Renewable Generation Integration Study by PLEXOS

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1. Introduction

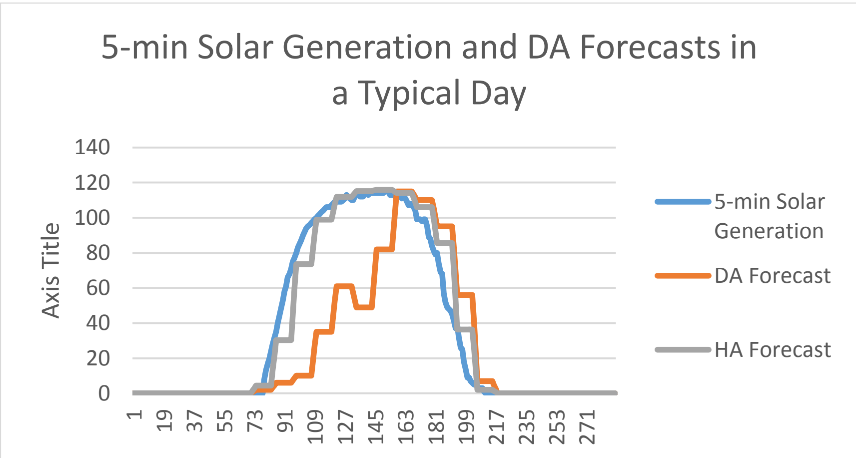
The uncertainty and variability nature of the renewable generation penetration creates integration challenges within the electric industry from the portfolio scale to the regional ISO level. The challenges include

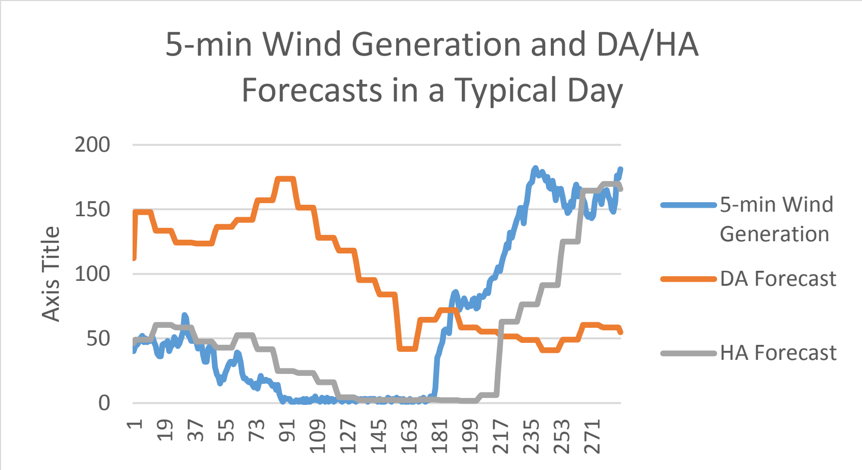
1. Is the Power Market or the portfolio ready for the renewable generation variability and uncertainty?
2. What can be done to be prepared for the renewable generation?
3. What is the cost for this readiness?
4. Any changes are needed for the power market or portfolio operational procedure?
5. Can new market products improve the readiness?
6. Intra-hourly inter-BAA generation and capacity sharing?
7. All questions are leading toward a better solution – Energy Imbalance Market (EIM).

This article first reviews the uncertainty and variability of the renewable generation; then briefly describes the approach to prepare the system for the renewable generation; third, the EIM is presented for the ramp capacity sharing between the Balancing Authority Areas (BAA) to improve the system readiness for the greater renewable generation penetration.

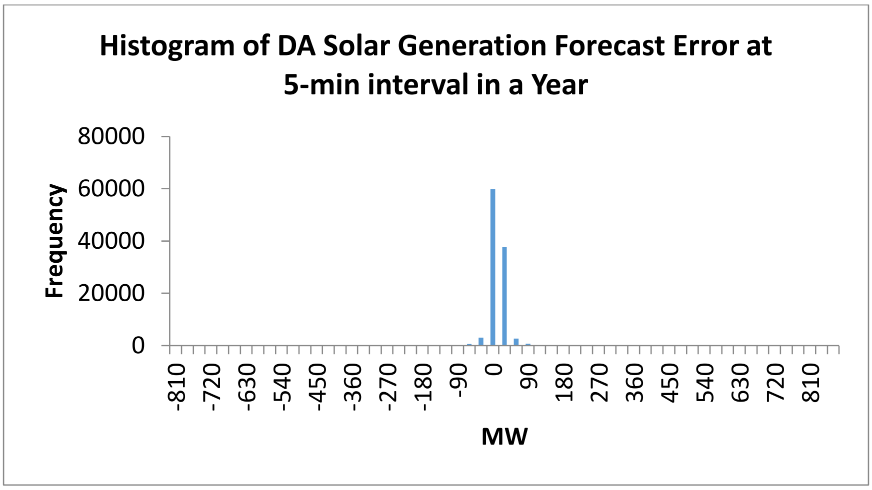
2. The Uncertainty and Variability of Renewable Generation

