Integrating Renewable Resources – Design Principles

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Overview

Ontario's Long Term Energy Plan reinforces the investment focus on renewable generation under the Green Energy and Green Economy Act (GEA) and the Ontario Power Authority's Feed-In-Tariff (FIT) program. The Plan acknowledges the significant commitments made to date - 5,800 MW of variable generation projects, primarily wind, are underway and are expected to be in commercial operation by the end of 2012, with 10,700 MW targeted for 2018. This rapid deployment of renewables across the province will fundamentally change the characteristics of the power system, challenging the IESO's ability to maintain reliable and cost-efficient operations. To meet this challenge, and help capture the benefits of Ontario's investment in variable generation, the IESO is adapting power system operations and the IESO-administered markets to accommodate the influx of renewables. The key principles for the IESO's Renewable Integration Initiative fall into three areas: forecasting, visibility and dispatch.

These principles are proposed to guide the IESO's future design and development processes. Building on consultations to date, they should also provide stakeholders, in particular variable and baseload generators, with clear expectations for the facility and operational requirements they will be expected to meet. Following the comment period, and consideration of that input, the principles will be finalized by the IESO and will form the basis for market rule development.

Forecasting

Principle 1:

The IESO will implement a centralized forecast for wind resources directly connected to the IESO-Controlled Grid and for wind resources with an installed capacity of 5MW or greater connected to a distribution system. Centralized forecasting will be expanded to include other variable resources such as solar as their aggregate installed capacity becomes material.

The less predictable nature of the output from renewable resources compared to conventional generation will pose operational challenges when integrating large volumes of wind and solar resources into the IESO-Controlled Grid (ICG). Accurately predicting variable generation output will be an essential tool for the IESO to maintain system reliability and market efficiency. This will require specialized forecasting tools and processes, including centralized forecasting for all wind and solar generators directly connected to the ICG and for all wind and solar generators with an installed capacity of 5MW or greater connected to a distribution system (i.e. an embedded facility). The forecasting products that will be integrated into the IESO system and market operations will evolve to include hourly, day-ahead, probabilistic and ramp event forecasting.

Centralized forecasting has been a prominent development within the industry over the past several years. The North American Electric Reliability Corporation (NERC) special report *Accommodating High Levels of Variable Generation*, published in April 2009, concluded that "variable generation output forecasts in multiple time frames are critical for reducing uncertainty and maintaining system reliability". It further states "forecasting techniques [for variable generation] must be incorporated into day-to-day operational planning and real-time operations routines/practices."[1]

In a subsequent report, *Variable Generation Power Forecasting for Operations*, NERC further noted that "in the interests of efficiency and convenience for the system operator, the trend today is toward central forecasts" and that "this can be seen in the high penetration wind areas in Europe (Germany, Spain, Portugal, Denmark, Ireland), as well as in the U.S. and Canada (California Independent System Operator, New York Independent System Operator, Electric Reliability Council of Texas, PJM Interconnection, Midwest Independent Transmission System Operator, Alberta Electric System Operator, Hydro Québec)."[2] A recently-issued FERC Notice of Proposed Rulemaking (NOPR) is moving the US toward a broad regulatory requirement for central forecasting of variable resources. (FERC Docket No. RM10-11-000)

Principle 2:

A real-time forecast will provide the information to allow for renewables dispatch and OPA contract settlement.

IESO forecast requirements will, to the greatest extent possible, use industry standard forecast products to:

- Facilitate the dispatch of renewable resources; and
- allow for the settlement of additional contract payment clauses in OPA contracts.

Given current forecasting capabilities, for short term forecasting (i.e. within one hour ahead) persistence of the current production level is the best predictor of future production. However, the IESO will require a real-time forecast for variable generators that have been dispatched down. When the IESO no longer requires a wind generator to operate at reduced output, an estimate of the available output for the next interval is necessary – just as is the case for other forms of generation. This forecast would use real-time meteorological and facility data to produce a five minute look-ahead forecast. For example, the real-time wind speed would be indicative of the production available from the facility, which would then be incorporated into the overall system dispatch process.

[1] *Accommodating High Levels of Variable Generation*, http://www.nerc.com/files/IVGTF_Report_041609.pdf at pages 58-59.
[2] *Variable Generation Power Forecasting for Operations*, http://www.nerc.com/docs/pc/ivgtf/Task2-1(5.20).pdf at page 15.

The real-time forecast will also be required to settle OPA contracts. For example, payment can be required for foregone energy when the IESO issues a dispatch instruction to the generator to reduce all or part of its output in order to mitigate over-generation on either the entire ICG or substantially all of the ICG. The real-time forecast less the generator's actual production would establish the generator's foregone energy for purposes of the OPA's payment calculation.

