SMARTSENSECOM, INC. COMMENTS ON PROPOSED STANDARD TPL-007-1

In recognition of the potentially severe, wide-spread impact of GMDs on the reliable operation of the Bulk-Power System, FERC directed NERC in Order No. 779 to develop and submit for approval proposed Reliability Standards that address the impact of GMDs on the reliable operation of the Bulk-Power System. In this, the second stage of that standards-setting effort, the Commission directed NERC to create standards that provide comprehensive protections to the Bulk-Power System by requiring applicable entities to protect their facilities against a benchmark GMD event.

In particular, FERC directed NERC to require owners and operators to develop and implement a plan to protect the reliability of the Bulk-Power System, with strategies for protecting against the potential impact of a GMD based on the age, condition, technical specifications, or location of specific equipment, and include means such as automatic current blocking or the isolation of equipment that is not cost effective to retrofit. Moreover, FERC identified certain issues that it expected NERC to consider and explain how the standards addressed those issues. *See* Order No. 779 at ¶ 4. Among the issues identified by FERC was Order No. 779's finding that GMDs can cause "half-cycle saturation" of high-voltage Bulk-Power System transformers, which can lead to increased consumption of reactive power and creation of disruptive harmonics that can cause the sudden collapse of the Bulk-Power System. FERC also found that half-cycle saturation from GICs may severely damage Bulk-Power System transformers. While the proposed standard addresses and explains transformer heating and damage with a model, NERC ignores the issues of harmonic generation and reactive power consumption caused by a GMD event that have caused grid collapse in the past.

FERC has also been very clear to NERC that it considered the "collection, dissemination, and use of GIC monitoring data" to be a critical component of these Second Stage GMD Reliability Standards "because such efforts could be useful in the development of GMD mitigation methods or to validate GMD models." *See* Order No. 797-A, 149 FERC ¶ 61,027 at ¶ 27. However, the proposed standard fails to tie the actions required under the standard to any actual grid conditions. In its place, the proposed standard relies entirely upon an untested system model with several suspect inputs and with no means for model verification and no affirmative requirement for real-time monitoring data as a means to enable GMD mitigation.

It has been nearly eighteen months since Order No. 779 and this comment cycle represents NERC's last opportunity to correct its course before it files TPL-007-1 with FERC. Based on the considerable volume of scientific evidence and the capabilities of modern measurement and control technology to serve as a mitigation method, the proposed standard is technically unsound and fails to adequately address FERC's directives. Rather than risk the operation of the grid on the perfection of an untested model, NERC should have provided requirements for the collection and dissemination of GMD information, such as data collected from real-time current and harmonic monitoring equipment, to ensure that the Bulk-Power System is able to ride-through system disturbances. NERC should include these measures in TPL-007-1 or be prepared for a likely FERC remand – leaving the Bulk-Power System exposed to the risk of GMD while NERC addresses the matters that it ought to have considered at this stage of the process.

1. TPL-007-1 Should be Modified to Account for the Impact of System Harmonics and VAR Consumption and Mitigate the Risk Created by Reliance On Untested System Models

In Order No. 779, FERC found that GMDs cause half-cycle saturation of Bulk-Power System transformers, which can lead to transformer damage, increased consumption of reactive power, and creation of disruptive harmonics that can cause the sudden collapse of the Bulk-Power System. Whereas TPL-007-1 takes pains to model transformer thermal heating effects, the proposed standard does not adequately address the risks posed by harmonic injection and VAR consumption. Failure to deal directly with the effects of harmonics and VAR consumption is irresponsible given the empirical evidence of their impact upon system reliability during GMD events. Real-time monitoring, as called for by FERC, would provide the real-time operating information necessary to account for – and mitigate – these negative system effects. Real-time monitoring information would also remedy the vulnerability created by standard's "model-only" approach to the GMD threat and provide a means to iteratively improve any model over time.

A. Failure to Account for Harmonics and VAR Consumption

In the presence of a GIC, a saturated transformer becomes a reactive energy sink, acting as an unexpected inductive load on the system, and behaves more like a shunt reactor.

Consequently, transformer differential protective relays may trip and remove the transformer from service because of the disproportionately large primary current being drawn and consumed by the saturated transformer. System VAR support devices, such as capacitor banks and SVCs, become particularly critical during such conditions in order to offset the undesired behavior of GIC-affected transformers. The magnetizing current pulse of a GIC-inflicted transformer injects substantial harmonics into the power system.

