Innovative Business Models to Meet Grid Challenges – BIEE Conference

I. Introduction

At the tail end of 2015, National Grid released its System Operability Framework (SOF) detailing how the Future Energy Scenarios (FES) could impact the energy system and the operability challenges foreseen. Currently, the mainland UK grid is under considerable stress as the margin between supply and demand continues to narrow (National Grid, 2015). However, the situation will only worsen with the planned closure of coal power stations, the forecasted increase of distributed generation, the evolving roles of energy market players, the lack of transparent and consistent energy policy, political uncertainty and the unpredictable outcome of on-going regulatory reviews.

According to National Grid's SOF, within 5 years the primary frequency response requirement is expected to increase by up to 40% and by 2030 the overall response requirement will be up by a factor of 4 by today's level (National Grid, 2015). National Grid has highlighted the implications of this by clearly stating that unless alternative business models are implemented, by 2035 providers will not be able to meet requirements as listed by any of the FES (National Grid, 2015).

The various type of grid challenges that the UK power grid is facing are of different nature but they are all driven by the fact that the generation mix is changing with a relevant impact on the system's inertia, a substantial increase in embedded generation and also a change in the demand profile. All these changes represent new performance requirements and new operational challenges that create new opportunities and need new solutions (National Grid, 2015).

There are various business models that can help meet these grid challenges and facilitate the transition to a lower carbon energy future. These different business models are discussed in this paper.

II. Overview of Current System Changes

In this section, the key challenges facing the mainland UK energy system will be explored and their impacts delineated.

A) Closure of Coal Power Stations

When Amber Rudd, former Secretary of State for Energy and Climate Change, unveiled the previous government's energy strategy in November 2015, she committed to shutting down all coal power stations by 2025 (Gosden, 2015). This was a fundamentally important pledge from government that indicated a support for lower carbon energy alternatives.

The eventual closure of traditional fossil fuel power stations has the potential to create a host of technical issues, including a reactive to active power imbalance on the grid as the number of generation assets with rotating shafts impacts system inertia and therefore frequency (National Grid, 2015).

Coal power stations, in addition to gas fired power stations, are currently responsible for supplying the vast majority of UK energy system flexibility. This flexibility is utilised when there is an unexpected increased or decrease in demand, generators are called upon to adjust their supply accordingly. With the closure of traditional power plants, it is vital that flexibility is extracted from lower carbon generation assets and demand customers.

B) Increase in Distributed and Renewable Generation

The growth of embedded generation over the last decade was unprecedented and further growth is forecast (Reuters, 2016) (DECC, 2013). The main embedded generation asset type National Grid has identified as a challenge is solar, specifically the large amount of PV panels expected to be installed in the south of England (National Grid, 2015).

The massive uptake in renewables can already be felt, with solar having produced more power than coal in May and July this year (Evans, 2016). These would place increased strain on the local network and would also require grid reinforcement as there currently isn't sufficient capacity or infrastructure, to transport the anticipated future supply from Scotland, where the majority of wind power is produced, to the south where demand is forecast to be highest (National Grid, 2015).

This transition to more embedded and renewable generation has also a relevant impact on system inertia and active to reactive power ratio as the majority of this new generation is non-synchronous. Currently, there are 3.5 GW of running non-synchronous generation in Scotland, 2.5GW in the South West and 3.2GW in the South East.

C) Evolving Roles of Energy Market Players

In order to transition to a green energy future, the roles of the various energy market players will need to adapt to meet the growingly complex system requirements. Perhaps the most notable, and most necessary, of these role changes will be the evolution of Distribution Network Operator (DNO) to Distribution System Operator (DSO), being responsible for frequency management and running balancing mechanisms on their own networks. This will allow them to better manage local constraints that would otherwise have a knock on effect on the transmission grid.

The DNOs will need to collaborate and work closely with National Grid to improve communications and data sharing. The increase in distributed generation will lead to the need of actively managing their networks. With better visibility and control over generators the capacity of the network can be maximised and network reinforcement can be deferred. New opportunities and business models will also arise from this new role of the DNOs.

III. Grid challenges and operability areas:

The continuously evolving generation mix, the closure of some coal power plants together with a strong penetration of distributed generation, will lead the UK power grid to face important technological challenges that will impact the way National Grid and the DNOs operate the grid to maintain it reliable and stable.

