entered and the primary fixed contact replaced. This involves the removal of 6 Turbulators. Due to a high number of removals the local team developed a manual handling device to assist in the removal of the Turbulators. The original which was developed weighed 12kg; this added to the 53kg of the Turbulator gives a combined weight of 65kg. A new redesigned and rationalised handling device would weigh in at around 3 to 4kg therefore reducing the overall weight down to 56 - 57kg. Future development to reduce the profile and structure has

<table>
<tr><td></td><td colspan="4">also been identified
 
JW420 Spring closing Gag In order to stop the CB opening when it is in the closed position a gag is fitted under the primary contact cradle. The gag prevents the CB from inadvertently opening when men are at work inside the CB.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6</td><td>-5</td><td>11</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Health & Safety - Working at Height, Slips Trips & Falls, Manual Handling– the provision of lightweight benches weight reduced from 15kg to 4kg, provision of a bespoke engineered rear access working platform weighing 8kg, provision of a bespoke engineered temporary flooring, a 1kg step and 4kg Turbulator manual handling device will provide a pieces of equipment which will reduce the effect of working at heights, the effort required for manual handling and reduce the likelihood of slips trips and falls, all these risks will be reduced to an absolute minimum.

The long / short term health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries we cause to our staff undertaking their routine duties cannot be underestimated.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">2 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£27k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The chances of delivering the projects 6 aspects to a satisfactory conclusion are very high.
1. Light weight access benches - High
2. A light weight rear access working platform connecting the 2 benches to allow 3 side access to the primary contacts - High
3. A Temporary 1kg step arrangement to allow access to the top damper plug – High
4. Port hole entrance temporary flooring. - High
5. Turbulator Manual Handling Device. – High
6. Primary contact closing gag – Medium</td></tr>
</table>

Project progress [Year to End of March 2012]	**2011 – 2012** After final minor modifications to the equipment, successful field trials followed to prove this redesign. This part of the project is due imminently for presentation for sanction to Senior MDE Management. A scheme has been raised to provide MDE staff with the device for use in the field. Unfortunately this project has been waiting to be funded for over 12 months due to the cost of implementing the solution throughout MDE, holding this project back from full roll out throughout MDE. **JW420 Turbulator Handling Device** Following final minor modifications to the equipment, field trials were conducted to prove this redesign. These trails were successful. This part of the project is due imminently for presentation for sanction to Senior MDE Management. Following this a scheme will be raised and sets purchased to provide MDE staff with the device for use in the field. **JW420 Spring closing Gag.** This period has seen significant progress in the development of the JW420 Spring Closer Gag associated with this project. The project has moved swiftly with designs moving to prototypes which have then been modified in line with comments from MDE Maintenance Staff made during field trials of the apparatus This part of the project is due imminently for presentation for sanction to Senior MDE Management. Following this a scheme will be raised to provide MDE staff with the device for use in the field. **2010 - 2011** This period has seen significant progress in the development of the benches and staging's associated with this project. The original designs have been modified in line with comments from MDE Maintenance Staff made during field trials of the apparatus. The Benches and stagings have now had 4 field trials and each has proved very successful. There is a potential issue in funding the implementation of the project due to Opex restrictions. The final design has now also been proof load tested to a satisfactory safety margin. This project is now reaching its conclusion.   **JW420 Turbulator Handling Device**. The Turbulator handling device has now been for field trials and proved very successful; compared to its predecessor. This project is now reaching its conclusion

	Before **After**   **JW420 Spring closing Gag.** This spring closer gag for the JW420 as mentioned in the maintenance work specification is an urban myth and will have to be developed from first principles. I am currently seeking a JW420 Trip latch mech to assist in the design of through word of mouth I have managed to locate a spring closer gag for the OW410 this is the 132kV version of the 275kV JW420. Through development of the OW410 spring closer gag a solution can be developed for JW420. This project is still in its infancy. 
Collaborative partners	
R&D provider	Spondon Developments, John Andrews Precision Engineering

<table>
<tr><td>Project title</td><td colspan="3">33Kv Voltage Transformer (VT) Shutter Locking Device</td></tr>
<tr><td>Project Engineer</td><td colspan="3">Dave Turnill</td></tr>
<tr><td>Description of project</td><td colspan="3">The development in the short term of an interim solution utilising an approved method to access and apply a locking device to the VT Shutters for safety switching activities. Reduction in the level of exposure to the danger from working at height.

The interim development of a shutter locking device will immediately reduce MDE's exposure to the dangers of working at height. But only when the final solution is developed will the dangers of working at height be reduced to zero

The development in the long term of a final solution where the VT shutter is modified to provide a locking function at ground level for safety switching activities. It is proposed the final solution will enable the lock to be applied from ground level. As a direct consequence it will reduce to zero the requirement to work above ground level.

The final development of a shutter locking device will take a prolonged time to implement due to the outage constraints the HV system places upon MDE. It is envisaged the final solution will take up to 5 years to implement fully and therefore an interim solution will be necessary to minimise MDE's exposure to the dangers of working at heights.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £3k
External £1k
Total £4k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £3k
External £6k
Total £9k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£13k</td><td>Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">The design of the AEI VSLP15/10 2000A, & VSLP15/15 2500A 33kV OCB has its synchronising VT mounted on top of the switchgear. The height of the OCB and VT is 3m from ground level (photo 1). The VT is racked out from ground level which retracts the VT from the spouts and an interlocked cover then automatically drops to cover the 3 spouts (photo 2)

1 2
  

During operational safety switching an Appointed Person (AP) is instructed to "Isolate & Lock VT Shutters" A lock and caution notice have to be applied to the yellow interlocked shutter to prevent accidental operation and re-energisation of the VT. In carrying out his duties the AP has to gain access onto the top of the</td></tr>
</table>

<table>
<tr><td></td><td colspan="4">switchgear to check the shutter has dropped and then apply the lock and caution notice.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6</td><td>-6</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The Interim Solution project will provide a system which is user friendly, very effective and can be implemented immediately to all OCBs of this type on completion of the development phase. It will ensure we give our MDE Appointed Persons the best working environment to carry out their duties and eliminate the risk to their health and safety by reducing the need to work at height when accessing the VT shutters.

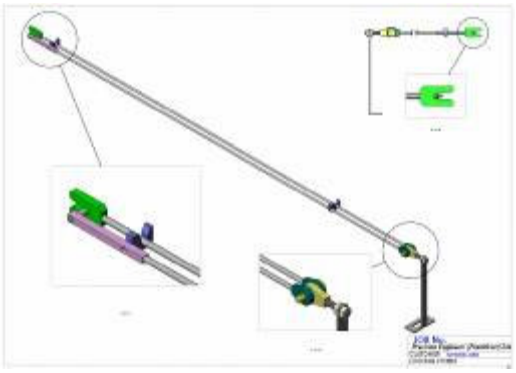
The Final Solution project will provide a system which is user friendly, very effective and will ensure we give our MDE Appointed Persons the best working environment to carry out their duties and eliminate the risk to their health and safety by removing the need to work at height.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">2 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£17k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">It is envisaged that there is a very high possibility of success with this project.

Interim Solution: - Although there is currently nothing on the open market which will fulfil our requirements fully we can utilise a combination of both open market solutions for access to the shutter level which will allow the application of a bespoke solution for the shutter locking device.

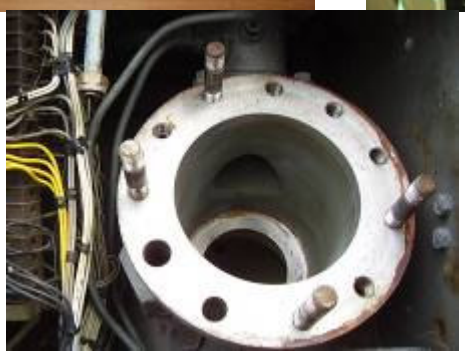
Final Solution: - Although there is currently nothing on the open market which will fulfil our requirements a bespoke solution to extend the shutter locking device to enable ground level locking can be developed and it is envisaged that there is a high possibility of success with this project.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">2011 – 2012, The project was presented for sanction to Senior MDE Management in November and has now been fully approved for use on the system assets. A scheme has been raised and sets purchased to provide MDE staff with the device for use in the field.

This project is now complete, implemented and closed

2010 – 2011, Interim Solution This period has seen very good progress with this project. Several field trials have now been held and the concept has proved very successful over several sites Having designed built and trialled both the access podium and locking device this project is now reaching its conclusion.</td></tr>
</table>

	Access Podium **Locking Device**    **Final solution**, After consultation in the field, whilst carrying out interim field trials, it is now considered not necessary
Collaborative partners	
R&D provider	Parkway Sheetmetal Bratts Ladders

Project title	**OB 14 Blast Valve Lifting Rig**		
Project Engineer	Dave Turnill		
Description of project	The project will deliver a safe method of manual handling the 70kg blast valve and the blast valve cover during its removal for maintenance purposes. The key objective is to safe guard the current workforce, This will be delivered in an effort to reduce the manual handling requirements for MDE Substation staff to complete maintenance activities in a manner which will not place unnecessary stresses on their bodies and thus reduce occupational health issues.		
Expenditure for financial year	Internal £7k External £1k **Total £8k**	**Expenditure in previous (IFI) financial years**	Internal £3k External £5k **Total £7**
Total project costs (collaborative + external + [company])	£15k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	During an outage in November 2009 an MDE maintenance operative sheared off the end of his finger. This unfortunate incident occurred during the routine maintenance of the OB14. In order to carry out the maintenance of the CB the work involves the removal of 3 blast valves, 1 per phase, in order to refurbish the contacts and seals. The CB has to be stripped of various components and a valve cover to expose the blast valve. The blast valve is then extracted by using 2 jacking bolts which lift the blast valve away from its housing (photo3). When you reach the limit of the jacking bolts the valve is manually handled to remove the valve to a barrow to be transported away to a workshop for repair. Once complete the process is reversed and the blast valve replaced in the blast valve housing and the cover replaced. It was during the refitting of the blast valve that the operative had his incident which was attributed to a lack of control on the 70kg blast valve. The proposed development will enable the work to be completed using a bespoke system which will give both excellent control and manual handling capability for completion of the work. Currently MDE staff employs a basic lifting rig (Photo 1) which was developed as direct result of the incident but still has many design flaws. The lifting rig now allows the use of lifting tackle and an A frame (Photo 2). There are currently 34 OB14 CB's on the system predominantly in the London area.		

	  			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		6	-6	12
Expected benefits of project	The project will remove unnecessary and undue stress / strain on MDE staff. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries we cause to our staff undertaking their routine duties cannot be underestimated.			
Expected timescale of project	2 years	**Duration of benefit once achieved**	5 years	
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£11k	
Potential for achieving expected benefits	This project is an addition to and development of an existing piece of equipment which is currently in use and is an incremental development to provide and improve safer / efficient working methods Although there is currently nothing on the open market which will fulfil our requirements it is envisaged that there is a high possibility of success with this project.			
Project progress [Year to End of March 2012]	2011 – 2012 Following final minor modifications to the device and the associated accessories, successful field trials followed to prove this redesign. Following this the project was presented for sanction to Senior MDE Management in November and has now been fully approved for use on the system assets. The device is displayed on the MDE Innovation and SharePoint site and is now available for MDE staff to procure			

This project is now complete, implemented and closed

Proposed Final OB14 Blast Valve Extraction Kit.

Which consists of :-

- 3x Extraction guide rods.
- 2 x 250mm Extraction Bolts
- 1x Blast Valve Lifting Rig

March 2011 - Carried out Modifications with Parkway as highlighted in previous trial, control handle fitted and stainless steel guide rods extended. Final visit to Bradwell required prove all mods now work and finalise latest MkIII prototype.

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Feb 2011 – Returned to Bradwell on 21st March. For trial of MK II prototype, proved successful though minor modifications to be carried out.

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Jan 2011 - Removed from site redundant OB14 Blast valve and taken to Parkway for further assessment and development in line with further site based consult and included 3 stainless steel guides to facilitate the safe controlled removal of the blast valve

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	Original Design 
Collaborative partners	
R&D provider	Parkway Sheetmetal

Project title	**GA ABCB Slow Closing Device**		
Project Engineer	Dave Turnill		
Description of project	The project will deliver a safe method of manual handling the spring loaded CB mechanism which has to be manually opened and closed during maintenance activities. The key objective is to safe guard the current workforce, This will be delivered in an effort to reduce the manual handling requirements for MDE Substation staff to complete maintenance activities in a manner which will not place unnecessary stresses on their bodies and thus reduce occupational health issues.		
Expenditure for financial year	Internal £3k External £1k **Total £4k**	**Expenditure in previous (IFI) financial years**	Internal £3k External £6k **Total £9k**
Total project costs (collaborative + external + [company])	£12k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	During the maintenance of both the GA6 and GA10 ABCB's it is necessary to manually open and close the CB in a controlled manner. Historically since GA6 and GA10 ABCB's were installed on the system in the 1950's the methods utilised by current workforce to slow open and close the CB during maintenance never had any bespoke tools provided by the manufacture to reduce the effect of manual handling. The method employed over the years is to extend a spanner with an extendable pole (Photo 1). This has proved an unsatisfactory solution in the past as the practice has resulted in muscular skeletal injuries. The Pentir team within NW1 have with limited resources been able to develop and manufacture a MKI prototype slow closing device. This solution utilises a torque multiplier in an effort to reduce the manual handling effort required open and close the CB. There are currently 43 GA10's and 19 GA6 ABCB on the system  		

<table>
<tr><td></td><td colspan="4">  </td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6</td><td>-6</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The project will remove unnecessary and undue stress / strain on MDE staff. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries we cause to our staff undertaking their routine duties cannot be underestimated.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">2 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£11k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">Although there is currently nothing on the open market which will fulfil our requirement it is envisaged that there is a high possibility of success with this project.

It is expected that the basic design of the CB slow closing device can be further developed into a successful tool which will assist MDE staff to carry out their maintenance safely, hence it is also expected that this project will have a high possibility of success.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">2011 – 2012

Following final minor modifications to the device and the associated accessories, successful field trials followed to prove this redesign. The implementation project was presented for sanction to Senior MDE Management in November and has now been fully approved for use on the system assets. The device is displayed on the MDE Innovation and SharePoint site and is now available for MDE staff to procure.

This project is now complete, closed and implemented.

2010 – 2011 Precision Engineering has manufactured a bespoke Male to Female adaptor which now conforms to the Tool BS7794:1995. The original adaptor did not conform. This is now ready for field trials along with a ¾” square</td></tr>
</table>

	drive ratchet. This particular drive has the feature of being able to be locked in the engaged position. This has the effect of being able to totally control the breakers isomaker primary contacts during maintenance activities The bespoke Male to Female adaptor and ¾" x 620mm Ratchet drive now on Final trial at Wylfa along with the breaker anchor plate and torque multiplier which makes up the GA ABCB slow closing kit. ENI have been approached and the solution discussed and accepted  It is envisaged this project will be sanctioned in the near future with 100% success
Collaborative partners	
R&D provider	Precision Engineering & Grays Engineering

<table>
<tr><td>Project title</td><td colspan="5">Fault Current Distribution in new type of EHV cables</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Ertugrul Partal</td></tr>
<tr><td>Description of project</td><td colspan="5">To derive and calculated the IGR (ground current return) for faults on XLPE cable. These derivations can then be utilised to calculate cable factor for different XLPE cable. These cable factors are then to be integrated into Digslient to enable fault current calculations to be carried out semi autonomously.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £13k
External £26k
Total £39k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£81k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£43k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Although Oil filled cables have well-established IGR and cable factors are set out in ER S34 (A guide for Assessing the Rise of Earth Potential at Substation Sites), XLPE cables have had no such study conducted on them. It is vital to understand the electrical properties of the cable sheath in returning some of the earth fault current as this is a key factor in the IGR. In order to analyse new types of XLPE cables, it is necessary to calculate cable parameters to a high degree of accuracy by software packages, numerical methods and formulae. This allows the effect of important variables upon ground return current (IGR) to be calculated.

At present time specialist contractors are utilised to calculate the IGR for any cable run. This project aims to codify this knowledge and integrate this into Digslient so IGR for faults can be calculated as a standard procedure.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>7</td><td>-2</td><td colspan="2">9</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">At the current time no XLPE cables are being laid due to the inability to calculate the IGR, this is resulting in a delay for load and non-load related connections. The ability to calculate IGR for XPLE will remove one of the potential delays that a new connection may face.

IGR in XLPE cables accounts for 5% of the workload received by QoS however, a typical single calculation set could take an experienced engineer about 1.5 months once he has obtained all the data. Creating this tool will enable IGR calculations to be completed in a week rather than 1.5 months, in addition a less senior engineer can complete the calculations. This tool should result in a saving of 5 working weeks per calculation. National Grid currently experiences 4 of these per year however this is set to rise.

5 days @ £330 per day x 5 weeks equals a saving of £8,250 per calculation. National Grid is currently experiencing 4 IGR fault calculations per year resulting in a saving of £33k per year.

In addition the project will produce a standardised auditable process for XLPE</td></tr>
</table>

	cable IGR calculations.		
Expected timescale of project	1 year	**Duration of benefit once achieved**	5 year
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£10k
Potential for achieving expected benefits	The likelihood of success of this project is high given the areas of expertise from the chosen supplier. Once these cable factors have been calculated they could have potential impacts on European standards.		
Project progress [Year to End of March 2012]	The final presentation by Prof Benato has been delivered at National Grid House on 27th April 2012. The final report and Matlab tool have also been handed to National Grid. This R&D work has been completed on time (30 April 2012) as agreed. This software tool will be used internally for new types of cables and OHL for 'specific' applications.		
Collaborative partners			
R&D provider	University of Padova-Italy		

Project title	**Exported potentials and profiles around earth electrodes and opposite-side injection for large-area earthing systems**		
Project Engineer	Dongsheng Guo		
Description of project	The project proposal is divided into five areas of investigation; Prediction of ground surface exported potentials and potential fall-off in the vicinity of earth electrodes Previous work has demonstrated that exported potentials can be measured fairly accurately using the developed techniques. It is proposed that these tests are carried out at Dinorwig and at Llanrumney test sites. Investigation into scalability of low-current injection testing Previous tests have shown that there is a current dependence of the measured earth impedance in the range 10mA to 5A. In this project, it is proposed to explore and understand these changes over a wider range of current magnitudes including the high current impulse test. Investigation of non-linear effects of earth impedance at low-current magnitude and associated polarisation These laboratory-based investigations will be focussed on clarifying the observed dependence of earth impedance on current magnitude. In particular, it will explore the physical phenomena involved with this behaviour, e.g. i) polarising effects at the electrode-soil interface and the soil-soil particle interface and ii) other non-linear effects including thermal dependence. Investigation into frequency effects of earth impedance An investigation into the frequency effects in earthing system measurements will be undertaken in the laboratory and in the field, to explore further the variability seen from the previous tests and allow a better understanding of the trends. Modelling of earth electrodes accounting for non-linear effects Comparison of the test results, obtained from the practical tests described in the points above, with computer simulations of the electrodes (CDEGS and physical modelling –Finite element and boundary element) will allow a better model and equivalent circuits of earth electrodes to be developed accounting for the non-linear effects.		
Expenditure for financial year 11/12	Internal £5k External £116k **Total £121k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£201k	**Projected 2012/13 costs for National Grid**	£103k
Technological area and/or issue addressed by	To determine the safety voltages, the extent of hot-zones and exported potentials accurately is crucial in terms of earthing systems design. This will allow developing efficient and reliable mitigation measures. In addition, current testing methods/instruments operate in the range of 10mA to		

<table>
<tr><td>project</td><td colspan="4">5A. Hence, the scalability of the measurement (to high fault current) is yet to be established. Non-linear effects were seen as a function of frequency and current for low magnitudes. Such phenomena will be investigated and the issue of scalability of test results will be addressed. This forms a significant part of this project.

Furthermore, the credibility and accuracy of predictions using simulation software packages has yet to be fully verified experimentally, and this project will address these challenges.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>1</td><td>7</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The following outcomes are expected from the project:
1. Comparison with simulation models will allow refining modelling techniques for such configurations to determine safety voltages and hot zones more accurately in the vicinity of National Grid’s installations.
2. The proposed tests will allow confidence building in the low-current measurement systems currently employed for earth impedance testing at National Grid substations and the subsequent extrapolation utilised to evaluate the prospective safety voltages at system fault levels. In this way, a better estimation will be obtained.
3. This work will enhance the understanding of the results obtained from the field tests and will also allow an insight into the main mechanisms involved with seasonal variation of earthing system performance.
4. The outcome of this work will allow a better extrapolation of the measured values of earth impedance at low current magnitudes to those applicable under real system fault levels.
Such outcomes will further allow:
• Higher confidence in earthing impedance measurements
• Higher confidence and accuracy in the extension of hot-zones, and in turn,
• More accurate determination of substation footprint and need of mitigation investment
• Potential savings: There are approximately 30 sites queried each year in regards to hot zone issues. A more accurate simulation tool would enable savings of £2-3k per site if successful. This project should result in a saving of £30 – 60k per year. Depending on the specific site situations, the saving on mitigation (although may not be NG’s direct responsibility) could be in the range of £100k and also reduce the sites footprint.</td></tr>
<tr><td>Expected timescale of project</td><td>2 years</td><td>Duration of benefit once achieved</td><td colspan="2">5 years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td colspan="2">£8K</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">Potential for achieving benefits is high as Cardiff University have carried out research projects covering some of the above issues with promising preliminary results. Furthermore, they have acquired necessary site facilities and experience. It is more likely that the above challenges will be addressed more</td></tr>
</table>

	efficiently and successfully. Furthermore, previous work carried out by the group at Dinorwig power station will be built on to address the most challenging issues of the research project.
Project progress [Year to End of March 2012]	Due to delays in recruitment, the start date of the main project work was moved to May 2012. However, preliminary work continued with a focus on finalising the previous results and carry out further detailed simulations. Such results allow better preparation for the next wave of tests. The results are now being incorporated in two Journal papers, which are being prepared.
Collaborative partners	
R&D provider	Cardiff University

Project title	**Rapid Deployment Ballistic Screen**		
Project Engineer	Graham Moss		
Description of project	This project is to deliver a cheap, effective and easily deployed ballistic screening module that is easily capable of withstanding the resulting debris from a typical catastrophic failure of porcelain clad HV transmission assets such as those seen in FMJL, FMVGs, SP2 breakers, bushings etc. It will be modular to cope with as small, or as large a deployment screen as required. Fully non-metal, it can be used within a live substation.		
Expenditure for financial year 11/12	Internal £4k External £130k **Total £134k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£184k	**Projected 2012/13 costs for National Grid**	£50k
Technological area and/or issue addressed by project	National Grid in the past has looked at the problem of screening from a very local viewpoint, and tended to rely on screening systems that are not capable of being easily transported, manoeuvred and put into the HV environment without outages, lifting equipment and substantial cost. The screening material under investigation is designed to primarily be completely effective in preventing all fragments of porcelain from a catastrophic failure at a distance of less than 10m. The system is designed to be modular, which means entire walls can be quickly assembled. The materials are to be extremely cost effective, relatively lightweight and will be designed to be easily fabricated to address several roles such as relay room protection, outer perimeter fence guards (for third party protection), window guards, safety 'pathways' through substations, wheeled screens for 'asap' coverage and emergency refuge shelters for those working within the substation, where travelling to a point of exit represents a danger in itself. The materials employed will be able to be 80% recycled (post use) on our substations as trench covers, with the lightweight transparent armour plate being recycled through normal recycling channels. It is thought that only the main stay frame will be the only component that will require disposal or return to the manufacturer. The entire system will be completed from non-conductive components, and assembled by Redman Composites, who currently are building blast protection screens for the enhanced security projects at many London substations. Due to the seriousness of the current situation, preliminary work has begun on the prototype design under the FMJL project budget. This will not cover construction of a full scale prototype and full testing at RADNOR		

<table>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>14</td><td>0</td><td>14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">1. Direct intervention to protect personnel from potential harm when access through risk management hazard zones is absolutely necessary
2. Protection to secondary assets from debris, such as relay rooms, temporary buildings and windows
3. Condition Monitoring systems can assist in providing a warning of a potential failure, but the inception period from notification to failure is unknown.
4. Ability to screen out the RMHZ in order to access assets for maintenance / routines
5. Ability to allow access through RMHZ for emergency repair work to other assets
6. Ability to reduce risk of debris leaving the substation and passing on to third party ground
7. Potential ability to look at safety screening for MEWPs
FMJL CT scheme, addressing failures, is currently costing £1m per year. An estimated 10% reduction in costs can reasonably be expected.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">1 year</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£65k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">Based upon preliminary work into the proposed screens, we are confident of the materials ability to withstand three times the highest energy impacts seen in the controlled disruptive failures conducted by the Royal College or Military Science in mid-2000.
The majority of this work is to focus on the high end testing by RADNOR who specialise in high energy impact physics and the work to turn plates of material into various types of protective screen for a multitude of applications.
Based on these aspects we are confident that the project will be a success.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">During the later months of 2011 and early 2012, the prototype materials and screen designs were appraised. Wind loading studies were conducted on 2 basic screen designs, 4 and 6m high.
Based on personal knowledge of the intrinsic physical properties of glass reinforced plastic (GRP) and monolithic polycarbonate (utilised in bullet proof screens), 4m sections of the defence screening material were taken to RADNOR for ballistic assessment.
Two basic types of laminated material were used. 50mm thick GRP grating (where each square hole of the grating is also 50mm x 50mm) and ‘micromesh’ whereby each 50 x 50mm hole is quartered were plated with 6mm polycarbonate sheeting.
These were attached to the prototype frame that would from the screen.</td></tr>
</table>

	In order to prove realistic fragment velocities, a specialised air cannon was used to fire 1kg mass ceramic masses (taken from actual HV insulating columns) were fired up the range to determine the correct muzzle velocity which delivered a realistic fall pattern as seen from real failures on National Grid sites. Velocities of approx 40m/s gave us a ground contact spread of approx 100m, which has a good safety margin on our 75m exclusion zones. At these velocities, the screens suffer no damage at 10m range. We continued testing with 1kg fragments with the screen able to prevent any penetration of the screen at velocities of 160m/s (approx 350mph) which is far beyond any known fragment velocity from a substation failure. The final test was the use of a 3m OHBR ceramic insulator column. This was secured vertically and loaded with a 22mm tube of high explosive. With the screen at 10m distance, the detonation shredded the column into fragments ranging from 1cm cubed up to pieces weighing over 1kg. The screen suffered no appreciable damage. Fragments were recovered in excess of 100m distance from the test site. The next stage of this work is to produce several variations to send out to MDE for study, feedback and actual safety screening. In parallel, personal lightweight 'tents' and refuge shelters are to be designed and tested. The delivery of screens to MDE for appraisal is expected for no later than September 2012, with testing of the personal screens starting no later than end of October.
Collaborative partners	
R&D provider	Doble PT, RADNOR, Redman Composites

<table>
<tr><td>Project title</td><td colspan="5">NSI5 Earthing Improvements</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Caroline Bradley</td></tr>
<tr><td>Description of project</td><td colspan="5">The Key objective of this project is to deliver an improved safe system of work for the removal of cross bonding and earthing links within cable link boxes and the application of maintenance earth bonds.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £3k
External £13k
Total £16k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£16k</td><td colspan="2">Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">As part of the review of ‘National Safety Instruction 5’, which covers working on cables, it became clear that the current equipment specified for earthing cable sheaths to enable maintenance is impractical and could be significantly improved. These original earths were specified when the link boxes were originally designed but these earths are bulky and difficult to apply. These earth bonds require equipment to be carried to remote locations to facilitate application which can be very heavy. Also as different kits are required for different situations this means multiple items are require to be kept and maintained.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>5</td><td>-7</td><td colspan="2">12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">Develop a one solution for all types of link box to reduce to requirement to carry multiple tools.
Reduce manual handling requirements by utilising new materials and work procedures
Improve safety of Staff by reducing the possibility of bonds being used in error
Improve ability to carry out task by improving the flexibility of the bonds and procedures.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">1 year</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£14k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="5">Areas for improvement have already been identified and the likelihood of success is high.</td></tr>
</table>

Project progress [Year to End of March 2012]	P&B Weir have won the contract to develop NSI5 Link Box earths. They are providing 1st stage earthing kit, contributing towards investigation and review of a revised aluminium cable harness, designing a temporary spring loaded clamp based on NSI11 equipment, creating prototype copper braid interconnecting leads and conducting continuous current and short circuit tests at ERA. The prototypes have been created and are awaiting testing.
Collaborative partners	
R&D provider	P&B Weir

Project title	**Air Receiver Inspection Cover Hinge**		
Project Engineer	Dave Turnill		
Description of project	The project will deliver a safe method of manual handling the elliptical door hatch which provides inspection access to both the Circuit Breaker (CB) Local Air Receiver (LAR) and substation air system Main Air Receivers (MAR). Both designs of air receiver have an elliptical inspection hatch that has to be manually handled to open and remove during routine WSE (Written Scheme of Examination) Inspection and maintenance activities. The key objective is to safeguard the current workforce. This will be delivered in an effort to reduce the manual handling requirements for MDE Substation staff to complete WSE inspection & maintenance activities in a manner which will not place unnecessary stresses on their bodies and thus reduce occupational health issues.		
Expenditure for financial year 11/12	Internal £9k External £21k **Total £30k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£30k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	During the WSE Inspection and maintenance it is necessary to open manually and remove the inspection hatch in a controlled manner. Historically ABCBs and a few specific types of MAR were installed on the system in the 1950s which were designed without an internal hinge. The internal hinge was added on later models to facilitate the safe manual handling of the door. The method utilised by current workforce to open and remove the CB LAR hatch during maintenance never had any bespoke tools provided by the manufacture to reduce the effect of manual handling. The method employed over the years is to extend to an array of locally derived methods, some of which can be seen in the photographs. All these solutions have proved unsatisfactory solutions in the past as the practice has resulted in muscular skeletal injuries. There are currently hundreds of CBs with Local Air Receivers on the system without the internal hinge on the inspection cover and approximately between 75 and 100 MARs which would benefit from the development of the Temp Hinge to assist the manual handling of the inspection cover. The usage is dependant on the Written Scheme of Examination under the Pressure Vessels Regulations. If an Air drier is employed to condition the air. It could be either 13 months for a wet air system or 26 months for a dry air system. Therefore the usage could be annually or bi annually.		

<table>
<tr><td></td><td colspan="4">    </td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>4</td><td>-4</td><td>8</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The project will remove unnecessary and undue stress / strain on MDE staff. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries we cause to our staff undertaking their routine duties cannot be underestimated.</td></tr>
<tr><td>Expected timescale of project</td><td>1 Year</td><td colspan="2">Duration of benefit once achieved</td><td>5 Years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£24k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">Although there is currently nothing on the open market which will fulfil our requirement, it is envisaged that there is a high possibility of success with this project.
It is expected that the basic design of the Air receiver Temp Hinge can be further developed into a successful tool which will assist MDE staff to carry out their maintenance safely, hence it is also expected that this project will have a high possibility of success.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">The Air Receiver Project can be further broken down to
1.Main Air Receiver and
2.Local Air Receiver
The MAR project has made significant progress this year following the design and development of an inspection cover handling device.
This has been extensively tested in the field by MDE staff and has proved very</td></tr>
</table>

	successful following a few minor modifications following recommendations from the field. The use of this device has been approved for use by VELOSI. It is expected the project will be sanctioned an approved for use on the system this fiscal year.  Following in the footsteps of the MAR the Local Air Receiver project is lagging behind and will be developed utilising many of the lessons learned form the MAR device.  A prototype has been designed developed manufactured it will go through extensive trails and development in the field this summer.
Collaborative partners	
R&D provider	Precision Engineering Pontefract

Project title	**Bascules and Safety Gate Accessories**		
Project Engineer	Dave Turnill		
Description of project	This project will deliver: 1. Lightweight Bascule – a lightweight bascule which will allow MDE field Staff to complete the routine maintenance activities when the current bascule is unsuitable. 2. Bascule Safety Gate – a lightweight Earthing Safety Gate designed to be deployed during earthing operations.		
Expenditure for financial year 11/12	Internal £10k External £21k **Total £30k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£30k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	1. Lightweight Bascule – there are a number of maintenance activities that the current bascule, whilst in current use, is not best practice. The access/egress to some of the 132kv Isolators in the Hall type substation is strictly limited and the equipment needs to be carried manually into the bay area and physically deployed The current conductor trolleys weigh between 43kg and 75kg dependant on the manufacturer and the identified deployment of the current bascules have significant manual handling issues. The lightweight bascule will be designed to have a total weight of less than 25kg which will ensure manual handling issues are kept to an absolute minimum. Bascule Earthing Safety Gate – The project will provide the provision of a bespoke lightweight Safety Gate which will be designed for use during maintenance Earthing activities. Currently MDE staff are exposed to the dangers of working at height every time they apply Portable Primary Earths during maintenance activities. On the system there are 17 substation of this design which utilise the deployment of bascules to facilitate maintenance activities. Within each substation there are on average 6 bascules per site dependant on the number of sections. We therefore have approximately over 100 bascules on the system. The bascules are only deployed when we carry out isolator maintenance on the reserve and main bar isolators. The maintenance frequency of an isolator is 3 yearly so dependant on the number of circuits within the sub station they could be utilised between 2 and 4 times per year		

Earthing Safety Gate

Deployed Bascule

Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		6	-3	9
Expected benefits of project	Health & Safety – the provision of a lightweight bascule will provide a piece of equipment which will reduce the manual handling risk to an absolute minimum. This project will provide a system which is user friendly, environmentally friendly, very effective and will ensure we give our Field Staff have the best working environment to eliminate the risk to their health. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries we cause to our staff undertaking their routine duties cannot be underestimated. As well as this equipment being developed for the benefit of National Grid it is anticipated that due to the location of the Hall type subs DNOs will also utilise the bespoke equipment provided. By providing the new light weight bascule with a captivated chain system the inspection regime can be reduced to a pre use inspection reducing the costs of 3rd Party inspections.			
Expected timescale of project	1 Year	**Duration of benefit once achieved**	5 Years	

Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£69k
Potential for achieving expected benefits	Although there is currently nothing on the open market which will fulfil our requirement it is envisaged that there is a very high possibility of success with this project.		
Project progress [Year to End of March 2012]	The Bascule project is subdivided into 2 projects Lightweight Bascules and Bascule Safety Gate Lightweight Bascule This project has made significant progress this year. The new lightweight bascule has been designed developed and manufactured using modern materials and techniques. The development has reduced the weight of the bascule from an original approximate weight of between 43kgs to 75kg, down to 24kg. The lightweight bascule has been trialled on site at Kingsnorth, redeveloped and re-trialled. Following these trials it is now necessary to trial the Bascules extensively in the field this summer to gather feedback from field staff prior to presenting this project for sanction. The Bascule Safety Gate has now moved forward following design and manufacture this is currently being trialled by MDE field staff and following any redesign work which may be required.		
Collaborative partners			
R&D provider	Spondon Engineering, Parkway Sheetmetal		

Project title	**Portable Earthing Trailer**			
Project Engineer	David Turnill / Martin Wilson			
Description of project	A machine to enable the installation / removal of substation portable earths to be completed in a controlled and safe manner. There are serious manual handling issues with installing portable primary earths within substations this machine will look to address these issues by providing a suitable mechanical aid.			
Expenditure for financial year	Internal £21k External £17k **Total £37k**		**Expenditure in previous (IFI) financial years**	Internal £29k External £164k **Total £194k**
Total project costs (collaborative + external + [company])	£384k		**Projected 2012/13 costs for National Grid**	£153k
Technological area and/or issue addressed by project	Health and Safety			
Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		11	-4	15
Expected benefits of project	This will aim to produce a machine which is both easily transportable within the substations and provides a manual aid to enable the portable earths to be both installed and removed in a safe and efficient manner. The main business benefit is both the immediate and long term welfare of the substation staff carrying out the task. In 2009/10 there was a fatality which has been directly attributed to the removal of portable earthing.			
Expected timescale of project	6 years		**Duration of benefit once achieved**	5 Years
Probability of success	60%		**Project NPV = (PV benefits – PV costs) x probability of success**	£170k
Potential for achieving expected benefits	The initial prototype is being designed to enable the concept to be proven. Once the prototype is available and trials are completed a more definite idea of the success and achievement of benefits will be available.			

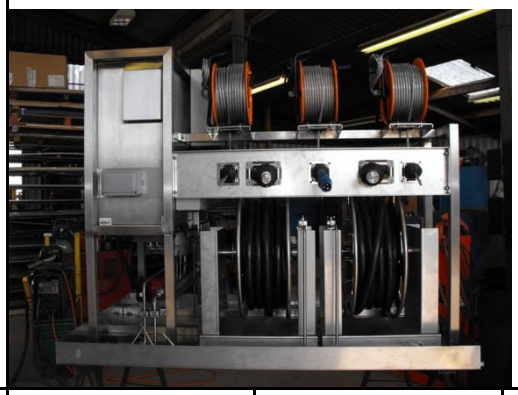
Project progress [Year to End of March 2012]	2011 - 2012 Although the proven concept has not moved forward in the form of a MKII version we have made considerable progress this year with the transition from concept to a fully functional working primary earthing device. Following the approval of the concept from MDE Senior Management and a desire to move the project forward the PET has been demonstrated to a wide audience of field staff in order to gain feedback and come up with a consensus of requirements for a MKII version of the PET. We have now engaged Aldercote who specialise in insulated booms and bespoke mini lifting equipment to assist design and build the project. Aldercote and Gold Consult are now taking all the design comments from the demonstration and are designing a MKII PET The MKI PET has now been trialled extensively on live substations with very positive reports from field staff and suggestions to be incorporated into the future development. 2010 – 2011 The concept trails have been completed and the product has been proven to work successfully. Further work may be needed to assess if the initial build costs can be reduced to build an economically viable production product. The benefits of this project are reduced manual handling and also increased safety due to up to three earths being applied during an earthing procedure. 2009 – 2010 The design of the prototype was progressed. The design was viewed by a number of substation staff with positive feedback. Prototype build initiated, some delays were identified due to concerns regarding the estimated build costs. The initial build is being completed to enable the concept to be proven by field trials, this was understood and the build was re-started. The prototype is expected to be complete by June 2010 at which point the concept trials will be completed. 2007 – 2009 The investigation and evaluation into the possible solutions was completed. A design brief was established and a consultant appointed to progress the design brief to a practical design.
Collaborative partners	
R&D provider	Gold Consult, Aldercote

Reliability

Optimising Asset Management

<table>
<tr><td>Project title</td><td colspan="3">Mobile Transformer Assessment Clinic</td></tr>
<tr><td>Project Engineer</td><td colspan="3">Graham Moss</td></tr>
<tr><td>Description of project</td><td colspan="3">The Mobile Transformer Assessment Clinic (MTAC) is designed to offer a finely engineered solution to the fundamental problem of the need to administer expensive and complex on-line dissolved gas analysis systems to oil filled transmission assets that are exhibiting divergence from ideal behaviour.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £3k
External £99k
Total £102k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £8k
External £173k
Total £181k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£284k</td><td>Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">Currently, on-line DGA systems are a ‘fixed’ solution, whereby to install an instrument which will take a measurement of the dissolved diagnostic gas profile from a transformer on an hourly basis. Typically this installation totals approximately £26k and takes a team of 3-4 engineers 2 days to complete.

In many situations this is not possible. For reasons of health and safety, system stability and security, there may be restrictions on working time within the locale of the asset, reducing contact time per person to 2hrs per 14 days. This means that without outage, we cannot install these instruments. Also, in many instances, there is simply not enough evidence to support the expenditure of a fixed instrument.

In order to overcome both these fundamental problems, the mobile system has been designed to allow full on-line DGA monitoring to be brought to site and connected (if required) within a 2hr timeframe. More over, the system is completely trailer-based, allowing for complete freedom of transport.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>15</td><td>-2</td><td>17</td></tr>
</table>

Expected benefits of project	Once tested and found to be functional in all aspects of it's design, it is expected each unit will be deployed to at least 4 separate assets each per year, saving the cost of a fixed asset installation each time (£26k). More importantly, they will give us the ability both financially and technically, to administer high resolution, high cost on-line DGA monitoring to any asset on the system without having to raise funding to do so. The cost of deployment of the MTAC system to any asset in the UK is typically going to be £2k		
Expected timescale of project	5 years	**Duration of benefit once achieved**	5 Years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£1k
Potential for achieving expected benefits	The probability of achieving the expected benefits stated is exceptionally high. The design and functional specification of the deployment solution has been meticulously researched and built up by vast field experience of the last 3 years of actual physical installation of some 24 fixed DGA systems. This experience has led us to a solution that will be able to rise to the challenges that it was designed to overcome. Grahame Barker (Doble Power-Test Engineer in charge of Project Delivery) has an unsurpassed knowledge and working experience of these issues and the problems surrounding the successful deployment of a mobile oil-handling unit for use on HV transmission assets.		
Project progress [Year to End of March 2012]	Both MTAC units have now been in service for over 2 years and have served more than 10 separate investigative and risk management assignments. During 2011 MTAC-3 (officially designated TARDIS-1 was bought by Asset Engineering to increase our capability from these important units. All three are in constant use. During this year, a new analyser (MTE Hydrocal 1008) has been investigated as an alternative for the large and heavy Transfix unit that currently serves the MTAC. Funding is required to build a manifold and oil pumping system for the unit to enable it to be built into a much smaller MTAC design. Labelled as Micro-MTAC, this will be able to be built into a deployment case the size of a large suitcase. Being much smaller means a trailer will not be required and emergency postage via courier will be possible. Based on current prices, the new system should be less than ½ the current MTAC price. Design work has been started in basic form on the manifold and it is expected to have (with funding) a prototype model by the end of 2012		

	
Collaborative partners	
R&D provider	Doble PowerTest LTD, Invisible systems

<table>
<tr><td>Project title</td><td colspan="4">OHL Data Collection (Original Title – Data Visualisation)</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Matthey Grey</td></tr>
<tr><td>Description of project</td><td colspan="4">The feasibility study will asses whether a map platform (initially google earth) will provide a suitable tool for consolidating all Overhead line condition and asset information data in a way, which allows for easy access in a geographical format. It will also looks at the potential to layer real time information feeds that are available (e.g. met office, environment agency information), over the geographical map lay out. The study will initially focus on one OHL route, however this will have the scope to be extended nationally and for use by Substations, L&D etc., providing a platform for other information including live feeds etc.

The study has produced a positive outcome and we are now moving onto the next stage of development.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td>Internal £8k
External £63k
Total £71k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£182k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£111k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">OHL has a number of information sources relating to assets, and their condition, ranging from actual asset information, condition assessments, foot patrols, helivisuals, Schwem, Cormon and conductor sampling. This is all held in different file locations and different databases, making it difficult to efficiently access all ranges of information regarding a particular asset or route.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>12</td><td>-2</td><td>14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">With the advent of the SAM platform and a need for the business to have access to accurate real time data, we want to expand on the concept that has been proved and produce a working model using a suitable mobile device, mapping system and secure communication link connecting the mobile device to the data base platform.

In addition to the above a further benefit would arise concerning the annual foot patrols undertaken by OHL operatives. OHL inspect and report on the visible condition of approx’ 15000 towers per annum. Presently the information is gathered via a script loaded on a PDA device and consists of 200+ questions which are repeated on each tower. There is a considerable delay period between collection of the data and limited visibility to the business. With a Mobile device linked to a live database the field operative would arrive at a tower, verify the tower location by GPS, followed by a download from the Database of the last known asset data for that tower. The operative would then report by exception to the known data, after which he would return the up to date information which, after verification, would lead to a database update in real time</td></tr>
</table>

	Other benefits that this new system will bring are :- Display information for any given tower and both associated spans (i.e. both high & low side) – where as at present it only shows 1 tower and 1 span. Ability to display, for any given span, asset condition on both circuits at the same time – currently the existing system only displays 1 circuit at a time. Resulting in the linesmen having to complete all questions for 1 circuit before completing questions for the other circuit, even though the linesman is walking alongside both circuits at the same time. Have the function to take a picture of any asset condition and send this to an OHL delivery Engineer i.e. significant conductor damage, ACD damage, insulator failures etc.		
Expected timescale of project	4 years	**Duration of benefit once achieved**	5 years
Probability of success	80%	**Project NPV = (PV benefits – PV costs) x probability of success**	£255k
Potential for achieving expected benefits	On target to complete the proof of concept and device selection during the summer of 2012. The next stage during 2012 will be to use the device and the software database on an actual foot patrol.		
Project progress [Year to End of March 2012]	During 2011/12 the project has redesigned and developed a new OHL asset condition database and established a series of new foot patrol scripts that will be placed onto the new handheld device. We are in the process of producing a database which will, on completion, hold all asset condition data on individual towers and spans. Using this data we have successfully proved the concept of overlaying this data onto a mapping platform. We want to investigate the possibility of aligning this database to the "S.A.M." platform which would allow real time interaction between this asset database and the operative in the field. Suitable devices have also been established to use on the final proof of concept field trial. We have been looking into how we collect and capture data. We are investigating the possibilities of moving to a tablet device with GPS capability. This would allow the use of real time mapping to match assets to data. We are in the position to advance this activity to a proof of concept stage which would involve the identification of a suitable device, the time of IT personnel to design a working solution and to complete field trials on an OHL route.		
Collaborative partners			
R&D provider	C3 Global		

Project title	**Magnetic Models for Transformers Transformer Core Modelling**			
Project Engineer	Paul Jarman			
Description of project	The project will deliver tools to analyse what happens to plant with a magnetic circuit when that circuit starts to become saturated because of extreme operating conditions. Examples of this are transformers under ferroresonant conditions, transformers subject to DC currents such as during geomagnetic (GIC or sun storm) events, series reactors under fault conditions and quadrature boosters under high load conditions Failure to properly analyse these conditions leads either to excessive capital cost in increasing core dimensions, or potential failure in service due to the heating of the magnetic circuit and other steel parts in the transformer or reactor.			
Expenditure for financial year	Internal £5k External £16k **Total £21k**		**Expenditure in previous (IFI) financial years**	Internal £11k External £90k **Total £101k**
Total project costs (collaborative + external + [company])	£221k		**Projected 2012/13 costs for national Grid**	£0k
Technological area and/or issue addressed by project	Optimum transformer design and operation within capability to prevent damage.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		11	-4	15
Expected benefits of project	The knowledge generated by this project will improve the modelling of ferroresonance, GIC and Quadrature Booster operation which will help to formulate designs, specifications and policy to mitigate these problems at minimum cost. Improved industry knowledge in this area should also improve designs and help to reduce unexpected operational problems as over fluxing phenomena are not usually tested in the factory. QBs cost approximately £10M and core saturation needs to be modelled in order to optimise their use and avoid failure. One of the most important operating parameters is the point at which the core saturates when the QB is acting to reduce power flow, this parameter is used to set the QB control system which limits tap-changing and therefore utilisation to avoid failure under these conditions. Better knowledge of the core saturation phenomenon will allow the settings to be optimised. Operational savings in increased utilisation are likely but are difficult to estimate, but a QB failure would be very expensive. Reducing the risk of QB failure by 1% will reduced the potential cost of failure over the QB fleet by about £20k per year, similar savings could be expected for increased utilisation. The need for mitigation measures against ferroresonance partly depends on what damage to transformers may be expected, the project should generate this			

	knowledge and potentially lead to savings of £100k per annum in reduced capital expenditure (where a ferroresonance scheme can be shown not to be required) or avoided failure (if a scheme is shown to be needed). Better knowledge of how series reactor impedance varies with current up to the short circuit current will lead to better calculation of fault levels, the benefit from this is hard to quantify but could avoid uprating of switchgear in certain instances. Better knowledge of the effect of GIC on transformers which caused two transformer failures in 1989 depends on understanding core saturation. The next GIC activity maximum is expected around 2013, refining operational guidance based on new knowledge could possibly reduce the risk of failure. Reducing the risk of one transformer failure in 2012 by 10% could save £200k in replacement costs alone, consequential costs of such a failure could be higher. Transformer capital costs are significantly influenced by the size of the core required to avoid saturation under certain system conditions, particularly high voltages on the lower voltage windings which might be experienced when local renewable generation is being back-fed into the HV system. Better understanding the limits can avoid over-specification or potential failure. A 1% reduction in the capital cost of transformers represents a saving of around £400k per year. The project will retain a useful modelling capability at Manchester that has been established during the course of the ferroresonance project and has been used directly by National Grid in failure investigations and capital project evaluation. This resource is not presently available elsewhere.		
Expected timescale of project	3 years	**Duration of benefit once achieved**	5 years
Probability of success	60 %	**Project NPV = (PV benefits – PV costs) x probability of success**	£7k
Potential for achieving expected benefits	The modelling capability at Manchester and the understanding of transformer magnetic phenomenon has already been used in a study of a voltage dip caused by transformer inrush. The potential for achieving further benefits are good. With an increased emphasis on understanding the impact of solar storms and other DC phenomena on transformers the knowledge gained under this project has become even more important.		
Project progress [Year to End of March 2012]	The modelling of the response of a transformer to DC currents in the neutral using conventional power system analysis tools has had some success and has broadly replicated previous work undertaken by National Grid using now obsolete software. Understanding the magnetic behaviour of steel at high levels of flux density, critical to the project has proven, as expected, to be difficult. A collaboration with the Magnetics Centre at Cardiff University has been started to further this understanding since very little existing work has been carried out in this area. Some interesting practical results have been obtained and the experimental technique has been developed but further work is required. It is likely that the pressing need for good models that can predict the effect of GIC will require additional resource to complete this aspect of the project quickly.		
Collaborative partners	Areva transformers and T&D are expected to resume funding a parallel linked project to improve their modelling techniques.		
R&D provider	Manchester University		

Project title	**Development of Multi response Stockbridge Damper at 400kV**			
Project Engineer	Dave Bedford / Martin Wilson			
Description of project	Meet all requirements of TS 3.4.7 on Zebra and Araucaria conductors Design attributes to ensure approval for future high temperature conductors More conductor friendly than current designs, expected to reduce damage and mechanical stresses at attachment points Improved damping efficiency - multi response as opposed to current twin response for increased conductor life.			
Expenditure for financial year	Internal £14k External £1k **Total £15k**		**Expenditure in previous (IFI) financial years**	Internal £12k External £67k **Total £79k**
Total project costs (collaborative + external + [company])	£94k		**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	National Grid currently uses a range of twin response dampers with bolted clamp attachment based upon optimum performance based on corona performance and mid range damping qualities. These generic designs are between 20 & 30 years old, with the improvements in analytical design tools National Grid are seeking to develop a damper that has acceptable corona performance at 400kV, increased reliability of attachment points, minimised conductor damage & improved damping efficiency.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		9	-2	11
Expected benefits of project	Reduced number of instances of inner layer damage caused by aeolian vibration, - therefore offering an extended life for conductors. Reduction of damages to outer layers of alloy conductors, minimising the risk of conductor failures. The recent ZPA conductor failure cost in the region of £24k to recover not including constraint costs. Removal of installation errors, impossible to over torque and can be reapplied more times than current guidance suggests for bolted attachments. Compatible with AGS / HSU applications.			
Expected timescale of project	4 years		**Duration of benefit once achieved**	5 Years
Probability of success	60 %		**Project NPV = (PV benefits – PV costs) x probability of success**	-£157k

Potential for achieving expected benefits	The supplier has already proved a number of the different concepts in various products in use in other parts of the world. The largest threat to the project is corona performance of the unit, It is anticipated that the joint knowledge of PLP & National Grid's experience of corona testing this can be overcome. The potential for success of this project is deemed to be good
Project progress [Year to End of March 2012]	March 2011 This project has reached the first milestone with Conceptual Design – Design Drawings & Proof of Concept all being completed. The required testing has been completed and the project has progressed to the stage where a line trial is to be completed to enable the effectiveness of the proposed solution to be verified. A trial location has been identified and the trials are planned to be completed between July & September 2011. A set of Vibrec monitors are being installed to benchmark the current solution before the new dampers are installed following which a further period of monitoring is to be completed. March 2012 update A line trial was conducted to ensure the solution developed actually provides the expected performance when installed on an actual OHL circuit. The trial required a period of vibration monitoring (approx 3 weeks) with the existing damper arrangements to establish a base line of the damper performance. Following this initial vibration study the data was downloaded and a set of the new dampers were installed. This was followed by a second period of vibration monitoring (6 weeks). At the end of the second study the vibration monitors was removed and the 2 sets of data where compared. Some issues with the monitors have been identified and therefore further monitoring was necessary to compensate the lost data. Following the completion of site trials the information downloaded from the Vibrec monitors will be analysed and the effectiveness of the new dampers can be determined. PLP have produced a draft report documenting the work undertaken to date with plans for work completion by April 2012.
Collaborative partners	N/A
R&D provider	Preformed Line Products GB

<table>
<tr><td>Project title</td><td colspan="4">Further Development of PFT in Service Cable Oil Leak Location Technique</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Mike Fairhurst</td></tr>
<tr><td>Description of project</td><td colspan="4">Goal – To provide National Grid with a leak free system oil filled cable system and to inject preventatively all transmission cables with PFT tagged fluid.

PFT in service leak location technique, employing Perfluorocarbon tracer (PFT) to “tag” the cable oil. has now been adopted as the main tool in oil leak location which has seen a significant step change in the way in which NG responds to oil leaks with improvement to the speed and accuracy of leak location combined with the sensitivity to locate low rate oil leaks, that in the past have been difficult if not impossible to locate with previous techniques, as a result major reduction in outage times to effect repairs (65%) are now being achieved.

Phase 1 & 2 of the original project proved the technique could be used on both 132 & 275kV cables without any detrimental effect to the long term performance of the cable and accessories.

Phase 3 of the project is further develop the technique for use at 400kV and to also reduce outage time by introducing the PFT in to the cable while the cable remains in service, without the need for an outage.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £10k
External £1k
Total £11k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £15k
External £203k
Total £219k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£245k</td><td colspan="2">Projected 2012/13 costs for National Grid</td><td>£15k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">High Voltage oil filled cables – Non intrusive cable oil leak detection with the cable in service.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>14</td><td>0</td><td>14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Reduction in costs and resources associated with cable oil leak location with potential to give an accuracy of within 2 metres on all cable voltage ranges. In 2003/04, 9 cable oil leaks required freezes for leak location, the cost of this work varied between £360k and £720k per leak location. Historically on average, National Grid spent £500k per year on cable oil freezes. Assuming PFT location reduces the requirement to freeze by 50%, this would realise a saving of £250k per year or £1.25 million over a 5 year period.

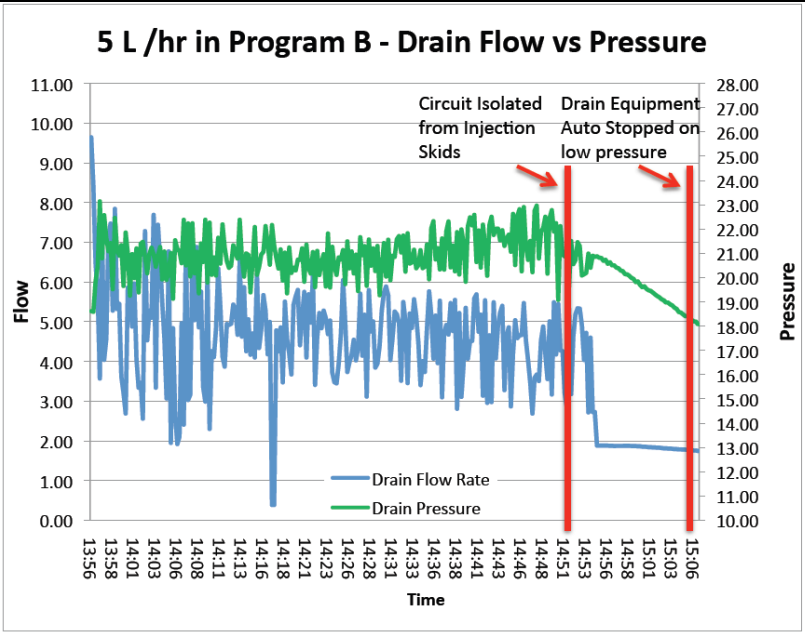
Following the completion of Stages 1 & 2 a three year contract was let to tag and locate leaks on 20 275 kV cables; contact value £2.3 million or £776k per year. To date 124 cable sections have been tagged, 42 leaks have been located and repaired, without the need to excavate and freeze for location, thus reducing</td></tr>
</table>

	repair costs by some £2 million over the last 2 years since contracts were placed. In addition outage and repair times have reduced by 66% this directly affects the oil loss with regard to moderate and low leaks as the volumes being lost has seen a significant reduction when compared with previous years. Phase 3 of the project will enable National Grid to extent the benefits on to the 400kV network and in addition improve the flexibility of the tagging process across voltage ranges by enabling the procedure to be carried out without the need for an outage. In summary, potential benefits are : • Improved response times for leak location hence overall repair time • Reduced oil loss resulting from improved response time • Reduced outage times and hence improved circuit availability. Improved response to cable oil leaks is an integral part of driving forward improvements in environmental performance and cable circuit availability and is consistent with National Grid's philosophy in promoting the use and development best available practise.		
Expected timescale of project	2 years	**Duration of benefit once achieved**	5 years
Probability of success	60 %	**Project NPV = (PV benefits – PV costs) x probability of success**	£318k
Potential for achieving expected benefits	Benefits are currently being realised from previous Phase 1 & 2 projects; reduction in OPEX costs, reduced circuit outage time (two thirds) reduction in civil works on roads therefore benefiting road users and local residents. It therefore expected that the benefits will be applicable to National Grids 400kV cable network.		
Project progress [Year to End of March 2012]	Prior to shipping the "Live Injection" equipment for field trials in the UK, we shipped the equipment within the US to ensure it shipped without damage. We discovered and corrected several vulnerable areas where damage occurred. Initial visual inspection of the Injection equipment indicated that the equipment had shipped safely to the UK. The entire electrical system was tested and no issues were discovered. During testing, as the systems ran, relatively large variations in the flow rate were observed. Rather than zeroing in on the user entered flow rate, the flow rate was observed to oscillate between two values. It was determined that the source of the issue was the difference in the viscosity between the dielectric fluid used in the US and that used in the UK. Alterations were made to the drain and injection equipment valves which allowed the flow rate to zero in on a target flow rate. Further examinations will take place once back in the US. Throughout all of the initial testing, all of the messaging, communications and data logging abilities were tested and successful.		

