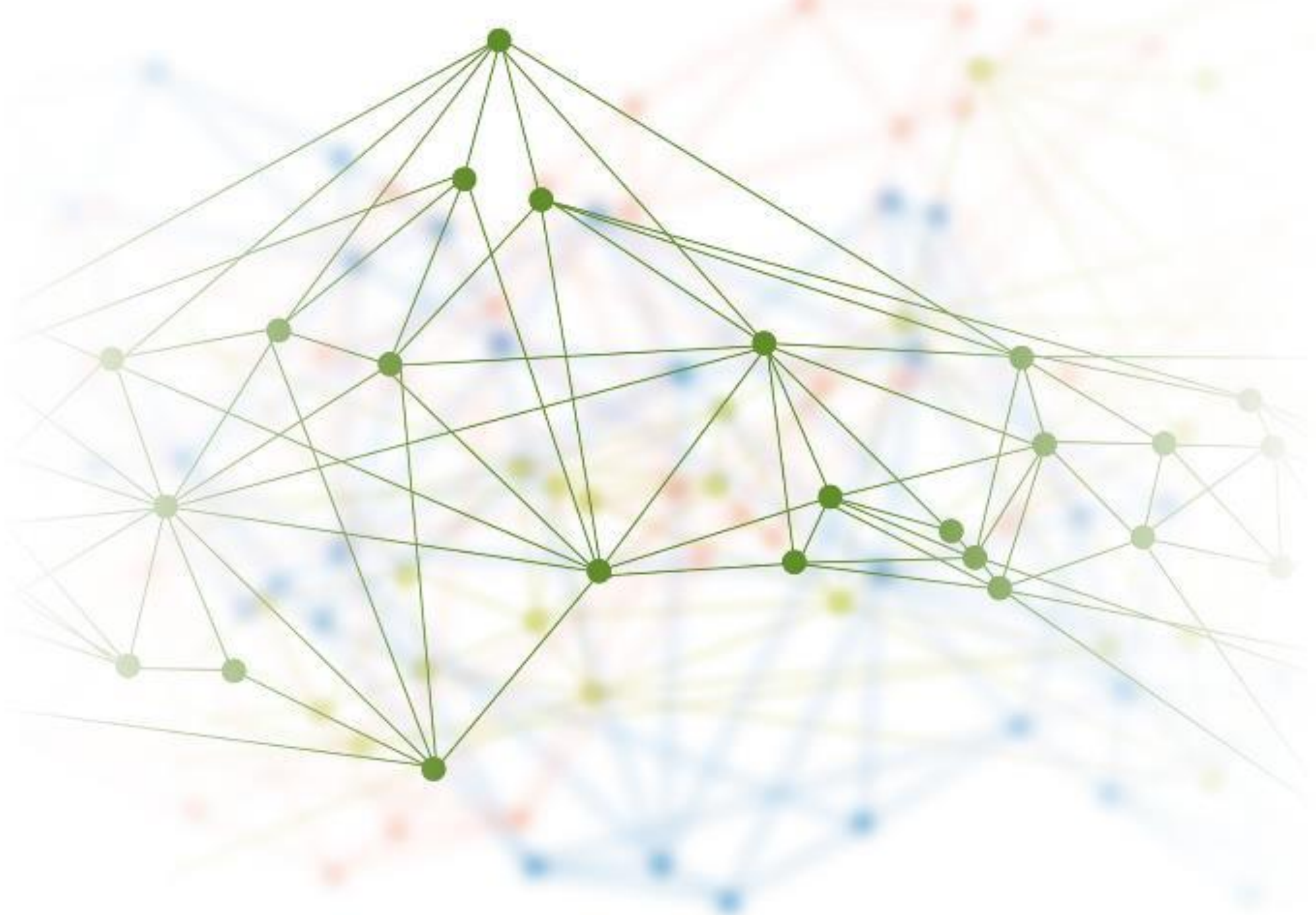
PHOENIX

Impact of SC / H-SC on existing balancing schemes and markets



About Report

Report Title	:	**Impact of SC / H-SC on existing balancing schemes and markets**
Report Status	:	FINAL
Project Reference	:	Commercial Deliverable SDRC 2.5
Date	:	Completed on 19/03/2021

Report Progress

Created by	:	John West and National Grid ESO Team	23/09/2020
Reviewed by	:	Not Applicable	
Signed-off by	:	Not Applicable	

Report History

Date	Issue	Status
23rd September 2019	Version 1	Working copy for Phoenix Team to construct
1st December 2020	Version 2	Draft for submission to CWG and SPEN
24th February 2021	Version 2.6	Final draft for Phoenix partner review & approval
15th March 2021	Version 2.7	Final draft for internal submission approval NGESO & JW
19th March 2021	Version 3.0	Final report for submission to SPEN

Contents

1. Introduction

This document reports the work to deliver Successful Delivery Reward Criteria (SDRC) 2.5 for the Network Innovation Competition (NIC) Phoenix project. SDRC 2.5 encompasses a report on the Impact of Synchronous Condensers (SC) and/or Hybrid Synchronous Compensators (H-SC) on existing balancing schemes and markets.

In considering the impact on balancing schemes and markets, this report examines the different deployment routes that are being used for SC and H-SC. It considers the range of services that are used by National Grid Electricity System Operator (NGESO) to support system balancing and operation and the different parties that provide these services.

The report is based on evidence gathered to date through the Phoenix project. It also takes account of related work being taken forward by NGESO to develop voltage and stability services. This report is linked to the report produced for SDRC 2.7 for Phoenix which covers regulatory considerations and recommendations for the future roll-out of SC and H-SC.

1.1. Introduction to SDRC 2.5 and Impact Assessment

Great Britain's (GB) electricity system operation and the commercial services that support operation are undergoing great change as system energy balancing and operation become more complex as the sector transitions to 'greener' forms of electricity generation and demand. NGESO is reviewing the range of services that it procures to support system balancing and operation.

Against this background of developing electricity system needs and developing GB markets, this report assesses the potential impacts and benefits of deploying H-SC (or SC) such as the H-SC which has been designed, commissioned and is currently being piloted on the GB transmission system as part of the NIC Phoenix project. As H-SC (and SC) could offer a range of benefits, they have the potential to impact several aspects of the balancing services market. Conversely, the shape of emerging GB market arrangements will have a bearing on whether benefits from H-SC (or SC) can be accessed effectively.

This report has been developed with input from the Commercial Working Group set up to support the Phoenix project. It is informed by the results of system studies and the results of the ongoing H-SC trials at the Neilston substation to verify what benefits H-SC are providing. If further impacts become apparent through these trials, these will be reported in later Phoenix project deliverables.

1.2. Key elements of SDRC 2.5 Scope

The key elements this work activity includes:

- Considering the benefits which can be provided by H-SC (and SC) and how GB electricity balancing services and service providers might be impacted by the wider deployment of H-SC (and SC).
- Reviewing how GB balancing services and associated markets are developing and determining whether these will enable H-SC (and SC) value to be accessed.
- Considering how the wider electricity industry might be impacted by the roll-out of H-SC (and SC).

1.3. Report Structure

The remainder of the report is structured as follows:

- Section 2 summarises the developing GB system requirements and developing technologies.
- Section 3 covers potential benefits through the deployment of H-SC (and SC) including the provision of voltage support, inertia and system strength. This section draws mainly on the system studies, as the Neilston trial is not yet complete.
- Section 4 describes the existing and developing services and market arrangements that are already being used and developed for voltage support, inertia and system strength.
- Section 5 considers the different approaches that have been proposed to access H-SC (and SC) benefits, and the impacts that these approaches would have.
- Section 6 covers conclusions including key H-SC (and SC) benefits, impacts and learning points for GB service development.

