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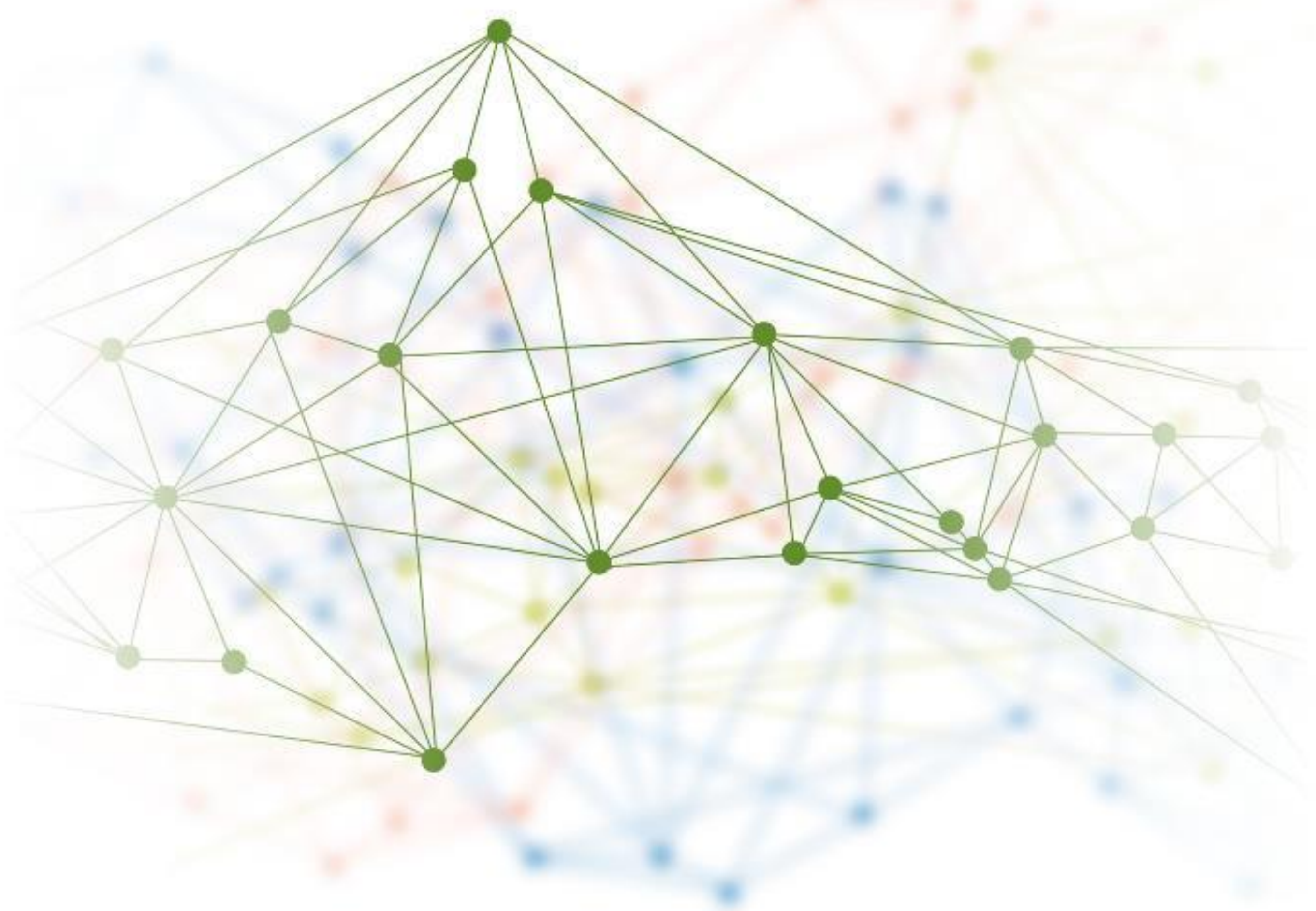
Report on regulatory considerations for future roll-out of SC and H-SC.



