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PSEG
Nuclear LLC

December 8, 2014

PJM Interconnection, L.L.C.
Attention: Steven Herling
955 Jefferson Avenue
Norristown, PA 19403

Re: PSEG Nuclear Comments for December 9th TEAC
Discussion Regarding Artificial Island Open Window

Dear Mr. Herling:

PJM Interconnection, L.L.C. (PJM) has invited all PJM stakeholders to submit comments regarding the Artificial Island open window process in connection with the scheduled TEAC special meeting scheduled for December 9th. As the party that may be most directly impacted by the ultimate decision in this open window process, PSEG Nuclear LLC (PSEG Nuclear) now submits the following Comments regarding Dominion's Project 1A, which uses both TCSC and SVC technology (hereinafter referred to as the Dominion TCSC Proposal).

I. EXECUTIVE SUMMARY

PJM previously determined the Dominion TCS Proposal to be technically deficient, yet it is once again being considered by PJM among the various finalist proposals. This proposal includes an application that combines thyristor controlled series compensation (TCSC) technology with Static VAR Compensators as a means to ensure transient angular stability for AI. This proposal attempts to address stability via active, substation-based components in lieu of constructing an additional conventional transmission line.

PSEG Nuclear believes the approach set forth in the Dominion TCSC Proposal poses considerable risk to the regional 500kV system and to the nuclear units themselves at Artificial Island by relying on a technology that has never been used or tested at this scale in the United States. The Dominion TSCS Proposal can pose the risk for sub-synchronous resonance, which could have serious consequences for the nuclear units. In addition, and most importantly, based on the potential consequences of failure of this new technology, the Dominion TCSC Proposal poses an unevaluated risk to overall nuclear safety.

PSEG Nuclear relies on the following key considerations in reaching this conclusion:

- Dominion's TCSC project is inconsistent with AI RFP requirements and presents substantial challenges in ensuring compliance with the NRC licensing basis for the plant relative to offsite power sources;

- The use of the second largest nuclear site in the U.S. as a test bed for a first of its kind transmission design is problematic and presents potentially dire consequences; and

- The Dominion TCSC Proposal introduces complex circuit elements with subsequent new active failure modes that increase the potential for sub-synchronous resonance (SSR) phenomena that can damage generation equipment.

- Finally, should PJM ultimately decide to select this proposal, it would need to ensure adequate indemnification protection for PSEG Nuclear associated with SSR-related damage and/or lost generation. This is an issue that has not yet even been discussed.

These considerations, which are detailed in the comments below, must be factored into PJM's overall assessment of the competing AI transmission proposals to arrive at a technically and economically defensible path forward. PSEG Nuclear submits that careful consideration of these points counsel against selection of the Dominion TCSC Proposal.

II. COMMENTS

A. Dominion's TCSC Presents Substantial Challenges in Ensuring Compliance With the NRC Licensing Basis for the Plants Relative to Offsite Power Sources.

The goal of the transmission enhancement being pursued by PJM in the current open window process is to simplify the complexity and operational challenges presented by operations under the current Artificial Island Operating Guide (AIOG). Yet, as explained below, the TCSC project proposed by Dominion not only undermines the Artificial Island RFP objective of AIOG simplification/elimination, it raises significant issues for compliance with AI's nuclear licensing requirements relative to offsite source reliability.

Current operation of the Salem and Hope Creek nuclear generating stations at Artificial Island must accommodate the challenging transient stability margins inherent in the grid configuration in the vicinity of the AI facility. This is accomplished through strict adherence to the AIOG, which governs aspects of plant operation that have a direct impact on maintaining angular stability under any NERC mandated contingency (e.g., minimum plant MVAR output, power system stabilizer availability, trip-a-unit logic). The worst case line contingency for the site is a stuck breaker fault on the 5015 line between Hope Creek and Red Lion.

Compliance with the AIOG inherently ensures compliance with key nuclear licensing requirements with respect to offsite transmission sources, as follows:

- First, the Salem and Hope Creek nuclear units' operation must comply with 10 CFR 50 Appendix-A General Design Criterion (GDC) 17 which requires that a plant's offsite sources:

..be designed and located so as to minimize to the extent practical the likelihood of their simultaneous failure under operating and postulated accident and environmental conditions.... provisions shall be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit or the loss of power from the transmission network.

