Grid Impacts and Solutions of Renewables at High Penetration Levels

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Executive Summary

In 2002, California established its Renewable Portfolio Standard Program, with the goal of increasing the percentage of renewable energy in the state's electricity mix to 20% by 2017. On November 17, 2008, Governor Arnold Schwarzenegger signed Executive Order S-14-08 requiring that California utilities reach the 33% renewables goal by 2020. Achievement of a 33% by 2020 RPS would reduce generation from non-renewable resources by 11% in 2020. This is currently the most aggressive Renewable Energy Portfolio (RPS) standard proposed by any of the US states. Other state governments have similar, although at lower penetration levels, but also aggressive RPS allocations.

As electric utilities prepare to meet their state's renewable portfolio standard, for example 33% by 2020 in California, and to comply with Global Warming Solutions Act of 2006 (AB32), it becomes evident that US utilities must adapt its planning and operations in order to maintain the high levels of service and reliability. The state initiatives require integration of significantly higher levels of renewable energy, such as wind and solar, which exhibit intermittent generation patterns. Due to the geographic location of renewable resources the majority of the expected new renewable generation additions will be connected via one or two utility's transmission systems. This presents unique challenges to these utilities as the level of planned intermittent renewable generation in relation to their installed system capacity reaches unprecedented and disproportionate levels as compared to other utilities in the state.

Entities, such as CEC, NERC, CAISO, NYSERDA, SPP, CPUC, etc., have initiated and funded several studies on the integration of large levels of renewable energy and most of these studies concluded that with 10 - 15% intermitted renewable energy penetration levels, traditional planning and operational practices will be sufficient. However, once a utility exceeds the 20% penetration levels of renewable resources, it requires a dramatic change in planning and operational practices. These studies support continuing transmission and renewable integration planning studies, and recommend that demonstration projects installations should be conducted by the different power utilities.

The USA, and especially California, has a different set of electric system characteristics than in Europe, but there is no experience or research in Europe that would lead us to think that it is technically impossible to achieve 20% - 30 % intermitted penetration levels at most US utilities. Long transmission distances between generation resources and load centers characterize the network in the US and especially in the WECC region. There are areas now in Europe that are highly penetrated with intermittent renewable, especially wind generation, at levels of around 30 – 40%.

Large scale wind and solar generation will affect the physical operation of the grid. The areas of focus include frequency regulation, load profile following and broader power balancing. The variability of wind and solar regimes across resource areas, the lack of correlation between wind and solar generation volatility and load volatility, and the size and location of the wind plants relative to the system in most US states suggest that impacts on regulation and load profile requirements resource smoothing will be large at above 20% penetration levels.

The European experience taught us that there are consequences of integrating these levels of wind resources on network stability that have to be addressed as wind resources reach substantial levels of penetration. A list of the major issue categories follows:

- New and in-depth focus on system planning. Steady-state and dynamic considerations are crucial.
- Accurate resource and load forecasting becomes highly valuable and important.
- Voltage support. Managing reactive power compensation is critical to grid stability. This also includes dynamic reactive power requirements of intermittent resources.
- Evolving operating and power balancing requirements. Sensitivity to existing generator ramp-rates to balance large scale wind and solar generation, providing regulation and minimizing start-stop operations for load following generators.
- Increased requirements on ancillary services. Faster ramp rates and a larger percentage of regulation services will be required which can be supplied by responsive storage facilities.
- Equipment selection. Variable Speed Generation (VSG) turbines and advanced solar inverters have the added advantage of independent regulation of active and reactive power. This technology is essential for large-scale renewable generation.
- Strong interconnections. Several large energy pump-storage plants are available in Switzerland that is used for balancing power. Larger regional control areas make this possible.

Technical renewable integration issues should not delay efforts to reach the renewable integration goals. However, focus has increased on planning and research to understand the needs of the system, for example, research on energy storage options.

