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Power Systems
Engineering Center

Monitoring and Control of PV Power Systems – Use Cases and Examples

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Presentation Outline

- Definition and scope of metering, monitoring and control (M&C)
- Examples of M&C requirements
  - APS (detailed)
  - CPS Energy
  - SCE
- Overview of M&C in advanced grid planning and operations

Presentation Terms – Scope of Discussion

- Metering – means of determining the energy production (kWh) of DER over time (e.g. monthly meter reads, 15 minute AMI data)
- Monitoring – near real-time methods that communicate system status, output level (kW), etc., to the utility and possibly others
- Control – direct utility control of a load-break element inline with DER grid connection (may include protection)
- Adv. Control – control of the DER/plant directly using externally derived set points to meet specific control objectives

The Value of Metering

- Metering (15 minute intervals, kWh)
  - Billing/production metering
  - Program compliance (State, local, utility, etc.)
  - Production performance assessment
  - Higher-resolution metering provides some level of situational awareness and ability to plan with higher-levels of confidence and accuracy

The Value of Monitoring

- PCC Monitoring (near real-time measurements)
  - Dist. planning: Aids in asset management (transformer sizing, phase balancing, load planning, protection review)
  - DER interconnection: improved future interconnection decisions (hosting capacity determinations)
  - Dist. operations: data used for load management (native load determination, reconfiguration planning, restoration)
  - High pen. DER scenario: data used for resource planning at BA/ISO-level, better estimate needed reserves, ramping etc., also sub-transmission planning and operations
  - ADMS applications: can inform the operation of other controllable equipment
  - Typically applied to larger commercial and utility scale systems

The Value of Control

- PCC Control (real-time)
  - Dist. operations: Safety, feeder reconfiguration, maintenance – hot line tag/arc flash mitigation, restoration, possibly additional protection applied at PCC control element (reduces DER downtime)
  - High pen. DER scenario: ISO could use control for mitigation of over generation (curtailment)

PCC control with protection is not necessarily a solution for islanding concerns of DER. The local protection typically applied at the PCC would disconnect the DER in case of faults on the distribution system or within the DER facility but if matched islanding conditions exist the PCC protection elements are unlikely to detect a fault and trip offline

PCC control can be used as a slower version of DTT if the PCC control element is triggered automatically by a substation breaker/recloser opening

The Value of Advanced Control

- Advanced DER Control (plant control, not PCC control)
  - Responding to control inputs for distribution-level services (e.g. voltage regulation, var support, scheduling, controlled curtailment, capacity management – supports equipment deferment, ADMS participation – IVVC, CVR, automatic reconfiguration, automatic fault isolation)
  - Active dispatch/participation in ISO-level services (e.g. providing reserves, following AGC)
  - With islanding capability – increase resiliency, higher reliability etc.

IEEE P1547 currently contains a section on interoperability of DERs to meet future grid needs

When Monitoring and Control are Typically Applied

The requirements for M&C are typically a function of the following:

- DER project size, monitoring applied first and then M&C at higher project levels
- Voltage level and overall aggregate DER penetration of a circuit
- Market requirements often supersede interconnection M&C requirements (participation in wholesale market often requires visibility from the ISO level)
- DER asset ownership may influence required M&C (particularly control) due to safety concerns

APS Example Requirements

- Metering: All parallel generating facilities (other than a backup generator)
  - Production meter (AMI meter or meter with analog phone line)
- Generating facilities > 1MW (individual or aggregate) – dependent on interconnection study. Some options are:
  - Control:
    - Transfer Trip (relay (SEL 351-7) + communications link)
    - Remote Trip (generator breaker, control circuit, + fiber or VG36 leased phone line + APS RTU)
  - Remote Monitoring (RTU)
    - EMS meter + communication (instantaneous Watts, kVA, VARS, Volts, Power Factor, Amps, cumulative kWh)
    - Hard-wired open/close contact status points + control wiring to RTU for any breaker with remote control capability
    - Communications: fiber or data quality VG36 leased phone line or radio
    - Functions: remote trip, block close/close permissive
- Advanced grid support features (for generators >10 MW)
  - Dynamic response
    - Power factor control mode ± 0.95 pf (default 0.98 leading/absorbing)
    - Fixed reactive power mode (“MVAR”)
    - Automatic voltage regulating mode (“AVR”) to regulate voltage from 0.95 pu to 1.05 pu