- Second, NRC NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, provides the primary guidance to NRC reviewers responsible for ensuring that a licensee complies with NRC regulations. Chapter 8 of NUREG-0800 provides review guidance regarding the design, analysis and testing of the offsite electrical system such that it meets the requirements of GDC 17. NUREG-0800 Chapter 8 states:

  > The results of the grid stability analysis must show that loss of the largest single supply to the grid does not result in the complete loss of preferred power. The analysis should consider the loss, through a single event, of the largest capacity being supplied to the grid, removal of the largest load from the grid, or *loss of the most critical transmission line*. This could be the total output of the station, the largest station on the grid, or possibly several large stations. (Emphasis added).

- Third, of particular relevance to the consideration of projects to address the AI FRP requirements, NRC NUREG-0800 further states:

  > The (NRC) reviewer should verify that adequate procedures, administrative controls, and protocols are in place to ensure that *no modifications to the offsite power system circuits credited for satisfying GDC 17 are implemented by offsite transmission system operating authorities, responsible for maintenance, modification, and operation of the offsite transmission grid, without the performance of a proper safety evaluation.* The safety evaluation of transmission system modifications is required to ensure that the transmission grid configuration, stability, and capability remain within the assumptions of the plant safety analyses. (Emphasis added).

If the Dominion TCSC Proposal is selected by PJM, stability of the system upon a fault on the critical 5015 line will no longer be ensured by the predominantly passive physics of protection provided by the AIOG, but will be predicated on the instantaneous operation of a first-of-a-kind scale of TCSC installation in coordination with an associated static VAR compensator (SVC) installation. As such, the selection of the Dominion TCSC Project could pose challenges relative to the existing licensing basis of the nuclear plants with regard to offsite power source.

B. Use of the Second Largest Nuclear Site in the U.S. as a Test Bed for First of its Kind Transmission Design Is Unacceptable and Presents Potentially Dire Consequences.

If selected by PJM, the Dominion TCSC Proposal would essentially use the second largest nuclear installation in the country as a test bed for a first of a kind application of advanced transmission components that have limited operating experience and track record in the world. Nowhere on the PJM system or, for that matter in the United States, has an integrated TCSC-SVC solution been developed to the scale proposed or used to control transient stability to the extent required for Artificial Island. Moreover, PJM is considering the approach of scaling this first of a kind technology up to compensation levels never used before, and to integrate its response with active SVCs to address stability constraints in a region of the system that has substantial challenges relative to maintaining and ensuring transient stability.

There is a significant lack of any real-world operational experience with the performance and reliability of the TCSC technology in question, especially with respect to the scale of its use in this proposal. This lack of operational experience, combined with the critical response time necessary for this solution to meet its performance objective, makes it imperative that PJM accurately model not only the "data sheet" performance of the system but also perform "real-world" sensitivity analyses to model non-ideal performance of the TCSC-SVC system (e.g., response delays, adverse timing interactions between TCSC and SVC components, non-optimum transient compensation levels, effects of inadvertent actuation, sensitivity to changing system conditions)).

Further, any theoretical benefits of such first of a kind technology use must be weighed against the consequences of the new technology not just failing, but failing at the second largest nuclear installation in the United States. In the event that this first of a kind technology application fails to operate, or does not function as modeled under a challenging contingency such as a fault on 5015, the likely consequences to the Salem and Hope Creek nuclear units would be greater than currently analyzed per GDC 17. Currently, operation under the AIOG ensures stability of offsite sources following any anticipated grid contingency. Under the TCSC proposed design, failure of these active devices in responding to a limiting grid contingency could cause one or more of the AI nuclear units to lose synchronism with the system, which could in turn result in the following cascading events:

- The immediate loss of offsite power to all three units resulting in the automatic shutdown of the units and post-transient reactor cool down operations using emergency diesel generators.
- The tripping of 3800 MW at Artificial Island may lead to a partial or system-wide black-out (PJM spinning reserve is only 1200 MW). This in turn can pose similar loss of grid challenges to regional nuclear plants.

