Benefits of Interconnectors to GB Transmission System

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Executive Summary

The aim of this paper is to provide an overview of the range of ancillary services which interconnectors can facilitate and the potential benefits associated with such services for the end consumer.

To meet carbon reduction targets, the UK needs to introduce significant volumes of low-carbon generation, such as photovoltaic (PV) panels and wind-driven turbines, to replace conventional generation that relies on burning coal and gas. Interconnectors will also play a significant role in meeting the carbon reduction targets. The European Commission set a target of having interconnection capacity of a minimum of 10% of generation capacity by 2020 and proposals to increase this to 15% by 2030. The annual UK Future Energy Scenarios (FES)[1] published by National Grid is designed to provide a credible analysis of energy scenarios up to 2036. The key changes for the electricity sector are expected to be in the way electricity is generated as mentioned above and how it is consumed.

The dynamic operation of the transmission system is largely dependent on the type of generation connected to it, as well as the nature of demand on it. Some of the key impacts of these changes to the system as reported by the System Operability Framework (SOF)[2] are:

- A reduction in system inertia and system strength;
- A greater variability of power flows; and
- The ability to restore the system following a potential blackout.

The ability to deal with the impact of these changes is dependent on the range of products and services available to the National Electricity Transmission System Operator (NETSO). Our analysis as part of the SOF shows that the GB power system requires new tools for managing these changes in order to ensure economic, efficient and coordinated system operation.

The GB electricity system is classed as an islanded power system with few links (known as interconnection) to other power systems.

The GB system currently has around 4GW of interconnection:

- Ireland (Moyle and East-West; 1GW in total)
- France (IFA link; 2GW)
- Netherlands (BritNed; 1GW)

These links are currently operating as merchant interconnectors and provide the capability for import/export of energy to different systems. Traditionally interconnectors have been primarily intended to provide capacity for energy flows between different synchronous areas. Interconnectors currently provide a range of services to the System Operator (SO) bespoke to each interconnector such as cross-border balancing and day ahead market trading.

[1] http://www2.nationalgrid.com/uk/industry-information/future-of-energy/future-energy-scenarios/
[2] http://www2.nationalgrid.com/uk/industry-information/future-of-energy/System-Operability-Framework

The technology used in the design of existing, and future interconnectors could allow for the provision of some of the new services which are required for future system operability. The services that could be provided by interconnectors include:

- Frequency response and reserve;
- Black start;
- Reactive power reserve;

Boundary capability and constraint management are other potential benefits from interconnectors and any benefit is considered in each interconnector's respective CION document.

These benefits are largely dependent on the system conditions, the need for the service in the proximity of the connection point of the interconnector, the technology used by the interconnector, and the arrangements which are in place with the other end of the interconnector to acquire such services.

The European electricity market is described in Section 7, together with the impact that this market may have on the potential benefits from interconnectors. The European network codes will determine how interconnected markets and ancillary services will operate which could affect the realisation of benefits from interconnectors.

Scope of the paper

This paper has been produced at the request of Ofgem to provide an overview of the range of services which interconnectors can facilitate and the range of potential benefits to the end consumer. This paper is an update on the December 2014 paper. For further information relating to concepts within this paper the reader is directed to the System Operability Framework.

This paper focuses on potential consumer benefits and does not consider how developers could extract value in delivering these benefits. It should also be recognised that further discussions are required with the adjacent TSO to ensure that neighbouring networks can support the provisions of services described.

1. Introduction

A fully operable power system requires real time control on how electricity is generated, transmitted and supplied. In order to deal with the variable nature of electricity demand, and to ensure security of supply, a number of measures known as “balancing activities” are performed by the NETSO. These activities are intended for either ensuring continuous balance between total power generated and consumed i.e. system frequency, or for the purpose of ensuring the system performance criteria (i.e., voltage, thermal) are met.

Interconnectors provide an opportunity for the NETSO to access some of these services (depending on the technology used) from other European transmission systems. They similarly provide the opportunity for GB market participants to offer such service into other European markets.

Existing interconnectors, predominately due to technology choices available at time of development, are currently facilitating limited service to the National Electricity System (NETS), whereas, new interconnectors, are capable of facilitating all of the above services depending on the developers design choices. Given that interconnectors provide access to a wider pool of generation, competition for the provision of these services is increased.