Below is a picture of the Injection Equipment in Rowdown Substation, The Injection Equipment, which includes all electrical and hydraulic components, can be seen, in addition to the tank of PFT concentrate.

Below is a picture of the drain equipment. The hydraulic components can be seen positioned on the drum, while the electrical components are resting below.

The results of the field test designed to simulate an actual Live Injection are shown in the graph below.

	 As can be seen from the graph, the system maintained the pressure (on average) above the Falling Alarm Point (21 psi), until we manipulated the process for testing purposes. Overall, PFT tech was very impressed with the operation of the "Live Injection" equipment on the field. Many man-hours were invested to ensure that the system was designed and operating properly, however, the true test was connecting the equipment to an actual circuit. Through all tests the equipment demonstrated its ability to establish and maintain a flow through a circuit, while injecting the proper quantity of PFT concentrate.
Collaborative partners	PFT Technology
R&D provider	Pirelli & PFT Technology inc

Project title	**SALVO**
Project Engineer	Michelle Le Blanc
Description of project	SALVO is a project to research and develop innovative approaches to decision-making in the management of mature assets. SALVO aims to develop simple, flexible and practical guidance and tools for determining what to spend and when in the following common, yet critical, decision scenarios: Individual activity or task level (for specific assets/groups of assets): "As the equipment ages, what changes to inspection, condition monitoring, functional testing or planned maintenance should I make?" "When is the optimal time to replace (or decommission) this equipment, and what are the cost/risk effects of delay?" "Should I replace with the same design (like-for-like), or with a technology change/upgrade/alternative design?" "Is it worth refurbishing the current equipment, to extend its life and, if so, by how much?" Is a (non-cyclic) modification project worthwhile, and how does this compete for value/priority with timing-sensitive or cyclic tasks (e.g. maintenance/renewal)? Programme integration level (only possible once the above questions can be answered individually and quantitatively): What is the optimal (life cycle value) combination of capital investment and operating/maintenance expenditures for a particular class of assets (i.e. optimising the mix inspection, maintenance and renewal)? What is the optimal integrated work programme (multiple activities for multiple assets) over the next XX years (including coordination opportunities, resource smoothing etc)? Given a specific capital investment budget, which projects or tasks should I spend it on? What are the investment and maintenance budget/resource needs for my asset portfolio in the next XX years? These questions all draw on certain common technical and process requirements. Such core components determine the SALVO R&D technical work elements (figure 1).

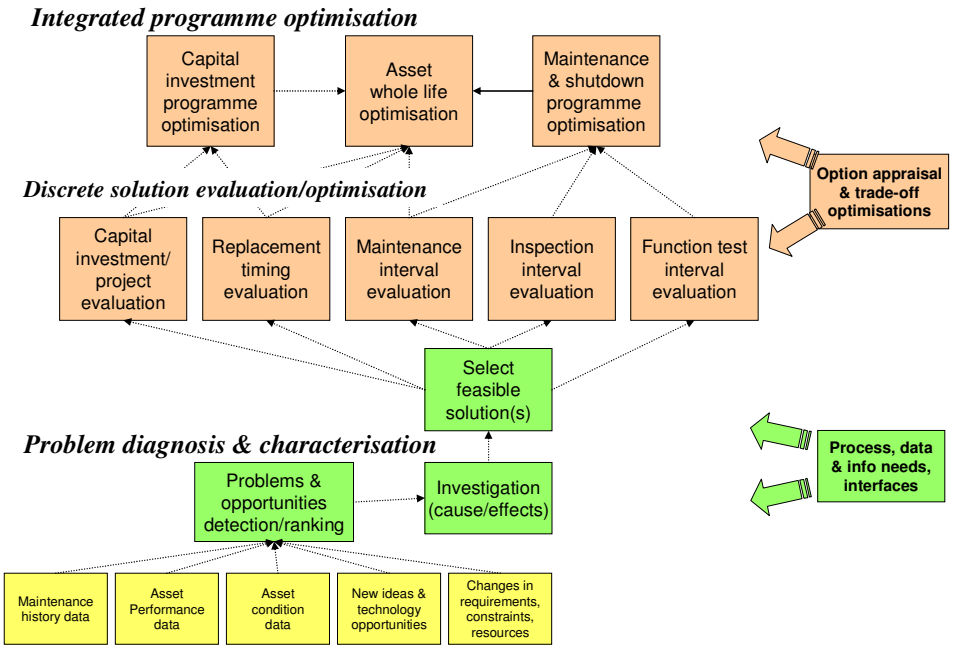


Figure 1 Technical module development requirements

Expenditure for financial year	Internal £12k External £16k **Total £28k**	**Expenditure in previous (IFI) financial years**	Internal £50k External £75k **Total £125k**
Total project costs (collaborative + external + [company])	£286k	**Projected 2012/13 costs for National Grid**	£33k

Technological area and/or issue addressed by project	Asset management, in particular decision-making in the management of mature assets. Asset management is a core capability for National Grid to enable optimal management of its assets across the whole life cycle. National Grid is committed to enhancing its asset management capability. It was the first utility in the world to gain BSI PAS 55 certification and is actively involved in developing asset management practice both internally and externally e.g. through leading and participation in Institute of Asset Management projects. National Grid sponsored and was an active contributor to the MACRO project and has extensive experience both developing and using asset management decision support tools.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		10	-2	12
Expected benefits of project	National Grid uses asset management to address current and future challenges and opportunities e.g. managing an ageing asset base, building a network to facilitate change in generation to meet climate change targets, maintaining the high reliability levels experienced by UK consumers, ensuring consumers get value for money whilst maintaining at acceptable levels, ensuring the network is sustainable in the future. This asset management requires sophisticated			

	analytical assessment and balancing of costs, risks and performance. £5 Billion in capital investment is identified to be needed in electricity transmission infrastructure in the next 5 years. Reasonable projections for the resultant savings in maintenance, capital investment (avoidance/ deferral/ improved value) and earlier adoption of high performance technologies represents a net estimated benefit to National Grid of £20-100 Million. This project will contribute an estimated 10% of the potential benefits.		
Expected timescale of project	3 years	**Duration of benefit once achieved**	5 Years
Probability of success	85%	**Project NPV = (PV benefits – PV costs) x probability of success**	£636k
Potential for achieving expected benefits	As above in the 'Expected benefits of Project' section. The confidence level in achieving these benefits continues to rise as the project progresses – the latest field trials have all confirmed early studies: large cost & risk savings through remixing intervention options and timing. For example, London Underground recently applied prototype SALVO methods to steelwork painting strategies and track maintenance – in both cases revealing multi-million £ benefits from optimisation of asset life cycle strategies. Similarly, SASOL has recently completed two studies – obsolescence/upgrade timings for distributed control systems/instrumentation and asset replacement programme for HV electric motors. Again, multi-million £ benefits were identified from optimising the plans.		
Project progress [Year to End of March 2012]	The project has suffered some delays – mostly due to the sponsor's available resources but also in the cost and duration of the software development efforts (to handle the ambitious scope and flexibility requested by the process definition working group). The project is now expected to complete in 2nd Qtr 2013 (rather than end of 2012 as originally planned). Currently the project managers, TWPL, are covering the incremental costs involved from this extension (estimated at an additional £200k). Deliverables so far include a set of process flows covering all 5 stages of the SALVO process (problem identification/prioritisation, solution(s) identification, individual intervention evaluations, combinatorial asset strategy optimisation and total programme summation/risk forecasting etc). These processes are currently being documented to 2 levels of detail: A public domain guidebook to the whole process, will stages explanations and illustrations A sponsors-only technical 'playbook' of detailed process specifications, including all inputs, process, outputs, constraints/controls and enablers/mechanisms. Case studies are an important deliverable of the project, and these are starting to emerge. A 'library' of exemplar cases is being developed for different decision types, asset types and industrial settings. These fulfil the dual purpose of benefits demonstration and providing 'template' guidance for the application of SALVO process in different circumstances. Software modules are in intensive 2nd stage development now (prototypes were developed last year and field-tested). The first module ("Lifespan") due for Alpha release on 21st June, to be followed by the 'batch' version in September. Maintenance, Inspection, Project modules are scheduled for Q3/4, and the combinatorial toolkit (bundling of interventions and total programme assembly) are rescheduled to 1st Qtr 2013.		

	Core sponsors of the project have been sharing experiences and resolving complex specification and navigation issues. Three further 'industrial associates' (Halcrow, Sodexo, AMT-Sybex) have joined the project in a lesser capacity, assisting in peer review and field trials – this has helped on resourcing of some working groups as well as diversifying the industry sector inputs.
Collaborative partners	Other Sponsors: Scottish Water, London Underground, SASOL 'Industrial Associates': Scottish Power, Halcrow, AMT-Sybex, IBM, Centrica, Sodexo
R&D provider	The Woodhouse Partnership Ltd, The University of Cambridge

Project title	**Impact of extending operational lifetimes of electromechanical relays**			
Project Engineer	Wen An			
Description of project	To ascertain through detailed scientific analysis and testing, the period of time for which certain models of electromechanical and solid state protection relays can remain in operation on the GB Transmission System. To determine the effects (if any) that the operational lifetime of the electromechanical and solid state protection relays has had on the reliability and anticipated design life of the units.			
Expenditure for financial year	Internal £5k External £26k **Total £31k**		**Expenditure in previous (IFI) financial years**	Internal £13k External £135k **Total £148k**
Total project costs (collaborative + external + [company])	£179k		**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	The results of this investigative analysis will feed back into Scheme 15328 – Control & Protection infrastructure replacement scheme.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		12	-1	13
Expected benefits of project	By accurately determining the length of time for which electromechanical and solid state protection relays can reliably remain in operation on the GB Transmission system, the financial elements linked to the various replacement options can be deferred to a later date – allowing greater flexibility in the asset investment process. Examples of these financial elements include; Decommissioning & removal costs of the electromechanical and solid state protection relays. Purchase costs of the replacement protection relays. Associated PDSA (Post Delivery Support Agreements) for the replacement NICAP solution Installation & Commissioning costs of the replacement protections. For a typical double busbar substation, the cost of installing a NICAP solution is in the order of £3m - £4m (including protection changes at the remote ends of the circuits.) It is anticipated that significant cost savings will be achieved from the additional flexibility this testing will provide for the asset investment process.			

Expected timescale of project	3 years	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£239k
Potential for achieving expected benefits	The electromechanical relays of different types have all been tested and results evaluated. The relays were subject to 5 types of ageing factors: temperature cycling, atmospheric corrosion, elevated temperature, vibration and repetitive operation. The duration and strength of the impact was generally set so that the impacts would be stronger than the impacts in the past on any of the sample relays received for testing. The tests, which emulated the ageing impacts, did not identify any ageing related failure mechanisms that would not be manageable by maintenance. Therefore it is highly feasible to continue using these relays for the intended time to allow a strategy of more orderly replacement with minimum impact on the system operation.		
Project progress [Year to End of May 2012]	A detailed technical report on electromechanical relays was drafted in November 2011 and reviewed in December 2011. The report was finalised in January 2012. A maintenance strategy has been proposed, with a detailed inspection form for use in future maintenance practice. The issue of obsolescence, particularly that associated with the seals, was highlighted. Work on solid-state relays has been started. The delay was caused by the departure of the Research Associate. A replacement was found in April 2012. Initial operational test has been conducted. On-going work is to test and understand the temperature cycling effects on relay performance and semiconductor or passive device characteristics. This will be followed by an investigation into the effects of salt spray. It is expected that conclusions can be reached faster with the experience gained through electromechanical relays.		
Collaborative partners	N/A		
R&D provider	University of Durham, GL		

Project title	**Improved Transformer Thermal Monitoring**		
Project Engineer	Gordon Wilson		
Description of project	This project map and data will deliver an improved transformer thermal model that enables accurate ratings to be calculated. A method for determining thermal parameters for those transformers without test certificates will be developed. The project will specifically address the effects of ambient conditions, changes in cooling state and the influences of the transformer surroundings, of particular interest in built-up locations. Met Office data from a previous scheme will be used to assess the effects of 'heat-wave' conditions, of especial importance in the South-East.		
Expenditure for financial year	Internal £4k External £104k **Total £108k**	**Expenditure in previous (IFI) financial years**	Internal £4k External £20k **Total £24k**
Total project costs (collaborative + external + [company])	£188k	**Projected 2012/13 costs for National Grid**	£56k
Technological area and/or issue addressed by project	National Grid uses transformer thermal ratings for planning purposes and day-to-day operation of the transmission system. The thermal ratings use transformer models based on IEC methods that are known to have shortcomings, particularly with oil temperature behaviour and where changes of cooling state occur. National Grid is now acquiring transformers cooled only by natural circulation or by three-stage cooling and these require modifications to the existing ratings process to be modelled properly. Transformer thermal capability is calculated from known test certificate data. However, some older transformers in key locations do not have test certificate data, resulting in the use of conservative ratings that will be restrictive. The relevant thermal parameters could be determined by the application of appropriate models to the measured data for these units. An attempt to determine thermal parameters for transformers at New Cross has been made based on long-term monitoring. However, the work at New Cross has highlighted significant shortcomings in the application of existing IEC models to actual data, leading to difficulties in estimating the thermal parameters accurately. The potential influence of ambient conditions and the effects of the environment in which the transformers are installed has also been shown. Measurements of ambient conditions were taken at New Cross that have not yet been incorporated into transformer models. These data will be analysed to assess the influence of the environment on transformer ratings. A transformer with known thermal parameters (and ideally with fibre-optic temperature sensors installed) will be fully instrumented at another location to enable an accurate model of transformer thermal behaviour, as installed at site, to be developed. Since the thermal and electrical parameters will be known beforehand (unlike at New Cross), the success of various methods in obtaining these values from the logged temperatures and loading data can be assessed, for application elsewhere. Particular attention will be given to the behaviour of the oil flow which is known to be quite complex. The effects of ambient conditions can be compared with those at New Cross. The resulting thermal models will be useable in the transformer rating program TRALC, and also for real-time rating estimates by the CTM.		

<table>
<tr><td></td><td colspan="4">The thermal ageing of transformer windings is governed by the detailed nature of the winding construction and oil flow rates, although average values for winding and oil temperatures can be obtained by factory test measurements. The TEFLOW program has been used for such detailed calculations in the past. It has proved valuable in the assessment of failures where the necessary detailed winding measurements can be obtained by inspection. Support will be provided to Manchester University in improving the TEFLOW thermal model and further developing the TEFLOW program.

The existing transformer loading program TRALC is used for calculating transformer ratings. Improvements to the thermal model derived under parts of this project described above will need to be incorporated in TRALC. In addition, the electrical model in TRALC will be re-assessed for its suitability in modelling load flow in either direction (HV to LV or LV to HV) and for estimating core flux more accurately. If necessary, the existing electrical model will be improved. A new specification for TRALC v3 incorporating the required changes will be produced. The EPRI transformer loading program PTLOAD will be assessed to ensure that National Grid follows best practice in transformer rating calculations.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>15</td><td>0</td><td>15</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The provision of enhanced ratings through calculation of potential enhancements provides large cost savings for National Grid and increases flexibility in placing outages. In recent times the potential for granting enhancements has been employed in evaluating load related schemes and deferrals have been possible. In some cases it has not been possible to provide enhancements because of the lack of a test certificate, for example upratings at Ninfield and North Hyde could not be modelled and Cowley, Kingsnorth and Mannington are affected by the same transformers; there are around 100 transformers for which models cannot be produced. This project will result in a method for accurately determining the potential enhancement of such transformers allowing deferral of capital investment at a moderate cost.

TRALC v2 has been revised and updated on a number of occasions since it was first developed; the software developers have suggested that further updates will become increasingly difficult (and more expensive) thus a new version will be required to allow inclusion of three stage cooling and ONAN transformers. It would also allow these transformers to be modelled correctly in the new version of CTM.

System Development are supportive of the research and have produced a model showing how deferrals might be possible depending on demand growth rate at GSPs and potential uprating resulting from more accurate models. Based on recent years the average number of new transformers installed for system development each year is six. Assuming relatively modest cyclic upratings and a moderate view of growth rate the potential to defer half of the annual load related transformer installations for 3 years seems reasonable. Given that many of these sites have transformers that can already be modelled a modest assumption would be that three transformers could be deferred for 3 years in the first 5 years of implementation. The unit cost of a GSP transformer is approximately £4m. For NPV calculations a three year deferral would be worth £300k. Given that implementation costs may be of the same order as this project then NPV would be positive in the first 5 years.</td></tr>
<tr><td>Expected timescale of project</td><td>3 years</td><td>Duration of benefit once achieved</td><td colspan="2">5 years</td></tr>
</table>

Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£78k
Potential for achieving expected benefits	Some of the development work will be carried out within CIGRE A2.38, a group that National Grid (Gordon Wilson) is already involved with. The collaborative output of this group will form a part of the deliverables and will ensure that National Grid's transformer ratings program remains state of the art.		
Project progress [Year to End of March 2012]	This project was late starting due to negotiations and a request for an urgent piece of work from the supplier (also for National Grid) which meant that this project could not progress. A candidate transformer had been selected for enhanced monitoring to provide data for the work but has since been made redundant as a result of network reinforcement at the substation concerned. An alternate has been identified. A specification for the monitoring required has been developed and instrumentation requirements have been identified and evaluated. The original equipment used for monitoring optical fibres has been located and appropriate connectors have been obtained but neither has been tested as yet. The project will be accelerated over the course of 2012/13 so that deliverables are not unduly delayed, noting that this is not the fault of the supplier.		
Collaborative partners			
R&D provider	Southampton Dielectric consultants Doble Power Test		

<table>
<tr><td>Project title</td><td colspan="3">Development of OHL Hot Joint Monitoring Tool</td></tr>
<tr><td>Project Engineer</td><td colspan="3">Martin Wilson</td></tr>
<tr><td>Description of project</td><td colspan="3">Development of an innovative modelling and monitoring tool for overhead line hot joints that are discovered and reported by the helicopter unit as part of their annual infrared patrols. The model will act as the central repository for all information relating to hot joints on the network (from identification to rectification) and include the deterioration prediction tool currently issued in TGN 200. Implementation via the National Grid SAM platform will allow access to multiple users at the same time and dramatically ease data sharing.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £3k
External £1k
Total £4k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £6k
External £48k
Total £53k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£58k</td><td>Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">National Grid currently complete helicopter borne infra red patrols on an annual basis for 70% of the circuits and every two years for the remaining 30%. Part of this inspection is the search for so called “hot joints”.

The current tool for sharing and recording hot joint data has become inadequate and presently results in long delays in rectifying hot joint problems.

Hot joints can potentially cost the system operator (and thus the consumer if passed through) thousands of pounds as well as possibly reducing system security. This is due to the fact that circuits must be downrated if a hot joint is discovered. Downrating of circuits can then result in constraint costs which can be significant.

As well as cost issues downrating can have a significant impact on the security of the network as circuits cannot be operated as designed.</td></tr>
<tr><td>Type(s) of innovation involved</td><td>Incremental</td><td>Project Benefits Rating
9</td><td>Project Residual Risk
1</td><td>Overall Project Score
8</td></tr>
<tr><td>Expected benefits of project</td><td colspan="3">Development of this modelling tool will greatly enhance the ability of National Grid to manage and monitor hot joints on the network. The new system will ensure that up to date information is made available in a timely manner to all concerned parties.

As well as greatly improving the efficiency of hot joint reporting it will also facilitate faster rectification of hot joint problems as they will be highlighted far sooner than previously possible, thus allowing for quicker defect repair and better planning of the maintenance programme.

This in turn will reduce the potential cost implications of hot joints.

An example of this is that between 7th April and 1st July 2010 the downrating of a single circuit due to a detected hot joint resulted in constraint costs of £625k. It is fair to say that swifter identification and rectification of this issue would have</td></tr>
</table>

	significantly reduced these costs as well as ensured that the network was operating at its optimum. As well as the benefits identified above further benefits will arise from the ability of the model to facilitate trend analysis that will allow a prognostic approach to hot joint monitoring thus allowing for even more efficient maintenance planning and thus a reduction in maintenance costs and a possible reduction in outage requirements for maintenance activities (this in turn may reduce constraint costs).		
Expected timescale of project	1 year	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£98k
Potential for achieving expected benefits	This project has a high chance of being successful due to the previous work that C3 Global have completed for ENI on the SAM platform, it is intended to operate this application via the SAM platform.		
Project progress [Year to End of March 2012]	**2011 – 2012 -** A small amount of internal time was spent early on in the year with the final report and findings being reviewed by National Grid this tool is now being integrated into National Grid's working practices. **2010 – 2011** – The hot joint model has been developed and is now live on the SAM portal. The model is now actively being used for the monitoring of the OHL hot joints. This has proven to be a useful tool during this short period of time.		
Collaborative partners			
R&D provider	C3 Global		

Project title	**Use of Fibre Optics in Substations to Detect Noise.**			
Project Engineer	Carl Johnstone (Oliver Aries)			
Description of project	To implement a pilot trial and asses the benefits and limitations of optic fibre sensing in a Substation Environment for asset management and operational needs. This project will deliver a fibre optic cable at Bolnely 400kV substation which will be routed around part of the perimeter fence and in the near vicinity of at least one 400/132kV SGT, a 13kV tertiary reactor, a 400kV air blast circuit breaker and other switchgear. This fibre will be lit using a sensor which has been developed by British Telecoms which uses the fibre to detect audible sounds. The data from this will be sent across an internet connection back to a BT server to analyse the noise signatures on site. A trial of this system will be carried out over a period of a year to determine its key benefit will be in the areas of Condition Monitoring using audible signatures Extension of maintenance regimes of transformers, reactors and switchgear using audible footprints. Detection of imminent equipment failure. The trial will also pay for BT support during the period. Another benefit that will be looked at will be in the area of Site security i.e. detecting for intruders also linking with a CCTV. Although this is not the key driver.			
Expenditure for financial year	Internal £3k External £1k **Total £4k**	**Expenditure in previous (IFI) financial years**	Internal £30K External £96K **Total £126K**	
Total project costs (collaborative + external + [company])	£130k	**Projected 2012/13 costs for National Grid**	£0k	
Technological area and/or issue addressed by project	BT have used this technique with Network Rail and it is now in production and has proved very useful for the location of Trains by triangulation from the sound source, Improving the safety at farm Railway Crossings (determining when next train will be) and fault diagnosis of trains whilst running on the track (diction of square wheels by analysing the sound footprint) and detection of Copper Thefts. It is believed this system can be tailored to suite a number of applications some of which may only transpire during the project.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		12	0	12

<table>
<tr><td>Expected benefits of project</td><td colspan="3">If successful this system will:

provide a ‘two voting system’ to minimise false alarms and increase confidence for attendance from external support services such as police (if deployed could save over £50k/annum on false alarms and potentially avoid copper theft’s)

• Increase maintenance cycles as detection of wear and faulty parts can be done on equipment in service and before failure occurs.

• Analysis of a system incident on site to determine more accurately the cause and effect.

• Single sensor technology that offers a simple yet diverse use, with a closer match in life with our assets

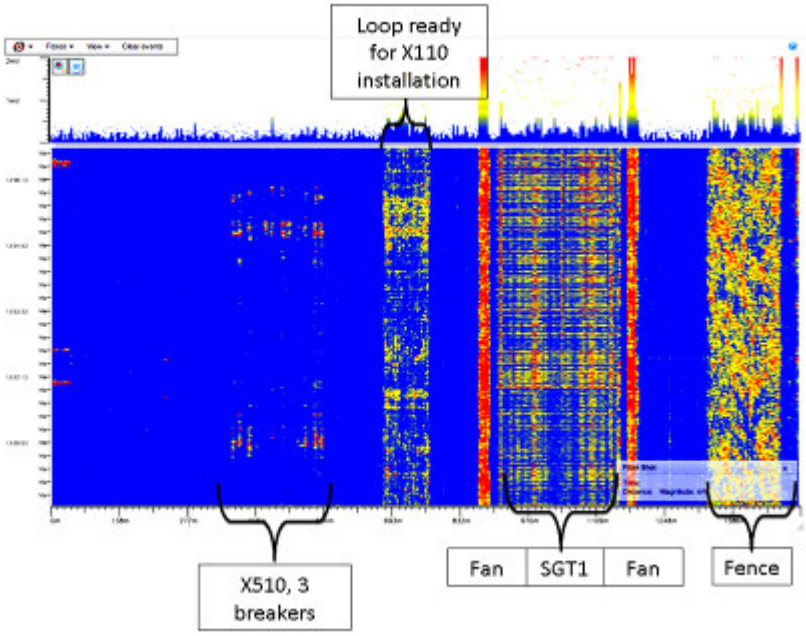
• It is difficult to put a cost to this but on the first point alone this could save around £400k pa in security costs.

In addition it is though the system might provide benefits in providing a cheaper way of securing a substation site (initially non-CNI sites) and if linked with CCTV should increase the success rate of capturing an intruder on camera anywhere on site</td></tr>
<tr><td>Expected timescale of project</td><td>2 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£7k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="3">It is predicted that the system should at least detect audible noise along the fibre route and pinpoint noise. BT with Network rail has successfully demonstrated this and its use for capturing a noise footprint. They have also successfully demonstrated its security objective. In the area of noise footprint of National Grid plant its success is less certain because although signatures can be taken for equipment, meaningful diagnosis of this data will be a steep learning curve and may not be possible to take into production during the trial period. However, the system is cheap to install and given time it is believed these applications should also prove to be successful for National Grid.

The biggest risk to this project is the background vibration noise from transformers. An aim of this project is to see if this is an issue, and f so can the 50hertz be filtered out and still give the systems potential benefits.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="3">Fibre and sensing equipment were installed in Bolney 400kV substation, enabling a sensing loop of fibre to be attached to circuit breakers and tap changer and fans of SGT1. The system was configured to listen to the High Voltage equipment and the cable troughs and fencing along the route.

A series of tests were conducted; switching circuit breakers and tapping transformers on and offline, to provide enough audible data to evaluate the capability and potential of the technology. The objectives of the project were considered by engineers in Asset Management and Network Operations; to explore the viability of the system as a condition monitoring tool and also; as a new strand of thinking developed during the experiment, as a risk management device to give “visibility” of personnel on towers and in tunnels.

The project’s limited time span did give sufficient information to appreciate that there is potential for a more intense project to explore a system to give Network Operations a device; utilising existing fibre on OHL earth fibre, to detect a human presence on towers and alert and similarly by using DTS fibres in cables, there</td></tr>
</table>

	appears to be prospect to use fibre sensing of sound to accurately locate a workforce in a tunnel, to support risk management of workers in a cable tunnel. Condition monitoring of assets using sound requires an intimate understanding of the individual noise features of an asset and a profile would probably have to be developed for each asset determine how healthy equipment sounds and a point or points could, perhaps, be defined or sounds identified at which the asset can be said to be ailing. Potential exists for a long term project, possibly in collaboration with manufacturers to develop this condition analysis technique and additional work to develop and research the technique would be of value. The value obtained during this project has prompted a follow-up R&D scheme; approved in July against Andrew Roxborough, again at Bolney substation to enable a more elaborate and refined investigation into the capabilities of the technology to monitor asset health and to detect incursion of towers, tunnels and RMHZ in substations.  **Fig: Sound Picture of the entire length of the FAM fibre at Bolney**
Collaborative partners	
R&D provider	MDE / BT

Project title	**Transformer and system reliability**		
Project Engineer	Paul Jarman		
Description of project	This project will deliver a methodology for assessing the maintenance and replacement strategies for transformers against system reliability requirements. In particular the derivation of transformer replacement priority from asset health index and perceived system criticality can be greatly refined using a detailed knowledge of transformer failure modes (common mode, sympathetic and hidden failures). The availability of such a methodology will ensure an optimum and justifiable prioritisation of transformer replacement and maintenance.		
Expenditure for financial year	Internal £4k External £79k **Total £83k**	**Expenditure in previous (IFI) financial years**	Internal £3 External £67 **Total £70**
Total project costs (collaborative + external + [company])	£228k	**Projected 2012/13 costs for National Grid**	£75k

Technological area and/or issue addressed by project	At present the risk and criticality approach to transformer maintenance and replacement is based on a relatively crude 3 point scale of criticality and a matrix. This method may be capable of improvement if a real network model is used together with an understanding of possible interactions between failures. Generally a transformer outage is of little consequence, but two or more simultaneous outages on certain parts of the network could have severe consequences. Identifying these situations and the sensitivity to linked failures is important for the correct and timely replacement of the most critical units. As far as can be determined there is nothing significant published on the interaction of transformer reliability and overall system reliability. One of the final parts of the transformer lifetime project which is in progress was to look at this area but it is unlikely that there will be time on this project to start this work.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		8	0	8
Expected benefits of project	Transformer replacement is worth some £20-£40M per year for many years to come, optimising this expenditure and reducing the likelihood of a costly system failure due to late replacement depends on the correct and timely identification of replacement candidates. This project will make a small but significant contribution to this process.			

Expected timescale of project	4 years	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£86k
Potential for	The project will use the combined expertise of the Transformer and System		

achieving expected benefits	research groups at the University of Manchester. There is therefore a significant background of knowledge that will be used. The probability of making progress towards a useable failure criticality model is high. It is possible that the problem will have to be simplified to make progress. This should however still result in useful results.
Project progress [Year to End of March 2012]	Two students are in place and have been working on the project. Power Factory software has been used to test the capability of making reliability estimates on a test system configuration often used for benchmarking. This has shown that some refinement of the reliability assessment method needs to be researched, but the desired outcome seems achievable. A model of the London system has been adopted and used but only preliminary results have been obtained. Permission from UKPN is required to use a model of the LV interconnection based on their data, this is required to obtain realistic results. Work on the transformer reliability model has produced a good paper condition based model from literature results and this now needs to be expanded to other aspects of transformer unreliability and to incorporate historical data. The students will be working closely with staff at National Grid to achieve this.
Collaborative partners	None.
R&D provider	University of Manchester

Project title	**Oil-less DGA Sampling (Prospective Trial)**		
Project Engineer	Graham Moss		
Description of project	This is a prospective trial to test the effectiveness of direct oil-gas separation across high surface area ceramic membranes coated with hydrophilic membranes. The aim is to prove the functionality of membrane extraction to be used on oil filled transmission assets where the oil content is of very low volume and successive sampling results in the requirement to 'top-up'. The end of trial will deliver quantitative data concerning extraction efficiency and most suitable membranes to use in the construction of a field worthy sampling system. It is expected that the trial will deliver as far as a proposed technical drawing of the field trial system, if not a working prototype to demonstrate the technology The second part of this work is to look at key molecular species which can identify winding faults, generated when copper in contact with oil pushes upwards to temperatures of 600 DegC and above. Identifying a key marker species may assist in distinguishing transformers suffering from winding faults from those suffering from non-critical overheating faults such as core-frame circulating currents.		
Expenditure for financial year	Internal £3k External £1k **Total £4k**	**Expenditure in previous (IFI) financial years**	Internal £3k External £16k **Total £19k**
Total project costs (collaborative + external + [company])	£22k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	According to theory, with the oil being exposed to a very large surface area membrane, the gas contained within the oil will transfer to the low concentration gas space on the far side of the membrane to achieve equilibrium. This process will be faster and more efficient with the greatest surface area profile. Ceramic membranes offer this property. It is expected the membranes will be formed from aluminium nitride and coated with a 5µm layer of various polymers. The choice of polymer is a major goal of this trial. The final field device will be a steel cylinder containing a series of very strong aluminium nitride tubes which give a potential surface area for the oil to act on of some $20m^2$ or above. The device will be designed to gently circulate oil to and from the same sample valve. The surrounding container (purged on delivery with argon) will begin to assimilate diagnostic gases from the oil. Diagnostic gas will be removed from the sampling system by syringe and analysed by a laboratory To reach a field test device, this project will be moved to a full R&D project. The copper species marker for winding fault identification will be carried out using a series of high-end analytical tools to primarily discover the abundance of		

<table>
<tr><td></td><td colspan="4">such markers directly through bench-top experimentation.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>1</td><td>10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Sampling low volume oil assets for DGA without removing any dielectric fluid, thus avoiding top-ups and risk of internal flash-over.
Oil-free DGA sampling also offers an environmental saving in not handling or transporting oil.
The ability to pinpoint a winding fault progression would ultimately help in avoiding the complete loss of a transformer when allied to on-line DGA analysis.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">2 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£19k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">This is a prospective trial to discover how efficient the extraction process is.
The extraction system will definitely work, the question being answered is the efficiency that the extractions system will operate at.
This small trial will give us quantitative data concerning the realistic timescales between samples, differences in gas ratios and the best polymers to use for highest extraction efficiency.
The presence of unusual copper species in oil from the high temperatures associated with winding faults would not be unusual. The experiment is to discover how abundant they become and can they provide enough advance warning of future failure.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">2011 - The sampling cell has now been constructed and the ceramic membranes have been selected as have the fluoropolymer coatings. The efficiency trails on the gas extraction should be completed by the end of September 2011.
2012- The gaseous extraction efficiency was studied on ceramic disks with extremely small and uniform pore dimensions. Each disk was coated on one side with a selected fluoropolymer. This polymer layer is extremely thin, less than 20microns. The disks were fitted into a cell created for experimentation whereby oil containing typical fault gases was allowed to circulate against the polymer side of the disk. The other side was a sealed vacuum space. The system was left for several days. It is important to note at this point, no oil migrated across the polymer or through the membrane, so the fundamental experimental point of this small scale test was successful. The clean side of the cell was analysed for any gases that had transferred across the membrane.
All diagnostic gases including acetylene were detectable via standard GC (FID/TCD). This gives great promise for the further work into a purposeful designed stainless steel vessel containing a number of tubular form ceramic elements (polymer coated) through which oil flows. Gases will collect within the sampling vessel.
The copper species part of this work is now intimately bound up with a novel electronic DLA sensor which holds great promise for a number of unique</td></tr>
</table>

	opportunities to study developing faults through intrinsic poor oil condition brought about through degradation products. We believe that this is especially relevant in pre-empting FMJL failure and selector faults, as well as general oil condition on almost all oil filled electrical transmission assets. The development would require the purchase of three DLA probes which will be integrated to wireless condition monitoring systems widely in use already. Two sensors would be used at the research station at Dungeness specifically to look at FMJL integrity whilst the final sensor would be built into a portable unit into which small volumes of oil would be injected to give an instant assessment of dielectric performance. It is intended to also build into this unit a standard relative saturation probe to rule out moisture contamination. If funding is agreed, the systems should be installed and providing information by October 2012
Collaborative partners	
R&D provider	Nynas AB IOM / Doble Power Test / Invisible Systems

Project title	**Tapchanger Spring Measuring Device**			
Project Engineer	Dave Turnill			
Description of project	The project will deliver the ability to measure accurately and consistently both the opening and closing spring pressures on Transformer Tapchangers. To allow ENI and Asset Policy build a clear picture of the condition of tapchanger spring contacts.			
Expenditure for financial year	Internal £3k External £1k **Total £4k**		**Expenditure in previous (IFI) financial years**	Internal £3k External £4k **Total £6k**
Total project costs (collaborative + external + [company])	£10k		**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	Historically MDE's staff have used a spring balance and piece of nylon line to determine the spring pressure on any single contact in a series of up to 25 contacts. The nylon line was attached to the contact and the spring balance to the line on pulling the balance a reading was taken. This has led to inconsistencies in the measured values obtained over the years. With this method it was also very difficult to build up a historical data base on the condition of springs with a view of determining any gradual degradation in the condition of the spring's strength. Both ENI and the transformer asset group are very interested in the project and fully support the imitative.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		6	-7	13
Expected benefits of project	With the implementation of the digital spring balance and associated measuring jigs ENI and the Asset Policy will now be able to gain a very accurate picture to the condition of the tapchanger springs which are in service on the system. ENI will then be able to minimise tapchanger gassing and reduce possible downtimes and expensive repairs. This will give both ENI and the transformer asset group the facility of documenting and building a picture of the present condition of the springs within the tapchangers			
Expected timescale of project	2 years		**Duration of benefit once achieved**	5 years
Probability of success	60%		**Project NPV = (PV benefits – PV costs) x probability of success**	-£8k
Potential for achieving expected	Although there is currently nothing on the open market which will fulfil our requirement it is envisaged that there is a very high possibility of success with this project.			

benefits	It is expected that the basic design of the Tapchanger Spring Measuring Device can be further developed into a successful tool which will assist MDE staff to safely carry out their maintenance, hence with the support of ENI and Asset Policy it is expected that this project will have a very high possibility of success.
Project progress [Year to End of March 2012]	2011 2012 Following final minor modifications to the device and the associated jigs, successful field trials followed to prove this redesign. Following this the project was presented for sanction to Senior MDE Management in November and has now been fully approved for use on the system assets. A scheme has been raised and sets purchased to provide MDE staff with the device for use in the field. This project is now complete, closed and implemented. 2010 2011 Feb 2011 - Precision Engineering have completed now completed the final package With ENI for field trials.  Jan 2011 - Held meeting with Precision Engineering to discuss the final designs minor modifications to be completed
Collaborative partners	
R&D provider	Precision Engineering & Grays Engineering

Project title	**Transformer Oil Passivation and Impact of Corrosive Sulphur (TOPICS)**		
Project Engineer	Gordon Wilson		
Description of project	The key objective of this project is to reduce the risk of transformer failure and unreliability resulting from corrosive sulphur in oil. This key objective will be met by: • Better understanding of the mechanism by which copper sulphide failures occur and the effectiveness of passivation • Fully understanding the effects, both chemical and electrical, of passivation on transformer insulation performance, • Investigating the reasons for silver corrosion in tap changers and to formulate monitoring/assessment strategies in order to provide a measure of asset health.		
Expenditure for financial year 11/12	Internal £4k External £66k **Total £71k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£163k	**Projected 2012/13 costs for National Grid**	£92k
Technological area and/or issue addressed by project	Formation of corrosive sulphur in oil and subsequent copper sulphide deposition in paper has led to a number of large transformer failures worldwide. It was the cause of the failure of Lackenby SGT4 and other transformers will be removed from the system early because the problem is believed to be advanced. Part of the complex process leading to transformer failure involves the mobilisation of copper containing material into the paper insulation surrounding the windings, which is known to be influenced by the presence of corrosive sulphur species in the oil, and extreme operating conditions. Although there have been many attempts to better understand the mechanism by which formation of copper sulphide occurs none have yet been conclusive. They have not led to sufficient understanding to allow diagnosis of the problem without inspection and better mitigation methods may still arise if the mechanism is better understood. Laboratory studies of the mechanism have largely focussed on the thermal aspects of the mechanism and also the interactions between oil, paper and the surface of copper conductors. This study will use facilities in the Tony Davies High Voltage Laboratory at the University of Southampton to evaluate corrosive sulphur formation in covered conductor samples that are carrying current and will attempt to recreate more accurately the conditions in a transformer in order to better replicate the mode of failure witnessed in transformers i.e. turn to turn failure. The mechanism by which copper sulphide migrates through the paper and the possible interaction of mobile copper ions and/or complexes in the oil will also be investigated. One mitigation strategy employed by transformer owners, including National Grid through OESB 9/08, is to protect the copper surface of the windings by the addition of chemical passivators, such as Irgamet 39TM, to the oil. Passivators are designed to interact with the copper surface to provide a protective barrier		

	and reduce corrosion. The long-term effects of passivation as a remedial strategy to keep transformers in operation are poorly understood and largely informed by experience over a limited number of years rather than laboratory studies that consider the potential chemical reactions. The effectiveness with which copper surfaces are coated with passivator following retrospective addition of Irgamet 39 TM to a transformer has not been studied. In this study we will investigate, and gain a greater understanding of, the chemical effects of passivation through laboratory based experiments and visits into the field. The proposed work will involve collaboration between the School of Chemistry at the University of Southampton and the Tony Davies High Voltage Laboratory, building upon a highly effective collaborative relationship developed during the recently completed IFI-funded feasibility study on corrosion in the gas phase. Questions that are to be addressed during this study include. What is the long term stability of passivator on the surface of copper? Is it necessary to add more passivator when it is consumed in the oil? How might one analyse the surface of copper for the presence of passivator? Can this be used on scrapped transformers to investigate whether the passivator gets through all the paper insulation to where it is needed? If passivator works by coating the surface of copper, which has a fixed surface area, why have others reported that more is required when you have a higher concentration of DBDS? To address the questions above, it is planned to develop chemical tests using a variety of analytical methods to study and quantify the passivator (e.g. Irgamet 39 TM) on copper strips in heated oil over time. Irgamet 39 TM reacts with the copper surface to provide a “protective coating” of benzotriazole on the surface, which can be analyzed using a variety of surface techniques. For example, SEM EDX can be used to monitor surface elemental composition (C, O, S and N), or some more sophisticated surface spectroscopic techniques such as surface Raman spectroscopy, TOF/SIMS to directly probe the nature of the chemical species bound to the surface). Oils designated as “corrosive” and “non corrosive” would be studied, and the effect of the passivator assessed both at the copper surface and through mobilisation of copper into oil. The effect of temperature and time on the passivated copper will be studied. Techniques such as Gas Chromatography-Mass Spectrometry (GC MS) and x-ray fluorescence spectroscopy are established in Southampton, and will be employed for oil analysis. The simultaneous application of techniques to monitor the condition of the oil and the copper surface will be powerful, and allow a more detailed understanding of the interactions of passivator, copper and DBDS (paper wrapping may also be added to the study at any point). Irgamet 39 TM is itself a reactive species designed to be soluble in transformer oil, which liberates a benzotriazole derivative (the active passivator molecule) at the copper surface. There are two byproducts from this process, namely formaldehyde and an amine, both of which may have an impact on the properties of the oil. The effect of these compounds may not emerge until additional amounts of passivator have been added. The effects of these compounds may also be studied using the vial tests. Samples of paper-wrapped windings from failed transformers (provided by National Grid) will also undergo passivation tests, to assess how effective passivation is on “at risk” plant. In parallel with developing understanding of the chemistry involved in the addition of passivators to transformer oil, studies will be undertaken to determine its effect on the thermal/mechanical/electrical properties of the paper/oil insulation system over time. In particular it is necessary to establish whether the addition of passivation effect interturn losses or cause increased operating temperatures. The work on passivation will involve close

<table>
<tr><td></td><td colspan="4">collaboration between two PhD students, one based within Chemistry and the other in the Tony Davies Laboratory.

Oil reclamation of transformer oil through heated clay columns has been used as a remedial measure when corrosive oil is detected and was successfully demonstrated as an effective technique in a previous IFI project. However, through that study and following regeneration of oxidised oil in recent years there has been undesirable corrosion in silver tap changers (OESB 4/09 refers). There is also some evidence of increased gassing in some transformers using reclaimed oil. It is suspected that the reclamation process is itself adversely affecting the oil, and possibly even introduces corrosive substances such as elemental sulphur.

During the first 12 months of this project a Research Assistant, predominantly based in Chemistry will also consider the issue of this silver corrosion in tap-changers. The aim of this study is to gain an improved understanding of how the reclamation process affects the chemical composition of the oil and how the amount of specific components such as elemental sulphur, DBDS and passivators are influenced by the reclamation process. Ultimately, an enhanced understanding of the reclamation process should provide methods to monitor oil quality and provide methods to remove corrosive substances from the oil.

The main objectives for the study will be:

• To develop methods to ensure that any identified corrosive substance such as elemental sulphur is removed from the oil during reclamation.

• To ensure that the reclamation process is not introducing specific corrosive substances.

In order to support these main aims, we will need to identify specific chemical components present in the oil that cause silver corrosion. We will develop and apply suitable tests and analytical methods to detect silver corrosion and specific chemical components in the oil that are of interest, such as elemental sulphur.

Part of the research will focus on the clay, and how different batches of clay can influence the reclamation. This will involve analysis of fresh clay, and clay that has been previously used in reclamation to see if residual sulphur remains in the clay after burning off. This may ultimately allow differentiation between “good” and unsuitable clays.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>-2</td><td>10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">A large proportion of National Grid’s transformers are affected by corrosive sulphur to some extent because of the long period during which the problem oil was available and the relatively low concentration of corrosive molecules required to make an oil corrosive. There are 31 transformers considered to be at high risk because they are of a design which means they operate at higher temperatures than typical transformers. From this group, Lackenby SGT6 and Rochdale SGT5 are scheduled for replacement in 2011 and 2012 respectively because they are believed to be at highest risk of corrosive sulphur related failure. The results of the scrapping of these transformers will be part of the proposed project. The information gained from the scrapping of these transformers will inform the future strategy for other transformers considered to be at greatest risk of reduced asset life or failure because of corrosive sulphur and their individual operating conditions. Due to evidence of localised ageing or heavy loading seven of the transformers are at Asset Health Index 2a or 2b the replacement cost of these assets is approximately £28m. Ensuring that mitigation strategies are effective will provide some protection against early asset write-off. Most immediately, understanding how the copper sulphide</td></tr>
</table>

	formation is developing in the two transformers already scheduled for replacement will impact directly on the decision on whether to replace Drakelow SGT5 and Ferrybridge SGT1A or whether they can be left in service for another 5+ years (approximate deferred cost of £100k pa per transformer). It should not be forgotten that the transformers may need to be replaced early because of the thermal design limitations even if copper sulphide formation can be prevented. Around 175 other transformers are known to contain oil with the potential to become corrosive because of their age and the remainder of the population (around 700 transformers) are being tested for potential corrosivity resulting from top-ups and maintenance activity. The mitigation strategy for these transformers has been to add passivator to the oil on the basis that this will coat all copper surfaces and prevent catalytic conversion of DBDS and other sulphur molecules into a more reactive form. Although this is the most widely used mitigation strategy its effectiveness is not fully known and whether there is a need to add more passivator after it has been consumed is open to question. The effectiveness of National Grid's mitigation strategy for transformers at risk from corrosive sulphur formation will be evaluated and improved through better understanding of the mechanism of copper sulphide formation and passivation of copper surfaces. The project sets out to achieve the following business benefits: National Grid will be able to better understand and potentially monitor the condition of transformers that are believed to be susceptible to corrosive sulphur Passivation can be used appropriately as a mitigation strategy and with knowledge of the likely long term effect on transformer performance. Better mitigation strategies should lead to a reduction of early asset write offs and avoidance of failures.		
Expected timescale of project	3 Years	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£266k
Potential for achieving expected benefits	This proposal seeks to build on a successful record of work relating to oil/paper insulation systems at Southampton University. The Tony Davies High Voltage Laboratory has over 20 years of experience of using insulation oils in high voltage testing and has observed changes in the characteristics of oil as a function of testing regime. Previous National Grid funded work relating to the ageing behaviour of DDB cable oil systems is world leading and has led to a complete chemical description of the process, the identification of key ageing indicators and the determination of end of life criteria. Chemistry at Southampton have experience and understating of the related chemistry, supported by a wide range of analytical techniques, and through the IFI project "CorrS" have provided National Grid with confirmation of the role of DBDS in the mechanisms that lead to the production of corrosive sulphur. Staff at Southampton have provided forensic support and services to utilities worldwide and have carried out numerous major fault inquiries and investigations. Although it is difficult to extrapolate performance measures and experience, the track record outlined above leads to the conclusion that it is highly likely that this		

	group will be able to: • Induce the effects of addition of passivators in the laboratory. • Apply appropriate techniques to characterize these. • Relate observed chemical to changes in key electrical properties. • Identify appropriate routes to improve transformer asset health. Despite the involvement of novel approaches to the understanding of the corrosive sulphur problem there remains a reasonable risk that identification of the progression of copper sulphide deposition in active transformers will not be possible through non-destructive means.
Project progress [Year to End of March 2012]	This is a relatively new project with only one of the PhD students already in position and the second due to start in September along with the post-doctoral research assistant. The first student has begun well having completed a literature review and has started designing experimental procedures to improve understanding of the formation mechanism and has started work on test methods for determining whether copper sulphide may be detected, The student submitted a paper for UHVNet and was one of the few asked to present on the day. In advance of the chemistry researchers starting work the OMU have been conducting trials and producing samples for analysis. The issue of silver corrosion and the influence of oil regeneration remain as baffling as ever.
Collaborative partners	
R&D provider	Southampton University

Project title	**Wireless condition monitoring sensors with integrated diagnostics**		
Project Engineer	Carl Johnstone, Ian Kerr		
Description of project	▪ A low-cost, readily distributed diagnostic system architecture suitable for operating wirelessly within a substation. ▪ A report detailing the feasibility and expected functionality of fully autonomous wireless sensors deployed in a range of environments when integrated with energy harvesting devices. ▪ Capability for integrating the technology within the SAM 'Smart Asset Management System' to provide real-time diagnostics (e.g. PD, environmental) to monitoring engineers. ▪ A technology demonstrator based upon a low-power partial wireless discharge (PD) detector and diagnostics package that can be used for PD identification.		
Expenditure for financial year 11/12	Internal £3k External £77k **Total £80k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£134k	**Projected 2012/13 costs for National Grid**	£55k
Technological area and/or issue addressed by project	Condition monitoring plays an increasingly important role in asset management and diagnostics for high-value equipment. New technology and advances in sensing capabilities enable us to understand more about the asset and thus make optimal maintenance decisions (e.g. maintain on condition). Minimising the requirements for installation and maintenance of these sensors, and removing the need for cables and batteries are the key aspects of the desirable “fit and forget” functionality. Existing approaches to substation diagnostics typically involve mains-tethered instrumentation for data acquisition. It is prohibitively expensive to roll out this type of scheme widely due to cost and cabling constraints, which inevitably leaves gaps in condition monitoring coverage that should ideally be filled. In addition, diagnostic systems have become significant assets in themselves, requiring trained personnel to operate them. This approach adds additional complexity to the task of a monitoring engineer, whose primary concern must be the operational state of plant rather than the intricacies of a diagnostic system. Therefore, a non-obtrusive, integrated approach to diagnostics should be followed. Recent developments in miniaturisation of digital electronic devices have fuelled the development of wireless sensor network technology. These networks are made up of a number of discrete sensor nodes, which integrate processing, sampling, storage and communications capabilities. By taking advantage of this technology, wireless diagnostic sensors have the potential to increase condition monitoring coverage without the need for cross-site cabling, simplifying		

<table>
<tr><td></td><td colspan="4">deployment and reducing costs.

Through identifying general requirements for wireless condition monitoring systems, a modular approach could be defined for a multitude of sensors to be attached to the same underlying platform (for instance: RF, ultrasonic and thermal). In addition to sensing, wireless sensors such as this with suitable analytical capabilities can also support a level of on-board defect diagnosis. By diagnosing defects on-sensor, the volume of monitoring data can be drastically reduced at source so that only pertinent defect information is transmitted to monitoring engineers. This reduces the burden of transmitting data back to corporate networks, increasing system scalability and minimising the requirement for wideband communications links.

An initial laboratory study into this type of approach, targeted at PD monitoring, has resulted in a promising new diagnostic technique built upon wireless sensor technology. This method has demonstrated detection and basic classification capabilities and, based on the knowledge gained from this study, implementing the UHF technique on a wireless sensor node has been recognised as feasible. Based upon this prior work, a wireless condition monitoring platform technology demonstrator could be created using partial discharge detection and diagnosis as a reference application.

Sensors of this type may also be integrated with an energy harvesting module to self-power the device from the ambient electromagnetic fields that are present within a substation. This will reduce the need for battery replacement and related maintenance. National Grid has already pioneered the funding of research into electromagnetic energy harvesting within substations, which would dovetail seamlessly with this new research into low-power sensors should it go ahead.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>10</td><td>0</td><td>10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The aim of this project is to prove the architecture and methodology underpinning a new approach to condition monitoring. This is likely to produce medium-term cost benefits, as National Grid may be able to set new industry standards for low cost wireless condition monitoring sensors in the future.

As the underlying technology matures, its deployment will allow National Grid to:

• Increase the coverage of condition monitoring systems through cost-effective deployments to lower-value assets;

• Allow the use of defect corroboration techniques among a larger pool of sensors to mitigate diagnostic errors that may result from sensor failure;

• Implement additional sensing applications by applying other sensor types to the diagnostic architecture;

• Provide better resolution of plant health through increased sensor coverage.

