Review of NSPI Transmission System Interconnection Requirements

April 30, 2021

Power Advisory LLC

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Offshore Energy Research Association

Content & Contacts

- Power Advisory was engaged by the Offshore Energy Research Association (OERA) on behalf of the Nova Scotia Department of Energy & Mines (DOEM) to review the recently released Nova Scotia Power Transmission System Interconnection Requirements (TSIR) and to identify any gaps between the recommendations made by Power Advisory in our August 2020 report, *Nova Scotia Ancillary Service Provision by Variable Output Renewable Energy Resources (Ancillary Service Report)*. This report outlined various changes to support the provision of ancillary services by variable output renewable energy resources in Nova Scotia and by so doing support their increased penetration.
- Our review of the TSIR is presented in 3 sections: (1) putting the TSIR in context, i.e., what's its appropriate scope; (2) reviewing some of the key ancillary services given the technical nature of these services; and (3) reviewing the TSIR and identifying any gaps between our recommendations that should appear in the TSIR and the content of the current February 25, 2021 version of the TSIR .

Prepared for OERA

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TSIR identifies minimum technical requirements for generation facilities

- Given its intended scope, the TSIR doesn't address all the recommendations in our earlier *Ancillary Services Report*. The TSIR establishes the obligation for Non-Synchronous/Inverter-based Resources (NS/IBRs) to provide various ancillary services; the compensation for these services will need to be established elsewhere (e.g., as part of the procurement process).
- The TSIR establishes a requirement for frequency response for NS/IBRs. This covers Fast Frequency Response (FFR), Primary Frequency Response (PFR), and Automatic Generation Control (AGC). FFR is a new and distinct service provided by NS/IBRs and can bridge the gap between inertial response (provided by synchronous generators) and Primary Frequency Response in some jurisdictions. We recommend that the TSIR be more prescriptive with respect to FFR performance requirements. This should help IPPs understand the impact of FFR provision requirements on their projects and should provide comfort with respect to the commercial reasonableness of these requirements.
- The PFR requirements in the TSIR conform to our recommendations.

TSIR identifies minimum technical requirements for generation facilities

- The TSIR requires the provision of AGC when a generator is curtailed. There isn't an opportunity cost associated with the provision of AGC when these resources are curtailed. Other elements of our recommendations with respect to AGC are commercial issues and not appropriately an element of the TSIR.
- However here as well, we believe that NS/IBRs developers my benefit from greater understanding regarding the technical and performance requirements for this service given that this could affect their equipment selection. Such technical and performance requirements are commonly specified in the interconnection standards for other jurisdictions and could be included in the TSIR.
- We believe that NS/IBR developers would likely benefit from some additional organization of section 7.6.6. We discussed this provision with the System Operator.
- The TSIR requires that wind farms connected to the transmission system be equipped with STATCOM functionality such that they can provide voltage control down to zero real power output.
    - This is a new requirement that aligns with the Ancillary Services Report and recognizes that this capability can be provided by these resources.

Project Scope

- The starting point for this assessment is to put the TSIR in the appropriate context. This is done by reviewing the TSIR's purpose and objectives. With this understanding we are better able to identify any significant gaps between the TSIR and recommendations in the August 2020 *Ancillary Services Report* that could represent a barrier to having non-synchronous/inverter-based resources (NS/IBRs) provide the desired ancillary services.
- An understanding of TSIR's purpose is important because as its name implies, the TSIR focuses primarily on interconnection requirements. The scope of our recommendations were considerably broader and focused as well on various commercial issues such as how NS/IBRs should be compensated for the provision of these services. Therefore, an assessment of any gaps in the TSIR needs to recognize its underlying purpose.

TSIR elements previously were specified in a range of different documents

- The TSIR was created to consolidate existing transmission interconnection technical requirements and reflect updates to industry standards, technology improvements now available, and current and future system operating constraints and conditions.
- The TSIR draws upon requirements that previously were in NSPI's Generator Interconnection Agreement (GIA), and the various System Impact Studies and Facilities Studies conducted for generating facilities.

TSIR establishes interconnection requirements for non-synchronous inverter-based resources

- The TSIR identifies the minimum technical requirements for interconnection of Generating Facilities and/or Transmission Customer Load Facilities to the Nova Scotia Power Inc (NS Power) Transmission System. These minimum requirements are specified to help ensure the reliability and stability of the Nova Scotia Power Transmission System as well as the safety of Nova Scotia Power employees and the general public.
- With the TSIR focused on the minimum technical requirements of generating facilities, it doesn't address all the recommendations in our earlier report. In general, the TSIR establishes the obligation for NS/IBR to provide various ancillary services. As discussed, the terms under which these services are to be provided (other than technical requirements) and compensation for these services will need to be established elsewhere.