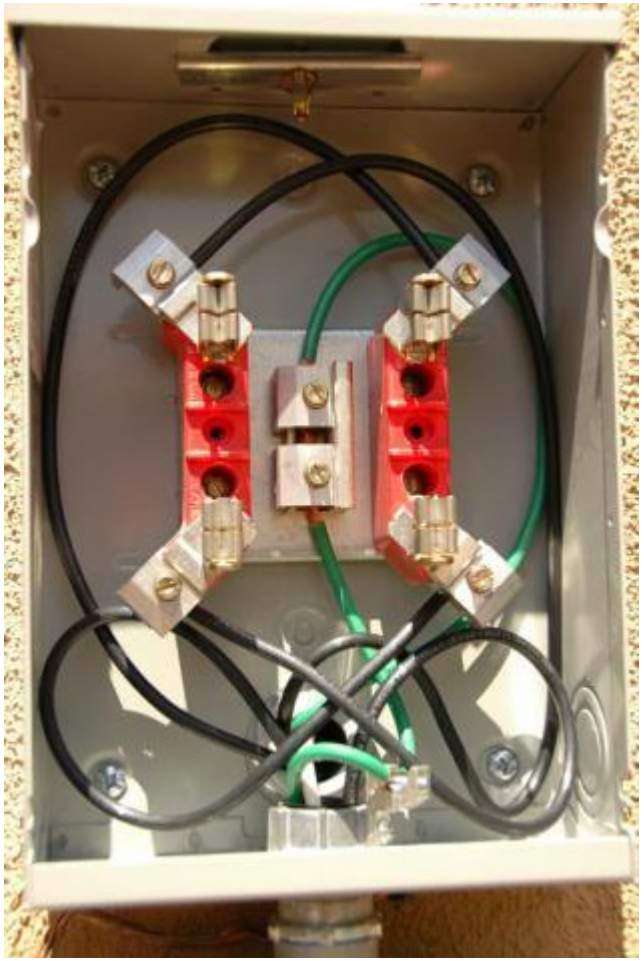
Source: APS interconnection requirements for DG rev 8.1, 4/2016 (p39-47)
https://www.aps.com/library/solar%20renewables/InterconnectReq.pdf accessed 1/16/17

APS Example: Metering Requirements

Production Metering – Section 9

Customer must provide and install, at Customer's expense, meter sockets and metering cabinets in accordance with APS service standards, in locations acceptable to APS

- 36" X 36" working space
- Meter height must be between 48" and 75" from finished grade
- Any CT rated production metering sections shall have suitable visual open disconnecting means, subject to APS approval.



Source: Frankie Greco, APS: http://www.nrel.gov/tech_deployment/pdfs/2014-06-12_lessons-learned-with-early-pv-plant-integration.pdf, June, 2014

APS Example: M&C Requirements

Remote Disconnect for 1MW and Larger – Section 8.8: Any Generating Facility with an AC Nominal Nameplate Rating of 1MW or larger will be subject to APS remote disconnect and monitoring requirements

- Customer will install an APS provided RTU enclosure.
- Customer will provide a breaker control circuit in which APS operations has control authority over.
- Customer will secure a communication path back to the APS communication system (i.e. VG36 leased line and/or fiber).

➢ **Systems less than 1MW may be subject to the APS remote disconnect and monitoring requirements depending on the generation type (i.e. synchronous generation).**

➢ **APS Operations requires remote disconnect and monitoring of larger generation sites in order to aid with forecasting/planning, load restoration efforts, and power quality concerns.**

Source: Frankie Greco, APS: http://www.nrel.gov/tech_deployment/pdfs/2014-06-12_lessons-learned-with-early-pv-plant-integration.pdf, June, 2014

APS Example: M&C Requirements cont.