All of these benefits will be at a reduced cost compared with conventional systems, in GIS and power transformers, for example.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">2 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x</td><td>-£110K</td></tr>
</table>

		probability of success	
Potential for achieving expected benefits	It is proposed that the platform be built upon standards-based wireless technology specifically designed for industrial environments. This technology is well documented and supported, and has already seen deployments within the oil and gas industry. Using this as a base mitigates significant risk from the project as the technology has already been proven in harsh environments. For the technical demonstrator, success of this project can be measured in terms of the proposed device's ability to capture and identify partial discharges, to diagnose defects, and to present appropriate diagnostic information to monitoring engineers. The principles of the proposed demonstrator's approach to low-power PD diagnostics have previously been demonstrated in the laboratory – this work was recently been published in a leading journal[1]. Based upon the knowledge gained from this study, it is highly likely that the UHF method may be implemented in a similar fashion. Significant previous work has gone into developing diagnostic methods for UHF PD data classification, including data-driven and knowledge-based techniques. These same techniques may be applied in a low-power context, depending on whether their requirements match the capabilities of the underlying sensor node hardware. Executing data-driven techniques has been shown to be feasible with existing sensor network devices, and as the capabilities of sensor nodes continue to increase, it is highly likely that even if established diagnostic methods cannot currently run on sensor node hardware, they will in the near future. A fully functional technical demonstrator could definitely be integrated with the National Grid Smart Asset Management system. An agent-based approach to building condition monitoring architectures has been proven to simplify the integration of discrete systems; this approach could be reused in this instance.		
Project progress [Year to End of March 2012]	The original goals were to investigate the state-of-the-art in industrial WSN protocols for substation CM apps, looking at a cheap, low-power PD monitor as an example application. The main outcomes so far are: • The ISA100.11a wireless sensor network standard is the strongest candidate to underpin such a system. It has a lot of industry support in the oil and gas sector, and from a theoretical standpoint there are several studies in the literature on its various components that support its use in power system environments. However, it is a relatively new standard so it needs further field testing. • A parallel wireless monitoring system has been deployed into the university microgrid laboratory to prove the concept of integrating an industrial WSN with a substation computer and SCADA system, the results of which are in the process of being written up. The microgrid ISA100.11a laboratory deployment has been tied into the lab SCADA system, demonstrating how this is carried out in practice. The technical aspects of the system have been fully documented, and an IEEE Transactions paper is nearing completion which documents its achievements. • ISA100.11 equipment from Nivis LLC has been used which has required		

[1] P. C. Baker, S. D. J. McArthur, M. D. Judd. A Frequency-Based RF Partial Discharge Detector for Low-Power Wireless Sensing. *Dielectrics and Electrical Insulation, IEEE Transactions on.* Vol. 17, Issue 1, pp. 133-140, February 2010

	more development work than expected to get up and running. A hardware and software platform for working with Nivis radios using off-the-shelf microcontrollers and sensors has been developed, and it has been signed off for release under MIT and Creative Commons licences which means that other university projects can work with it and develop the fundamental platform, where the improvements will be available to everyone. The platform has no inherent research value apart from being a platform for novel research activities, so 3rd party development only lowers the barriers to developing more advanced wireless CM systems in the future. The Power Networks Demonstration Centre and the Wind Turbine CM group at Strathclyde have already expressed interest in using the platform. There still remains an opportunity to publicise NG and Strathclyde involvement in this as it represents the first open source standards-based industrial WSN platform of its kind, so is truly a world leader in that respect. • The ISA100.11a standard provides native time synchronisation giving an accurate timing reference on each sensor node. One of the key contributions of the project is the proposal that this timing information can be used to phase resolve RF PD data. Investigations into this have found that the theoretical models of sensor network timing errors suggest that clock accuracies in the region of tens of microseconds are obtainable, which equates to a phase error of a fraction of a degree. Further work has been proposed to test this under experimental conditions. • Simulation of PD defect classification in the presence of clock errors has found that PD classifiers are generally tolerant to up to half a millisecond of clock error. This demonstrates that when classifying a PD defect in the presence of clock error, a clock error of up to a few hundred microseconds has little effect. This level of precision is theoretically possible under ISA100.11a, so it is feasible that remote RF PD sensor nodes can resolve PD activity against electrical phase using their own local clocks (and a suitable scheme for resolving phase against absolute time). • One of the key bottlenecks of building such a sensor is deploying and maintaining diagnostics on-sensor. This is a problem diagnostic models may not be applicable to certain pieces of plant or may become obsolete over time. Through investigating 3 different statistical feature vectors which distil raw PD pulse measurements into statistical measurements, it was found that an optimised feature vector developed by Georgia Tech gives meaningful diagnostic results with a very small feature set and low processing and memory footprint - ideal for microcontroller applications. The COMMAS system developed by Strathclyde over the past 10 years used a 101-feature vector developed by Gulski which is fairly computationally complex. Georgia tech only has 7 features and their method of calculation trivial to implement, only requiring a few hundred bytes of memory. The most interesting result of applying Georgia Tech's work is that it obviates the need to deploy diagnostics on-sensor. With only 7 values to transmit, statistical features can be transmitted over the wireless link and diagnostics and trending can be carried out on a PC. Initial results from using this also identify it as having the potential to be used as an anomaly detector, which could potentially be used to weed out non-PD events or identify changes in PD activity over time. • Investigations into off-the-shelf devices for PD detection have been fruitful. The MAX4003 RF detector is used in mobile phones to calibrate RF transmitter power. This device was identified, amongst similar devices, as being a candidate for an off-the-shelf PD detector. A study into the performance of this device has found that it can detect PD down to at least -60dBm, nominally using 7mA at 3V. The MAX4003 chip only requires an additional 2 capacitors and a resistor so they are cheap (< $1 at volume) and simple to implement. • The most difficult part of the puzzle is digitising PD pulse data on a

	microcontroller so that measurements can be supplied to a feature vector calculator. While the MAX4003 supports low-power PD detection and the Georgia Tech feature vector supports low-power, on-sensor data processing, capturing PD pulses using the current generation of analogue-to-digital converters is not feasible without the development of interfacing circuitry which, in its nature, will affect the measurement precision. This is still an open problem and requires further work to implement.
Collaborative partners	
R&D provider	University of Strathclyde

<table>
<tr><td>Project title</td><td colspan="5">Voltage Optimiser Pilot</td></tr>
<tr><td>Project Engineer</td><td colspan="5">John Fitch/Jude Robinson</td></tr>
<tr><td>Description of project</td><td colspan="5">This Project is to pilot the installation of a Voltage Optimiser at Rayleigh substation. This is to evaluate the claimed benefits of energy savings on electricity consumption by reducing the incoming LVAC supply voltage by a fixed amount into the site LVAC board. There are also additional benefits which are due the reduced heating and insulation stresses on the substation connected equipment, which should improve asset life and reliability.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £6k
External £1k
Total £7k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£57k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£50k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Introducing a voltage reduction system into incoming supplies is common practice for office and industrial installations and large savings in energy consumption are claimed.
This pilot is to install an EMS Powerstar Voltage Optimiser on one of the incoming LVAC supplies at Rayleigh substation and to carry out an evaluation of the benefits and any deployment issues over a period of 1 year.
There are 2 proposed options with different potential benefits:
• 1 x 500kVA unit on one transformer, cost £27.5k inc. installation
• 2 x 500kVA units, 1 on each transformer, cost £54.75k. Inc. installation
This solution has already been described in a Strategy Brief and the pilot installation at Rayleigh has been supported in principle at EEPIG in April 2011.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>10</td><td>-6</td><td colspan="2">16</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">The benefits are reduced energy consumption on energy metered sites and potentially improved asset life of LVAC connected equipment, due to reduced heating effects and insulation stresses. There will also be energy savings which will result in financial and emission savings benefiting National Grid.
EMS Powerstar has no moving parts and therefore minimum maintenance costs and procedures.
A desktop study on a typical site concluded:-
• Consumption 01/08/09 – 31/07/10 = 1,074,382kWh
• Site voltage: Min: 233.6, Max 241.9, Ave: 237.8
• Potential to reduce site voltage by 15V
• Resulting in a percentage saving of kWh = 9.4% of kWh (100% guaranteed)</td></tr>
</table>

	• kWh savings 100,992kWh, Tonnes of Carbon Dioxide saved 55.2 tCO2 If the desktop study is representative, there is potential savings of £2,760 saving in $C0_2$ per year, per site (cost of CO_2 @£50 / tonne) and a saving of £6,000 in energy consumption (assuming 6p per kwh), resulting in a saving of approximately £9,000 per site. If this was applied to all 337 substations nationwide and they were all similar, it could result in a year on year saving of approximately £3m per year.		
Expected timescale of project	2 years	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£5k
Potential for achieving expected benefits	This project carries little financial risk as if the expected benefits are not achieved, then there will be minimal cost to National Grid. An agreed success criteria will be agreed and form part of the commercial terms with EMS Powerstar. It is however expected that the claimed benefits will be achieved, due to the wide experience of installed installations worldwide. The main concern is on the impact on LVAC equipment unique to National Grid and this will be part of the evaluation. The likelihood of success is therefore considered to be very high.		
Project progress [Year to End of March 2012]	The project has just started. The planning for the trials is in place and orders raised.		
Collaborative partners			
R&D provider	EMS – Powerstar		

Project title	**A Probabilistic Wind & Ice Map for the UK**		
Project Engineer	Boud Boumecid		
Description of project	The Main objective is: • To provide a probabilistic UK wind/ice map to be used in the design of overhead lines using BSEN 50341/50423.		
Expenditure for financial year 11/12	Internal £3k External £39k **Total £42k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£81k	**Projected 2012/13 costs for National Grid**	£39k
Technological area and/or issue addressed by project	Currently UK electricity network owners have adopted BSEN50341 and BSEN50423 standards using either the 'general' approach to line design (BS8100) or the deterministic 'empirical' approach using fixed wind/ice parameters. The latter approach has been used for the design of National Grid's exiting OHL network. CENELEC standards allow alternative line designs based on probabilistic methods if evidence can be given of wind/ice loads. The COST727 project will provide the modelling tools necessary to develop a wind/ice map of the UK which will relate weather data to conductor ice loads. This will allow return periods of wind/ice loads to be evaluated on a geographical basis. Future UK line design can follow these new wind/ice loads which are expected to be less onerous than those predicted by BS8100, produced in 1986 mainly for the design of communication towers. Due to the tremendous developments over the last decades in global weather observations and computer capacities, the knowledge of physical and dynamical processes in the atmosphere have progressed accordingly, and indeed led to greatly improved quality and reliability in modern weather forecasts. It is therefore now possible to better describe the water cycle and the related phase transitions in clouds, as well as details in the formation of precipitation. In addition, the accuracy of forecasts of air temperature, wind speed and wind direction has improved significantly. In order to obtain such details in the lower atmosphere, it is also necessary to include adequate details of land and sea surface properties such as topography, land surface conditions, (forests, towns, lakes, farm land, snow cover, etc.), and also sea surface temperatures. By using nesting technology from global scales, it is possible to model local weather down to spatial scales relevant for span lengths of electric overhead power lines in 3-D topography. Every 6 hours the state of the atmosphere is analysed on a global scale and all parameters are stored in a 3-D gridded data base, covering the globe and throughout the atmosphere. This data base represents a synthesis of all measurements and observations from regular weather stations, radar automatic stations in remote areas of the Earth and radio soundings, in addition to data from radars and satellites. Hence, each grid point will provide comprehensive and reliable information on the state of the atmosphere to an extent which hardly any single weather station can comply with, other than for particular site specific applications. A model often used for advanced atmospheric applications is called the		

<table>
<tr><td></td><td colspan="4">“Weather Research and Forecasting”, (WRF), model, and is a state-of-the-art meso-scale numerical weather prediction system, used both in operational forecasting and also in atmospheric research. WRF solves coupled equations for all important physical processes, such as winds, temperatures, stability, liquid water content in clouds, types and amounts of precipitation, etc., in the atmosphere based on initial fields and lateral boundary values derived from global or regional analysis data. Hence, the WRF model provides realistic input data for post processing with conventional models concerning accumulation of different types of atmospheric icing, including rime, (in-cloud), icing, wet snow and freezing rain.

Due to atmospheric icing often occurs as a very local phenomenon, and icing intensity varies greatly in space, especially in complex terrain, modelling of icing requires a very high horizontal resolution. To deal with this challenge the model may apply grid spacing often in the range of 0.4 – 0.8 km, which is considered as extremely high resolution for meso-scale models

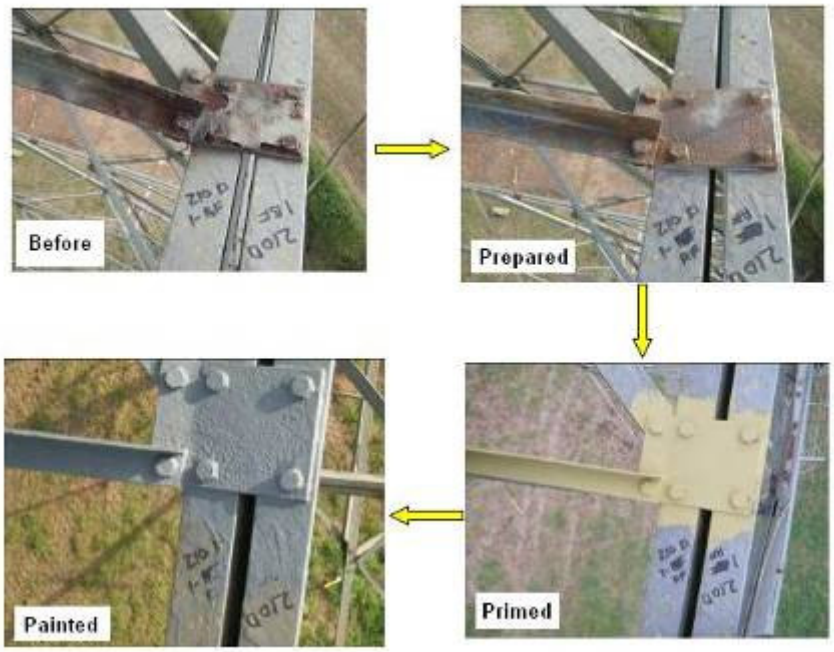
The WRF-based icing model developed by Nygaard under the COST programme will be applied to the UK Overhead Line network with the aid of Svein Fikke, a consultant meteorologist who has worked on ice load predictions for Norway and Greenland for many years.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>12</td><td>0</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Currently, tower and foundation strengthening work is being carried out on many OHL schemes, depending on geographical location and the proposed conductor system.

On the ZK and ZX OHL routes, an approach has been adopted by collecting local wind data form the MET office for the purpose of developing a wind map specific to parts of these routes. Savings > £10M have been achieved including a reduction of 60T strengthening steelwork, upgrading of 40 foundations was avoided and 60-70 towers avoided replacement. This cost excludes double circuit outage charges and health and safety and environmental impact.</td></tr>
<tr><td>Expected timescale of project</td><td>2 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>80%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>£342k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The Project has a likelihood of success high.</td></tr>
</table>

Project progress [Year to End of March 2012]	Stage 3 of the development of a probabilistic wind and ice map for the design of overhead lines in the UK is near completion (forecast July 2012) and is currently being finalised. Stage 3 deliverables included: • Production of high resolution wind only, ice only, combined wet snow and rime ice maps of UK. • These maps to be provided at a 2km resolution for a 50 year return period with wind speeds at 10m above ground • The ice loads (wet snow and rime ice) to be presented as kg/m ice loading on a geographical basis at actual land heights • The output will be based on OS grid reference points or GPS locations which will include both wind and ice loads at the specified resolution of 2 or 10km boxes. Actual stage 3 deliverables are: • The final resolution obtained was 500x500m, not 2km as stated as a deliverable. • A further map was produced based on the successful validation of estimations of the liquid water content of snowflakes. • This allowed the 'stickiness' of snow flakes to overhead lines to be evaluated (wet snow sticks when the liquid water content is between 15 and 40% of the snowflake). • This process also allowed the densities of the accretions to be determined. • This was also produced as an additional map to allow for radial ice thickness to be determined from the ice loads – required for wind loads. A stage 4 is currently being proposed as below: • The scope of the project is to take the information obtained in Stage 3 of this work and use this to provide a user-friendly software programme to determine exact loadings based on a number of User Inputs to determine the exact loads applied to conductors in the 500mx500m grid. This information can further then be fed into Overhead Line Design packages.
Collaborative partners	
R&D provider	EA Technology Ltd

Project title	**In-situ remediation of OHL Tower Steelwork**		
Project Engineer	David Smith		
Description of project	This project will consider a range of technologies, as employed in other industries, for the remediation of structural steelwork. It will assess the suitability of these technologies for use on lattice steel structures carrying live 275kV and 400kV conductors. The 3 key deliverables of this project will be: • The adaptation of recognised methodologies (techniques for cleaning the steel and combinations of products for re-coating it) for remediation of structural steelwork and the demonstration of the effectiveness of this solution (through trials and accelerated weathering tests) for use on National Grid's overhead line towers during outage & non-outage conditions. • The creation of a procedure/manual to support ongoing implementation of the techniques developed • Development of a training package to ensure consistent recording & communication the condition of the steelwork prior to and after remediation.		
Expenditure for financial year 11/12	Internal £64k External £18k **Total £82k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£137k	**Projected 2012/13 costs for National Grid**	£55k
Technological area and/or issue addressed by project	National Grid is in the process of investing over £150m on the refurbishment of OHL lattice steelwork towers over the RIIO period. Current asset policies require the replacement of steelwork identified as Grade 4 (in accordance with TG4) or worse – and this policy is being reviewed by a steelwork strategy team. One of the outputs of this team has been the identification of a need to consider the in-situ remediation of Grade 4 tower steelwork on main structural members as the volumes of steelwork involved are extensive and current methodologies require several circuit outages or a lengthy double circuit outage to complete the works. Faced with a growing capital programme and the need to minimise circuit outages, it is necessary to consider alternative methodologies to resolve this problem. The key issues to be addressed by this project are therefore the identification, recording and remediation of Grade 4 steelwork on primary structural members of National Grid's lattice steel towers under outage & non-outage conditions.		

Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		12	-2	14
Expected benefits of project	The most significant benefits to be delivered to the business by this project are: • The minimisation of circuit outage time required for the remediation of tower steelwork. It will be possible to undertake the majority of the steelwork remediation under non-outage conditions, with only essential cross-arm works to be completed during the outage. When this is compared to the current methodology (circuit 1 outage to transfer circuit to temporary towers, followed by circuit 2 outage to dismantle tower, replace steelwork & re-erect; followed by a final circuit 1 outage to transfer back to refurbished tower) it can be seen that this will be a much simpler process, allowing the utilisation of more staff over the non-outage season. • The reduction in cost per tower for the remediation. In the majority of cases there will be no requirement to transfer circuits to temporary towers resulting in a simpler, faster remediation process. The unit cost element of this will be established during the project, once a remediation methodology has been established and assessed, but is estimated to be up to £30m against a predicted budget of £150m.			
Expected timescale of project	2 years	**Duration of benefit once achieved**	8 years	
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£1,632	
Potential for achieving expected benefits	The likelihood of success is believed to be high, although this will be verified as the project progresses, initially a medium likelihood of success are estimated against the full benefit. The technologies to be assessed are used daily to resolve similar problems in other industries. The adaptation process will be undertaken by specialists in tower remediation, supported by other industry specialists in corrosion & remediation techniques. This will bring the right knowledge bases together to identify the right methodologies to be applied in any given circumstance. This will allow us to translate the results of this assessment into a repeatable process and identify the appropriate industry standard training for all personnel who will be involved in this type of work. The use of C3 Global in the development of a methodology to record & report the condition of tower steelwork builds upon their expertise in the deliver of the SAM (Strategic Asset Management) platform. The intention of the project would be to utilise this platform as the backbone of the reporting process, feeding back asset data in a manner similar to the other data sets being currently & successfully transmitted.			
Project progress [Year to End	The project has progressed well, though a little slower than originally hoped. Initial trials of the techniques have been encouraging and a full scale trial on the Cellarhead – Daines/Macclesfield scheme will take place early in the			

of March 2012]	2012 outage season. The likelihood of success is high. A number of safety concerns have been raised by team members, referred to specialists and answered. A reporting tool (for use on hand-held electronic devices, such as i-Pads) is being developed; this promises to be better than the original proposals of the team. The draft written standard is well developed and should be ready for issue within about 3 months. The technical specification and policy document have been drafted and will be progressed by a sub-group at a meeting on in June 2012. Project completion is expected by the end of 2012 such that all documents and processes will be approved and ready for use for the 2013 outage season. 
Collaborative partners	
R&D provider	Capcis, C3 Global, Electricity Alliance East, Electricity Alliance West, National Grid Tower Painting Contractors (CLC, PDC & Fountains)

<table>
<tr><td>Project title</td><td colspan="5">GIC DGA Monitoring and Alerting</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Graham Moss</td></tr>
<tr><td>Description of project</td><td colspan="5">This project will deliver the ability for National Grid to not only quickly access whether significant DC current (induced from charged particles streaming into the atmosphere from solar events) are passing through power transformers, thereby allowing instant notification of potential over-flux and failure, but also for the first time, an integrated system of on-line dissolved gas analysis systems which will produce the evidence of any fault activity caused by the DC current within minutes of the event. All data captured will be high resolution (second by second) and be handled, viewed and automatically alarmed through the Condition Monitoring SAM platform.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £4k
External £202k
Total £206k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£258k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£53k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">During periods of high solar activity, millions of tonnes of highly charged particles are ejected away from the sun during solar flares. As these particles approach earth, depending on the polarity of the particles, the earths magnetic field will either deflect them or draw them into the upper atmosphere down the lines of magnetic field.

As the particles stream through the atmosphere, then induce ground level charge of the opposite charge (much like lightning only of several orders of magnitude higher current). This induced ground current (under earth rotation) travels across the surface of countries, passing along the easiest (or most conductive) route. Unfortunately this often means overhead lines and cables. On the whole, the lines and cables are able to cope with this, but the transformers at the end of each circuit are at significant risk of over-fluxing and consequently the AC power component spills out of the core windings and flows around sections incapable of supporting it.

Overheating and damage to internal components can be disastrous, causing potentially catastrophic damage to windings. In these cases, it is not enough to simply detect the presence of the DC current, but it is absolutely necessary to have in place the ability to detect the early signatures of gas being produced from early failure modes.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>10</td><td>0</td><td colspan="2">10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">1. Direct, early detection of Geo-magnetically Induced Current (GIC) using ISL gateways to run second by second analysis via a Hall Effect CT
2. Direct, early detection of any fault activity in the wake of a GIC event at the transformer using on-line gas analysers, also monitored through the</td></tr>
</table>

	ISL gateway. 3. Condition Monitoring data from the substations to be monitored and alarmed automatically via SAM 4. Ability to detect onset of catastrophic failure thereby enabling early switch out of the asset 5. Ability to detect unusual gas activity alerting Asset Engineering of the need to keep a close eye on those assets. 6. Ability to reduce risk of to personnel working on the substation of a failure through early warning systems already in use for OESB04/2005 7. Ability for Network Configuration changes to deal with impending loss of multiple assets.		
Expected timescale of project	5 years	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£241k
Potential for achieving expected benefits	Based upon preliminary work assessing the new DC detection CT's coupled with our confidence of SAM based monitoring of on-line gas analysis systems to pick up early stages of asset failure the chances of success are very high.		
Project progress [Year to End of March 2012]	15 Transformers have been fitted with the prototype Hall Effect CTs for monitoring GIC effects along with 15 gas analysers for follow up evidence as to whether any GIC event caused internal damage. Paul Jarman has now taken up lead on tuning this system and some new CTs are expected to be required for specific levels of GIC. Some work is required on the data flow from site through ISL to SAM, but generally information from all installations is working. It is expected some further funding will be required to enable Doble to make adjustments and calibrations to the existing 15 units. Going forward a scheme needs to be raised to cover more transformers once the final details of the R&D system is ironed out.		
Collaborative partners			
R&D provider	Doble PT, Invisible Systems, C3Global		

Project title	**Non conventional current sensors**		
Project Engineer	Tahasin Rahman and John Fitch		
Description of project	This R&D Project aims : To evaluate the practicability, reliability and benefits of implementing alternative non conventional current sensors (i.e. Rogowski coil) based differential unit protection for Cable systems (i.e. Cable only and Cable & overhead line OHL) hybrid installations) over conventional Current Transformer (CT) based protection. To carry out the preliminary evaluation a pilot installation is recommended on Pitsmoor-Wincobank cable circuit in April 2012 as a monitoring unit. To determine the system's suitability to be utilised as Emergency Return to Service (ERTS) system. This will help to formulate a technical and operational knowledge base for Non Conventional Instrument Transformer (NCIT) protection systems which could lead to evaluation of future technical and procurement strategy to deploy as replacement and/or new Cable system protection.		
Expenditure for financial year 11/12	Internal £5k External £1k **Total £6k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£101k	**Projected 2012/13 costs for National Grid**	£95k
Technological area and/or issue addressed by project	Public perception towards OHLs and limitations on rights-of -ways in populated areas could potentially lead to an increase in construction of Cable only and Cable & OHL hybrid circuits in future. This situation presents a unique challenge for cable protection systems especially on the Hybrid one as protection systems must differentiate between cable and OHL faults to ensure the greater reliability of the power system. Current practice in National Grid is to implement two main unit protection schemes sourced from two different suppliers by using conventional CTs for 275kV and 400kV cable systems. However, CT installation and maintenance on cable circuit is immensely cumbersome due to bulk structure of CTs and space constraints associated with cable tunnels and trenches. Moreover, CTs on cable circuits are subject to a high magnitude of charging/discharging current during switching on and off, a condition which could lead to potential CT core saturation and mal-operation of the protection relays. For green field application these constraints may be addressed by an appropriate design solution; however on refurbished circuits especially where part of the OHL circuit is undergrounded by using cables, it becomes challenging to achieve the prescribed selectivity and security with conventional CT based protection scheme. In addition, to increase the operational reliability and reduce down time it is imperative to detect and discriminate transient faults i.e. lightning strikes on OHLs of hybrid systems to enable the Delay Auto Re-close as stated in TS 3.24.7 and PS (T) 10.		

<table>
<tr><td></td><td colspan="4">Through work with CIGRE and contacts with other utilities, an alternative non conventional current sensor i.e. Rogoswki coil base cable protection system by Cooper power systems has been identified as a potentially ideal solution which could offer greater operational, safety, and construction benefits over conventional protection systems due to the following features :

Linearity and no saturation even at high fault currents and magnetic inrush reducing the likelihood of protection mal-operation. This characteristic could also used for monitoring and profiling of insulation degradation which could lead to better asset management practice.

Light weight and compact size to address the space constraint issue.

Increased safety as opening secondary wiring during operation does not result in hazardous voltages ic

Installation does not require opening of the primary conductors owing to the splitcore design which could reduce outage time for installation and hence has the potentiality to be deployed as ERTS system.

Transmission Operator in Portugal, Rede Eléctrica Nacional (REN) is trialling and installing this solution for 220kV power cable systems including hybrid of cable & OHL since May 2010. They published a CIGRE paper titled “Experiences with Protection of Combined Overhead Line/Cable Circuits based on Non-Conventional Current Sensors” at Study Committee B5 Colloquium on September 2011. Their positive experiences and intrinsic benefits of this solution over conventional system have given greater confidence to National Grid to trial a pilot installation and if successful subsequently adopt a solution to meet UK transmission requirement. This could offer greater asset management benefits in the longer term, especially when managed and supported by well trained internal staff.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6</td><td>-4</td><td>10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The output from this project if successful will lead to adoption of the system for UK transmission system and feed into future technical and procurement strategy.

The benefits will include the following: -
• Development of new Cable Protection Strategy and Policy using NCIT based protection
• Standardised plant interface and “one off” standard solution

CAPEX savings:.

• For budgetary comparison with traditional approach: -
• Installed cost of 400kV single phase CT is £50k = £300k for 2 x 3phase sets
• Traditional two ended NICAP installed Feeder Protection Panel typically £500k. Total cost is approx £800K.
• The estimated commercial cost for this equipment is approx £200k which is 25% cost of the traditional approach.

OPEX savings (train internal staff and reduce PDSA cost. Also, the equipment is delivered with 10years warranty).

Reduced System Access for extensions and future replacement increase personnel Safety (No risk of hazardous voltage when the secondary wires are opened in-service inadvertently)

Increase system reliability and reduce down-time.</td></tr>
</table>

Expected timescale of project	1 year	**Duration of benefit once achieved**	5 year
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£30k
Potential for achieving expected benefits	This project will collaborate closely with the internal (ENI, MD(E) and Construction) and external resource (Cooper Power Systems and REN) pools for adoption of the solution on the UK Transmission system. The likelihood of success is high due to positive experience of REN with the similar installation.		
Project progress [Year to End of March 2012]	The Project team has been formed and the 1st project inaugural meeting was held with Cooper Power in December 2011. Consecutive meetings were held with MD(E), Construction and Cooper powers to establish any technical issues related to installation and system interface. Procurement process is in progress to purchase the necessary service and equipments. The protection system is planned to be commissioned by the 25th of May 2012.		
Collaborative partners			
R&D provider	Cooper Power System, USA		

Project title	**Detection and Measurement of ACSR Corrosion**				
Project Engineer	Michael Hannon				
Description of project	Development of a replacement for existing ACSR Conductor Corrosion detection equipment.				
Expenditure for financial year 11/12	Internal £8k External £1k **Total £9k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**		
Total project costs (collaborative + external + [company])	£154k	**Projected 2012/13 costs for National Grid**	£145k		
Technological area and/or issue addressed by project	Conductor life and reliability are of increasing importance as ACSR conductor reaches the end of its technical asset life. Conductor condition information is vital when making optimised asset replacement decisions. Approximately 20 years ago, the CEGB developed non destructive test equipment to measure steel core loss. The equipment developed from this project is still in use and is the only proven method of detecting loss of galvanising in ACSR conductors. The existing equipment is obsolete and increasingly difficult to operate and maintain. The analysis software runs only on legacy hardware and with unsupported DOS software only. There is no modern equivalent equipment available world-wide.				
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**	
		10	-3	13	
Expected benefits of project	There is a requirement to maintain and reliably operate ACSR conductor to end of asset life. Investment decisions on scope, timing and prioritisation of full refurbishment or fittings only schemes are informed through condition information. The capability to deliver an optimised OHL asset replacement plan relies on the ability to select suitable routes for fittings only schemes. Without ACSR corrosion test equipment, extensive in span destructive sampling would be required leading to additional longer system outages, additional site resources and thus higher costs for collecting the condition information. With a sharp increase in OHL asset replacement schemes planned it is essential that National Grid can continue to use a non destructive test to measure steel core loss and ensure condition information can be accurately and efficiently collected. Without this equipment it is expected the costs for collecting the condition information will increase from £1500 to £4500 for each section of a route where condition information is collected. This could equate to an additional cost of £800k for the tests which are required to support the plan.				
Expected timescale of project	2 year	**Duration of benefit once achieved**	5 year		

Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£232
Potential for achieving expected benefits	Very High. The principles of the technology are already proven. Hydro Quebec have an extensive R&D capability, driven by the same needs as National Grid and are fully committed to develop a reliable long term replacement using modern hardware and software.		
Project progress [Year to End of March 2012]	National Grid and Hydro Quebec are working in collaboration to establish an updated version of the ACSR condition assessment probe. During 2011/12 we have joined forces to understand the theory behind the technology and began work on a working prototype. Initial testing of probe configurations has proved successful and we are working towards trialling a working prototype, scheduled for Sept 2012.		
Collaborative partners			
R&D provider	Hydro Quebec – IREC		

Project title	**Measuring alcohols to determine early stages of cellulosic insulation degradation**		
Project Engineer	Gordon Wilson/Ruth Hooton		
Description of project	This project will look at the potential for identifying the early stages of insulating paper degradation by measurement of methanol and ethanol in oil. Earlier detection of cellulose breakdown will provide greater visibility of transformers that are ageing but not in danger of imminent failure and would improve longer term transformer replacement plans. It might also be possible to identify thermal design issues during heat run tests of new transformers.		
Expenditure for financial year 11/12	Internal £6k External £5k **Total £11k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£11k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	When cellulose chains that form paper insulation in transformers degrade they are known to produce a class of compounds called furfurals and this has been used an indicator of paper ageing for many years. However, the excellent correlation that is typically seen in laboratory studies between concentration of furfurals (FFA) and reduced DP (degree of polymerisation – an indicator of paper condition) is not usually seen in transformers as they age. The presence of FFA at relatively high concentrations (>1.5ppm), especially evidence of an increasing trend in concentration, is a good indicator that the paper is nearing end of life. When FFA is present at lower levels, or it is apparently stable, then the link to ageing is less clear. Complications arise because of a number of factors: FFAs are not thermally stable and will degrade at a rate dependent on the temperature The temperature affects the concentration because it is in equilibrium between the oil and the water in the paper. Some transformers contain oils that were contaminated during refining and the FFA measurements are uninformative FFA may be produced in large quantities in a localised area and give the same concentration in a sample as a low level FFA production throughout the windings. Therefore FFA measurements are generally regarded as contributory evidence of paper degradation and no direct relation to DP values can be reliably inferred. In the last few years, IREQ in Canada have been developing diagnostic methods of detecting paper degradation by measurement of alcohols (methanol and ethanol) in oil. Primarily this research has focussed on using these markers for ageing of thermally upgraded paper in sealed transformers. At the recent Cigre A2/D1 Colloquium in Kyoto, Laborelec of Belgium presented their own research in this area. Laborelec are already working with EdF to consider the possibility of detecting paper degradation by alcohol measurement in transformers with Kraft paper in sealed transformers. Laborelec have developed the tools for measurement and have found the presence of alcohol in transformers as well as		

<table>
<tr><td></td><td colspan="4">in laboratory studies. Further work is required to elucidate the relationship between alcohol concentrations and the significance for paper degradation.

It is proposed that a feasibility project is conducted with Laborelec to see if alcohols may be found in National Grid's free-breathing transformers in service and also whether any alcohols may be found in oil during heat run tests of new transformers. If the feasibility study is successful then further work would be proposed to develop our understanding of the significance of the results, i.e.

Is it possible to identify the early stages of degradation of Kraft paper in free-breathing transformers so that our understanding of the condition of transformers in replacement category 10+ years is improved?

Is it possible that transformers with weaker thermal designs can be picked up during heat run tests even though FFAs are not produced?</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>4</td><td>-3</td><td>7</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Better understanding of the degradation of transformer insulation will improve longer term transformer replacement planning and ranking of apparently similar asset replacement candidates.

Identification of thermal design weaknesses in transformers during heat run tests would be extremely beneficial as it could prevent early asset write-offs that cost £millions. Design changes to transformers such as the family that included Lackenby SGT4, SGT6 and Rochdale SGT5, which have weak thermal designs, might have been made earlier and prevented many of them being replaced less than 20 years after manufacture. The potential benefit must be weighed against the probability that future designs will have such weaknesses and that they will be identifiable during heat run tests as this may be low.</td></tr>
<tr><td>Expected timescale of project</td><td>1 year</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£7k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">Research in this area is still fairly new and the likelihood of the final objectives being successful would be far from guaranteed. However, as the technique for measuring alcohols in oil is reasonably well developed the likelihood that the feasibility study will successfully identify whether further work is justified is high.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">A number of samples were submitted for analysis and tested by Laborelec. Methanol was detected in only a small number of cases and only at levels just above the detection limit. This would suggest that methanol may not be as good an ageing marker for free-breathing transformers as for those that are sealed.

No further work is planned in the short term but we will continue to take an interest in ageing markers, including methanol, through EPRI projects and a new CIGRE working group. Where opportunities arise we will submit samples for analysis or take a more active role in the studies if appropriate</td></tr>
<tr><td>Collaborative partners</td><td colspan="4"></td></tr>
</table>

R&D provider	Laborelec (Begium)

Project title	**Partial discharge monitoring of DC cable (DCPD)**		
Project Engineer	Greg Tzemis		
Description of project	To investigate and develop a method for monitoring partial discharge (PD) activity in mass impregnated (MI) HVDC cable. The outputs will enhance National Grid's understanding of high power HVDC cable and facilitate the development of improved Technical Specifications. The test method developed should be sufficiently effective and efficient to allow its deployment within the constraints of a commercial Type Test programme.		
Expenditure for financial year 11/12	Internal £3k External £23k **Total £26k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£14k	**Projected 2012/13 costs for National Grid**	£41k
Technological area and/or issue addressed by project	National Grid's Technical Specifications require MI cable to be tested to the internationally accepted CIGRE test procedures. As the operating voltages of DC cables increase cable manufacturers are progressively taking the view that the CIGRE test voltages are too severe and unless the test voltage is reduced (particularly during the cooling phase of heat cycling) there is an unacceptably high risk of the cable failing the type test. In order to achieve type registration of these cables it will be necessary for National Grid to consider relaxing the test voltage. There is no published basis to justify this reduction and it is difficult to assess the risk of accepting cable systems which cannot meet the CIGRE requirements. There is a possible mitigation strategy based on applying condition monitoring techniques during type testing so that the test is not reliant on simple withstand criteria. When a MI HVDC cable fails the heat cycle type test it is likely to be the result of accumulated PD damage. Hence PD monitoring appears to be the most appropriate option to investigate. PD detection in DC systems is significantly more difficult that in AC systems because (i) the discharge repetition rate if far lower and (ii) there is no alternating voltage to which the discharge activity is synchronised. It is therefore difficult to distinguish between PD activity and random background noise. Recent work at Southampton on PD from AC cable systems indicates that clustering algorithms can be used to distinguish between PD from different sources. It appears feasible to use this technique during DC testing to distinguish between PD from the cable and that from the terminations or external noise sources. The technique relies on analysing the PD signals to measuring the energy content in a number of time and frequency windows. The multi-dimensional results are converted to a pseudo 3-dimensional data set for easier visualisation and automatic classification. In addition to developing a procedure to detect and classify DC PD signals the work will emphasise the need for the technique to be suitable for implementation during DC cable type tests. This requires that PD testing can be done safely in an industrial laboratory without impacting on the smooth running of the type test.		

Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		5	-1	6
Expected benefits of project	The research will provide a more informed test regime, which will give a better understanding of the performance of the cable system. From this National Grid will gain the information needed for a well-managed change in its Technical Specifications. This will increase the number of suppliers that can become type registered without significantly increase the risk of a major system failure. The estimated costs of a failure on a major HVDC submarine link are in excess of £15m due to the timescales to make a cable repair. Having an increased number of qualified suppliers will lead to reduced capital cost and/or delivery timescales on large HVDC projects.			
Expected timescale of project	1 year	**Duration of benefit once achieved**	5 years	
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£76k	
Potential for achieving expected benefits	This proposal seeks to build on the successful record of work at Southampton University on partial discharge testing of HV cable system; This has including PD testing of long lengths of submarine cable in a factory environment. Initial work suggests that the instrumentation system is capable of acquiring PD data during DC testing. The excellent results of recent work on the use of clustering algorithms to distinguish between multiple PD sources in AC cable gives a good degree of confidence that the project will have successful outcomes.			
Project progress [Year to End of March 2012]	Literature search completed 2011, first report issued to National Grid, awaiting update of testing. Delayed start to test activities, project completion now for September; still within Western Link TR timescales.			
Collaborative partners				
R&D provider	Southampton University			

<table>
<tr><td>Project title</td><td colspan="5">Transformer lifetime modelling</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Paul Jarman</td></tr>
<tr><td>Description of project</td><td colspan="5">This project is aimed at optimising capital investment in replacement transformers. For long term replacement planning purposes transformers have been given asset lifetimes of 40 to 80 years based on experience and engineering judgement. Actual replacements are based on condition, using several assessment methods which have been successfully developed and applied. There is however a gap in the knowledge of transformer end-of -life modelling linking the probabilistic and deterministic approaches of the long and short term plans. This project has the objective of building on existing knowledge of ageing mechanisms to provide a model to bridge the gap and provide credible predictions of medium term (4-10 year ahead) requirements for transformer replacement volumes. The basis for the plan would be the existing policy of maintaining system reliability and unplanned transformer replacements at existing levels. The dependence of system reliability on plant reliability would be part of the study. Transformer replacements will cost between £10M and £30M per year for the foreseeable future, failure to plan effectively could have significant implications for regulatory review and system reliability.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £5k
External £115k
Total £120k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £27k
External £220k
Total £247k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£367k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Optimising modelling techniques to support capital replacement planning for transformers</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>6</td><td>-1</td><td colspan="2">7</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">Being able to accurately predict transformer replacement numbers, and justify those predictions to the regulator will optimise capital expenditure and allowable income. The expenditure is likely to be in the range £10M to £30M over the next 20 years or more. Conservatively assuming that the accuracy of the investment in new transformers could be increased by about 1% as a result of the knowledge gained, would lead to a saving of about £150k per annum either in the capital programme or in the costs associated with reducing system reliability.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">4 years</td><td>Duration of benefit once achieved</td><td colspan="2">5 years</td></tr>
</table>

Probability of success	50%	**Project NPV = (PV benefits – PV costs) x probability of success**	£4k
Potential for achieving expected benefits	The potential for achieving potential benefits is as the original plan. Some very interesting results on the effect of cooler thermostat setting temperatures on lifetime have resulted in a program to lower them on some units with expected additional benefits in extending lifetimes. Expected transformer lifetimes have been revised partly based on this work to optimise the replacement plan. Practical work on oil and paper insulation systems and the effect of moisture and aging has not shown any serious or unexpected phenomenon that would undermine existing lifetime assumptions.		
Project progress [Year to End of March 2012]	The project is now complete with the PhD theses from both Manchester and Southampton written and successful. Thermal modelling aspects of the project have been very successful and highlight the importance of good thermal design in the life of a transformer, this knowledge is being used in the assessment of new transformer designs. The statistical analysis of transformer failure data has validated the early end of the lifetime model. The work together with some other inputs has been used to review asset lifetimes. The thermal modelling aspect of the project is running to plan and has highlighted deficiencies in existing calculation methods that could well be important for assessing transformer designs for long lifetimes. There were significant delays on the transformer rig at Southampton because of accidental equipment damage which was covered by insurance. This aspect of the project intended to demonstrate how inter-phase barrier damage can lead to breakdown was only partially successful. The scaling factors (about ¼ scale was used) mean that sustaining partial discharge without breakdown was harder than expected. The results however indicate that no particular new ageing mechanisms exist and that moisture although needing control is not likely to be a barrier to the continuing reliability of older transformers.		
Collaborative partners			
R&D provider	Manchester University, Southampton University		

<table>
<tr><td>Project title</td><td colspan="5">Effective Protective Coatings for OHL Towers</td></tr>
<tr><td>Project Engineer</td><td colspan="5">David Clutterbuck</td></tr>
<tr><td>Description of project</td><td colspan="5">A number of tests have been carried out by EA Technology on behalf of a group of ESI companies. This includes the evaluation of a number of new products and special purpose paint systems.

Inspections of trial towers painted with a newly developed environmentally friendly water based system have also been carried out. National Grid has requested the opportunity to participate in the final stages of the testing. Participation will ensure access to all test results to date and the final report when complete.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £11k
External £7k
Total £18k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £21k
External £26k
Total £47k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£124k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£0</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Impending European legislation may restrict further the use of high VOC paints for any industrial use. The only approved National Grid tower paint product falls into this category. Maintenance policy requires the painting of approximately 1200 towers per year.

Predicated ongoing spend on tower painting is £6.85 million per year, hence requirements have been identified for continued research to test and evaluate the performance of alterative paint products to ensure the company is prepared for any changes to legislation.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>9</td><td>0</td><td colspan="2">9</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">The expected benefits of undertaking this research are as follows:
• Compliance with European Law regarding VOC emissions.
• Reduction to single coat paint systems (two coats currently used).
• Reduction of steelwork replacement during OHL refurbishments.
• Optimised Asset Management approach for managed paint maintenance.
• Improved algae removal solution.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">5 Years</td><td>Duration of benefit once achieved</td><td colspan="2">5 Years</td></tr>
</table>

Probability of success	80 %	**Project NPV = (PV benefits – PV costs) x probability of success**	£3,048k
Potential for achieving expected benefits	The original alternative epoxy paint proposed has proved problematic and not fully effective during field trials, however significant progress has been made with alternative low VOC and water based coatings. The alternative coatings being tested show good potential for meeting both VOC compliance and performance. The new products are still improving but are already being introduced ahead of European legislation changes.		
Project progress [Year to End of March 2012]	Development of improved single coat paint solutions. Interest from additional suppliers for supply of paint systems. A number of paint systems have been tested and discounted. For non-corroded steelwork a single coat is proving effective while for corroded steel, enhanced preparation and a 4 coat patch system is being tested. This work is ongoing and a change control is being prepared.		
Collaborative partners	United Utilities, Scottish Power, CE Electric UK (NEDL), Scottish and Southern Energy, Central Networks, EdF Energy.		
R&D provider	EA Technology		

<table>
<tr><td>Project title</td><td colspan="4">Phase III Centrifuge Modelling and Field Monitoring of Wind Induced Loads on Transmission Towers</td></tr>
<tr><td>Project Engineer</td><td colspan="4">D Clutterbuck</td></tr>
<tr><td>Description of project</td><td colspan="4">To carry out enhanced environmental modelling of full OHL support system fully instrumenting a short section of line.

To carry out centrifuge modelling to expand the range of foundation and soil types currently considered, using the data collected by the environmental modelling.

To assess the appropriateness of current British Standard method for determining tower foundation uplift capacity and influence the change of industry design codes.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £11k
External £74k
Total £85k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £20k
External £194k
Total £214k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£299k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The outsourcing of all National Grid Tower design activities for OHL refurbishment using Pre-Sanction Engineering (PSE) has highlighted a difference in approach taken by NGT and its contractors to assess the capacity of existing structures and foundations. Contractors use the current design code BS EN 50341 (normally intended for new build). The contractors' analyses have indicated that tower foundations have a substantially lower capacity to resist uplift forces than previously assumed. To date, foundation-strengthening work identified by PSE has been put on hold pending further R&D by National Grid. These issues have been partially addressed by recent R&D work ref NSETH118. This previous work has successfully established a method of testing 1:50 scale foundation models in centrifuge apparatus capable of giving full scale results.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>0</td><td>9</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">National Grid will benefit from this research by being able to assess OHL foundation capacity reliably, optimising tower strengthening upgrades and avoiding unnecessary foundation reinforcements.

The research will contribute to updating to National Grid's Technical Specification for line refurbishment and provide a high level of confidence that National Grid structures are fit for purpose.

This research will help significantly reduce the number of foundation upgrades required during the planned capital refurbishment program.</td></tr>
</table>

Expected timescale of project	7 years	**Duration of benefit once achieved**	5 years
Probability of success	50%	**Project NPV = (PV benefits – PV costs) x probability of success**	£3,398k
Potential for achieving expected benefits	High given the initial results and the skills in the university group.		
Project progress [Year to End of March 2012]	Scale testing for the final solution revealed additional complexities that were not anticipated by the equipment solution supplier and their ability to complete the work was put in doubt. As a result Southampton have modified the solution and changed suppliers. This has introduced a delay in the final site work. Site testing work will recommence 16th July 2012		
Collaborative partners			
R&D provider	University of Southampton		

<table>
<tr><td>Project title</td><td colspan="5">OHL Conductor Asset Lives</td></tr>
<tr><td>Project Engineer</td><td colspan="5">David Clutterbuck</td></tr>
<tr><td>Description of project</td><td colspan="5">To review the technical asset life for ACSR Conductors</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £14k
External £1k
Total £15k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £12k
External £40k
Total £52k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£67k</td><td colspan="2">Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Historically, conductors used on the system are aluminium conductors, steel-reinforced (ACSR) of Zebra (400mm2, 54/7, 28.62mm diameter) design, but with different levels of grease protection, and past exposure to environmental conditions that vary widely throughout the UK. Other stresses (e.g. conductor vibration due to subconductor oscillation) may also have a significant influence on remnant life. This project is to determine the condition of conductors, both in service and taken from service, assess the extent and form of any damage and corrosion, and determine the likely remnant life of conductors</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>12</td><td>-3</td><td colspan="2">15</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">There is a requirement to maintain and reliably operate ACSR conductor to end of asset life and produce an optimised plan for replacement. To optimise replacement decisions, an accurate view of remaining life for installed conduction on a range of environmental conditions is required. The OHL asset replacement budget is in excess of £500 million planned for this and future 5 year periods. The work will provide information to feed into a review of ACSR conductor asset lives by enhancing the understanding of corrosion and fatigue as deterioration mechanisms. Confirmation of existing lives with the recent sample data will give confidence that the current asset lives are valid and if possible there may be scope for life extension and replacement deferral. If one 200km scheme is deferred beyond the current price review period as a result of this project, this will lead to deferral of £60m of capex.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">5 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60 %</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>£16k</td></tr>
</table>

Potential for achieving expected benefits	End of life for ACSR conductors has historically been taken as a 15% loss of conductor strength. However recent forensic work has found slower rates of loss of strength than previously expected. This work is to better understand the degradation mechanisms. Potential for achieving this goal is high.
Project progress [Year to End of March 2012]	The final report for this work has been completed and published by ERA. The conclusions were that ACSR conductor shows a slow decrease of tensile strength over time. Rate of strength decrease is linked to the installed environment and fittings condition. Where corrosion is not an issue loss, of strength is linked to metal fatigue. The 15% loss of strength remains an appropriate definition for end of asset life but in some cases the rate of deterioration is slower than previously anticipated.
Collaborative partners	None.
R&D provider	ERA Technology

Information Security / Knowledge

Project title	**HVDC EngD - Richard poole**			
Project Engineer	Paul Coventry / David Fidler			
Description of project	An EngD student with an interest in National Grid in an area of the company which will become increasingly important over the upcoming years.			
Expenditure for financial year	Internal £3k External £10k **Total £13k**		**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£17k		**Projected 2012/13 costs for National Grid**	£5k
Technological area and/or issue addressed by project	HVDC			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		5	-2	7
Expected benefits of project	The improvement of a National Grid employee and working on an area identified as a weakness within the business. Even if the issues surrounding the project are solved, the knowledge and learning by Richard will be directly translated back into the company considering it is around HVDC.			
Expected timescale of project	4 years	**Duration of benefit once achieved**	Years	
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£17k	
Potential for achieving expected benefits	There is a high likelihood that the student will complete the EngD, therefore the knowledge learning and understanding will be directly transferred into the business.			

Project progress [Year to End of March 2012]	Started to carry out modelling on Power World Simulator versions 15 and 16 to gain an appreciation and high level understanding of how HVDC interacts with the AC network. Areas such as fault analysis, outage scenarios and reactive power issues have been investigated as part of the original Literature review expected during the first 12 months of the EngD programme. The knowledge gained from this initial phase of the literature review will now be carried forward to the next phase to be applied to Powerfactory power system analysis software to start the first official project of the EngD programme looking at HVDC and AC system interaction (Faults/outages etc.)
Collaborative partners	N/A
R&D provider	University of Hertfordshire

Network Protection and Control

Project title	**Voltage Transformer Comparison**		
Project Engineer	Josh Jones		
Description of project	To evaluate the performance of the three types of Voltage Transformer used in National Grid with respect to Quality of Supply and System monitoring capabilities.		
Expenditure for financial year 11/12	Internal £3k External £24k **Total £27k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£34k	**Projected 2012/13 costs for National Grid**	£7k
Technological area and/or issue addressed by project	There are an escalating number of increasingly complex and non-linear loads and generators being connected to the transmission network. To ensure that the network remains secure, background harmonic levels must be checked before a new generator is connected. At present measurements are usually taken up to the 50th harmonic, but recently it has not been unusual for measurements to be required up to the 100th harmonic. A lot of work is being carried out to find suitable and reliable monitors to measure and record the data. When a portable monitor is taken to a substation to measure harmonic data, it is connected to a Voltage Transformer (VT). At present, there are three types of VT, a Wound VT (WVT), a Capacitor VT (CVT) and a Resistor Capacitor Divider VT (RCD VT). It is commonly accepted that the RCD VT is the most suited to this purpose, as it specially tuned to each application; unfortunately this also makes it very expensive. A WVT is also more expensive due the amount of copper required and although it is more expensive it is not particularly suited to measuring harmonics as it has a low bandwidth, only allowing measurements up to around the 12th with any good accuracy. The third option is to use a CVT that has been fitted with a PQ Sensor. This is a simple technology that increases the accuracy and the bandwidth of the CVT, which is otherwise limited in accuracy to measurements at fundamental frequency. At present there are only six RCD VTs on the network and a very limited number of CVTs that have been retro fitted with a PQ Sensor (PQCVT). This means most of the Quality of Supply (QoS) measurements are carried out using a WVT. It is proposed that we install a PQ Sensor at a site and do a comparison of the three VTs, to confirm or refute the hypothesis surrounding Voltage Transformers with regards to QoS. Once this study has been carried out it will provide a sound understanding of VTs and aid informed decisions when reviewing any policy surrounding the use of VTs for QoS and Dynamic System Monitoring applications. A difficulty with this trial has been finding a site with the three types of VT on the same circuit. One such location is Singlewell 400 kV Substation. The next problem was finding an outage on the correct circuit to provide us with an opportunity to retrofit the CVT with a PQ Sensor. The next outage that we could do this during is 31/10/11 – 04/11/11. If this outage is missed a comparison will not be possible for another two years (2013). To make this VT comparison fair three identical monitors are to be used.		

<table>
<tr><td></td><td colspan="4">Although we have two types of power quality monitor, of which we have three units, these monitors are not able to measure over the 50th harmonic. For the purposes of this trial we would like to measure as high as possible to give us a true indication of the accuracy and capability of each VT. It is also proposed to purchase two power quality monitors to carry out this comparison.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>5</td><td>-4</td><td>9</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">By carrying out this comparison, we will understand what effect using different types of VT will have on the accuracy of Quality of Supply and System Monitoring data.

This in turn will have an effect on how future policy is written with regards to quality of supply and deliver more accurate data in any reports relating to harmonics and quality of supply.

This comparison will also confirm whether retro fitting CVTs is the economic solution to enhance functionality of the CVT for the purposes of QoS.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">1 year</td><td>Duration of benefit once achieved</td><td>5 year</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£30k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The comparison is very likely to be carried out successfully due to the proven track record of PQCVTs as experienced by other utilities and the numbers being deployed by these utilities.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">At present, site surveys have been carried out, RAMS have been produced and we are now awaiting a date from planning for when we are able to carry out the work. A successful installation has been completed at Deeside 400kV substation, but a comparison has only been made against the existing CVT. It is expected the installation will take place in summer 2012.</td></tr>
<tr><td>Collaborative partners</td><td colspan="4"></td></tr>
<tr><td>R&D provider</td><td colspan="4">BVM Systems and GMC Instrumentation</td></tr>
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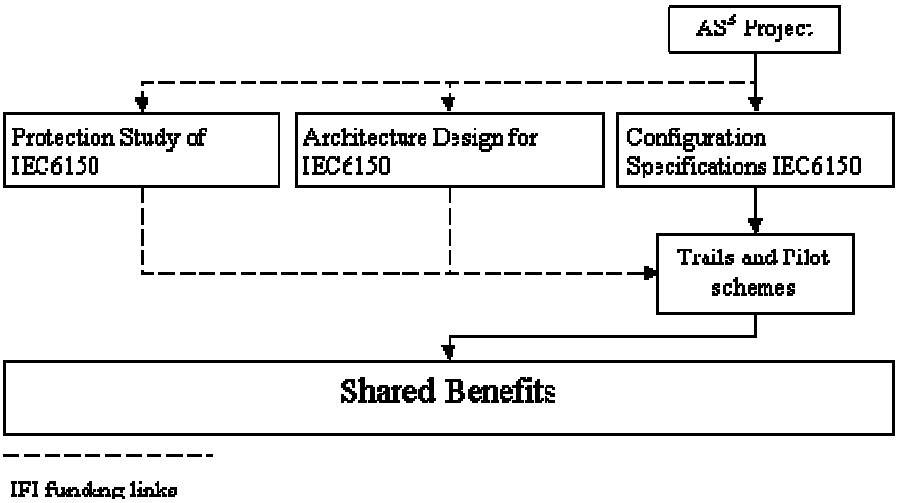
<table>
<tr><td>Project title</td><td colspan="4">Architecture for Substation Secondary System (AS3) Project</td></tr>
<tr><td>Project Engineer</td><td colspan="4">An Wen</td></tr>
<tr><td>Description of project</td><td colspan="4">The project entails:
Review of current policy and practice
To identity and understand the whole life cycle issues for the existing protection and control systems.
Strategy document for substation secondary systems
To develop a road map to show the strategy for the application of protection and control new technology in the short, medium and long term.
Feasibility Study
To investigate new technologies
To collaborate with major suppliers/Alliances to share information.
To standardise Substation primary and secondary system interface
To benchmark with leading utilities.
Trials and Pilot schemes
To try the new approach in parallel with existing systems with outputs disabled - “Piggy-back” trials
To apply the new approach to some real projects as pilot schemes (Min 2)
New Policy
To develop a new policy for the substation secondary system,
To develop associated technical specifications.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £56k
External £1k
Total £57k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £157k
External £535k
Total £692k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£749k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">To form a new policy for substation light current systems aimed at maintaining high availability and reliability of the transmission network by balancing the whole life-cycle risk, performance and cost of assets.
To develop a new architecture for substation secondary systems by introducing new technologies, targeting a quicker and easier approach for the installation and replacement of protection and control equipment beyond 2011.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>10</td><td>3</td><td>7</td></tr>
</table>

Expected benefits of project	This project is to identify and understand the potential benefits and risks associated with designing and implementing new substation secondary system architecture. It will do this by deploying new technology/developments such as standard interface modules, bay process bus and IEC61850 communication protocol. It is important the National Grid take a leading role in this area so we can provide manufacturers with specification as to what is needed rather than being led into this system by the manufacturers. AS^3 has linked IFI projects that contribute to the overall shared benefits of the project increasing the likelihood of success as the project progresses as shown below.  The benefits expected from this project will not be appreciated until the AS^3 system has been implemented. The full benefit of the project will only be seen when all AS^3 systems have gone through a complete life cycle estimated to be roughly 20 years. This project will investigate the possibility of this new architecture which will have a long lasting interface to the primary plant, which should not have to be altered or replaced should the secondary systems need to be replaced. This project is investigating the feasibility of achieving whole life cycle benefits, so that the asset life of light current system in a substation can be optimised. The project will investigate benefits in the following areas: • The design and development potentially can be standardised at all levels (station, bay and interfaces) within a substation. This will allow proven solutions be used repeatedly for different projects/sites, thus the project risks and resources will be minimised saving time and money. • The installation and commissioning will be much safer and quicker than traditional approaches. The “plug and play” will be possible for the installation and replacement due to use of IEC61850 based fibre optical bus and standardised interfaces. Therefore the required outages of primary system will be significantly reduced ensuring availability is maintained. Safety, health and environment are improved by reducing the need for cross-site secondary circuit cabling migrating associated risks. • The operation and maintenance could greatly benefit from the new approach. Full deployment of digital technology and removal of copper wirings should make the operation of the secondary system more reliable as faults can be more easily recognised and replaced. This would also challenge the traditional concept/requirements for maintenance. The new technology will enhance functions such as condition monitoring and remote access, which should further improve the operation and maintenance by

<table>
<tr><td></td><td colspan="3">providing real time information to enable the operator to take the best-informed action. Also this process will be safer as the new secondary systems transmit data of CT and VT analogue signals via bay process bus. This poses no safety risks of opening CT circuits, and hence improving the safety when the protection replacement is carried out with primary circuit in service.

• The replacement and de-commissioning can be achieved in a quick “plug and play” manner. Components used will no longer be limited to a specific manufacturer due to Inter-operability/Inter-changeability facilitated by the IEC61850 protocol. This will significantly reduce the requirements and costs for the Post Delivery Support Agreement (PDSA). By enabling any unit to be replaced by any other IEC61850 machine therefore not tying National Grid into uncompetitive PDSA’s
The new technology using IEC 61850 communication protocol will enable vendor interoperability and easier modification and extension of the secondary schemes, particularly allowing reconfiguration and feature enhancement by software means, rather than the modification of hardwiring as would have been the case in the past.

