Nova Scotia Ancillary Service Provision by Variable Output Renewable Energy Resources: Executive Summary

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Prepared for Offshore Energy Research Association (OERA)

This work was supported by a diverse group

- Power Advisory would like to acknowledge the support and insights provided by the following individuals and organizations. The Project Management Committee provided oversight, guidance and feedback on all draft work products. Stakeholders provided valuable insights on the various issues addressed in the report. However, the report was drafted by Power Advisory who accepts responsibility for any errors or omissions. Furthermore, any conclusions or recommendations do not necessarily reflect the opinions of the organizations represented on the Project Management Committee or of the various stakeholders.

Project Management Committee
Russell Dmytriw, Offshore Energy Research Association (Project Manager)
Peter Craig, Nova Scotia Department of Energy & Mines
Leigh-Anne Outhouse, Nova Scotia Department of Energy & Mines
Chris Milligan, Nova Scotia Power
David Stanford, Nova Scotia Power System Operator
Thomas Levy, Natural Resources Canada
Bala Venkatesh, Ryerson University

Stakeholders
ENERCON
GE
Canadian Renewable Energy Association
Wind Energy Institute of Canada
NextEra Energy
Invenergy
Suncor
Alternative Resource Energy Authority
Natural Forces

Content & Contacts

- Power Advisory has been engaged by the Nova Scotia Offshore Energy Research Association (OERA) on behalf of the Nova Scotia Department of Energy and Mines to perform a study recommending changes to the standard form Power Purchase Agreement (PPA) and procurement process to support the provision of ancillary services by variable output renewable energy resources.
- This study's intent is to identify the types of ancillary services that could be procured as part of a renewable energy project and determine how providers may differentiate their bids by offering these services. The objective of this study is to help define a new, enhanced PPA for use by Independent Power Producers (IPPs) and Nova Scotia Power Inc. (NSPI) that provides more value to NSPI ratepayers.
- This is the Executive Summary of the report.

Prepared for Offshore Energy Research Association

John Dalton, President

jdalton@poweradvisoryllc.com

(978) 369-2465

212 Thoreau Street

Concord, MA 01742

www.poweradvisoryllc.com

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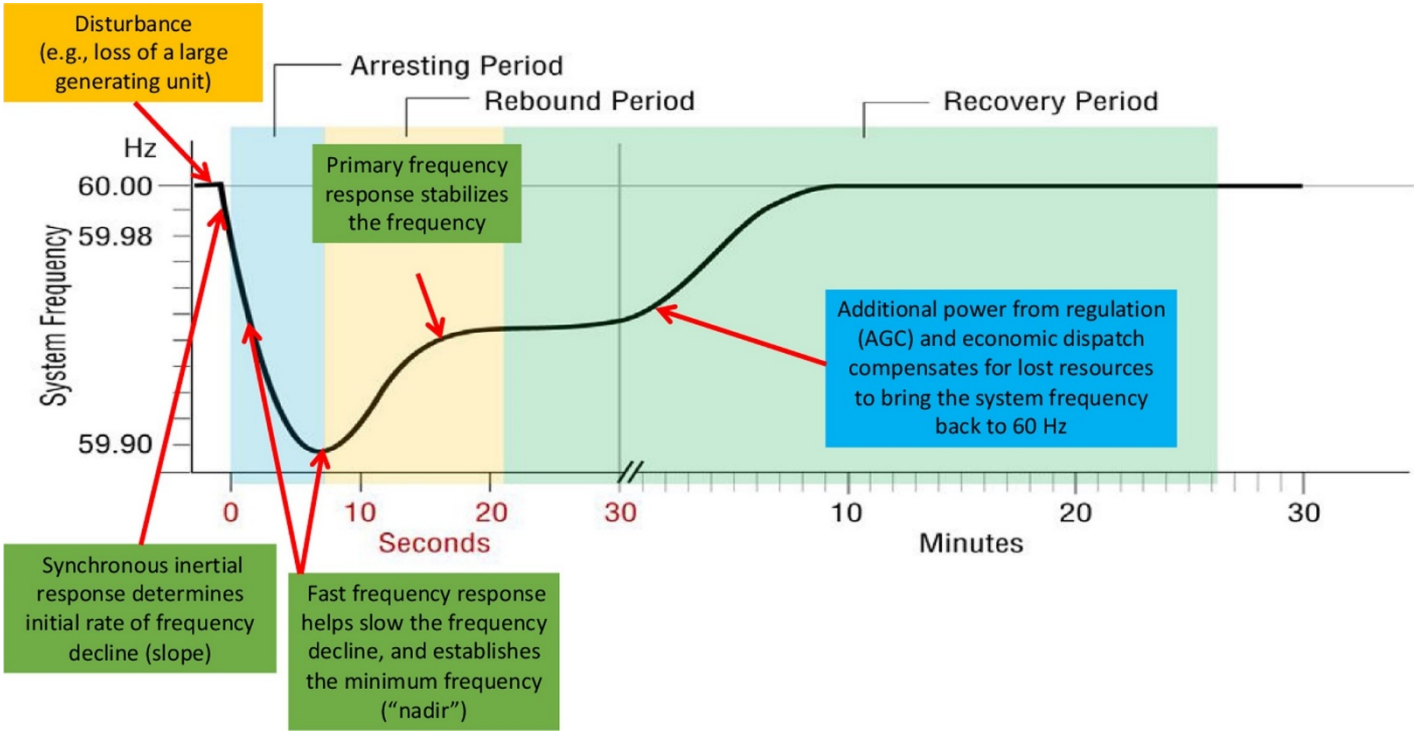
Ancillary services that variable output renewable resources are able to provide and are needed in Nova Scotia