The most important operability areas where National Grid will need to invest resources are (National Grid, 2015):

RoCoF management:
System Inertia continues to decline because of the lack of synchronous thermal power stations and high volume of converter connected generation technologies such as solar PV, wind and import across our High Voltage Direct Current (HVDC) interconnectors. This decline impacts RoCoF relays, so there is a need to expedite the relay setting update programme to avoid increasing operational costs in coming years.

Frequency management:
Managing the system frequency is still one of the key areas due to the reduced inertia in the system. The frequency response requirement will increase by 30-40% in the next five years.

Voltage management:
Voltage containment has been challenging for a number of years and the studies show a significant increase in need for additional reactive compensation over the next twenty years.

Protection System Effectiveness:
Short circuit levels continue to reduce at periods of minimum demand. This minimum fault level has always had importance to protection design and operation. Also, decommissioning of large synchronous plants together with the rapid growth in embedded generation highlights the need for additional Fault Ride Through requirement.

System restoration capability:
The system restoration capability represents a grid challenge because the studies show a trend towards the unavailability of generation capable of black-starting the system.

Low Frequency Demand Disconnection:
To maintain the stability of the transmission system, new capabilities are required and both TSOs and DNOs must work more closely to address these issues given that a number of solutions require coordination of services between transmission and distribution networks. Another key highlight of this year's analysis is the need for review of Low Frequency Demand Disconnection (LFDD) relays which are affected by an increase in embedded generation.

Commutation of HVDC Links:
High voltage direct current interconnectors can also help in supplying extra dynamic voltage support.

IV. New strategic services

It is essential that new system services are developed to access existing enhanced capabilities from generation (particularly wind farms, solar and interconnector technologies) whilst facilitating the provision of new capabilities. Transmission and distribution companies must continue to look at the whole-system impact of new technologies and greater access to services from demand side. In this context, the viability of accessing multiple services through different operator models across the whole system and layering of services should be considered from both technical and commercial perspectives. The value of system services, in particular flexibility, should be considered by the manufacturers and developers of new plants, and form the basis of revenue streams which ensure new developments incorporate the system needs in their design. For example, the more flexible operation of new nuclear, gas and other synchronous plant is likely to be of much greater value going forwards (National Grid, 2015)

The type of services that will be needed in the coming years could be grouped in the following categories:

1) Demand side services:
   Demand response services could help in RoCoF management, frequency management and low frequency demand disconnection
2) Energy storage:
   Active management of energy storage assets could help the grid in RoCoF management, Frequency management, voltage management, system restoration capability, and low frequency demand disconnection.
3) Flexible synchronous generation:
   Integration of flexible synchronous generation could help in multiple areas such as RoCoF and frequency management, voltage management, protection systems, and in commutation of HVDC links.
4) Flexible non-synchronous generation:
   Non-synchronous sources will help in RoCoF and frequency management.
5) Interconnector services:
   Enhanced interconnector services could enhance the operability of the grid in multiple areas, such RoCoF, frequency and voltage management, together with Low Frequency Demand disconnection and system restoration capabilities.
6) Synchronous compensator:
   Integration of synchronous compensator will help in the same areas as the flexible synchronous generation.

7) Support from Embedded generation

   Embedded generation, when properly managed, could help in frequency and voltage management.

8) Distribution system operators services

   DNO's should provide services that help the overall grid in frequency and voltage management and also in system restoration capabilities.

V. Business Models

As it has been described in the previous section, there are various business models that can be implemented to aid the transition to a smarter energy system and solve some of the existent and future grid challenges. We discuss below some of the most relevant ones:

A) Flexible Renewable Connections

Flexible connections allow distributed generators to connect to the distribution network on the basis that their generation can be curtailed by the DNO based on network constraints, the parameters of which are agreed at the time of contract signing (UK Power Networks, 2015). The distributed generators can be notified/curtailed via automated systems or by manual dispatch systems. The technological challenge is the integration of the automated trigger system with the inverter. In the majority of the situations these renewable connections only need local control and do not need any sort of remote dispatch.

Flexible connections provide developers with an upfront CAPEX saving on their connection cost and speed of connection in areas of network congestion in return for having their generation curtailed.

The Low Carbon Networks Funded Flexible Plug and Play project led by UK Power Networks pioneered flexible connections through innovative commercial arrangements in mainland Great Britain (UK Power Networks, 2015). This pilot project integrated a total of 54.4MW across wind, Photovoltaic (PV), Anaerobic Digestion (AD) and Combined Heat and Power (CHP) (UK Power Networks, 2015).