The following sections will review these potential benefits, explore (at a high level) future system requirements, and discuss how interconnectors can help facilitate the provision of these services.

For further information relating to the system operability challenges and specific benefits of interconnectors the reader is directed to the 2015 System Operability Framework[2], where possible direct references are included within this document.

2. Technology overview of Interconnectors

Two power systems can be connected via either High Voltage Alternating Current (HVAC) or High Voltage Direct Current (HVDC) links. Examples of AC links are the overhead transmission lines and cables across the NETS. In Europe, most countries are connected via AC links given the relatively short distance between the connection points and operating at the same system frequency, which make AC connection viable.

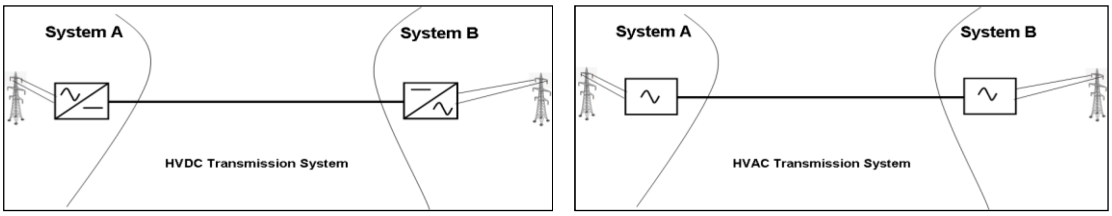

Figure 1: HVDC and HVAC Transmission Systems

The HVDC option, however is often used when there is significant distance between countries (or if they have different nominal frequencies). In the case of interconnection between GB and other countries, because of relatively long distance between the countries, all existing interconnectors are based on HVDC technology. Connecting two systems via HVDC links not only enables flow of energy between the two systems, but also decouples the two systems providing many benefits such as eliminating the effect of disturbances happening at one end from propagating to the other. The technology used in HVDC links also allows various services such as fast power ramp up/ramp down, voltage control, and black start, which can be provided at a small incremental cost, due to the inherent nature of certain types of HVDC technology.

HVDC links are based on either Current Source Converter (CSC), or Voltage Source Converter (VSC) technology. The latter (being a more recent technology) is also capable of operating within weaker systems, and is less susceptible to disturbances. VSC technology is also more capable of facilitating the delivery of ancillary services which will be explained further later in this paper.

3. Frequency Response & Reserve Service from Interconnectors

3.1 Definition of Service (SOF^2 Section 4.4)

System frequency is a continuously changing variable that is determined and controlled by the second-by-second (real time) balance between system demand and total generation. If demand is greater than generation, the frequency falls while if generation is greater than demand, the frequency rises.

National Grid has a licence obligation to control frequency within the limits specified in the 'Electricity Supply Regulations', i.e. ±1% of nominal system frequency (50.00Hz) save in abnormal or exceptional circumstances. National Grid must therefore ensure that sufficient generation and / or demand is held in automatic readiness to manage all credible circumstances that might result in frequency variations.

There are two types of Frequency Response Dynamic and Non Dynamic Response. Dynamic Frequency Response is a continuously provided service used to manage the normal second by second changes on the system. While Non Dynamic Frequency Response is usually a discrete service triggered at a defined frequency deviation.

Non-dynamic response is often termed as reserve and is used were National Grid needs access to sources of extra power in the form of either generation or demand reduction, to be able to deal with unforeseen demand increase and/or generation unavailability. These additional power sources available to National Grid are referred to as Reserve and comprise synchronised and non-synchronised sources. Different sources require different timescales in order to be ready to deliver the services

There are a variety of sources, which require different timescales to be ready to deliver the services. By having a range of variety of sources it will facilitate the determination of the optimum system performance and increase competition to allow these services to be delivered at the minimum cost to the end consumer.

3.2 Future Challenges (SOF^2 Section 4.4.2)

Future changes in the energy mix, such as increasing renewable generation capacity (in particular wind power and larger generators such as the proposed new nuclear plants) will drive the need for additional reserve and frequency response to cater for the variability and intermittency of generation sources. The 2015 SOF shows a 3 - 4 times increase in the amount of frequency response required by 2030. It is therefore important for the SO to access additional tools and services to manage system frequency so as to minimise operating costs.