2. Changing GB System Requirements

2.1. Impacts of Reduced Synchronous Generation

The requirements for assets and system services[1] to support GB electricity system operation are changing as energy balancing including frequency management and voltage management become more complex. Traditional thermal-dominated generation is declining, replaced by distributed generation and significant investment in low-carbon technologies. This transition creates challenges for system operation. With fewer synchronous generators operating, many system characteristics that previously have not had a strong influence on system operation are now of greater importance. For example:

- Lower system inertia has caused increased Rate of Change of Frequency (RoCoF) to become a limiting factor and this is affecting how large system infeeds, including interconnectors, are operated.
- Lower short circuit levels can affect the operation of plant (e.g. High-Voltage Direct Current (HVDC) interconnectors) and fault detection by protection systems.
- New generation sources may be remote from load centres in parts of the transmission network with limited capacity. With less synchronous generation available to support system operation, system voltage and stability constraints[2] are more likely to limit power system transfers.

NGESOs' Future Energy Scenarios (FES) suggest that the operation of synchronous generation will further decrease, and more non-synchronous generation will be installed.

To support the transition to a low carbon electricity system, there is a requirement to both decrease reliance on fossil fuel generation to stabilise the system and learn to operate with less predictable and more dynamic power generation sources. As the GB system moves to a low carbon electricity system with increased energy efficiency, more power is coming from distributed generation and renewable sources. This means the amount of synchronous generation running at any time is reduced and, without intervention, the stability of the GB transmission system reduces due to the reduction of short circuit level and inertia that synchronous generation provides.

NGESO manages voltage levels by maintaining a balance between elements on the system, which either absorb reactive power (decreasing voltage) or generate reactive power (increasing voltage). NGESO requirements for both reactive power generation and absorption are currently met through a combination of balancing services and network assets.

NGESO already uses several tools to help manage reducing stability levels:

- it can reduce the largest infeed loss to limit the potential frequency perturbation from a single interconnector circuit or power station unit dropping off the system;
- it can increase levels of inertia on the system by re-dispatching out of merit synchronous generation through the balancing mechanism instead of non-synchronous generation to access additional stability capability; and
- it can procure increased volumes of fast acting response services to limit frequency changes in the event of a system incident such as the sudden loss of an interconnector circuit or power station unit.

The diagram in Figure 1 outlines what is changing on the system, key impacts, the effects on stability and the potential solutions being explored by NGESO.

The potential stability effects include:

- system voltage and frequency stability,
- the ability of synchronous generators to remain synchronised with the remainder of the system (rotor angle stability),
- the stability of HVDC convertors,

---

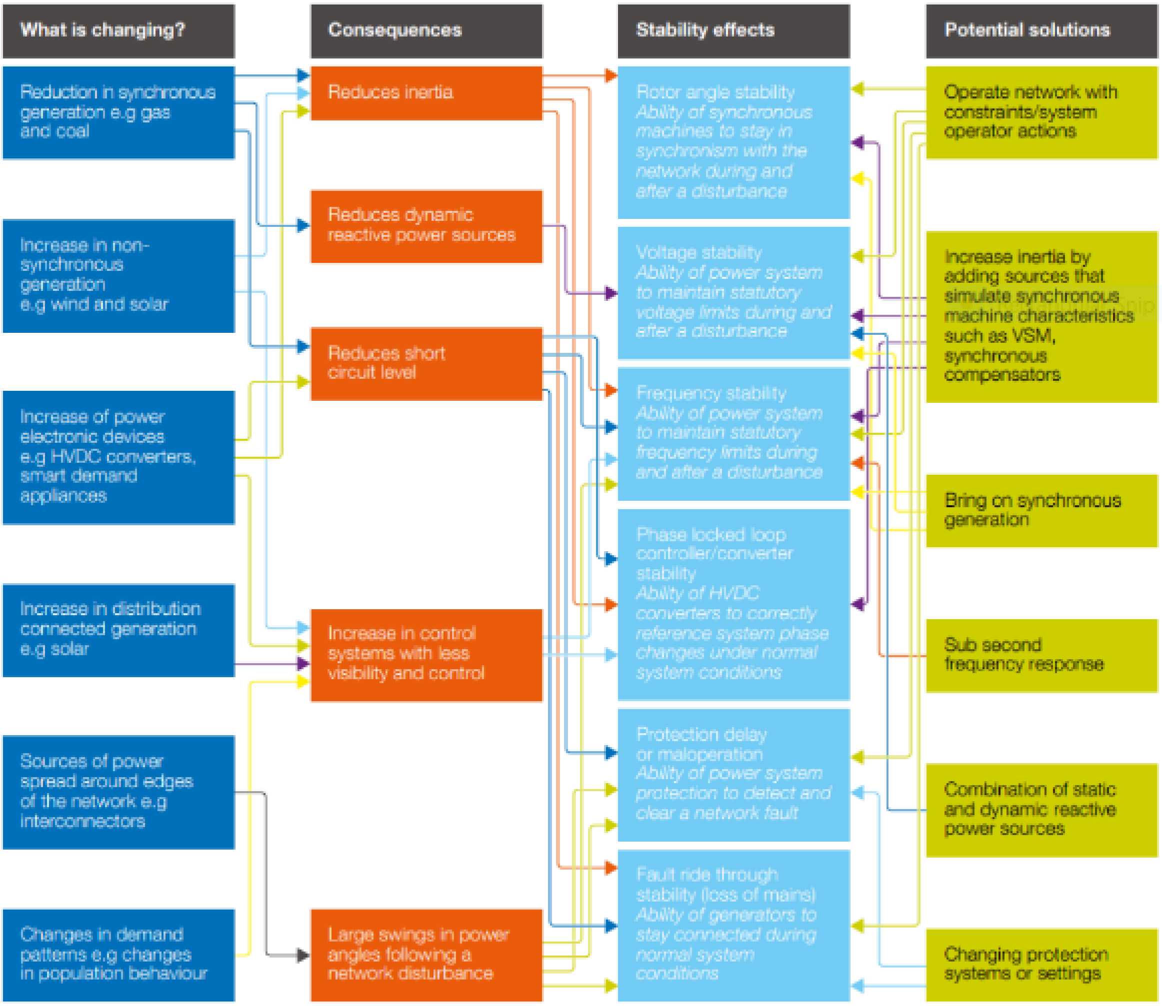
[1] In this report, system services are a range of services that are needed to enable stable and effective energy balancing and the stable transfer of energy across the transmission network.

[2] With less synchronous generation to provide voltage support and stabilise the system, transmission faults and other unexpected events are more likely to cause system instability. As a result, power transfers are constrained to lower levels.

- the ability of protection systems to operate effectively, and
- the ability of generators to remain connected during system disturbances (fault ride-through).

Figure 1 indicates that there are several potential solutions to mitigate these stability effects. One solution that could address several effects is to provide H-SC and/or SC. H-SC will increase system inertia and system strength and provide dynamic voltage support. The potential benefits of H-SC and SC are further considered in Section 3.

Figure 1 – System Stability topics



The critical and urgent need to resolve system stability issues was indicated in the National Grid System Operator Innovation Strategy published in March 2018[3] where the issue was covered through 3 separate priorities: volatility in a low-inertia system; enabling more non-synchronous connections; and supporting voltage and reactive power. These three areas were subsequently combined in the refreshed System Operator Innovation Strategy published in 2019[4] where System Stability became the top innovation priority. System Stability remained the top innovation priority in the most recent Electricity System Operator Innovation Strategy published in March 2020[5].

Previously there was no need to procure inertia as the system was designed around the inherent provision of inertia provided by synchronous generation. As well as System Stability becoming a key priority for innovation, NGESO through the System Operability Framework (SOF)[6] documents identified the need to examine the market opportunities for different technologies and approaches to meet system stability requirements. This has led to the broadening of the Network Options Assessment (NOA) approach to include stability and voltage, and the use of this to identify requirements and compare network and commercial solutions through stability pathfinding projects.

[3] SO Innovation Strategy-2018
[4] SO Innovation Strategy-2019
[5] SO Innovation Strategy-2020/21
[6] The System Operability Framework (SOF)

Innovation projects such as the NIC Phoenix project will allow the Electricity System Operator (ESO) and industry to understand alternative sources/solutions which may provide grid stability. The NIC Phoenix project is demonstrating a sustainable design, deployment and operational control of a Synchronous Compensator and Static Compensator (STATCOM) using an innovative hybrid co-ordinated control system.