- Nova Scotia has approximately 600 MW of installed wind generation capacity and off-peak loads of less than 700 MW in summer months, making integration of this variable output generation in certain hours a challenge. Identifying operating strategies (e.g., have wind projects provide frequency response) could reduce the requirement for thermal units to operate to limit these system reliability challenges and produce production cost savings and lower electricity sector carbon emissions in the province.
- Interviews with NSPI and NSP System Operator indicated that the ancillary services that warrant the greatest focus given operating conditions in Nova Scotia as well as the capabilities of variable output renewable resources that are connected to the grid via power electronics (aka non-synchronous generators/inverter-based resources) are:
    - **Frequency regulation** in the form of:
        - **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,
        - **Primary frequency response** is the automatic response by turbine speed governors on conventional synchronous generators and demand to correct frequency excursions and ultimately stabilize frequency, and
        - **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; and
    - **Reactive support and voltage control** to maintain system voltages throughout the grid.

The relationship between nadir and various forms of frequency response or control are shown below



Source: Michael Milligan, "Sources of grid reliability services," The Electricity Journal Volume 31 Issue 9, November 2018.

- This graphic shows the corrective actions taken to respond to a loss of generation or transmission including inertial response, FFR, PFR and AGC.

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

- Frequency response ensures the frequency of the bulk electricity system can be maintained at 60 hertz and is stable for both normal and abnormal (loss of components) conditions.
- A review of industry literature and interviews with technology providers and developers confirmed that most wind turbines as well as solar and battery storage projects are capable of contributing to the frequency response services that Nova Scotia requires to maintain the reliability of its electricity grid, with the exception of synchronous inertia.
    - Non-synchronous generators/inverter-based resources (wind, solar PV and battery energy storage) have been configured to allow for the provision of a fast frequency response (FFR). This can be an important tool in mitigating frequency declines after a system disturbance, by very rapidly correcting the supply-demand imbalance.
    - While there might be some incremental operations and maintenance expenses associated with the provision of this service, ENERCON notes that its wind turbines can provide this service "without significant wear and tear." However, the Wind Energy Institute of Canada (WEICan) notes that the impact of incremental loading on the drive train and blades may have service and asset life implications and that this could have an impact on coverages under their service & warranty agreements. Power Advisory believes that the differences of opinion between ENERCON and WEICan may be explained by in part by the robustness of ENERCON turbines and ENERCON's experience where wind turbines have been called upon to provide FFR infrequently.
    - To ensure sufficient FFR capability from wind turbines to meaningfully impact system reliability retrofits to existing wind turbines will need to be considered. This may require an agreement to cover any incremental fixed costs associated with the provision of this service.
    - Based on our discussions with wind turbine manufacturers we expect these incremental fixed costs to be modest at least for those projects where such an investment is deemed to be reasonable. We would expect that an estimate of the potential benefits would be developed and this would be used to determine an appropriate cost threshold for undertaking such an investment.