3.3 Potential Benefits of Interconnectors (SOF^2 Section 8.3.6)

Interconnectors can provide both frequency response and reserve. Depending on the technology employed they have a key advantage of being able to rapidly change their power output (Import/Export) across their full operating range, subject to the operating conditions at both ends of the interconnector.

The key benefits from interconnectors providing frequency response and reserve is summarised below:

- Contribution to frequency response: interconnectors provide high speed delivery of response which allows active power to be rapidly delivered or taken from the system to provide frequency response.

- Potential reduction in reserve costs: By allowing the sharing of reserve, and SO to SO trade, interconnectors can reduce long-term capacity requirements and potentially reduce costs for holding system reserve. This is possible as interconnectors can facilitate pooling of reserve resources on a European basis rather than providing the entire service purely from GB.

In order to evaluate the benefit to the end consumer by providing frequency response, we will undertake quantitative analysis to assess the future frequency response requirements which can be offset by the fast response provided by the interconnectors against the FES.

4. Black Start Capability

4.1 Definition of Service (SOF[2] Section 5.8)

Black Start is the procedure to recover from a total or partial shutdown of the GB Transmission System which has caused an extensive loss of supplies. This entails isolated power stations being started individually and gradually being reconnected to each other in order to form an interconnected system again.

In the event of a Black Start situation, the service requires the provider to start up its main generator(s) in order to power up sections of the National Transmission System and distribution network. This service would be initiated under the instruction of National Grid and proceeds under the general guidance of a site specific restoration plan.

The Black Start generator may also be required to provide start up supplies to other power stations as the system restoration progresses and will eventually be required to connect to other power islands.

4.2 Future Challenges (SOF[2] Section 5.8.2)

Restoration services or Black Start capability are currently contracted from an array of strategically located thermal, hydro and pumped storage stations at specific locations, which are capable of re-energising the system. The future generation mix is expected to be dominated by non-synchronous generation which is unlikely to contribute to Black Start. For Synchronous plant, UK nuclear plants have not traditionally been able (technically or from a safety perspective) to support emergency restoration. The reliability of CCGT and coal for emergency restoration tends to be inversely proportional to the time since warmed, and the potential availability of even "cold" synchronous reserves is set to decline to a few modern plant units.

Current system restoration methods have been designed to deal with a total system black out rather than partial, regional black outs as experienced in the past. As system strength and the number of Black Start providers decline, the restoration strategy must be adjusted. Otherwise, re-starting the system becomes dependent on a very small proportion of generation remote from the load, leading to weaker power islands, which are more prone to voltage deviation and a requirement for more reactive power support locally.

SOF 2015 shows a reduction in traditional black start plant over the next 15 years, this will naturally increase costs. Interconnectors could potentially decrease these costs as no additional plant is required for delivering this service (for example installing an auxiliary gas turbine when contracting with a CCGT). Interconnectors will also provide supply diversity to provide additional system security.

4.3 Potential Benefits of Interconnectors (SOF[2] Section 8.3.6)

HVDC interconnectors, based on VSC technology, are technically capable of providing Black Start capability.

An interconnector may provide access to generators in an area which is not blacked out, which may provide opportunities to reduce the cost of achieving an appropriate level of Black Start capability. They can also potentially enable quicker restoration times for the transmission system and provide access to a greater diversity of fuel sources improving overall resilience. However, more interconnection to Europe exposes the GB transmission system to the effects of European wide black outs. With significant flows on interconnectors, a European wide black out could potentially lead to a black out of the GB system.

The benefit to the system will be service strategy and location-dependent (at both ends) and the diversity of location of interconnectors to the GB system will be a key factor in achieving the benefit. We are currently in discussions with interconnectors to develop this capability and investigate the potential economics of providing this service.

5. Reactive Response

5.1 Definition of service (SOF[2] Section 5.4)

The flow of reactive power on the transmission system affects voltage levels. Unlike system frequency, which is consistent across the network, voltage is a local issue which is uniquely related to the prevailing real and reactive power supply and demand in a local area. The SO must manage voltage levels locally. Without the appropriate injections of reactive power at the correct locations, the voltage profile of the transmission system will exceed statutory limits.