2.2. Meeting Changing System Needs

There are different ways in which the additional requirements for stable system operation can be met. The use of H-SC is one of these. In other electricity transmission networks around the world, SC are increasingly being used to improve system stability.

Table 1 illustrates that different technologies might be effective in providing different types of system services to address the stability effects outlined in Figure 1. As well as SC and H-SC, there are other technologies which can also address system stability effects.

*Table 1 - **Different Approaches to Maintaining System Stability and Providing System Services**[7]*

	Synchronous Generator Stability	RoCoF & Frequency Management	Voltage Management	HVDC Converter Operation	Protection System Effectiveness	Fault Ride Through Stability
Operate Network with Constraints	Operate to avoid risk of excessive losses	Constrain generation & largest loss	Limit potential losses	Constrain generation to increase system strength	Constrain generation in specific areas to increase system strength	Operate to avoid risk of excessive losses
Demand Side Services		Provision of Fast Response	Provision of Voltage Support (location dependent)			
Energy Storage		Provision of Fast Response	Provision of Voltage Support (location dependent)			
Flexible Synchronous Generation	Additional generation to increase Inertia	Additional generation to increase Inertia	Provision of reactive power	Increasing Fault Infeed	Increasing Fault Infeed	Increasing Fault Infeed
Services from Non-synchronous Generation		Provision of Fast Response	Enhanced Reactive Support			
Interconnector Services		Provision of Fast Response	Provision of reactive power			
Grid Forming Converters	Can help maintain synchronous generation stability.	Can maintain system frequency.	Can maintain voltage stability.	Can increase Fault Infeed	Can increase Fault Infeed	Can increase Fault Infeed
Static & Dynamic Reactive Power Devices			Provision of reactive power			
SC / H-SC	Increasing the System Inertia	Increasing the System Inertia	Provision of reactive response	Increasing Fault Infeed	Increasing Fault Infeed	Increasing Fault Infeed
Support from Distributed Generation		Provision of Fast Response	Provision of reactive response			

[7] A version of this table was first used in National Grid's System Operability Framework on page 180, published in 2015. This version has been updated to better reflect the options that are now available.

As one example, synchronous generator technologies can be adapted to be more flexible e.g. operation with a clutch to disengage the prime mover to offer reactive power services at 0 MW; to provide reduced Stable Export Limit (SEL); to provide increased reactive power range; and high-speed excitation for enhanced dynamic stability.

System services can also be developed from renewable generation e.g. reactive power and high frequency response. Energy storage technologies can be utilised to provide reactive power and fast speed of response to contain and recover system frequency in low inertia systems. One example of this is the Enhanced Frequency Response (EFR) balancing service. In another example, energy storage technologies are being used to deliver the fast frequency response (FFR) requirements of Ireland's DS3 programme where the minimum speed of response is 150-300 milliseconds. Distribution connected and demand side resources can also be further utilised to provide wider system services.

Work is also being carried out to develop Grid Forming Converter (GFC) technologies. In this approach to maintaining stability, the converters that are used to convert Direct Current (DC) or other asynchronous power sources to synchronous power system are used to provide frequency and voltage references, and behaviours similar to synchronous generators.

3. Potential benefits from SC and H-SC

3.1. Hybrid Synchronous Compensator (H-SC)

The Phoenix H-SC installed at Neilston substation consists of a 70 megavolt amperes (MVA) SC and a 70 MVA Static Compensator connected through a single three-winding transformer, with an innovative hybrid control mechanism to maximise the benefits of SC and STATCOM.

The H-SC provides the following benefits:

1. Both the SC and STATCOM could provide steady state reactive power support and dynamic reactive power support. The reactive power support could improve the voltage profile and voltage stability of the system.
2. The short circuit contribution from the SC could increase fault current level and hence the system strength. The increased system Short Circuit Level (SCL) could improve the operation of Phase Locked Loop (PLL) controllers and ability of HVDC converters to correctly reference system phase changes. The increasing SCL through H-SC installation would help to ensure the correct operation of protection devices.
3. The inertia contribution from the SC will improve the system inertia, that could improve the system stability limit and the system frequency response. The higher system inertia would improve the RoCoF values and frequency nadir following any system event that could reduce the amount of generation to be constrained to keep RoCoF and frequency within limits.

3.2. Learnings from Phoenix System Studies

The hybrid controller developed for Phoenix device allows connection of both SC and STATCOM through a single transformer with a master controller to control both devices. This master controller avoids conflicts between the individual equipment controllers. It reduces the number of transformers required such that the total capital cost of the system is reduced. The Phoenix device controller has additional functions such as:

1. Power Loss Minimisation (PLM)
2. Inertia Support Maximisation (ISM)
3. Fast Transient Compensation (FTC)

With the PLM function, the hybrid controller shares the reactive power support from SC and STATCOM optimally to reduce power losses. With the current configuration of 70 MVA SC and 70 MVA STATCOM, the reduction in power loss is not significant. However, it could be possible to reduce the power losses with higher ratings of STATCOM [ABB Report 1[8]].

The objective of the ISM function is to maximise the inertial response by decreasing or increasing the power consumption by STATCOM by switching the STATCOM device OFF or ON following the frequency event. The ISM function provides very little or no additional benefit in this combination at Neilston [ABB Report 1[8]], as the STATCOM consumes very little power.

The STATCOM and SC together with the hybrid controller improves the total response time of H-SC compared with a SC system alone, as the STATCOM response is much quicker compared with the SC. The FTC function allows the hybrid control to maximise the response from STATCOM, following an event, and hence improves the total response time of H-SC. FTC should improve the voltage control speed of the hybrid device compared with an uncoordinated STATCOM and SC [ABB Report 2[9]]. The performance of H-SC with FTC provides a faster response when compared with a standalone SC but slower when compared to a standalone STATCOM.

The system studies have shown that interconnectors' loading levels (current source converter (CSC) HVDC, in particular) are affected by the SCL of the system. The installation of H-SC/SC would increase the SCL and better operation of HVDCs could be achieved which would enable the transfer of more power through a boundary. For locations where more SCL contribution is required, a higher rating of

[8] "Testing Requirement and Innovation Outcome for Future Installations", Doc. No. 1JNS10266D1S153, 03-06-2020
[9] ABB report on "Functional Specification for H-SC Innovative Outcomes", Doc. No. 1JNS10266D1S139.

SC in the H-SC could be used compared with the STATCOM rating. The future HVDC connections, which use Voltage Source Converters (VSC), could employ Grid Forming technology. This could increase the system SCL to some extent and may reduce the need for H-SC installations to provide SCL. The comparison of H-SC with Grid Forming Technology has not been considered in the Phoenix project system studies.

The system studies have also shown that for systems with voltage collapse limits, fast dynamic response is required. For this condition, a higher rating of STATCOM in a H-SC could be selected compared with the SC component. With the fast-dynamic response availability, more boundary transfer could be achieved without voltage stability issues.

Similarly, for a system that requires to improve the system inertia level, a higher rating of SC could be selected in a H-SC. In the Phoenix device, the inertia constant of SC is 1.34s. The international market analysis report showed that there are SC installations where higher SC inertia levels have been achieved. The inertia of SC could be increased by technologies such as adding flywheels to the system. Likewise, the inertia contribution from STATCOM could be increased by adding battery storage. With the increased inertia level, the maximum infeed loss that could be achieved without violating RoCoF and frequency limits could be improved and could reduce the amount of generation constraints.

3.3. Further Considerations

Learnings from Neilston H-SC Trial

The benefits of H-SC will be further tested through the H-SC installation at Neilston. This H-SC trial commenced at the end of October 2020 and will continue through to October 2021.

At this time, it is too early to include conclusions from the Neilston trial. To date the trial has included several unplanned system events which will be fully evaluated over the coming months. Any learnings from the trial will be captured in the report for commercial deliverable SDRC 2.4 covering the pilot installation and performance.

H-SC – Expected Asset Life and Availability

The SDRC 2.2 report “Cost benefits of SC and H-SC based on System Studies” provided information on the expected asset life and cost range of H-SC devices. The asset life of an H-SC is expected to be around 40 years with a control system upgrade (H-SC controls and cooling system controls), once every 20 years. The expected number of forced outages per year is less than 2-3 times and the H-SC device should achieve an availability of around 98%.