PFR typically provided by generators' governors which automatically respond to frequency deviations

- PFR actions begin within seconds after system frequency changes and are mostly provided by the automatic and autonomous actions (i.e., outside of system operator control) by natural gas, coal, and nuclear plants.
- 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 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.
- Wind turbines that are being relied upon to provide PFR cannot also provide FFR given that the control algorithms for each service are different and need to be specified prior to any system frequency event. Because FFR can be provided without incurring any opportunity cost, we expect that NSP SO may elect to have wind resources focus on the provision of FFR, with PFR provided when there's surplus wind generation.
- Battery resources can also provide PFR.

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Secondary frequency response is provided by generators with AGC

- This has typically been coal, gas-fired and hydroelectric units where the AGC allows the generator to respond to second-by-second dispatch signals from the system operator to increase or decrease output.
- Many US frequency regulation markets are divided into regulation-up (reg-up) and regulation-down (reg-down) services, allowing resources that have capability to increase or decrease their power when the AGC command is positive or negative.
- This is particularly important for wind, solar and energy storage resources given that these projects may have different capabilities to provide these services given their operating conditions. In addition, there are opportunity costs associated with the provision of this service that need to be considered. For example, because the energy output from wind or solar resources is determined by the available resource, they are generally only able to provide Reg-up service when they are operating at less than their available output using headroom.
- To the degree that the wind or solar project would otherwise be curtailed then there would be no opportunity cost from the provision of reg-up service.
- Power Advisory had preliminary discussions with the NSP SO to assess obstacles to allowing non-synchronous/inverter-based generators to offer reg-up and reg-down services separately. The NSP SO indicated that based on its preliminary assessment there were no obvious barriers to doing so.

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Reactive Supply and Voltage Control

- The primary objective of voltage support is 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.
- Without a specific package to provide voltage control and reactive capability, VAR capability is reduced at low wind speeds as various WTGs drop off as wind speeds drop below the minimum threshold.
- Voltage stability can be a challenge, particularly where a large wind project is connected to through a long transmission line. Changes in wind speed result in changes in active project output, which can lead to changes in reactive power output.
- Some wind installations (e.g., in New Brunswick and PEI) are required to have separate independent reactive control devices such as Static Compensator (STATCOM).
- We understand that the NSP SO is considering changes to its Grid Code to obligate generators to have the capability to provide voltage support under such a wide range of operating conditions.

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Obligation to Provide A/S

- Power Advisory recommends that the capability to provide FFR, PFR, AGC and voltage control and reactive support should be mandated for all new non-synchronous/inverter based generation as part of interconnection standards for generation projects above a threshold size.
- Such a requirement would apply to all new projects.
- Some existing wind farms may have the ability to provide the same A/S as new facilities provided they can meet the technical requirements. This will presumably require retrofits to these facilities.
    - Based on conversations with OEMs Power Advisory understands the costs for retrofits to be modest for recently installed projects and may be modest for older projects, but the actual cost for existing projects varies on a site by site basis depending on the current configuration.
- Given that the costs for retrofits for most existing projects are expected to be modest the obligation to provide these frequency response ancillary services should be placed on them. Once again, WEICan expressed concern with the service and asset life implications of these requirements.
    - We understand that the overall costs for retrofitting voltage control and reactive support capabilities is considerably higher and that the value of this service is location specific. Therefore, we recommend that imposing this obligation on existing projects be considered on a case-by-case basis.