The fully digitised fibre optical architecture will also form an additional “isolation layer” for the electromagnetic noises from primary system. This will significantly improve the reliability of secondary systems and consequently reduce the requirements for the costly Electro-Magnetic Compatibility (EMC) for the protection and control devices.

A similar pilot scheme by GE has reported potential savings of 25% in the installation of secondary systems, using a plug in and play system of installation.

Estimating a saving of approximately £50K (5%) per substation with AS3 implemented, with an expected roll out rate of approximately 50% of substations refurbished or newly built to have AS3 each year making a total saving of approximately £500K per year.</td></tr>
<tr><td>Expected timescale of project</td><td>3 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>50 %</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£19k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="3">Technically, it has a good potential to achieve expected benefits as:

• International committees such as IEC and CIGRE have set up working groups to carry out studies on relevant technical subjects; some standards and application guides have been published. National Grid is participating in most of the working groups directly or indirectly.

• All the major suppliers have been working in this area for more than 10 years, product prototypes are being produced and tried. Some trials and pilot schemes with leading suppliers are planned within this project.

• Some leading utilities such RWE, Tennet have started some pilot schemes. Benchmark with those utilities is one of the key feasibility studies within this project.

• This project is governed and managed with a hierarchical structure including a sponsor, project board, project manager and working groups, to ensure that all the planned activities will be properly delivered.

However due to market readiness and resource seconded to support System Strategy (ENSG Vision 2020), it is expected that the AS3 project will be delayed</td></tr>
</table>

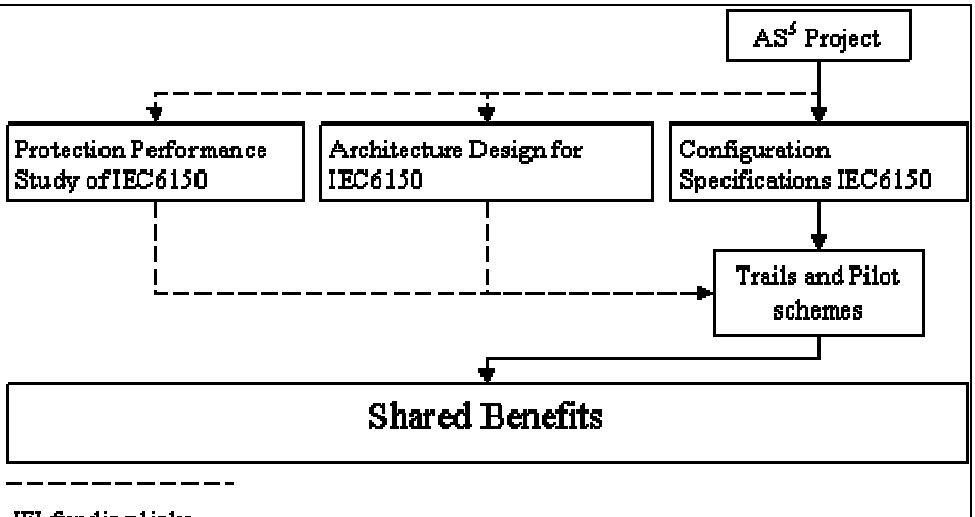
	for a period of 12-18 months
Project progress [Year to End of March 2012]	The project continued to progress well in the first half of the 2nd year, and some key deliverable were successfully completed. However with consideration of the market readiness and urgent resource needs to support System Strategy (ENSG Vision 2020), the AS3 project was consolidated into 4 work streams (WS) from 09/2009 to 04/2010, consequently the key deliverables have been re-focused to the following areas and subsequently a Change Control is being issued: • WS1: R&D project for AS3 Architecture & Reliability analysis • WS2: R&D project for Protection Performance Study with AS3 architecture, • WS3: IEC61850 Configuration Guideline/Merging Unit Guideline • WS4: Siemens Process bus trial at Radcliff substation with Switchbox (SB) development With the revised programme, it is expected that AS3 project will be delayed for 12 – 18 months. The progress to date of all the planned activities under original 5 key deliverables are: **1. Review of current policy and practice** AS3 Working Group 1 has successfully completed this key deliverable. Seminars and workshops were held with National Grid internal departments and external suppliers to identify the whole life-cycle issues regarding protection and control systems. Some high level policy and specifications were also reviewed. **2. Strategy for the development of substation secondary systems** Strategy Document SD(T)012 has been produced by AS3 Working Group 2. This document specifies the strategy (road map) for the application of new technology in the development of the substation secondary system in the short, medium and long term. **3. Feasibility Studies** 3.1. The draft documents for Testing & commissioning philosophy and Scheme Implementation Strategy have been produced by WG8 and WG3 respectively. And a high level specification for Switch Box was drafted by Safety & Operation working group (WG9). WS1: AS3 Architecture & Reliability analysis, • Produced proposal for the optimal AS3 architectures • Developed methodology for reliability/cost analysis to identify optimal architectures • Establishing testing facilities for the IEC61850 9-2 process bus products Project is complete: For the detailed progress of WS1, see separate IFI annual report for "TAOOL146 AMRDE1044 10-11 Evaluation of process bus…" WS2: Protection performance study All the planned activities within WS2 are under R&D project "the Protection Performance Study with AS3 architecture". The project is co-founded by Areva which jointly delivering some process bus systems/equipment with University of Manchester and bath for the testing. For the detailed progress, see separate IFI annual report for TAO/20627 the Protection Performance Study with AS3 architecture. 3.2. WS3 has finalised the draft document "IEC61850 Configuration Guideline" with participation and contribution from all NG alliances/suppliers. • Using the same set-up, the working group was also assigned with a new

	task to explore the requirement for the merging units to meet the needs for all the protection and control functions/devices on the process bus as well as their interoperability and interchangeability. A "Merging Unit guideline" has been successfully drafted by the Working Group, which has also been forwarded to IEC TC38 as a reference for developing international standards 3.3 AS a UK regular member, National Grid participates the following CIGRE working groups which are directly beneficial to this project • B3-10 Primary / Secondary system interface modelling (Standardisation I/O signals), which is in the final stage of preparing a technical brochure. • B5-27 Implications and Benefits of Standardised Protection Schemes • B5-24 Protection Requirements on Transient Response of Voltage and Current Digital Acquisition Chain 3.4. Benchmark took place with Tenet (Dutch) and RWE (German) for their pilot projects using Locamation and Siemens systems respectively. **4. Trials and Pilot Schemes** Dedicated working groups were set up with Areva/SE alliance, ABB/central alliance, Mitsubishi/SW alliance, Siemens/North alliance, to pursue the collaborations and *"Piggy-back" trials*. Linked to WS2, Areva is upgrading their existing trial at National Grid Osbaldwick substation to further develop it into a feeder bay trial with the AS3 Architecture. Under WS4, Siemens has installed and commissioned a Process bus trial with "conceptual units" of Switchbox (SB) at NG Radcliff substation. This WS is aimed to; • Finalise Technical specification for the Switchbox • Examine the philosophy for installation, tests & commission • Trial with Siemens process bus technology at Radcliff substation Now all the planned activities under WS4 have been completed. Siemens has produced a final report to summarise the experiences/results from the site trial. The Switch Box Technical Specification TS 3.24.89 and Technical Guidance Note TGN (E) 241 have also been drafted for final approval. Four IEC61850 protection and control panels have been purchased from a relay manufacturer in China. The system is to be installed on a 400 kV circuit in November 2012 for interfacing with conventional instrument CTs and VTs. ABB has installed an IEC61850 trial system at Bodelwyddan substation. The system interfaces with non-conventional instrument CTs and VTs. The Switching Box Technical Specification TS 3.24.89 and Technical Guidance Note TGN (E) 241 have been issued. 5. New Policy Statement and Associated Engineering Documents Some high level strategy analyses have been performed on the management of technologies, risk assessment, long term costs/benefits. A business case interim report has been produced to summarise the study result to date. Based on the first two year's project progress as well as the development of IEC61850 technology and NG internal business, a strategic direction paper of the AS3 project was produced and approved by the project board to • summarise the achievement to date, • identify some earlier applications/benefits, • confirm the further developments:

	ACHIEVEMENTS TO DATE: • Policy & Practice Review • SD(T) 012 Strategy Document for Substation Secondary Systems • AS3 Generic Architecture – 4 key elements identified • IEC61850 NG configuration Guideline (final draft) • IEC61850 Merging Unit Guideline (draft) • Strategy for AS3 Scheme Implementation (draft) • Philosophy for AS3 installation, testing & commission (draft) • Switch Box TS 3.24.89 and TGN(E) 241(draft) • Cigre B3-10 ”interface model” Brochure (standard I/Os, primary) • AS3 ”Business Case” Interim Report • Areva feeder unit protection trial at Osbaldwick Substation • Siemens’ trial (process bus + Switch box) at Radcliffe Substation STRATEGIC DIRECTIONS The key drivers and business needs for AS3 project have not changed. The 4 key elements based AS3 Architecture will provide a sustainable solution to the whole life cycle of light current assets, which can be implemented in stage approach: • IEC61850 station bus o Ready for single vender applications, o Need pilot schemes for vender interoperability using the National Grid IEC61850 configuration specification(draft) • Standard Bay Solutions(SBS) remain largely the same as SICAP • Switch box for the I/O interface should be deployed as soon as practically possible o Technical Specification finalised, low risks o “Quick-win” benefits both SICAP and future AS3 architecture o covers all application scenarios-current, future & changeover Further R&D: IEC61850 Process Bus o MU Specification (draft) to be finalised o Hybrid technology for feeder bay solution (one end process bus and other ends conventional), a potential replacement scenario. o I/O standardisation (P&C alarms and events)
Collaborative partners	A potential collaboration with National Grid US and PG&E from the west coast of US are under discussion/preparation.
R&D provider	ABB, Areva, Mitsubishi, Siemens, Univ. of Manchester Univ. of Bath

<table>
<tr><td>Project title</td><td colspan="4">Protection Performance Study for IEC61850 Process Bus Architecture of Substation Secondary Systems (AS3)</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Wen An</td></tr>
<tr><td>Description of project</td><td colspan="4">Maximising economic and effective utilisation of the transmission asset and network is the key objective. The deployment of the technology advocated for this IFI will allow ongoing substation secondary equipment retrofitting (refurbishment) projects to proceed whilst limiting the duration and frequency of circuit outages, required to facilitate the work. Once the new technology is installed, secondary equipment renewals occurring mid-life in the primary plant lifecycle can be undertaken in a safer, quicker and easier way with much reduced outages of primary systems. At any time, secondary system upgrades and modifications can be undertaken without a primary circuit outage. This will also significantly reduce the outage period required for substation extensions.

In order to pursue this strategy, sufficient confidence must be demonstrated in the philosophy and the new technology, hence the need for the IFI research. The work is thus strategic, aligned to the AS3 project and is designed to understand the impact of the emerging technology of process bus architecture on the performance of protection and control equipments.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £11k
External £52k
Total £63k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>Internal £28k
External £174k
Total £202k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£405k</td><td colspan="2">Projected 2012/13 costs for National Grid</td><td>£14k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The key objective of this project is to investigate, quantify and optimise the level of security, dependability and operating speed in secondary schemes using IEC 61850. As a precursor to wide deployment of the philosophy in AS3 project, it must be ensured that the performance of the protection and control scheme meets or exceeds that of its hardwired predecessors.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>2</td><td>6</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">This project is linked to the AS3 project contributing to increased likelihood of success of the project and therefore has shared benefits with AS3</td></tr>
</table>



The separate business benefits of the project are:

- Understanding the impact of emerging technologies on the future protection and control systems to support National Grid's decision-making.
- Taking full advantage of the emerging technologies while identifying and minimising potential risks.
- Providing a proper basis for the development of future protection systems based on the experience of the protection schemes being studied.
- Less site commissioning required for the new protection systems. Most of the tests can be carried out in factory by software simulation using the IEC61850 process bus.
- Much reduced outage required for the future replacement of the new protection and control equipments.
- Maximising economic and effective utilisation of the transmission asset and network.
- Safety, health and the environment is improved by reducing the need for cross-site secondary circuit cabling, mitigating the associated risks

Expected timescale of project	4 years	**Duration of benefit once achieved**	5 years
Probability of success	40%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£219k
Potential for achieving expected benefits	Following the literature survey and evaluation of possible topologies for bay process bus and station bus architectures, it became apparent that current 100 Mb Ethernet switches and Merging Unit (MU) limit the number of MU on a process bus to a maximum number of 8 units. This limitation may restrict the application of the IEC61850 architecture depending on the size of a substation. It is anticipated that 1Gb switches and MU will be developed by manufacturers, the full benefits of the project can then be achieved when the 1 Gb units are available. The test on the feeder bay using different manufacturer's merging units revealed some compatibility issues. The test results obtained so far indicate that with current prototype of merging units, the IEC61850 system has some reliability issues, however when manufacturers fully develop their products say in 2 ~ 3		

	years, the reliability will be improved and the process bus of sampled values can then be implemented.
Project progress **[Year to End of March 2012]**	The project started in Jan 09, during the first three months, literature survey of the IEC61850 process bus architecture and its impacts on protection performance have been completed. The trial topologies to interconnect the protection relays have been established. The project is delayed by due to delay on signing the contractual Agreement by all parties. This was signed in July 2010. The protection panels have been built and delivered to University of Manchester for testing. Relay firmware has been updated. Initial tests on relays using simulation software of IEC61850 data have been completed. Test bench using Omicron test sets has been set up and relays were configured for the stage 1 testing. Full stage 1 tests have been completed and have highlighted complications with the merging units. Both the feeder protection and the transformer protection schemes have been tested and reports submitted. These have confirmed the correct operation of these units. Simulation studies have examined the characteristics of the main variants for the process bus topologies and these have been supported by practical implementations. Based on these and practical considerations of the operation objectives of using the IEC61850 system, Star configurations have been chosen for the process buses. Having developed simulation models of the process bus structures, initial studies have been undertaken on the possible failure modes of the IEC 61850 based communications. It has been generally confirmed that the current 100MB communications will handle the communications requirements of the scheme being examined. Further analysis is in progress, using probabilistic studies to better define the 'safety margins' and predict where data congestions may occur and their consequences. Tests on the feeder protection units and the transformer protection units using the RTDS test system demonstrated that the IEC61850 protections performance was comparable to the conventional protections. Tests to determine the response to communications system collapse and overload demonstrated that the IEC61850 relays performed as required albeit slower under any of the test conditions and during communications overload. These results have dispersed any concerns over communications system failures. Attention is being given to documenting the results and findings from the research. Several papers have been written and presented in support of this study.
Collaborative partners	Areva, Scottish Power, Scottish & Southern Energy
R&D provider	University of Manchester, University of Bath

Project title	**Alternative Bus Bar Protection Solution**			
Project Engineer	John Fitch			
Description of project	This project aims to deliver an evaluation and desk top design solution of an alternative digital bus bar solution architecture. This will help formulate a future technical and procurement strategy for bus bar protection, potentially leading to a pilot installation, evaluation and deployment as a replacement (or new) bus bar protection system.			
Expenditure for financial year	Internal £4k External £76k **Total £80k**		**Expenditure in previous (IFI) financial years**	Internal £3k External £0k **Total £3k**
Total project costs (collaborative + external + [company])	£99K		**Projected 2012/13 costs for National Grid**	£16K
Technological area and/or issue addressed by project	A policy for single Digital Bus Bar Protection has been employed on the National Grid UK Transmission network since 2002 either as a replacement system (for duplicated high impedance schemes) and for all new build double bus bar substations. These systems have a distributed architecture with remote bay units (interfacing to the plant) for each protected circuit with ruggedized cross site fibre connections to a central processing unit. Where a substation has a centralised relay room (e.g. GIS) layout, the bay units are co-located in a suite of cubicles and connected with a network of fibre patch cords. A number of systems and versions have been installed from National Grid's preferred protection suppliers and Alliances over the past 20 years and these have required additional support through contracted PDSAs to provide field staff with the resources to manage faults and defects. A recent protection policy change also requires a second (hot standby) central processing unit to be deployed (with it own dedicated fibre connections) to better manage contingency issues for central processing unit failures. The systems installed to date have proven to be generally reliable; however each system is bespoke to each supplier with a limited technical life, leading to issues with future substation extensions and potentially the need to consider equipment upgrades and early asset replacement of the complete system. This will have major issues on future system access to carry out this work across a complete substation. Through work with CIGRE, contacts with other utilities and National Grid US, it has been found that an alternative centralised bus bar protection system may offer greater asset management benefits in the longer term, especially when managed and supported by well trained internal staff. This project is desk top evaluation of an alternative bus bar protection design and the interface and application on the UK Transmission system.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**

		6	-2	8
Expected benefits of project	The output from this project if successful will feed into a second stage project to establish options for a pilot installation. The benefits will include the following: - • Development of Bus Bar Protection Strategy and Policy changes • Standardised plant interface and "one off" standard solution • CAPEX savings (reduced equipment costs) • OPEX savings (train internal staff- reduce PDSA) • Extended Asset Life (elimination of short life components e.g. fibres) • Reduced System Access for extensions and future replacement			
Expected timescale of project	2 years	**Duration of benefit once achieved**	5 years	
Probability of success	95%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£11k	
Potential for achieving expected benefits	This project will review designs and products used by other utilities for adoption on the UK Transmission system. The likelihood of success is high.			
Project progress [Year to End of March 2013]	The contract has been placed with SEL (Concord) and the design of the Bus Bar Protection Panels has been received. Following review of the design drawings by end users, some improvements have been requested to the design and build. These modifications are currently being implemented, prior to final panel build, inspection and test. MDE staff have been involved in assessing these designs and gaining familiarity with the SEL Bus Bar Protection solution and its application. They have also helped develop some technical training programmes.			
Collaborative partners				
R&D provider	SEL			

<table>
<tr><td>Project title</td><td colspan="4">Design of a smart tool for detecting hidden errors in protection setting files</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Wen An</td></tr>
<tr><td>Description of project</td><td colspan="4">This project will deliver an intelligent tool (a computer software application or expert system) which can open a setting file and interrogate the protection functions and settings in the file. Knowledge-based rules and/or cases (and possibly other knowledge-representation methods) will be extracted and these will be deployed within an intelligent system in order to ascertain that no settings are erroneous. This includes checks that relay settings are correct and that no features are inadvertently enabled or disabled.

The knowledge used to assess the validity of settings will be derived from National Grid protection application/settings policy documents and also (possibly) from structured knowledge elicitation interviews conducted with expert personnel from the company.

A simple power system model will be used by the tool to test the settings to validate that they are correct and to provide a further means of checking for hidden errors by applying various in-zone and out-zone faults on the power system model.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £6k
External £33k
Total £39k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£78k</td><td>Projected 2012/13 costs for National Grid</td><td>£38k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Relying solely on people and procedures to assess the validity of protection relay setting files has not always been successful and occasionally hidden errors were not detected until after a relay mal-operated. In addition, a mal-operation related to an inappropriate setting may only become apparent when the power system is operating in a stressed or abnormal state and consequently might cause a local black-out or trigger a regional collapse.

Setting errors, or hidden problems in the setting files used in protection relays, have resulted in mal-operations. This project will investigate a method based on an expert system that will detect hidden errors in a setting file.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>1</td><td>7</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Recent increases in the complexity of numeric relays, and the associated rise in the number of settings applied to a relay, have increased the risk of an incorrect setting failing to be detected. The consequence could be a multi-circuit trip, or in a worst scenario, a blackout. The proposed expert system will detect the setting error and prevent it being applied to a relay before commissioning. Additionally, the existing settings previously approved and commissioned can be verified and corrected if necessary. Therefore, the main business benefits are improved</td></tr>
</table>

	transmission system reliability, minimisation of protection mal-operations and the maintenance of National Grid's reputation for quality.		
Expected timescale of project	3 years	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£225k
Potential for achieving expected benefits	The track record of Strathclyde in collaborating with industry for the research and development of intelligent systems, and in particular, the analyses of protection system design and performance, is excellent. Strathclyde has carried out several Research Council and industry-funded projects, including: EPSRC SUPERGEN5 Asset Management and Performance of Energy Systems (AMPerES), Highly Distributed Energy Future (HiDEF), Highly Distributed Power Systems (HDPS) and FlexNet. It also enjoys several longstanding industrial partnerships with Rolls Royce (Rolls Royce University Technology Centre in Electrical Power Systems), ScottishPower (Scottish Power Advanced Research Centre), SSE (SSE Research Centre), EDF Energy (EDF Energy Advance Diagnostics and Condition Monitoring Centre), with a track record of delivering prototypes and demonstrator systems to partners. It remains at the forefront of intelligent systems research for power engineering applications. The prior experience and capabilities of the academic team at Strathclyde, the established relationship with National Grid and the extremely high quality of the identified PhD candidate all contribute to an increase in the likelihood of success of the proposed project.		
Project progress [Year to End of May 2012]	The project has been progressing according to the project plan since its start in October 2011. The initial research and literature review of intelligent and power protection systems have been completed. Existing techniques and research relevant to this project has been reviewed. Several artificial intelligence techniques that may have relevance to this project have been studied. National Grid protection setting policy (PS (T) 010) has been received and studied in great detail. An annual report that summarised the work in 2011 has been submitted, which also includes an improved structure of the smart tool based on the original structure presented in the project proposal. Through initial research, the tool that will be used for the system development has been selected as Drools (a powerful rule engine for rule-based expert system development) and Eclipse. The programming language is Java, which has a good compatibility with many operating platforms and hardware devices. Simulation exercises that have characterised simple power and protection systems have been carried out to ensure that the student has a good understanding of the mechanism of protection system and its settings. This exercise is also a preparation for later activities that will test the smart tool's performance when a prototype is produced later in 2012. At the moment, the investigation of how to make use of Drools to build a rule-based expert system is on-going. A number of simple rules have been built and tested. The prototype is expected to be finalised and demonstrated to National Grid before the end of the year. In conclusion, the project has progressed well and in alignment with the agreed schedule.		
Collaborative partners	N/A		
R&D provider	University of Strathclyde		

Environment

The Environment and Reducing Emissions

<table>
<tr><td>Project title</td><td colspan="5">Sustainability First - Smart Demand Forum</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Nigel Fox</td></tr>
<tr><td>Description of project</td><td colspan="5">The project will investigate and build a systematic picture of GB demand-side potential from today into the 2020's with a strong focus on commercial, regulatory, customer and policy issues needing to be tackled to realise demand-side response.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £6k
External £1k
Total £7k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£27k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£20k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Demand side response (DSR) is likely to be a key balancing service as wind intermittency increases and we look for more flexible providers of balancing services.
The project will build on the Sustainability First demand-side work (published 2010), taking on board the I&C sector and demand-side role of micro-gen. The work programme will essentially be carried out by Judith Ward and Gill Owen (from Sustainability First) with analytical work carried out by Brattle. Work will be coordinated via an independent cross-industry / consumer group – a Smart Demand Forum with representatives from all funding parties; these are expected to be Elexon, Ofgem, DECC, large users, equipment manufacturers, consumer bodies, DNO's and energy retailers.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>12</td><td>-1</td><td colspan="2">13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">This project will help National Grid realise the magnitude of these services and will enable us to direct our resources to the best effect. It is our belief that demand could potentially play a significant part in the provision of Balancing Services, thereby offsetting some of the reliance on generation. By understanding what demand assets are around and will be around in the future together with an understanding of their use by customers, National Grid will be able to maximum the use of such as assets and avoid procuring generation whose costs are solely recovered through the provision of the service. National Grid is starting to see the benefit from such provision through the use of Responsive Load Technology employed within supermarkets that are providing dynamic response to the system. Use of this type of demand allows National Grid to reduce the number of generators held part loaded and the number of generator required on the system. Frequency response spend today is</td></tr>
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<tr><td></td><td colspan="3">approximately £200m per year and will increase when the SQSS changes to accommodate an 1800MW generation loss. We conservatively estimate that greater knowledge in this area could lead to 1 or 2% of response being provided by demand rather than generation leading to a yearly saving of £0.5m to £1m.

In addition and as a paying member, we will have a seat at the forum and will be able to influence proceedings and provide thought leadership as well as providing the System Operator's perspective.</td></tr>
<tr><td>Expected timescale of project</td><td>3 years</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£155k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="3">There is a high likelihood of the project delivering its objective.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="3">The project has delivered well in the period to 31 March 2012 with the core deliverables of the project, namely a series of analytical papers, being delivered on time. The first year of the project has been characterised by papers that aim to fully explore and evaluate the demand for electricity and its existing capability to be flexible in response to various stimuli. The programme of papers scheduled for delivery in the forthcoming year are also expected to be in areas of interest to National Grid and are focussed on the potential and value of demand side response.

The papers being delivered are proving to be extremely valuable as a source of information on and analysis of the demand side of the electricity industry. There is a huge amount of industry, regulatory and governmental interest in the demand side at present. However there is very little independent authoritative research or analysis in this area. By being involved in this Sustainability First led project we are able to be closely involved in their research, offering our views and highlighting the publically available information on our existing balancing services that currently have demand side participation.

The papers delivered in the period up to 31 March 2012 were:

• Sustainability First - GB Electricity Demand - Paper 1 - Context and 2010 Baseline Data - October 2011

• Sustainability First - GB Electricity Demand Project - Paper 2 - GB Electricity Demand 2010 and 2025 - Initial Brattle Electricity Demand-Side Model - February 2012

• Sustainability First - GB Electricity Demand - DECC Electricity Demand Data Sources - Summary Note - March 2012

In addition the following papers are planned in the period 1 April 2012 – 31 March 2013 (hyperlinks to those already delivered are included)

• Sustainability First - GB Electricity Demand - Paper 3 - What demand side services could customers offer in 2010 - Household demand- April 2012

• Sustainability First - GB Electricity Demand - Paper 4 - What demand side services can provide value to the electricity sector -June 2012

• Sustainability First – GB Electricity Demand - Paper 5 – 'The Electricity Demand-Side and Wider Energy Policy Developments'.

In addition Sustainability First has schedule quarterly "Smart Demand Forum"</td></tr>
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	meetings which National Grid has attended. These are primarily designed to assist in the review of draft papers, but they also allow for wider debate with a range of industry stakeholders on the present and future need for demand side response. This has again allowed National Grid to learn about others views on the potential for demand side response use in other sectors if the electricity supply industry, and in turn to share own views and experiences of demand side response with the same wide group of stakeholders. Overall our view of the project remains positive and that it continues to deliver value for money and we look forward to supporting it over the remaining two years of its life.
Collaborative partners	
R&D provider	Sustainability First

Project title	**Acoustic Emissions from HV Overhead Conductors**
Project Engineer	Richard Morris
Description of project	The key objective of the proposed research is aimed at understanding the causes of excessive noise from overhead line conductors and how this might be alleviated. The aims of the project are as follows: Characterise the surface ageing processes, including corrosion, on conductors including GAP, AAAC and solid aluminium: The deposition of species (e.g. sea salt, dust, soot, pollutants, etc.) from the atmospheric environment onto the conductor surface and how these influence local processes such as pitting corrosion and hydrophobicity. Determination of initial surface chemical state for the conductor, including hydrophobicity; how this chemistry changes as a function of environmental stresses, including: moisture, atmospheric deposition, high voltage, etc. Determination of initial surface physical state for the conductor, this being predominantly surface roughness; the progression of roughness as a function of environmental stresses (i.e. as above) Study interactions (if any) within the conductor, including effect of internal moisture, greasing and galvanic corrosion between steel core and aluminium conductor. Identification of the key factors involved in physico-chemical deterioration of the surface and, hence, development of a model of surface damage with time. Characterise the corona discharge activities resulting from wet high voltage surfaces: Audible discharge activity will be characterised in terms of volume and frequency content as a function of surface hydrophobicity, surface conductivity, surface roughness, and moisture conductivity The impact of the physical form of the substrate (conductor) will be determined, including conductor geometry strand size and shape and pitch The way in which moisture behaves macroscopically on a conductor will be determined including the impact of wind, inclination, geometry and hydrophobicity Measurements of force generated by discharges will also be determined Provide a model showing the causes of excessive corona discharge leading to noise and radio frequency interference (RFI) from ‘gap’ type conductors: The way in which complete spans of conductor might be excited to generate excessive corona discharge, noise and radio discharge from discharge activity will be modelled Electrodynamic behaviour resulting from the novel conductor structure will also be considered as a potential cause of the noise and radio discharge. Generate at least one solution for to the problem of excessive corona discharge producing noise (considering requirements for existing and new installations) Working with National Grid engineers, potential remedial solutions will be identified. Information will be supplied in a form suitable for inclusion in future National Grid specification to minimise future exposure.

<table>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £11k
External £86k
Total £97k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £16k
External £617k
Total £633k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£828k</td><td>Projected 2012/13 costs for National Grid</td><td>£97k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The environmental impact of assets is a key concern to the community and National Grid. One key aspect of this is the audible noise produced by plant. Noise resulting from high voltage overhead lines is well studied, and models exist for traditional conductors and conductor bundles. However, recent experience of Matthew GAP conductor has demanded a rethink of the fundamental, largely empirical models used.

This work will challenge existing models and create data on which to base new models suitable for application on any form of conductor. This will allow novel conductors to be deployed with a clear understanding of their acoustic and EM noise emission characteristics

The corrosion characteristics of new conductor materials will allow improved asset management, and the implications of ageing on acoustic noise to be determined.

Additional focus is now being directed towards developing a coating solution which can be applied retrospectively to single spans as part of a strategy to manage complaints.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>7</td><td>3</td><td>4</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">National Grid has already spent £1.35M reconductoring just a few spans at one location on the ZO route, costs such as this could easily escalate should National Grid begin to receive more complaints from members of the public following reconductoring with Matthew Gap conductor. The avoidance of only one repeat event of this type would save £1.35m and more than repay the project costs.

The avoidance of costs associated with conductor cleaning or inspection. The cleaning of conductor on only one span of the ZDA cost in the region of £25k for direct expenditure only, so future annual savings can be in the region of £12.5k per annum if one intervention can be avoided every two years, plus savings in outage planning and project management time.

Avoidance of staff time taken up in managing complaints, both in liaising directly with complainants and local Environmental Health Officers, and undertaking monitoring visits. This is estimated to be in the region of £20k per annum, suggesting potential savings of £20k per annum if a doubling in the number of problem areas is avoided.

There are no clear mitigation measures available at present, so the avoidance of costs and extended time scales associated with having to resort to presently available alternatives, for example the use of triple instead of twin bundles, requiring the diverting of routes and/or rebuilding of towers, and the potential requirement to apply for Section 37 consents. The savings here can be considerable.</td></tr>
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	Better specification for conductors on future schemes will reduce the need to respond reactively following complaints and so there are considerable resource saving Additional business benefits include: A greater understanding of the processes resulting in excessive corona discharge leading to conductor noise and radio interference Better modelling of conductor noise for planning and selection of appropriate conductor types and specification Reduction in the number of complaints from members of public, leading to a positive public image Better understanding of the causes of noise and radio interference and therefore more ability to respond effectively and efficiently Less man hours required for responding to complaints Reduction in the number or outages (for example to carry out conductor cleaning); this may in itself generate more outage opportunities Alleviate existing H&S concerns by reducing future need for manual intervention A more professional approach and better understanding of the issues will improve our reputation with our complainants and other stake holders.		
Expected timescale of project	4 years	**Duration of benefit once achieved**	5 Years
Probability of success	60 %	**Project NPV = (PV benefits – PV costs) x probability of success**	£34k
Potential for achieving expected benefits	Developing background knowledge to support the application of existing and new conductor technologies will be supportive of improving transmission capability and managing the environmental impact of our overhead line infrastructure. In addition this will rebuild a core competence for National Grid and its Partner in the University of Manchester. It will also leave a legacy capability of laboratory-based noise and corrosion measurement on HV equipment for further work.		
Project progress [Year to End of March 2012]	The three strands of work: studying corrosion processes, modelling electric fields and acoustic energy, and measuring acoustic emission have come together to show this comprehensive approach was correct and will yield a holistic view of the processes not previously achieved. The project continues broadly to plan, with the theoretical side in advance of expectation and the experimental some what slower. Experimental work to test a range of conductor samples is due to commence in the HV lab in May 2012, catching up with the original plan. Corrosion Processes: Research continues on increasing our understanding of the potential corrosion processes that may give rise to changes in the surface morphology, roughness and surface chemistry of conductors during atmospheric exposure. • Controlled experiments have been conducted by collecting residues from ultrasonic cleaning, and re-applying these. Sample conditions investigated include: as received, ultrasonically cleaned, steam treated and washed in acetone and ethanol.		

Salt fog tests have been used to simulated industrial conditions

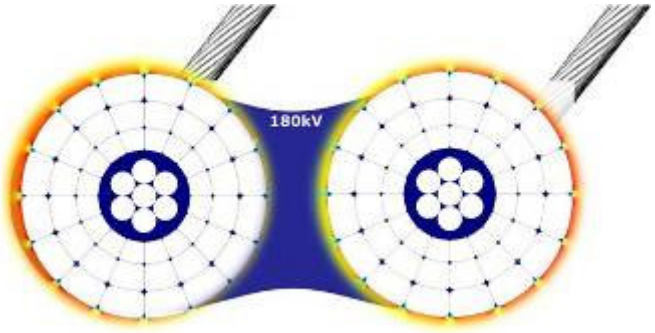
Contaminated samples exhibit higher hydrophobicity than relatively cleaner ones, as evidenced by droplets retained on sample surfaces (below) and a longer time-of-wetness.

The nature of pollution has been shown to be critical in the ageing process, and this has been quantified on a strand-scale.

Concepts of coatings to improve hydrophobicity are being developed, on a small scale with an intention of scaling up for testing in the anechoic chamber.

Field Modelling:

- A review of existing commercial packages for predicting noise has been completed. The data on which these models have been based has also been reviewed.
- The FEA modelling has shown the limitations of conventional approaches. An improved process for field modelling has been developed and is being published.This will be used to develop the final models for the project.



- Models of field over the whole conductor are being used to determine potential acoustic power development.

Acoustic experimentation:

- Three rigs have now been completed each of a different scale. The smallest can examine the movement of individual water droplets; the second is used to test behaviour of 1 m samples, and the largest can test samples up to 5 m in length.

	• Each of the rigs can be set up with PD, UV, Acoustic measurements and also high speed camera recording. • A clear difference in behaviour has been identified between different conductor types, with hydrophobicity and strand shape being seen as controlling features. • A difference has also been seen between water droplet behaviour at 50 Hz and 60 Hz. This is important when comparing experimental results in different countries. This is likely to impact only low frequency noise. • In the coming period, a range of conductors will be measured informing and enabling quantitative models to be generated and allowing better informed technical decisions on conductor selection, and offering methods of amelioration for existing issues
Collaborative partners	N/A
R&D provider	University of Manchester

<table>
<tr><td>Project title</td><td colspan="4">Optimising the operation of an integrated DC link within an AC system</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Alex Carter</td></tr>
<tr><td>Description of project</td><td colspan="4">Determination of how the system should be operated with the introduction of offshore HVDC lines to maximise the exploitation of renewable energy resources, especially wind and the types and amounts of reserve that are likely to be required.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £3k
External £40k
Total £42k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £4k
External £21k
Total £25k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£112k</td><td>Projected 2012/13 costs for National Grid</td><td>£20k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">National Grid has a good history of operating the AC network and also utilising a DC link as an interconnector. However National Grid has no experience in operating an integrated HVDC link in conjunction with the AC system.
The first intra-network HVDC line is planned to be operational from 2013 to accommodate the significant increase in wind generation being installed in Scotland. It will be the responsibility of the System Operator to determine the optimum power flow on this link by balancing the risks and flows between the parallel AC and DC networks.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>10</td><td>0</td><td>10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Endure that the correct balance between security and efficiency is maintained by advising on the best strategies to approach setting the flow between the parallel AC and DC networks. This will need to factor in transmission losses and stability for a range of different operating conditions and understand the consequences that this will have.
The main benefits to the system will be a study enabling the understanding of:
• The risks associated with different levels of power dispatched pre-fault on the HVDC link that is being operated in parallel with the AC
• Advice on suitable levels of dispatch on a parallel HVDC link
The dimensions of risk are expected to include: risk of overloads on the AC system; and risk of rotor angle instability on the exporting side of a boundary following a fault outage. The scope for different levels of inter-trip to manage the above risks will also be explored alongside the need that remains for pre-fault constraint of generation under different circumstances. Finally, through liaison with CIGRE JWG C4.B4.C1.604 (“Embedded HVDC”), knowledge will be sought on emerging international practice in respect of the above and on fault rates on the HVDC side.
This study will be critical into maximising the exploitation of the renewable</td></tr>
</table>

	energy resources in the North of Britain. As well as ensuring minimisation of balancing services costs associated with operating the system. Analysis was carried out in July 2010 to assess the Interim Connect and Manage over the period 2010/11 to 2014/15 and shows that the boundary between England and Scotland will remain congested and constraint costs are likely to be approximately £75k/MW/year. The cost of the project is therefore equivalent to the constraint cost of reducing pre-fault flows by 2MW for one year.		
Expected timescale of project	4 year	**Duration of benefit once achieved**	5 years
Probability of success	50%	**Project NPV = (PV benefits – PV costs) x probability of success**	£187k
Potential for achieving expected benefits	An encrypted version of the GB network model is now available and Strathclyde has the correct level of knowledge so this project has a high likelihood of success		
Project progress [Year to End of March 2012]	A PhD student was been appointed from the University of Strathclyde's partnership scheme with North China Electric University. Co-funding has been obtained from the Scottish Energy Technology Partnership (ETP). Objectives in the first year concerned attendance of Master's level classes to improve background knowledge and conduct of analyses of power system steady state security. Some analysis has been carried out to determine the optimum flow on the HVDC circuit and has indicated that it should be maximised over the flow on the AC network. It is anticipated that transmission loss optimisation may be required at lower cross border flows. However, some issues have been encountered with the suitability of the student and the option to convert his study to an MPhil is being explored. Discussions are underway to determine the next steps required for the project.		
Collaborative partners	STP		
R&D provider	University of Strathclyde		

Enhanced Capacity

Project title	Composite Cross Arms study
Project Engineer	Boud Boumecid
Description of project	**Task 1. Case Study Specification** Upon commencement of the project, National Grid (NG), The University of Manchester (UoM) and EPL Composite Solutions Ltd (EPL) will meet and agree specifications for the L2 and L3 lattice tower cross arms. The specification will include the following. Current construction details in steel; 1. Design rules and standards for both structural and electrical performance (these being based on existing cross-arm / insulator standards); 2. Current weight and installed cost for steel cross arms / insulators, which will be used for benchmark purposes. The specification will also include the required life time, handling techniques, maintenance practices, installation characteristics etc that may be essential or useful to take into account during the design process. This specification will be used as a reference document through the course of this and any future phases of the project to ensure that the final product is fit for purpose and satisfies the requirements of NG. **Task 2. Techno-Economic Benefits Of The Case Studies** Given that the uptake of this technology would rely on the development of an economic case, it is essential that this is considered within this phase of work. UoM and EPL will provide to NG the benefits that can result from the composite cross-arm. This information will be largely based on work already presented to NG with some refinements based on recent work. It is anticipated that while UoM and EPL will contribute to this task with engineering support, the bulk of this work must be undertaken by NG who can cost the potential benefits of the technology. **Task 3. Resolution Of Technical Barriers To Composite Cross-Arm Development** This task aims to carry out an initial analysis of the following aspects of the composite cross-arm technology. These specific areas were all identified in the phase 1 report to NG as potential barriers to the development of the composite cross-arm technology. • Solution to allow maintenance access to conductor fittings • Selection and test of an appropriate coating technology • Selection of an appropriate pultrusion profile • Identification of a suitable shedding profile for the pultrusions • Design and fabrication of a wet test facility for the prototype • Consideration of failure mechanisms of existing composite insulators in relation to composite cross-arms • Software development for modelling of lateral loading • Development of method to provide co-ordination gaps It is not expected that these phases of work will be fully resolved in terms of defining the final solution by the end of this project phase. However, as a

	minimum, the challenges will have been more clearly defined and initial developments will have allowed potential final solutions to have been identified. For example, it is highly unlikely that a choice for the optimum silicone rubber coat will be selected in this work but the main challenges will be understood in terms of both manufacturing and electrical performance. The emphasis is therefore in the continued reduction of risk associated with the issues presented in the phase 1 report. At the end of this task, the expectation is that the additional knowledge gained will lead to a review of the three composite cross-arm design options previously presented (fully profiled, flat with insulator or lightly profiled with insulator). **Task 4. Manufacture And Test Of Full-Scale Prototypes** Within this task, a full-scale mechanical prototype (defined in task 1) will be manufactured and tested. EPL will design a structure that can be used to support the cross-arm for the purposes of mechanical testing. A second electrical rig will be developed that will be used in the UoM HV Laboratory for electrical testing only (this rig being relatively light-weight as it will not support significant load). The cross-arm will be designed using software developed in phase 1 of the project which will be updated to include lateral load applications and relevant commercial codes. The testing will be performed according to the specification defined in task 1. However, in terms of mechanical testing, it will check the ability of the prototype to withstand static loads only and not consider long term durability at this stage. Through the mounting of the cross-arm on the test rig (replicating a tower) and by the inclusion of a conductor fitting allowing the installation of a length of conductor, electrical tests will assess the ability of the cross-arm to withstand AC, lightning and switching voltages. An assessment of the levels of visual corona will also be carried out. **Task 5. Development Of Future Project Road Map** At the end of this project phase, the feasibility of a composite cross-arm should be fully established. It is therefore essential to have a future project road-map that builds on the proposal previously presented to National Grid. This task of work will be carried out by EPL and UMIP (the University of Manchester Intellectual Property Company). Ways to include the alliance partners of NG and cooperation with other organizations such as Hydro Quebec and EPRI will be discussed in terms of the remaining research and development phases of this work. **Timescales & Costing** UoM and EPL aim to commence this project as soon as possible. The aim is to complete this stage of work by the end of March 2009 to allow the showcasing of the technology to a number of selected individuals (potentially including the Chief Technology Officer of NG USA and the Executive Director for Transmission of NG UK) in/around May 2009. The Gantt chart gives a more detailed representation of the likely project timescales. Due to the need to develop a full scale prototype within this stage of the work in a short timescale, the spend per month is relatively high owing to the number of people working on the project. This work will also equip EPL and the University of Manchester with many of the hardware and software tools they need for the project going forward. It is intended that future phases of this project will be supported with funds from other sources.		
Expenditure for financial year	Internal £9k External £252k **Total £261k**	**Expenditure in previous (IFI) financial years**	Internal £35k External £628k **Total £664k**

<table>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£1,152k</td><td colspan="2">Projected 2012/13 costs for National Grid</td><td>£227k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Overhead line cross-arms. The use of an insulating cross-arm potentially allows the upgrading of an L3 275 kV tower to operate at 400 kV and the elimination of the insulator strings on other tower types.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Tech Transfer</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>1</td><td>7</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">If it proves feasible to upgrade L3 towers to 400 kV operation there are several areas of the transmission network where future generation connections, that would ordinarily require new overhead line routes to be constructed, could be accommodated by upgrading a 275 kV route to 400 kV operation, increasing its power carrying capability, thereby avoiding the need to construct a new line.</td></tr>
<tr><td>Expected timescale of project</td><td>5 years</td><td colspan="2">Duration of benefit once achieved</td><td>10 years</td></tr>
<tr><td>Probability of success</td><td>70%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>£370k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">There is very high potential for realising the above benefits. Work to date has been focusing on studying the feasibility of replacing a steel L3 tower crossarm with an equivalent composite capable of operating at 400kV. Research studies, electrical and mechanical tests have been successfully carried out to confirm this application is feasible.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">The project to develop insulating composite cross-arms is proceeding very well. Leverage has been obtained by shared funding from SSE, NG and the University of Manchester. The University and EPL have developed all the design skills required to consider virtually any opportunity. Designs can be generated for upgrading of 132 KV or 275 kV lines, or alternatively for reducing ground clearance of existing 132 kV, 275 kV or 400 kV lines. Opportunities also exist of optimising new line capacity and minimising visual impact with this technology. New designs of towers can also be considered and the skills developed are also being accesses to support the T-Pylon project. Integrating new cross-arm designs with the opportunities presented by novel conductor technology are also improving the benefits of the technology.

Part of the design process development has been to develop the FEA modelling capability for complicated geometries. This has led to world-class modelling and enabled the development of sophisticated stress management techniques: which has also generated a new patent application. The manufacturing processes are now well developed with a range of products now having been fabricated and installed at the St. Fergus test site.

The University, via its commercialisation Company UMI3, has setup a spin-out company (Arago Technology Limited) to commercialise the technology.</td></tr>
</table>

	The 400 kV test site in St Fergus, in an Aberdeenshire SSE substation, has been designed, built, commissioned and run for several months with proto-type cross-arms. The first full version of cross-arms were installed in May and are now running 24/7. Two cross-arms are installed, and each of the 8 composite insulators is being monitored for leakage current. Multiple cameras and detailed environmental monitoring equipment are also providing online data. Early results are very positive suggesting the design of the test facilities is reliable and yielding the information required. Mechanical and electrical testing of the cross-arm continues in the laboratory and we continue to gain information and confidence in the product. The installation in the Lecht has proven the mechanical viability of the product, and will be terminated after the summer, having given two years of high wind and snow exposure. An image of the cross-arms at the St Fergus trial is included below: 
Collaborative partners	The field trials in Scotland are funded by SSE
R&D provider	University of Manchester (and EPL composite solutions)

Connections

System Access

Project title	**Ratings of cables in tunnels (ROCIT)**				
Project Engineer	David Payne				
Description of project	The objectives of this project are to: Review the ratings methods used to design cable tunnels. Assess existing operational data from cable tunnels, including Distributed Temperature Sensor (DTS) data. Develop a specification for a rating method for cable tunnels installations with independent cable circuits.				
Expenditure for financial year	Internal £7k External £15k **Total £21k**		**Expenditure in previous (IFI) financial years**	Internal £16k External £137k **Total £153k**	
Total project costs (collaborative + external + [company])	£306k		**Projected 2012/13 costs for National Grid**	£132k	
Technological area and/or issue addressed by project	Rating methods employed in the design of both forced cooled and naturally ventilated cable tunnels.				
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**	
		4	-3	7	
Expected benefits of project	A better understanding of rating of cables in tunnels would lead to: Increased use of existing tunnels for new cable installations Potential use of smaller cables for a given rating through understanding the true rating capability of cables. Optimisation of tunnel cooling systems or in some cases removing the need for any cooling system from better understanding of natural ventilation effects.				
Expected timescale of project	6 Years		**Duration of benefit once achieved**	2 Years	
Probability of success	70%		**Project NPV = (PV benefits – PV costs) x probability of success**	£78k	

Potential for achieving expected benefits	Very High. Algorithms developed under the forced ventilation stages of the project have already been used to assess cable ratings for at least two tunnel schemes.
Project progress [Year to End of March 2012]	2012: Forced ventilation study completed. Implementation phase approved and algorithms developed by Southampton will be integrated into existing rating software. Natural ventilation studies to commence shortly. 2011: A review of existing rating methods has been carried out. Several tunnels have been visited and data gathered for further analysis. Algorithms have been developed to consider tunnels with more than one type of cable construction with forced ventilation tunnels. Further data is being gathered to further verify models. Progress to consideration of naturally ventilated tunnels has been delayed due to urgent requirement to assess ratings for live schemes.
Collaborative partners	None
R&D provider	Southampton University.

<table>
<tr><td>Project title</td><td colspan="4">Live Line working Equipment</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Matthew Grey</td></tr>
<tr><td>Description of project</td><td colspan="4">Live Line working was initially introduced in the 1960s and actively utilised in the 1990s. This was a high profile project and an example of how an integrated Transmission Company can use innovative Transmission Owner techniques to manage defects in a timely manner and also deliver benefits to the System Operator. These benefits are primarily around access to the system in order to ensure OHL defects are rectified also increasing minimising system outages to carry out work and so increasing system security. There are also maintenance activities that can only be undertaken using Live Line techniques. Since the introduction of Live Line in the 1990s, the system has been less constrained and deadline access more easily available (hence the decline in use). However the Transmission System is likely to become increasingly constrained over the next 5-10 years, based on forecast constraint costs, new access arrangements, continued asset investment requirements and new generation connections. Live Line Working offers significant opportunities in enabling maintenance and defect OHL work to be carried out against this background, however significant investment and commitment is required in order to re-establish previous Live Line capability.

The re-establishment of Live Line Working within National Grid has already been approved by National Grid’s internal governance committees and discussions with OFGEM and the HSE on this matter have already begun.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £94k
External £299k
Total £393k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £61k
External £752k
Total £813k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£1,206k</td><td>Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Live line working in support of improved, more efficient system access in critical system areas.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>13</td><td>-4</td><td>17</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">1 Benefits of Live Line Working
• Live Line working would provide greater flexibility and efficiency in rectifying OHL defects, particularly as we move towards a Dynamic Asset Management model.
• Increased System Security due to reduced requirement for system outages
• Elimination of hazards associated with dead line working due to tower</td></tr>
</table>

climbing and earthing requirements i.e. manual handling, management of induced voltages and circulating currents (this risk has significantly increased since Live Line working was first introduced)

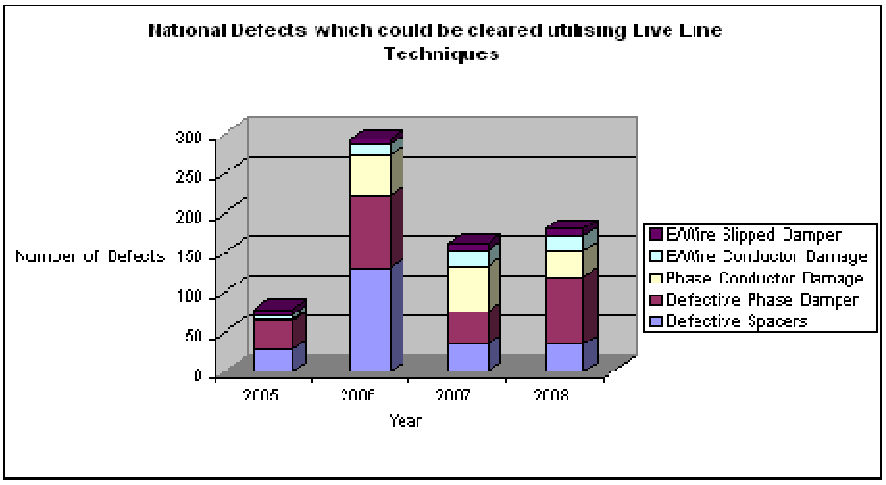
- Increased maintenance productivity levels when dealing with larger volumes, e.g. de-spacering. Typical rates of de-spacering using traditional techniques are approximately 4 - 6 span per day, whilst at the peak of Live Line use, the team were achieving up to 15 spans per day (and typically 10 spans a day).
- Additional contingency providing a further option/method of working when responding to major faults or incidents.
- There is some works that can currently only be carried out using helicopter access live line techniques (although the circuit may be de-energised), e.g. high crossing work on XL Severn River Crossing. If National Grid Live Line working is not re introduced we would be reliant on RTE to carry out this work on our behalf.
- Reduced estimated return to service time (when using helicopter access on de-energised lines) due to no requirement to isolate and earth and apply double dress earth systems to allow access to the circuits.
- Potential avoidance of System Outage Costs

2 Key Drivers For Increase in Live Line Working

2.1 Current Potential Usage Of Live Line Working

Going forward due to adjustments in our capital plan, aging assets and operating cost pressure, we will increasingly be taking an approach of Dynamic Asset Management. This will require having the capability to respond quickly and effectively to significant defects. Live Line working would strongly support this asset management approach, removing any system access issues, which could otherwise delay defect rectification.

In addition, based on current OHL outage defect levels, approximately £27,600 is spent per annum on monitoring of defects that could be rectified using Live Line techniques.



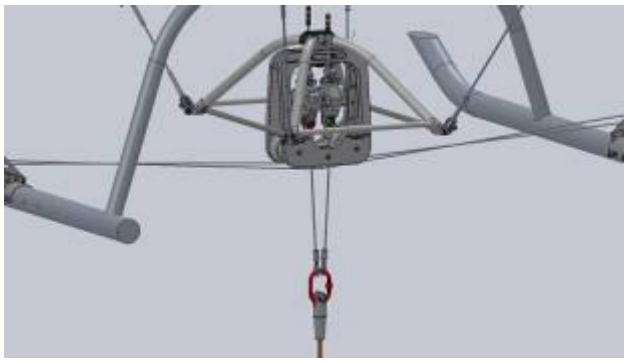
2.2 Short Term Transmission Access Issues

There are a number of longer term drivers that will place an upward pressure on system access:

- Continued high levels of asset replacement on the UK Transmission system
- New Generation
- Development of new Transmission Access arrangements

These system access issues will also be in conjunction with a greater emphasis

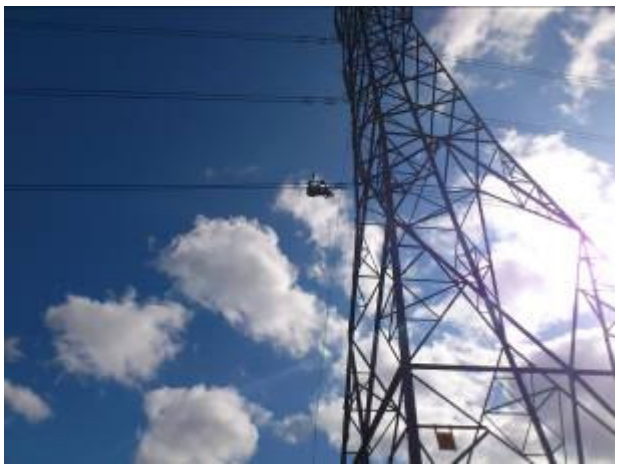
	on a dynamic asset management approach. Furthermore there is only one feasible provider to National Grid for Live Line work. Development of National Grid capability would introduce competition in this market and potentially allow for savings to GB consumers. 3 Cost Benefits To 2015 there are a minimum of three schemes that will require helicopter access work. These include the re-conductoring of the Severn crossing, in 2014/15, which will require the dampers to be removed and then to be replaced (i.e. 2x helicopter access work). In 2011 we will be introducing our first capital scheme which will replace fittings on ACAR (Aluminium Core Alloy reinforced), as the outer aluminium strands are very soft, a trolley will not be used to access the conductor, and helicopter access will be required. If Live Line/helicopter access techniques were developed by National Grid, the in-house cost for this work would be approximately £40k for each scheme involving Helicopter access work (i.e. £120k). If this work was to be outsourced based on previous contract costs, this would be at least £190k for each scheme (i.e. £570k, £450k more than in- house costs). There is also a significant amount of earthwire repair work that would normally be undertaken using Live Line helicopter techniques. Earthwire damage could be repaired typically within a day using helicopter access techniques (either deadline or live line). If the work had to be carried out using traditional deadline techniques, this would involve earthing (1 day for a simple circuit, 2 days for a complex circuit). It would take 2 - 3 days to lower (and then raise) the earthwire (if crossings are involved this would require the use of scaffolding or skycradle etc.), plus several hours for the actual repair. The work would therefore take anywhere between 3-5 days, depending on the complexity of the circuit, and crossings.		
Expected timescale of project	3 years	**Duration of benefit once achieved**	5 years
Probability of success	60 %	**Project NPV = (PV benefits – PV costs) x probability of success**	£190k
Potential for achieving expected benefits	On target to deliver live line working during 2012 and therefore avoid potential costs to outsource the work to an external contractor. One project already planned in for completion by the National Grid live line team is the Usk River crossing in South Wales.		
Project progress [Year to End of March 2012]	Throughout 2011/12 National Grid has been working on a comprehensive R&D programme to facilitate the reintroduction of Live Line working on our overhead line (OHL) network. The main focus was placed on Live Line Work using Helicopter Access Techniques. During 2011/12 National Grid has worked closely with an aviation company in producing the design of equipment for Live Line Helicopter Access work. This project also includes development of a new live line insulated rope and all necessary certification and ongoing continuing airworthiness of all the equipment in line with European Aviation Safety Agency (EASA) regulations. The equipment will include a new rope system, basket and attachment points onto the helicopter, a load and visual monitoring system will also be included in the helicopter cockpit, with the aim to make use of new technology and materials to improve the environment in which the pilots and linesmen are subjected to.		

	New Rope System  New Helicopter Attachment & Release Points  New basket 
Collaborative partners	N/A
R&D provider	Bond Aviation Group, Roblon and English Braids

<table>
<tr><td>Project title</td><td colspan="5">Overhead Line Robotic Technology</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Michael Hannon</td></tr>
<tr><td>Description of project</td><td colspan="5">Investigate the possible solutions available for the deployment of robotic technology on overhead lines to assist with asset condition and maintenance activities. To trial world leading technology on our system to gain understanding of compatibility and potential impact..</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £13k
External £63k
Total £76k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£76k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">To assist with delivering our capital plan we are seeking to gain an understanding of alternative methods of inspection and maintenance of our overhead line assets. With system access being a major concern we wish to gain an insight into possible technologies that can be deployed and operated on live circuits.