Project Scope focuses on Asynchronous Generators

- A primary focus of this review are the requirements applicable to NS/IBRs or Asynchronous Generators as specified in Section 7.6 of the TSIR. Special requirements are specified for NS/IBRs (referred to as asynchronous generators), with some requirements just for wind turbine generators.
    - Sections 7.1 and 7.4 also apply to NS/IBRs. Some elements of Section 7.4 are particularly relevant to NS/IBRs including Voltage Ride-Through, Frequency Variations, Islanded Operation, Reactive Power Requirements, Dynamic Reactive Power Requirements, Power Quality, Automatic Voltage Regulation, and Synchronizing Facilities.
        - Voltage ride-through wasn't a major focus of the review in *Ancillary Services Report:* we noted its importance, but didn't delve into technical issues. Reactive power requirements and voltage regulation were a focus, but are also addressed in Section 7.6.
- The specific subsections for "asynchronous generators" are identified on the following page along with an indication of the degree to which they were addressed in the Ancillary Services Report and whether the TSIR's treatment of them is reviewed in this report.
    - We focus on Section 7.6 because this is the part of the TSIR that applies to NS/IBRs and therefore applies to the recommendations made in our Ancillary Services Report.

TSIR focus on Asynchronous Generators covers

- This section (7.6) of the TSIR provides for:
  - Transformer Configuration (7.6.1) – not addressed in A/S Report [N/A]
  - Reactive Power & Voltage Control (7.6.2) – addressed in A/S Report and below
  - Voltage Ride-Through – (7.6.3 & 7.6.4) reviewed in A/S Report – no changes required
  - Power Quality – (7.6.5) not addressed in A/S Report [N/A]
  - Active Power Control (7.6.6) addressed in A/S Report and below
  - Inertia Response (7.6.7) addressed in A/S Report and below
  - Anti-Icing Mitigation (7.6.8) addressed in A/S Report and below
  - Low Ambient Temperature Requirements (7.6.9) addressed in A/S Report and below
  - Operational Wind Data Requirements (7.6.10) not addressed in A/S Report
  - High Speed Cut-Out (7.6.11) addressed in A/S Report and below
- For many of the items that were reviewed in our Ancillary Services Report and addressed in the TSIR little comment is required.

Project Approach

- The TSIR was first issued in December 2020 and subsequently updated in February 25, 2021. We reviewed the February 21, 2021 version.
- We interviewed the NSP System Operator twice to better understand the rationale and basis for requirements specified in the TSIR and identify any apparent issues with these requirements.
    - A draft of this report was also shared with them for comment.
- We also reviewed the Hydro-Quebec TransEnergie, Technical requirements of connection of power plants to the transport network of Hydro-Quebec, which was translated from French. Hydro-Quebec TransEnergie was one of the first utilities to impose a requirement on wind projects for the provision of frequency response services.

Frequency Response: Inertial response is provided in the first few seconds after a frequency disturbance

(1) Inertial Response: is traditionally provided by conventional synchronous generators using the stored kinetic energy of the total rotating mass directly coupled to the AC grid.

- In the first few seconds following the loss of a large power plant or transmission circuit, the grid frequency starts to drop. In traditional power systems, the frequency drop is limited by the inertial response of the on-line synchronous generation that have "spinning momentum" or large rotating masses to offset frequency disruptions.
- The synchronous generators release their stored kinetic energy into the grid, reducing the initial rate of change of frequency (RoCoF), allowing slower governor actions (e.g., primary frequency response) to catch up and contribute to frequency stabilization.
- Inertia limits the frequency drop during the first 7 to 10 seconds, providing time to allow other resources to increase/decrease output and bring energy and demand back into balance.

(2) Primary Frequency Response (PFR): is the automatic response by turbine speed governors on conventional synchronous generators and demand to correct frequency excursions and ultimately stabilize frequency.

(3) Secondary Frequency Response: is typically provided by generators with Automatic Generation Control (AGC) (e.g., coal and gas-fired and hydroelectric units), which allows the generator to respond to second-by-second dispatch signals from the system operator to increase or decrease output in order to balance supply with demand in real-time.

Non-synchronous generators do not inherently provide inertial response

- Non-synchronous generators/inverter-based resources (wind, solar PV and battery energy storage) have been configured to allow for the provision of a new distinct service known as **fast frequency response (FFR).** FFR can bridge the gap between inertia and PFR. The primary function of FFR is to arrest the frequency decline and "buy time" for PFR to commence.

Reactive Supply and Voltage Control

- Voltage support is used to maintain transmission system voltages within a secure, stable range. Voltage support is location specific and requires reactive power control from resources distributed throughout the power system.
- Controllable sources for voltage support include generators that are able to vary their reactive power output, inductive and capacitive compensators, and transformers which are utilized to inject and absorb reactive power and keep voltage between the necessary minimum and maximum levels. These sources work with other elements of the electric system to collectively provide voltage control.