VAR support devices are a low impedance path for harmonic currents and subsequently these devices begin to draw large currents too. A power flow “tug-of-war” ensues between the saturated transformers and VAR support devices. The sustenance of the VAR support devices is paramount as their failure may result in system voltage instability and collapse. However, harmonics doom these devices on multiple counts. For example, the large harmonic currents being consumed by capacitor banks may affect other components in the device that cannot withstand such high magnitude currents and result in damage and the unwanted tripping of the capacitor bank. Additionally, harmonics often result in the improper operation of protective equipment, such as overcurrent relays. Therefore, harmonics are ultimately predisposing system VAR support components to failure and increasing the vulnerability of the grid to voltage instability and collapse. See Duplessis, *The Use of Intensity Modulated Optical Sensing Technology to Identify and Measure Impacts of GIC on the Power System* (attached).

Accounting for GIC-related harmonic impacts is also essential considering that where GICs have caused significant power outages, harmonics have been identified as the primary system failure mode through the improper tripping of protection relays in known GMD events. For example, the 1989 Quebec blackout was traced to improper protective device tripping influenced by the GIC-induced where seven large static VAR compensators were improperly tripped offline by relays. See Department of Homeland Security, *Impacts of Severe Space Weather on the Electric Grid*, Section 4.4. In light of FERC’s directive to address and explain how the standard address these issues, it is clear that TPL-007-1 be modified to directly account for the reactive power and harmonic effects of GMD events.

B. Over-Reliance on Untested Models

The core of the proposed standard is a series of models designed to approximate the "worst-case" scenarios of a GMD event which are, in turn, used to determine system vulnerability and whether corrective action is required. This "model-only" approach is technically insufficient and leaves the grid open to unnecessary risk. Moreover, no mechanism exists in the standards to validate the GMD models through the use of actual operating data.

First, genuine concerns exist regarding whether the "worst-case" GMD scenario is actually being modeled or whether the model substantially underrepresents the threat. For example, according to empirically-based arguments of John Kappenman and William Radasky in their White Paper submitted to the NERC earlier this year, the NERC Benchmark model under-estimates the resulting electric fields by factors of 2x to 5x. Kappenman *et al*., *Examination of NERC GMD Standards and Validation of Ground Models and Geo-Electric Fields Proposed in this NERC GMD Standard*. The thermal heating model also relies upon a 75 amps <u>per phase</u> assumption (equivalent to total neutral GIC of 225 amps) as the modeled parameter. As shown in the Oak Ridge Study, it was found that at as little as 90 amps (or 30 amps per phase) there is risk of permanent transformer damage. *See, e.g.*, Oak Ridge National Laboratory, FERC EMP-GIC Metatech Report 319 at 4-8 ("Oak Ridge Study"). Indeed, the Oak Ridge Study found that a 30 amps per phase level is the approximate GIC withstand threshold for the Salem nuclear plant GSU transformer and possibly for others of similar less robust design in the legacy population of U.S. EHV transformers. *See* Oak Ridge Study at Table 4-1 (finding 53% of the Nation's 345kV transformers at risk of permanent damage at a 30 amps <u>per phase</u> GIC level). In addition, the system model specified in Requirement 2 should also be run on the assumption that all VAR support components on the system (e.g., capacitor banks, SVCs, etc.) become inactive (i.e., removed from service by undesired operation of protective devices caused by the harmonics that GIC affected transformers are injecting into the system).

That the models appear to substantially under-estimate the expected GMD impact is critical as it the models alone – under the proposed standard – that drive the vulnerability assessments and corrective action plans that require owners and operators to implement appropriate strategies. As written, these models have the effect of greatly reducing the scope of the protective requirements that will be implemented, potentially allowing sizable portions of the grid to be wholly unprotected and subject to cascading blackouts despite the adoption of standards. The extensive analysis and findings of the Kappenman-Radasky White Paper and the Oak Ridge Study suggest that the modeling approach elected by NERC is technically unsound, does not accurately assess a "worst case" scenario as it purports to do, and, in any event, should not be the sole basis for the standard's applicability.

Second, the proposed standard provides no means to validate or update the standard's models in light of actual operating data. This amounts to little more than a gambler's wager that the model will adequately protect the Bulk-Power System from a substantial GMD event, when it has never actually been tested. As the model is designed, actual operating data has no means to influence or override actions based upon the model. This is inappropriate. As discussed above, it is likely that the model developed will underestimate the effects of a GMD event. To rely on a model to simulate actual equipment performance over a range of potential GMD disturbances, it is essential that that model must not only contain adequate information (i.e. – an accurate up-front estimate), but that it must also correspond to actual reported field values. NERC should modify the standard to provide that actual operating data be used to regularly verify and improve the model.