- The physical impact/damage to the nuclear turbine generator(s) from falling out of synchronism would likely require a significant and indeterminate period to correct.

Based on the potential cascading events described above, reliance on this first of a kind technology will introduce a consequence of failure beyond that currently analyzed for the nuclear units at Artificial Island.

C. Dominion TCSC Proposal May Potentially Trigger Additional NRC Review And Impose Additional Design and Licensing Costs.

In evaluating any changes to nuclear plant equipment, processes or procedures, PSEG Nuclear must evaluate the change per 10 CFR 50.59, *Changes, tests and experiments*, to determine if the change is outside the bounds of the licensing basis of the plant and requires NRC approval prior to implementing the change. This is generally referred to as "a 50.59 review." Given that the AIOG is considered a critical design document for the site, a 50.59 review is required to implement any change to the document. The 10 CFR 50.59 review assesses a proposed change against prescribed questions relative to its impact on the safety-bases upon which the NRC has licensed the plant. Of these questions, the two that are directly challenged by the design being considered by PJM are:

> *Does the change create a possibility for a malfunction of a Structure, System or Component (SSC) important to safety with a different result than any previously evaluated in the final safety analysis report (as updated)?*[1]
>
> *Does the change result in more than a minimal increase in the consequences of a malfunction of an SSC important to safety previously evaluated in the final safety analysis report (as updated)?* [2]

Regarding the first question above, given that the scope and magnitude of the TCSC-SVC solution being considered by PJM has never before been developed anywhere in the United States, modeling assumptions for this project are incapable of being validated through real-world operating experience. Therefore, the failure modes and associated consequences of the proposed solution cannot be considered fully vetted. In light of this, PSEG Nuclear would need specific technical insights into the design and modeling of the solution, well beyond what has been publicly provided by Dominion, in order to properly address this question.

Similarly, relative to the second 50.59 review question, consequences of failure of the TCSC/SVC solution, as described in the previous section, pose a significant challenge in addressing this question, especially in light of the fact that loss of offsite power is considered one

[1] Code of Federal Regulations, Title 10 Part 50.59 – Changes, Tests and Experiments
[2] 10CFR50.59

of the largest contributors to core damage frequency in terms of Probabilistic Risk Assessment to a nuclear plant.[3]

Based on these two questions, formal PSEG Nuclear and possible NRC review and acceptance of the subject design will be necessary before any substantial changes to the AIOG and its associated operational guidelines can be made. This review will need to be conducted to the extent necessary to satisfy any NRC inquires relative to the station's assessment of the design against the above 50.59 questions. Based on the recent publication of NUREG CR 7175, *Susceptibility of Nuclear Stations to External Faults*, the NRC has a heightened interest in vulnerabilities of nuclear plants to offsite grid disturbances. Based on this heightened level of licensee oversight in grid issues, NRC's assessment of licensee's changes relative to offsite source reliability will be also be heightened. This may extend to the point where the NRC assesses the adequacy of the TCSC design as an independent validation of the review performed by PSEG Nuclear. Considering the scope and complexity of this solution, and that the issue is a matter of first impression, such effort will likely result in additional review and processing fees being imposed on PSEG Nuclear as the licensing entity that must respond to any NRC questions and directions related to this change.

Given the above, PSEG Nuclear submits that any and all review costs, including any NRC fees, associated with this effort should be borne by Dominion. Accordingly, PJM should take such costs and schedule impacts into consideration in identifying overall project costs associated with the Dominion TCSC Proposal.

Until a safety determination can be made by PSEG Nuclear that is deemed acceptable for the regulator, Salem and Hope Creek operations would still need to comply with the AIOG as currently configured despite the status of TCSC-SVC system installation. Potential operation of the nuclear units at AI per the requirements of the current AIOG alongside operation of the subject TCSC-SVC installation would likely be incompatible to system operations and would negate the ultimate goal of the Artificial Island open window process.

D. The Dominion TCSC Proposal Introduces The Risk of Sub-Synchronous Resonance Phenomena That Can Damage Generation Equipment.