4. Current and Developing Market Arrangements

Alongside the technical development of new solutions to provide voltage support, inertia, system strength and other services, NGESO is reviewing the range of system services that it procures to support energy balancing and stable operation of the transmission system. For example, NGESO has published roadmaps for Reactive Power, System Restoration and Wider Access to the Balancing Mechanism.

NGESO has also announced its ambition that, by 2025, electricity system operation would have transformed such that the system can be operated safely and securely at zero carbon at times when there is sufficient renewable generation available to meet the total national demand. In the documents it has published, NGESO anticipates designing more competitive services going forward and sourcing these from a wider range of providers. Network Option Assessment (NOA) Pathfinders initiative, from NGESO, is a key element of this system services work.

Balancing services are services procured by NGESO to balance demand and supply to ensure that the security of supply is across Great Britain's transmission system. Balancing services, sometimes also referred to as ancillary services, are the tools / additional capacity available to the ESO for overall system balancing and maintaining appropriate frequency levels on the system. These are services that have been made available by providers / contracted for ahead of time to be available at certain periods to be called on to support system balancing. The balancing services currently being procured by NGESO fall under frequency response services, reserve services, reactive services, constraint management and restoration services. The list of and further details of all balancing services can be found on the NGESO Future of Balancing Services [10] website pages.

To further support system balancing activities, NGESO also has wider access to the Balancing Mechanism (BM) where providers can submit their assets into the commercial market closer to real time to support system balancing. The BM is the last stage for trading electric energy. It plays an essential role, as production and consumption levels must match during the operation of the system. This is the primary tool used by the ESO to ensure the efficient management of supply and demand.

The current operability challenges being experienced due to the reduction of synchronous generation on the system, leading to reduced short circuit and inertia levels, are being addressed through several approaches. These include aiming to understand what can be provided by new technology types and developing new services for support to be provided by market participants. These are covered in the following sections on market arrangements.

4.1. Voltage Management and Market Arrangements

Reactive power services are how NGESO ensures voltage levels on the system remain within a given range, above or below nominal voltage levels. NGESO instructs generators or other asset owners to either absorb or generate reactive power to manage voltage levels.

Managing voltage levels comes from maintaining a balance between elements on the system, which either absorb reactive power (decreasing voltage) or generate reactive power (increasing voltage). Voltage management is carried out on a regional basis. Reactive Power generation and absorption of Reactive Power within a region of the electricity system needs to be met by Reactive Power sources from that region.

NGESO requirements for both Reactive Power generation and absorption are currently met through a combination of balancing services and network asset investment. Historically, Reactive Power has been provided through a combination of synchronous generation and network assets such as Reactive Compensation equipment. Network assets for Reactive Power (capacitors, reactors) which have historically provided most of the baseload for Reactive Power, have been very cost effective against market options. These are required to comply with the system's security standards, or to meet Reactive

[10] Balancing Services Link

Power requirements. NGESO uses balancing services to fill the gap when network assets are not available and/or when system requirements are higher.

NGESO can procure Reactive Power generation and absorption through two routes in the market; however, it can only use these if the provider is running to provide real power when there is a Reactive Power requirement. The routes described below do not enable NGESO to ensure a provider is available:

1. The Obligatory Reactive Power Service (ORPS), which is outlined in the Connection and use of System Code (CUSC) and must be provided by all generators with a Mandatory Services Agreement.
2. The Enhanced Reactive Power Service (ERPS) is a tendered commercial service as outlined in the CUSC. It is for providers who can go beyond the Obligatory Reactive Power requirements. It is also for providers who do not have to offer ORPS but can meet or exceed the ORPS performance standard. NGESO have not had a contract for this service since October 2009 and have received no tenders since January 2011.

As patterns of generation and demand have changed on the system, the availability of ORPS providers at the times when they are needed most has become more challenging. This is most frequently seen during low active power demand periods in the summer, when conventional thermal plant that provides ORPS is less likely to run. This leads to some regions of the country not having enough ORPS providers available when needed, making those areas more challenging to manage and potentially giving rise to a voltage constraint. A voltage constraint occurs when there is not enough Reactive Power generation or absorption regionally. This means that voltage levels will go outside of secure limits unless the level of Reactive Power changes.

There are significant challenges to managing voltage levels on a zero-carbon network. The approach taken by NGESO has been to define requirements and seek alternative solutions. This includes enacting a 'learn by doing' approach to identify alternative solutions through the pathfinder projects borne out of the NOA.

There is also a plan to develop a long-term strategy for delivering a zero-carbon solution to voltage management in 2025. NGESO Network Development Roadmap[11], outlines an ambition to apply a NOA type approach to regional voltage challenges on the transmission network. The process used to identify the Mersey and Pennines requirements shaped the proposed methodology, which is now being tested for the current Mersey 2022 pathfinder tender.

The pathfinder projects for Mersey and Pennines have identified requirements for ensuring efficient management of system operability; and are testing the principle of commercial solutions against traditional regulated assets. Following Ofgem approval of the proposed methodology, NGESO are conducting the first screening process to identify and prioritise the voltage regions to take through to detailed power system studies.

The process will involve working collaboratively with transmission and distribution owners to prioritise areas and confirm required timelines for seeking solutions. The process will include analysis of historic costs in the relevant regions, a review of the impact on these regions that Future Energy Scenarios and planned/potential network changes may have, and provision of our view on the likelihood of these events occurring in the future.

4.2. Inertia & System Strength Management and Market Arrangements

The electricity system is designed to operate with a stability capability which has inherently been provided by large amounts of synchronous generation operating on the network. We are transitioning to a system with a significantly lower proportion of synchronous generation and we need to ensure that the system remains secure under these new conditions. To manage this transition, there is currently work under way to:

[11] NGESO Network Development Roadmap

- Update standards to ensure they are appropriate for a system with less synchronous generation. This includes revised Loss of Mains protection requirements and updates to the Security and Quality of Supply Standards (SQSS) to better manage low inertia.
- Identify new sources of stability capability by improving our understanding of new technologies and taking the first steps in introducing a new market to procure this capability through the Stability Pathfinder and through the development of a specification and development of a future GB Grid Forming Market.

Each of these approaches being taken by NGESO aimed at supporting system stability requirements are at varying stages and are covered below.

Accelerated loss of mains

The accelerated loss of mains change programme is aimed at reducing the number of generators with inappropriate loss of mains protection settings to reduce the volume of generation at risk of disconnecting in response to a large loss (and subsequent high rate of change of frequency) or electrical fault (and subsequent vector-shift) on the system. This change will alleviate the RoCoF and vector shift constraints, which are now the dominant factor when managing system inertia and reduce the cost of balancing the system. This will also allow NGESO to operate the system with lower levels of inertia which is a key step to enable operation with zero carbon in 2025. This data will be used to inform the actions taken in the control room and ultimately result in a reduction in actions and cost required to manage this constraint. Once loss of mains relays have been removed as the key factor limiting the rate of change of frequency allowed on the system, faster frequency response services will become key to containing frequency. Rather than RoCoF, it will be the absolute change that becomes the constraining factor. Faster response services will be required to arrest the change before frequency limits are reached.

Inertia Modelling

Contract arrangements have also been put in place with GE and Reactive Technologies (two providers) to provide real-time monitoring of the system inertia on the GB transmission network. NGESO are the first System Operator (SO) to adopt either of these systems as both are first of their kind systems that will measure the combined inertia-like effects of conventional synchronous generation, power electronic converted generation (such as wind and solar) and passive load responses. Deploying an accurate inertia measurement application is critical in plans to manage the system frequency in the future.

One system is non-intrusive, continuously monitoring boundary activity and using machine learning to forecast the inertia up to 24 hours ahead. The other solution includes one of the world's largest ultracapacitors which will be used to 'inject power' into the grid, while Reactive Technologies' measurement units directly measure the response, enabling the full system inertia to be established.

These approaches are being built and tested, once there is enough confidence in the output of the measurement, the data will be used to inform operational policy. NGESO has an ambition to implement a first of a kind system, to measure system inertia in real-time and use it to optimise real-time operation, service procurement and network development. These projects will support the milestones to develop markets for stability and faster response products by improving overall understanding of the requirement close to real-time.