Principle 3:

The costs paid to the centralized forecast service providers will be treated as procured service charges and will be recovered from consumers through existing procurement market recovery mechanisms.

Similar to the procurement of ancillary services, defined in the market rules as "*...services necessary to maintain the reliability of the IESO controlled grid, including but not limited to, regulation, black start capability........and any other such services established by the market rules"*, the IESO will establish centralized forecasting as a new procured service, with the IESO's costs (primarily consisting of service provider charges) recovered through an uplift consistent with ancillary service costs.

This cost treatment is consistent with the majority of North American jurisdictions, with consumers funding forecast service costs in total or in part, either directly through a market charge or indirectly through the system operator. PJM, MISO and ERCOT recover the entire cost from consumers, while CAISO and NYISO recover a portion of the cost. In the IESO's case, funding the service provider and related costs through an uplifted charge to consumers will also facilitate the necessary evolution of forecasting requirements.

Centralized forecasting is expected to improve market efficiency, reducing costs to the market overall, and is consistent with other market mechanisms or programs to integrate specific generation types into the market. For example, the generator cost guarantee program for gas generators ensures these types of facilities come to market. Like centralized forecasting, this program is only required because of a specific generator technology, with the costs being collected from the consumers who benefit from the added reliability.

Visibility

Principle 4:

All wind based resources subject to centralized forecasting will provide static plant information and data. Solar or other variable generation requirements will be developed as these resources are incorporated into centralized forecasting.

Static plant data, i.e. data that describes the physical layout of the facility, will be identified in the course of the Connection Assessment and Registration processes (or at a time to be determined for generators that do not require a Connection Assessment.) The IESO will require the following static plant data describing the physical layout of the facility and details of the turbines[3]:

- Turbine Hub location and elevation (latitude and longitude)
- Meteorological Tower location and elevation (latitude and longitude)
- Type of turbine
- Manufacturer's power curve
- Cut in speed
- Cut out speed
- Cut out temperature
- Cold weather operations information

Relevant static plant data are necessary inputs for the forecasting services and situational awareness tools relied on by System Operators. General turbine information, such as power curves and cut in/out speeds, as well as facility layout information are used by forecast providers to initialize their forecast models. Additional information may be requested depending on the jurisdiction. Hydro Quebec, for example, collects information on turbine cold weather packages whereas CAISO does not. Quality wind facility data provides the IESO and forecast providers with the necessary inputs for reliable wind power production forecasts.

Principle 5:

All wind based resources subject to centralized forecasting will provide dynamic data (real-time telemetry). Solar and other variable generation requirements will be developed as these resources are incorporated into centralized forecasting.

The dynamic data requirements for centralized forecasting are well established in many North American jurisdictions. The IESO is adopting best practices from other jurisdictions and will augment these practices with Ontario specific requirements only when needed. As a minimum, the IESO will adopt the following NERC recommended dynamic data requirements:

- meteorological information (wind speed, wind direction, ambient air temperature, barometric pressure and relative humidity);
- power output; and
- wind turbine outage/availability information (including icing-related issues).[4]

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[3] The IESO will be developing a detailed data requirements document for variable generation registration.
[4] *Variable Generation Power Forecasting for Operations*, http://www.nerc.com/docs/pc/ivgtf/Task2-1(5.20).pdf at page 14.

Industry reports note that "meteorological and operational data from the wind plant play an important role in determining the forecast performance that can be achieved for a specific facility. Data from the wind-generation facility are used to optimize the relationship between meteorological variables and facility-specific power output and to correct weather forecast model errors."[5] The recently-issued FERC NOPR on Integration of Variable Energy Resources contemplates a regulatory mandate requiring similar information.

NYISO currently requires each wind turbine at the plant site to be within 5 kilometres of a meteorological tower. Similarly, CAISO's requirement is that wind speed and direction be reported from multiple locations within the footprint of the wind facility such that all turbines are within a distance of 5 x the average distance between a turbine and its closest neighbour from any measurement point.

In order to support forecast accuracy, and consistent with other North American jurisdictions, dynamic meteorological data will be required from independent meteorological towers located such that all turbines are within 5km of a measurement point. If the farm size is less than 10MW dynamic data may be provided from turbine mounted sensors. As pointed out in a recent IEEE report, "an inadequate representation of the spatial variability in the wind plant data set can lead to lower forecasting quality."[6] For example, in one study, power production was forecast for two adjacent wind plants of similar size for a period of one year, with one facility providing data from six meteorological towers distributed throughout the plant and the other facility providing data from only one meteorological tower. For the facility with six meteorological towers, the production forecast had much less scatter, resulting in a 23% lower mean absolute error compared to the facility providing data from one meteorological tower[7].