5.2 Future Challenges (SOF[2] Section 5.4.1 & 5.4.2)

The way we use electricity is changing the reactive demand on the transmission system and in recent years, the reactive demand has been falling[3]. Closure and lower utilisation of conventional power plants on the system, reduces the system capability to control the voltage, and may result in the need for investment in additional reactive compensation. Future interconnectors utilising the right technology could contribute to providing reactive power services to the GB transmission system.

5.3 Potential Benefits of Interconnectors

Interconnectors based on HVDC VSC-technology are designed with inherent reactive compensation plant that can be utilised to generate or absorb reactive power as required without the need for any additional equipment. By locating these links appropriately, there is the opportunity to utilise their reactive power capability to meet the changing needs of the transmission system and to reduce the need to procure reactive services from other sources.

Interconnectors can also provide Dynamic Voltage Control depending on the technology employed. The reactive plant can provide continuous voltage control during load variations. HVDC VSC can also respond almost instantaneously to disturbances on the network and thus enhance voltage stability by

[3] Electricity Ten Year Statement 2015, Section 2.2, Demand

maintaining system voltages during large disturbances. It should be noted however, that HVDC VSC technology will be required for dynamic voltage control.

6. Boundary Capacity and System constraints

It is acknowledged that interconnectors will affect system boundaries and change overall constraints costs. The analysis relating to these changes is covered in depth in the CION document which is written for each interconnector.

7. Dependency of benefits to the European electricity market

Exchange and sharing of ancillary services is critical both for the integration of increased volumes in renewable energy integration and to enhance the efficient use of available generation capacities. There is currently a great diversity of arrangements for ancillary services throughout Europe. Common rules for cross border exchanges of such services are included within the future Network Code on Electricity Balancing and the Transmission System Operation Guideline. The European Council, Commission and Parliament are currently working together to develop the energy policy required to meet our 2030 energy goals around climate change and energy security. These European legislative bodies have clearly stated how they believe additional European interconnection is a cornerstone of achieving a single European electricity market and removing isolated electrical networks. Further interconnection will facilitate the removal of both physical and market based cross border constraints. This in turn will allow a greater number of providers to participate in a far larger, single market both for the provision of balancing services, as well as energy, which will ultimately provide lower costs for end consumers.

The Network Code on Electricity Balancing facilitates the development of cross-border exchanges of balancing energy. It allows for the reservation of cross-border capacity for the purpose of balancing energy, however only where TSOs can demonstrate that such reservations would provide socio-economic efficiencies. Provision of interconnector services will be affected by the compatibility between balancing market models and how new European codes will harmonise these balancing services. Further the Transmission System Operation Guideline, increases harmonisation of cross border Ancillary Services. Together both codes will have a considerable impact on the availability and value of ancillary services available to the GB system operator.

A number of benefits associated with interconnectors is dependent on the market environment, and physical characteristics of the system the interconnector is connected to. For example, the provision of frequency response at one end may have an impact on the other system and as such may limit the capability and benefit associated with the interconnector. The technical capability of an interconnector to deliver ancillary services, within various timescales should be carefully evaluated, considering both the technical characteristics of the interconnector and the technical definition of the products in the market.

In exploring the benefits interconnectors could facilitate, it should be noted that further discussions will be required with the relevant TSOs to ensure the benefits that we have identified are available. The availability of these benefits will be based on:

- network restrictions of adjacent networks which restrict availability of these services; and
- technical availability of the services from each interconnector and their convertor station.

8. Conclusion and Next Steps

The provision of additional HVDC interconnections to the European power network offers a number of potential benefits to GB and the end consumer. The degree of benefit depends in some cases on the location of the interconnector, and the technology employed. The European Network codes will also influence the ability to realise GB benefits from interconnectors.

Going forward at the request of Ofgem, we will be undertaking further assessments to quantify the potential benefits and value that interconnectors connecting to the GB transmission system can provide to the GB consumer. This analysis will help support Ofgem in their assessment of the Cap and Floor regime for near term projects and Ofgem have indicated the combinations of projects for assessment.