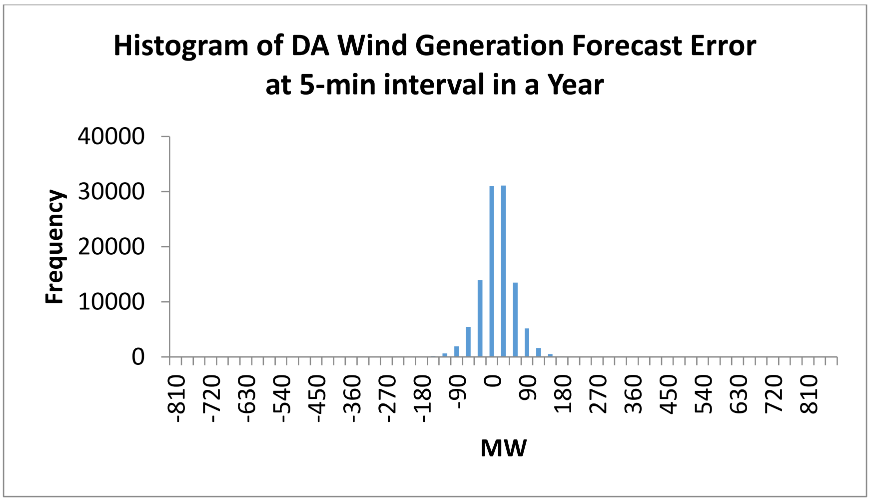
Here the renewable generation usually refers to the wind miller generation and solar generation. The following two tables shows the 5-min actual solar and wind generation and Day-ahead (DA) and Hour-ahead (HA) forecasts for a 130 MW solar project and a 220 MW wind project.





The following histograms shows the solar and wind generation forecast error distributions.





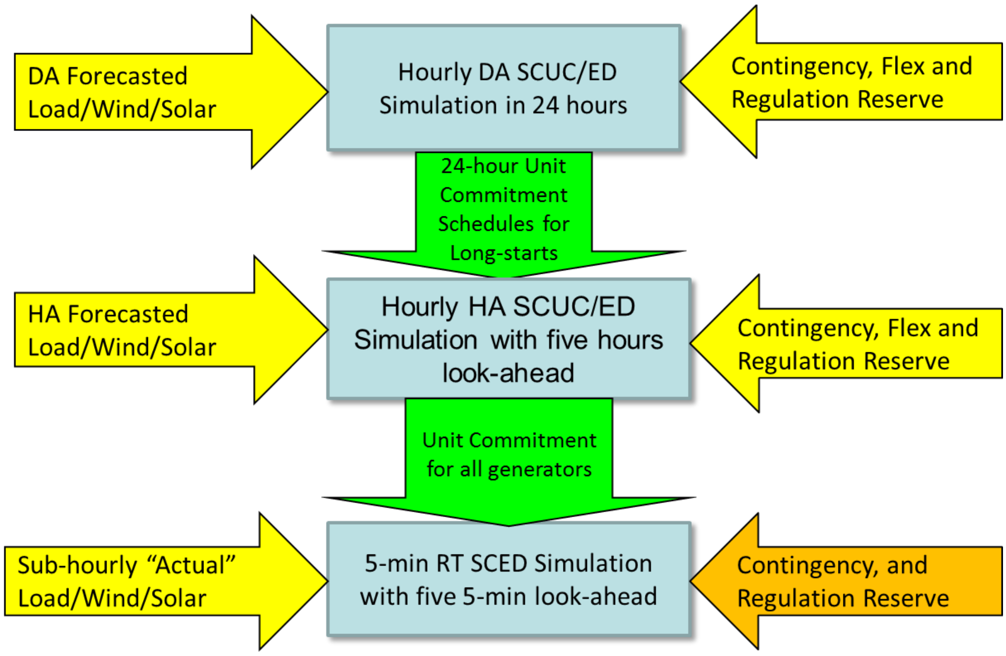
The DA and HA unit commitment will be performed based on the DA and HA solar and wind generation forecasts. Especially, the DA unit commitment may be quite off from the actual solar and wind generation.

3. What Can Be Done to Prepare For the Renewable Generation?

To cover the uncertainty and variability of the renewable generation, additional reserves can be introduced during the DA and HA unit commitment. The additional reserves are usually called "Flexibility Up" and "Flexibility Down" reserves. For the detail description of the reserves for the renewable generation, please refer the article[1].