About Report	
Report Title	: **Report on regulatory considerations for future roll-out of SC and H-SC**
Report Status	: Final
Project Reference	: Commercial Deliverable SDRC 2.7
Date	: Final report to be completed by 14/05/2021

Report Progress		
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Report History

Date	Issue	Status
22nd December 2020	Version 1	Initial draft report.
11th January 2021	Version 2	Working copy for Phoenix Team. Updates to working copy for review meeting on 6/1/21
14th January 2021	Version 3	Draft report including initial conclusions / recommendations for SPEN review
12th April 2021	Version 4.7	Final version to be signed-off by NGESO before submission to SPEN
14th May 2021	Version 5.0	FINAL approved version to SPEN

Contents

1. Introduction

This document reports the work to deliver Successful Delivery Reward Criteria (SDRC) 2.7 for the Network Innovation Competition (NIC) Phoenix Project. SDRC 2.7 encompasses a report on regulatory considerations for the future roll-out of Synchronous Condensers (SC) and Hybrid Synchronous Compensators (H-SC) assets.

1.1. Introduction to SDRC 2.7 and Regulatory Considerations

Great Britain (GB) electricity system operation and the commercial services that support its operation are undergoing great change as energy balancing, frequency and voltage management become more complex with fewer synchronous transmission connected generators.

It is expected that the need for system inertia and other grid services will further increase over the next few years and different ways in which these services might be provided are being considered. National Grid as GB's Electricity System Operator (ESO) is reviewing the range of services that it procures to support system balancing and operation. For example, National Grid Electricity System Operator (NGESO) is developing mechanisms to provide system strength services through its stability pathfinder initiative[1].

Against this background of developing system needs and developing GB electricity markets, this report assesses the regulatory changes that require consideration to support the use of Hybrid Synchronous Compensators (H-SC), Synchronous Condensers (SC) and similar options. Such devices could provide a range of benefits to power systems including voltage support, inertia and system strength. To access these benefits efficiently, different regulatory and ownership arrangements are considered. For example, H-SC could be installed and owned by Network Companies and could be used in a similar way to other reactive compensation equipment. Alternatively, they could be developed and installed by Third Parties to provide services.

This report has been developed with input from the Commercial Working Group (CWG) set up to support the Phoenix project. The report is also informed by the results of system studies and the results of the H-SC trials at the Neilston transmission substation to verify what system benefits the H-SC is providing.

1.2. Key elements of SDRC 2.7 Scope

The work envisaged for SDRC 2.7 anticipated that appropriate ownership and regulatory models may be needed to access H-SC value. The ongoing work to develop balancing services is important in understanding ownership models as is the likely extent of H-SC and SC development and deployment. For example, the numbers of H-SC and SC opportunities might favour different regulatory solutions.

The key elements of this part of the Phoenix commercial work includes:

- Understanding the extent of the system benefits that might be delivered by H-SC or SC.
- Comparing options including Network Company ownership, Third Party development, procured commercial services and other approaches.
- Identifying and recommending any changes to regulatory arrangements to ensure fair and effective use of H-SC & SC.

1.3. Report Structure

The remainder of the report is structured as follows:

- Section 2 summarises the GB system requirements, developing technologies and the potential benefits through the deployment of H-SC (and SC);
- Section 3 addresses regulatory considerations relating to H-SC (and SC) capability, and considerations relating to the deployment of H-SC (and SC) on the GB transmission network;
- Section 4 includes conclusions and recommendations.

[1] https://www.nationalgrideso.com/future-of-energy/projects/pathfinders/stability

2. GB system requirements and potential benefits from H-SC

The requirements for assets and system services to support GB electricity system operation are changing as energy balancing including frequency and voltage management become more complex. Traditional large-scale thermal generation is declining, replaced by distributed generation and investment in low-carbon technologies. This transition creates challenges for system operation:

- Lower system inertia has caused 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 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.

Balancing services are services procured by NGESO to balance demand and supply and to ensure security of supply across the GB'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 managing system frequency. These are services that have been made available by providers or contracted for ahead of time to be available at certain periods to support system balancing. The services previously procured by NGESO have included frequency response services, reserve services, reactive services, constraint management and system restoration services. Recently, new services to help ensure system stability have also been developed and introduced. These new services look to increase levels of system inertia and short circuit levels[3].