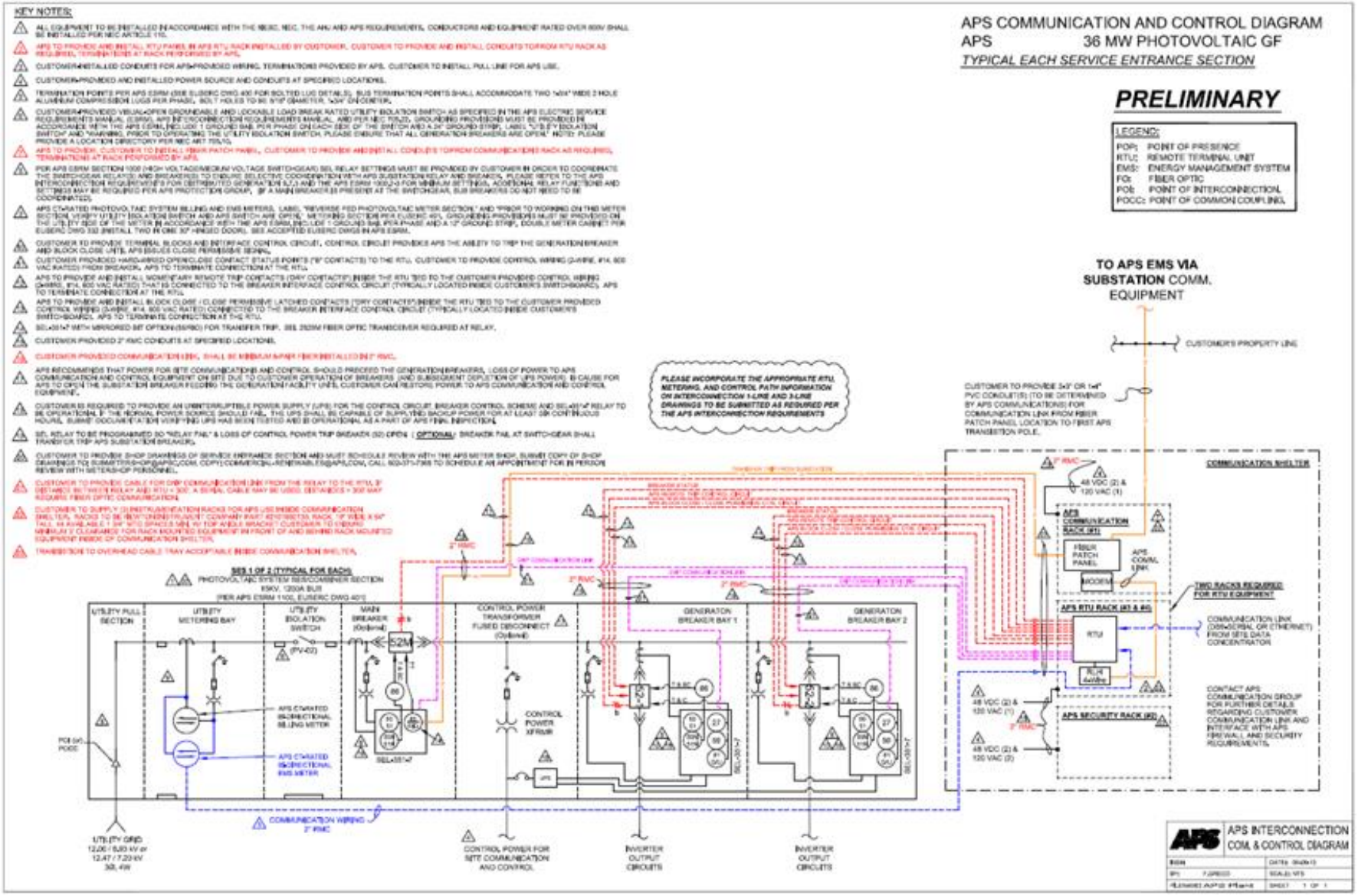
Remote Disconnect for 1MW and Larger – Section 8.8 continued:

APS Requires an RTU (Remote Terminal Unit) and comm. equipment to handle remote disconnect and Remote Monitoring (SCADA).

FYI – APS had installed over 32 sites between 2009 and 2014 that were 1MW and larger with remote disconnect and monitoring capabilities.

Source: Frankie Greco, APS: http://www.nrel.gov/tech_deployment/pdfs/2014-06-12_lessons-learned-with-early-pv-plant-integration.pdf, June, 2014

APS Example: Communications & Control Template



CPS Energy Example

- 7 MW PV system, non-utility owned
- 15 kV class interconnection,
- Required metering, monitoring and utility control

SCE Example

- 2 MW PV system, utility owned
- 15 kV class interconnection,
- Required metering and monitoring (system was subject to wholesale tariffs
- No additional control (recloser) required to my knowledge

