NYSEIA's Views on Implementation of IEEE 1453:
New York's Leadership Role

NY Interconnection Technical Working Group

Albany, NY

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Efforts to Implement IEEE 1453 for Variable Loads

- Some of the earliest efforts to implement IEEE 1453 were done at PacifiCorp for variable loads such as motors with unpredictable operation
- This work dates back over a decade to at least 2007 following the 2004 adoption of the flickermeter approach in IEEE 1453
- The solar industry detailed some of these efforts in our July 19th 2017 presentation at the ITWG

References to IEEE 1453 in Interconnection Standards Abound

- A small cooperative utility (Altamaha EMC in Georgia) included flicker limits based on IEEE 1453 as far back as 2011, one of the earliest we could identify
  - "Parallel operation of the generating equipment shall not cause voltage flicker to exceed the visible flicker limit as defined by IEEE 1453 as measured at the primary terminals of the interfacing transformer."
    - Distributed Generation, Interconnection Procedures, June 21, 2011
- Between 2012 and 2014, California, FERC, and Massachusetts all added a supplemental review screen requiring compliance with IEEE 1453 "or utility practice similar to IEEE [Standard] 1453"
- In 2014, the latest version of IEEE 519 removed any reference to the so-called Flicker Curves in their entirety. This left the methodology in IEEE 1453 as the only active IEEE standard for flicker.

References to IEEE 1453 in Interconnection Standards Abound

- Since that time many other jurisdictions have explicitly or implicitly adopted IEEE 1453 as the standard for visible flicker.

- However the development of implementation guidelines for applying IEEE 1453 in a priori analyses of solar PV systems has been limited

- This is due, we feel in large part, to the fact that extensive experience with systems in the real world as well as multiple analyses of solar irradiance data have shown that it is very unlikely that visible flicker (as opposed to voltage variation) will be a concern for solar PV installations

Some have provided limited guidance

- In their *Interconnection Requirements Study* document detailing the required scope of work, Hawaiian Electric states

- 7.7 VOLTAGE FLICKER
- The Consultant will perform voltage flicker analysis to ensure that the Project will not create objectionable flicker for other customers and will meet the requirements for IEEE-1453 . When performing the flicker study evaluate the PV under full on and then full off conditions.

Case Study of Minnesota

- One of the few states other than New York to tackle the question of implementation of IEEE 1453 in great detail to date has been Minnesota

- This was triggered by disputes filed with the Independent Engineer concerning Xcel Energy's use of the outdated GE flicker curves

- This included a July 2016 filing by Sunrise Energy Ventures in which the Indepenent Engineer concluded
  - "The IE finds that Xcel Energy should be using IEEE Standard 1453 in the evaluation of flicker impact on the distribution system with the interconnection of DER."
    - Decision Resolving Solar Garden dispute with Xcel Energy, Date September 2, 2016

Case Study of Minnesota

Study	PV/DG Facilities	Study Locations	Output Change	Threshold
Single DG Facility (RVC)	Individual Facility	All Feeder Nodes	100%->0%	**3%**
All Feeder DG Facilities (RVC)	All Facilities on Circuit	All Feeder Nodes	100%->0%	**5%**
Voltage Fluctuation at Voltage Regulation Devices	Individual Facility	Voltage Regulator Nodes	100%->25%	**1.5%***

**effectively 2% for change from 100% to 0%.*

- Decouples voltage flicker from voltage regulator tap changes.
- Recognizes geospatial smoothing between individual facilities.
- Fails, however, to recognize smoothing within individual facility.
- Is not, in fact, a flicker standard. The use of rapid voltage change does not match the latest guidance in IEEE P1547 and would need to be updated when the new standard is in effect.