We have already looked tentatively into this area, seeking out the world leaders in this technology, which has led us to forming an association with IREQ, the research institute of Hydro Quebec, Canada. They have developed and deployed an overhead line inspection / maintenance Robot known as “Linescout”.

This project will develop the technology with respect to the GB network.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>22</td><td>-4</td><td colspan="2">26</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">Demonstration of evolving innovative technology which would allow inspection and maintenance of OHL assets, removing the need for human intervention and system access to carry out certain tasks. Business benefits include removal of persons from towers (health and safety) and operations on live circuits. The ability to undertake inspections and maintenance tasks under live conditions provides us with the ability to remove the need for system access, thus protecting the business from constraint costs which, depending on system configuration and loading, could be in excess of £3M for a given outage.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">1 year</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>£70K</td></tr>
</table>

Potential for achieving expected benefits	The potential for achieving the expected benefits is high. Hydro Quebec has already agreed to this demonstration, subject to costs and condition agreement. After demonstration we will be in a position to evaluate this type of technology.
Project progress [Year to End of March 2012]	We have been able, through negotiation, to agree to Hydro Quebec visiting the UK in the autumn of 2011 to demonstrate this technology on our system both in dead and live situations.  Hydro Quebec undertook a demonstration of the Linescout technology on National Grid's system during September 2011. The object of this demonstration was to establish the compatibility of using the robot on the National Grid network. The trial proved a success with over fifty Managers and key personnel taking the opportunity to see and gain an understanding of the technology. Key learning points were established with reference to spacings, communication and operation of Linescout on the UK network.  Further collaboration and technical proving activities are scheduled for 2012 with the eventual aim of integrating this technology into National Grid.
Collaborative partners	
R&D provider	IREQ (Hydro Quebec, Canada)

Project title	**Live Working in Substations (Feasibility Study)**			
Project Engineer	Dave Skellon			
Description of project	Live Line working was initially introduced in the 1960s and actively utilised in the 1990s on the Overhead Lines. The project will enable National Grid use to use innovative techniques to deliver benefits to the System Operator. These benefits are primarily around minimising system outages to carry out work and reducing system operator costs. The Transmission System is likely to become increasingly constrained over the next 5-10 years, based on forecast constraint costs, new access arrangements, continued asset investment requirements and new generation connections. Live Working in substations offers significant opportunities in enabling certain maintenance and defect work to be carried out against this background, however to provide assurance that the long term investment and commitment is workable on the existing network, a more in depth assessment of the substations is required in order to establish the criteria for live working can be met. This assessment would be undertaken by the French Electricity Company RTE who are one of the worlds experts on live working at High Voltages. The re-establishment of Live Line Working on OHL within National Grid has already been approved by governance groups within national grid and discussions with OFGEM on this matter have already taken place. Substation live working is the next logical step to undertake. Historically the HV equipment maintenance work in substations has been undertaken on circuits which have been de-energised, isolated and earthed. This requires longer return to service times of circuits and limited access availability. Because of the way the network is being developed and enhanced to facilitate the build of new generation and asset replacement etc it will become increasingly more constrained and hence even more difficult to get system access for essential maintenance and defect repairs. To fully undertake live working in substations, further investment in staff training and specialist equipment is required and hence, to justify this investment, the existing substations will need to be assessed to see if the configurations used will be compatible with the established criteria for live working.			
Expenditure for financial year 11/12	Internal £21k External £11k **Total £32k**		**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£122k		**Projected 2012/13 costs for National Grid**	£90k
Technological area and/or issue addressed by project	Live substation working in support of improved, more efficient system access in critical system areas.			
Type(s) of innovation involved	Technological substitution	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**

		8	2	6
Expected benefits of project	**1 Benefits of Live Working** • Increased System Security and potential avoidance of System Outage Costs • Reduced estimated return to service time due to no requirement to isolate and earth to allow access to the circuits. • Elimination of hazards associated with dead line working i.e. management of induced voltages and circulating currents (a significantly increasing risk on the network) • Additional contingency providing a further option/method of working when responding to major faults or incidents. • Ability to utilise Live Working techniques on dead (switched out only) circuits for certain work eg CT oil sampling, thereby enabling increased productivity with circuits switched out only with no establishment of isolation, earthing and safety document issue/cancellation ie more samples could be taken in one day. **2 Key Drivers to invoke Live Working** Going forward due to adjustments in our capital plan, aging assets and operating cost pressure, we will increasingly be taking an approach of Dynamic Asset Management. This will require having the capability to respond quickly and effectively to significant defects. Live working would strongly support this asset management approach, removing any system access issues, which could otherwise delay defect rectification. There has been a significant step change in constraint costs since the start of BETTA and more so in future linked to the increase in asset replacement and construction works. Indications are that this trend will continue for the foreseeable future. Live working techniques can be seen as another tool for constraint risk mitigation in England and Wales and there are a number of longer term drivers that will place an upward pressure on constraint costs: Continued high levels of asset replacement on the UK Transmission system New Generation Development of new Transmission Access arrangements **3 Cost Benefits** Long term reduction of system constraint costs in providing access to the network Justification of the future expenditure of investing in the full implementation of live working based on the knowledge that the existing network configurations will enable the established criteria for live working to be invoked.			
Expected timescale of project	2 years		**Duration of benefit once achieved**	8 years
Probability of success	60%		**Project NPV = (PV benefits – PV costs) x probability of success**	-£109k
Potential for achieving expected	• The preliminary investigations into the project have indicated a high likelihood of success due to evidence of successful implementation by other			

benefits	utilities around the world. • National Grid's representation on the CIGRE international Live working group will assist in identifying and develops best practice. • The outcome of the more intense and close up assessment of the existing substations by RTE will determine and justify the above mentioned investment to fully invoke live working in substations. • An initial meeting with H.S.E. confirmed that the justification for Live Substation working is no different than Live Line working.
Project progress [Year to End of March 2012]	After an extensive scoping piece of work where live substation was observed in Australia, Brazil and France RTE international was selected as the company that was most appropriate to conduct a feasibility study on a National Grid site to asses if Live substation working was possible on National Grid system. In the third quarter of the year National Grid hosted RTE international to complete a site visit to prior to conducting a feasibility study. After that initial study it was concluded that there was no reason to continue with a feasibility study at 400kV substation as the phase-to-phase distance on the centre phase is insufficient for live working. However during that meeting RTE investigated drawings of a 275Kv substation and concluded that Live substation working may be possible. In the last quarter of last year RTE arrived for a second site visit. From that visual assessment and investigating the drawings RTE concluded that a feasibility study on a 275kV substation would be worthwhile. Work on the feasibility study is due to start in September 2012, the feasibility study is due to start late in the year due to the availability of the RTE live working team due to summer work load on the French system.
Collaborative partners	
R&D provider	RTE international

Smarter Transmission Philosophy

Project title	**Finite element analysis for ratings (FEAR)**			
Project Engineer	David Payne			
Description of project	To improve the delivery of cable ratings calculations through the use of more flexible and accurate finite element analysis (FEA) modelling methods.			
Expenditure for financial year	Internal £5k External £10k **Total £16k**		**Expenditure in previous (IFI) financial years**	Internal £12k External £97k **Total £109k**
Total project costs (collaborative + external + [company])	£125k		**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	Verification of the rating methods used for cable ratings under various laying conditions and considering cable joint rating methods. A review will be carried out using Finite Element Analysis (FEA) methods to confirm or otherwise existing methods.			
Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		8	-3	11
Expected benefits of project	A better understanding of cable ratings and in particular cable joints by analysis using FEA could lead to cable thermal rating enhancements providing more flexible operation of the transmission network, facilitating outage planning and avoiding generation constraints.			
Expected timescale of project	8 years		**Duration of benefit once achieved**	5 Years
Probability of success	20%		**Project NPV = (PV benefits – PV costs) x probability of success**	£545k
Potential for achieving expected benefits	The expected benefits for the original project were achieved and Finite Element Analysis has been used to assess/verify cable ratings under real conditions. The project has been extended to consider the effect on ratings of cables crossing in close proximity.			

Project progress **[Year to End of March 2012]**	The project has clearly demonstrated the use of FEA for providing analysis of complicated cable rating problems. Crossings studies have been carried out and a draft report produced. This indicates that IEC methods are reasonably accurate compared with FE methods as long as dry-out of backfill is not considered. Consideration of dry-out decreases the accuracy of IEC. An actual crossing situation is to be determined and the method applied to demonstrate the success of the methodology.
Collaborative partners	None
R&D provider	Southampton University.

<table>
<tr><td>Project title</td><td colspan="5">Oil/paper insulation HVDC performance</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Gordon Wilson/Paul Jarman</td></tr>
<tr><td>Description of project</td><td colspan="5">The project will investigate the performance of the oil-paper insulation system used in HVDC transformers under a variety of electrical stress conditions. It will attempt to determine the effects of oil resistivity and other insulation condition parameters on the capability of the insulation to withstand the electrical stresses seen within HVDC transformers particularly during polarity reversal or other changes in stress.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £5k
External £121k
Total £126k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £3k
External £70k
Total £74k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£282k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£82k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Recent work in CIGRE has highlighted that oil resistivity can greatly influence the stress distribution within an oil-paper insulation system in a DC stress environment especially during voltage changes such as polarity reversals. There have been several failures of bushings at Sellindge during or shortly after polarity reversals and there is evidence that the factory testing of DC transformers is inadequate to cover service conditions. A new CIGRE group is being established to look at this further and this work could usefully link to this group. The measurement of the DC conductivity of oil is not routine and a repeatable method needs to be established. This project will provide the knowledge to specify appropriate tests on new transformers and make sure that oil quality in service is maintained to suitable levels.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>20</td><td>3</td><td colspan="2">17</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">Given the likely investment in DC technology planned in the next decade it is important to have up-to-date knowledge and independent research to ensure that correct specification and operational choices are made to ensure long-term reliability. This project addresses the most likely cause of unreliability in HVDC transformers, the change in insulation condition between factory test and service and its interaction with the time/stress relationship of the polarity reversal. DC transformers cost in the region of £5M per phase and failures have significant outage costs. If this research can indicate how to manage the oil in these transformers or influence design and testing of transformers to improve reliability then significant savings may be possible.

The HVDC transformer failure rate is historically about 5-10 times worse that normal transmission units based in international figures. If we have a population of 30-50 units, which seems possible with strategic investment plans, then a failure every 1-2 years is expected unless the rate can be reduced.</td></tr>
</table>

Expected timescale of project	4 years	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£270k
Potential for achieving expected benefits	Southampton University has significant expertise in measuring space charge distribution in polymer insulation systems and has recently demonstrated the technique in paper systems. They also have experience in more general measurements of the dielectric properties of oil-paper systems. It is very likely that useable results will be obtained that support the specification and operation of HVDC equipment.		
Project progress [Year to End of March 2012]	All students are now in place but the project was delayed in starting owing to the difficulty in getting suitable applicants; a change control was submitted during the year. Bridge formation of cellulose particles in DC and AC fields have been observed as part of the study of pre-breakdown phenomena and computer modelling has been employed to simulate the experiments but this is proving challenging. The students have successfully constructed a pulsed-electric acoustic (PEA) system that will be the primary technique employed during the project. Further improvements are planned to optimise the study of oil/paper and pressboard system and the movement of space charges under DC fields and during polarity reversal. As part of the project the project supervisor is participating in a CIGRE working group looking at oils in DC environments and to that end have performed spectroscopic analysis of two oils as part of a round robin. This has highlighted the difficulty of studies in this area as reproducibility was poor.		
Collaborative partners			
R&D provider	Southampton University		

Project title	**Electromagnetic transients (EMT) in future power systems – Phenomena, stresses & modelling**		
Project Engineer	Forooz Ghassemi		
Description of project	A collaborative research group is being established, made up of utilities, manufacturers and research bodies, to investigate the electromagnetic transient (EMT) interaction of renewable generation on transmission equipment. The focus of the project will be on the EMT modelling of components (transformers, cables, circuit breakers, instrument transformers etc.) to provide best practice and expert opinion on their interaction with the power system. System and plant measurements will be carried out to validate the models, which can then be used to simulate and demonstrate the power system interaction phenomena on equipment such as current inrush, harmonic penetration, resonant overvoltages, etc. The work will consider transformer modelling (both in terms of modelling expertise and laboratory facilities), and acquiring cable lengths for the purpose of model validation (complex multi-phase cables with steel armouring). In addition, a number of system studies will be performed in order to highlight special transient phenomena such as how CT/VT saturation may impact on protection performance. Participants will highlight their interests, for instance, EDF want to compare case studies using PSCAD and EMTP-RV packages, Statkraft would like an activity on modelling oil-filled cables, Vestas is very interested in black-box cable modelling, etc. In summary, the work will: • Develop component models to characterise the range of phenomena associated with transient conditions • Examine the network architecture • Validate EMT models in different simulation packages • Disseminate the results and models to the partners.		
Expenditure for financial year 11/12	Internal £7k External £37k **Total £44k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£74k	**Projected 2012/13 costs for National Grid**	£30k
Technological area and/or issue addressed by project	The future power system is going to be highly complex, integrating renewable generation, smart grids, voltage upgrades, increasing usage of long cables and HVDC. Successful implementation will require extensive computer simulations during all the planning and engineering phases. Existing simulation tools have limited accuracy for representing some critical components such as transformers and cables. The project will produce models that are sufficiently accurate and compatible with available circuit simulators, and make use of the models in system simulation studies in order to pinpoint bad configurations. There is also limited understanding of these interactions, such that development project and		

<table>
<tr><td></td><td colspan="4">designers do not know what can cause the problems and how to avoid designing potential problems.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>7</td><td>1</td><td>6</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The business benefit is primarily the attainment of knowledge, cross industry experience and establishing best practice in the field of electromagnetic modelling of equipment in the context of future networks. Taking a number of recent incidents into consideration it is very evident there is generally a shortage of information and perspective on this topic.

This work will help to facilitate the connection of £50bn of renewable generation (25GW) onto the network, through understanding the level and impact of transient voltages that will arise from these types of connections to renewable generation and designing solutions to mitigate or neutralise their occurrence. Failure to do this could, in the worst case, lead to substation equipment failure and a consequential loss of supply.

The consortium is already formed and looking to share costs, National Grid has an opportunity to leverage funding through access to a €2.5m research programme. In addition we will have the opportunity to direct, to some degree, the scope and prioritisation of work. National Grid could also build on and accelerate research on certain topics, by offering some work previously carried out namely transformer modelling (University of Manchester) and cable/transformer circuit modelling (Cardiff University).

A range of component models will be made available for National Gris to utilise in its own EMT studies to assess the unique impact on the National Grid system.</td></tr>
<tr><td>Expected timescale of project</td><td>5 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£128K</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">There is a high likelihood of success in developing a suite of models and validation of EMT models in different packages. The valuable experience gained during the pilot will help to reduce risks significantly during the ensuing project roll out.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">Plan and objectives of the project have been approved by the steering committee.

A tool has been produced to quantify and correct for the capacitive current effect in transformer factory no-load test results.

A test rig with associated measurement procedure has been developed to determine the linear component of a low voltage power transformer for model validation.

Measurement and test on a sub-sea power cable is being planned for model validation.</td></tr>
<tr><td>Collaborative</td><td colspan="4"></td></tr>
</table>

partners	
R&D provider	SINTEF, Delft and others

<table>
<tr><td>Project title</td><td colspan="3">Control of Cable Tunnel Ventilation (CCTV)</td></tr>
<tr><td>Project Engineer</td><td colspan="3">David Payne</td></tr>
<tr><td>Description of project</td><td colspan="3">The aim of this project is provide a proposed advanced ventilation control strategy for force ventilated cable tunnels which will ensure the minimisation of ventilation running costs while maintaining a high emergency rating for the installed cable systems.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td>Internal £7k
External £32k
Total £39k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£39k</td><td>Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">National Grid’s cable tunnel network is a vital component of the power transmission grid within the London area, with the length of cable installed in tunnels scheduled to increase significantly in the coming decades. In order to achieve the required circuit ratings for tunnel cable installations, a degree of forced cooling is necessary. Typically this is achieved through the installation of large ventilation fans to force air through the tunnel network, removing heat generated by the operation of the cable system. Where high circuit ratings are required, very large fans may be specified to provide the appropriate flow rate of cooling air through the tunnel. The maximum emergency rating of the cable circuit can be achieved through operating the fans on a 100% duty cycle, however the costs of such operation (in terms of the electrical power utilised) represent a significant contribution to the operating costs associated with the tunnel. This project will investigate the feasibility of advanced ventilation control schemes which will be designed to ensure the minimisation of ventilation running costs while maintaining a high emergency rating on the cable circuits installed in the tunnel. The following Work Packages will be undertaken:

1. Data Acquisition

In order to accurately specify parameters during control design, it is necessary to obtain thermal data from an operational cable tunnel subject to a reasonably high level of loading. The following quantities will be monitored for a minimum of 2 weeks:

• Air inlet and outlet temperatures
• Relative humidity of inlet and outlet air
• Cable circuit loads
• Cable temperature data from the tunnel DTS system
• Air velocity data
• Fan duty cycle data
• System Load data
• Existing ventilation speed data</td></tr>
</table>

<table>
<tr><td></td><td colspan="4">2. Data Analysis

The data collected will be compared with predictions obtained from the models developed under the Ratings of Cables in Tunnels (RoCiT) R&D project to ensure that the effects of any changes to the ventilation strategy can be accurately modelled.

3. Control System Design

Upon the completion of the data analysis tasks, estimations of the time constants of both the cables and the tunnel will be obtained. A comprehensive review of control strategies will be undertaken in order to select the most appropriate controller for development. The selected strategy will then be deployed in software to allow full tuning of the control system parameters against the data obtained in work package one.

4. Control system simulation

Once an adequately robust controller has been developed, the control logic will be integrated to a RoCiT based tunnel model. Through the analysis of example load flow scenarios (including “unexpected” emergency rating situations) it will be possible to determine the best set of control rules to both minimise the cost of operating the tunnel while maximising the operating potential of the cable circuit.

5. Reporting

A final report will be issued, outlining the following:

• Summary of data collected from the tunnel
• Discussion of possible control strategies and selection of the most suitable
• Details of simulation studies to demonstrate the performance of the control system
• Benefit analysis in terms of reduced fan operating hours compared to existing control schemes</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>10</td><td>2</td><td>8</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">In order to provide maximum emergency cable ratings, existing tunnel ventilation generally tends to be run on a 100% duty cycle even when the cable loading is low. However this results in high running costs. For one tunnel this has been shown to be as high as £15,000 - £30,000 per month. If ventilation can be controlled intelligently to ensure the cable and tunnel cooling level is appropriate to the load being carried by the cable, the duty cycle can be reduced thus minimising running costs. The London Cable Replacement scheme is underway and the output from the research would feed into the tunnel ventilation design process.</td></tr>
<tr><td>Expected timescale of project</td><td>1 year</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>£120k</td></tr>
<tr><td>Potential for achieving</td><td colspan="4">There is a high level of confidence that the stated objectives will be delivered within the required timescales.</td></tr>
</table>

expected benefits	
Project progress [Year to End of March 2012]	Discussions have been held with National Grid and contractors to determine inputs required for ventilation control. Algorithms are being developed so that a control philosophy can be described. Completion is expected by Summer 2012.
Collaborative partners	
R&D provider	Southampton University

Project title	**ESO Future Transmission System Stability Analysis**		
Project Engineer	Fan Li		
Description of project	As the UK moves towards a decarbonised energy sector, there is an increase in the scale and volatility of power flows on the power system expected, this is predominately due to the increased percentage of renewable [intermittent] generation. 15GW by 2015 and 30GW by 2020. This analysis will focus on system stability, specifically caused by the large network flow changes at periods of low demand when a high proportion of synchronised generation is being generated from renewable sources [offshore wind]. The analysis is going to focus on voltage stability but will also include transient and dynamic system stability. DigSilent will produce an independent report with the support from National Grid experts in modelling system stability, and generator dynamic performance, using the current off-line model and making approximations of future system conditions. The analysis will detail system wide conditions and specific boundary issues as defined by National Grid Engineers.		
Expenditure for financial year 11/12	Internal £6k External £64k **Total £69k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£69k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	Between 2011 and 2017, it is anticipated that the installed wind generation capacity in the National Grid transmission network will increase from 1877MW to 8671MW. Together with changes to the network topology, this increase will have a substantial influence on stability constraint boundary flow limits in the National Grid system. The studies will look at the network configuration of the following study years and base cases: • Year 2010/2011: minima and maxima load profiles • Year 2014: minima and maxima load profiles • Year 2017: minima and maxima load profiles The studies will be based on one network topology per study year (the analysis of different network schemes is out of the scope of the studies). The generation profiles and planned network expansions of these years will be obtained from the National Grid Seven Year Statement (SYS) 2011. The feasibility study will illustrate the potential of a tool for system operation and improve our operator capability in the ENCC and hence enable the transmission system to be operated more efficiently and less risk adverse as the rate of decarbonisation increases going forward. Such a capability isn't currently available; hence the development and implementation will be a first for National Grid delivering an innovative solution in this area, into production within the ENCC.		

<table>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6</td><td>0</td><td>6</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Expert independent analysis is required in this area to detail the extent that stability will be an issue for the system operator, as a result of decarbonisation, greater interconnection, and the introduction of FACTS devices on the transmission system. This will support our capital expenditure requirements in developing innovative capabilities for the system operator in this area, to ensure that the power system is optimally operated and the maximum benefit in new transmission assets and renewable generation are realised (ie cost of transmission constraints are minimised).

The analysis will help to justify and inform the requirements of the planned expenditure of £21m in the RIIO-T1 period, in developing our capability to manage stability in operational timescales. A maximum of 5% of this benefit is estimated against this project.

The report will also be utilised in stakeholder and supplier engagement on the need for innovative developments in this area,

Utilising DIgSILENT also allows for this analysis to be carried out with no impact on current resource and recruitment requirements.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">1 year</td><td>Duration of benefit once achieved</td><td>8 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£14k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">National Grid has a proven tack record of working with DigSilent, and with the expertise in network modelling that DigSilent can provide, they can forward project system topology using our current model. They have carried out similar analysis for other transmission operators. Therefore the likelihood of success is considered to be good.

Such analysis has not been undertaken in house, due to the unavailability of network models for the future system, along with resource constraints within the business.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">DigSilent have carried out some of the study work and have come back to National Grid with some questions to allow completion of the study work. Delays have occurred in the life cycle of the work due to significant staff changes at DigSilent.</td></tr>
<tr><td>Collaborative partners</td><td colspan="4"></td></tr>
<tr><td>R&D provider</td><td colspan="4">DigSilent</td></tr>
</table>

Project title	**Constraint and reserve optimisation for wind generation (CROW)**		
Project Engineer	Biljana Stojkovska		
Description of project	This project will deliver an assessment of the effects of including both generation and demand side reserve in real time operation and transmission capacity planning in systems with significant penetration of wind generation. The twin objectives are to: assess how network constraints impact on allocation of spinning and standing reserve; and, investigate whether investment in new transmission capacity may provide more efficient access to reserves needed to support cost effective integration of wind generation. This work should provide information that will be used to assess if the network planning approach should change to incorporate reserve requirements in National Grid systems with wind generation. The research will: a) Assess the importance of an approach to reserve management that dynamically optimises the allocation of spinning and standing reserves in the presence of transmission constraints b) Develop a methodology for quantifying the impact that generation and demand side reserve has on the transmission capacity requirements. c) Against current NGET generation and transmission reinforcement predictions for the year 2020 identify where and how much additional transmission capacity would be justified to allow generation and demand side reserve to be effectively utilised in order to reduce operational cost and support wind integration. The opportunities for generation and demand side reserve will be characterised against the predicted demand and generation background for 2020.		
Expenditure for financial year 11/12	Internal £6k External £1k **Total £7k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£108k	**Projected 2012/13 costs for National Grid**	£101k
Technological area and/or issue addressed by project	Current NETS SQSS network operation and planning standards do not take into consideration reserve requirements when determining network capacity. A rapid growth in wind generation in the future will significantly increase the requirement for various forms of reserve and explicit consideration of the impact on network constraints on the allocation of spinning and standing reserves across the system may become important. Similarly, increased reserve requirements may impact on the need for transmission capacity. It is expected that under some circumstances, it may be appropriate to reinforce the transmission network in order to access cost effective resources of reserve that may be in the form of generation or demand. If this work shows that there are significant benefits from incorporating reserve requirements in network planning, this could be used to consider changing network design standards to include reserve requirements in addition to considering peak demand conditions and constraint costs. It is proposed to carry		

<table>
<tr><td></td><td colspan="4">out this analysis on predicted generation and demand background for the year 2020 and investigate whether the inclusion of generation and demand reserve in planning methodology would deliver economics benefits.

Imperial College will undertake a research project, under the supervision of Prof. Goran Strbac to establish this understanding and to propose alternative methodologies that might be practical to be applied to a real power system.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>-2</td><td>11</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Currently, planning of the transmission system capacity does not consider the availability and utilisation of generation and demand reserve. The growth in wind generation will lead to an increase in reserve requirements. Identifying whether or not current operational and planning practices will deliver sufficient transmission capability for economic dispatch of reserve has the potential to deliver significant future savings. NGET estimates that reserve requirements by 2020 will be 4 times the current level which will significantly increase the reserve cost.

Prior to the start of the research work the development of an optimisation tool is predicted to reduce the current £700m balancing cost by 1% per annum. This is a conservative estimate, so is very likely that once delivered, the tool will deliver much higher benefits.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">2 year</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£601k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">There is high change of success. Imperial College have previously produced work in this area and have delivered a number of projects for NGET.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">The project has started and is progressing very well. All project tasks are according to the timetable and first meeting was very successful, with Imperial College presenting very good results and conclusions.

We are now preparing for second meeting which will be held in Wokingham at 29 May.</td></tr>
<tr><td>Collaborative partners</td><td colspan="4"></td></tr>
<tr><td>R&D provider</td><td colspan="4">Imperial College</td></tr>
</table>

<table>
<tr><td>Project title</td><td colspan="5">Test of multi-terminal Voltage Sourced Converter (VSC) HVDC control strategies by means of an analogue test rig</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Paul Coventry & Wen An</td></tr>
<tr><td>Description of project</td><td colspan="5">The key objective of the proposed work is to test and demonstrate the performance of control strategies for multi-terminal VSC HVDC systems. The tests will be carried out by using an analogue 4-terminal VSC-HVDC test rig. The rig can be configured to a grid source (3-terminals) and an off-shore wind-farm for National Grid required configuration.

The tests using the analogue 4-terminal VSC-HVDC test rig will complement the innovation work of the RTDS simulations to be studied by the University of Birmingham. As Cardiff University already have a 3-terminal test rig built, National Grid will be able to obtain some quick test results (in 6 months) to give us an early indication whether the control strategies proposed for a 4-terminal VSC-HVDC link is feasible, and to identify potential problems with application of the technology and inform specifications and risk register.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £5k
External £41k
Total £46k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£62k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£16k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Multi-terminal VSC-HVDC links are being considered by National Grid to provide additional capacity across transmission boundaries in the onshore transmission system and potentially to be used in the connection of offshore generation. Such a multi-terminal HVDC link might prove to be the most overall economic and efficient solution available when wider developments are taken into account.

National Grid has not previously implemented VSC HVDC converters on the transmission system and no multi-terminal VSC HVDC system has been implemented anywhere in the world. VSC HVDC and multi-terminal application therefore fall within the definition of new technology in accordance with PS(T)013 and their introduction onto the transmission system must be managed in a manner that takes due consideration of the risks. The tests proposed in this project form an essential part of the risk management strategy.

Cardiff University have done extensive research work in the area of multi-terminal VSC-HVDC for connecting off-shore wind-farms. They have built a 3-terminal test rig and tested the control strategies of the multi-terminal VSC-HVDC lines. The test rig can be easily added with another terminal to meet National Grid required configuration.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>7</td><td>1</td><td colspan="2">6</td></tr>
</table>

Expected benefits of project	The main benefit of the proposed work is management of the risks associated with introducing new technology onto the electricity transmission system in accordance with PS(T)013. The work is essential in order that the use of multi-terminal VSC HVDC on the transmission system may be permitted under National Grid governance to enhance the flexibility and increase the power transfer capacity. The savings in deploying such a solution in preference to less economic and efficient options is likely to be more than £100 M. In addition to the above, any problem in application of the technology which causes delayed commissioning of the HVDC link or interruption of its operation when in service will result in costs of the order of £5m per month being incurred in constraint costs alone. The proposed work will identify potential problems before contract placement and allow the above costs to be avoided. This project could contribute up to 5% savings against the above costs. The tests of the control strategies using an analogue test rig are complementary to the RTDS simulation work and National Grid will be able to get quick test results by utilising Cardiff's existing test rig, leveraging at least £30k against existing hardware from previous EPSRC supported work.		
Expected timescale of project	1 Year	**Duration of benefit once achieved**	5 Years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£30k
Potential for achieving expected benefits	The likelihood of success of the project is high as Cardiff University have already done similar tests on their existing 3-terminal VSC-HVDC test rig successfully and acquired rich experience on the experimental platform. For this project, they need to add another terminal to build a 4-terminal VSC-HVDC test rig for our required tests.		
Project progress [Year to End of March 2012]	The project started on 1st February 2012. Based on the existing devices and configuration of the 3-terminal test rig, Cardiff University has ordered the 4th terminal from the equipment provider, Cinergia, in Barcelona. The supplier will deliver the 4th terminal in May 2012. A preliminary test plan for the next stage had been prepared, which included the configuration of the 4 terminal HVDC network, test objectives, and test procedures. Reconfiguring the existing 3 terminal rig and control interface is being carried out to accommodate the 4th VSC. It is expected that the 4th terminal will be commissioned in May, and tests will then be started.		
Collaborative partners			
R&D provider	Cardiff University		

Project title	**Flexible rating options for DC operation (FRODO)**		
Project Engineer	David Payne		
Description of project	This project aims to: • Develop tools for the rating and technical assessment of high power HVDC cable options. The work will initially concentrate on cables with mass impregnated insulation. • To provide National Grid with techniques to evaluate continuous, transient and dynamic (real time) ratings for DC cable circuits and to evaluate the options and limits for features such as current dependent voltage control.		
Expenditure for financial year 11/12	Internal £3k External £43k Total **£46k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k Total **£0k**
Total project costs (collaborative + external + [company])	£108k	**Projected 2012/13 costs for National Grid**	£62k
Technological area and/or issue addressed by project	National Grid is currently evaluating DC cable schemes to increase the transmission capacity of the UK network, particularly for increasing the import of electrical energy from renewable sources in Scotland. The calculation of current ratings for DC cable is significantly more complex than that for AC cable. The rating is often determined by electric stress constraints rather than considerations of thermal ageing. Ratings are also strongly influenced by thermally induced pressure transients within the cable. In some cases the rating of the cable can be restricted by the cable being too cold. As the normal operating voltage of the cable increases the cable can experience high levels of electric stress while the cable is hot. As the cable cools it is susceptible to electrical failure. Some manufacturers require the converter station to reduce its operating voltage if the current on the link is reduced. The implementation of these current dependent voltage control systems may help protect the cable, but this approach does not align well with the concise cable rating sheet used as part of the CUP package. This introduces an additional level of complexity for Network Operations Modelling the complex interactions of thermal and electrical parameters is essential if National Grid is to make a thorough assessment of tenders for HVDC cable schemes. The modelling of transient thermal conditions and the behaviour of the cable insulation under reversals of power flow will provide guidance for the development of dynamic rating algorithms and operational regimes suitable for high power HVDC cable circuits. The thermal and electrical models will be constructed in such a way that the outcomes of planned R&D work on pressure transients and partial discharge ageing can readily be incorporated at a later date. The models will also be suitable for assessing the effect of fast polarity reversals on the cable system. This will provide guidance on more flexible operation of existing and future HVDC links. In some circumstances the opposite scenario will apply (a cable link where the direction of power flow is rarely if ever reversed). In this case the outcomes of this project could allow restrictions on cable voltage or		

<table>
<tr><td></td><td colspan="4">overload capability to be lifted; again increasing the flexibility of the link.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>13</td><td>-1</td><td>14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Without more sophisticated time-dependent models it is not possible to carry out a full assessment of tenders for HVDC cable. As converter station and cable control systems become more sophisticated, analysis of the complex interactions between the electrical and thermal ratings are needed to ensure that DC links operate efficiently and reliably.

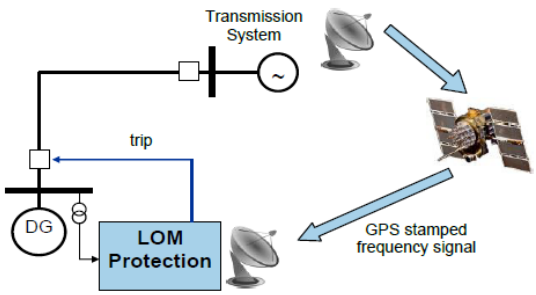
This research project will enable tenders to be analysed to ensure that cable design is appropriate for the expected burial conditions. This will ensure that capital is invested efficiently and the risk of cable system failure is minimised. The estimated costs of a failure on a major HVDC submarine link are in excess of £15m due to the timescales to affect a cable repair.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">2 Years</td><td>Duration of benefit once achieved</td><td>40 Years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£771k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The potential is high based on building on a successful record of work relating to HVDC cable systems at Southampton University.
• The Tony Davies High Voltage Laboratory has over 40 years of experience of using both numerical modelling and experimental work to improve cable rating calculations.
• Staff at Southampton have extensive experience of providing cable rating support to National Grid, particular in the areas of numerical modelling and the provision of independent verification.
• Staff at Southampton have world-leading experience of the design and assessment of HVDC cables and submarine cable systems; projects involving National Grid include EFI, Basslink, NSI, BritNed and the Western HVDC Link.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">The project has just started with the Literature review.</td></tr>
<tr><td>Collaborative partners</td><td colspan="4"></td></tr>
<tr><td>R&D provider</td><td colspan="4">Southampton University</td></tr>
</table>

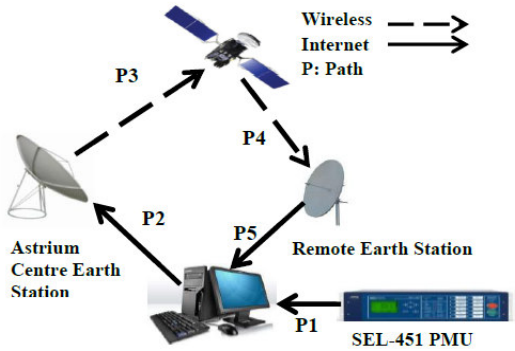
Facilitating Connections

Project title	**Improve reliability of future system by enabling integration of new generation**			
Project Engineer	Tarek Ismail			
Description of project	Collaboration projects with developers and manufacturers of power plant to ensure that design of new low carbon plant (CCGT,Clean Coal, Nuclear) meets minimum technical system requirements.			
Expenditure for financial year	Internal £42k External £1k **Total £43k**		**Expenditure in previous (IFI) financial years**	Internal £46k External £0k **Total £46k**
Total project costs (collaborative + external + [company])	£139k		**Projected 2012/13 costs for National Grid**	£50k
Technological area and/or issue addressed by project	Frequency response capability, load rejection and operation under power system split situation, Black start capability, reactive capability and control system stability.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		11	-5	16
Expected benefits of project	• Provide NGET with a timely and efficient means of understanding new generation technology limitation • Reduce the impact of the new generation technology on power system security by the timely development necessary codes and standards evolved from technical knowledge			
Expected timescale of project	6 years		**Duration of benefit once achieved**	For the life time of the generation plant which is between 20 and 60 Years
Probability of success	60%		**Project NPV = (PV benefits – PV costs) x probability of success**	£28k
Potential for achieving expected benefits	Very good			

Project progress 31st March 2012	The project to-date has been very successful in engaging manufacturers of generation plant equipment with the work NG is doing going forwards to meeting system needs together with the "Gone Green Scenario" for 2020/30. Following on from the initial stages of the project which focused on the performance of the plant interims of reliability and robustness/stability and the need to meet GB Grid Code requirements in areas such as fault ride through, minimum frequency response criterion and load rejection, on to issues focused mainly on the future mix of plant on the GB system in 2020. Additional flexibility and operation at very low loads to ensure the ability of the some plant technologies to be synchronised and also operate at reduced outputs (e.g. 20% of rated) the development of these option ensures that some plant could potentially have the capability of carrying 80% of their output as spinning reserve with the added bonus of increased inertia to assist with lower system inertia resulting from large volumes of wind generation with low or no inertia. The work also included the introduction of a new manufacturer Pratt & Whitney to GB Grid Code and technical requirements. Pratt & Whitney have specialist expertise in the manufacture of compact power plants - units in the range of 25 to 120 MW suitable for fast build on small plots of ground (20m X 50m) in 4 wks. Such plant is high efficiency low cost/fast start (from cold to full output in 10 min.) This type of plants can play a big part in the reserve market (STOR) for example and this would also be a good fit and a complement to the 2020 needs; NG have indicated that the total requirements for reserve can be as high as 12GW made up of a mixture of spinning reserve and fast standing reserve. The work also need to progress with the impact of the inclusion of carbon capture and storage modifications and new instillation for generation plant focusing of the ability of capture technology and flexibility of operation. This work also includes the use of gasification plant and issues relating to operational flexibility.
Collaborative partners	
R&D provider	Work supported within ENI

Project title	**Satellite based LoM**			
Project Engineer	Dr William Hung			
Description of project	The unreliability and instability of Loss of Mains (LoM) protection is a well know problem. This protection is designed for avoiding any embedded station being islanded but they are often triggered unnecessarily due to disconnection of generation under large system disturbance conditions (e.g. large loss of infeed or generation). This could be a risk to system security. As the volume of embedded plant has increased to over 6 GW and is expected to continue to increase, the risk on the system could become unmanageable. It is therefore important to improve the reliability performance of this type of protection. The proposed project is to explore an alternative way of using up-to-date technology for LoM protection without jeopardising system security.			
Expenditure for financial year	Internal £5k External £15k **Total £20k**		**Expenditure in previous (IFI) financial years**	Internal £3k External £14k **Total £17k**
Total project costs (collaborative + external + [company])	£92k		**Projected 2012/13 costs for National Grid**	£9k
Technological area and/or issue addressed by project	This research project will investigate the potential for further improvement of the stability of DG connections during system-wide events by taking advantage of existing and emerging communication technologies such as satellite and/or internet. Satellite communications may form a particularly viable solution for remote and offshore locations (where many wind farms are, or will be, installed); whereas internet could preferably be used in urban areas. Satellite communications have not been widely applied in protection systems due to the assumed limited (or rather unknown) reliability of this medium. Therefore, it is believed that in addition to the development of novel LoM methods, the key to the successful deployment of such technologies in the protection domain is the rigorous assessment of the reliability of the communication media. The project partners are University of Strathclyde, National Grid, Scottish and Southern, AREVA			
Type(s) of innovation involved	Tech Transfer	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		7	-6	13
Expected benefits of project	The key benefits of the project can be summarised as follows: for power system utilities – by using new improved protection methods the network operators will be able to accommodate more energy sources; for protection manufacturers – by adopting new protection methods and algorithms the manufacturers will be able to develop and offer new products meeting the demands of the future active power systems; for distributed generation developers – by using new protection solutions the developers will be able to connect new energy sources at lower connection			

	costs. for the engineering standardisation and regulatory bodies – the outcomes of this research should lead to major changes and standardisation in the fault performance of the distributed energy sources. for the society – improved level of stability and security of electrical power delivery.		
Expected timescale of project	5 years	**Duration of benefit once achieved**	5 Years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£18k
Potential for achieving expected benefits	University of Strathclyde has already undertaken a substantial body of investigative research into the assessment of the existing LoM protection methods [1] and the development of new algorithms [2-3]. Moreover, the University has a state of the art real time simulation facility (RTDS) for hardware testing under realistic system conditions. The above factors greatly increase the potential for meaningful practically applicable result.		
Project progress [Year to End of March 2012]	The project had a late start because of availability of the PhD student. The first project meeting was a very constructive discussion on the subject mainly the impact of small embedded generation because the inconsistent ROCOF operation on transmission system performance. The project is focus on using other means (ie Satellite based) of LoM protection rather than relying solely on independent ROCOF relay operation. The concept is illustrated in Fig 1.  Figure 1: Satellite Based LOM Protection [4] A telephone conference meeting 'application of space technologies for power system applications' was held on 12/10/2011 and detailed requirements and the set up of a test trial were discussed. For demonstration of the concept, a laboratory trial was set up with the communication nodes as shown in the Figure below.		

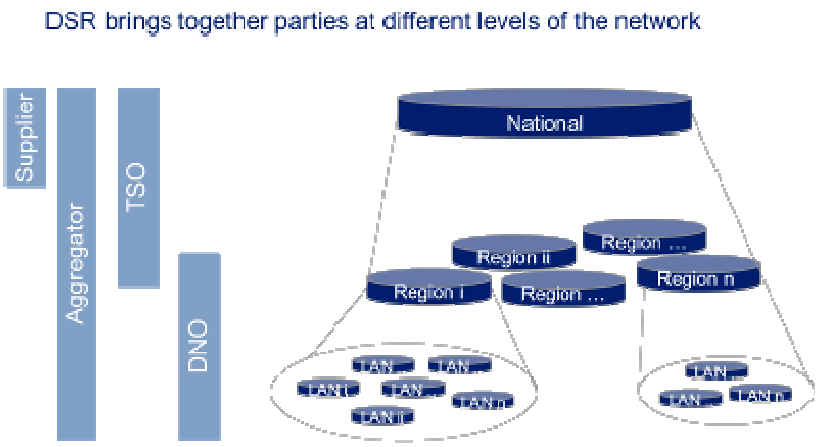
	 Figure 3: Proposed Structure of a Laboratory Trial The work was supported by Astrium Services Ltd. A conference paper on 'Assessment of the reliability of LoM protection incorporating satellite communications' was submitted and accepted.
Collaborative partners	EPRC Doctoral Training Grant £46k SSE (TBC)
R&D provider	Strathclyde University

Customer Satisfaction and Commercial

Charging Volatility

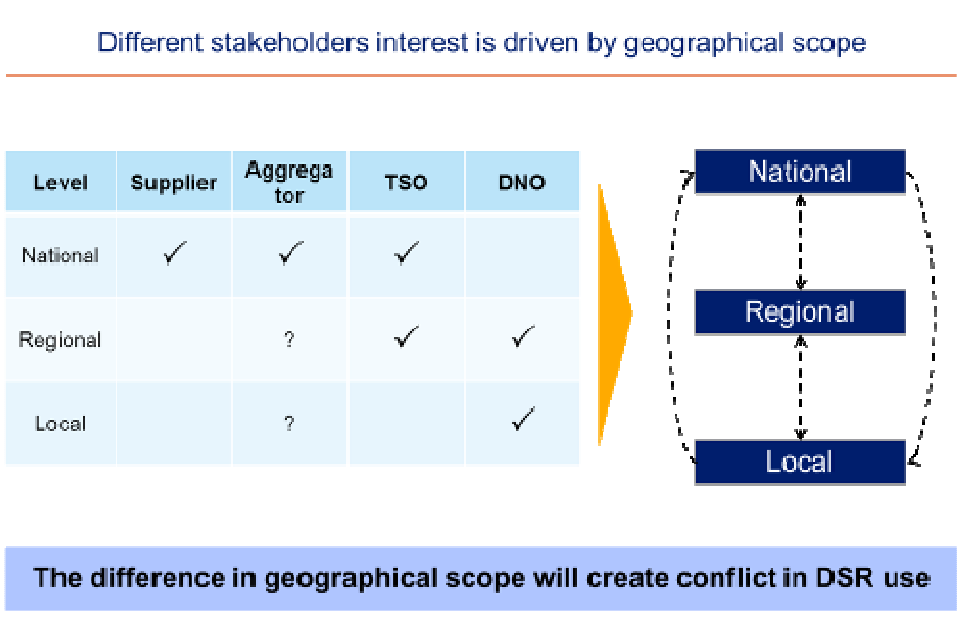
Project title	**Scenario Scoping for DSM Price Signals**		
Project Engineer	Michael Edgar		
Description of project	To develop an understanding of when the stakeholders of Demand Side management (DSM) (TSO, DNO and supplier) are in tandem or in conflict and to present an initial quantification of the value associated with various uses of DSM. A detailed quantitative assessment can take place as an extension of this study if it is deemed useful in light of this initial work.		
Expenditure for financial year 11/12	Internal £3k External £16k **Total £19k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£38k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	Originally Poyry provided a report to ENWL which gave: "an initial indication of whether the strength of price signal ENWL might be able to provide to a market where the distribution network is at risk would be strong enough to over-ride signals from Grid and suppliers." Subsequently ENWL approached National Grid to participate in a joint study looking at the uses and interaction of DSR (Demand Side Response) in general. The analysis requires the definition of drivers by stakeholders and scenario analysis in order to be able to begin to quantify the total value of the different ways in which DSM can be used by different parties. Understanding the drivers and scenarios will allow beginning to see when uses of DSR by different stakeholders may be in conflict and when they might be aligned. This is in turn allows to investigate the value to different parties of DSR in particular circumstances and hence the way in which it may be used. This will ultimately feed into the analysis of commercial arrangements that need to be struck between parties. There are five key dimensions of understanding the uses of DSR Magnitude: How much DSR will be needed (in MW terms)? Duration: How long will the DSR need to be used for (minutes, hours etc)? Timing: When will DSR be dispatched (time of year, time of day etc) and what is the frequency associate with this (how often within season, within week)? Notice period: Over what period of time will DSR be utilised and how far in advance will this be known (minutes, hours, days etc)? Location: When will the use of DSR need to consider locations i.e. where and at what level of the T&D network will DSR be used (and how localised)?		

Figure 1 – Where do the different stakeholders sit in the smart grid hierarchy?



The perception of value attached to DSR from each stakeholder will depend on where in the hierarchy they sit (national v. localised). This means that the different stakeholders will want to use DSR for different things and will have different perspectives on the best use of DSR. For example, DNO's will be interested in the impacts of DSR at the Local and Regional levels whereas the Supplier will be interested in the impacts of DSR at the National level. As a result, there will be interaction; including conflict and harmony, across the different levels of DSR. The dotted lines in the right hand side of the Figure 2 indicate the influence of a level other levels.

Figure 2 – The different geographical interest of stakeholders drives DSR use



Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	Overall Project Score
		6	-1	7

Expected benefits of project	Optimising network investment – Additional (unnecessary) investment in transmission networks could be avoided. Energy balancing – The DSR will be used to balance the wholesale market; this includes energy balancing of system and ensuring system frequency stays within tolerable limits. Demand could be used to balance energy / frequency. Provides cost effective or reduce cost of ancillary services. DSR will be used to manage network constraints pre and post fault (to maintain system balancing).		
Expected timescale of project	1 year	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£20k
Potential for achieving expected benefits	Likelihood of achieving the deliverables is high. However the implementation of the achieved results is uncertain at this moment in time and it will depend on the findings from this study.		
Project progress [Year to End of March 2012]	A Final report was published in February and can be found at this link http://www.enwl.co.uk/docs/about-us/assessment-of-dsr-price-signals---december-2011.pdf . Key conclusions of the report are: 1. Some form of common platform and process should be put in place to enable effective coordination and efficient use of DSR by different key end users. This is necessary to ensure that there is minimal wastage and maximised cost effectiveness. 2. For DSR services of highest value to networks, the requirements for reliability and the consequences of failure to deliver are such that commercial signals may well need to be reinforced or augmented by mandatory/enforced approaches which ensure the full benefits of DSR can be realised without risk to security of supply. 3. Where there is insufficient cross-stakeholder coordination in place and the dispatch of DSR purely comes down to price signals, the DNO will suffer the most as: DNO price signals will be swamped by those from other stakeholders; at the same time, the responsive demand lies on the distribution network; and thus it is the DNO that will face network capacity related problems when DSR is used to meet the objectives of other stakeholders.		
Collaborative partners	Electricity North West		
R&D provider	Poyry		

Strategic

New Materials and Technologies

Project title	**Alternative Fluids for Transformers**			
Project Engineer	Paul Jarman			
Description of project	Evaluate alternative fluids to use as an insulating fluid for transformers to determine if they can be used at voltages of interest to National Grid. Specifically to look at one synthetic ester and two natural ester materials. Particular emphasis will be placed on investigating dielectric performance at high voltages. Ideally the project will enable sufficient confidence to be gained to enable a trial of the fluid in an in service transformer (a trial would not be part of this project).			
Expenditure for financial year	Internal £7k External £6k **Total £13k**		**Expenditure in previous (IFI) financial years**	Internal £14k External £86k **Total £100k**
Total project costs (collaborative + external + [company])	£3,758k		**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	Use of sustainable materials for plant and reduction of potential environmental impact on failure.			
Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		6	-4	10
Expected benefits of project	Use of mineral insulating oil as used in existing transformers has potential disadvantages in terms of environmental compatibility, fire safety and sustainability. The use of other fluids particularly vegetable based products could give an alternative which could prove vital if the environmental or supply situation with existing products became unsustainable. The key environmental benefit with vegetable fluid relates to its biodegradability when compared with mineral oil. Some vegetable fluids also have a higher flash point than mineral oil and have a lower energy density when aflame making them beneficial when where fire risk would have significant consequences (e.g. built up areas). In addition, ageing tests conducted by other researchers have reported that for paper impregnated with vegetable fluids, the paper lifetime could be extended. Use of vegetable oil could also contribute positively to the image of the company and more widely the electricity supply industry in adopting sustainable solutions. At the moment vegetable fluids are more expensive than mineral oil but through this project National Grid will be in a position to evaluate how to take forward if the background changes.			

Expected timescale of project	4 years	**Duration of benefit once achieved**	5 years
Probability of success	60 %	**Project NPV = (PV benefits – PV costs) x probability of success**	-£58k
Potential for achieving expected benefits	Results have shown that ester oils have a somewhat different behaviour to mineral oil at high voltages in highly divergent electric fields, typical of the situation where partial discharge has been initiated, but breakdown has not occurred. This would indicate that special precautions to avoid partial discharge would need to be taken in the design of very high voltage transformers for use with ester liquids. This is an important discovery and could avoid significant costs in terms of unexpected failures if the technology was to be adopted.		
Project progress [Year to End of March 2012]	The project as originally conceived is now complete and findings have been published at a CIGRE colloquium and in a paper selected for the main CIGRE session in Paris in August 2012. The project has produced a large amount of very useful data indicating that it would certainly be feasible to use vegetable oils at high voltage, but certain precautions would need to be taken. In particular the velocity at which discharges travel in ester fluids seems to be significantly higher than in mineral oil particularly for positive polarity impulses. This means that if discharge can take place breakdown is more likely. This puts a premium on good design and discharge free operation, but shows that there is potential to use ester fluids in high voltage transformers if the benefits of low fire and environmental compatibility are compelling. There may be a good case for offshore installations where weight of oil containment and fire protection would be at a premium. In service diagnostics of the ester fluids have been shown to be possible, and although some fluids are more difficult to handle (forming a gel on contact with oxygen) these problems could have technical solutions. Good co-operation between the partners is one very positive aspect of the project and it would be desirable to repeat this format with other transformer projects.		
Collaborative partners	EdF, Areva, EPSRC, M@I Materials, TJH2B Electricity North west, Scottish Power		
R&D provider	Manchester University, Leicester University		

<table>
<tr><td>Project title</td><td colspan="4">Investigation into the performance of a nano coating for High Voltage substation insulation</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Tony Westmorland</td></tr>
<tr><td>Description of project</td><td colspan="4">To evaluate the electrical and pollution performance of a nano coating, Voltshield, manufactured by RITEC International ltd, for application to substation ceramic insulator systems (such as Current Transformer & Voltage Transformer weather shields, circuit breaker bushings, substation post insulators etc.)
• To understand the life expectancy of the product.
• To understand the application issues of the product.
• To provide an alternative solution to grease/washing of insulators to manage pollution related flashovers.
• To estimate the comparative costs of greasing and/or live washing systems and the application of Voltshield as an alternative, through the case study of a site/location.
• To identify a suitable site and apply the first application (Trial) of the product.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £3k
External £1k
Total £4k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £11k
External £73k
Total £84k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£88k</td><td>Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Pollution performance of substation insulators</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Tech Transfer</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>12</td><td>-1</td><td>13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Successful completion of the project will;
• Remove the need to regularly remove old grease and apply fresh grease to insulator systems at defined substations.
• Remove the need for/reduce the frequency of live washing systems at defined substations.
• Make on going Opex savings associated with the above tasks.
• Provide an alternative to greasing/ washing to reduce pollution related flash overs.
• To remove and reapply grease to a 275kV post insulator costs on average £233. By comparison, cleaning and applying Volt-shield to a 400kV post insulator costs approximately £100. These costs only include labour and</td></tr>
</table>

	product and do not take access and site engineer costs into consideration as these costs should be the same for both applications. In conclusion Volt-shield will enable National Grid to save up to 57% per insulator on product and labour. Based on an estimate of 50 sites with 200 insulators per site should reduce the cost by £1.3m over 6 years.		
Expected timescale of project	3 years	**Duration of benefit once achieved**	5 years
Probability of success	60 %	**Project NPV = (PV benefits – PV costs) x probability of success**	£10k
Potential for achieving expected benefits	The first phase has been completed successfully and confidence is high that the expected benefits can be achieved.		
Project progress [Year to End of March 2012]	Salt Fog testing of insulators treated with Voltshield has been completed. The tests successfully demonstrated that Voltshield significantly improves the pollution performance of ceramic insulators and would be a viable alternative to greasing and washing. The second phase of the project to determine the life expectancy of the treatment has been significantly delayed. On further discussion with the coating supplier and the testing agency, it now appears that the proposed environmental test specification is too severe and would not produce realistic results. It has been decided therefore to seek guidance on the testing with an external consultancy before proceeding further. Once a suitable specification is agreed testing will commence. Until this is resolved, it is not possible to give any accurate dates but it is hoped that the project can be completed by the end of 2012.		
Collaborative partners	N/A		
R&D provider	RITEC for coating FGH Test Lab for Pollution and Electrical Testing Cardiff University for Accelerated Environmental test		

<table>
<tr><td>Project title</td><td colspan="5">Non Conventional Instrument Transformers (NCIT) Pilot Project Closures</td></tr>
<tr><td>Project Engineer</td><td colspan="5">John Fitch</td></tr>
<tr><td>Description of project</td><td colspan="5">This Project aims to deliver closure, reporting on the learning achieved and the potential whole life value benefits of 3 pilot installations of NCITs, which are currently installed as shadow /non operational systems on the National Grid Electricity Transmission System. This will help formulate future strategies and direction for future NCIT trials and implementations.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £3K
External £1K
Total £4K</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £3k
External £5k
Total £8k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£31K</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£19K</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">As part major construction projects in the late 1990s and early 2000s, 3 pilot installations of NCITs were installed as “shadow” systems by substation project companies to help them gain some operational experience with this new technology. These projects have since lacked a focus and any value output, so this R&D project is to manage these trials through to a mutually agreed completion and outcome, with reporting on the lessons learnt and benefits achieved. It will lead to a planned decommissioning, removal and disposal of these non-maintained assets.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>9</td><td>-1</td><td colspan="2">10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">Lessons learnt form these three pilot installations will be documented and recorded and fed into future strategy and policy changes. This will include the following:
• Installation Issues
• Asset Performance
• Asset Reliability and Stability
• Maintenance Issues
• Health, Safety & Environmental Issues
• Asset degradation mechanisms
• Decommissioning and Disposal Issues
Risks to the UK Electricity Transmission Network will be reduced by removal of non maintained/non operational assets connected to the HV system and auxiliary supplies.</td></tr>
<tr><td>Expected timescale of</td><td colspan="2">2 year</td><td>Duration of benefit once achieved</td><td colspan="2">5 years</td></tr>
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project			
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£19k
Potential for achieving expected benefits	With a project focus to manage these 3 off NCIT pilot installations and commitment from product suppliers, the likelihood of success is high.		
Project progress [Year to End of March 2012}	The NCIT on MSC CB at Sundon substation (NextPhase Optical CT) trial has been taken over by Alstom GRID (from Siemens) and the trial is to continue for a short period, following installation of an anti vibration mounting kit. Final test results will be collated demonstrating any improved mechanical performance and an R&D closure report completed. The unit will then be decommissioned and removed as the NextPhase NCIT design has now been improved. The Alstom GRID GIS NCITs (Rogowski CT and Electronic VT) installed on a section of GIS at Osbaldwick substation will be inspected; test results collated and a closure report written. As this site is now considered unsuitable for a future AS3 trial, the NCITs will be decommissioned and the prototype Merging Units and Protection Relay cubicles removed from site. The ABB NCIT at Trawsfynydd still requires a final inspection, the test results collated with any required forensics, prior to decommissioning and removal from the system. A check to be carried out on any NCIT installation at Cottam substation.		
Collaborative partners			
R&D provider	Alstom GRID & ABB		

Project title	**Polymeric Insulation - Evaluation**			
Project Engineer	John Fitch			
Description of project	This R&D Project aims to gain an understanding of the technical performance and market experience of the material compounds available, preferred manufacturing process and optimum choice of shed profiles for polymeric insulation systems. This will enable clear policy and specifications to be established for the future application of polymeric insulation in substation applications such as Instrument Transformers. This will form part of the risk management process for the introduction of this new technology into replacement and new build substation projects.			
Expenditure for financial year	Internal £4k External £37k **Total £41k**	**Expenditure in previous (IFI) financial years**	Internal £4k External £10k **Total £14k**	
Total project costs (collaborative + external + [company])	£55k	**Projected 2012/13 costs for National Grid**	£0k	
Technological area and/or issue addressed by project	Traditionally ceramic insulation has been used for all substation devices required to provide HV conductor to ground insulation clearance. Examples are CTs, VTs, Bushings and Post Insulators which use a special shed profile to optimise on size, strength, creepage and provide weather and pollution resilience. This technology is well proven, reliable with a predictable life and has been used for over 50 years. However these devices can fail catastrophically and unexpectedly and cause serious injury and collateral damage to other plant and equipment. In addition they are heavy and susceptible to damage during manufacture, transport and installation phases and require larger civil foundations and structures to support them than those made from lighter materials. Polymeric insulation is now a viable alternative to ceramic insulation and there is growing adoption and experience in other utilities. However there are a number of choices on the market, particularly relating to material, shed profile and manufacturing processes. There is also uncertainty over the mechanical strength, proven life, maintenance needs and performance over time. This project will engage NAREC (NDSL) to carry out a technical survey, evaluate and report on the choices available and provide recommendations for optimum selection. This will enable National Grid to risk manage the introduction of polymeric insulation into main projects. This work will also include a market study to examine the worldwide experience of major utilities in the use or trial of polymeric insulators on post type current transformers in substation applications.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		11	-1	12

Expected benefits of project	The output from this project will enable policy and specifications (based on IEC standards) to be established for the future procurement of polymeric insulation in devices, initially post CTs (e.g. FMJL replacement). The benefits will include the following: - • Non explosive – safer in service for people and adjacent plant • Lighter devices – reducing the need for machines and man handling requirements • More robust – less likely to damage, reduce wastage • Sustainability– potential to reduce the carbon costs due to material extraction, manufacture and transport • Standardised approach – reduce range of spares • Disposal and environmental impact – to be determined • Compact – reduced installation foot print and smaller supporting structures		
Expected timescale of project	2 year	**Duration of benefit once achieved**	5 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£8K
Potential for achieving expected benefits	This project will engage NAREC (NDSL) to produce an market survey, evaluation and recommendations of the optimum choices for polymeric insulation for application by National Grid and has a high likelihood of success.		
Project progress [Year to End of March 2012]	The market survey and evaluation is complete and report has been issued by NAREC, the R&D provider. The report with recommendations has been analysed by National Grid's New Technology Team and will be used to produce policy and specifications for the future procurement of primary plant with composite insulation anticipated to be by end of August 2012.		
Collaborative partners			
R&D provider	NAREC (NDSL)		

Project title	**33kV Fault Current Limiter**		
Project Engineer	Barry Reeves		
Description of project	Key learning to be delivered by the project is the understanding of the circumstances under which the superconducting fault current limiter (SCFL) can be used to mitigate fault level issues which are a barrier to distributed generation (DG) connection and how the SFCL can then be designed into and operated. Specifically the following learning outcomes would be expected: • Identification of network and physical circumstances where use of the SFCL could be used to mitigate fault level issues and address potential future DG connection issues. • Identification of design, construction, commissioning, protection, control and operational issues associated with use of such equipment. If the trial proves successful in mitigating faults this could also reduce the need for transmission reinforcements across the UK. • Assessment of actual carbon benefits/confirmation of initial carbon case. • Assessment of impact of equipment on policies, codes of practice, section level procedures, financial authorisation processes (including the financial justification) and identification of required revisions. • Dissemination will be through the production of a "how to" manual that details the new knowledge outlined above. Demonstration Objectives This project trials a specific piece of new equipment that has a direct impact on the operation and management of the distribution system and potentially the transmission system. Phase 1: to identify suitable locations for the SFCL installation and undertake a feasibility and systems readiness study to analyse the network, outline the optimum application and specification, and confirm the business and carbon cases. This has been completed. Phase 2: is to design, build, install and commission a three-phase 33kV SFCL on the CE distribution network. It is proposed, subject to site surveys and agreement with National Grid and other partner organisations, that the unit is installed at a 275/33kV substation in South Yorkshire to limit the fault current to within the rating of the 33kV switchgear. This is currently managed through an operational management switching procedure which in some circumstances may increase the risk of loss of supplies to customers.		
Expenditure for financial year 11/12	Internal £37k External £1k **Total £38k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£2,921k	**Projected 2012/13 costs for National Grid**	£7k

<table>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The Government's targets for reducing carbon emissions mean the UK needs to reduce its dependence on fossil fuels and adopt cleaner energy sources. Generators using renewable energy are sited near their energy sources (on hills for wind, by the sea for tidal and wave power, near landfill sites or digesters for gas, etc). Combined heat and power schemes, which recover waste heat from the process of generating electricity, need to be installed in locations where there is a need for heat. These sites are rarely connected to the National Grid system and in any case connecting to this voltage level would be unfeasible for generators of moderate capacity (typically under 50MW) which are likely to be connected in Sheffield.

