IEEE 2800

Implementation in the NYCA

Reigh Walling

WESC

Walling Energy Systems Consulting, LLC

Why Adopt IEEE 2800?

- Urgent need to set standards applicable to IBR in order to protect BPS security
  - Rapidly increasing IBR penetration
  - Actual system events as observed in WECC and ERCOT demonstrate threats
- Development of IBR standards requires much effort and a diversity of expertise – IEEE 2800 is already done
- IEEE 2800 development and balloting had wide participation, consensus
- OEMs are (or will be) designing equipment for compliance with IEEE 2800
- Familiarity; developers are dealing with the same standard elsewhere
  - Minimized misinterpretations

It may be imperfect, but it beats starting from scratch!

Adoption and Implementation of IEEE 2800

- IEEE standards are, by definition, voluntary
- Adoption of a standard by an entity having jurisdictional authority then makes the standard mandatory and enforceable by that entity
- Adoption of a standard can be:
  - *In toto*
  - Partial adoption, by clause
  - With additional requirements
  - With modified requirements
  - With clarified requirements; e.g., more rigorously defined
- NYSRC might choose to defer some non-reliability requirements to TOs or other entities for adoption (e.g., power quality)

WESC

Potential Interference from NEC Application

- National Electric Code claims scope of all non-utility electric facilities
  - Requires all electric equipment to be “listed” (i.e., certified to UL test standards)
  - Only UL standard for inverters has been UL-1741, based on distribution interconnection standards (IEEE 1547)
  - Primarily affects solar because of familiarity to electric inspectors
  - Inappropriate for major transmission-connected generation resources
- Yet to be seen if there will be a conflict between these standards
- Perhaps this can be addressed by regulators

Clause-by-Clause Relevance to System Reliability

Clause	Sub-Clause	Title	Scope Summary	Relevance to BPS Security	Recommendation to NYSRC
4		**General interconnection technical specifications and performance requirements**			
	4.1	Introduction	Clarifies that other devices that power inverters can be used to meet performance at the defined Reference Point of Applicabiity	Sets the context for the remainder of the standard	Adopt
	4.2	Reference points of applicability (RPA)	Defines where performance is to be achieved	Sets the context for the remainder of the standard	Adopt
	4.3	Applicable voltages and frequency	Defines the characteristics of voltage and frqeuency that are appliable; e.g., phase-phase and phase-ground fundamental-frequency voltage	Sets a definition for the remainder of the standard	Adopt
	4.4	Measurement accuracy	Specifies only accuracy of measurements reported to SCADA and for event recording	Relatively non-critical.	Adopt
	4.5	Operational measurement and communication capability	Requirement to be capable of interconnection with TSO's SCADA, as specified by TSO. Little detail is specified in the standard.	Important for system operator to have visibility	Adopt
	4.6	Control capability requirements	Requirement to accept external control inputs, such as curtailment orders.	Important to system control.	Adopt
	4.7	Prioritization of IBR responses	Sets the pirority of various requirements to avoid potential conflicts	Important because this clarfifies other requirements of the standard	Adopt
	4.8	Isolation device	Switchgear requirement; visible disconnect	Relatively non-critical.	Defer to TO
	4.9	Inadvertent energization of the TS	Prohibition of energization of a de-energized system, except as an authorized black start sequence.	Relatively non-critical.	Adopt
	4.10	Enter service	Defines system voltage and frequency parameters for reconnection after a trip, or for startup. Disallows operation where IBR is signaled not to operate.	Has implications to system restoration. Some of the requirements could have negative BPS consequences in some cases, such as by disallowing IBR to reconnect when the system support might be desparately needed. This subclaise needs close review.	??
	4.11	Interconnection integrity	Requirement for protection to have standard EMI withstand (e.g., as from mobile radios).	Relatively non-critical.	Exclude*
	4.12	Integration with TS grounding	Effectively requries IBR to present a grounded source to effectvely grounded systems and to not provide a ground source (zero sequence admittance) when not compatible with the grid.	Non-critical to BPS, primarily a TO concern.	Defer to TO