Stability Market / Stability Pathfinders /Accessing Stability Solutions

The main route at present for the ESO to access any additional stability capability required on the system is to instruct out of merit synchronous generation to run via payments through the balancing mechanism. NGESO is developing approaches which aim to access stability capability in a more economic and sustainable way. The network development roadmap is looking at including a wider range of requirements and solutions in the NOA methodology. One of the requirements NGESO is investigating is stability, including inertia, short circuit level and dynamic voltage support. NGESO is using pathfinder projects to enable it to learn how it can include requirements in NOA and consider network and market solutions.

The stability pathfinder process allows NGESO to outline its requirement for stability, seek feedback on proposals and what solutions may be feasible, and run tenders to determine the most economical solution to meet these requirements. To date NGESO has launched two phases of the Stability pathfinder process.

- Stability Pathfinder phase 1 was the first tender for a stability service. The tender was a short procurement exercise to determine if any economic stability solutions could be delivered quickly across GB. In January 2020 NGESO awarded 12 tenders to 5 providers across 7 sites, securing 12.5GVAs of inertia until 31st March 2026. With a total contract exposure of £328m, NGESO expects to save consumers between £52m to £128m over this period as a result of having to take less actions in the Balancing mechanism to address system stability. Several synchronous compensators were successful in receiving contracts to provide stability service in phase 1. These were a combination of new and existing plant as well as assets being converted to synchronous compensators. This demonstrates that it is possible for this technology type to meet the technical specification required by the ESO and be commercially viable. The commissioning and proving tests for these assets to deliver the stability service, will further inform the wider conclusions for project Phoenix.

- Stability Pathfinder phase 2 which is currently underway with the launch of an Expressions of interest on 30th September 2020. This phase provides a longer tender process to support new technology types participating. Phase two is seeking to fulfil a specific locational requirement in Scotland, this approach will later be expanded to other areas of the network based on a prioritised view of requirements. This pathfinding process is informing the updates to the NOA methodology and stability will be included in the methodology developed during 2020/21 to ensure an enduring approach for procuring solutions is delivered. This will also enable NGESO to review requirements for stability alongside requirements for voltage and identify areas where these requirements may be combined. There will be future tenders for Stability Pathfinders after the completion of phase 2, work is underway to define the stability needs for the entire GB system. There is an ambition to run a GB wide procurement exercise after phase 2 completion.

Note - To a large extent, the Stability Pathfinder approach is already providing the inertia and short circuit level (SCL) markets that were envisaged as part of the original Project Phoenix proposal in 2016. Through the Stability Pathfinders, essential levels of inertia and SCL services are being secured in different regions.

New Technology

New technologies solutions that are being explored to meet system stability requirements include Project Phoenix and work on Virtual Synchronous Machine (VSM) technologies.

As part of Project Phoenix, the ongoing H-SC trial at Neilston will enable measurement and a better understanding of:

- H-SC availability, reliability and response to network disturbances and faults,
- Mega Volt Amps (reactive) (MVAr) utilisation from the H-SC and estimation of the value of that contribution using the Obligatory Reactive Power Service rate, and
- Improvements to boundary capability before and after the asset is operational through system studies. (This will be done through offline analysis across various periods and network conditions during the year.)

As noted in section 3.3 of this report, further learnings from the Neilston trial will be included in the report for commercial deliverable SDRC 2.4 covering the pilot installation and performance.

The work on VSM technology is intended to enable non-synchronous assets (e.g. wind generation, batteries, HVDC) connected to the system via converters to behave more like synchronous machines. This capability is increasingly being referred to as Grid Forming capability. With Grid Forming capability, non-synchronous assets can deliver the stabilising qualities which are required to operate the system.

Through a variety of innovation projects, and through work by Grid Code working group (GC0137), a non-mandatory technical specification for Grid Forming capability has been developed. If this is agreed, it will enable manufacturers and developers to design equipment to deliver this capability in a way which is most beneficial to the system, and to participate on an even basis in any stability procurement approach that is developed.

VSM (or Grid Forming capability) is an important solution to investigate as it should be possible to deliver stability services using existing assets, albeit these assets will need to compromise their normal output to provide headroom for the stability services. However, Grid Forming capability is not, by any means, the only answer and NGESO remains technology-neutral to solutions. Having a standard for Grid Forming capability will help broaden the range of technologies which can provide a stability solution. This supports the milestone to have a range of technologies in a test area and to develop a stability market.

4.3. International Comparisons

In the International Product review[12] carried out under the Phoenix project and published in 2019, several different regions including Continental Europe, Australia and the United States were reviewed, to better understand how similar challenges are being addressed elsewhere.

This showed that there are several regions with similar system challenges to the GB electricity network and with increasing levels of wind and solar energy production. Typically, multiple approaches are being used in these regions to help increase renewable energy use including the installation of SC. Different market and regulatory structures are also being developed including Transmission System Operator (TSO) models, the United States Independent System Operator (ISO) model and the Australian National Electricity Market (NEM) model with Australian Energy Market Operator (AEMO) setting levels for system strength and inertia, and generation developers and transmission providers taking forward works to meet these levels.

Conclusions of the international review included:

- There is no single or standard approach to addressing system strength or inertia challenges and where there are increasing levels of inverter connected renewable generation, different approaches are being employed to support transmission networks often including the use of SC.
- SC are being used to address voltage management and system strength challenges in different geographic areas and in areas with different market structures (e.g. Europe, US and Australia.)
- SC can be provided quickly in comparison to other transmission solutions and the conversion of generators or the installation of new SC have been used to provide voltage support and improve system strength where generation has been closed or has become expensive to operate. Usually, generator conversions to SC have taken place where system support is needed most urgently.
- Where new SC are installed at transmission voltages, voltage support and system strength are the primary reasons. In a few cases, system inertia has also been cited as a reason.
- The MVAr rating of new SC connected to transmission networks tend to be larger than the Neilston device (typically in the range 150 to 250MVAr) and the SC are often designed to meet specific local system challenges (e.g. to have a high value of inertia constant H in MWs/MVA).
- In the main, new SC are tending to be owned by TSOs though the need is first tested through local planning processes. Some competitive mechanisms for the provision of the SC are developing.

[12] Phoenix-International Project Review

5. Alternative Approaches to Access SC / H-SC Value

There are different regulatory and commercial arrangements that have already been considered and/or used in GB to access SC / H-SC value. These arrangements are introduced below in section 5.1. Section 5.2 goes on to introduce a set of questions that are used to further consider how the deployment of H-SC or SC through these different arrangements might impact existing balancing schemes and markets.

The discussion of the different approaches in this report is limited to considering the impacts of H-SC and SC deployment on existing schemes and markets and does not attempt to compare these approaches to deployment or suggest improvements. The pros and cons of different approaches to deployment, and suggested improvements, are further considered in the report for SDRC 2.7 “Regulatory Considerations for the Future Roll-out of SC and H-SC”.

5.1. Introduction to Alternative Approaches to Deployment

SC or H-SC have been considered for deployment in GB using three different approaches to deploy and fund investment. These are: i) as regulated assets taken forward by network companies to maintain agreed levels of system performance, ii) as assets recommended through the NOA process, and iii) as assets tendered through the Stability Pathfinder process. These approaches are outlined below.

1) **Network Company Regulated Assets** – SC or H-SC could be installed by network companies and remunerated in the same way as other regulated assets such as static reactive compensation equipment. For example, if Transmission Owners (TO) were remunerated for providing assets to meet specific network voltage or system strength requirements, TOs would take forward reinforcements to their networks to address shortfalls.

   In this approach, once the requirement for SC or H-SC had been identified, TOs would install and connect the assets in areas where SC and H-SC services are required. Where SC and H-SC assets are connected they would be made available to provide voltage, inertia and system strength capability and could reduce the need for NGESO to contract for services.

   The installation of SC and H-SC as TO owned and regulated assets would involve a long term commitment to fund and maintain assets. Regulatory assets are typically depreciated over periods similar to the technical asset life which may be much longer than the requirement for voltage, inertia or system strength services. Over time, if the requirement for the SC or H-SC is diminished through other changes to networks or connected resources, then the value provided by the assets could be reduced.