As well as the seeking new services from market participants, the operability challenges brought about by the reduction of synchronous generation, are being addressed through other approaches including research into new technology types. Innovation projects such as Phoenix will allow NGESO and industry stakeholders to understand alternative sources/solutions which may provide grid stability. The Phoenix project is demonstrating a sustainable design, deployment and operational control of a Synchronous Condenser and a Static Compensator (STATCOM) using an innovative hybrid co-ordinated control system[4].

2.1. Hybrid Synchronous Compensator (H-SC)

The Phoenix H-SC device consists of a 70 Megavolt amperes (MVA) SC and a 70 MVA STATCOM connected through a single three-winding transformer, with an innovative hybrid control mechanism to optimise the benefits of the 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 improve the short circuit level (SCL) of the system and hence the system strength. Increased system SCL could improve the operation of Phase Locked Loop (PLL) controllers and enable HVDC converters to correctly reference system phase changes. Decreases in SCL could impact the operation of protection devices and increasing SCL using H-SC 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. Higher system inertia would improve the RoCoF values and frequency nadir following any system event and could reduce the amount of generation to be constrained to keep RoCoF and frequency within acceptable limits.

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

[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.
[3] https://www.nationalgrideso.com/future-of-energy/projects/pathfinders/stability
[4] https://www.spenergynetworks.co.uk/pages/phoenix.aspx

At this time, only early learnings from the Neilston trial have been included in the report. Further learnings from the trial will either be included in an update to this report or captured in the report for commercial deliverable SDRC 2.4 covering the pilot installation and performance.

3. Regulatory Considerations

3.1. Specific Value Provided by H-SC

The report on Cost Benefit Analysis (CBA) of SC and H-SC (SDRC 2.2 report)[5] and the report on the potential wider roll-out of SC and H-SC (SDRC 2.6 report) have shown that H-SC can provide cost effective solutions to meeting network requirements by improving network boundary capability, system inertia and system strength.

However, the benefits that have been assessed from H-SC compared to discrete SC and STATCOM solutions have not yet been shown to be substantial. The use of H-SC compared to other comparable solutions is discussed as follows.

H-SC vs Co-located SC & STATCOM

If H-SC are compared with discrete co-located SC + STATCOM solutions, the characteristics of H-SC that make them more attractive could be:

i) Capital Cost – for the H-SC, its three-winding transformer configuration can give it a cost advantage compared to a discrete SC + STATCOM solution of similar capacity which would require two transformers and additional switchgear. (For the Neilston H-SC, this benefit was around £3m.) However, this cost advantage is relatively small compared to the other costs and benefits which may arise through transmission boundary limitations or other system constraints.

ii) Running Costs –The H-SC master controller has a Power Loss Minimisation (PLM) function to reduce power losses by allocating the loading of SC and STATCOM branches appropriately. In the Phoenix device, the SC and STATCOM ratings are the same (70MVA SC and 70MVA STATCOM). For this configuration, the reactive power sharing remains almost equal using the PLM function and no significant reduction in power losses has been observed. For other configurations of H-SC, with a higher rating of STATCOM than SC, it may be possible to reduce H-SC power losses using PLM.

iii) Improved Response Time - the H-SC master controller has a Fast Transient Compensation (FTC) function which improves the performance of H-SC in terms of rise time and settling time, compared with the performance of H-SC without FTC. The performance of H-SC with FTC provides a faster response when compared with a standalone SC. However a standalone STATCOM provides a quicker response when compared to the H-SC with FTC.

iv) Control Flexibility – As yet, we have not seen evidence that the H-SC master controller flexibility will provide additional value, however this may become apparent through the Neilston trial.

H-SC vs Non Co-located SC & STATCOM

If H-SC are compared with solutions where SC and STATCOMs are installed in different locations, depending on the system requirements at those locations the separate SC and STATCOM solutions can be more effective. Whilst the benefits of having the H-SC control scheme would be lost, there are locations where SC characteristics are more important and locations where STATCOM characteristics are more important.

As an example, the wider system studies for Scotland indicate that SC capability might be more relevant on the western side of the network if additional fault infeed is needed to support operation of the Western HVDC cable. On the eastern side of the network, the studies indicate that voltage stability is often the key issue limiting system capability. This requirement for voltage stability can be as efficiently met by the provision of a STATCOM solution, provided wider system strength is maintained to meet future network requirements.