Studies and actual operating experience indicate that it is easier to integrate wind and solar energy into a power system where other generators are available to provide balancing power and precise load-following capabilities. The greater the number of wind turbines and solar farms operating in a given area, the less their aggregate production is variable. High penetration of intermittent resources (greater than 20% of generation meeting load) affects the network in the following ways:

- Thermal and contingency analysis
- Short circuit
- Transient and voltage stability
- Electromagnetic transients
- Protection
- Power leveling and energy balancing
- Power Quality

The largest barrier to renewable integration in the USA is sufficient transmission facilities and associated cost-allocation in the region to access the renewable resources and connecting these resources to load centers. Other key barriers include environmental pressure and technical interconnection issues such as forecasting, dispatchability, low capacity factors and intermittency impacts on the regulation services of renewable resources.

In the US, the sources of the major renewable resources are remote from the load centers in California and the Midwest states. This results in the need for addition of new major transmission facilities across the country. Wind and solar renewable energy resources normally have Capacity Factors between 20 – 35%, compared to higher than 90% with traditional nuclear and coal generation. These low capacity factors place an even higher burden on an already scarce transmission capacity. Identification, permitting, cost-allocation, approval, coordination with other stakeholders, engineering and construction of these new transmission facilities are major barriers, costly and time consuming.

There are numerous environmental issues associated with renewable integration. In addition to the environmental issues associated with transmission line construction, there are the impacts to birds from

Although energy production using renewable resources is pollution free, wind and solar plants need to be balanced with fast ramping regulation services like peaker generator or hydro generation plants. Existing regulation generation is too slow and is polluting much more during ramping regulation service. The increased requirements in regulation services counteract the emissions savings from these renewable resources. Currently the frequency regulation requirement at the CAISO is around 1% of peak load dispatch, or about 350 MW. This is currently mainly supplied by peaker generating plants and result in higher emission levels. It has been calculated that around 2% regulation would be required for integrating 20% wind and solar resources by 2010 and 4% to integrate 33% renewables by 2020.

With the integration of wind and solar generation the output of fossil fuel-plant needs to be adjusted frequently, to cope with fluctuations in output. Some power stations will be operated below their maximum output to facilitate this, and extra system balancing reserves will be needed. Efficiency may be reduced as a result with an adverse effect on the emissions. At high penetrations (above 20%) wind and solar energy may need to be 'spilled' or curtailed because the grid cannot always utilize the excess energy.

To integrate high penetration levels like 33% intermittent renewable resources by 2020 in California, several planning and operational solutions should be followed. There is no silver bullet but requires a combined effort on three major levels:

- Generation mix to utilize different complementary resources.
- Advanced transmission facilities, including fast responsive energy storage, FACTS, HVDC, WAMPAC, etc.
- Demand response, including distributed resources on the distribution feeders, distributed energy storage, SmartGrid, Plug-in Hybrid Vehicles (PHEV), Demand Side Management (DSM), etc.

The purpose of increased transmission planning is to identify complete and preferred transmission plans and facilities to integrate these high levels of renewables. The clear goal would be develop a staged transmission expansion plan, facilities and storage options to integrate this potential level renewable penetration levels.

Most of the models for these advanced wind and solar facilities have not been fully developed yet and need to be validated. The generator models for wind and solar generation technologies need to be upgraded and validated to include short circuit models, dynamic variance models like clouding and short-term wind fluctuations.

The European experience with high levels of intermittent resources up to 80% penetration levels does not transfer fully due to the difference in US grid design and load density. The integration of renewable energy at this scale will have significant impact, especially if the addition of energy storage devices (central and distributed) and FACTS devices utilized to counterbalance the influence of the intermittent generation sources. Utilities and ISOs in the US should conduct RD&D projects and commence studies to fulfill its obligation to accurately and reliably forecast the impacts on future system integrated resource planning. Due to the long lead time for some of the proposed technology solutions, it is recommended that utilities engage these challenges sooner versus later. If technical challenges manifest, a timely solution cannot be implemented if studies, demonstration installations and field tests still have to be conducted. Additionally, utilities should study all conceivable options that may severely affect transmission system integrity and stability. Otherwise, utilities may experience unintended consequences due to unforeseen technical issues resulting from high penetrations of new renewable energy sources.