   In respect of determining whether the SC or H-SC offers the most cost-effective solution compared to possible alternatives to meet voltage or system strength shortfalls, the relevant TO would compare different solutions in its investment assessment and decision process.

   Both H-SC and SC solutions have recently been proposed by Scottish Power Transmission (SPT) As part of its RIIO-T2 business plan, SPT proposed the installation of an H-SC based solution at Eccles to increase the Anglo-Scottish boundary capability, and in the longer term, to help maintain system strength without Torness generation. In its final RIIO-T2 determinations published on 8th December 2020, Ofgem allowed baseline funding for the Eccles H-SC.

   In its RIIO-T2 business plan, SPT also proposed installation of SC at its Hunterston 400kV, Strathaven 400kV and Kincardine 275kV substation sites to help meet operability challenges. At each of these sites 2 x 150MVA rated SC were proposed. In its draft RIIO-T2 determinations published on 9th July 2020, Ofgem acknowledged the need for intervention but raised concerns on the impacts of these SPT proposals on other markets including the Stability Pathfinder process. Ofgem noted that the proposed investments could be considered further through the proposed Medium Sized Investment Projects (MSIP) re-opener but also sought views on alternative approaches. In its final RIIO-T2 determinations published on 8th December 2020, Ofgem did not allow any baseline finding for the proposed SC but noted that SPT could bring forward funding requests in relation to SC through the MSIP re-opener where NGESO confirms a need for the works.

2) **NOA Process** – Where it has been identified that additional network capacity would be beneficial to increase transmission boundary capability, the Networks Options Assessment (NOA) process allows the costs and benefits of different options to be compared. The "least regrets" option can be identified and recommended by NGESO.

The NOA process enables specific boundary requirements to be identified by the NGESO, and different options to be proposed by TO and other industry participants to meet these requirements. For boundaries where voltage performance limits capability, then SC and H-SC can be compared against other solutions and the preferred option can be identified. If a SC or H-SC is demonstrated to be the best available solution for a capacity shortfall, this can be taken forward by the proposer.

As part of the 2020 NOA process, SPT proposed installation of 2 x 300MVA rated H-SC at Eccles to increase the capability of the transmission boundaries between the south of Scotland and the north of England. Each of these H- SC was based on a 150MVA SC element and a 150MVA statcom. The H-SC was assessed by the GB ESO and recommended for installation by 2026. (This requirement for increasing the capability of these transmission boundaries and for installing the H-SC at Eccles has been reviewed as part of the 2021 NOA process and the H-SC continues to be recommended for installation by 2026. As noted above, funding for the H-SC at Eccles has been allowed in SPT's RIIO-T2 baseline.)

The NOA process provides a means to compare different options for addressing network requirements and to recommend a preferred option. However, in isolation, the NOA process does not provide the means to fund the recommended option. If a network reinforcement is recommended through NOA and is to be taken forward by a TO, Ofgem have determined through its RIIO-T2 final determinations of 8th December 2020, that funding can be provided through the Incremental Wider Works (IWW) mechanism in the case of NGET, or the Medium Sized Investment Project (MSIP) mechanism in the case of SPT or SHET (and also NGET where the IWW does not apply).

If other industry parties bring forward options to meet NOA requirements, and these options are recommended, the means to fund the recommended option remains unclear. However, the Early Competition Plan being developed by NGESO may provide a means for funding such works when this is finalised.

3) **Stability Pathfinder** – The Stability Pathfinder Phase 1 and 2 commercial tenders have built on the NOA process to allow different solutions to be compared to address identified shortfalls in inertia and short circuit levels. It has already been demonstrated that SC and H-SC can meet the technical requirements set out for Stability Pathfinder and may be tendered as solutions.

The Stability Pathfinder process allows SC and H-SC to be considered by a wide range of developers as the means to provide a service. NGESO can compare tendered SC and H-SC solutions against other solutions that have been offered and can select those options that are the most cost effective and most suited to meeting the specific requirements that have been requested. Contracts are then put in place for the most suitable solutions.

Potential benefits through the use of SC and H-SC via Stability Pathfinder include a commitment to pay for the service for the period over which the need for the service is clear. This means that there is a lower risk of the consumer paying for services beyond the timescale over which the service is required.

On the other hand, the need to locate the SC / H-SC at a suitable site to connect to a TO network may mean that the position of the SC / H-SC is not optimised and the connection could take longer to achieve.

As part of the Phase 1 Stability Pathfinder, new SC are being installed at sites at Keith and at Lister Drive by Statkraft UK Limited. In addition, Uniper UK[13] are building two new synchronous compensation units at Grain and repurposing redundant steam generators at Killingholme. All these services are expected to begin operation in April 2021.

[13] Uniper Press Release dated 6th February 2020

5.2. Questions used to consider SC / H-SC Impacts

As SC / H-SC might offer a range of benefits, they have the potential to provide multiple system services. They also have the potential to impact the operation of other markets for system services. For example, the installation of an H-SC to improve system strength in an area of the electricity system also provides an asset that might be used to support voltage.

The deployment of SC / H-SC through the different regulatory and commercial arrangements noted in section 5.1 above is considered further in the following sections. In considering the impacts of deployment through these approaches, some questions are considered. These questions cover a range of potential impacts including the wider benefits SC / H-SC could bring to consumers through deployment, whether benefits can be accessed quickly, and the potential for adverse impacts on wider competition.

The questions considered have taken account of Ofgem's February 2020 consultation on the Regulatory treatment of CLASS as a balancing service in RIIO-ED2[14]. In this consultation, Ofgem included an assessment on the effects on competition of DNOs offering CLASS as balancing services. The factors considered in the February 2020 assessment included the ability of the service provider to gain market power, the ability to discriminate against competitors due to having a monopoly role, and the potential to indirectly impact other markets.

- ***Would SC / H-SC deployment help enable net zero targets or reduced costs for electricity consumers?*** In considering this question, the wider benefits of SC and H-SC installation are considered such as the potential for increased connection of renewable generation resources. Cost factors include the cost of the SC / H-SC or service, the way in which the full range of benefits offered by the assets can be accessed, and whether network requirements might change going forward such that SC / H-SC are no longer of value.

- ***Could SC / H-SC deployment allow particular parties to gain unfair competitive advantage?*** This considers whether competitive arrangements might by adversely affected through potential conflicts of interest or unfair access to information.

- ***Are there impacts on other commercial services or incentive arrangements? And, would the deployment of SC / H-SC adversely impact other stakeholders including parties that are already providing services to help manage the electricity network?*** The installation and use of H-SC and SC to support voltage, inertia and system strength could affect services being provided via other mechanisms to meet system requirements. Factors include whether the use of SC or H-SC would have any direct impacts on other commercial services or incentive arrangements, whether the developers and asset owners that are already providing these services still have the opportunity to provide the services, and whether service providers can stack services and revenue streams. The volumes of SC / H-SC provided will also determine the degree to which other parties are affected.

- **Do the impacts change with larger numbers of SC / H-SC?** – This question considers whether different approaches may be more suitable to address the installation of larger numbers of SC or H-SC should these be required. In addition, given the potential asset life of SC / H-SC, the installation of larger numbers to address voltage and stability requirements could preclude the use of other solutions that are being developed.

- **How quickly can the SC and H-SC benefits be accessed?** – This question considers whether some regulatory and commercial approaches are more agile and would enable the SC / H-SC benefits to be accessed more quickly.

In the following sections 5.3 to 5.5, these questions are further considered for the 3 different approaches to SC / H-SC deployment that were introduced in section 5.1. The most relevant impacts are drawn out for each table.