This business model allows to speed up connection agreements and also can reduce their costs. A certain layer of Active Network Management needs to be implemented by the DNO but no major technical challenge needs to be implemented on the Distributed Generation side since the control of the asset is local. Also, since it is not a fully integrated solution without centralised control, this solution only helps the grid in voltage management.

B) Reactive power support

DNOs are currently offering trial projects to provide reactive power and voltage support in specific areas of the network. These type of projects are more generic than the ones that target only flexible non-synchronous renewable connections, because they can increase and decrease generation, generation and also modulate the amount of reactive power that is spilled onto the grid. Low or high voltage pockets are usually linked to poor or lack of reactive power control, therefore, projects that are specifically designed to monitor reactive power are more effective.

For instance, specifically in the UK, there are an increasing number of network constraints in the South East that are limiting the existent and future connections. In this part of the country is where the penetration of PV panels is the largest, which impacts strongly on the active / reactive power ratio. Resolving these constraints traditionally involves constraint management or reinforcements of the network. Distributed Energy Resources could be used to economically resolve local constraints and allow further connections.

This solution requires the Distributed Energy Resource to be called on in real-time and to be reliable. This implies hardware and control software installation in every resource and it requires constant monitoring via automated systems that would respond to trigger signals. Its deployment needs of a coordinated approach between the System Operator, the DNOs and the owner of the Distributed Assets.

This business model allows using the full flexibility of the Distributed Energy resources to increase, decrease their active and reactive output. The limitations are that only assets that have controllable power factor output can be used. Since the solution is designed to solve a local effect, the solutions are designed to respond only locally; therefore no centralised control is needed. However, this limits the scalability of this solution, because an extra layer of Active Network Management needs to be implemented to control all local assets. At the same time, this business model is only implementable in regions where there is risk of reactive power imbalance, which limits also the scalability of the project.

C) Virtual Power Plant

Virtual Power Plants (VPPs) help smooth peak demand, frequency and RoCoF management, voltage and reactive power management, system restoration capabilities, low frequency demand disconnection and defer network reinforcement by harnessing the inherent flexibility of various types of assets connected to the distribution network and can also help in addressing local but also global effects (Gallucci, 2016). They represent a very generic and flexible approach to aggregate several types of assets and combine them accordingly to deliver different services. They represent an ideal optimization platform for the coming transformation of the power grid (Bayar, 2013).

Supported by cloud-based software, monitoring and automation equipment and an optimisation engine, VPPs are able to extract flexibility out of small - scale generators and demand customers, allowing them to respond to varying amounts of renewable supply on the system whilst being compensated for doing so, respond to frequency deviations, modulate the reactive power output in certain regions, manage demand response and react to low frequency by disconnecting demand or increasing generation. VPPs are capable of producing aggregated effects because they are built with centralised control on top of the local control layer. This benefits grid operators as they are able to delay, or completely avoid, costly and carbon intensive grid reinforcement by unlocking existing capacity and also avoid the implementation of an Acitive Network Management Layer. VPPs, although excellent at correcting short-term demand variations, are unable to fully correct seasonal demand variations. For fully seasonal demand corrections, coordination of demand peak shaving techniques with large grid scale generators with relevant ramp up and ramp down capabilities needs to be implemented.

There is immense value in implementing VPPs in areas of high-embedded generation density. VPPs are a proven business model already implemented in various countries, including Germany and the USA. German utility pioneer RWE started operating VPPs in 2012 that now has over 2 GW of capacity across the German RWE group.

They represent a more cost effective approach to solve grid challenges because with one single tool that has coordination capabilities with centralised control, one can solve multiple grid problems with one single infrastructure. Initial development and implementation has larger costs but it represents a scalable, flexible and multipurpose solution.

VI. Conclusion

The substantial UK energy system challenges described in this paper, namely the planned closure of coal power stations, the forecasted increase of distributed generation, the need for the evolution of energy market players can be surmounted through the implementation of VPPs.

VPPs allow for excess capacity and demand flexibility to be extracted from the distribution network and harnessed for grid benefit. By leveraging existing assets on the distribution network, VPPs can help bridge the supply gap left by the closure of traditional, carbon intensive coal power plants, without the need of building large power plants but aggregating assets to behave like one, whilst providing other extra services.

VPPs can absorb increased distributed generation on the system whilst mitigating technical issues, such as voltage vacillations and lack of inertia, by helping maintain distribution network operators and the transmission system operator balance frequency and allowing them to either defer, or completely avoid, costly and carbon intensive reinforcement. Also, Virtual Power Plants provide distributed generators and businesses with new revenue streams that reinforce their business cases.

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