Generator connections are therefore being made to local distribution networks but these have limited capacities to handle short circuit fault currents.

To facilitate the connection of generation from renewable sources at the distribution voltage level, the network needs to be capable of withstanding these consequential increases in fault level. Traditional approaches to managing increasing fault levels lead to time consuming, costly infrastructure upgrades which may cause the proposed generation development not to proceed.

The project is largely funded by the Low Carbon Network Fund (assumed costs of superconductor fault limiter is in the order of £2m), which has been made available by Ofgem. The LCNF project will pay for the superconducting fault current limiter and the monitoring and testing of the system.

Sheffield 275kV ring main was selected due to the following reasons:

Alleviate immediate fault level issues so that operational restrictions may be removed and existing 33kV and 11kV switchgear may continue to be used and operated as originally envisaged.

Improve the network resilience to 33kV faults whilst the operational procedures associated with the restrictions are being implemented.

Facilitate the connection of distributed generation without triggering fault level concerns.

Allow the 33kV network to be run with some of the interconnection circuit breakers operated normally closed, to increase load capacity.

Jorndenthorp was selected as the site for the trail. Jordanthorpe is a 275/33kV substation equipped with two 100MVA transformers connected to the 275kV network. At 33kV, Jordanthorpe can be connected via an intermediate substation to Norton Lees Substation. The 33kV AEI switchgear board has one bus section but there is no spare breaker. It is situated on the southern edge of the city in an almost rural location with space to install additional equipment.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Technological substitution</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6</td><td>-6</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The benefit to the business is understanding the integration of a super conducting fault current limiter into the electricity networks and its impact on the distribution systems and potential scalability to a transmission size super conducting fault current limiter.

This project has large potential benefits for the customer, if the trial proves successful in mitigating faults, through the potential to connect generation to the electricity system without large modification to the existing system, minimising costs and disruption to customers.

Also as part of National Grid's innovation Strategy, this project addresses a reputational issue of driving the carbon agenda with the support of our</td></tr>
</table>

	distribution colleagues, ensuring that the energy industry is seen to be making headway into the reducing carbon dioxide emissions and facilitating the changing energy market. This project aims "To facilitate the connection of generation from renewable sources at the distribution voltage level, the network needs to be capable of withstanding these consequential increases in fault level. Traditional approaches to managing increasing fault levels lead to time consuming, costly infrastructure upgrades, which may cause the proposed generation development not to proceed." The deployment of an SFCL (assumed total costs of this demonstrator project of £2.6m) will have the following (multiple and overlapping) technical and commercial benefits to operators and owners of electrical networks by: 1. Observing this development on the Distribution system we will learn (from a technology and a business perspective) whether or not it could be scaled up for application at Transmission voltages 2 Speeding up the connection of Distributed Generation at 6.6kV – 33kV (ultimately at higher voltages) and eliminating the costs of network reinforcement associated with rising fault levels. This also supports the use of locally available primary energy resources 3. Reducing losses. They allow the network to be interconnected (meshed) without replacing switchgear to cope with rising fault levels. Meshed networks generally have lower losses and more load capacity headroom, allow for improved power quality (due to lower network impedances at times other than at times of network faults) and availability. Application of SFCLs will further allow the use of lower impedance transformers in asset replacement / reinforcement schemes) and removal of series reactors both of which would reduce network losses 4. Reducing asset management costs whilst improving network safety, stability and efficiency. SFCL should be able to offer lower cost alternatives compared to conventional means of reinforcing and maintaining fault levels at an acceptable level. 5. Bi-directional fault flow in smart networks arising from the connection of distributed generation can have an adverse impact on the performance of some protection schemes. Depending on the relative magnitude of the fault currents from generation and the transmission system, application of SFCLs can improve the capability of an existing protection system to cater for increased levels of distributed generation2. For Transmission protection we may be able to take advantage of changed settings and reduce the impact of faults on other network equipment or we may discover unforeseen impacts which we need to mitigate 6. Allowing for a safe and sustainable solution at substations where reinforcement related time constraints could defer a generation connection 7. Allowing for increased overall network lifetime and reduced likelihood of subsequent faults, as a result of limiting short circuit currents rather than installing higher rated equipment to cater for them.		
Expected timescale of project	1 year	**Duration of benefit once achieved**	8 years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£313k

Potential for achieving expected benefits	There is a strong likelihood of success of the trail succeeding in obtaining applicable and transferable knowledge, however, there is a low likelihood that this project will be scalable to the transmission system.
Project progress [Year to End of March 2012]	The project is currently in the detail design stage i.e. how is the SFCL going to be physically connected into the HV system and the protection systems at Jordanthorpe. There have been many meetings with the DNO to discuss what is needed to protect National Grid's and the DNO's existing assets if the SFCL were to fail in service; these will continue through 2012. A set of test requirements for the SFCL , short of type registration, but following the principles of type registration, have been agreed with the DNO and the supplier ASL.. The HAM unit Risk Hazard Management Zone (RHMZ) is still causing issues. As outages can not be secured to replace the two sets of HAM units that are impacting on the access road and the SFCL construction area, ballistic screening of these areas is the only option left. This is being progressed but as the screening will sit inside the (RHMZ) outages are needed to allow installation. Outages for the main works in 2013 have been agreed.
Collaborative partners	Low Carbon Network Fund
R&D provider	Applied Superconductor

Project title	**Trial & Performance Assessment of ACCR Conductor (3M)**		
Project Engineer	Mike Fairhurst		
Description of project	Assess the suitability of the new generation of high temperature low sag OHL conductors currently available on the market, for deployment on the UK transmission network, in terms of mechanical capability & performance, erection methods, maintenance & repair. At present National grid have installed both GAP and ACCC (CTC) conductors on the bottom & middle phase on the de-commissioned YYO line near Sheffield in order to evaluate the mechanical performance. The goal of this project is to string ACCR (3M) on the remaining Top phase in order to evaluate and compare the stringing, sagging and termination of these three HTLS conductor types, to monitor their mechanical behaviour during simulated ice loading conditions and to evaluate the practical application of the three. HTLS conductors and their component materials have been extensively tested both during and after their development by the manufacturers and various research organizations, but to date National Grid have yet to carry out such works.		
Expenditure for financial year 11/12	Internal £13k External £151k **Total £164k**	**Expenditure in previous (IFI) financial years**	Internal £0 External £0 **Total £0**
Total project costs (collaborative + external + [company])	£394k	**Projected 2012/13 costs for National Grid**	£230k
Technological area and/or issue addressed by project	There are many sorts of power flow limitation in modern power systems. If the problem can be solved by a relatively large increase in the thermal rating of an overhead line, re-conductoring the line with HTLS conductor is a possible solution. These conductors are capable of high temperature operation with minimal change in electrical and mechanical properties and have low sag at high temperature when compared to conventional conductors. In order to increase a line's thermal rating without rebuilding or replacing its structures and foundations, the original conductor can be replaced with a special high-temperature, low-sag (HTLS) conductor having the a similar dimensions and properties as the original, but which can be operated safely and reliably at much higher temperatures with far greater ampacity. The 3M Company was established in 1902 with $27 Billion Sales in 2010 over 80,000 employee's world wide. ACCR conductor has over 10 years service history with no reported failures in service and no failures during installation. To date there are 90 successful installations, in over 60 different countries, with more scheduled for 2011, 2012 & 2013. With the most recent installation being in National Grid USA, as part of the Western Massachusetts Transmission Reinforcement Strategy, 3M are currently investing in expanding manufacturing capacity to meet demand.		

Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		13	1	12
Expected benefits of project	The advantage of the high temperature low sag conductors is their ability to operate continuously at temperatures of 150°C or above with less increase in sag and little or no loss of strength, the net result being increased line rating from existing assets Manufacturer tests of ACCR(3M) indicate that it can be operated at 210°C continuously without changing its mechanical or electrical properties, with a post fault temperature of 240 °C. Providing increased capacity on existing overhead line routes and increased operational flexibility of the network under post fault conditions. The initial cost is considerably more than conventional conductor systems (5 times), however a proportion of this cost will be off set by the eliminating the requirement to strengthen existing towers and foundations as is currently the position when existing lines are up-rated, with larger heavier conductors (nominally £30 - £40k per tower) , estimated in the forward planning to 2021 as 950 circuit km (nominally 3 towers per km leading to potential £100m saving on towers offset by increased conductor costs resulting in a conservative £10m benefit).			
Expected timescale of project	2 years	**Duration of benefit once achieved**	8 years	
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£3,189k	
Potential for achieving expected benefits	As stated earlier many countries around the world are adopting this new technology with much design review and testing. With respect to the ACCR (3M) conductor there have been no reported problems since the earliest installation some 10 years ago. National Grid in the US is currently refurbishing and re-conductoring a 110kV line in Massachusetts			
Project progress [Year to End of March 2012]	The materials necessary to move forward with the project have now been procured. However, difficulties with the delivery of the materials have caused the delivery date to slip to August. The next stage of the project is progress the access development works.			
Collaborative partners				
R&D provider	3M & MDE			

<table>
<tr><td>Project title</td><td colspan="4">FEA modelling of Current Transformers with composite insulators in various rigid Busbar configurations</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Tony Westmorland</td></tr>
<tr><td>Description of project</td><td colspan="4">The structural performance of post type current transformers (CTs) fitted with composite supporting rigid tubular busbars cannot be practically demonstrated by direct testing methods alone. Finite Element Analysis (FEA) offers a reliable method of determining the behaviour of materials under various conditions and scenarios that can be envisaged in typical busbar configurations. The data collected from the FEA modelling study is anticipated to lead to the introduction of composite insulators on post type current transformers as a safe alternative to current transformers fitted with ceramic insulation.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td>Internal £3k
External £36k
Total £39k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td>£44k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£5k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The recent catastrophic failures of GEC FMJL post type current transformers represent significant safety hazards to National Grid personnel and third parties. Failures have resulted in complete disintegration of the ceramic insulator and widespread dispersal of porcelain fragments over large areas of the site. Sites affected currently have Risk Managed Hazard Zones (RMHZ) of up to 75 metres around each FMJL unit which is preventing system access to carry out essential capital infrastructure and replacement work.

As an alternative to porcelain, composite insulators can be supplied as an option by most of the post type CT manufacturers. These are typically of silicon rubber material which has the advantages of being lightweight, superior in terms of pollution performance and more importantly are inherently safer then porcelain insofar that they will not shatter or fragment.

This project will investigate the impact of replacing current transformers with porcelain insulators for composite insulated current transformers and how these composite insulators will behave in typical busbar arrangements under static and dynamic load conditions.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>15</td><td>-1</td><td>16</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The introduction of composite insulation for post type current transformers is anticipated to eliminate the risk of explosive events occurring as with the CTs supplied with ceramic insulators, to date failures and risk management have incurred costs in excess of £1m per year. This project will contribute to avoiding future risk management costs (10% is a conservative estimate).

The superior pollution performance of composite materials produces a more economic design than porcelain in terms of electrical creepage length and can</td></tr>
</table>

	result in a single standard design as opposed to two designs for different pollution severity levels. There is an additional weight advantage over porcelain which could be utilised when designing the structures supporting the current transformers.		
Expected timescale of project	1Year	**Duration of benefit once achieved**	5 Years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£219k
Potential for achieving expected benefits	The potential for this project achieving the expected benefits is high. The project is expected to provide significant structural data to enable a direct comparison between composite and porcelain insulators. This data will be used to demonstrate that current transformers with composite insulators are capable of being used as a support insulator when used in rigid busbar arrangements.		
Project progress **[Year to End of March 2012]**	The project was briefly suspended to enable FEA modelling of the FMVG replacement units which was considered a higher priority. Work has subsequently recommenced and is proceeding in line with the revised timescales. Preliminary results are expected within the next two weeks with the final report due to be completed by the end of the June 2012.		
Collaborative partners			
R&D provider	Alstom Grid, Research & Technology, Stafford UK		

Project title	**Enhanced Lubrication for National Grid HV maintenance**			
Project Engineer	Pete Denyer			
Description of project	Determine the most effective modern lubricants to ensure enhanced reliability and performance, replacing obsolete, ineffective and possibly environmental harmful lubricants.			
Expenditure for financial year	Internal £19k External £85k **Total £104k**	**Expenditure in previous (IFI) financial years**	Internal £40k External £168k **Total £209k**	
Total project costs (collaborative + external + [company])	£312k	**Projected 2012/13 costs for National Grid**	£0k	
Technological area and/or issue addressed by project	Lubrication and maintenance			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		11	-1	12
Expected benefits of project	Extension of maintenance frequencies for a large proportion of National Grid HV equipment. Increased availability and reliability. Rationalisation of existing lubricants.			
Expected timescale of project	3 Years	**Duration of benefit once achieved**	3 Years	
Probability of success	35%	**Project NPV = (PV benefits – PV costs) x probability of success**	£412k	
Potential for achieving expected benefits	The expectations are that this project will achieve the benefits expected as good lubrication is the key to reducing maintenance costs whilst ensuring good availability and reliability. Technology in the tribology field has developed considerably and this project will ensure National Grid will use the most suitable lubricants available.			

Project progress [Year to End of March 2012]	2012: All the work by Imperial College has now been completed.. The final reports and recommendations have been received. Implementation of the recommendations is being discussed internally within National Grid. A technical paper "The Development of Laboratory Screening Methods to Optimize Lubrication Maintenance of High Voltage Equipment" has been presented at NGLI with significant interest: **Abstract:** National Grid Electricity Transmission owns and operates the high voltage transmission network in England and Wales that connects power stations to local supply networks, transmitting electrical power from the generators to the end users. The equipment used in substations may stand idle for several years, being exposed to outdoor conditions, but in the case of circuit breakers be expected to operate within milliseconds to break the circuit. The combined effects of the environment and long maintenance intervals can lead to degradation of the lubricants used on the equipment. Although component failure due to poor lubrication is extremely rare, National Grid Electricity Transmission is committed to further improvements to the maintenance protocols and this is the focus of the current paper. The paper reports the background to the problem, the analysis of main degradation mechanisms and the development of laboratory tests to assess lubrication requirements in different environments across the network. The relevant degradation mechanisms were identified as UV oxidation, long-term, low temperature volatility loss and water-washout. The most important parameter determining failure was identified as static friction which if excessively high may delay component response. Static friction results are presented for a limited number of candidate lubricants for fresh and artificially degraded samples. 2011 - A Research Associate was appointed and visited National Grid refurbishment centres and sites. All current and historic lubricants have now been identified and compared based on constituent products. Interim recommendations have been submitted for the bay refurbish program. Extensive aging tests on many greases and oils have been carried out. The aging tests have been along the lines of elevated temperature, intensive UV and water washout. Analysis has been done using an infrared spectrometer and stiction & friction tests. These tests are continuing and the results being analysed and collated into a format that will be useful to field staff. Additional work has been identified for research into spray greases.
Collaborative partners	None
R&D provider	Imperial College

Project title	**Long term performance of silicone based composite Insulators**			
Project Engineer	Boud Boumecid			
Description of project	The key objective of this project is to advance the ageing model for composite insulators in order to maximise the return on previous research work in identifying and managing any risks associated with their use on the National Grid transmission system			
Expenditure for financial year	Internal £3 External £47 Total **£50k**		**Expenditure in previous (IFI) financial years**	Internal £14k External £317k Total **£331k**
Total project costs (collaborative + external + [company])	£407k		**Projected 2012/13 costs for National Grid**	£26k
Technological area and/or issue addressed by project	Overhead line insulation systems/asset management implications of using new technology (principally life expectancy and associated ageing mechanisms.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		12	3	9
Expected benefits of project	The further development of the ageing model will provide National Grid with and asset management tool that enables cost-effective management of composite insulators used on the transmission network. This could lead to significant mid-life refurbishment savings, improved health and safety performance and improved grantor relations. Furthermore, composite insulators are proving to provide better pollution performance than ceramic insulators with a resultant increase in network reliability.			
Expected timescale of project	7 years		**Duration of benefit once achieved**	5 years
Probability of success	20%		**Project NPV = (PV benefits – PV costs) x probability of success**	-£356k
Potential for achieving expected benefits	Based on the research studies carried out to date, including the fundamental study of the nature of low current discharges on surface insulation, allowing a better understanding of the low level long term damage caused during the service life of insulators. Also, the work funded by Scottish and Southern Energy on some ex-service insulators has been fed into this project and enabled study of insulators with more advanced ageing. This has shown the importance of the geography of installations and also, because of particular physical features of the insulators, the way in which water movement controls discharge and biofilm development.			

	The above work has favourably contributed to the increased confidence and high potential in achieving the expected benefits.
Project progress [Year to End of March 2012]	Two models have been built and published which show the energy developed in low current arcs on the surface of insulators. It is the energy from these arcs which leads to long term damage of polymeric insulator surfaces. In particular these models show the importance of water movement on the surfaces, a feature not recognised previously, and also the change in energy as a discharge develops into an arc and is eventually extinguished. The key challenge now is to understand better the transfer of energy form the arc to the surface of the material. Experimental techniques to measure the temperature of the non-equilibrium arcs (i.e. the electronic temperature is higher than the gas temperature) using spectroscopy are being developed. This is in collaboration with the University's School of Chemistry. Measurements and models of nitrogen temperatures have been used, and in the cases studied, rotational temperature is considered as the macroscopic temperature which is equal to the gas temperature. It is steady during the observation process, and the temperatures measured by different systems are similar. However, the vibrational temperature varies during the experiment. The rotational temperature (gas temperature) rises with increase of V-I level when the arc length is a constant. If the V-I level is fixed, the rotational temperature goes down with the increase of arc length. The nature of effective electrodes to the discharge (water droplets etc) are critical to behaviour and this is now being studied further. The ongoing work will support development of ageing models and will enable better asset management and product tests to be established The generalised asset management tool generated within the Supergen Amperes Consortium has been specialised for overhead line insulation management. The work has also been used to support the development of the Composite Cross Arm technology.
Collaborative partners	National Grid is currently exploring possible collaborative funding of this project with Scottish Power and Scottish and Southern Energy. Should they agree to support this project it is anticipated that the funding split would be 80 %/10 %/10 % National Grid, Scottish Power and Scottish and Southern respectively.
R&D provider	The University of Manchester

<table>
<tr><td>Project title</td><td colspan="4">Power Cable Materials Related TSB Project: Sustainable Power Cable Materials Technologies with Improved Whole Life Performance</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Mike Fairhurst</td></tr>
<tr><td>Description of project</td><td colspan="4">This project seeks to develop a new generation of polymeric power cable materials which are required to address the growing medium voltage (MV) and high voltage (HV) power utility markets in the UK and the rest of the world. This is driven by replacement of existing aged HVAC systems, new power system connections, especially for renewable (HVDC) and for infrastructure development. Current polymeric cable materials based on cross linked polyethylene do not provide adequate high temperature performance; neither do they offer low environmental impact over their service lives and at end of life. This proposal seeks to remove these limitations by developing and assessing new high-temperature low-loss, recyclable polymeric materials, evaluating their performance in cable designs and by developing and applying a whole-life assessment tool to quantify the whole life benefits.</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £4k
External £14k
Total £18k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £58k
External £156k
Total £213k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£295k</td><td>Projected 2012/13 costs for National Grid</td><td>£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The project addresses a new generation of polymeric high voltage cables with higher thermal rating performance than conventional polymeric cables for medium and high voltage applications. It addresses development of the materials and model cables and life cycle economic-environmental tools which account for the full life cycle performance including cable deployment and operation.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>-2</td><td>11</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">This project contains an element of basic research which involves the development of thermoplastic materials having low electrical losses, high thermo-mechanical stability and good voltage endurance characteristics require for high voltage (HV) cable operation. The immediate market opportunity relate to the HV power cable market in the UK, Europe and globally. However, the application of the materials technologies developed is expected to extend to the global medium voltage (MV) cable market and beyond.

The proposed new generation of polymeric power cables will address the large and growing HV and MV power utility and distribution markets in the UK, Europe and the rest of the world. It will also address the largely MV cable requirements of large energy users such as metal processors and the chemical and petrochemical industries all of whom have aging power systems in addition to new plant requirements both on shore and off shore. The utility market is driven</td></tr>
</table>

by new power systems in developed countries including the UK.

Western Europe including the UK have the greatest forecast growth rates for MV cable deployment, with HV cables second, both in the range 2 to 3% p.a. in contrast to Eastern Europe which has a forecast rate of 5% p.a. for MV cables and 7% p.a. for HV cables.

In 2004 Western Europe production accounted for 20% of world wire and cable production with a sector value of £12 billion. A total of 1.1 M tonnes of polymeric materials are used for insulation and sheathing purpose and just over 400,000 tonnes is accounted for by polyethylene's and this is expected to grow to 480,000 tonnes in 2009. This growth and the value-add in the UK and Europe links directly to:

- Increase urban growth and renovation with under-grounding cables preferred due to their lower environmental and social intrusion than overhead lines.
- Need for increasing reliability in the presence of increasing storm damage and the potential for terrorist action which favour under-grounding.
- Expansion of offshore windfarms and growth of wavepower requiring underground and undersea cable connections (usually DC)
- Increase efforts in Europe (EC and organisations such as UCTE, ETSO) to reinforce inter-country links and improve European power network stability and reliability.
- Development of greater reliability and safety particularly in eastern European countries.

The likely market for the new materials developed in this project are estimated to grow to 100,000 tonnes p.a. when the material is proven in HV and MV applications - this is 25% of the current market and will be worth £50M p.a. and the cable technology approximately £500M p.a.

There is a parallel market opportunity in the provision of the decision support tools that will be developed to support the project and which are likely to find application in other power systems studies and in electrical equipment design, manufacture and deployment. We estimate the market in software licences and consultancy services to be worth £10M p.a. by 2012

This initial project is strategic for National Grid with benefits likely to accrue in the long term.

Over the coming 5 years National Grid is to invest £750 million per annum in the electricity infrastructure of England and Wales. This investment is based on both growing demand and the need to replace high voltage equipment at the end of its life. The need for investment will likely continue at this level well beyond the current Ofgem price review period. Of the total, £500million will be invested in cable related projects. This situation is not unique to the UK, with networks across Europe all experiencing the same drivers to invest in new cables to reinforce the electricity supply infrastructure in major cities.

It is predicted that the demand for materials to service the high voltage (HV) and extra high voltage (EHV) cables industry will grow as old oil filled cables are replaced by environmentally cleaner polymeric cables and where like-for -like replacement will not be a viable option. The vast majority of new cable projects at all voltage levels will be based on cross linked polyethylene unless an alternative can be developed. This sector of the market accounts for approximately 95% of the total installed circuit kilometres globally over the last 5 years. Although the HV and EHV sector is small compared to the MV market, the technologies to be developed under this proposal will likely be readily adopted in this sector. This is in part due to many of the technical issues with existing HV / EHV cables being eliminated in the solution proposed here and providing highly

	recyclable cables.		
Expected timescale of project	3 years	**Duration of benefit once achieved**	5 Years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£768k
Potential for achieving expected benefits	Successful evaluation of the both the first and second thermoplastic blend based minicables have shown that the both cable significantly outperforms existing cable materials technologies based on XLPE. The second blend materials formulation has been shown to provide even higher performance thermally, electrically and mechanically. Both variants of the new generation of polymeric materials meet the higher cable operating temperatures which are the goal of the project. Thermal rating and system studies have advanced significantly and the life cycle assessment model has been completed to evaluate the operational and whole life benefits of these new cable materials technologies. These show that the greatest benefits are associated manufacturing energy and process cost reduction and in operation with emergency ratings which far exceed those of existing cable technology. The project has conclude e and it has achieved all of the original project objectives and exceeded them in regard to the very high electrical performance that has been found. The expected benefits are very high and may exceed the original expectations although there is some project risk/uncertainty if distribution companies and suppliers do not get involed in the next stage of the project. Despite this, two cable companies are committed to the next phase of development.		
Project progress [Year to End of March 2012]	The findings of the initial work have been presented at conferences throughout the year as stated in last years annual report two strong candidate polymeric materials have been identified and variants produced and measured showing that they meet the original objectives for the materials. The first minicable based on the first formulation has also met expectations and the second minicable based on the second formulation has also exceeded expectations. The first materials formulation is subject to a patent application and the second formulation is at the invention disclosure stage. National Grid was involved in the initial scoping of the second phase of the project which has been kicked off this year. Although National Grid are no longer an active partner in the project as the focus has shifted to medium voltage cables. National Grid are keeping a watching brief on the project as will actively look to reengage with the project as it progresses to high voltage cables.		
Collaborative partners	GnoSys, Dow Chemicals, University of Southampton.		
R&D providers	All partners.		

Long Term Research

Project title	**EPRI Substations**		
Project Engineer	Jenny Cooper		
Description of project	This project encompasses National Grid Electricity Transmission's participation in selected Power Delivery projects from the EPRI (Electric Power Research Institute) R&D Programme. Projects are selected to enable maximum beneficial project interaction and maximum leverage on funds. Additional technical collaborations and access to existing products are included as part of the agreed collaboration at no additional cost together with access to the Technology Innovation Program and participation in the Research Advisory Council.		
Expenditure for financial year 11/12	Internal £36k External £655 **Total £691k**	**Expenditure in previous (IFI) financial years**	Internal £123k External £1,723k **Total £1,846k**
Total project costs (collaborative + external + [company])	**£16,183k**	**Projected 2012/13 costs for National Grid**	£690k
Technological area and/or issue addressed by project	Project areas: • Greenhouse Gas Reductions Options • Inspection, Assessment and Management of Overhead Transmission Lines • Conductor and Wire Corrosion Management • Compression Connector Management • Live Working Research for Overhead lines • Porcelain & Glass Insulator Integrity Assessment • Transmission Line Design Tools • Lightning Performance & Grounding of Transmission Lines Polymer and Composite Overhead Transmission Line Components • High Temperature Operation of Overhead Lines • Transformer End-of-Life & Condition Assessment • Transformer Life Extension • Circuit breaker condition assessment and life extension • Using relays for circuit breaker diagnostics • Fault current management • Protection and control • Advanced Conductors • Assessment & Evaluation of Next Generation HVDC Technologies • Life Extension and Best Practices Guidelines for Substation Equipment • Improving Overall Substation Maintenance Management		

<table>
<tr><td></td><td colspan="4">

SF_6 Environmental Management and Equipment Performance
Solid-State Fault Current Limiter/Circuit Breaker Development
Management of Substation Ground
Ground Grid Evaluation, Maintenance Refurbishment
Energy Storage (Transmission)
AC/DC Line Conversion
Antenna arrays and wireless mesh sensors for partial discharge location
ZedMeter instrument to measure the grounding impedance of Transmission lines
Technology and Innovation Programme including sustainability

</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>-2</td><td>13</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">
EPRI is probably the largest research organisation in the world with a large-scale interest in the electricity Transmission business. The organisation is keen to implement research programmes between suppliers and utilities, thus encouraging innovation and bringing novel ideas closer to the market. National Grid has also been invited to be a member of the Research Advisory Group – the executive level group steering the complete research programme.

The key benefits to National Grid of being involved with such an

environment include:

Gain access to a wide range of R&D objectives both underway and planned
Participate in multi-user discussion and networking including setting the direction of applicable EPRI projects
Commercialisation of R&D into products that can be purchased with minimum risk due to knowledge gained in R&D
Trials comparing diagnostic tools – benefit gained from collaboration as National Grid would not support this activity individually
Evaluation of benefit from application of techniques/software currently in development through EPRI projects
Establish further opportunities for tailored collaboration for demonstrations and trials with further shared risk and cost sharing
Access to experts with complimentary skills to in-house specialists
Access to existing products (value up to 10% of contracted costs) – both reports and intellectual property/applicable knowledge
To influence the direction of the EPRI programme to National Grid’s best interests through participation in EPRI project working groups and advisory councils.
Significant leverage on funds estimated to be 50:1 in substations.
Access to EPRI information is open to all National Grid Transmission employees with a password enabling access to the specifically funded projects and the technology innovation projects.
The National Grid selection from the EPRI programme delivers applied research with defined benefit to National Grid’s assets including improved

</td></tr>
</table>

transformer analysis, SF_6 leakage recommendations and substation monitoring via antenna array technology that grew out of Strathclyde University into a successful spin-off company. EPRI's collaboration around this UK-based project brought the input and funding from over 10 further utilities to bear – and accelerated the development based at Strathclyde University.

- The total project portfolio for EPRI in the transmission research area is $104million per annum, National Grid's selection forms part of this total activity giving significant leverage and potential for developing multi utility collaboration on projects leading to networking, cost and risk sharing.

Specific benefit areas:

Transformers: National Grid has a major transformer replacement programme; understanding the end-of -life processes, condition assessment methods and any possibilities for life extension is required to optimise this expenditure. The EPRI projects provide an international perspective to this activity to supplement the other work, both past and ongoing, that is saving something in the region of £5M per year in capex in terms of avoided replacement and failures if the replacement decision making process was less well informed. Additional incremental benefit from ongoing research is difficult to quantify precisely, but failure to be informed and up to date in a critical asset management area would have a damaging effect on both revenue and reputation. The EPRI work contributes at least 1% of the £5m per annum and is applied via National Grid's transformer specialist. Specific research in EPRI's transformer area cover six main themes that are of benefit to National Grid:

Novel sensors: Under this theme, EPRI conducts research on new sensors for assessing transformer condition. The research develops specialized sensor hardware to provide insights into transformer health that are not obtainable using traditional techniques - or provide a step change decrease in overall implementation costs. Research also helps National Grid understand new emerging sensors in the marketplace - both in the utility industry and in other industries where sensor advances could be easily translated to transformers.

Training and knowledge transfer: EPRI's flagship guidelines under this important theme are the development of the Copper Book. The Copper Book is a comprehensive transformer reference book that focuses on all aspects of transformer operation, maintenance, procurement, and life-cycle management. It is uniquely written from the perspective of a utility engineer and comprehensively addresses each phase of activity from specifications through to end-of-life. The Copper Book serves as a valuable training aid and guides engineers through case studies of common calculations necessary for transformer specification and management.

Transformer Algorithm development: Under this theme, EPRI uses the knowledge and experience gained from years of research to develop actionable information from data gathered from transformer sensors. This topic is growing in importance as more sensors in National Grid send larger volumes of data from transformers in the field.

Transformer Aging assessment: Improved estimates of a transformer's remaining life offer significant financial and reliability benefits. EPRI is researching the dynamic behaviour of new chemical markers in the oil that hold the potential for significant improvements in the accuracy of transformer life estimates - possibly even without knowledge of the history of the transformer or the oil.

Transformer life extension: New research has demonstrated the possibility for continuous online filtration of oxygen and moisture with new membrane technologies that offer the potential for low cost and minimal maintenance. This would open the door for life-long filtration and corresponding life extension to

	transformers in National Grid. Transformer forensics - linking diagnostics and maintenance with true internal condition: EPRI research is carefully examining retired or failed transformers and relating the evidence to both transformer operations and diagnostics data. The resulting forensics library provides National Grid with new insights into likely end-of-life scenarios for the increasing population of aging transformers. Circuit breakers: The EPRI project provides an international perspective of risk based asset management, condition assessment methods, guidance on material selection and application, maintenance task and timing and any possibilities for life extension required to optimize expenditure. Benefits come from being able to develop rationale necessary for ongoing and future maintenance and asset management policies and staying abreast of industry maintenance and asset management practices. Standards based multi-vendor Protection & Control approaches. Good successes in 2011 with benefit achieved through development of approaches that help demonstrate, educate and create awareness among utility staff. Research conducted includes laboratory development, testing and technology transfer through workshops attended by US and International Utilities. SF_6: Strong environmental driver to be involved. Good successes in previous years with benefit achieved through the development of leak sealing technology and partial discharge trials, both leading to implementation on the system. Using relays for circuit breaker diagnostics – There has been a sharing of utility practices to better understand how data in relays is being used for circuit breaker diagnostics and techniques to incorporate this data into SAM using standards based approaches. In coming years, there will be more opportunities to field try EPRI research findings and apply results. Circuit breaker condition assessment and life extension – Application of ongoing EPRI research results enables utilities in improving their maintenance procedures and specification and procurement practices. Specifically for National Grid the progress achieved so far has enable National Grid to define the rationale to standardize products – for example, circuit breaker greases. Prior to engaging in this work National Grid had over 85 products in use for circuit breakers all over the system. Furthermore, the information exchange through a 7 day session with EPRI collaborative utilities in a workshop environment assist in creating further awareness especially in prevalent maintenance practices. Earthing: The benefits of collaboration on the earthing (grounding) project will allow for alternative methods of test to be examined and validated, resulting in a potential cost saving to National Grid Transmission through efficient incorporation of the techniques into National Grid's operation. **Overhead Lines:** **Specific focus on specific components (e.g., insulators and compression connectors) and issues (e.g., lightning and grounding, and transmission capacity). Inspection and Assessment reference material helps workers keep abreast of new inspection and maintenance practices, tools and issues.** Providing corrosion control and management practices for overhead ground wires, phase conductors and hardware can help National Grid reduce unplanned outages, improve reliability, and reduce associated repair Splice failures are expected to increase with increased demand for heavier loading operations. Due to the limitations of existing inspection techniques, isolating the components early enough to avoid failure is a challenge. EPRI's research provides understanding of thermal threshold limits for existing tools and investigates new technologies to improve decision making. Lightning prediction software can be used by National Grids resources to

	optimize the lightning performance of transmission lines using internal resources. The lightning and grounding reference guide (Gray book)can be used to address the loss of institutional knowledge Reliability-based Transmission Structure Designs manual provides designers with most current information on concepts of reliability-based designs for structures and this information can be used to fine-tune National Grid's own design Composite components have certain disadvantages and uncertainties. Concerns include selection, application, and inspection. EPRI's tools and information can increase National Grid's confidence and reliability in using these components Millions of ceramic insulators are approaching or have exceeded the end of their intended service life. Concerns are growing about the availability of inspection techniques to identify high-risk units prior to failure. A prototype inspection tool was demonstrated at National Grid. The technology is being further developed to be remotely controlled with some automated features. In addition, the technique is being refined to identify cracks in the insulators located underneath the metal cap The effects of high operating conductor temperature are reduction in conductor ground clearance, loss of conductor strength, and damage to connectors and other overhead line components. EPRI has developed solutions and models to allow power companies to raise transmission line capacities safely, reliably, and with confidence. , The benefit of this research can help National Grid increase confidence in operating overhead lines at high temperatures, avoid damage to overhead line components and subsequent line failures and adopt mitigation measures to achieve increased power flows The long-term in-service performance of Advanced conductors (also known as high-temperature low-sag or HTLS conductors) is unknown. The most immediate need is to investigate technologies using a carbon fibre core conductor. This is the least known and most novel of all advanced conductors. The benefit of this work is that it provides information and tools that are currently unavailable to evaluate the performance of various advanced conductors, and provide maintenance procedures and recommend tools to ensure the safety of utility personnel and the reliability of transmission lines. Specifying, applying and long-term in-service performance of Advanced conductors (also known as high-temperature low-sag or HTLS conductors) is unknown. The most immediate need is knowledge of the long-term performance of these high-temperature conductors, especially those with a carbon fibre composite core. Specifications for the purchase and evaluation of these conductors are also required. Application of Transmission Line Work Station modelling software to analyse performance of current and future assets. Complimentary work to ensure knowledge of asset management of composite components in terms of lifetime, handling etc. Facilitating reduced operations and maintenance costs while supporting an aging infrastructure with reduced capital expenditure for new and refurbished equipment and drive to improve reliability and worker safety Substations: Safety of people and equipment during operations and outages. Enhancing system reliability, performance, and life of equipment on ever-decreasing maintenance budgets has become essential for an infrastructure that has reached its design life of 40 years. Advanced technologies and tools are needed to maintain and operate substation equipment in the increasingly competitive energy marketplace Transmission System Development: Safeguard, protect, and modernize transmission grids. Increasing transmission capacity utilisation is necessary to ensure grid stability. Need to eliminate or relieve transmission bottlenecks to the market reach of competitive generation. Need to increase the robustness of the

	transmission grid through use of tools that enhance both steady and dynamic state performance. Sustainability: Understanding implication for National Grid – Model for building sustainability in terms of inputs, operation and delivery of energy. Combined utility view of benefits of sustainability in terms of reduced impact on asset management leading to environmental and cost benefit to the customer.		
Expected timescale of project	Ongoing	**Duration of benefit once achieved**	Ongoing
Probability of success	50%	**Project NPV = (PV benefits – PV costs) x probability of success**	
Potential for achieving expected benefits	Total cost of 2011 EPRI program that National Grid contributed to in part, was $26.8m. EPRI feedback from combined utility membership indicates that with a leverage of up to 50:1, there is potential for achieving benefits through Maintenance guidelines can extend equipment life by 5–10 years Condition-based maintenance reduces maintenance costs by up to 30% SF_6 management can reduce losses by up to 50% Predictive maintenance will reduce maintenance costs by up to 10% Preventing failure of critical transformers will save £2–5 million per unit New overhead line design tools that can reduce capital expenditures by up to 5% Accurate overhead line component condition assessment will be improved to accurately diagnose incipient fault conditions, increasing transmission reliability. Increased knowledge and understanding of technology-based methods to alleviate transmission capacity constraints and help them optimize use of existing transmission assets Extending the market reach of competitive generation by eliminating or relieving transmission bottlenecks Enhanced experience and knowledge about which technologies will increase the robustness and integrity of transmission grids by avoiding or minimizing the impact of cascading failures, voltage collapse, and other major disturbances. Membership of the EPRI Lightning &Grounding Task Force has delivered National Grid guides on the different types of OHL earthing and how to apply them, as well as guidance on the different types of test methods and when to use them. The Task Force is also in the process of delivering a specification for a test meter to allow the earth impedance of individual towers to be measured without removing the earthwire at the peak. This Task Force is also responsible for the development and maintenance of the Tranmission Line Work Station (Lightning & Grounding Module) software which is used to manage the risks associated with lightning and OHLs, specifically the software allows the probability of an OHL being struck by lightning to be calculated and the potential consequences to be evaluated. Application of the Antenna Array trials has reduced radio frequency interference surveys – removing need for weekly surveys and hence saving manpower directly (estimated as 100 hours minimum per survey). Potential failures avoided this year have been a current transformer and a supergrid transformer due to bushing failure on a supply to a major consumer. The avoided costs from these failures are considerable amounting to an estimated £5m but also avoided		

	potential disruption to customers. The Scope of the project has been increased due to the large variety of partners in the project which has identified additional benefits to the system. Pollution has successfully been monitored and also small cracks in insulations. The project is now looking to find the limitations of the device, the best way of dealing with Noise and how the data can be realistic cleansed. There have been proactive replacements of equipment from partners in this project already in the trial stages cementing the potential benefit this project could have on the network. Work to develop a technique of testing ceramic insulators for cracks with the circuit energised has developed and demonstrated at Eakring test facilities. The next stage is to better understand how level and location of damage affects the vibration signature and to attempt to exploit that character to identify a broken insulator in a population. Sunburst – Work is currently ongoing to update the hardware from the late 90's to enable the system to be used inline with SAM and EPRI forecasting studies are to be incorporated into the system. Sunburst – Work is currently ongoing to update the hardware from the late 90's to enable the system to be used inline with SAM and EPRI forecasting studies are to be incorporated into the system. SF_6 – Alternatives to SF_6 are still being investigated at the moment. There has been a sharing of best practice for leak repair techniques which has been incorporated into SAM. Using relays for circuit breaker diagnostics – There has been a sharing of utility practices to better understand how data in relays is being used for circuit breaker diagnostics and techniques to incorporate this data into SAM using standards based approaches. In coming years, there will be more opportunities to field try EPRI research findings and apply results. Circuit breaker condition assessment and life extension – Application of ongoing EPRI research results enables utilities in improving their maintenance procedures and specification and procurement practices. Specifically for National Grid the progress achieved so far has enable National Grid to define the rationale to standardize products – for example, circuit breaker greases. Prior to engaging in this work National Grid had over 85 products in use for circuit breakers all over the system. Furthermore, the information exchange through a 7 day session with EPRI collaborative utilities in a workshop environment assist in creating further awareness especially in prevalent maintenance practices.
Project progress [Year to End of March 2012]	Previous deliverables are outlined in previous years' IFI reports and highlights can be found on www.epri.com. Below are specific developments related to National Grid in progress or delivered in EPRI Power Delivery and the Technical Innovation Programme: **Replacement of SF_6 in transmission switchgear:** The project at Liverpool University will develop an understanding of the fundamental physical mechanisms of arc quenching by chemical components produced from solid particulate material and subsequently deliver a demonstration interrupter unit for transmission applications that does not require SF_6 for its operation. Sulphur Hexafluoride (SF_6) gas has excellent arc interrupting properties which have lead to it being the only commercially available technology for circuit-breakers in electricity transmission applications. It does, however, have an extremely high global warming potential and its use raises questions on environmental grounds. Much work has been done in the search for alternative gases, but candidates having the appropriate chemical and physical properties also tend to exhibit high global warming potentials. Recent work performed at the University of Liverpool has adopted an alternative approach. An arc interruption technique has been demonstrated that uses chemical components produced in the presence of the arc from solid particulate materials. Its basic performance has been assessed with fault currents of up to 60 kA with moderated rates of rise

	of recovery voltage of up to 1.2 kV/μs. The work is continuing at present as part of AMRDE 1043 'Use and management of SF_6'. In the proposed work, the fundamental physical mechanisms of the technique will be studied and the four stages of arc interruption, thermal recovery, dielectric recovery and dielectric withstand will be optimised such that an interrupter unit for transmission applications can be developed. An approach using modelling and experimentation will be adopted and a demonstration unit for transmission usage developed. Although the technique for interruption without SF_6 has been demonstrated in the laboratory, there is a significant level of risk associated with the project. Out of arc quenching, thermal recovery, dielectric recovery and dielectric withstand, it is the latter that is expected to present the greatest challenge. The likelihood of success is estimated to be 40 to 50%. Given the current imperative to reduce greenhouse gas emissions, a successful outcome to the research is likely to result in significant pressure for implementation. Production prototype devices will need to be built and type tested at a short circuit test laboratory. The involvement of a switchgear manufacturer will be essential for production of a commercial device. The tests at Liverpool are done on a full sized circuit breaker unit and at fault current levels of 63kA and with an injection voltage of 1.2kV/□s. A non- SF_6 self-blast type interrupter unit has been designed to utilise the accumulated thermal arc energy to build up high pressure in the expansion volume. In the case of a high-current arc interruption, the resultant high pressure gas is released at current zero to help extinguishing the arc. For a low-current operation, the present design mainly exploits the effects of polymer reaction induced pressurisation and arc quenching phenomena to assist arc interruption. The use of polymer materials in the arc discharges currently forms part of the development of new interrupter methodologies for replacing SF_6 in future switchgear systems. The schematic diagram of the test interrupter unit is shown on Fig. 1. One of the aims of the experiment is to compare the effects of pressure build-up by introducing additional ablative wall materials and some other micron-size polymer particles within the test unit. It is known that the presence of additional polymer materials can lead to an increase in the pressure build-up inside the expansion volume which subsequently intensifies the gas flow flushing and arc cooling process.

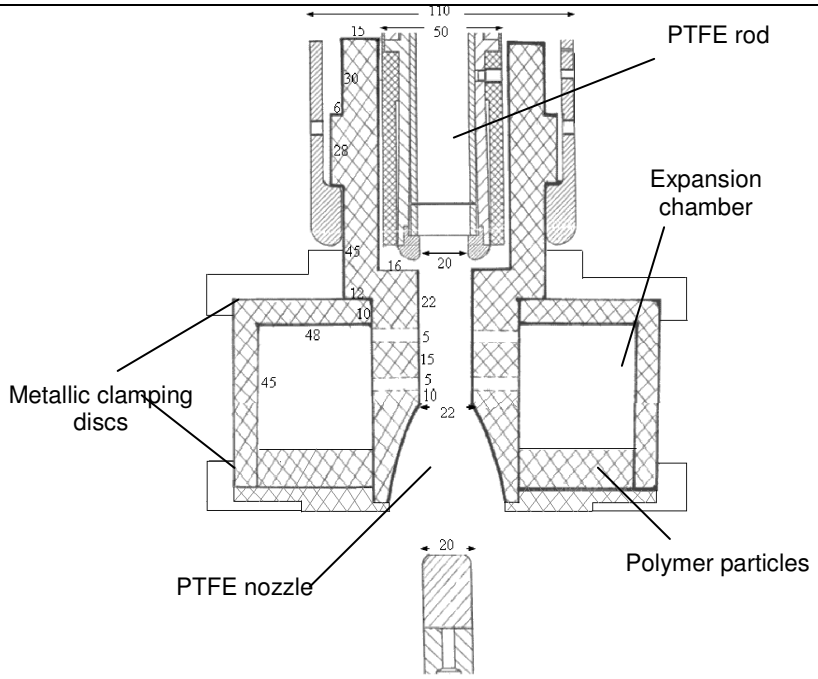

Fig. 1: Test unit with an additional PTFE core inside the hollow fixed contact.

In the current test arrangement, an additional ablation element (PTFE rod) is placed inside the hollow fixed contact. The design modification is aimed at reducing the overall arc-heating volume, as well as increasing the mass ablation, in order to generate a larger pressure build-up inside the expansion volume. Tests are performed on the test unit in Nitrogen and also SF_6 at 1 bar pressure. Their results are first used to establish a benchmark against which the performance of the test unit can be evaluated.

In addition, a polymer injection apparatus (see Fig. 2) will be used to supply a pressurised nitrogen gas flow into the expansion chamber at a certain fixed timing during the arcing event. The external gas flow will make the polymer particles which are pre-loaded inside the expansion chamber become buoyant in the air. Some of the particles may be expelled into the arcing column via the existing vent holes. Overall, this setup increases the surface area of polymers being exposed to the arc plasma, subsequently leading to the increased rate of polymer reaction.

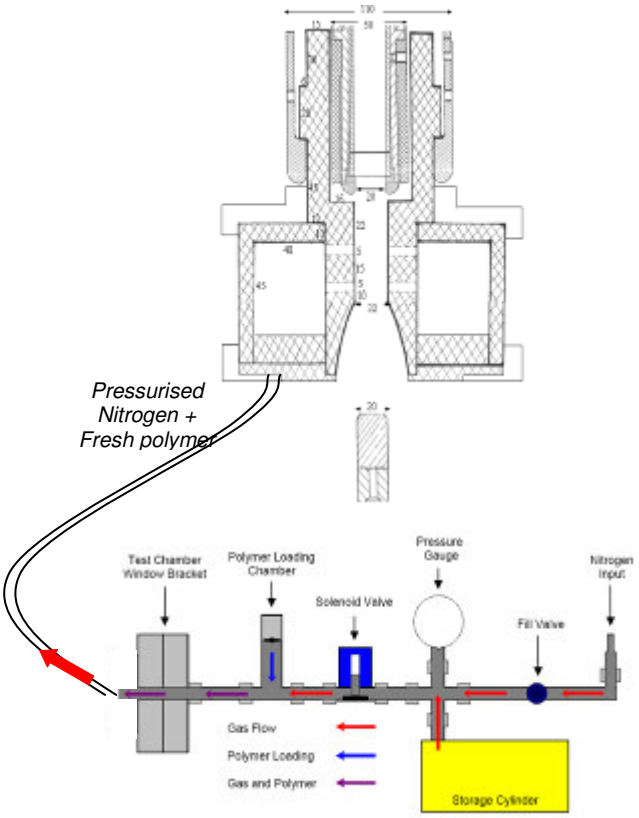

Fig. 2: Polymer injection apparatus to propel pressurised nitrogen and polymer particles.

The major activities of the R&D project in year 2011/2012 are finishing off the project and engagement of EPRI.

The project final report was submitted in July 2011 and the approval of the report marked the end of the project. Building on the achievements in the previous periods, extensive lab tests and experiments were carried out, using circuit breaker interrupter designs much closer to the potential real-life configurations. Supported by the detailed analysis and simulations, these experimental data have made the project fruitful. Following fundamental research on the performance of various polymer materials, the concept of a SF_6-free breaker is proved highly likely to be technically achieved.

After the project was finished, discussions were carried with EPRI in the us making use of the framework arrangement with EPRI to carry this project on under their Technical Innovation programme. The research team, as well as the National Grid sponsoring engineer, managed to produce a number of demonstration tests for the proof of validation, in the duration of 3 months. Based on the satisfactory demonstrations, EPRI has taken over this project into a new phase. National Grid is following the progress and is also trying to establish the economical/political impact the new design would introduce.