Case Study of Minnesota

- IEEE 1453-2015
  - 6.5 Rapid voltage change
  - "Voltage changes due to events such as motor starting, capacitor switching, and voltage regulator switching are classified as rapid voltage changes (RVC) as the changes are sustained over several cycles…"

Table 3—Indicative planning levels for rapid voltage changes (IEC 61000-3-7)

Number of changes, N	ΔV/Vr (%)	
	MV	HV-EHV
$N \leq 4$ per day	5−6	3−5
$N \leq 2$ per hour	4	3
$2 < N \leq 10$ per hour	3	2.5

Case Study of Minnesota

- “Ongoing Cloud Caused Fluctuation Limit
- The ongoing voltage fluctuation perception limit for clouds can be based on IEEE 1453.1”

- “Double ramp
- For a ramp duration of 1 second, F = 0.2 (Figure E.2), for a 1 minute cycle period, the rectangular wave curve (Figure A.1) gives 2.6% ΔV for N changes per minute = 2 for a Pst = 1 at 2 changes per minute.”

  - Northern States Power Company, doing business as Xcel Energy, *Compliance – Transition to Incorporating the Standards of IEEE 1453*, Community Solar Gardens Program, Docket No. E002/M-13-867, April 26, 2017

Case Study of Minnesota

- “The worst possible voltage variation due to passing clouds would result in a perception Pst of a fraction of 1.0. If the figures are extended to longer repeat periods and slower ramps, the effect would be an even smaller actual Pst.

- A passing cloud will cause a less than a 100% array power dip. A reasonable conservative approximation is a 75% dip of the ΔV for an individual PV farm trip.

- **Flicker Perception Limit Recommendation: do not impose a PV perception based flicker limit as the RVC limit is more restrictive.**”

Case Study of Minnesota

- Instead of visible flicker the RVC limits used by Xcel are governed by concerns over ANSI C84.1 limit violation on trip / restart of DER
  - "A step-change will occur either for a single facility tripping due to internal problems or for part or all of the DER facilities on the feeder due to system problems. A second step change will occur when DER automatically resumes operation. The resumption step change may be mitigated through ramp rate limiting or partially through staggered restart times. The resumption of operations poses several challenges. When a PV trips, the voltage drops. With higher penetrations, controlling voltage rise to maintain service within ANSI C84.1 Range A is a challenge."

Case Study of Minnesota - RVC

- “**VI. RAPID VOLTAGE CHANGES**
- RVCs Rapid Voltage Changes] from PV plants may occur when the PV plant trips offline. Typically, PV plants do not cause RVCs when they come back online because the PV output power is ramped during startup, whereas tripping causes a stepwise change.”
  - *Voltage-based Limitations on PV Hosting Capacity Of Distribution Circuits*, Michael E. Ropp, Dustin Schutz, Chris Mouw, Milad Kahrobaee, Northern Plains Power Technologies, Minnesota Power Systems Conference, November 8, 2017

Case Study of Minnesota - RVC

- "A normally-operating PV plants under normal system operating conditions would be expected to cause fewer than 4 RVCs per day, **which according to IEEE 1453.1 means that the allowable ΔV could be as large as 5% of the nominal value**. **RVC limits should be imposed on PV plants individually, because it is extremely unlikely that multiple PV plants would trip at once under normal system operating conditions.** (Note that during system transients, such as an undervoltage or a frequency transient in which all PV plants on a circuit would be expected to simultaneously trip according to IEEE 1547-2003 requirements, the RVC limits do not apply.)"

RVC vs Flicker under Pterra's Assumptions

- Taking the smallest emission limit (EP_{st}) of 0.35 and setting that equal to the P_{st} derived from the limit on $\Delta V/V$ for two changes per minute and a 1 second ramp rate as was done by Pterra we find
- $(\Delta V/V \ / \ 2.568\%) \times 0.2 = 0.35$
- $\Delta V/V = (0.35 \ / \ 0.2) \times 2.568\% = 4.494\%$
- Thus, the Pterra supplemental screen will be more conservative than the 5% RVC limit proposed by Ropp *et al.* and supported by NYSEIA based on the rarity of large systems spontaneously tripping off line

Case Study of Minnesota – Proposals for Alternative Analyses

June 19, 2012

Mr. Ron Lewis
Manager, Engineering
Dayton Power & Light Company
1900 Dryden Road
Dayton, Ohio 45439

Subject: **Solar Impact Study**

Dear Mr. Lewis:

SAIC Energy, Environment, & Infrastructure, LLC (SAIC) has completed the Solar Impact Study, which includes a review of the impact of the addition of a 3.38-MW solar photovoltaic (PV) generation site on the Dayton Power and Light (DP&L) distribution system at the intersection of Sebring Warner Road and Jaysville St John Road, Greenville, Ohio. Details of the analysis and findings are summarized below and include:

- A review of the short circuit calculations including contribution from the proposed PV site
- A review of the maximum voltage fluctuation on the distribution system experienced when the PV output drops off, before voltage is regulated back at the substation
- A review of any thermal overload or voltage limit violations resulting from the PV site interconnection compared to the ratings provided in the DP&L CYME® model
- A summary of system improvements required to interconnect the PV site
- A review of feeder voltage regulation and capacitor switching requirements and settings
- A review of voltage flicker caused by the intermittent output of the PV site
- A review of the PV site protection specified by the developer and any grounding requirements

Feeder and PV Site Data

Feeder LD1219, on Greenville Substation, was chosen as the interconnection location for the 3.38-MW PV site. Power is to be generated at 480 volts, then stepped-up to 12.47 kV using two three-phase, 1000-kVA, grounded wye – delta and two three-phase, 750-kVA, grounded wye – delta transformers. Power is assumed to be generated at unity power factor for the purposes of this analysis. From the PV Powered inverter data provided by the manufacturer, Advanced Energy, the PV site was studied with a total fault current contribution of 1200 amps per 260-kW inverter and 766 amps per 100-kW inverter at 480 V.

Voltage Flicker Calculation Methodology

Trishia Swayne, P.E., Leidos

Proposal for IEEE 1453 Flicker Study

Sunrise Energy Ventures, LLC

Customer Reference: N/A
Document No.: L2Cid-HOU-P-01-A
Date of issue: 16 Nov 2016
Date of last revision: N/A
GL PwrSolutions, Inc.

Case Study of Minnesota

- SAIC, Liedos, and DVL GL all proposed to use proxy irradiance data or power output data for a nearby array to determine ΔV values that could be combined with the ramp shape factors to produce approximate P_{st} values
- Specifically they each proposed to calculate
  - d = relative voltage change = $\Delta S/S_{sc}$
    - where ΔS is the change in power output and S_{sc} is the maximum available fault current at the PCC
  - T_f = flicker time (in seconds) = $2.3 \times (100 \times d \times F)^3$
  - $P_{st} = \sqrt[3]{\frac{\sum T_f}{10\ min}}$

Implementation of Long-term Dynamics Simulation Using IEEE 1453 as a Basis for Analysis

National Grid

"National Grid is the only other company Xcel Energy has found that does a time series analysis today."

Northern States Power Company, doing business as Xcel Energy, *Compliance – Transition to Incorporating the Standadards of IEEE 1453*, Community Solar Gardens Program, Docket No. E002/M-13-867, April 26, 2017

National Grid - Massachusetts

nationalgrid	[redacted]	[redacted]
		[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]

3.4 Flicker Analysis

The IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems, IEEE Std. 1453-2004 was used as a basis for flicker and voltage fluctuation analysis.

This Facility was modeled using the Long Term Dynamics module of CYME[1]. A long term dynamic profile for the Facility was used that simulates the voltage fluctuation of the site over a 6 hour period. Other significant DG existing or in process ahead of this Project were modeled at full output, and modeled with the appropriate voltage fluctuation curve to simulate normal cloud passage.

The long term dynamic DG profile used is based on live metered data from a PV site that is similar in size to this Project. The data is intended to simulate a typical day with cloud cover passing over the site, resulting in a varied output from the PV.

Conclusions

- New York is a leader in defining the application of IEEE 1453 at the level of supplemental review
- The application of 1 second ramp rates and 2 changes per minute with a 100 to 0% PV output transition is highly conservative and is more conservative than a realistic RVC limit based on rare system trip events
- Given the highly conservative nature of this screen the solar industry continues to recommend the use of long-term dynamics modules that represent realistic levels of ramping and can take appropriate account of the geographic diversity of systems on a circuit.
- Our recommendation is consistent with the findings of the 2013 Broderick *et al.* Sandia report (SAND2013-0537)