C. The Solution – Collect, Disseminate, and Use Real-Time Reactive Power and Harmonic Content Information to Mitigate GMD Impacts

While the standard's model-based approach to GMD mitigation efforts may have some limited utility as a first step towards identifying vulnerabilities and developing forward-looking correction action plans, the standard would provide far better protection with a requirement for the collection and use of accurate, real-time data regarding current, reactive power consumption, and system harmonics. Real-time data should underpin any GMD mitigation efforts, substantially reducing the risk of outages and damage to critical equipment in the event of a GMD, and would also improve the reliability of system models. Modern grid measurement and control technologies are capable and readily deployable to mitigate GMD events.

First, real-time monitoring enables protective devices to be efficiently managed during a GIC event, initiating control signals that enable devices to “ride-through” GMD where they may otherwise trip offline during a period of normal operation. In these instances, the detection of harmonic content could be used to sense transformer saturation and override normal protective device trip settings in order to maintain key equipment online and not be “fooled” into tripping by the harmonics generated by the event. Given the diversity of protective devices for equipment used throughout the Bulk-Power System, a technically preferable approach would be to actively manage protection schemes based upon real-time operating data. Regarding the system’s VAR response, if system voltage becomes unstable when VAR support is inhibited during a GIC event, operators would have an available solution through the identification of atypical harmonics, which can be associated with a GIC event, and this information used as a trigger to implement alternate protective schemes for VAR support components for the duration of the GIC event.

Second, if a GMD event is detected through the monitoring of systemic VAR consumption and harmonic content at key points in the network (which may include current monitoring on vulnerable transformer neutrals and monitoring of harmonics and VAR consumption on phases), this real-time monitoring data could be used to draw down, and ultimately cease, GMD operating procedures as the GMD event passes. Moreover, the VAR and harmonic derived from real-time operation information may also be used to trigger operating procedures, which is necessary given that the existing operational standard relies on space weather forecasts as the trigger for the implementation of operating procedures, despite the substantial error rates associated with these forecasts. Since GMD procedures impose transmission constraints that do not permit wholesale energy markets or system dispatch to achieve the most efficient use of available resources, ultimately affecting the prices paid by consumers, NERC should seek to minimize the frequency and duration of mitigation efforts. Real-time monitoring of harmonic content and reactive power would enable a more efficient approach to recognizing and reacting to GMD events, harmonizing the Phase I and Phase II standards and providing greater overall protection to the grid.

Further, real-time monitoring information must be used to validate models that are used to inform the means by which owners and operators will prepare for, and react to, GMD events. Currently, the models presented in the standard are the sole means to trigger the implementation of protection measures and the availability of actual operating data that questions the model's outputs have no means to override the model-based approach. The use of actual operating data to verify the standard's model would improve the accuracy of model verifications needed to support reliability. A better approach would be to use modeling and real-time monitoring in tandem to constantly verify and enhance the model, while still maintaining protections for "missed" events that the model is likely to inevitably overlook. The people of the United States should not have the ongoing Bulk-Power System reliability put at risk by an unverified model.

NERC should use its authority to insure that real operating data will, over time, be employed to verify and improve any reference model and that real operating data will be employed as a means to ensure ongoing system reliability when events render the reference model unequal to its protective task (which evidence suggests will happen). The proposed standard should be modified to require the collection, dissemination, and use of real-time voltage and current monitoring data which will provide the reactive power and harmonic content information necessary to effectively and efficiently manage the system in response to GMDs.

2. Conclusion

FERC was clear in its direction to NERC that the collection, dissemination, and use of real-time GIC monitoring data was a critical component of these Second Stage GMD Reliability Standards "because such efforts could be useful in the development of GMD mitigation methods or to validate GMD models." See Order No. 797-A, 149 FERC ¶ 61,027 at ¶ 27. FERC also was clear that harmonic content and reactive power consumption created by GMD events constituted serious threats to system reliability that must be addressed. Order No. 779 at ¶ 7. The draft standard offered by NERC simply fails to meet the needs identified by FERC – which are amply supported by the record established in these proceedings – a reasonable person could reach no other conclusion.

To create a reasonable and prudent standard, NERC needs to address the reactive power and harmonic generation aspects of GMD events, and it needs to provide for verification and improvement of the model included in the draft standard. The only route to meeting those needs that is supported by the evidentiary based findings and FERC's directives is a mandate for the collection, dissemination, and use of real-time GIC current and harmonic data to drive protection schemes. With clearly articulated requirements for such data, NERC can fill the gaps in the current standard and provide a means by which to adequately protect the Bulk-Power system.

Respectfully submitted,

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Date: November 21, 2014