Successful Grid Integration of Renewable Energy:Integration is the Name of the Game

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The Issues: Power market and system operators have increasingly to cope with extreme conditions

Renewable energy (RE) power generation is increasing rapidly around the world, and this trend is expected to continue at an accelerated pace. In 2012, the number of PV megawatts (MW) installed increased, from 28.8GW the previous year, to 30.5GW. The wind capacity installed in 2012 hit a record of 48.4GW, up from 42.1GW in 2011 . However, effectively integrating a higher share of RE into power systems remains a difficult problem for system operators, regulators and policy makers.

RE, and in particular wind and solar, are characterised by a high degree of variability and intermittency, and their availability cannot be forecast with certainty. That makes the task of system operators increasingly complex. System operators (or grid operators) are the entities who ensure that electricity is delivered to all consumers reliably when they need it, at the lowest possible cost. They have to balance power systems on a real time basis, ensuring that supply covers demand 24 hours a day, 7 days a week, 365 days a year, even in the presence of unexpected outages or unavailable capacity because of clouds or lack of wind. That task is particularly difficult in the presence of a high level of unpredictable RE supply.

Moreover, a high proportion of RE is often linked to an increase in distributed generation, as many RE power generation capacity additions are in small sizes (rural electrification, residential roof-top solar panels, etc.). Small residential and commercial RE generators can turn into consumers drawing supply from the grid when a cloud prevents solar generation or wind stops blowing. Managing the load in real time is a difficult task, but is crucial to maintain system reliability.

The growing penetration of intermittent supply of electricity and of distributed generation requires stronger networks, better management of interrelated generation and transmission assets and the large scale development of smart grids.

Key system operation issues in the presence of a high level of RE are: supply variability, supply and demand uncertainty, balancing, stability, adequacy, net load, etc…When wind was first introduced on a large scale in the 1990s, those issues were addressed by increasing the amount of reserve capacity. It was usual to plan the addition of 1MW of fast ramping capacity (combustion turbine) for each MW of wind installed. But that was costly and impeded large scale RE deployment in the absence of strong incentives. Nowadays better techniques are developing to increase the flexibility of the power systems and their ability to cope with intermittency and reliability.

A flexible electricity system is one that can respond reliably and rapidly to sudden changes and fluctuations in demand and supply, due to scheduled or unforeseen variations. System flexibility is essential when integrating a high degree of RE into the power system because of the variability and low predictability in renewable availability. Flexibility of a power system can be increased in several ways:

- Addition of flexible fast ramping capacity
- Diversification of the capacity mix
- Storage
- Congestion management that provides better access to flexible generation assets
- Regional integration and the development of cross-border transmission capacity
- Demand-side management (DSM), that allows better management of load to contribute to system balancing.

However, large scale development of RE have pushed conventional thermal power plants, that can act as back-up reserve, up the merit order curve, and reduced their profitability. Many of these plants in high RE markets such as Spain or Germany are now earmarked for shut-down. To keep them on standby, thereby improving system flexibility, those plants should be remunerated appropriately (for instance through a capacity mechanism), to prevent them from shutting down. Market design, policy and regulation., therefore, all have a key role to play in ensuring power system flexibility and reliability in presence of a high share of RE.

From an operational point of view, the ability to cope with intermittency improves when the quality of RE availability forecasts improves. A better knowledge of availability to the grid (or load requirements for distributed generation) helps system operators in their task of system balancing and provision of reliable supply. All operators in markets with a high RE penetration are developing better weather and solar/wind

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forecasting tools and improved real-time decision support tools.

The Solutions: Integration of short-term and long-term, of planning and operations, of generation and transmission and of national markets into regional power pools

As discussed above, a high level of RE penetration makes the task of the power system operator more complex. The system operator needs to integrate several dimensions into its planning and operational activities, coordinating information on physical assets, operation of the power system, information on availability and status of every producer and consumer and economics of the generation and transmission assets.

Coping efficiently and at least cost with RE integration can be done through the integration of several dimensions of power system planning and operations:

i. Integration of planning and operating decisions: long-term capacity expansion planning models used to be run separately from dispatch models. To minimise the need for reserves, capacity expansion models need to take into account the stochastic nature of RE and the ability of the system to address intermittency without necessarily relying on large back-up reserves. This will lower the system cost of RE integration.
ii. Integration of short-term and long-term decisions and processes: besides integration of planning and dispatch models as discussed above, system operators should use consistent information and forecasting tools for short-term and long-term decisions. If operators have access to better forecasting tools, then they will have a better ability to predict availability, therefore, reducing the need for expensive back-up capacity. Ability to handle intermittency in operational decisions need to be incorporated in planning models that decide on reserve needs. Integration of weather forecasts and RE availability into operational and planning tools is critical to RE integration at least cost.
iii. Integration of power generation and transmission: capacity expansion planning and transmission planning used to be separate tasks. Given that flexibility of a power system can be improved by calling on generators in a different balancing area, using transmission infrastructure to wheel power, generation and transmission need to be integrated both in planning and operational decisions. This task is being made more difficult with unbundling and multiplication of players following market liberalisation.
iv. Integration of national markets into regional power markets: regional integration facilitates a high degree of RE penetration, as larger power systems have more "flexibility" than small isolated systems. Merging balancing areas improves flexibility and reliability through geographical spread (wind less likely to be absent simultaneously in geographical distant areas), generation portfolio diversification, sharing of flexible generation assets and sharing of back-up reserves.
v. Integration of policy making, regulation and utility decision-making: power markets should be designed to remunerate stand-by capacity that can ramp up rapidly in case of lack of RE availability, support frequent rescheduling/redispatching, encourage effective transmission congestion management and promote the development of an ancillary services market. Incentive schemes for RE have to reflect the real service they provide, as not all RE capacity supply firm power. Most FiT schemes based on LCOE do not reflect the intermittency and lack of reliability of RE. Finally regulation should be harmonised between interconnected national markets—to create well-functioning regional markets—to encourage reserve sharing, transmission stability and the development of regional markets for ancillary services. An adequate framework of governance is essential to support market coupling, with robust contractual agreements between grid operators and power exchanges/market operators.

Conclusions: A difficult task made possible by better decision support tools

The task of balancing power system in real time in the presence of high RE penetration is complex but made possible thanks to improved algorithms, models, software and decision support tools. System operators are developing comprehensive data bases on RE characteristics, RE availability forecasting models, sophisticated dynamic stochastic models integrating capacity expansion planning and dispatch and multi-nodal (including across countries) models for dispatch, transmission planning and congestion management.

Success also requires coordination of all relevant players, from governments to regulators to operators and a good governance framework, with robust contractual agreements.