Clause-by-Clause Relevance (cont'd)

Clause	Sub-Clause	Title	Scope Summary	Relevance to BPS Security	Recommendation to NYSRC
5		**Reactive power-voltage control requirements within the continuous operation region**			
	5.1	Reactive power capability	Steady state reactive power capability	Can be essential for adequate transmission system voltage source.	Adopt
	5.2	Voltage and reactive power control modes	Specifies voltage regulation and reactive control characteristics	Important to maintaining good steady-state and dynamic voltage control.	Adopt
6		**Active-power-frequency response requirements**			
	6.1	Primary frequency response (PFR)	Eseintially, governor type response specified, to the degree that power headroom and footroom are available. Does not mandate pre-curtailment or storage.	Critical to frequency stability as IBR penetration increases.	Adopt
	6.2	Fast frequency response (FFR)	Specifies fast-acting power resonpse to tansient frequency drops as a mitigation for lack of inherent inertia in most IBR.	Critical to frequency stability as IBR penetration increases.	Adopt
7		**Response to TS abnormal conditions**			
	7.1	Introduction	Specifis that all ride-through requirements be met at the "reference point of applicability" (typically, the HV side of the facility main transformer).	Supportive requirement that helps define ride-through.	Adopt
	7.2	Voltage	Establishes voltage ride-through requirements	Highly critical; lack of ride-through can possibly result in massive resource loss during faults.	Adopt
	7.3	Frequency	Establishes frequency ride-through requirements. Includes frequency rate-of-change and phase jump ride through.	Highly critical; lack of ride-through can possibly result in massive resource loss during during frequency events..	Adopt
	7.4	Return to service after IBR plant trip	Simple cross reference to Clause 4.10		

WESC

Clause-by-Clause Relevance (cont'd)

Clause	Sub-Clause	Title	Scope Summary	Relevance to BPS Security	Recommendation to NYSRC
9		**Protection**			
	9.1	Frequency protection	Requirement that frequency protection, if used, shall not interfere with ride-through and is coordinated with TSO requirements	Important to ensure ride-through compliance and avoid trips that can aggravate grid disturbances.	Adopt
	9.2	Rate of change of frequency (ROCOF) protection	Requirement that ROCOF protection, if used, shall not interfere with ride-through and is coordinated with TSO requirements	Important to ensure ride-through compliance and avoid trips that can aggravate grid disturbances. There have been suggestions to use sensitive ROCOF settings to avoid islands, but which could cause unnecessary resource loss during a severe system frequency excursion event.	Adopt
	9.3	AC voltage protection	Requirement that overvoltage protection, if used, shall not interfere with ride-through. Requires transient overvoltage protection to use filtered quantities in order to avoid trips due to transient surges.	Critical. Several large-scale IBR trip events in WECC and ERCOT have been attributed partly due to peak-sensitive instantaneous voltage protections.	Adopt
	9.4	AC overcurrent protection	Requirement that overcurent protection, if used, shall not interfere with ride-through.	Critical. External grid faults can cause significant overcurrent for some types of IBR (e.g, Type III wind turbines), and this protection needs to be coordinated such that overcurrents due to ride-through events do not result in a trip.	Adopt
	9.5	Unintentional islanding protection	Requirement that any unintentional island protection, if used, shall not interfere with ride-through.	Many IBR are made up of relatively small inverters that are primarily designed for the distribution (DER) market where island protection is mandated. These schemes can potentially interfere with ride-through or produce other undesired interactions with teh BPS.	Adopt
	9.6	Interconnection system protection	Essentially, these are protectin requirements for the HV tie line between the IBR plant and the transmission system POI.	Has impact on the BPS, but not particulary unique to IBR.	Adopt

WESC

Clause-by-Clause Relevance (cont'd)