Under current IESO requirements, dynamic data would be provided to the IESO via a Remote Terminal Unit (RTU), consistent with existing requirements detailed in Market Manual 6 – Participant Technical Reference Manual. However, alternative internet-based communications requirements are being investigated to determine whether they can meet requirements for accurate and timely provision of the dynamic data necessary for accurate forecasting and situational awareness tools. In California's experience, when data quality is an issue forecasting accuracy suffers. Forecasts rely on high quality data made available in a timely manner to the forecast providers and as such, improving telemetry data from wind sites has been an ongoing focus for CAISO.[8]

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[5] IEEE Power & Energy. Change in the Air. Grant et al. Vol 7, No. 6, NOV/Dec 2009, p.53.
[6] IEEE Power & Energy. Change in the Air. Grant et al. Vol 7, No. 6, NOV/Dec 2009, p.53.
[7] Ibid, p.54.
[8] Revised Analysis of June 2008 – June 2009 Forecast Service Provider RFB Performance, http://www.caiso.com/2765/2765e6ad327c0.pdf, at page 8.

Principle 6:

All meteorological data and forecasts will be publicly available.

The IESO believes that publishing forecasts will enhance economic efficiency and help the IESO manage operational impacts on the remainder of the generation fleet. Market efficiency and reliability are, in part, maintained by providing relevant and timely information to all market participants so that they can respond to changing market conditions.. Market participants will be able to identify periods of large or small amounts of expected wind as well as periods of expected wind ramp, which may influence their own availability. Conventional generation may find it advantageous to be available when wind variability is forecast so as to take advantage of potential price movements. Additional generation availability during variable wind periods would increase system flexibility and assist the IESO in maintaining system reliability.

Against these benefits, there does not appear to be any compelling basis to assert confidentiality of meteorological data and forecasts.

Publishing forecasts and meteorological data would also be consistent with NERC recommendations, which note that "ongoing innovation is needed, with both government and private industry involvement. "[9] The public availability of raw meteorological data and forecasts will facilitate continued research, development and improvements to forecasting techniques.

Dispatch

Principle 7:

Actively dispatch all variable resources connected to the IESO-Controlled Grid on a five-minute economic basis.

Ontario's variable generation resources will soon represent a significant portion of the province's baseload fleet, and as a mainstream resource requires integration of these resources into market operations. Reflecting this reality, the IESO intends to actively dispatch all grid connected variable resources through the five minute security constrained economic dispatch[10].

[9] *Variable Generation Power Forecasting for Operations*, http://www.nerc.com/docs/pc/ivgtf/Task2-1(5.20).pdf at page 26.

[10] Exemptions may be developed for existing wind generators who have technological limitations in responding to a five minute dispatch instruction. Operating limitations are captured as part of the Registration process and are respected in the dispatch process.

Achieving reliable dispatch at least cost, referred to as security constrained economic dispatch, is the cornerstone of the IESO's reliable, market-based, grid operations mandate. With the integration of renewable resources into the economic dispatch, the IESO will be in a better position to direct the operation of all generation facilities to produce energy at the lowest cost while balancing operational issues such as ramp needs and surplus baseload generation situations. This will allow the IESO to manage the supply of reliable and efficient power to consumers while recognizing the operational limits of generation and transmission facilities. Other North American jurisdictions with high levels of renewable penetration, notably NYISO and ERCOT, are also integrating their variable generation into the real-time economic dispatch. PJM has a working group developing recommendations for fully integrating wind energy into the PJM market, as does CAISO.

The dispatch of variable resources will be limited to those that are directly connected and participate in the IESO administered markets. All embedded variable generators that are not market participants will, as today, continue to be accessible to the IESO if needed to resolve a reliability problem. However with the growing volume of embedded generation, the IESO intends to review its authorities over embedded facilities, and update those rules as necessary.

If a sufficiently large number of renewables connect to the distribution system such that insufficient resources exist in the wholesale market to consistently resolve reliability problems, then it may become necessary to expand dispatchability to embedded generators.

Principle 8:

Variable generators should operate within a compliance deadband when ambient conditions offer sufficient fuel.

The variability of renewable resources will require additional dispatch compliance rules. Typically the same compliance deadband that exists for dispatchable resources will apply to renewable generators.[11] However variable generators will also require a rule to enable the facility to remain compliant if ambient conditions change such that the maximum output from the facility is less than the lower threshold of the deadband. Provided ambient conditions offer sufficient fuel, a generator should be within the compliance deadband. If fuel disappears over the dispatch interval, what is considered compliant will be revised and subsequent dispatches will adjust to the change in output capability.

[11] For dispatchable facilities with an installed capacity greater than 30MW, the individual compliance deadband is the greater of +/-15MW or +/-2% of the facility's dispatch. For dispatchable facilities with an installed capacity less than 30MW, the individual compliance deadband is +/-10MW.