Introduction of series compensation for the first time into a congested region of the system like EMAAC poses significant concern regarding sub-synchronous resonance (SSR). The potential for SSR can result from series compensated networks and, if unmitigated, can result in opposing torques to prime movers resulting in prompt and extensive turbine-generator rotor shaft cracking. Generators most at risk to SSR are those that are electrically closer to the series capacitor and those that are long shaft / multi-mass turbine generators. The characteristics

[3] Nuclear Regulatory Commission - NUREG/CR-6890 Vol. 1 – Reevaluation of Station Blackout Risk at Nuclear Power Plants – Analysis of Offsite Power Events 1986-2004 – Published 2005

of the proposed project and its proximity to large nuclear generating units directly support the potential of developing SSR in the region of Artificial Island. Another phenomenon, Sub-Synchronous Oscillation (SSO), can occur when fast acting controllers of active power system components (e.g. TCSC or SVC controllers) have an unintended resonant point close to the system electrical resonance. SSO can result in rapidly growing currents or voltages on the system potentially challenging the design limits of transmission components.

In order to assess whether regional generators are susceptible to SSR, complex analyses must be performed based on system data, as well as extensive dynamic inertial machine data from potentially affected turbine generator systems. These data are often times not readily available, subject to change, or are of unknown accuracy and validity. It is not clear how PJM can conduct a complex assessment of SSR on regional generators, given that the critical input data to such analyses have questionable fidelity to the actual machines.

The subject SSR analysis is not a one-time effort, but must be routinely performed as the regional system changes due to upgrades, changes in regional generating units and planned and emergent outages. Planned and unanticipated system changes may have profound impacts on the tuning of the SVCs and thyristor control algorithms associated with the series capacitors. PJM must be able to accurately model all planned and forced outages and configuration changes in the region and promptly factor these changes into the configuration and tuning of TCSC-SVC controls to assure proper stability protection and prevent potentially catastrophic SSR-induced turbine shaft cracking in regional generators. PJM currently does not have these SSR concerns in this portion of their system and likely has little, if any, in-house expertise on the phenomenon or the analytical studies necessary to ensure that these issues are avoided. It is not clear how PJM can perform these complex studies on demand to meet unexpected system conditions and maintain this proposed solution in an "operable" state.

E. Should PJM Decide to Select the Dominion Proposal, PJM Must Ensure Adequate Indemnification Protection for PSEG Nuclear Associated with SSR Related Damage and/or Loss of Generation.

As mentioned above, PJM has limited, if any, experience in the application of series compensation and the associated SSR analyses that accompany this technology. Given that SSR can quickly damage generation resources and lead to cascading outages, the presence of SSR characteristics must be independently monitored in real time. In addition, depending on the results of SSR analyses and/or mandates by Nuclear Electric Insurance Limited (NEIL), some means of SSR trip protection of potentially vulnerable units may be necessary. It is not apparent to PSEG Nuclear who will be responsible for the installation and maintenance of any forced tripping protection (e.g., torsional relays, SSR current relays) on the units at AI, if they are deemed to be required. Any increased risk fees that may be mandated by NEIL due to the potential for SSR and its impact on main turbine shafts should be borne by Dominion. Also, if

forced tripping is required, PJM needs to address the issue of providing indemnification to PSEG for any lost generation in response to spurious or legitimate SSR-based tripping of one or more PSEG Nuclear units must be addressed.

Finally, and most importantly regarding implementation of this design, it will need to be explicitly clear to PSEG Nuclear that, assuming PJM selects the Dominion 1a proposal as its preferred solution, PJM and/or Dominion will 1) take full responsibility for addressing any discovered turbine generator shaft cracking at the AI units in response to independent indications of SSR and 2) provide indemnification for all repair and lost generation associated with repair/replacement of damaged turbine generator shafts/components.

III. CONCLUSION

The risks associated with a first of a kind design such as that proposed by Dominion are not conducive to nuclear safety and overall reliability of the transmission system. Rather, when one objectively weighs the risks associated with the subject proposal and the consequences resulting from potential adverse impacts on nuclear safety and grid reliability, as described above, the Dominion TCSC Proposal should not be the recommended solution. The potential consequences arising from a failure of the proposed design to provide both stability and SSR protection when called upon are simply unacceptable from a nuclear safety perspective.

Very truly yours,

Christopher Schwarz
Vice President – Operations Support
PSEG Nuclear