---

[14] Regulatory Treatment of CLASS as a Balancing Service

5.3 Deployment as Regulated Assets with Allowances Agreed as part of Price Control

Description Installation of an asset by a network company to maintain defined levels of network performance and funded by the allowances agreed through a price control review.	
Question	Discussion
Q1 - Would SC / H-SC deployment help enable net zero targets or reduced costs for electricity consumers?	From work carried out internationally, the installation of SC by network companies has been shown to be a cost effective way to resolve system stability challenges. By installing SC in regions including Continental Europe, Australia and the United States, network companies have also increased the volume of renewable resources connected to networks. In GB, the installation of both H-SC and SC have been proposed as network company regulated assets. In its RIIO-T2 Business Plan, SPT proposed expenditure of £94m on two H-SC at Eccles to improve boundary transfer capability and to maintain future system strength. This investment had previously been recommended for completion by 2026 through the NOA process. Following its review of SPT's Business Plan, Ofgem allowed baseline funding for the Eccles H-SC. SPT also proposed expenditure of £155m on SC at 3 sites to address net-zero operability challenges. In its RIIO-T2 determinations, Ofgem acknowledged the need for intervention but raised concerns on the impacts of the proposals on other markets including the Stability Pathfinder process. Ofgem did not allow baseline funding for the SC but noted that SPT could bring forward funding requests for SC through the MSIP re-opener where NGESO confirms a need for works. Other points in respect of costs include the following. **Overall Cost-Benefit** - The broader cost benefit analysis carried out as part of the Phoenix commercial work has demonstrated that H-SC can prove a net benefit in meeting specific GB network requirements. If a TO were to propose installing SC or H-SC, it would carry out investment analysis to ensure that the benefits outweighed costs. **Access to Asset Benefits** - If the SC / H-SC is installed as a regulated asset and is made available to NGESO for system management, then it is likely that the full range of SC / H-SC benefits (voltage support, inertia, system strength) can be accessed. However, specific requirements for levels of asset availability may help ensure the assets are available for system management when required and to avoid the NGESO incurring additional balancing services costs. **Efficient Connection Costs** - In connecting the SC / H-SC, the TO will have access to available substation sites and may be able to optimise the location of the assets to maximise network contribution and limit connection costs. **Risk of Stranding** - An SC / H-SC is likely to be remunerated over a 20-40 year lifetime if it is installed as a regulated asset. If the local requirements change such that the need for voltage support, inertia and system strength are reduced, then the value of the H-SC may be diminished over time. **Running Costs** - There will be ongoing costs to maintain and operate the assets (including power losses incurred by the equipment) that will need to be met over time.
Q2 - Could SC / H-SC deployment allow parties to	The deployment of SC / H-SC as regulated assets by a network company should not lead to the network company having an unfair competitive

gain unfair competitive advantage?	advantage in the provision of services. The SC / H-SC would be part of the regulated asset base of the network company and would not be competing to provide services tendered for by NGESO. However, as noted in the discussion of question 4 below, given their asset life, the wide-scale installation of SC / H-SC could rule out the use of other innovative solutions to stability challenges that are being developed.
Q3 - Are there impacts on other commercial services or incentive arrangements? Would the deployment of SC / H-SC adversely impact other stakeholders including parties that are already providing services to help manage the electricity network?	**Impacts on Existing Service Arrangements** - The installation of SC / H-SC as regulated assets would reduce the requirements to seek commercial services for voltage, inertia and system strength. For example, if many assets were installed by a TO in a particular area, wider voltage and system strength services may no longer need to be procured. **Impacts on Existing Service Providers** - The installation of SC / H-SC as regulated assets would reduce the opportunities for other parties to provide services and innovate new solutions.
Q4 - Do the impacts change with larger numbers of SC / H-SC?	**Small-Scale Deployment** - If only a small-scale deployment of SC / H-SC is carried out, then the wider impacts on the need for other services are likely to be small. (e.g. the inertia benefits of a small number of H-SC such as that installed at Neilston would have a negligible impact on the wider GB requirements for inertia.) **Large-Scale Deployment** - If a larger deployment of SC / H-SC is carried out, then the impacts are likely to be greater. For example, a large-scale deployment of SC / H-SC in a particular area could remove the need for other voltage or system strength services to be provided locally. (e.g. the installation of three larger H-SC in the south west of Scotland would provide significant system strength benefits to the GB network.) In addition, as the assets would be in situ for over 20 years, further solutions may not be required for that period ruling out the use of other innovative solutions.
Q5 - How quickly can the SC / H-SC benefits be accessed?	**Deployment of Assets** - If TOs take forward the installation of SC / H-SC, they may be able to install assets at available connection sites relatively quickly without the need for a connection application process or a commercial tender. In practice, there are often a limited number of sites where connections can be achieved quickly and less expensively.

In summary, if SC / H-SC are deployed as regulated assets, then the key impacts on existing balancing schemes and markets are:

1) SC have already been deployed internationally to address system imitations and to enable the increased connection and operation of renewable resources.
2) The installation of SC / H-SC as regulated assets wouldn’t create an unfair competitive advantage in the provision of services but, depending on the volumes of SC / H-SC installed as regulated assets, the requirements to procure existing voltage and stability services would be reduced.
3) As the SC / H-SC would be in place for >20 years, there is a risk that the value of the assets could be diminished if system conditions change over time.
4) If many SC / H-SC assets were to be installed, the need for other solutions that are being developed to address stability requirements would be reduced.

5.4 Deployment through the NOA Process

Description Installation of an asset by a network company or a third party to meet a NOA recommendation.	
Question	Discussion
Q1 - Would SC / H-SC deployment help enable net zero targets or reduced costs for electricity consumers?	Given the recommendation of an H-SC based solution at Eccles through the 2019/20 and 2020/21 NOA processes, H-SC installation has been shown to be a cost-effective means to increase transmission boundary capability. By increasing boundary transfers, H-SC will reduce generation curtailment and enable increased levels of renewable resources to operate. Other points in respect of costs include the following. **Overall Cost-Benefit** - The broader cost benefit analysis carried out as part of the Phoenix commercial work has demonstrated that H-SC can provide a net benefit in meeting specific GB network requirements. **Access to Asset Benefits** – Following a NOA process, if the SC / H-SC is remunerated as a regulated asset and is made available to NGESO for network management, then it is likely that the full range of SC / H-SC benefits (voltage support, inertia, system strength) will be accessible. Likewise, if the SC / H-SC were to be installed by a third party through the Early Competition arrangements that are being developed, then the contract arrangement that would be entered into following the tender process could ensure access to the required range of SC / H-SC benefits. **Efficient Connection Costs** - In offering an SC / H-SC as a solution to a capacity shortfall identified by the NGESO, the network company would have considered connection aspects. The network company should be able to optimise the location of the SC / H-SC in respect of optimising network contribution and limiting connection costs. To help enable third parties to achieve efficient connections, information on available connection options may need to be provided, and connection agreements may need to be integrated with the contract arrangement. **Risk of Stranding** - An H-SC is likely to be remunerated over a 20-40-year lifetime if it is remunerated as a regulated asset. If the local requirements change, then the value of the H-SC may be diminished over-time. **Running Costs** - There will be ongoing costs to maintain and operate the assets (including power losses incurred by the equipment) that will need to be met over time.
Q2 - Could SC / H-SC deployment allow particular parties to gain unfair competitive advantage?	The deployment of SC / H-SC by a network company or third party through the NOA process should not lead to that party having an unfair competitive advantage in the provision of services. The SC / H-SC would be deployed to meet a specific network requirement and would not be competing to provide services tendered for by NGESO.
Q3 - Are there impacts on other commercial services or incentive arrangements? Would the deployment of SC / H-SC adversely impact other stakeholders including parties that are already providing services to help manage the electricity network?	**Impacts on Existing Service Arrangements** - The installation of SC / H-SC to meet a specific NOA requirement would reduce the requirements to seek commercial services for voltage, inertia and system strength. **Impacts on Existing Service Providers** - The installation of SC / H-SC to meet a NOA requirement would reduce the opportunities for other parties to provide services.

Q4 - Do the impacts change with larger numbers of SC / H-SC?	The requirements identified via the NOA process are identified on a boundary specific basis and the large-scale deployment of a specific technical solution such as SC / H-SC is less likely to be carried out.
Q5 - How quickly can the SC and H-SC benefits be accessed?	**Deployment of Assets** – The timing of the SC / H-SC installation via the NOA process would be weighed up as part of the recommendation. If the SC / H-SC cannot be deployed sufficiently quickly, other options may be preferred.