Principle 9:

Variable generators will be entitled to Congestion Management Settlement Credit (CMSC) payments.

Like other dispatchable generators, variable generators who respond to dispatch instructions would be eligible for Congestion Management Settlement Credit (CMSC) payments.

Principle 10:

The IESO may establish various floor prices for offers from baseload generators, i.e. wind, must-run hydro and nuclear, to ensure efficient dispatches during periods of local and/or global surplus baseload generation (SBG) events.

In every circumstance the IESO attempts to dispatch generators to achieve the lowest cost (i.e. efficient) dispatch to meet demand. During instances of local or global SBG, there may be times when submitted offers do not produce appropriate outcomes. For instance, is it appropriate to reduce or shut down a nuclear unit for 72 hrs or more to solve a 3 hour surplus condition that can be managed with fewer impacts and at a much lower cost by curtailing wind? Similarly, is it appropriate to pre-emptively spill hydro that has operational and safety risks to solve surplus conditions that can be managed by curtailing wind?

For example, if a nuclear unit shutdown is used to manage surplus baseload generation the following impacts can occur:

- Environmental – nuclear will typically be down for 48 to 72 hours (minimum) irrespective of how long the SBG condition lasts and its output must be replaced. In many cases replacement will be from gas or coal, both carbon emitting resources.
- Consumer costs will increase :
  - First, due to higher marginal cost replacement energy, increasing one or both of:
    - Global Adjustment
    - Market Clearing Price
  - Second, due to increased uplifts when replacing nuclear resources with gas/coal generation
- Asset risks increase – Increase wear and tear leading to accelerated loss of life and increased outage rates.

Instead of accepting these impacts, new rules would establish various floor prices for offers from baseload generators such that the dispatch algorithm would, typically, dispatch wind generators first, followed by spilling must-run hydro, followed by nuclear shutdowns.

To achieve this, the IESO would limit a wind generator's offer to $0/MW (or some other reasonably small negative value to account for any lost opportunity). The next marginal resource would typically be must run hydro, as it raises regulatory, environmental and safety issues associated with spilling. These resources would be expected to bid according to their ability to spill. The lowest marginal cost resource is assumed to be nuclear. Normally, nuclear would have a marginal cost less than hydro because manoeuvring a nuclear unit has safety and mechanical issues, as well as a mandatory shut down period. Nuclear resources would be allowed to offer as low as the current minimum market price of negative (-) 2,000$/MW. Similar practices have been implemented or are currently being considered in other North American jurisdictions.

Principle 11:

Directly connected variable resources (or embedded resources that are market participants) will be eligible to participate in Operating Reserve and ancillary markets where technically feasible. (Such integration will be considered on a cost benefit basis and is not likely to be addressed in the near term)

When a wind generator is dispatched below its maximum available output, the resource effectively has available capacity and an ability to increase its output in response to a dispatch instruction. As such, no physical limitations exist to preclude that excess capacity from being offered into the Operating Reserve market.

Summary

With dramatic growth occurring in Ontario's renewable resource fleet, the IESO is identifying and addressing the requirements for the integration of renewables into market operations through the Renewables Integration Initiative. Work is concentrated in three areas: forecasting, visibility and dispatch. Within each of these areas the IESO will be deploying the appropriate tools and procedures to both facilitate the integration of renewables into the wholesale electricity market and maintain the reliability of the IESO controlled grid. The following principles are being proposed to guide the Renewables Integration Initiative:

Principle 1: The IESO will implement a centralized forecast for wind resources directly connected to the IESO-Controlled Grid and for wind resources with an installed capacity of 5MW or greater connected to a distribution system. Centralized forecasting will be expanded to include other variable resources such as solar as their aggregate installed capacity becomes material.

Principle 2: A real-time forecast will provide the information to allow for renewables dispatch and OPA contract settlement.

Principle 3: The costs paid to the centralized forecast service providers will be treated as procured service charges and will be recovered from consumers through existing procurement market recovery mechanisms.

Principle 4: All wind based resources subject to centralized forecasting will provide static plant information and data. Solar or other variable generation requirements will be developed as these resources are incorporated into centralized forecasting.

Principle 5: All wind based renewable resources subject to centralized forecasting will provide dynamic data (real-time telemetry). Solar and other variable generation requirements will be developed as these resources are incorporated into centralized forecasting.

Principle 6: All meteorological data and forecasts will be publicly available.

Principle 7: Actively dispatch all variable resources connected to the IESO-Controlled Grid on a five-minute economic basis.

Principle 8: Variable generators should operate within a compliance deadband when ambient conditions offer sufficient fuel.

Principle 9: Variable generators will be entitled to Congestion Management Settlement Credit (CMSC) payments.

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