Obligation to Provide A/S

- NSP SO should specify the specific operating parameters for resources providing these services including the speed, magnitude and duration of response (sustaining time). These operating parameters are likely to be specified as a range or maximum.
  - For example, GE notes that for frequency control of its wind turbines a complete set of droop and limit parameter can be defined, with the droop curve selection done by the project owner and/or some external command from the system operator.
- With a mandate to provide these A/S, projects would continue to compete on the basis of the $/MWh price offered for energy. This would simplify the evaluation process.
  - There would be one exception: hybrid projects where the incremental value of the BESS would be considered. How the value of this alternative could be considered in the evaluation process is discussed below.
  - Alternatively, a decision could be made to not allow hybrid projects participate. Given experience elsewhere as discussed further in the jurisdictional scan, Power Advisory believes that hybrid projects are likely offer additional value and should be considered.

Compensation for Relevant A/S

- With the ability to provide these A/S mandated, proponents presumably will embed any incremental fixed costs to provide the A/S in their contract pricing.
- However, the opportunity cost and incremental operating and maintenance (O&M) cost of providing these services should be specified in the PPA so that suppliers are kept whole.
- Incremental operating and maintenance (O&M) expenses are less obvious and more difficult to discern. Wind turbine manufacturers have indicated that incremental O&M expenses from the provision of these services are relatively insignificant, particularly given the limited number of instances that they are typically called upon (e.g., less than 10 times per year in Quebec).
    - Our proposal for considering these O&M costs is outlined below.

Compensation for Relevant A/S

- With respect to FFR, where the kinetic energy of the rotors are used to provide a power boost and there would be the greatest potential for additional stress on project components, ENERCON asserted this service can be provided "without significant wear and tear" provided it is used infrequently. GE offered a similar perspective. This suggests that little to no incremental compensation is required for this cost. Nonetheless, given the uncertainty regarding these variable O&M expenses and the value of the provision of this service by wind turbines and other IBRs adding a nominal per use payment upon successful delivery is reasonable (e.g., $20/MW). This per use payment could be specified by the Procurement Administrator working with the NSP SO. However, it isn't clear that there's a sound analytical foundation for estimating such a payment.
    - 'Arming' the service would not trigger the payment – it would be based on actual use. There is little to no opportunity cost for this service given its infrequent use and minimal impact on total production.
- WEICan expressed concern with respect to the incremental loading on the drive train and blades from "overdriving" the wind turbine and the resulting service implications and facility life implications as well as potential impacts on service and warranty agreements.

Compensation for Relevant A/S

- A/S provision should be rewarded for good performance and failure to provide A/S when called upon by the NSP SO or provision of a lower quality service than offered should be penalized.
- Penalties would vary depending on the A/S. For AGC, a number of RTOs have used the concept of a performance score to compensate resources based on the quality of service that they provide, with performance typically measured in terms of the degree to which the resource responds accurately to dispatch signals. This approach is applicable for AGC provision in Nova Scotia, but less appropriate for other services.
- Penalties for other services typically have a deadband (e.g., =/- 10%).
    - This deadband should reflect the underlying uncertainty associated with providing the service given resource availability, signal error etc.
- Penalties for failure to perform or deliver the committed A/S often involve rebating the payment that was received.
    - Repeated failure to meet minimum standards for delivery can result in suspension in the ability to provide the service until a compliance plan is developed.
    - Testing to ensure ability to meet standards could be required where there is poor performance and/or very infrequent use of the service.

Key Rationale for Recommendations

- Capability for non-synchronous/inverter-based resources to provide ancillary services will reduce integration challenges and provide the NSP SO with additional tools and resources for managing real-time reliability challenges.
- The proposed compensation models will allow services to be provided while compensating providers for appropriate opportunity costs.
- The proposed approach allows existing projects to provide these services as well to the degree that NSP SO determines there is incremental value to the system.
  - Existing projects are at a minimum kept whole in the framework.
- The requirements proposed are relatively standard capabilities for wind generators and are consistent with many other markets.
  - As such the requirements will not result in excessively costly procurements.
- The recommendations establish expected capabilities for non-synchronous/inverter-based resources combined with a compensation framework – the model and procedures for actual use of the services is not contemplated.

John Dalton
President, Power Advisory
jdalton@poweradvisoryllc.com

Kris Aksomitis
Director
kaksomitis@poweradvisoryllc.com

Carson Robers
Senior Consultant
crobers@poweradvisoryllc.com