TSIR establishes a requirement for frequency response

- The TSIR specifies that "*Asynchronous Generators* connected to the *Transmission System* must be capable of controlling active power in response to frequency deviations and control signals from the NSPI System Operator to the extent enabled by the technology utilized." (p. 29).
    - This language provides considerable flexibility with the qualification "to the extent enabled by the technology utilized." As our earlier report demonstrates these technologies have this capability.
- There previously was a requirement for responding to over-frequency conditions. This requirement was specified in the GIA.
- In particular, the TSIR specifies that "Asynchronous Generating Facilities must be capable of being rapidly and automatically curtailed to preset limits of 66%, 33% and 0% of rated output. Curtailment signals will be delivered via the NS Power Supervisory Control and Data Acquisition (SCADA) system and the *Generating Facility* must acknowledge the curtailment signal and limit plant output within 60 seconds of receipt of the curtailment signal." (p. 29).
- In addition the TSIR specifies "While the *Asynchronous Generating Facility* is not curtailed, it shall provide self-regulation for over-frequency conditions in excess of 60.2 Hz at a droop characteristic of 4%." (p. 30)

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The TSIR establishes a requirement for Fast Frequency Response underfrequency for NS/IBRs (1/3)

- Of particular relevance are the active power control requirements, which are used to support system frequency. This covers FFR, PFR, and AGC, the later two are reviewed in a subsequent slide.
- Recall that FFR is a new and distinct service provided by non-synchronous generators/inverter-based resources and can bridge the gap between inertia (provided by synchronous generators) and Primary Frequency Response in some jurisdictions.
- There are different operating costs associated with the provision of FFR by wind, solar and batteries. These are likely to influence whether these resources are called upon to provide these services, in particular solar. Nonetheless, it is still likely to be appropriate to require new projects to be able to provide this service. There's likely to be little incremental capital cost to solar associated with the ability to provide this service.
- The GIA previously had a requirement for frequency response for over-frequency conditions.

The TSIR establishes a requirement for Fast Frequency Response underfrequency for NS/IBRs (2/3)

- The TSIR specifies that "WECS Generating Facilities shall support short-duration frequency deviations by providing inertia response equivalent to a Synchronous Generator with an inertia factor (H) of at least 3.0 MW-s/MVA for a period of at least 10 seconds." (p. 30)
- Power Advisory understands that these requirements are based on securing a comparable level of inertial support as offered by synchronous generation.
- While comparability of service is a reasonable standard, we believe that recognizing that how wind projects provide this service and the unique performance characteristics of this service provision is also important. In particular, wind turbines will have an energy recovery period after FFR is provided, recognizing these differences through alternative technical standards for wind projects is likely to be appropriate.
- HQ TransEnergies's requirements for wind projects are more prescriptive and specify a deadband between -0.1Hz and and -1.0Hz of the nominal frequency; limit the rise time to reach the maximum overproduction to 1.5 seconds or less; limit the decrease in active power during the energy recovery period to approximately 25% of rated power; be effective for each wind turbine in service when production is about 25% or more of rated power.

The TSIR establishes a requirement for Fast Frequency Response underfrequency for NS/IBRs (3/3)

- Being more prescriptive with respect to FFR performance requirements should help IPPs understand the impact of FFR provision requirements on their projects and should provide comfort with respect to the commercial reasonableness of these requirements.
    - The NSP System Operator may wish to indicate how these requirements will be tested or how compliance will be measured. This doesn't necessarily have to be in the TSIR, but would likely need to be clarified prior to any procurement.
- The FFR obligation in the TSIR is a new requirement for Nova Scotia and a change that conforms to our recommendations. The scope of the requirement appears appropriate for the TSIR. There a number of issues that pertain to the commercial arrangements for the provision of this service including compensation, penalties/rewards for poor/strong performance that still need to be addressed, but aren't appropriately within the narrow confines of the TSIR.
    - The proposal for greater specificity with respect to FFR performance requirements should be addressed in the TSIR.

The TSIR provides a requirement for Primary Frequency Response for NS/IBRs when curtailed

- Recall that the *Ancillary Service Report* noted that there is an opportunity cost associated with providing the headroom required for PFR for wind turbines and solar PV. Having generators incur an opportunity cost so that they are able to provide PFR is likely to be uneconomic in most operating conditions because they would be called upon to provide PFR in rare circumstances. Therefore, there would be a limited number of operating conditions when under an economic dispatch wind generators would be called upon to reduce output so as to create headroom for the provision of PFR.
- However, this could occur during high wind output periods when under some operating conditions wind might otherwise be dispatched down. Under these conditions there would be little to no opportunity cost.
- The TSIR therefore requires: "While the Asynchronous Generating Facility is curtailed, it shall offer over-frequency and under-frequency control with a deadband of +/- 0.2 Hz and a droop characteristic of 4%." (p. 29)
    - This is a new requirement.