2011 Deliverables – EPRI Research – Overhead Transmission (Program 35)

investigation and analysis

Conductor, Shieldwire and Hardware Corrosion Management

Inspection and Assessment of Overhead Transmission Line Hardware Inspection and Assessment of Overhead Transmission Line Hardware Near Infra-red (NIR) Spectroscopy Development as a Predictive Tool

Compression Connector Management

	Comprehensive Compression Connector Inspection Guide Compression Connector Inspection: Utility Case Studies High Temperature Low Sag Conductors: Application of the conductor cleaning tool. Lightning Performance of Transmission Lines **Grounding Practices for Structures close to Substations** TLSA: Mechanical considerations for installation **Transmission Line Surge Arrestors: In-service Inspection Technologies** Lightning prediction modeling software Lightning & Grounding Reference Book Overhead Line Design and Research **Reliability-based Transmission Structure Designs** Live Working: Research, Techniques and Procedures **Training Materials for LW with high-temperature conductors** **LW friendly/unfriendly structures** **EPRI Live Working Reference Book** Polymer and Composite Overhead Transmission Line Components **Polymer Insulator Population Assessment Software:** Short-Term Tests to Evaluate Aging Performance Composite Component Failure Database **Polymer Insulator Vintage Guide** E-field Modeling Software **Polymer Insulator Reference Book** Porcelain / Glass Insulator Integrity Assessment Evaluation of New Porcelain/Glass Discs Units Evaluation of Aged and New Porcelain Insulators Electric Field Modeling Performance and Maintenance of High-Temperature Conductors **Maintenance of High-Temperature Conductors Guide for Selection and Application of High-Temperature Conductors** Previous deliverables are outlined in previous years' IFI reports.
Collaborative partners	World-wide utilities and universities through EPRI collaboration.
R&D provider	EPRI

<table>
<tr><td>Project title</td><td colspan="3">Power Networks Research Academy</td></tr>
<tr><td>Project Engineers</td><td colspan="3">Jenny Cooper,</td></tr>
<tr><td>Description of project</td><td colspan="3">The Power Networks Research Academy (PNRA) has been established through a strategic partnership agreement between the Engineering and Physical Sciences Research Council (EPSRC), electricity transmission and distribution companies, related manufacturers and consultants, that will fund and support PhD researchers in power industry related projects and help maintain and improve the research and teaching capacity in power engineering subjects.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £3k
External £85k
Total £88k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £12k
External £127k
Total £139k</td></tr>
<tr><td>Total project costs (collaborative + external + internal)</td><td>£10,257k</td><td>Projected 2012/13 costs for National Grid</td><td>£30k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">PhD Award Holders
Details of research projects, the lead academic, the university and the name of the PhD award holder are set out for each of the years below, National Grid supported projects highlighted:
<table>
<tr><th>Project Title</th><th>Lead Academic</th><th>University</th><th>PhD Scholar</th></tr>
<tr><td>Overhead Lines Measurement System (OHMS)</td><td>Manu Haddad</td><td>Cardiff</td><td>Stephen Robson</td></tr>
<tr><td>Application of Artificial Immune System Algorithm to Distribution Networks</td><td>Jovica Milanovic</td><td>Manchester</td><td>Nick Woolley</td></tr>
<tr><td>System Impacts and Opportunities of HVDC Upgrades</td><td>Tim Green</td><td>Imperial College</td><td>Yousef Pipelzadeh</td></tr>
<tr><td>Protection</td><td>Tim Green</td><td>Imperial</td><td>Nathaniel</td></tr>
</table></td></tr>
</table>

		Issues of Inverter-Interfaced DG			Bottrell	
		Electrical Network Fault Level Measurement For DG and other applications	Andrew Cruden	Strathclyde	Steven Conner	
		Reactive Power Dispatch for Distributed Generation	John Morrow	Queens	Stephen Abbott	
		Protection of future power systems encompassing DG, converter interfaces and energy storage	Campbell Booth	Strathclyde	Kyle Jennett	
		Intelligent Insulation Systems	Paul Lewin	Southampton	Alex Holt	
		Early Frequency Instability Measurement	Vladimir Terzija	Manchester	Peter Wall	
		Protection of Series Compensated Transmission Lines based on synchronised measurement technology	Vladimir Terzija	Manchester	Shantanu Padmanabhan	
		Influence of oil contamination on the electrical performance of power transformers	George Chen	Southampton	Shekhar Mahmud	

		Alternatives to SF_6 as an insulation medium for distribution equipment	Manu Haddad	Cardiff	Phillip Widger
		Reducing the risk of sub-synchronous resonance in meshed power networks with increased power transfer capabilities	Jovica Milanovic	Manchester	Atia Adrees
		Solid state devices for electrical power distribution	Stephen Finney and Tim Green	Strathclyde Imperial	Gordon Connor -April 2011 start
		LV Cable Monitoring Using Domestic Smart Meters	Simon Rowland & Peter Green	Manchester	Berihu Mebrahtom
		Effect of climate change on design and operation of meshed networks	Keith Bell	Strathclyde	Kirsty Murray
		State Estimation for Active Distribution Network	Bikash Pal	Imperial	Sara Nanchian

Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		2	-2	4

Expected benefits of project	It is expected that the Academy will: • promote a stronger, more active and robust R & D environment in power networks disciplines at UK universities; • provide capacity and capability to undertake the specialist research needed by industry and wider stakeholders; strengthen the teaching capability at those institutions; • focus on building the health of discipline across a number of power research

	universities; • facilitate a resource of trained engineering staff with academic capability, who will be capable of tackling electrical power engineering challenges; and • deliver research output that is industrially relevant. See online for further information at http://www.theiet.org/about/scholarships-awards/pnra/		
Expected timescale of project	5 Years	**Duration of benefit once achieved**	5+ Years
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£172k
Potential for achieving expected benefits	The potential for achieving the benefits are high. It is expected that the PNRA will achieve the expected benefits.		
Project progress as of March 2012	Since 2008 fourteen projects for PNRA scholars have been selected from a number of submissions, using a two tier process. This process comprised; an initial sift to determine the project's industrial relevance and an independent peer review to determine their academic excellence. Scholars were subsequently recruited and a brief summary of the progress on National Grid supported transmission projects achieved to date are detailed below. National Grid also receives benefit from the DNO supported projects, most applicably the Alternatives to SF_6 as an insulation medium for distribution equipment at Cardiff University which will be considered as part of National Grid's review of alternatives to SF_6. **System Impacts and Opportunities of HVDC Upgrades (Imperial College, London)** A major change in generation mix and demand growth is anticipated by 2020 in the GB network, with 35% of total energy demand to be supplied by renewable generation. This includes an additional 45 GW of power generation. The major generation supply (Wind generation in particular) is in the North, whilst the demand is predominately in the South. The circuits between these regions operate near their maximum transfer stability limit and the prospect of overloading the transmission network in GB demands major transmission network reinforcements to accommodate the anticipated growth. Managing this change will require the electricity industry to tackle new legal, technical, commercial and regulatory challenges. Its envisaged that the feasible options are first to maximise the utilisation of the existing assets through installation of series compensators within the stressed 275 kV Scottish/English corridors resulting in boundary flows between regions to operate closer to the thermal capacity and second, exploit the latest technological solutions to ensure demand is met with minimal environmental impact. As such High Voltage Direct Current (HVDC) is envisaged to play a vital role to meet this target. In light of these system reinforcements, the project attempts to address some of the technical challenges in improving the angular stability and system security be means of intelligent supplementary control techniques acting through HVDC devices. The expected benefits of the project are		

	The modelling and control of (i) Line Commutated Converter (LCC) and Voltage Source Converter (VSC) based HVDC transmission networks, (ii) Offshore wind farms connected via HVDC links and, (iii) small to large scale study systems in PowerFactory DIgSILENT. Develop a tool to identify the poorly damped low-frequency modes of large-scale transmission networks using wide-area monitoring signals. The tool should be capable of accurately providing linear models. Demonstrate the opportunities for both LCC and VSC based HVDC links for damping low frequency power oscillations using wide-area signals, thereby increasing the transfer capacity of host AC networks. Develop a practical (robust, low-order, distributed and coordinated) control scheme for supplementary damping control within VSC HVDC links. Demonstrate coordinated control of offshore wind farms and VSC-HVDC links for effective power oscillation damping. Investigate the impact of significant wind penetration and HVDC upgrades on the stability of future grids. Development a method to allow for inertial response from remote offshore wind farms connected through VSC-HVDC links without the need for communicating the grid frequency to the offshore site.. Identification of reinforcement opportunities through coordinated control of Wind-Farms and HVDC, TCSC, etc. in GB network The research underpinning the expected benefits is well advanced. It has not been possible to yet obtain a suitable GB network test model for GB specific studies of the methods developed. Research progress has been good and results have been positive. Relevant control techniques have been successfully applied and adapted for the cases studied. The results have been disseminated through academic publications: Submitted 4 conferences and 2 Journals papers to IEEE/IET. Presented work at an International conference in North America every year. Presented work at U.K conference/events every year. Currently working towards 2 CIGRE conference papers and an IEEE journal paper for July. A 2.5 month industrial placement at National Grid in Warwick was undertaken. Another placement will be considered before completion of the PhD Tasks 5, 6, 7 mentioned above were developed during the periods between April 2011 and March 2012. Two conference papers and 1 journal paper was submitted and presented on each respective topic. The latter part of this period was used to write up the PhD Thesis. The abovementioned tasks have been addressed in this project with around 9-10 publications accepted in IEEE, CIGRE and IET during the period of the research work. **Early Frequency Instability Predictor Based on Synchronised Wide Area Measurements - E-FIP (Manchester)** The goal of the E-FIP project is development of a new tool that will support frequency control. The tool will provide this support by predicting the post-disturbance frequency behaviour. Where, a disturbance is a significant change in the active power balance of a system. Examples of a disturbance include the disconnection of a generator or a large change in load. This prediction of frequency behaviour should allow the system operator to optimise the actions taken to control any deviation in frequency.

	The expected benefits of the E-FIP tool are enhanced transmission system performance, in the form of: Reduced stability margins A significant reduction in the investments made in procuring frequency response support. The methods currently being considered depend upon the value of system parameters that may be difficult to estimate in the time available after a disturbance. This dependence does cast some doubt on the potential realisation of the expected benefits. Although with the time available it is likely that this problem can be overcome. A model based method for estimating the magnitude of the steady state frequency deviation that will occur after a disturbance has been developed. A literature review of direct methods for stability assessment, based on an energy function, is in progress. Based on the current state of this review it appears possible that a direct method can be employed, if a suitable energy function can be produced. Work has continued on inertia estimation. This has focused on dealing with some of the issues that make practical implementation of inertia estimation difficult and has produced some promising, although only initial, results. The progress made in this project since April 2011 mainly consists of: The finalisation of a method for the online estimation of system Inertia and the time of a disturbance The development/testing of approximate natural response and governor models An investigation of Pattern Classification theory and its possible application to frequency prediction Review of network reduction techniques for the purpose of developing an approach for selecting the separate 'prediction areas' in a power system The initial development of a Digsilent power system model with certain control measures implemented to allow the demonstration of the benefits offered by frequency predictions Protection of Series Compensated Transmission Lines Based on Synchronised Measurement Technology (Manchester) Transmission networks across the world face the challenge of increasing electricity demand requiring an increased power transfer capacity for the transmission lines. More specifically to UK, a large amount of distributed generation is expected to be connected to the Great Britain transmission network as a part of vision 2020. The large distances between the distributed generation and the load centres can be met provided the transmission capacity of the system is increased. Series compensation provides an effective solution to this problem and also provides increased transient stability to the system. Series compensation may be in the form of Fixed Series Compensation (FSC) or Thyristor Controlled Series Compensator (TCSC). There are however, a number of problems associated with series compensated lines such as protection and fault location. The changing impedance of the series compensators during the fault makes it very hard for conventional impedance based protection to distinguish the appropriate zone where the fault has occurred. This may cause mal-operation of protection for faults outside its zone. The impedance introduced by the Series Compensator will also cause inaccurate fault location when using conventional fault location algorithms (FLA). As a result, in recent years a number of improved protection systems and FLAs have been developed specifically for Series Compensated lines. Most these algorithms are impedance based and require line parameters. Thus the main aim of this project is to develop a settings free numerical algorithm that does not require any line

	parameters. This algorithm is required to be based on the Synchronised Measurement Technology (SMT). This technology uses synchronised voltage and current samples from both terminals of the line. This algorithm is later required to be validated using Real Time Digital Simulator (RTDS) at the National Grid Power System Research Centre at the University of Manchester. The expected benefits of this research are: Numerical algorithm for asynchronous distance protection of series compensated transmission lines (SCTL) Fault location algorithm for fixed SCTL using SMT Fault location algorithm for thyristor controlled SCTL using SMT Asynchronous fault location algorithm for fixed SCTL using SMT. Given the facilities at the University of Manchester and current progress, the potential for achieving the expected benefits is high. It is very likely that these benefits are realised. Targets that had been set at the start of the project have been met. These include: Literature review of protection and fault location of series compensated transmission lines Creating a reliable model for thyristor controlled series compensated transmission lines Creating the appropriate simulation framework for the protection of series compensated transmission lines The progress is ahead of schedule and the student is now working on a robust settings free algorithm for fault location of SCTL using SMT. Between April 2011 to March 2012 the following tasks were accomplished: A new parameter-free algorithm for traditional lines was proposed in phasor domain. This algorithm was programmed and it was validated against simulations obtained from ATP-EMTP. A TCSC model in ATP-EMTP was developed. **Influence of oil contamination on the electrical performance of power transformers (Southampton)** In the present proposed project, we intend to extend our initial work to consider both metallic and insulating particles under both dc and ac voltages. This is extremely important to power converter transformers which are one of the key components in high voltage dc transmission systems. Power converter transformers experience the combination of dc and ac voltages during operation. To fully understand the characteristics of contaminants under the combined dc and ac voltage, bridging characteristics under dc and ac voltage will be studied separately. In addition to live optical observation and capturing of bridging phenomena between two spherical electrodes in oil under different voltages, contamination levels and oil and paper insulation conditions, electrical conduction currents and partial discharges will also be measured simultaneously during bridging. Finally, the electric breakdown tests of these various contaminated oils will be carried out. To simulate extreme cases of non-uniform electric field and its influence on pre-breakdown characteristics of contaminated transformer oil, a needle-plane electrode system will be further investigated. Similar tests to the two spherical electrodes outlined in the above section can be performed. As the project develops forward, practical application will be considered such as

	the effects of electrode and temperature. The influence of coated/wrapped electrode on bridging dynamics can be explored. As transformers are typically operated at elevated temperatures, therefore, it is vital to extend the above research to a higher temperature regime. Particle bridging characteristics as a function of oil viscosity will be revealed as oil viscosity changes with temperature. The comprehensive experimental results will allow us to establish a good understanding of contamination and its relation to electrical performance and pre-breakdown phenomena. To aid the understanding of bridging dynamics in the contaminated oil, a numerical model of particle movements and their accumulation at high field regions will be developed. It will be based on the hydrodynamic drift-diffusion approximation for the particles' motion under dielectrophoresis (DEP) forces. Additionally, the effect of particles shape and surface roughness on dust migration will be studied and an average (and easy measurable) parameters to characterise a wide variety of dust particles will be found from the simulation. This will create a link between the simulation and the practice, plus provide a verification tool for the model. The model assumptions will be tested by experiments with variety of dust particle (bunches of different sizes and shapes). By assigning appropriate conductivity values to the oil and contaminant, it is possible to obtain the current that flows during the bridging. It will be compared with the electrical conduction current measured under various conditions. Furthermore particles' percolation as a function of particles geometry and volume fraction will be modelled and the effects of dust accumulation around the electrodes on breakdown initiation will be understood. This step by step approach will provide us with essential knowledge of oil contamination on the electrical performance of power transformers so that a set of criteria about oil contamination levels can be established to reduce potential transformer failures in power systems. The student will be involved in comprehensive experimental work and computer simulation. This will equip the student with a broad range of skills and knowledge for future carrier in either industrial or the academic world. In addition to research specific skills training, the school involved in this project has a large and well-established postgraduate school offering a wide range of (compulsory and optional) courses covering subject specific and generic skills, as well as exciting seminar programmes. The student will have regular opportunity for scientific discussion, problem solving and presentation of the work at meetings with the industrial partner and at international conferences. Written skills and report writing are enhanced through the monthly report system, which includes presentation of experimental details and recorded data. The University has a well equipped High Voltage Laboratory to carry out all the experiments for this project. All the necessary software for this project is also provided. Progress to date has included: Presented current work to National Grid team during a visit at Southampton University Purchased necessary equipment for experiment Liaised with HVLAB team to get a place for setting up the experiment Continuous Learning of COMSOL Multiphysics **Reducing the Risk of Sub-Synchronous Resonance in Meshed Power Networks with Increased Power Transfer Capabilities. (Manchester)** Following the first two reported shaft failures in Mohave power station (USA) in 1970 and 1971 due to torsional oscillations, a number of studies have been carried out to explain the phenomenon and to propose countermeasures. Torsional (mechanical torques) oscillations are usually associated with sub-

	synchronous resonance phenomenon. Undesirable sub-synchronous oscillations that may lead to SSR (sub-synchronous resonance) and significant increase in mechanical torques, can arise in general in any compensated or uncompensated power system when natural frequency (fm0) of mechanical system is very close or equal to the complement (fc=50-f0) of the natural frequency (f0) of the electrical system. The potential sources of sub-synchronous oscillations can be classified into three categories. Series capacitance compensation of network Interactions with series compensators Interactions with HVDC controllers It is anticipated that in order to increase power transfer between critical areas and accommodate new generation (mainly offshore wind) without building new AC transmission lines, future Great Britain power network and other power networks around the world could include multiple series compensated lines and HVDC lines. These types of lines give rise to SSR under certain conditions. There have been studies related to control of SSR in networks with compensated transmission lines with FACTS devices and very a few with HVDC lines. The SSR phenomenon in meshed power network with multiple, relatively short, series compensated AC lines and HVDC lines operating separately or in parallel as GB transmission network could look in near future has not been investigated in the past at all. The objective of this research is to explore in detail, scenarios which can lead to SSR in meshed power networks with relatively short but heavily compensated AC transmission lines operating in parallel with HVDC lines and to propose, using probabilistic risk based index, adequate AC/HVDC topologies that minimise the exposure to SSR. Expected benefits of this research are summarised below Clarify significance of SSR studies for future networks considering that type and size of energy generation will change leading to significant changes in transmission network. Provide quantitative and qualitative comparison among different transmission network structures with respect to avoidance of SSR. Small and large disturbance studies carried out during this research, under various operating scenarios including multiple uncertainties in electrical and mechanical system parameters will help to establish robustness of different compensation and power transfer technology options and to identify safe operating ranges for each of the feasible solution. Contribute towards the growing research work to meet carbon reduction target of 2020 (EU renewable energy directive) and 2050 vision for UK power systems. Significant progress in the work has been made to date and objectives of this research are realistic. It is expected that all objectives of this research will be fully achieved and benefits will be realised. Progress in the period April 2011 – March 2012 has been A LCC HVDC system has been built and integrated in four machines multiple bus AC network in DigSilent.SSR studies are carried out using linear and nonlinear analysis methods in AC system and the AC system with HVDC line. A VSC HVDC system also has been built and integrated in the AC system in DigSilent.SSR studies are carried out in AC system with VSC HVDC line. Above studies provide a platform to compare the effect of different HVDC system on SSR. Detailed investigation of modal damping and torsional torques has been carried with different HVDC technologies, uncertainties in turbine generator mechanical system being modelled probabilistically.

	SSR analysis is also carried out for different levels of symmetrical and asymmetrical compensation in four machine,multiple bus test system. A sixty eight bus, sixteen machine test system has been built in DigSilent. Initial studies have been completed to develop risk index for generators based on proximity to SSR with different network topologies and different types of lines. A basic TCSC model also has been built in DigSilent. Above studies have resulted into three (accepted) conference papers. Subsynchronous Resonance in Meshed Networks with HVDC Lines. (accepted for IEEE Innovative & Smart Grid Technologies Conference 2011) The Effects of Uncertainties in Mechanical Parameters on Torsional Torques in Meshed Networks with HVDC Lines.(accepted for IEEE Power & Energy Transmission & Distribution Conference 2012.) The Effects of Uncertainty in Mechanical parameters on SSR in Meshed Power Networks with Different HVDC Technologies. (accepted for PMAPS 2012) **Effect of Climate Change on Design and Operation of Meshed Networks,Kirsty Murray, Strathclyde** The GB power network suffers from regular faults with a percentage of them caused by adverse weather. With the current worry about climate change and the possibility of increased and less predictable adverse weather there is a concern that this will affect the reliability of the network. The Met Office's Hadley Centre has just completed work for GB operators on the risk of climate change effects on the network, thus allowing network operators the chance to change their design standards or make adjustments to the way they run the network. The Met Office's work mainly looked at the distribution network due to the difficulty of quantifying the impact on the transmission network. This is much harder to measure on the transmission network due to the way that it's designed and operated i.e. in a meshed fashion with a higher redundancy. This means that faults on the transmission network that cause a loss of supply are classed as low probability but high impact, they can lead to long restoration times and blackouts and therefore should not be ignored. The aim of this project is to assess the risk of disturbances on the transmission network due to weather and to draw a comparison between today's weather effects and future weather effects after climate change The expected benefits of this research are: To provide the transmission operators the chance to see how adverse weather affects the transmission network and how the effect of climate change (more adverse weather or different types) will affect the networks in the future. Allow the operators to plan and manage the system more effectively Allow them to look at the suitability of network design and allow relaxation of network security when certain weather types are forecast It is likely that the benefits of this project will be achieved in conjunction with the three transmission companies with the provision of their data in an adequate volume for simulations in order to provide realistic results. Progress in the period October 2011 – March 2012 has been: So far a large amount of reading has been completed to give a good base of understanding for what work has previously been undertaken in similar areas. Fault data has been collected from National Grid with on-going work to gather as much information as possible Using National Grids 2010 fault data for weather faults attempting to determine the weather that cased the fault

	The National Grid weather fault from years 1996-2009 have been grouped together into weather causes rather than the year the fault occurred, ready for more detailed analysis Contact has been made with Scottish Power with the promise of gathering fault data for their transmission area SSE have been contacted, but no further progress has been made The Value of Security Assessor (VaSA) code, which will be used to run the simulations, has been acquired and the student is currently learning how to program in Fortran Attended a course on Optimisation and Simulation Methods for Large Power Systems run by EES – UETP and National Technical University of Athens Attending EE573/EE973 Advanced Power System Analysis & Protection which is run by Strathclyde University Attended Durham University's Risk day and National Grids Talking Networks. Visited National Grid in Wokingham.
Collaborative partners	PNRA: EPSRC, National Grid, Scottish and Southern, Central Networks & EDF Energy Networks.
R&D providers	PNRA: Universities of Cardiff, Manchester, Queens (Belfast), Southampton, Strathclyde, and Imperial College London.

Project title	**SuperGen – HiDEF (Highly Distributed Energy Future)**			
Project Engineer	Dr William Hung			
Description of project	The Consortium will develop the analytical, sustainability and economic evaluation tools, interface technologies and coordination strategies that are required to demonstrate the credibility, test the feasibility and engineer the integrative solutions of a future power system that delivers sustainability and security through the widespread deployment of distributed energy resources (DERs) and thus contributes to national and international ambition for a low carbon future.			
Expenditure for financial year	Internal £7k External £31k **Total £38k**	**Expenditure in previous (IFI) financial years**	Internal £3k External £20k **Total £23k**	
Total project costs (collaborative + external + [company])	£4,586k	**Projected 2012/13 costs for National Grid**	£25k	
Technological area and/or issue addressed by project	The Highly Distributed Power Systems Consortium has developed plans for renewal that will demonstrate a radical vision of a highly distributed energy future that enables all end users to participate in system operation and real time energy markets and thereby more fully exploits the potential of distributed generation and active load resources to deliver a more sustainable and resilient provision of energy for the future. This Highly Distributed Energy Future (HiDEF) programme researches the essential elements of a decentralised system that could be implemented over the period 2025 & 2050, but at the same time has been structured to support the evidence base relating to key questions of current concern within the stakeholder community and in this way its relevance extends beyond the limits of its decentralised system vision. In concept, the research vision is one of decentralised resources, control and market participation extending to include end users at system extremities. This challenges the current fit-and-forget strategies for the incorporation of such small elements within the power system that fails to capture the potential added value of this distributed technology. Furthermore, this approach opens up new opportunities that are not feasible in the conventional centralised structure, such as local heat and cooling grids, or district biogas schemes. In recognising this, the consortium's scope has broadened from electrical power systems to future energy systems. This builds naturally on the extensive device based modelling work and conceptual work conducted under HDPS 1. In particular, the cell concept developed by HDPS 1 becomes the mechanism for localised management of not only electrical energy but also gas/heat/cooling and to extent energy for transportation. The HiDEF project strongly complements the research, development and demonstration activities of TSB, the Carbon Trust, ETI, industry and EPSRC. A cross-cutting systems perspective is taken by the HiDEF team, building from detailed bottom-up modelling and systems level requirements. In this way the consortium is particularly qualified to contribute to an understanding of distributed resources and loads, their optimal coordination, and mechanisms for comprehensive integration.			
Type(s) of innovation	Tech Transfer	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**

involved		5	-4	9
Expected benefits of project	The project will help to deliver efficient highly distributed embedded generation, flexible demand and actively managed network which will improve utilization of generation capacity and optimise balancing services. This will not only optimise system operation cost but reduce CO2 emission. National Grid's participation in SuperGen HiDEF was planned for £20k pa and 13 man days per year for 4 years.			
Expected timescale of project	5 years	**Duration of benefit once achieved**	5 years	
Probability of success	50%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£86k	
Potential for achieving expected benefits	Medium to high likelihood of success based on current output from the consortium. Success will also depend on National Grid's engagement and direction. NGET has been contributing to the consortium from a Transmission system perspective to ensure any development in this area will be complementary to the Smart Grid Development.			
Project progress [Year to End of March 2012]	Attended 2 HiDEF Consortium management meeting and project report workshop in Cardiff (May 2010) and Strathclyde (Sept 2010). The purpose of the meetings are to allow NGET to participate in the £4.5m project supported by Utility companies and 5 universities. The key objective for NGET's involvement is to establish close collaborative work with Industrial and academic partners to steer future changes to deliver efficient highly distributed embedded generation, flexible demand and actively managed network which will improve utilization of generation capacity and optimise balancing services. This will not only optimise system operation cost but reduce CO2 emission. The HiDEF project strongly complements the research, development and demonstration activities of TSB, the Carbon Trust, ETI, industry and EPSRC. Some of the key issues which NGET have raised are robustness of small embedded generation (eg inconsistent and unstable ROCOF operations), effect of increasing 1320 to 1800 MW contingency loss on ROCOF operation and co-ordinated strategy in smart meter based demand side management. These if not managed correctly could jeopardise future system supply security and quality of supply. NGET will continue to contribute in the Consortium and the development in the different Work streams and more information can be found in the project website http://www.supergen-hidef.org/Pages/Home.aspx			
Collaborative partners	Approx £4.5m from other sources EPRSC Additional Utilities/companies also link.			
R&D provider	University Consortium Project Manager–Prof Graeme Burt (Strathclyde U) Imperial Collage, Oxford, Cardiff, Bath, Loughborough and Strathclyde universities			

<table>
<tr><td>Project title</td><td colspan="5">EU-Real Smart</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Alex Carter/ William Hung</td></tr>
<tr><td>Description of project</td><td colspan="5">The overall scientific and technical aim of the REAL-SMART project is to take a pivotal role in the creation of technology for intelligent operation of wide-area AC transmission grids using emerging measurement technologies. The project integrates in-depth understanding of the operational issues with analysis of state-of-the-art measurements and first-principles physical knowledge to invent and develop tools that will be deployed in the field in case studies with the transmission operator partner</td></tr>
<tr><td>Expenditure for financial year</td><td colspan="2">Internal £4k
External £3k
Total £8k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £3k
External £0k
Total £3k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£2,500k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£5k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Electrical transmission and distribution in Europe is entering a period of significant renewal and technological change. Transmission grids such as the Nordic system, the National Grid in the UK and the UCTE system in continental Europe are accepting power injections from new and variable energy sources, especially from large-scale wind power generators, and will therefore face major future challenges to operate and control. Policy documents from the US DOE, EU and UCTE and the National Grid have highlighted (i) the need for improved grid infrastructure and advanced control technologies and (ii) the importance of emerging measurement-based technology in enhancing the stability and security of AC transmission in an increasingly complex operating environment.

Changes happening in the process industries also have an impact on electrical supply. Sustainability, efficiency and maintenance considerations are leading to electric motors taking over from traditional gas turbine drivers for rotating machinery such as compressors. Understanding and managing the interface between these large and variable electrical loads and the transmission grid is of great interest for smooth operation of the transmission system.

Trained, experienced and knowledgeable people are required to achieve the ambitious agenda for operation of the European electricity supply networks in the future. Meeting the target will require collaboration between academia and industry and people able to do creative research who are also trained to convert the technologies into industrial systems and products. The changed operating, business and technical environment in the industry requires new ways to monitor and manage system stability security and reliability. This proposal presents a balanced programme of applied R&D to address measurement-based monitoring and management of the high voltage transmission grid.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>7</td><td>-10</td><td colspan="2">17</td></tr>
</table>

Expected benefits of project	For very low cost National Grid can have exposure to the latest thinking surrounding how infrastructure should be best reinforced and advances in control technology as well as being kept informed on the important area of measurement-based technology enabling stability and security of the AC transmission system in an increasing complex environment. The three research themes of this project align with National Grids views and concerns of the future. Providing knowledge in these areas can assist in avoiding misinformed investments resulting in stranded assets. Also ensuring the correct measures are taken to enable the continuing security of supply the uk currently experiences.		
Expected timescale of project	2 years	**Duration of benefit once achieved**	Ongoing
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£9k
Potential for achieving expected benefits	The consortium is well managed and well supported by a range of members from Utility Companies, suppliers and academic institutes; there is sufficient output form the work streams demonstrating progress towards successful outcome.		
Project progress [Year to End of March 2012]	Following the two international academic researchers spending 3 month placements at the ENCC (ie Jukka Turunen from Aalto University, Helsinki Prof Herwig Renner from Technical University Graz, Austria) have completed their project reports which provide some useful insight for National Grid to follow up in enhancing our inhouse modelling and monitoring capabilities. Their work proved invaluable in being able to compare historic and current measurements and the corresponding analysis techniques with modelled results. It also gave a useful overview of the real system issues and has provided a very useful start to the project. The two days project meeting at Krakow in Nov 2011 was useful and both Jukka and Herwig had presented their findings at NG and report finalise earlier on this year. The work in some of the WS are useful to NG including probabilistic planning of offshore wind and SSR detection on generating plant proposed by GE. There are six work streams in the Consortium and the level of participations varies depending on the relevance of the work to NG's business. These work streams are as follows: WP1- Network modelling and control to enhance power system security WP2 – convert real time WAM data to informative information WP3 – convert historical WAM data into system operation and performance WP5 - Quantifying dynamic impact of Wind generation on the Grid WP6 - Probabilistic planning methods for integration of large scale of wind generation (I'm the reviewer of the secondment work at FinGrid)		
Collaborative partners			

R&D provider	Imperial

Project title	**iTESLA (Innovative Tools for Electric System Security within Large Areas)**		
Project Engineer	Parry Batth		
Description of project	With increasingly complicated grid studies, new techniques will be required to enable the operation of the transmission system. This project aims to provide these initial studies and develop operational practise that can be used across the Europeans TSOs		
Expenditure for financial year 11/12	Internal £3k External £1k **Total £4k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	€23,200k **(Euros)**	**Projected 2012/13 costs for National Grid**	£40k
Technological area and/or issue addressed by project	The pan European transmission grid will have to be reengineered progressively in order to accompany the electric system decarbonisation, shaped by a first set of intermediate targets in 2020. This long term transition will make transmission networks more and more complex with impacts on normal and emergency operations. 1. Much larger power transfers over longer distances. 2. Predicting accurately the scheduling of power plants across Europe will become more difficult, which, in turn, will require conventional generators to balance the whole system. 3. With the rapidly increasing penetration of renewable electricity generation and the difficulty to build new overhead power lines, each TSO in Europe will no longer be able to comply with the classical preventive N-1 security standards all year round. 4. When operating a power system close to its stability limits, unstable dynamic phenomena may appear after a contingency. The standard static security assessment based on power flow calculations is not anymore sufficient. Overall, transmission operators take margins (limits below the “true” physical limits) in their day-to-day decision making process, which allows ensuring system security. The pan European system will be more and more stressed: it will become less and less possible to keep such margins safe. An improved assessment of the limits and of the distance to these limits is a prerequisite to avoid considering the system as unsafe and uncontrollable, even in “normal” operating conditions. New concepts, methods and tools are therefore needed to define security limits and to quantify the distance between an operating point and the nearest security boundary: this requires building the most likely description of the pan European Transmission Network and developing a risk based security assessment accounting for the dynamic behaviour of the system. These needs are relevant at both the national and pan European level, with the pressing constraint of keeping any assessment as reliable as possible while system complexity keeps increasing. The resulting tools should then be accessible through a comprehensive tool box, shared and used by TSOs at ENTSO-E level and		

	having three overarching functional goals:

Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
Expected benefits of project	This project is aimed at the changes that will arise on the networks in meeting the intermediate steps of 2020 Climate Change targets. National Grid will be exposed to the risks outlined in the background. This project aims to provide a toolbox of operational practise to mitigate these risks. In order for National Grid to meet the 2020 targets and continue to supply the security of supply the UK currently experiences it is vital that these areas are researched.			
Expected timescale of project	4 years	**Duration of benefit once achieved**	Ongoing	
Probability of success	30%	**Project NPV = (PV benefits – PV costs) x probability of success**		
Potential for achieving expected benefits	This consortium consists of 19 different institutes all keenly aware of the issues surrounding the transmission of electricity. This is a European centric problem due to the high population and unavailability of land. The project proposal compiled by the consortium has the highest risk of failure at 30% so the project committee give a high percentage chance of success.			
Project progress [Year to End of March 2012]	The project is divided into work packages and associated deliverables. Progress towards these deliverables is outlined in the table below. **Deliverable 1.1 "Formulation of the overall problem encountered by TSOs"** The participants in WP1.1 have developed a questionnaire to gather information about the expectations of the iTESLA TSOs regarding different aspects of the grid security assessment (from two days ahead to real time) in Europe in the coming years. The aim of this survey was twofold: to have a better view about the current practice of the iTESLA TSOs (including the possible problems and limitations encountered) and to collect their expectations of the project. On the basis of the answers to the questionnaire, the deliverable D1.1 "Formalization of the overall problem encountered by TSOs" has been prepared. This document includes a synthesis of the recommendations and expectations of the TSOs and will serve as an input for deliverable D1.2 "Formalization of a possible functional solution". **Deliverable 1.2 "Formalization of a potential solution"** In parallel, a general functional overview of the iTESLA toolbox has been developed. This functional diagram will serve as a basis for discussion between the members involved in the definition of the functional architecture of the iTESLA toolbox and as a starting point for the development of deliverable D1.2 (expected in M6). It will also be an important input for the definition of the IT architecture of the iTESLA toolbox. **Deliverable 1.3 "Definition of the overall IT architecture and recommendations of coherent IT solutions"** "Definition of the overall IT architecture and recommendations of coherent IT solutions" will include two main parts: specifications of the common platform for development of the iTESLA toolbox, IT architecture of the iTESLA toolbox itself.			

	The participants in WP1.2 have developed the first part. This document describes the different tools that will be used to make code development more efficient and productive (code version control system, bug tracking system, continuous integration system, binary repository, etc.). The objective is to have a fully operational development platform at the end of the 2nd quarter 2012, which suppose to start the selecting process of a hosting provider in April. The issues of maintenance and user support (software and hardware) have to be examined thoroughly. Regarding the second part of deliverable D1.3 (expected in M9), the participants in WP1.2 have started a brainstorming phase. Solutions for IT architecture are closely linked to the functional architecture of the toolbox (output of task WP1.1). Several issues that need in-depth investigation have been identified: needs of the on-line and off-line iTESLA platforms in terms of HPC (High Performance Computing) and/or HTC (High Throughput Computing), and in particular needs of the data mining process in terms of computing resources. **Deliverable 2.1 "Definition of required external data needs"** A very first draft of deliverable D2.1 has been developed. It includes a preliminary high level list of required external data. A work plan has been defined in order to go further into details and the work has not yet been assigned to partners involved in this task. **Deliverable 3.1 "Requirements for validation of phasor time domain simulations"** Work on WP3.1 has progressed on schedule. A very first draft of deliverable D3.1 "Requirements for validation of phasor time domain simulations and limitations of current modelling approaches" has been prepared. A clear work plan has been defined and the work has been assigned to each partner involved. Deliverable 8.1 "Public web pages" The iTesla website has been developed together with some visual identity guidelines (i.e. logo of the project), cf. Figure 3. The specifications of the website were validated by the partners of the consortium and the logo was chosen by the members of the Steering Committee (7 different logos were put forward). On the midterm, most of the consortium's internal communication will be ensured by the web platform to be set up for software development and data exchange between partners. A complete description of the project website can be found in deliverable D8.1. The address of the website is: http://www.itesla-project.eu .

Figure 3: mock-up of the iTesla website (homepage) with the iTesla logo in the upper left corner.

Deliverable 8.5 "Joint cooperation between iTesla and Umbrella"

WP8.7 has not yet started. A first coordination meeting between both projects is scheduled first week of April. The goal of this meeting will be to discuss the content and organization of the first common workshop towards the TSOs community and to start developing a document about the list of data to be exchanged between both projects in the framework of the validation of their respective toolboxes

Deliverable 9.3 "Quality management plan"

The Quality Management Plan has been sent to all partners by the Coordination for validation. This document is deliverable D9.3 (expected in M3). It includes the description of the governance structure of the project, the reporting procedure (technical and financial periodic reports), the procedures for validation and approval of deliverables, validation of milestones, the procedures for information exchange, the list of key performance indicators and the risk management plan.

Collaborative partners	**The iTESLA project** 6 TSOs (Belgium, France, Greece, Norway, Portugal and United Kingdom), CORESO and a pool of 13 R&D providers **The Umbrella project** consists of 15 beneficiaries, including 9 TSOs (Austria, Czech Republic, Germany, Netherlands, Poland, Slovenia, and Switzerland), 5 universities and 1 research institute
R&D provider	RTE EDF Transport SA, TenneT TSO GmbH

Project title	**Resilient Electricity Networks for Great Britain (RESNET)**		
Project Engineer	Doug Dodds		
Description of project	The RESNET project is funded by EPSRC to allow researchers from the University of Manchester and the University of Newcastle to examine the future resilience of the UK electricity network to climate change. The resilience of the UK electricity network is being addressed on three fronts: 1. Representation of changed performance of network components under future climatic conditions (operational resilience): We shall use reported datasets and models to construct performance curves of the system components under a range of climatic conditions (e.g. transmission line capacity for given ambient temperature). To represent the range of performance for each component type, and capture uncertainties in data, these will be presented as probability density functions. 2. Risk of failure modelling of components under extreme weather events (infrastructure resilience): Fragility functions will be developed to describe failure of energy infrastructure from weather related phenomena (e.g. probability of transmission tower collapse as a function of wind speed). Relevant loading variables will be specified for each element and fragility functions subsequently established by (i) literature review and analysis of past events (e.g. failure patterns during the 1987 storm) (ii) interaction with our stakeholder partners and (iii) finite element analysis of selected components. 3. Whole system modelling: We shall develop quantitative estimates of the effect of climate change on the day-to-day performance of the electricity grid, first using the existing National Grid and one or more existing distribution networks before analysing scenarios and adaptations from other work packages. Monte Carlo simulations will be used for each case with the difference in performance of the system between the base case and the modified cases measured using the following criteria: Increase in operating cost required to maintain the standard level of service; Quantified demand response or load shedding needed to maintain service; Probability of customer outages and expected energy not served; Quantity of renewable energy spilled To address this dual challenge, the project will see the development of a comprehensive approach to analyse, at the UK scale, the resilience of the electricity network and the development of tools for testing adaptation measures that enhance the resilience of the network. The project will explore adaptations at a broad spatial scale and over extended timescales (2020, 2050 and 2080)		
Expenditure for financial year 11/12	Internal £3k External £31k **Total £35k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£87k	**Projected 2012/13 costs for National Grid**	£52k

<table>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">National Grid has previously completed work on the weather related risks to national grid and how they may increase/ decrease with time. This work is investigating the electrical systems ability to cope with the changes that climate change will have on the electricity transmission system. This work not only aims to incorporate the change in climate but also the change in supply and demand, which is predicted, with changing climate and a growing population.

The proposal also states that it will model the network on a nodal basis to enabling an investigation of the entire system.

This project is a result of an EPRSC research call on Climate change and was awarded to the University of Manchester and the University of Newcastle, it combines the system knowledge of Manchester Electrical Engineering department with the Tyndale centre a leading centre on Climate change with Newcastle universities expertise in weather systems and structural knowledge.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>4</td><td>0</td><td>4</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">This work will have impact on National Grid’s strategies with respect to climate change or extreme events.

This work will assist National Grid’s ability to mitigate the risk related to climate change, while both investigating the changes in demand due to climate change and the effects that this loading coupled with changing external environment will have on the electrical equipment that exists on today’s system. This is vital for National Grid to maintain its reputation and security of supply to the country. Full benefits are not know at this time however there are potential cost avoidance if it is proved that the electrical equipment on the system can withstand the changes that may occur due to climate change.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">4 years</td><td>Duration of benefit once achieved</td><td>8 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£137k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">National Grid has a good working relationship with University of Manchester.

The Tyndale Centre and Newcastle are leaders in the fields that they are bringing to the project. That said the likelihood of success is medium as there are many variables that are being included in this project and the scope of work is far reaching.</td></tr>
</table>

Project progress [Year to End of March 2012]	Fault statistics data and knowledge has been shared with Sean Wilkinson of Newcastle University. Ian Cotton of the University of Manchester requested to meet up with key stakeholders at National Grid Wokingham. This was organised with 5 presentations covering Energy forecasting, line rating and NG 2020 operational vision on 28th March 2012. At the end of this workshop there may be rethink on some aspects of the RESNET project. Sean Wilkinson is considering including some aspects of National Grid adaption risk report from Cranfield University.
Collaborative partners	
R&D provider	University of Manchester, Newcastle University

Project title	**Supergen 1 - FlexNet**		
Project Engineer	Jenny Cooper		
Description of project	FlexNet is a four year (2007-11) programme focused on seven themes. Of these "Intermittency", "System Operation" and "Multi-terminal High Voltage Direct Current (HVDC) Systems" are particular challenges for the UK Government's 2020 Low Carbon Transition Plan (LCTP). The other themes: "A More Electric Future", "Visions and Scenario", "Customer Participation" and "Active Distribution" are topics that prepare for the 2030 onwards agenda. The uncertainty of the future means that flexibility continues to be an important objective. The programme aims, where possible, to showcase its insights and achievements so that these can be taken up by the commercial sector, government and regulators for practical implementation.		
Expenditure for financial year	Internal £4k External £1k **Total £5k**	Expenditure in previous (IFI) financial years	Internal £23k External £100k **Total £123k**
Total project costs (collaborative + external + [company])	£7,103k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	The issues being addressed by the work-streams and reported under each of the themes are as follows: • Intermittency - The 40% renewable electricity target will be met mainly by wind energy (intermittent generation). This creates challenges for system balancing and security of supply. This research aims to ensure that cost-effective integration of wind generation is achieved. • System Operation - FlexNet's planned research in system operation is proving well-aligned with the Electricity Networks Strategy Group (ENSG) and Energy Technologies Institute (ETI) reports. The work is focused on building a modelling and analysis base for testing increased boundary transfer limits and of corrective post-fault control. The planning of strategic network investment beyond 2020 is key topics currently being pursued. • Multi-Terminal HVDC Systems - This theme re-focuses on power systems electronics in response to the growing development of offshore renewable generation exploitation of which will require a departure from conventional AC-based transmission. To date, HVDC deployment has been limited to point-to-point connections; realisation of DC networks will require significant research into both control methodologies and underlying hardware. • More Electric Futures - The dramatic cuts in CO2 in the electricity sector require radical changes. This work investigates these changes and examines the implications for the energy networks through five projects. The first project addresses the demand placed on the electricity system in GB from the increased use of electricity as the vector for energy transmission and distribution. The second project looks at how significantly increased electricity use should be accommodated within the GB power system. • Visions and Scenarios - The work carried out for FlexNet supported the 'Long-term Electricity Network Scenarios (LENS) project. • Customer Participation - The emphasis here is on the end use of electricity in		

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<tr><td></td><td colspan="4">economic, technical and human sense. Work is being undertaken on engaging consumers about the necessary transition towards the 2020 objectives. This is focused on understanding how people view the electricity supply system and their flexibility in interfacing with it.

• Active Distribution – The work examines the distribution planning problem as a stochastic maths programme. Work is underway on control room interfaces for active networks, and on an active power distribution network and data acquisition simulator/emulator.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>13</td><td>2</td><td>11</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Each area of FlexNet's work is delivering benefits and expected to deliver further benefits as highlighted below:-

• System Operation – Insights gained will be showcased through grid models, flexible protection and control platforms including WAMS, and demand-side data sets.

• Multi-Terminal HVDC Systems - Control system designs for power flow regulation in MT-HVDC have been established and tested in standard power system simulators.

• More Electric Futures –This theme has already contributed evidence for policy development through the LENS project.

• Visions and Scenarios – The outputs of the LENS scenario have been used in various responses for the fifth Distribution Price Control Review; the OFGEM 'RPI-X@20' project; National Grid in their 'Operating the Electricity Transmission Networks in 2020' consultation (June 2009); the Gone Green scenario (Nov 2008); as well as a joint Electricity Networks Futures Group (ENFG) and Energy Networks Association (ENA) project which is seeking to understand the long term (2020-2030) requirements for distribution systems.

• Customer Participation – To achieve the envisaged decarbonisation of the electricity sector beyond 2030, most of the demand for electricity will need to be able to align itself with the availability of carbon-free generation, The work programme across FlexNet is developing some of the key enablers for this objective including self-regulating buildings, electricity market designs catering for flexible demand.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">4 years</td><td>Duration of benefit once achieved</td><td>5 Years</td></tr>
<tr><td>Probability of success</td><td colspan="2">10%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£77k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">FlexNet has continued to produce a number of PhD graduates familiar with issues associated with distribution and transmission networks. The new concepts, techniques, prototypes and demonstrations will inform network operators of the options that could become available in the next few years.

Some examples of cases where investigators have indicated that IP has been generated to date are listed below:

• Fault blocking module design for multi-modular power converters. A patent filing has been discussed. Alstom have funded four further studies on</td></tr>
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	specific aspects of this technology and has now launched a first product line in this area of HVDC with established circuit topologies while the newer ideas stemming from FlexNet and the follow up work are made ready for use in this product line. • Design of a power electronic diverter for an on-line tap changer (OLTC) and design of a mechanical switch for an OLTC to complement the power-electronic diverter. Diverter patent content and switch design have been discussed in detail with Machinefabrik Reinhausen, MR (the market leader in OLTC) and they are to fully-fund a further study and prototype development • A Dataset of simulated wind outputs from a fleet of wind stations around the UK, hourly, using wind data from British Atmospheric Data Centre, originally provided from the Meteorological Office. • Methods and data analysis for devising optimal bidding strategies for wind generation in forward electricity markets. Janusz Bialek and Chris Dent (Durham University) have held discussions with Ofgem over the relationship between wind owners' bids and economic fundamentals. • Centralised adaptive overcurrent protection system for electrical distribution networks. • Suite of new methods for assessing tidal current energy and dataset of simulating potential UK tidal production. • High spatial resolution model of UK and Irish on- and offshore wind speeds and power production.
Project progress [Year to End of March 2012]	*FlexNet (http://www.supergen-networks.org.uk/)* has now completed with outcomes in simulation models and experimental test results, full information can be found on the website. Flexnet sees flexibility as the crucial response to the challenges facing those engaged with planning, financing, building and operating electricity networks in a low carbon economy. It set out to provide the business case and the technical design of the network and advanced detailed examples of technology that will provide that flexibility. The project, now complete, encompassed the search for engineering solutions to the technical problems of high renewable energy penetration for 2030 and decarbonisation of the electricity sector for 2050; the development of economic ideas that support that change; and analysis of the social acceptability of engineering interdependencies of the challenges and the interdisciplinary nature of the work through flexibility, imagination and careful co-ordination of effort from the many contributors. The outputs have and will shape the development taken up by industry and provide Government, regulators and others with signposts about market investment behaviour and public acceptance. The FlextNet view is that network problems can be solved with non-network solutions. In other words, in many cases providing flexibility in control and operation of existing assets or new forms of assets should be a cheaper overall solution that building more traditional assets (cables, overhead lines, substations). As formal collaborators National Grid has attended the steering committee, the annual assembly and some of the other workshops and work-stream meetings to help steer and advise. The student placements have provided value to both the hosts and the students. Industrialists and other users have helped shape the research by elaborating use cases and providing examples. The three one-week cross-discipline training courses (in engineering, economics and social psychology) were offered to the collaborators as well as the researchers and proved popular. Ofgem and DECC are the intended audience for some of the work but the relationship is two way. Ofgem offered secondments and student placements to FlexNet. FlexNet provided direct support (in the form of analysis) to many Ofgem

	projects including Long-Range Electricity Network Scenarios (LENS), Electricity Market Reform (EMR), Transmission Access Review (TAR) and review of (Supply Quality and Security Standard (SQSS). The Infrastructure and Planning commission has considered the findings of the Deliberative Engagement work task. FlexNet has produced internationally leading work in the analysis that quantified the benefits of smartness in networks themselves and in demand-side action. It has also informed the revision of design rules that determine how networks are built in a regulated industry. It has provided verification of specific proposed technologies to implement smartness. There are many examples of where consortium working has gone well and a sample of these are reported below: · Management Executive – this has been well attended by both institutions and industrial partners, with significant participation by all. A researcher representative was also a member of the Management Executive to act as a communication channel between the leadership of the project and the PhD students and RAs. · Annual Assemblies – this brought all aspects of a disparate programme together allowing networking, knowledge sharing and other benefits. · Books – two books have been produced and published by inter-disciplinary and interinstitution teams. · Parallel development of analytical techniques and case study models. Keith Bell at the University of Strathclyde has produced a GB network model used by several other consortium members. · An adaptive protection system - developed by Raj Aggrawal at the University of Bath and tested on laboratory facilities at the University of Strathclyde. · Network operators have helped with the follow-up of hybrid tap changer with one of their key suppliers.  Demonstration at the Glasgow Assembly 2011
Collaborative partners	EPSRC and the following industrialists: CE Electric UK, Central Networks, UK Power Networks. Scottish Power Energy

	Networks and Scottish and Southern Energy.
R&D provider	University of Bath, University of Birmingham, University of Cambridge, Cardiff University, University of Durham, University of Edinburgh, University of Exeter, University of Manchester, University of Strathclyde and Imperial College London.

Project title	Strategic R&D
Project Engineers	Jenny Cooper
Description of project	This project is a combination of strategic projects being carried out largely by university groups as part of major strategic collaborations. Projects are supported under EU funding, Electricity Supply Research (ESR) network funding and Engineering and Physical Sciences Research Council (EPSRC) funding in conjunction with contributions from international utilities. The projects focus on understanding the potential of techniques or technologies to impact the electricity Transmission network. **Electricity Supply Network -** A coordinated network of electricity supply companies which combines links to the majority of electricity research related academic institutions and links to current EPSRC funded energy projects. Projects are identified in the current EPSRC portfolio that are of interest to at least one member company and that the academic is willing to share the project progress. **Forecasting Average Circuit Reliability (Industrial Mathematics Knowledge Transfer Network)** - National Grid has a requirement to understand the unavailability of the electricity transmission system as a result of asset unreliability and has built up a large amount of historical data over several years. The project aims to use this data to forecast anticipated network unavailability for the years ahead. **Modelling and control of AC-DC system with significant generation from wind (Imperial) -** This PhD project will investigate into the modelling, analysis and control aspects of AC-DC system with synchronous and non synchronous generation. The modelling will be in general multi-machine framework. The expectation is that the HVDC grid side converter control will be supplemented through system level control to mitigate the impact of any time critical dynamic event limiting the transfer capacity of the system. A further research objective is also to see that the undesirable dynamic interaction of the wind generation with a DC link is also controlled through the wind generation side converter system level control. A significant effort in this PhD besides modelling will be concentrated on the control design of these system level controllers for both the converters. **The Development of an Equivalent Power Network Model for HVDC Studies (Imperial) –** This PhD aims to develop an equivalent network model using the Matlab/Simulink in connection with the Western HVDC project and to run the DC and AC load flows at different conditions to assess the model's robustness. **Transmission Tower Field Testing and analysis (Southampton) –** An EPSRC CASE award to support the longer term aspects of transmission Tower Field Testing and analysis (Dynamic Resistance of Transmission Tower Footings) by addressing the following: • Develop a modern design methodology incorporating field research into rate loading effects and failure mechanisms and to apply these findings in the assessment of existing transmission tower foundations systems. • Identify tools and develop a system for recognising locations and conditions where geotechnical uplift and compression issues are present. **A Wide-area System for Power Transmission Security Enhancement using a Process System Approach (Imperial) -** National Grid and Imperial College London have a long term aim of discovery of new uses for measurements from fast SCADA and Wide-Area Monitoring Systems (WAMS). The long term aim is enhanced operation of power transmission systems where the stability and

	power security will be threatened in future by generation from renewable resources such as wind power. The collaboration will contribute towards the long term aim by providing operational insights into the technical issues and specification of the system requirements. **UK Infrastructure Transitions Research Consortium (ITRC)** Inform the analysis, planning and design of national infrastructure, through the development and demonstration of new decision support tools **Transforming Utilities Conversion Points (TUCP)** A project aiming to re-think and re-design the conversion points of different utilities. **Energy Efficient Cities initiative (EECi)** Cross-disciplinary research project aimed at strengthening the UK's capacity to address energy demand reduction and environmental impact in cities. **Undermining Infrastructure Avoiding the Scarcity Trap** To design a truly adaptable, sustainable, low-carbon infrastructure and deliver it without bottlenecks caused by materials scarcity and waste management Produce Vulnerability Index to quantify the risk posed by resource scarcity to continued operation of existing infrastructure, or the proposed introduction of the new infrastructure. **Shock (NOT) Horror** http://research.ncl.ac.uk/shock/aboutourproject/methodology The purpose this research two-year project is to study infrastructure shocks through medical allegories will enable a fundamental shift in thinking of current infrastructure to understanding it as a system of systems of infrastructural interconnections that can help foster sustainable futures. Thus, the aim of this project is to explore trauma as an allegory for infrastructure system shock. The objectives are therefore: To construct models of systems under trauma; To use these models to develop models to visualise the socio-technical configuration of integrated infrastructure system; To test the validity of the allegory of trauma as an allegory of infrastructure system shock; To ensure that these models reflect the interest and priorities of the relevant stakeholders. To integrate the views of stakeholders.		
Expenditure for financial year	Internal £16k External £90k **Total £106k**	**Expenditure in previous (IFI) financial years**	Internal £97k External £275k **Total £371k**
Total project costs (collaborative + external + internal)	£1200k	**Projected 2012/13 costs for National Grid**	£86k
Technological area and/or issue addressed by	**Electricity Supply Network –** Projects areas currently being monitored by National Grid through the network include Knowledge Discovery from On-line Cable Condition Monitoring Systems – Insulation Degradation and Aging Diagnostics (Glasgow Caledonian University and the University of Strathclyde), Energy Efficient Cities (University of Cambridge), Development of Transformer		

<table>
<tr><td>project</td><td colspan="4">and Fault Current Limiter for High Power DC Networks (University of Aberdeen) and Energy Loss Study for AC Excited Superconducting Coils (University of Cambridge).

Forecasting Average Circuit Reliability - One of the key metrics for understanding network unreliability is the Average Circuit Unreliability. It has been reported as in internal KPI for many years and is also fundamental to the annual Regulatory Reporting Pack submission. It describes % network unavailability as a result of asset unreliability (outages related to faults, defects and failures etc). As part of the Network Output Measures methodology there is a requirement to forecast Average Circuit Unreliability. The present techniques are embryonic and limited to just a year’s forecast.

The KTN for Industrial Mathematics, acting as an agent of EPSRC, receives an annual allocation of funding for Industrial Mathematics Internships for short projects to support postgraduate researchers working on industrial-academic collaborations in mathematics. An Internship involves a high calibre PhD student taking time off from their studies and joining a company for a period of 3 to 6 months to work on a stand-alone project specified by a company. This project is co-funded with EPSRC, who will fund 50% of the student’s stipend. The project for National Grid will involve developing a more sophisticated forecast technique for the Average Circuit Unreliability metric.

Modelling and control of AC-DC system with significant generation from wind - In 2008 alone 2000 MW of new wind capacity was connected to the UK grid. With further 6000 MW under construction and 10,000 MW under planning stage in the first round, the UK transmission system in the next 5-10 years is going to face unprecedented operational challenges. The challenges are envisaged to be contributed by many factors such as locations, characteristics of new generation and planned retirement of more and more centralised synchronous generations.

As majority of the wind uptake is going to be in North West of Scotland and demand growth will still be dominated in the down south in England, secured transfer of the energy is going to be a major problem across the Scotland-England inter connector which is already stability limited.

The Development of an Equivalent Power Network Model for HVDC Studies - To assess the performances of the DC system under various operation conditions and assess the influence of the HVDC transmission on system security and AC network performance.

Transmission Tower Field Testing and analysis -Following previous work there is an understanding of the uplift capacity of National Grid’s existing transmission tower foundations under steady state and dynamic loading conditions.

A Wide-area System for Power Transmission Security Enhancement using a Process System Approach – Anticipated outputs are the specification for systems for detection and isolation of root causes of disturbances in power transmission systems, power system security enhancements and data sets from fast SCADA and WAMS systems for the testing of research ideas.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6</td><td>4</td><td>2</td></tr>
</table>

Expected benefits of project	**Electricity Supply Network and EPSRC projects –** The outturn from the managed EPSRC projects is an awareness of current research issues and potential to implement via addition IFI projects, for example via application of condition monitoring developments. **Forecasting Average Circuit Reliability -** One of the key requirements of the Network Output Measures work was to understand network reliability, including on a forecast basis. A simple technique to forecast Average Circuit Unreliability was developed and presented as part of the 09/10 Regulatory Reporting pack and rollover TPCR submission. At present the methodology is embryonic, only forecasting for the year ahead and there is scope to develop a more sophisticated model. The methodology can also disaggregate the data to further develop an understanding of and forecast the unreliability of the lead asset groups: overhead lines, cables, switchgear and transformers. **Modelling and control of AC-DC system with significant generation from wind -** While the dynamic consequence of Scottish and English interconnected AC system is well understood and can be managed by generator additional control (power system stabilizer) the dynamic performance of the system in the presence of wind generation and HVDC transmission is not well investigated. Existing research in wind generation modelling addresses the dynamic and control performance of wind generator connected to the AC grid. The modelling details of the grid is neither very comprehensive nor in multi machine small signal stability framework which is often necessary for planning studies for the interconnected utilities. Inclusion of HVDC link adds further complexities giving rise to difficult research issues. Through networks such as the Electricity Research Network access is gained to government funded research with potential impact to the networks. Not only is there the potential to be made aware of new knowledge and technology but also the potential for National grid to inform and influence the research of large collaborative projects leading to more successful research with potential future impact to consumers. **The Development of an Equivalent Power Network Model for HVDC Studies -** The work could potentially results in a benchmark model for the National Grid. **Transmission Tower Field Testing and analysis -** Assist in the interpretation and implementation of UK and European standards into general National Grid specifications, in particular relating to geotechnical and overhead line foundation design and testing. **A Wide-area System for Power Transmission Security Enhancement using a Process System Approach -** The benefit to National Grid is that early pre-publication results of the EPSRC project will be available to them on an non-exclusive basis. The benefit to Imperial College London is enhanced understanding of technical and operational issues in power transmission.		
Expected timescale of project	Ongoing	**Duration of benefit once achieved**	5+ years
Probability of success	25%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£319k
Potential for achieving expected benefits	Although speculative or strategic by nature, these projects are expected to feed in to National Grid through knowledge transfer from typically academics to the relevant specialist engineer. The work is expected to form the basis of further research or developments, most likely as a specific project.		