Clause	Sub-Clause	Title	Scope Summary	Relevance to BPS Security	Recommendation to NYSRC
10		**Modeling data**	Loosely defines models of IBR units and IBR plant controls that must be provided to the TSO/TO. Extends to EMT and short-circuit models, as well as dynamic models.	Highly critical to predicting compliance with ride-through and other critical requirements. Also important to post-event analysis.	Adopt
11		**Measurement data for performance monitoring and validation**	Specifies operational data and measurements that must be monitored, recorded, and retained.	Critical to compliance monitoring and post-event analysis	Adopt
12		**Test and verification requirements**			
	12.1	Introduction	Clause defines, in general, what must be tested and evaluated.	Verification of compliance is critical, but also very difficult and complex.	Adopt
	12.2	Definitions of verification methods	Defines, in general terms, type tests, design evaluation, commisioning tests, and post-commisioning monitoring and testing.	Verification of compliance is critical, but also very difficult and complex.	Adopt
	12.3	Conformance verification framework	Tabulates which test and verification steps are applicable to each clause of the standard	Verification of compliance is critical, but also very difficult and complex.	Adopt

AGIR

- IEEE 2800 refers to the "Authority Governing Interconnection Requirements" – AGIR
- AGIR is defined as:

  "…a cognizant and responsible entity that defines, codifies, communicates, administers, and enforces the policies and procedures for allowing electrical interconnection of inverter-based resources interconnecting with associated transmission systems."[1]
- We can assume for implementation of this standard in the NYCA, NYSRC is the AGIR
- IEEE 2800 also refers to:
  - Transmission system operator: entity responsible for operating transmission system
  - Transmission system owner
- Standard provides various forms of discretion to TS Operator and TS Owner
- As the AGIR, NYSRC should have the authority to define what is required for these discretionary issues

[1]IEEE Std 2088™ IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems

Specific Discretionary Items

- While NYCR can impose whatever requirements it deems necessary for reliability, IEEE 2800 specifically states that certain items are discretionary to AGIR, TS Owner or TS Operator
- System operating conditions for which specified performance is required
  - Much performance is defined by system strength; e.g., disturbance recovery performance, voltage regulation dynamics, etc.
  - Should be defined in terms of contingency level
  - Consider different levels of performance acceptable for level of contingency
  - What about future system changes that affect performance?
    - System weakening due to synchronous generation retirement
    - Addition of potentially interacting equipment (e.g., series capacitors, FACTS devices, etc.)
- Option for changing RPA for some requirements from the POM to another location; e.g. POI
  - E.g., offshore wind that can have GVAR of cable charging between POM and POI

Discretionary Items (cont'd)

- Communication protocol for data interoperability with TS Operator EMS
  - Most reasonably deferred to TS Operator (NYISO) or TS Owner
- Definition of IBR plant control inputs to be directly controlled by TS Operator
  - E.g., curtailment limits, voltage regulation setpoints, etc.
  - Most reasonably deferred to TS Operator (NYISO)
- "Enter service" settings (voltage and frequency parameters allowing startup)
  - Consider implications to system security during severe events
  - Perhaps larger IBR should be subject to TS Operator dispatch
- Utilization of reactive capability under zero active power output
  - Standard requires *capability* for vars at zero power; not utilization of this capability
  - Defer to the ancillary services market?
- Reactive power controls modes (voltage, pf, or fixed reactive)
  - Most reasonably deferred to TS Operator (NYISO)
- Step response time for voltage regulation performance
  - Actual response time dependent on real time grid strength; can't specify a fixed value
  - Reasonable to specify a maximum response time, or one that is based on short-circuit ratio
- Voltage regulation parameters (setpoint, droop)
  - Most reasonably deferred to TS Operator (NYISO)

Discretionary Items (cont'd)