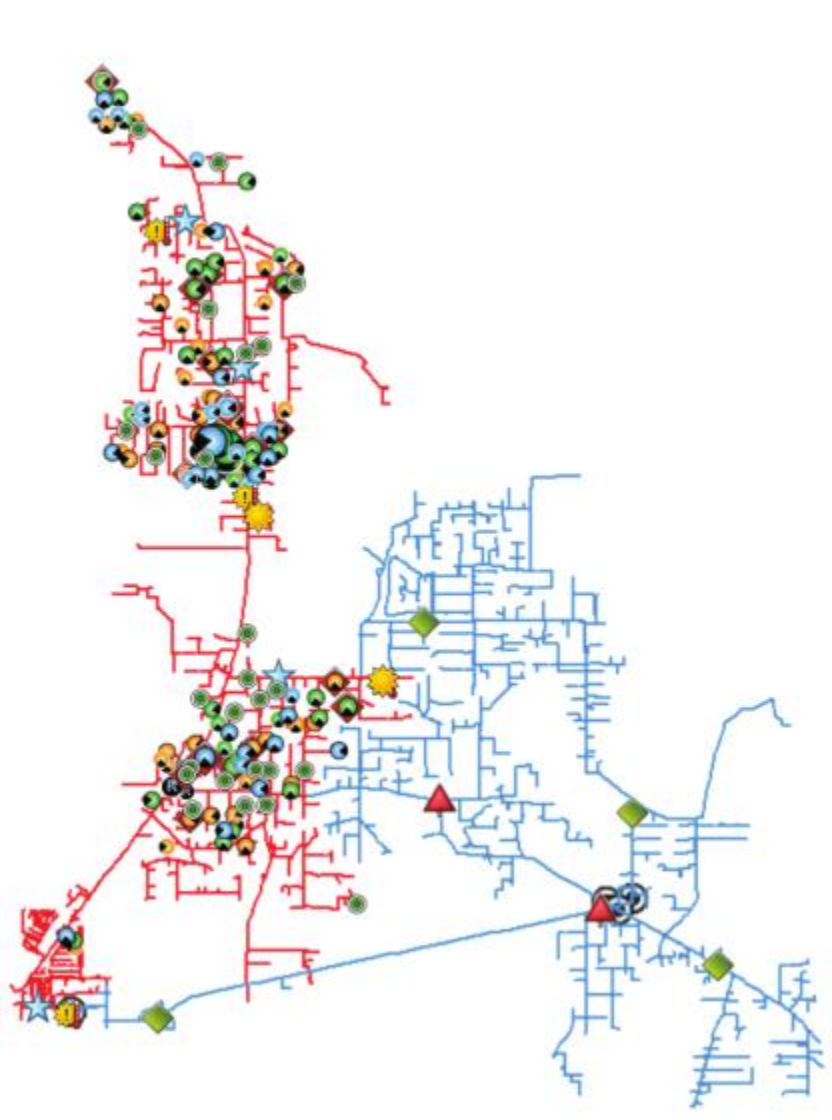
- Utility has access to PV inverters to lock/tag out generation system
- There are also instances of similar sized non-utility systems with similar requirements

What Level of Capability is Needed? Points to Consider

- Grid Operations
  - during normal ops and emergencies,
  - distribution & transmission,
  - load management, safety, reliability, interconnection standards
- System Planning
  - distribution & transmission
- Fleet Dispatch/Power Marketing & Trading
  - aggregated forecast, resource planning
- Utility Equipment Interoperability
  - existing - voltage profile – voltage regulators, cap banks
  - new – smart inverters, IVVC, energy storage
- IT/Infrastructure Requirements
  - Field hardware/communications
  - IT/back-end tools & processes, presentations/dashboards

Source: D. Narang, APS: http://www.nrel.gov/tech_deployment/pdfs/2014-06-12_lessons-learned-with-early-pv-plant-integration.pdf, June, 2014

What does better information about DERs get you?



Situational Awareness

feeder topology (GIS)
- equipment specifications/ratings
- DG size, location, orientation, specifications
- DG point of interconnection "stiffness ratio"
- adjacent feeder characteristics

feeder historic peak load (manual process - annual)
- feeder minimum daytime load

substation transformer loading (EMS)
- measurements interior to feeder

equipment status/state/settings (mix – EMS, manual)
- reclosers, cap banks, fuses

ADMS?
- settings for dynamic voltage control devices

solar irradiance
- historic, real-time, forecast

Power System Studies & Tools

steady-state
- load (power) flow
- short-circuit/protection coordination
- feeder PV hosting capacity

dynamic
- voltage stability (transmission)
- interactions between smart grid devices
- dynamic PV hosting capacity

advanced scenarios
- optimal location & size of energy storage
- control settings for smart inverters
- feeder reconfiguration
- microgrid applications
- aggregation of DG, forecast

Transients - harmonics

Source: D. Narang, APS: http://www.nrel.gov/tech_deployment/pdfs/2014-06-12_lessons-learned-with-early-pv-plant-integration.pdf, June, 2014

NREL … Providing Solutions to Grid Integration Challenges

Thank You!

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