Project progress as of March 2011	**Electricity Supply Research Network –** Knowledge Discovery from On-line Cable Condition Monitoring Systems – Insulation Degradation and Aging Diagnostics, Prof C Zhou (Glasgow Caledonian University) and Dr M Judd (University of Strathclyde) - a very interesting project, which is progressing well. It has however met difficulties and delays due to changes in support and staff. Reported via condition monitoring engineer. Energy Efficient Cities, Prof I Leslie, University of Cambridge. This very large project is now holding six monthly seminars, which ESR Network are invited to. The individual strands of the project are progressing very well, but the challenge will be to bring them together. Development of transformer and Fault Current Limiter for High Power DC Networks, Dr D Jovcic, University of Aberdeen. This is a new project which has set of extremely well. Three member Companies attended first meeting. Energy Loss Study for AC Excited Superconducting Coils, Dr Tim Coombes, University of Cambridge. A new project which has set off well. Two member Companies attended first meeting. **Forecasting Average Circuit Reliability -** There are a number of mathematical techniques available which could be employed to forecast the Average Circuit Unreliability and these have been be explored in order to develop the best methodology going forward. The intern used the ACU data and supporting information to develop the forecasting technique at a network level and also as an asset level by equipment group. The output is a model from which ACU and other data can be input and which will produce a forecast for future ACU, disaggregated by equipment type. A technical report detailing the modelling has been produced **Modelling and control of an ACDC system** **with significant generation from wind -** Modelling of an AC and an ACDC network with a current source converter link have been conducted in Power Factory and Matlab, for comparison. Some Matlab simulations have been conducted on a DC link with voltage source converts. These simulations were conducted to solve load flows within ACDC networks. Furthermore wake simulations on a wind farm were developed in Matlab. The simulations take the operating regime of the wind turbine into account. Results are shown for each wind turbine and for the whole farm, for 12 sectors of wind directions. The work included the submission of an initial research plan and technical report to Imperial College. The Development of an Equivalent Power Network Model for HVDC Studies – Ziming doing **Transmission Tower Field Testing and analysis** - The design has been completed and a scale model built feeding in to verifying the main project outcome (reported separately **A Wide-area System for Power Transmission Security Enhancement using a Process System Approach –** Project on progress with final delivery and potential implementation within National Grid to be followed up next year. **UK Infrastructure Transitions Research Consortium (ITRC)** A comprehensive feedback on the Executive Summary of ITRC Report was relayed to the project lead. This will be incorporated in the next phase of the Report.

	A summary of the January workshop was circulated widely within National Grid. A productive ITRC Energy workshop in Oxford on the 8th March 2012 has produced a very close link with National Grid commercial dept for further exchange of information and ideas of sharing advance results before publication by ITRC project lead. **Transforming Utilities Conversion Points (TUCP)** Data request on National Grid assets and background to National Grid views on current 2020/2050 vision provided. This project has produced two briefing notes. **Energy Efficient Cities initiative (EECi)** Following the workshop on the 15th March 2012, a summary on some aspect of EECi work which may benefit National Grid Commercial has been shared. **Undermining Infrastructure Avoiding the Scarcity Trap** National Grid has provided a set of slides identifying issues that concern us with repect to this project. **Shock (NOT) Horror** A workshop has been held to examine three sectors: Energy, Transport and Water under 3 headings of: 1. Landscapes of Infrastructure 2. Infrastructure SHOCKS 3. Resilience infrastructure All the above three sectors were then assessed in terms of socio technical transitions under three headings of: 1. Landscape 2. Regime 3. Niche
Collaborative partners	EPSRC, ENW, SSE, EoN, Alstom Grid, Dooson Babcock
R&D providers	Manchester University / Industrial Mathematics KTN, Imperial College, University of Strathclyde, Southampton University

Project title	**Electric and Magnetic Fields and Health**			
Project Engineer	David Renew			
Description of project	The possibility that there may be effects of EMFs on health is an important issue for National Grid. This project will enable National Grid to strengthen its position in the face of the external threat posed by the EMF issue, through helping it to avoid unjustified constraints in its operations while at the same time ensuring that the EMFs associated with the operations are not the cause of any adverse health effects. This is an umbrella project providing resource for a variety of aspects of research on EMFs and Health, including resource directed towards management of projects funded elsewhere.			
Expenditure for financial year	Internal £76k External £399k **Total £475k**		**Expenditure in previous (IFI) financial years**	Internal £251k External £2,108k **Total £2,359k**
Total project costs (collaborative + external + [company])	£9,319k		**Projected 2012/13 costs for National Grid**	£486k
Technological area and/or issue addressed by project	Interaction of electric fields and magnetic fields with people, and the assessment of fields associated with the use of electricity			
Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		11	2	9
Expected benefits of project	While there is not likely to be a direct financial gain from this long-term research, without it there may be considerable additional costs and constraints imposed on the electricity industry operations arising from lengthy and costly debates about EMF and from unwarranted exposure limits or other constraints on operations. For example an assessment provided to the then DTI about the possible cost to National Grid of implementing the EU Recommendation (1999) on public exposure to EMFs included estimates of up to £850M. Another assessment, to the HSE, about the cost to National Grid of implementing an early version of the EU Directive on occupational exposure to EMF identified costs of the order £10-100M per year. In 2005, the Assessment published by the Stakeholder Advisory Group on EMFs estimated compensation costs payable by National Grid to landowners if an EMF risk because established as potentially several hundred Millions.			
Expected timescale of project	Ongoing		**Duration of benefit once achieved**	Years: Indefinite

Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£2,500k
Potential for achieving expected benefits	The EMF issue has existed for many years, and so has funding of research in this area by National Grid and its predecessors. It is clear that this funding up to now has made real difference in both the lay and scientific arenas – for example the conclusion of the WHO Environmental Health Criteria which focus on childhood leukaemia as opposed to other widespread health outcomes such as breast cancer. Nevertheless the issue is so broad and continuously developing that continued efforts will be needed for the foreseeable future.		
Project progress [Year to End of March 2012]	The multiple strands of this long-term project progress at different rates, leading towards publication in the scientific literature. EPRI in the USA conduct EMF research which is funded by National Grid among many other electricity industry companies. They have continued to seek answers to questions surrounding childhood leukaemia and magnetic field exposure and related issues. EPRI research submitted for publication in the peer review literature includes a study on childhood leukaemia survival rates in relation to EMF exposure; refinement of a job exposure matrix for electric shocks to identify jobs where exposure to electric shocks and magnetic field exposure are separated; a study of birth weight in relation to incidence of childhood leukaemia, magnetic field exposures in petrol vehicles, and very recently a study of residential distance to overhead power lines and risk of Alzheimer's and other neurodegenerative disease using Danish registry data, and a study comparing exposure to small "contact voltages" in the home with exposure to magnetic fields. Reports have also been produced including potential effects of currents in submerged electrical cables and aquatic life, the use of transmission line corridors for the benefit of bees, and the measurement of RF emissions from smart meters. A 24-page public information brochure on "EMF and your health" has been produced. A study of microshocks and cyclists was completed. Preparations are in place to fund a study at the University of Manchester on the effect of weather conditions on the hydration and electrical properties of skin and therefore on the variation of perception of microshocks between people and weather conditions. Preparations are being made to provide funding for a study in London Ontario of the thresholds for magnetic fields stimulation of magneto phosphenes which is relevant to exposure limit legislation. The EMF Biological Research Trust, are funded by National Grid (but not as part of IFI for 4/11 to 3/15), and manage independently a program of research into biological effects of magnetic field. Their projects are all published in the peer review literature. They have eight "current" projects five of which started during the year to March 2011. In addition three new projects have now been developed and are to start during 2012. These latter three are at Oxford University (Evaluation of sleep associated behaviours in response to low frequency magnetic fields, 3 years), the University of Manchester (Transient radicals: carriers of magnetic field MF-sensitivity on humans, 3 years), and University of Oxford department of chemistry (Magnetic field effects on cryptochromes, 4 years). National Grid also contributes to the wider electricity industry research on EMFs and, although this strand is not within IFI, it is run as a single integrated programme by the Energy Networks Association. This includes ongoing work on the health of electricity industry employees, using the database of staff created in the 1970s, which continues to provide reassuring results and is now being expanded to look at incidence of some cancers not just fatalities. The addition of cancer incidence data is complete and an analysis of standardised incidence		

	ratios has been submitted for publication. Previous analyses (which used mortality data only) of association between occupational exposure to magnetic fields to leukaemia and to brain cancer are to be repeated with larger numbers of subjects from.
Collaborative partners	Energy Networks Association, Department of Health, EPRI, Children with Leukaemia, Childhood Cancer Research Group, EMF Biological Research Trust (some of these partners are involved in the components of the research programme which do not come under IFI)
R&D providers	Resource Strategies Inc, Manchester University – HVRDC, EMF Biological Research Trust and others via collaborative partners including HPA-RPD, UCLA, Microwave Consultants Ltd, SAHSU, Institute of Occupational and Environmental Medicine (University of Birmingham). (some of these providers are involved in the components of the research programme which do not come under IFI)

System Operability

Smarter System Operations

Project title	**TSO-DSO Real time data exchange for Smartgrid operation**			
Project Engineer	Alex Carter			
Description of project	The project will assess the requirements for, and demonstrate the viability of enhanced data exchange between National Grid (as Transmission System Operator) and the Distribution Network Operators to facilitate the secure and effective operation of the GB electricity networks following the introduction of Smart Grids.			
Expenditure for financial year	Internal £5k External £1k **Total £6k**		**Expenditure in previous (IFI) financial years**	Internal £6k External £47k **Total £53k**
Total project costs (collaborative + external + [company])	£59k		**Projected 2012/13 costs for national Grid**	£0k
Technological area and/or issue addressed by project	The introduction of SMART Networks within Great Britain will potentially introduce increased uncertainty in the operation of the overall Transmission network, in terms of both the increased level of volatility in demand and the consequent impact on Transmission Network flows. Without adequate data exchange and the development of suitable analysis tools and data visualisation between both the Transmission company and the Distribution Network Operators it will not be possible to ensure that appropriate levels of security are maintained across all networks, ultimately potentially impacting the reliability of supply in Great Britain.			
Type(s) of innovation involved	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		14	-2	16
Expected benefits of project	HIGH- both WPD and National Grid are highly supportive of taking this work forward			
Expected timescale of project	2 years		**Duration of benefit once achieved**	Enduring
Probability of success	80%		**Project NPV = (PV benefits – PV costs) x probability of success**	£482k

Potential for achieving expected benefits	GE are the established supplier of Transmission and Distribution SCADA systems in GB, the trial will also demonstrate the implications for sharing the data across SO and DO SCADA Systems and help demonstrate the data required both parties in a SMART enabled environment.
Project progress [Year to End of March 2012]	2011 - National Grid and WPD have agreed the initial data to be exchanged in the first phase of the trial and the ICCP data link has been established between the two systems. The installation of the GE Power on Fusion software at WPD which establishes the capability at WPD to supply data using the agreed aggregation methodology has caused delay. Currently data has been set up on the National Grid SCADA system to receive the agreed test data from WPD but test data has yet to be exchanged between the two systems, although attempted twice in the past two weeks.
Collaborative partners	25% Funding up to a maximum of £33k from DECC SmartGrid funding initiative agreed.
R&D provider	GE

Project title	**Voltage transducers for power quality measurements**		
Project Engineer	Foorooz Ghassemi		
Description of project	The aims of this proposal are : To devise test procedures for determining HV and EHV voltage transducer frequency response. This can be incorporated in international standards such as IEC. To determine frequency characteristic of typical wound voltage transformers (WVTs) in National Grid's network and hence assess the accuracy of the historical data. To examine the frequency response of residual current devices (RCDs). To examine the use of capacitor voltage transformers (CVTs) for power quality measurements by considering the use of a new add-on device, the PQSensor, to a standard CVT. The device response and capability would be examined. Key Deliverables 1: Specification for source, test rig and procedure (4 months) 2: Design, build and commissioning of source and test (12 months) 3: Specification for reference measurement system. (1 months) 4: Design and build of reference measurement system (4 months) 5: Review and update of test specification (2 months) 6: Review and update of specification for reference measurement system (1 months) 7: Test on different type of Wound VTs (2 months) 8: Test on different type of RCDs (2 months) 9: Test on CVTs with new sensors. (2 months) 10: Analysis of data and reporting (6 months)		
Expenditure for financial year	Internal £3k External £21k **Total £24k**	**Expenditure in previous (IFI) financial years**	Internal £21k External £186k **Total £208k**
Total project costs (collaborative + external + [company])	£232k	**Projected 2012/13 costs for National Grid**	£0
Technological area and/or issue addressed by project	To assess the suitability and accuracy of voltage transducers for power quality and wide band measurement.		

Type(s) of innovation	Incremental	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**

involved		6	-1	7
Expected benefits of project	This project will result in a saving of almost £500k considering just wind farm connections and HVDC schemes planned. 1. WVTs have been used by National Grid as the acceptable transducer for power quality measurements. This is because of their wider bandwidth. 2. Power quality measurements are limited to sites with WVTs, which are not available at all substations because of their costs and size. 3. When considered for substations, due to their costs and space requirements, only a single unit has been used usually connected to the yellow phase. 4. Accuracy of measurements taken so far and are being taken through WVTs are not known. Recent comparative measurements have indicated discrepancies in measurements even at low order harmonics. 5. WVTs are expensive and not being used as standard transducers in schemes. They have to be specified on the project by project basis. 6. RCDs are required to be specified in schemes related to tractions, HVDC and other polluting loads. 7. RCDs must be used in parallel with CVT, nearly doubling the cost of the installation. 8. WVTs and RCDs require additional substation space. 9. Instead of WVTs or RCDs, CVTs together with new accessory, the PQSensor, can be used in power quality monitoring, which in turn will reduce cost and save space, outage time and civil work. 10. PQSensor can be ordered with the new CVTs or retrofitted to the in-service units. 11. CVT and its add-on also make it possible to readily carry out power quality monitoring at all substations as CVTs are present in all EHV substations. 12. IEC standards for instrument transformers need be reviewed so far as power quality requirements are concerned. There is no reference to power quality measurement capability in present IEC standards. 13. At National Grid, a new policy paper for monitoring requirement is in preparation. The project's results will help to incorporate voltage transducer requirements into the paper. 14. The project outcome should show that the cost of voltage transducers can be reduced in schemes.			
Expected timescale of project	3 years		**Duration of benefit once achieved**	6 years
Probability of success	35%		**Project NPV = (PV benefits – PV costs) x probability of success**	-£47k
Potential for achieving expected benefits	The project is slightly behind due to a delay in finding a suitable reference transducer and difficulty in design of isolation between high voltage 50Hz and harmonic sources. The project is getting back on track and should achieve the benefits.			

Project progress [Year to End of March 2012]	A 400kV (230kV ph-N) has been tested at the fundamental frequency component of 210kV plus superimposed harmonics up to 5 kHz. The limitation of the test rig is being investigated to increase the voltage rating to 230kV. This is the first of its kind in the UK or possibly the world. This test rig has been initially designed to test any instrument transformer with low capacitive input impedance. Because of a lack of availability, a purchase order has been issued to acquire a 400kV RCD so that its frequency response can be tested. The design capability is being improved so that it can be used for high capacitive loading such as CVTs. A smaller version of the same design was initially designed and set up for instrument transformers up to 33kV. 11kV and 33kV instrument transformers have been tested. The test system is semi-automatic and signal generation and control are performed in a computer.
Collaborative partners	
R&D provider	Areva, ABB , University of Manchester (UMIST)

Project title	**SmartZone project**		
Project Engineer	Mark Osborne		
Description of project	The SmartZone project will develop and pilot a range of intelligence based applications to enhance the boundary rating and network utilisation, this includes dynamic rating, new operational tripping and wide area monitoring control and protection (WAMPAC) tools, with the intention to have these production ready for National Grid to deploy where constraints or 'Connect & Manage' dictate. The trial will be a staged programme based in the Humber group to develop a 'fit for purpose' communications and data management architecture capable of providing Smarter Transmission. The project will commence in 2011 and aims to have production tools by the end of 2014. The attached report expands on the work. In summary, the pilot will intend to: 1. Install a variety of sensors to collect system and asset data 2. Develop a number of applications which enhance asset performance of circuits and transmission boundaries or enable post fault capacity beyond current deterministic levels 3. Design the appropriate architecture and identify the upgrades necessary in the IS infrastructure to support these new tools 4. Understand the impact these applications will have on existing operation and procedures. Stage 1 will look at the end to end issue around installing one application (2010-11), while stage 2 will expand the range and scope of applications (2011-13) and stage 3 concentrates on the implementation programme into daily operation (2013-14).		
Expenditure for financial year	Internal £53k External £156k **Total £209k**	**Expenditure in previous (IFI) financial years**	Internal £21k External £200k **Total £221k**
Total project costs (collaborative + external + [company])	£430k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	The Humber estuary is going to be a key import/interface region for offshore generation and as such will be a major beneficiary of developments in dynamic rating and congestion management. The ENSG report 'Our Electricity Transmission Network: a vision for 2020' provides greater detail on the network expansion. There are a number of new technologies being considered which can be used to extract or utilise more capacity out of existing assets through better intelligence on the parameters which determine the thermal operating limits of assets. Overhead line circuits are very dependent on weather conditions, so are obvious candidates for dynamic enhancement, especially since this will be coincident with the peak output for intermittent generation sources like wind. Improved network data will enable a new breed of automatic control and protection schemes to be developed.		

<table>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>16</td><td>2</td><td>14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The strategy documents WAMPAC (SD010) and Smarter Transmission (SD01x) both advocate the need for this trial as an integral part of preparing the network for the future.

Under Connect & Manage, constraints costs can definitely be expected to rise, to at least a mean of £50m pa, but most likely higher. It is not unreasonable to expect that basic improvements in dynamic rating, could permit up to a 5% increase in circuit thermal ratings, and in turn would reduce these costs by 10%; thus a £5m pa saving can be reasonably claimed. Although unproven and not integrated at this time, the installation of a dynamic line rating (DLR) system will cost approx £200k-300k/circuit. In terms of constraint saving on a specific circuit this could equate to between £350k & £750k a day. Across the constraint boundary the saving is typically 2-3 times higher so the constraint savings could be in the order of £1m-1.5m.

A range of asset awareness tools will be the key to facilitating system access ensuring connections, asset replacement and maintenance can be achieved.</td></tr>
<tr><td>Expected timescale of project</td><td>4 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years, until industry confidence is sufficient to revise Energy security policy regarding network design.</td></tr>
<tr><td>Probability of success</td><td>60%</td><td colspan="2">Project NPV = (PV benefits – PV costs) x probability of success</td><td>£519k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The project will be carried out in a staged manner. Stage 1 involves establishing a dynamic rating pilot in the Humber. Phase 2 will expand this to wide area congestion management and WAMPAC tools, with Stage 3 concentrating on the implementation challenges for production tools.

There is a reasonable likelihood of success in developing a working solution. The valuable experience gained during the pilot will help to significantly reduce risks during the enduring project roll out.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">This is a multi work stream project. The key development in 2011-12 include;
• Report produced by GSS to identify communications architecture options to support Smartzone applications in the Humber. Data management will utilise the Sandpit server developed in the SAM project.
• Specifications for PMUs and Policy established for wide area monitoring (WAM).
• Report to quantify the economic impact of dynamic rating and power flow control on this region (University of Manchester).
• Ampacimon Dynamic line sensors manufactured and delivered awaiting installation summer 2012 (£180k). These have also been showcased at National Grid Leadership conferences.</td></tr>
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	 • University of Manchester is developing an algorithm to replace conventional operational tripping schemes (OTS). GSS has developed a System Integration Protection System (SIPS) solution.
Collaborative partners	This will be a multiple stage project. Phase 2 will be approximately £1.86m, Phase 3 £360k. Only 50% of the 2011/12 costs are sanctioned at this time. Leverage will be sought through a number of channels and we will look to coordinate application development with Scottish Power and SSE. Work with solution providers to develop new tools (Alstom Grid, Siemens, Psymetrix) and coordinate with parallel National Grid Strategies SAM, RAMM, IS Smartvision ,etc
R&D provider	Multiple

<table>
<tr><td>Project title</td><td colspan="4">Quantifying benefits and risks of applying advanced network control and demand response technologies to enhance transmission network performance</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Mark Osborne</td></tr>
<tr><td>Description of project</td><td colspan="4">The research will inform and develop tools for the business to establish the benefits and risks, in quantitative terms, of adopting complex control methodologies (wide area control, automation & protection) in place of traditional reinforcement techniques. The project will run as three concurrent work-streams (PhDs):

Workstream A will identify strategies for using advanced network control systems to improve system flexibility as alternatives to system reinforcement and constraints. The costs and benefits of each strategy will be determined.

Workstream B will develop methods for understanding the impact on system resilience (SIL assessment) of the use of more complex control schemes, including higher levels of intertripping. The method will provide quantitative measures to allow relative comparisons of a range of network development options.

Workstream C will provide information about current and developing demand management technologies. It will identify the extent to which they can be used to benefit system design and operation, and identify optimum levels of penetration.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £4k
External £171k
Total £175k</td><td>Expenditure in previous (IFI) financial years</td><td>Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£315k</td><td>Projected 2012/13 costs for National Grid</td><td>£140k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The electricity industry is undergoing a period of rapid change across all sectors – new generation technologies, unprecedented volumes and more remote locations; in addition demand characteristics will change, and new transmission system technologies are being constructed to absorb these changes. A full understanding of the impact of the changes and the potential benefits and risks associated with new technologies is needed, to ensure efficient development of the transmission system.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>3</td><td>6</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The use of control technologies will have significant impacts on the way the network is managed. In the design phase they have potential to reduce the need for difficult and expensive developments such as new circuits and introducing greater flexibility for the system operator is likely to reduce system constraints. However, as the control system complexity increases, the consequences of their failure become much greater, impacting on system resilience and reliability. The benefits of this project will be to establish a mechanism to provide informed decisions on when the use of new technologies instead of more expensive</td></tr>
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	development is appropriate, and when the risks are too great. In terms of cost impact, the failure to properly understand the risk and cost of a wide area control scheme could result in a range of impacts; ranging from an inability to reduce constraints across a boundary (£1-2m) to collapse or de-synchronisation between parts of the network and the cost of constraint or possible islanding which could be loss of demand and generation (£10m constraints).. The project itself involves joint funding with Imperial funding £320k via in-kind resourcing.		
Expected timescale of project	3 years	**Duration of benefit once achieved**	5 year
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£22k
Potential for achieving expected benefits	There is a medium, hopefully increasing to high chance of success. Whilst the scope of the project is large and complex, Imperial College have previously produced work in this area and have delivered a number of projects for National Grid.		
Project progress [Year to End of March 2012]	The three workstreams are delivering according to plan. The students have had a 6 week familiarisation period within National Grid to understand the challenges we currently face and our perspective of the challenges ahead. The students are working with National Grid engineers to develop models and studies which can evaluate a system wide controller, coordinated QB control and demand side management strategies.		
Collaborative partners			
R&D provider	Imperial College		

Project title	**Fault Management of the Multi-terminal VSC HVDC using Delayed Auto-Re-Configuration (DARC) Schemes**		
Project Engineer	Dr Ray Zhang /Dr Paul Coventry		
Description of project	This project is to examine a Fault Management method for a Multi-terminal VSC HVDC using Delayed Auto-Re-Configuration (DARC) Schemes • A Delayed Auto Re-Configuration (DARC) scheme is going to be developed to deal with a persistent fault on the DC network of a multi-terminal VSC HVDC system, and automatically restore the healthy part of the network, • The transient and dynamic behaviour of a VSC HVDC system after a DC fault, which will have significant impact on the design for each stage of the DARC consequence, will be investigated and establish achievable operation time for the re-configuration. • Some practical experience drawn from the Operational Tripping Schemes (OTS) and DAR schemes within National Grid Transmission System will be used in the DARC simulation using a real time digital simulator (RTDS) at the University of Birmingham. • The results will be presented in a Cigre VSC HVDC conference while some general conclusions will be drawn for the application of DARC in VSC HVDC systems.		
Expenditure for financial year 11/12	Internal £5k External £26k **Total £31k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£31k	**Projected 2012/13 costs for National Grid**	£0k
Technological area and/or issue addressed by project	Voltage Sourced Converter (VSC) HVDC technology becomes increasingly popular due to its capability of providing reactive power support and flexible bi-directional power flow control as well as black start. It is also well suited to multi-terminal HVDC connections. However managing the faults, particularly those ones on the DC side remain as a major challenge for a real application of such a HVDC system. Under current situation where there are no commercially available DC circuit breakers (CB) in the market, one practical way to clear a DC fault is to use AC CBs to shut down the whole HVDC network which need to be quickly restored after the fault is cleared. The work proposed here is to examine the use of the Delayed Auto Re-Configuration (DARC) scheme to automatically manage such a situation. The Delayed Auto-Reclosure (DAR) scheme has been widely used by the utilities to automatically restore circuits tripped by a fault. This is based on the statistics that over 80 percent of faults on the Over Head Lines (OHL) are transient ones. In most cases, after the first re-closure attempt, if the circuit is tripped again within a “re-claimed” time, the fault is deemed to be persistent, and the DAR will be “lockout”. Such schemes are usually not used for the faults on cable, busbar or primary plant except for the Mesh Corner substations. Although the DARC scheme for the HVDC system has many similarities to the traditional DAR scheme, its principle is fundamentally different. The aim of the		

<table>
<tr><td></td><td colspan="4">proposed DARC here is to deal with a persistent fault on the DC network of the VSC HVDC system, and automatically restore the healthy part of the network back to service. A typical DARC sequence will include Trip, Time delay, Fault locating and isolation, DC circuit reconfiguration, and converter re-energisation, etc.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>14</td><td>2</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">This project is likely to have short-medium impact (1-5 years). This initial research would potentially form part of a larger project which will significantly contribute to the feasibility study and installation of the multi-terminal VSC HVDC within National Grid. The work to be developed will enable National Grid to better understand transient and dynamic behaviour of a VSC HVDC system, examine the use of the Delayed Auto Re-Configuration (DARC) scheme to automatically manage the system DC fault, hence develop new protection and control strategy of the emerging multi-terminal HVDC system, improve the reliability and security of the Multi-terminal VSC HVDC and achieve the optimal asset management within the electricity transmission system.

The loss of availability of a multi-terminal HVDC transmission line caused by a DC fault would potentially cause loss of connected off-shore wind generation and also constrain off generation located in Scotland. The proposed work seeks to minimise the duration of such interruptions and automatically return the healthy part of HVDC system to service.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">1 year</td><td>Duration of benefit once achieved</td><td>5 years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£495k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The knowledge and experience at the University of Birmingham give National Grid the confidence that the output of this project will help to understand the feasibility of the proposed scheme.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">Good progress has been made against all deliverables of this project in 2011/12. The final report is currently expected early in 2012/13. It is anticipated that the learning from this project will be further explored in future work at Birmingham University once a more sophisticated test facility has been implemented.</td></tr>
<tr><td>Collaborative partners</td><td colspan="4"></td></tr>
<tr><td>R&D provider</td><td colspan="4">University of Birmingham</td></tr>
</table>

Project title	**Simulation of multi-terminal VSC HVDC system by means of real time digital simulator (RTDS)**		
Project Engineer	Damien Culley		
Description of project	The key objective of the proposed work is to simulate a multi-terminal Voltage Source Converter (VSC) HVDC link using a real time digital simulator (RTDS) in order to study its operation on the electricity transmission system. An RTDS is a powerful state of the art simulator that allows power system simulation of various power system components in real-time timescales. The use of an RTDS will allow for the technology to be modelled in significantly more detail and accuracy than available via software solutions such as PowerFactory, PSSE or PSCAD. RTDS systems are also capable of outputting analogue signals allow for the testing of equipment such as protection relays etc. The simulation will fulfil the role of a phantom trial in accordance with National Grid's policy for the introduction of new technology. The work aims to demonstrate that a multi-terminal VSC HVDC system as proposed is feasible, to identify potential problems with application of the technology, areas of further research and to inform specifications. The use of the RTDS will allow for the simulation and evaluation of any converter topologies or control strategies that have been made public by suppliers or proposed by other parties. Further to the primary objective of this research is the added benefit of developing the UK research capability in the field of HVDC. It is the aim of industry and academia to establish significant expertise in HVDC in the UK in order to ensure that the rapid expansion of complex HVDC systems across the UK and Europe occurs as smoothly as possible. This project supports this aim and will be followed by further proposals in the future.		
Expenditure for financial year 11/12	Internal £3k External £279k **Total £282k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£347k	**Projected 2012/13 costs for National Grid**	£65k
Technological area and/or issue addressed by project	In July 2009, the three Great Britain Transmission Licence holders supported by a Project Working Group published their report to the Electricity Networks Strategy Group (ENSG) on the strategic reinforcements required to facilitate connection of the generation mix to the GB transmission networks by 2020. The report presents generation and demand scenarios consistent with the EU target for 15% of energy to be produced from renewable sources by 2020 and identifies and evaluates a range of potential electricity transmission network solutions that would be required to accommodate these scenarios. Among the options currently under consideration is the use of a multi-terminal HVDC link to provide additional capacity across transmission boundaries in the onshore transmission system and potentially to be used in the connection of offshore generation. Such a multi-terminal HVDC link might prove to be the most overall economic and efficient solution available when wider developments are taken into account.		

<table>
<tr><td></td><td colspan="4">National Grid has not previously implemented VSC HVDC converters on the transmission system and no multi-terminal VSC HVDC system has been implemented anywhere in the world. The introduction of this technology onto the transmission system must be managed in a manner that takes due consideration of any potential technology risks.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>-2</td><td>4</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The main benefit of the proposed work is management of the risks associated with introducing new technology onto the electricity transmission system in accordance with National Grid policies. The work is essential in order that the use of multi-terminal VSC HVDC on the transmission system may be permitted under National Grid governance. The savings in deploying such a solution in preference to less economic and efficient options is likely to be more than £100m.

In addition to the above, any problem in application of the technology which causes delayed commissioning of the HVDC link or interruption of its operation when in service will result in costs of the order of £5m per month being incurred in constraint costs alone. The proposed work will identify potential problems before contract placement and allow the above costs to be avoided.

An additional benefit will be the development of capability in this field. Whilst the RTDS system will remain the property of Birmingham University, National Grid will continue to have access to it. It is also envisaged that as National Grid's HVDC R&D portfolio increases access will be provided to other R&D suppliers such as other universities who do not possess this modelling capability.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">2 years</td><td>Duration of benefit once achieved</td><td>5 year</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£1,706</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The use of RTDS is well established in the area of HVDC technology and the simulation may be carried out with confidence. It is believed that multi-terminal VSC HVDC will be found to be feasible, but this requires to be demonstrated, hence the proposed work. It is certain that learning points will emerge. Difficulty in obtaining precise details of converter structures and component parts is anticipated and where necessary a range of possible solutions will be studied. It is anticipated that models will be refined as new information becomes available.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">Due to the long lead times required for purchasing test hardware (RTDS), progress in 2011/12 has been limited to agreeing the scope of the project, resourcing and procurement of equipment. It is envisaged that the first deliverables of the project will be achieved by Q3 of 2012/13.</td></tr>
<tr><td>Collaborative partners</td><td colspan="4"></td></tr>
<tr><td>R&D provider</td><td colspan="4">University of Birmingham</td></tr>
</table>

<table>
<tr><td>Project title</td><td colspan="5">Future Real Time Demand Forecasting</td></tr>
<tr><td>Project Engineer</td><td colspan="5">Alex Carter</td></tr>
<tr><td>Description of project</td><td colspan="5">This project will produce a flexible computer model of current and future electricity system demand for use in near term demand forecasting. It will first understand the current makeup of demand and will then introduce the impacts of expected changes in demand as decarbonisation drives changes in domestic, commercial and industrial demand. This model will enable different scenarios to be examined to understand the different influences on a range of developments such as heat pumps, electric vehicles, distributed generation and improved insulation and the consequential impact on final electricity demand. This will help to define what developments are needed to improve near term demand forecasting.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £6k
External £161k
Total £167k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£167k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£0k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Decarbonisation will change the demand that needs to be supplied from the electricity transmission system. Some examples are heat pumps, electric vehicles, distributed generation and improved insulation. Some of these will increase electricity demand whereas others will reduce it. Approximately 15GW of distributed generation is anticipated to be connected. National Grid therefore needs to understand the impact of different take up rates of these developments on the real time electricity demand and the uncertainties associated with them to ensure that we continue to be able to accurately forecast demand so we can operate securely and economically in to the future.

National Grid currently forecasts maximum demand to an accuracy of approximately 1%. Decarbonisation to meet the EU and Government 2020 CO2 emission targets will change the nature of electricity demand and potentially reduce our ability to accurately forecast it. Increasing amounts of intermittent generation being connected to the transmission system, 30GW by 2020, also means that demand at all times of the day becomes important and not just the historic evening peak. Accurate demand forecasting ensures that the correct amount of response and reserves are held to ensure that electricity is supplied securely and reliably, and at an economic cost that is ultimately borne by electricity consumers.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>6</td><td>2</td><td colspan="2">4</td></tr>
</table>

Expected benefits of project	Under or over forecasting demand typically increases system operation costs, this is conservatively estimated to be 1 action per week costing ~£100k which this project would look to assist in removing through better demand forecasting. i.e. 52 x £100k = £5.2m. These actions are expensive because short term balancing actions are required on marginal plant such as hydro and open cycle gas turbines. A greater understanding of the different ways that demand may develop under different scenarios will ensure that appropriate mitigating changes can be made to our demand forecasting processes to prevent our forecasting accuracy decreasing and therefore significantly increasing our system operation costs. We are currently planning to spend approximately £4m on developing our forecasting capability between 2011 and 2020 and this project will ensure that the developments are focussed in the right areas. Future work with the project partners could look at the impact of future energy saving measures on the balance between electricity and gas demand.		
Expected timescale of project	1 year	**Duration of benefit once achieved**	8 years
Probability of success	60%`	**Project NPV = (PV benefits – PV costs) x probability of success**	£45k
Potential for achieving expected benefits	It is highly likely that the project will deliver the stated objective as the Energy Saving Trust, who will be delivering the project, are experts in understanding domestic energy use with extensive historic data and also have expertise in the industrial and commercial sector and also the expected impact of new technologies. They will be working with other expert partners as well as National Grid experts to understand the relevant issues.		
Project progress [Year to End of March 2012]	The Energy Saving Trust has delivered a beta version of their software that has been deployed at National Grid sites. This version is being tested by a group of experts to evaluate the validity of the answers being generated. The application provides forecasts at DNO and National level for eight archetype days in 2015 and 2020. There are a number of pre-set scenarios that can be used (e.g. Gone Green, Slow Progression etc.). The application also has a User Defined facility where the level of adoption can be changed using sliders on the screen Data can be downloaded to Microsoft applications such as Excel or Access. Comments on this version of the software will be returned to the Energy Saving Trust. Final documentation should be delivered in the next couple of months. One of the key features of this application that has proved of most interest is the use of propensity measures to predict how different consumers will behave in different parts of the country.		
Collaborative partners			
R&D provider	Energy Saving Trust		

<table>
<tr><td>Project title</td><td colspan="5">A Combined Approach to Wind Profile Prediction</td></tr>
<tr><td>Project Engineer</td><td colspan="5">David Lenaghan</td></tr>
<tr><td>Description of project</td><td colspan="5">The aim of this project is to develop efficient and effective algorithms for wind profile prediction based on synergies between the signal processing approach and the computational fluid dynamics approach. One of the main deliverables will be a PhD thesis which contains the source code and prediction methodology details.</td></tr>
<tr><td>Expenditure for financial year 11/12</td><td colspan="2">Internal £3k
External £11k
Total £13k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Internal £0k
External £0k
Total £0k</td></tr>
<tr><td>Total project costs (collaborative + external + [company])</td><td colspan="2">£23k</td><td>Projected 2012/13 costs for National Grid</td><td colspan="2">£10k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="5">Wind profile (including speed and direction) prediction at different scales (short-term, mid-term and long-term) plays a crucial role for efficient operation of wind turbines and wind power prediction. This problem can be approached in two different ways: one is based on statistical signal processing techniques and both linear and nonlinear (such as artificial neural networks) models can be employed either separately or combined together for profile prediction; on the other hand, wind/atmospheric flow analysis is a classical problem in computational fluid dynamics (CFD) in applied mathematics, which employs various numerical methods and algorithms, although it is an extremely time-consuming process with high computational complexity.

On the CFD side, in the simulation/prediction of the atmospheric flows on the surface, one particular difficult regime is the case with stable stratification. Stable stratification leads to internal gravity waves. The interaction between the waves and turbulence remains a challenge for the modelling of turbulent atmospheric flows. Among the various issues, an important one is how to accurately account for the incoming/outgoing waves in the boundary conditions. If not properly handled, artificial waves can be generated in the simulations, which could destabilize the simulations.

On the other hand, the signal process methods developed in EEE at Sheffield are particularly suitable for capturing the wave components in a noisy signal. Therefore, the synergy between the two approaches can be particularly valuable for the simulation/prediction of wind profile/atmospheric flows.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td colspan="2">Overall Project Score</td></tr>
<tr><td>4</td><td>-1</td><td colspan="2">5</td></tr>
<tr><td>Expected benefits of project</td><td colspan="5">Increased forecasting accuracy which will have the consequent benefit of reducing the reserve requirement kept on the system due to the wind.</td></tr>
</table>

Expected timescale of project	2 years	**Duration of benefit once achieved**	8 year
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	-£26k
Potential for achieving expected benefits	Very likely. The proposed project is innovative and theoretically sound and promising. The University of Sheffield has academics with a track record in the work that they are doing and the initial student has a first class honours degree. The student has access to expertise from all departments within the University of Sheffield, also expertise from Imperial College London and John Hopkins University in the US through the collaboration work of the two project supervisors.		
Project progress [Year to End of March 2012]	The initial student from Sheffield has withdrawn. The project is therefore paused until a new PhD student is found.		
Collaborative partners			
R&D provider	University of Sheffield		

Project title	**Multi-terminal VSC HVDC operation, control and ac system integration**		
Project Engineer	Paul Coventry		
Description of project	The objective of the project is to improve understanding of the problems of Voltage Sourced Converter (VSC) HVDC integration into the existing transmission system. The project aims to make progress in three related areas: 1. Multi-terminal VSC HVDC operation; 2. AC/DC VSC HVDC interaction – control and 3. AC/DC VSC HVDC interaction – detailed model (fast transients). These areas have been identified as requiring to be addressed as part of the risk managed introduction of the technology onto the transmission system. The project will deliver reports on the results of studies and a documented set of models for use in National Grid's internal system studies. The work forms an essential step in being able to implement the technology on the transmission system. It is important that at all stages a close working relationship is maintained between National Grid engineers and University of Manchester researchers in order to ensure timely transfer of knowledge.		
Expenditure for financial year 11/12	Internal £4k External £80k **Total £84k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£213k	**Projected 2012/13 costs for National Grid**	£129k
Technological area and/or issue addressed by project	As a consequence of the European Union Renewable Energy Directive, the UK is committed to a target of more than 30% of electricity to be generated from renewable sources by 2020. The transmission reinforcements necessary to allow the EU 2020 renewable target and longer-term energy goals to be achieved in an effective and efficient manner were studied by the Electricity Networks Strategy Group (ENSG) and detailed in their report 'Our electricity transmission network: A vision for 2020'. It was recognised in the report that due to planning constraints and environmental concerns, traditional methods of enhancing system capacity can be difficult to achieve and consideration was given to employing the latest technology, especially where this would yield additional economic and/or environmental benefits. One such technology potentially contributing to the achievement of the above aims is Voltage Sourced Converter (VSC) HVDC transmission. Furthermore, VSC HVDC is, in principle, well suited to multi-terminal applications which would allow optimised designs integrating onshore and offshore networks to be achieved and such solutions are under consideration for the GB transmission system. However, while the technology is believed to be achievable, National Grid has not previously implemented VSC HVDC on the GB transmission system and multi-terminal VSC HVDC has not previously been implemented anywhere. It is essential, therefore that an adequate understanding of the application issues be developed. In order to initiate work in this important and urgent area, it is proposed that National Grid fund three PhD students who are available to start work immediately at the University of Manchester. Each student would address one of the three areas		

indicated above.

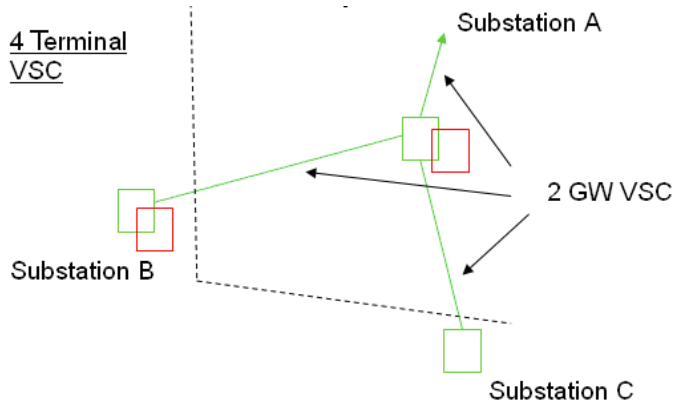

Figure 4. Example schematic for possible multi-terminal HVDC link to be studied(Red = AC, Green = HVDC)

The figure above outlines a possible layout of a multi-terminal HVDC link and is indicative of the type of system that may be studied. However, this work is not limited to embedded HVDC systems and multi-terminal HVDC wind farm connections will also be studied in a range of configurations and topologies.

The work is complementary to the simulation of multi-terminal VSC HVDC system by means of real time digital simulator (RTDS) at the University of Birmingham which is the subject of a separate R&D proposal. It is also proposed that all parties involved in this project work closely with National Grid engineers in order to ensure minimal duplication of effort and in order to ensure that the project delivers the best results and that these can be used straightway in our modelling and network studies.

Type(s) of innovation involved	Significant	**Project Benefits Rating**	**Project Residual Risk**	**Overall Project Score**
		10	3	7

Expected benefits of project

The proposed work forms part of the risk managed introduction of multi-terminal VSC HVDC onto the transmission system. VSC HVDC has not previously been implemented on the GB transmission system and multi-terminal VSC has not previously been implemented anywhere. It is essential therefore to understand how a multi-terminal VSC HVDC system would interact with the existing transmission system and how control of the different converters of a multi-terminal system would be coordinated. The proposed work is intended to identify application issues associated with the technology and allow control measures to be evaluated. Failure to identify and manage such issues ahead of commissioning might have severe implications for operation of the link. If delayed, commissioning or unavailability of the link pending a solution would result. Each month that the HVDC link is delayed could result in significant constraint costs being incurred. This project will help to ensure that all appropriate measures have been taken to avoid a delay in VSC projects.

In addition to this, this project will help to inform National Grid policy regarding the construction and operation of multi-terminal HVDC systems (of which there may be many) that are connected to our system.

Expected timescale of project	4 years	**Duration of benefit once achieved**	1 year

Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£59k
Potential for achieving expected benefits	The project is certain to increase understanding of the issues associated with application of a multi-terminal VSC HVDC system on the GB transmission system. There is a high likelihood that such studies will allow application issues to be identified, better understood and enable their mitigation to be evaluated.		
Project progress **[Year to End of March 2012]**	Milestones achieved: • Multi-terminal control review (report submitted) • This report reviews existing public domain information on multi-terminal control systems for HVDC (including line commutated systems). These are evaluated for VSC-HVDC systems and a research strategy going forward is proposed. • Review of DIgSILENT PowerFactory capability for VSC-HVDC system modelling (3 reports – load-flow, short-circuit, transient studies). • This software is the current standard for network modelling within the UK for AC networks. These reports outline existing capability of the software and indicate indicative models that could be used with inherent PowerFactory capability and thus provide a scoping study for the way forward in the later part of this project. • Scenario review of offshore networks and modelling requirements • This report outlines the modelling requirements of key hardware in the UK system and allows the modelling requirement for the key scenario to be captured, as well as looking forward to more wide-spread use of the developed models (for future studies in the wider UK network).		
Collaborative partners			
R&D provider	University of Manchester		

Project title	**MI HVDC Cable Load Cycling (Load cycling and radial flow in mass impregnated HVDC Submarine cables)**		
Project Engineer	Gregory Tzemis		
Description of project	To determine what load conditions (power ratings and load patterns) typical high voltage direct current (HVDC) mass impregnated paper insulated cables can be subjected to without risking cavity-induced dielectric breakdowns during a cool-down period after a power reduction or turn-off. To establish an informal North Sea cable working group towards collaboration on HVDC link projects, potential sharing of spares holding and repair resources. Project Deliverables: Obtain a detailed physical understanding of the processes that lead to cavity formation and the importance of various operational, environmental and cable design parameters to these processes. Develop a numerical model that quantitatively describes the radial mass flow and cavity formation under load cycling. Determine the operational constraints for one or more HVDC subsea cables presently in service.		
Expenditure for financial year 11/12	Internal £9k External £60k **Total £69k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£1,867k	**Projected 2012/13 costs for National Grid**	£131k
Technological area and/or issue addressed by project	HVDC MI Cables have complicated stress processes that are particularly vulnerable in the cooling stages immediately associated with power reductions or emergency shut downs, especially when occurring during the delivery of short term overloads, however the behaviour of MI cables under different load conditions is not clearly understood. This knowledge would be of great benefit to Utilities. Mass impregnated HVDC subsea cable has for long been and still remains the state-of-the-art technology. The electrical insulation of such cables consists of paper impregnated with a high viscosity oil (the ”mass”), enclosed by a lead sheath that prevents water ingress. Recent installations operate at typically 400 - 450 kV and have a continuous power rating per cable of up to more than 500 MW. Two HVDC links are presently in operation between Norway and the European continent, and more are expected to come. In a future pan-European electrical power grid, subsea cables in the North Sea are expected to play a crucial role, both for exchanging power between the UK, Scandinavia and the European continent, and for transferring power generated in large off-shore wind farms. It is generally accepted that the cooling period after a power reduction or turn-off is the most critical part of the operation of subsea mass impregnated HVDC cable. Consequently, the power rating of such cables, both with regard to short-term overloads and on a continuous basis, is largely set by considering the risk of having a dielectric breakdown during a power reduction or turn-off. However,		

<table>
<tr><td></td><td colspan="4">as will be described in some detail below, the behaviour of the cable insulation under different load conditions, and thereby the risk of having such breakdowns, is far from fully understood. Hence, it is reasonable to assume that the true capacity and operational flexibility this cable technology can offer, are not fully exploited.

Ohmic loss in the conductor is the main source of heat generation in a loaded cable. Hence, the conductor will always be at a higher temperature than the surroundings, and there will always be a heat flow and an associated temperature gradient in the radial direction through the cable insulation.

The thermal expansion coefficient of the mass impregnation is ten times that of paper. During load increase, the associated thermal expansion causes the volume of the insulation to increase and the lead sheath is inelasticaly deformed. If the elastic properties of the armouring combined with the external water pressure do not compress this volume sufficiently during cooling, cavities will form in the insulation. Moreover, the greater temperature reduction and thus a larger thermal contraction of the inner parts of the cable than of the outer parts, is also expected to contribute to cavity formation.

These cavities greatly reduce the dielectric strength and may cause long breakdown channels extending tens of centimetres and even meters, in the axial direction.

Moreover, thermal cycling may over time lead to a lasting and irreversible displacement of the mass impregnation. The inner insulation layers become depleted, while mass accumulates between the outer insulation layers and the lead sheath.

The existing knowledge about the importance and significance of the various factors expected to influence on the cavity formation and their interaction is indeed limited, even though such relationships essentially determine the power rating and safe operational patterns for a subsea HVDC mass impregnated cable. In other words, subsea transmission systems are presently operated under constraints that probably are unnecessarily strict.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>11</td><td>-3</td><td>14</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">This could allow enhanced use of existing interconnectors as well as better specification of future HVDC cable systems

An increase in operation flexibility of a matter of a few percent could greatly enhance ability to reduce the constraint boundary where we have seen 2 incidences of the wind being turned off costing the industry circa £800K and £1M in the year 2011. The majority of this cost is in the last few percentage of supply removal meaning this project could potentially have savings in the region of £500k per year on constriants.

Knowledge is applicable to existing HVDC Links such as BritNed and the French interconnector as well as for future HVDC Links such as the Western HVDC link and future offshore developments for which many MI HVDC cables would be required.

The partnerships with the Norwegian and Dutch Utilities will allow the exchange of know how on an informal basis which together with the working relationships will be of benefit to future proposed links and the maintenance and operation of existing links.</td></tr>
<tr><td>Expected timescale of</td><td>4 years</td><td colspan="2">Duration of benefit once achieved</td><td>5 years</td></tr>
</table>

project			
Probability of success	60%	**Project NPV = (PV benefits – PV costs) x probability of success**	£536k
Potential for achieving expected benefits	The participants have a good track record and facilities leading to a strong likelihood of success to develop important knowledge. The test method carries some risks, but other PD methods could be adopted, although this might impact in the programme.		
Project progress [Year to End of March 2012]	The project has recently been initiated and a first meeting held in Trondheim. Research work had begun. Initial milestones were late as the funding had been delayed, but this has been caught up and deliverables are generally on target. An Msc Thesis on the testrig has been completed and shared with all parties. A PhD student has been found and is due to start in July 2012. Regular progress reporting and a project area have been created.		
Collaborative partners	Sintef Energy and NTNU (Trondheim) via Consortium with Statnett & TenneT		
R&D provider	Sintef Energy and NTNU (Trondheim)		

Project title	**Development of Advanced LCC HVDC Model for System Studies**		
Project Engineer	Ziming Song		
Description of project	The objective of the project is to develop the PowerFactory Line-Commutated Converter (LCC) HVDC converter model for performing power flow studies and the network stability studies by National Grid engineers. The project aims to add the reactive power control, the filter switching and the converter transformer tap changes into the PowerFactory model. These areas have been identified as requiring to be addressed when the model is used to represent the thyristor based HVDC systems and operate not only at the DC system full rating but over a wide range of power transfer levels of the DC link. The project will deliver a model that can be integrated with any simplified circuits and the entire National Grid network model for power flow studies and stability studies. The work forms an essential step in developing National Grid's capability of network performances studies		
Expenditure for financial year 11/12	Internal £3k External £15k **Total £18k**	**Expenditure in previous (IFI) financial years**	Internal £0k External £0k **Total £0k**
Total project costs (collaborative + external + [company])	£28k	**Projected 2012/13 costs for National Grid**	£10k
Technological area and/or issue addressed by project	As a consequence of the European Union Renewable Energy Directive, the UK is committed to a target of more than 30% of electricity to be generated from renewable sources by 2020. The transmission network reinforcements and expansion necessary to allow the EU 2020 renewable target and long-term energy goals to be achieved in an effective and efficient manner were studied by ENA's Electricity Network Strategy Group and detailed in their report "Our electricity transmission network: A vision for 2020". It was recognized in the report that due to planning constraints and environmental concerns, traditional methods of enhancing system capacity can be difficult to achieve and consideration was given to employing the latest technology, especially where this would yield additional economical and environment benefits. One such technology potentially contributing to the achievement of the above aims is HVDC transmission. The Western HVDC link uses the thyristor based AC/DC converter technology and was proposed to be built as a major link across the Anglo-Scottish border to increase the inter-area power transfer capability and eliminate the constraints currently imposed on the border transfer for stability reason. In addition, there are many more HVDC projects that are currently under consideration and require a model which can be used in simulation studies effectively, accurately and easily. National Grid has not previously implemented HVDC modelling in the old system analysis suites – Ella and others. The model provided by DIgSILENT in PowerFactory has been studied comprehensively and the results were reported in TR (E) 466 – Computer simulation Tests of HVDC converter model in DIgSILENT. One of the major short comings identified in the model is the lack of the representation of the reactive power control while the converter operation		

<table>
<tr><td></td><td colspan="4">moves from one level to another. It is essential and urgent to develop the reactive power control function and incorporate it into the current model for future use.

The developed model will be crossed checked and verified by means of a real time digital simulator.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Incremental</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>9</td><td>-3</td><td>12</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">It is essential to include the reactive power control, filter/capacitor bank switching and converter transformer tap change into the PowerFactory model. With these functions successfully developed, the PowerFactory model will be able to present the HVDC station control and the control of the reactive power with reference to active power flow. The model will comprehensively represent the HVDC operations over a range conditions within the existing transmission system, one of major features required for the automation of a series of computer simulation studies, reducing the time. The proposed development is a must to have in the converter model for power flow studies in steady state conditions and stability studies during transient conditions.

It will lay a foundation for the future development of the model to include the advanced control functions, if they are required.

The estimate of savings through the use of this model, against manpower spend, to do the simulation studies is £160k.</td></tr>
<tr><td>Expected timescale of project</td><td colspan="2">1 Year</td><td>Duration of benefit once achieved</td><td>5 Years</td></tr>
<tr><td>Probability of success</td><td colspan="2">60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>£63k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The potential for achieving the expected benefits is high based on the detailed project proposal and a close co-operation between National Grid and the supplier, essential to ensure the project delivers exactly what is needed. In addition the supplier has many years experience of PowerFactory and has test facility specifically for the HVDC studies.</td></tr>
<tr><td>Project progress [Year to End of March 2012]</td><td colspan="4">The activities for project progress from the collaborative partners, the University of Birmingham, are listed as follows:

1. 16-31, Jan 2012: References reading to build a deep understanding of LCC-HVDC models for operation and control in normal conditions and under disturbances;

2. 1-9, Feb 2012: Training for DIgSILENT PowerFactory 14.1 to get familiar with elements of LCC-HVDC models such as 6-pulse rectifier and inverter and AC filters, how to build LCC-HVDC models and carry out simulations for power flow and transient stability analysis.

3. 10, Feb 2012: First group meeting with collaborative partners from National Gird and at University of Birmingham to discuss about the key issues, the further work plans for Stage 1 based on the summary of the understanding of the LCC-HVDC systems and the work progress.

4. 13, Feb- 2, Mar 2012: Building the Bipolar LCC-HVDC model for RMS-type power flow analysis and stability analysis in DIgSILENT</td></tr>
</table>

	PowerFactory 14.1 for the requirements of research proposal. 5. 5-6, Mar 2012: Investigating the National Grid Bipolar LCC-HVDC model in DIgSILENT PowerFactory at National Grid Company and discussing with Dr. Ziming Song about the key issues of the further studies and the further work plans for Stage 2 and completing two tasks for Stage 1 as follows: 6. A review of the LCC HVDC model in PowerFactory 14.1 and providing an in-depth description of the model. 7. An investigation of the capabilities and limitations of the model running for RMS type power flow and stability studies. 8. 7-16, Mar 2012: Modifying the Bipolar LCC-HVDC model with functions similar to National Grid's model and validating its performances for RMS-type power flow analysis and stability analysis to meet the requirements for further tasks for Stage 2. 9. 19-23, Mar 2012: Carrying out simulations and completing rest of the tasks for Stage 1 listed as below: 10. Identifying the percent errors in Vac, Iac etc. when the model experiences unbalanced fault conditions. 11. Studying the reactive power flow of the converter under different operation modes and investigating the relationship of Q vs. P over a range of power flows from 10 to 110 percent of the full rating. 12. Investigating the effects of a build-in transformer in comparison with an external transformer (tap-changing control is not considered at this stage). 13. Generalising the model for representing the systems having different ratings, such as 1000MW, 1500MW and 2000MW. 26-30, Mar 2012: Investigating the feasibility of user-defined controllers using DIgSIELNT Simulation Language (DSL) and DIgSILENT Programming Language (DPL) to realise the automatic switch control of AC filter banks and tap-changing of built-in and external converter transformers for Bipolar LCC-HVDC model.
Collaborative partners	
R&D provider	Birmingham University

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