- Primary frequency response (governor function)
  - Activation of primary frequency response
  - Droop settings – defer to TS Operator (NYISO)
- Primary frequency response parameters
- Voltage ride-through magnitudes and durations
  - Specification of parameters differing from values stated in standard is very likely to result in confusion
- Reactive current vs. active current priority during voltage ride-through
  - Default in standard is reactive current priority
  - In the Eastern Interconnection, voltage support is generally more critical than frequency support, so default is recommended
- Current injection magnitude during ride-through; positive and negative sequence
  - Consider deferring to TS Operator, based on interconnection studies
- Harmonic voltage limits
  - Defer to TS Owner if the PQ clauses is adopted by NYSRC, N/A if not adopted

Discretionary Items (cont'd)

- Plant-level model submission requirements
  - Defaults are power flow, dynamic (user written and/or generic), EMT, short circuit, and harmonics models
  - Schedule for periodic updates
- Model verification methodology
  - Very complex and difficult subject

WESC

IEEE 2800 Compliance Verification

- Complicating factors
  - IEEE 2800 applies almost all requirements at the plant level (at PoM) and not on individual IBR units
  - IBR plants obviously cannot be laboratory tested
  - Even many individual IBR units are too large for practical full-scale testing
- Compliance verification requires integration of several different processes
  - **IBR unit type testing** – cannot directly confirm plant complies, primarily to verify models and obtain input data for other processes
  - **Design evaluation** – simulation studies and engineering calculations based on verified models of IBR plant components (IBR units + *supplemental IBR devices*)
  - **As-built installation evaluation** – confirm that what has been constructed and applied settings are consistent with design evaluation process
  - **Commissioning tests** – limited by allowable impacts on grid, and grid conditions at time of test
  - **Post-commissioning monitoring –** real life, the ultimate test. IEEE 2800 has extensive data measurement and archiving requirements
  - **Periodic tests** – similar to commissioning tests to confirm that nothing has been changed
  - **Periodic verification** – studies initiated when substantial changes are made
- Details of these steps are to be defined by IEEE P2800.2 – far from complete, presently

Implementation of IEEE 2800 prior to IEEE P2800.2 completion

- Will make adoption of IEEE 2800 more complex in the short run
  BUT IBRs are being connected to NYCA at too great a pace to wait years
- Contrasting approaches
  - Distribution/consumer level approach is to rigorously type test, certify, then assume compliance (e.g., IEEE 1547 & 1547.1 for DER)
  - Large BPS resources are not easily tested for POI compliance; they are modeled and analyzed, but ultimate "stick" is sanctions for observed non-compliance
- NYSRC will need to lean toward the latter for at least the interim period
- Adaptation of the interconnection process is needed to ensure compliance

Design Review

- Evaluation of inside-the-plant design has not traditionally been part of the interconnection review process
  - Experience has been that some developers do not provide an adequate design
  - Legal mess if plant is denied interconnection after construction
- Many performance factors cannot practically be physically confirmed until the BIG EVENT happens; then it's too late
- Modeling is essential, but there are many, many challenges
- Changes of equipment or even firmware require re-performance of studies
  - Can result in a resource-consuming iterative process

Model Challenges

- Some OEMs do not have models
- Models often do not reflect the equipment model and firmware to be utilized
- Varying degrees of physical model validation – often very little
- Models are usually incomplete (e.g., critical protective functions left out)
- Models don't represent all equipment that affects compliance (e.g., auxiliary equipment that could trip and take resource off line)
- Submitted models often use generic parameters, not the actual parameters to be applied to the specific project
- Individual IBR unit models don't represent total plant performance; plant-level control systems must also be modeled (sometimes not same OEM)
- Multi-unit plants need to be modeled as a single-unit equivalent, with some loss of validity