In summary, if SC / H-SC are deployed through the NOA process, then the key impacts on existing balancing schemes and markets are:

1) Deployment of SC / H-SC to address system boundary limitations should enable the increased connection and operation of renewable resources.
2) The deployment of SC / H-SC by a network company or third party through the NOA process should not lead to that party having an unfair competitive advantage in the future provision of services.
3) Where SC / H-SC are installed as the result of a NOA recommendation, the requirements to procure existing voltage and stability services would be reduced in those areas.
4) There is a risk that the value of the assets could be diminished if system conditions change over time.
5) The funding of assets proposed and taken by non-TO parties has yet to be resolved. This may be addressed through ongoing developments including the Early Competition Plan.

5.5 Deployment through Stability Pathfinder

Description Installation of an asset to deliver a Stability Pathfinder service.	
Question	Discussion
Q1 - Would SC / H-SC deployment help enable net zero targets or reduced costs for electricity consumers?	The provision of services through Stability Pathfinder is intended to improve electricity system stability and enable the improved system operation with increased levels of renewable resources. Other points in respect of costs include the following. **Overall Cost-Benefit** - The cost benefit analyses carried out to underpin the Stability Pathfinder tender and contract award process would ensure that contracts were only placed where SC and H-SC would provide a net benefit (from a cost and effectiveness perspective) in meeting specific GB network requirements. As part of the contract award process, SC / H-SC options would be compared to other tendered solution options. This should help ensure that they are only taken forward where they are the best option. **Access to Asset Benefits** – The Stability Pathfinder contract provisions would ensure that the required range of benefits of value to NGESO for network management (e.g. voltage support, inertia, system strength) could be accessed. **Efficient Connection Costs** - The costs of connecting SC and H-SC would be accounted for in the contract costs. The Stability Pathfinder requirement would highlight preferred locations and information on potential connection sites could be made available to tenderers to help ensure efficient proposals are developed. **Risk of Stranding** - The contract period would cover a firm requirement for services. If the local requirements changed after this period such that the SC / H-SC was no longer required than further costs would not be incurred. If local services continued to be required after the initial contract, then it is likely that the SC / H-SC could be tendered for a further contract. **Running Costs** - There will be ongoing costs to maintain and operate the assets (including power losses incurred by the equipment) that will need to be met over time. (For Stability Pathfinder Phase II these costs are to be borne by service providers i.e. not reimbursed by NGESO.)
Q2 - Could SC / H-SC deployment allow particular parties to gain unfair competitive advantage?	Where network companies are competing to provide services through the installation of SC / H-SC, potential conflicts of interest can be raised where third parties are also seeking to connect assets at possibly the same location to provide services. Concerns have been raised by some commercial service providers that TOs have an advantage through access to connection sites and through having better information on where to locate assets compared to third party providers. However, there is no evidence that TOs have used such information to gain an advantage in the Stability Pathfinder Phase 1 process. In addition, TOs have existing license obligations not to discriminate in the provision of connections.
Q3 - Are there impacts on other commercial services or incentive arrangements? Would the deployment of SC / H-SC adversely impact other stakeholders including parties that are already providing	**Impacts on Existing Service Arrangements** - The use of SC / H-SC via the Stability Pathfinder solution would avoid separate arrangements being put in place to secure voltage and system strength services. **Impacts on Existing Service Providers** - All parties that fulfil the eligibility criteria of the Stability Pathfinder service that are able to provide voltage, inertia and system strength services at present would be able to tender services via Stability Pathfinder. To determine eligibility, the service

services to help manage the electricity network?	includes an "additionality" criterion which excludes existing assets that are already providing SCL and/or inertia.
Q4 - Do the impacts change with larger numbers of SC / H-SC?	The overall services requirements for an area and a duration would be tendered for. It is likely that a mix of different providers would be offered and taken forward. Where SC / H-SC are successful in Stability Pathfinder tenders, as they are long-life assets, they could be tendered for future stability service contracts in the same or different areas of the network. As the capital costs for asset procurement and installation would already be sunk, these existing assets could have some cost advantage over other solutions that were being developed. (The treatment of any residual value of long-life assets is being further considered as part of Stability Pathfinder.)
Q5 - How quickly can the SC and H-SC benefits be accessed?	**Deployment of Assets** – If a new SC / H-SC is awarded a contract, this is likely to be in place around 18 months after contract award. This timescale might be reduced if existing assets can be relocated. Where there are existing assets already in situ, benefits can be accessed straight away. Achieving a network connection is likely to be the limiting factor on timescales. If connection aspects can be considered as part of the tender process, such that options for quicker and less expensive connection can be identified, then both TOs and third commercial providers should be able to provide earlier access to benefits.

In summary, if SC / H-SC are deployed through the Stability Pathfinder process, then the key impacts on existing balancing schemes and markets are:

1) Sufficient services would be deployed to meet foreseeable requirements. SC / H-SC would be compared to other tendered solutions.
2) The Stability Pathfinder process is likely to greatly reduce the requirement to procure further voltage and stability services in the relevant area until the end of the contract period.
3) The deployment of long life assets such as SC / H-SC through Stability Pathfinder could allow the same assets to be tendered for further stability contracts.
4) There are some concerns that TOs participating in Stability Pathfinder could have a competitive advantage compared to third party providers through having better information on network requirements and through having better access to available connection sites.
5) Existing assets that are already providing capability are not eligible to compete to provide services.

6. Conclusions

This section notes conclusions relating to balancing schemes and markets based on the discussion in the earlier sections.

<u>Conclusions on H-SC Benefits</u>

The H-SC provides system benefits which will become of increased importance as the sector continues its transition to lower carbon forms of generation and demand:

1. Both the SC and STATCOM elements of the H-SC could provide steady state reactive power support and dynamic reactive power support.
2. The short circuit contribution from the SC would improve the fault level of the system and hence the system strength.
3. The inertia contribution from the SC will improve the system inertia, that could improve the system stability limit and the system frequency response.

System study results based on H-SC installation at Neilston location have been presented in the SDRC 2.2 report entitled "Cost Benefit Analysis of SC and H-SC based on System Studies". Further study works based on multiple H-SC in future potential sites in GB system will be reported in SDRC 2.6.

H-SC can provide an alternative approach to provide system stability services which can operate alongside other assets and service providers in managing system stability. The use of H-SC adds to the options currently available to the ESO.

As yet, the H-SC studies and trial haven't demonstrated particular system benefits that suggest H-SC should be widely deployed ahead of other solutions. The Neilston H-SC trial will continue to October 2021 and will provide further data as to the effectiveness and usage of the device on the network during operational conditions on the system. If results of the trial indicate that there may be further benefits, these will be reported in later Phoenix project deliverables.

<u>Existing Routes to Market for SC / H-SC</u>

Since the Phoenix project was initiated, new GB commercial arrangements to address voltage and system stability requirements have developed. SC / H-SC can already be deployed through existing regulatory and commercial arrangements, including the NOA process that has been developed to recommend options for increasing system power transfers and through Stability Pathfinder tenders to address system strength and inertia requirements. Both these options require SC / H-SC to be cost effective against other technology options. Using these deployment routes, SC / H-SC can be deployed (connected) and operational in the timescales required by the system.

As there are existing and effective routes to market for SC / H-SC, a further commercial mechanism to support SC / H-SC deployment is not needed. SC / H-SC are being proposed within the existing mechanisms and there is no evidence that their deployment is detrimentally affecting existing balancing schemes or service providers. The existing mechanisms look to ensure that a range of technical solutions can be considered to meet system needs. If these mechanisms are operated so that a range of providers can offer services, then SC / H-SC solution will be compared on a level playing field with other potential solutions to voltage and stability challenges. At this stage, it seems unlikely that a range of solution will be offered and the GB network will not become over reliant on a particular technology.

Effective functioning of services will require the ESO to be transparent on system requirements, both now and in the future to optimise deployment at the optimal location on the grid. Some adjustments to deployment approaches may also be required and these will be further considered when the pros and cons of the different ways in which H-SC and SC may be accessed are considered in the report for the Phoenix commercial deliverable SDRC 2.7.