The flexibility up and down reserve requirements are determined by the statistics of the renewable generation forecast errors. The flexibility up and down reserves are provided by the generator ramp capacity. However to quantify the system readiness is best through the sub-hourly simulations with the flexibility up and down deployment.

Energy Exemplar performs a few renewable generation integration studies using the 3-stage DA-HA-RT sequential simulation approach. This approach can be illustrated in the following flow-chart.



The 3-stage DA-HA-RT sequential simulation approach is described as follows.

- **PLEXOS DA simulation mimics the DA Security Constrained Unit Commitment and Economic Dispatch (SCUC/SCED)**
  - Day-ahead forecasted load/wind/solar generation time series are used;
  - Hourly simulation interval;
  - The SCUC/ED optimization window is one day plus a few hour look-ahead;
  - The transmission network is modeled at the zonal or nodal level;
  - The contingency, DA flexibility / regulation up and down reserves are modeled.
- **PLEXOS HA simulation mimics the intra-day or Hour-ahead SCUC/SCED**
  - 3-hour-ahead forecasted load/wind/solar generation time series are used;
  - Hourly simulation interval;
  - The SCUC/ED optimization window is a few hours plus a few hour look-ahead;
  - The transmission network is modeled at the zonal or nodal level;
  - The contingency, 3-HA flexibility / regulation up and down reserves are modeled;

[1] "Operating Reserves and Variable Generation" By Erik Ela, Michael Milligan, and Brendan Kirby, http://www.nrel.gov/docs/fy11osti/51978.pdf

    - The unit commitment patterns from the DA simulation for the long start up generators are frozen;
- **PLEXOS RT simulation mimics the 5-min real-time SCED**
    - The "actual" 5-min load/wind/solar generation time series are used;
    - 5-min simulation interval;
    - The SCUC/ED optimization window is a few 5 minutes plus a few 5-min look-ahead;
    - The transmission network is modeled at the zonal or nodal level;
    - The contingency and regulation up / down reserves are modeled. However, the flexibility up and down reserves are not modeled. The implication is that the capacity held in the 3-HA simulation for the flexibility reserves is deployed to cover the load and renewable generation variability and uncertainty at the 5-min interval;
    - The unit commitment patterns from the DA simulation for all generators, except the peaking generators, are frozen.

The solutions from the 5-min RT simulation will include the over-generation, un-served energy, contingency and regulation reserve shortfall. Usually the non-zero values of these indices indicate the system is not completely ready for the renewable generation or the inadequacy of the system ramp capacity. In addition, the 3-stage Da-HA-RT sequential simulation approach can be used to quantify the effectiveness of the system operation procedure evolution, new products, etc.

4. Energy Imbalance Market

One of the effective operation procedure is the Energy Imbalance Market (EIM). In a EIM, each BAA in the EIM performs the DA and HA Security Constrained Unit Commitment and Dispatch to minimize its production cost. However, at the sub-hourly level, the members of the EIM will provide the generation ramp capacity in a form of sub-hourly bidding quantity and price. The generation ramp capacity will cover the sub-hourly load and renewable generation uncertainty and variability in the EIM in an economic manner. Therefore, EIM allows the generation and flexibility and regulation reserve provision sharing at a sub-hourly interval to cover the renewable generation variability and uncertainty with the minimum cost. For the details of the EIM studies and VGS studies, please refer to the project reports [2],[3].

To evaluate the benefit of the EIM, the sub-hourly RT simulation in the 3-stage DA-HA-RT sequential simulation is performed twice: the Business As Usual (BAU) and EIM. In the sub-hourly RT simulation for the BAU case, the hourly interchange between the BAA's from the HA simulation are frozen to mimic the current BAA operation practice. In the sub-hourly RT simulation for the EIM case, the constraints of the hourly interchange between the BAA's is relaxed to allow the sub-hourly interchange among the members of the EIM. The produce cost difference of these two simulations is the benefit of the EIM.

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[2] "Examination of Potential Benefits of an Energy Imbalance Market in the Western Interconnection" by M. Milligan, K. Clark, J. King, B. Kirby, T. Guo and G. Liu, http://www.nrel.gov/docs/fy13osti/57115.pdf

[3] "Balancing Authority Cooperation Concepts to Reduce Variable Generation Integration Costs in the Western Interconnection: Intra-Hour Scheduling" by Matt Hunsaker, Nader Samaan, Michael Milligan, Tao Guo, Guangjuan Liu, Jacob Toolson, http://www.wecc.biz/committees/BOD/TEPPC/External/VGS_BalancingAuthorityCooperationConcepts_Intra-HourScheduling.pdf