Modeling Platforms

- Rules and protocols may restrict usage of state-of-art modeling capability
- Conventional planning tools (e.g., positive-sequence fundamental-frequency dynamic simulations) are often not adequate to verify IBR performance and compliance
  - Conventional dynamic models of IBR represent what is *supposed* to happen, not how it happens
  - Inherent bandwidth (response speed) limitations of phasor-based computations
  - EMT models are needed (e.g., PSCAD, EMTP-RV, ATP, etc.)
- IBR OEMs have generally been restrictive in dissemination of EMT models
  - Concerns that IP (and potential IP infringements) are exposed
  - NDA requirements are typical; thus models cannot be shared
  - Generally, "black box" compiled models
- TO and TSO planning staffs generally are not experienced with EMT analysis and software
  - Complex and typically not user friendly
  - Outsourcing likely to be necessary, but qualified consultants are few and heavily backlogged

As-Built Evaluation and Commissioning

- As-built evaluation generally not done presently, except for checks of protection settings
- Commissioning tests have been the responsibility of the TOs, and must continue under their control
  - Varying scopes and procedures for commissioning
  - Presently may not address all of the IBR-specific performance issues
- Need for standardization and assignment of responsibility
  - E.g., guide-form scopes
  - Recommended testing processes
  - As-built evaluation checklists

Performance Monitoring

- Huge amounts of data will be acquired by IBR plants under IEEE 2800
- Who reviews?
  - Is there a need for an assigned staff to do this?
- When are the data reviewed?
  - Review of performance only after severe events risks non-detection of critical problems before they manifest as newspaper headlines
  - Some review of IBR performance during routine local disturbances is needed to validate performance, as well as models and studies
  - Model validation may require performing simulation studies based on actual system conditions during these routine events
- What should the sanctions be for non-performance?
- What is to be done if models prove to be grossly inaccurate?

Phase-In of Requirements

- Industry not prepared for immediate adoption of all IEEE 2800 requirements
  - Equipment capabilities vary
  - OEMs need time to modify and test equipment to support new requirements
- May need to phase in requirements
  - Early adoption of specific requirements that are reasonably achievable by today's equipment
  - Priority given to requirements most vital to bulk system security
- Full adoption may need to be delayed until testing standards are finalized
- Consider resources needed for verification and enforcement
- Applicability to projects in the pipeline

Conclusions

- IBR standards need to be applied to ensure NYCA reliability
  - IEEE 2800, or modifications of IEEE 2800 offer the only practical path to timely implementation
  - Other standards (i.e., NEC) may get in the way
- Implementation will require many decisions
  - Which parts of IEEE 2800 to adopt and when
  - Modifications and clarifications of requirements
  - Decide on discretionary specifications
- Phased adoption likely to be necessary
- Compliance enforcement will need to lean toward the “stick” approach (like NERC) and less on the pre-emptive approach (like IEEE 1547/UL-1741 DER certification)
- Compliance verification will be a great challenge
  - Processes must be defined
  - Inevitably will require human resources in short supply and high demand

WESC

BACKUP

Harmonic Distortion Specification Issues

- Specification of harmonic performance is complicated because the characteristics of the grid affect both harmonic current and voltage; i.e., not solely determined by the IBR plant
  - Grid harmonic impedances
  - Ambient voltage distortion in the grid from other sources
- Primary IEEE 2800 specification is based on harmonic current
  - Follows the precedent of IEEE 519 for loads
  - Not consistent with long-standing large-scale transmission-connected inverter interconnection specifications (i.e., HVDC) and international practice
- As a compromise, IEEE 2800 recommends that TSO *should* specify harmonic voltage limits
  - No specific harmonic voltage limits are recommended by IEEE 2800
  - IEEE 2800 allows TSO to waive harmonic current limits if harmonic voltage limits are not exceeded
- Ambient grid distortion issues:
  - IEEE 2800 current limits apply to currents caused by ambient distortion in the grid
  - However, current limits are not applicable if the voltage distortion is greater than IEEE 519 limits
  - The standard’s current limits at particular frequencies do not apply if the current reduces the voltage distortion (e.g., if shunt filters are located in IBR plant that “sink” ambient grid harmonics

WESC