Droop used to characterize PFR response

- **Droop** refers to the variation in real power (MW) output due to variations in system frequency and is typically expressed as a percentage (e.g., 4 percent droop). Droop reflects the amount of frequency change from nominal (e.g., 4 percent of 60 Hz is 2.4 Hz) that is necessary to cause the main prime mover control mechanism of a generating facility to move from fully closed to fully open.
  - The generator's output and frequency are inversely proportional. When frequency decreases, output increases. If a generator has a 4% droop setting, for example, then a 4% decrease in frequency will increase the unit's power output by 100%. However, the increase in active power output will be limited by the headroom available.
  - The Droop settings in Nova Scotia have typically been 4%.

TSIR also establishes an obligation for NS/IBRs to provide AGC

- "The active power controls shall also react to continuous control signals from the NS Power Automatic Generation Control (AGC) system to control tie-line fluctuations when required." (p. 29) This sentence is in the same paragraph and follows a sentence that references the asynchronous generating facility being curtailed. If the generating facility is curtailed it would be able to provide both "reg up" and "reg down" services.
  - There isn't an opportunity cost associated with the provision of AGC when NS/IBRs are curtailed.
- We recommended that the service for these resources be disaggregated between "regulation down" and "regulation up" service. However, this and other elements of our recommendations in this area are commercial issues and not appropriately an element of the TSIR.
- As discussed with respect to FFR, we believe that NS/IBRs developers my benefit from greater understanding regarding the technical and performance requirements for this service given that this could affect their equipment selection. Such technical and performance requirements are commonly specified in the interconnection standards for other jurisdictions and could be included in the TSIR. How these are "operationalized" can become a commercial issue.

Further organization of the TSIR provisions regarding active power control may be helpful

- We believe that NS/IBR developers would likely benefit from some additional organization of section 7.6.6. This could include a section that discusses active power control (1st paragraph) and then goes into: (1) FFR, possibly in section 7.6.6.1. With a section that includes requirements when not curtailed (1st paragraph p. 30) and the material in Section 7.6.7, which pertains to wind projects and may warrant a separate section, followed by second paragraph on p. 30; (2) PFR, possibly in section 7.6.6.2. This could include 1st sentence in last paragraph on page 29; (3) AGC, possibly in section 7.6.6.3, and include the second sentence in the last paragraph on page 29.
    - We discussed these changes with the NSP System Operator.

Other requirements for WTGs include:

- High speed cut-out control regime for wind projects 30 MW or greater that reduces and restores "output of a WECS *Generating Facility* at a ramp rate no greater than 20 MW per minute. This requirement is limited to WECS *Generating Facilities* rated at 30 MW or greater." (p. 30).
    - Such a requirement was discussed in our August report and is reasonable.

Reactive Power and Voltage Control

- The GIA for wind projects required that projects shall maintain a power factor of from .95 leading to .95 lagging, but didn't specify that the reactive power be available through the full range of real power output from zero to full power.
- The TSIR requires that wind farms connected to the transmission system be equipped with STATCOM functionality such that they can provide voltage control down to zero real power output.
  - "Rated reactive power shall be available through the full range of real power output of the *Generating Facility*, from zero to full power." (p. 28)
  - This is a new requirement that aligns with the Ancillary Services Report and recognizes that this capability can be provided by NS/IBRs.

The TSIR specifies an anti-icing requirement

- The TSIR requires that customers provide icing models and conduct icing studies for their wind projects, with a requirement that the icing detection and mitigation systems be installed as specified in the System Impact Study or GIA.
- The Ancillary Services report discussed cold weather capability
- NSP SO may wish to reference the: IEA Wind, "Expert Group Study on Recommended Practices: 13. Wind Energy Projects in Cold Climates" February 2017. This document outlines a framework for making these determinations. This might help wind project developers assess these requirements and provide greater transparency.

The TSIR specifies low ambient temperature requirements

- The TSIR requires that NS/IBRs be capable of operating at ambient temperatures as low as -30 degrees C.
- This appears to be new and aligns with the recommendations offered in the Ancillary Services Report.

The TSIR specifies high speed cut-out requirements

- The TSIR requires that wind projects greater than 30 MW should reduce and restore output at a ramp rate no greater than 20 MW per minute.
- This is a new requirement and aligns with the recommendations offered in the Ancillary Services Report. As noted in the Ancillary Services Report having such a requirement reduces the need for the system operator to maintain resources to provide replacement power. This provision is appropriate.

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