[5] https://www.spenergynetworks.co.uk/userfiles/file/Phoenix_-_Cost_Benefits_of_SC_and_H-SC_Based_on_System_Studies.pdf

H-SC may provide some additional flexibility compared to discrete solutions. For example, if the system conditions change in Scotland over time, the SC element of an H-SC may become more beneficial on the eastern side of the network when the system strength requirement increases. Similarly, the STATCOM element of an H-SC may become more beneficial on the western side of the Scottish Power Transmission (SPT) network when the dynamic reactive power requirement increases.

Ultimately, the selection of a solution can be finely balanced. For example, the installation of H-SC at Eccles by 2026 has been recommended through the 2019 and 2020 NOA processes and has been included in the SPT RIIO-T2 plans. As well as improving the Anglo-Scottish B6 Boundary capability, the H-SC solution has been proposed to improve system strength.

H-SC v Other Potential Solutions

The costs and benefits of H-SC against other solutions (e.g. synchronous generation development[6] or battery storage) have not been compared. The conclusions focus on comparing H-SC with SC and STATCOM solutions.

H-SC Control Modes

The Neilston H-SC has been equipped with control functions including Power Loss Minimisation (PLM), Inertia Support Maximisation (ISM) and Fast Transient Compensation (FTC). These control functions are further described in section 3.2 of the report for SDRC 2.5 (Impact of SC/H-SC on existing balancing schemes and markets). From the results to date the three control functions work with the FTC likely to be of most benefit to system operations.

Further Consideration of H-SC

In summary, the assessment to date has shown that H-SC can provide effective solutions to system stability challenges. In particular, in areas where there are multiple challenges such as a need for increased voltage stability and increased short-circuit level, H-SC provide a cost-effective means to achieve this. In other situations, where specific requirements need to be met, other solutions may be just as, or more effective.

Given that GB system requirements could change quickly as net-zero targets are pursued, it has been identified by the Phoenix CWG that an H-SC option that can be deployed quickly would be a useful option where time is constrained.

The recommended technical specifications[7] of a H-SC device are being developed and will be reported in SDRC 8.2 (Report on emerging technical standards for SC). The provision of this technical specification for H-SC will help ensure that where H-SC can provide an effective solution, the design and procurement can progress quickly.

[6] Generation could be developed to provide infeed or inertia at lower levels of generated MWs.

[7] The technical specification for the H-SC will help ensure that the H-SC will perform adequately under normal and abnormal system conditions when connected to the transmission network. This technical specification should not be confused with the functional requirements for a commercial system service (e.g. Stability Pathfinder).

3.2. Pros & Cons of Existing Routes to Market

There are three existing approaches to deployment (routes to market) that have been identified for SC and H-SC. These are i) deployment as a regulated asset to meet Transmission Owner (TO) licence requirements, ii) deployment through a Network Options Assessment (NOA)[8] recommendation, and iii) deployment through the Stability Pathfinder Process[9].

In considering the different approaches, it is helpful to consider the possible roles for key parties including NGESO, TO and Third Party service providers. These are summarised below in Table 1.

Table 1 Possible Roles for Parties in Providing Stability Services

NGESO Roles & Accountabilities	TO Roles & Accountabilities	Third Party Roles & Accountabilities
• Identify transmission system requirements. • Form holistic view of requirements. • Provide signals to markets on what services are required. • Facilitate "level playing field" for competition to provide services.	• Install and maintain cost effective assets to provide stability services. • Ensure assets are available when required by ESO. • Provide efficient network connection for assets providing stability services. • Perhaps be a fall-back provider of services if the market falls short.	• Install and maintain cost effective assets to provide stability services. • Ensure assets are available when required by ESO.

The pros and cons of the existing approaches to deployment are tabulated below. Particular concerns on the different approaches, including those raised by CWG members, are noted after each table.

i) Deployment as a Regulated Asset to meet TO Licence Requirements

Regulated Asset to meet Standards

Place requirements on transmission network owners (TOs) to maintain minimum levels of system capability and performance (e.g. voltage limits, system strength). For example - In Australia, AEMO sets levels of system strength & inertia that TOs need to deliver. Where a TO installs SC or H-SC to help deliver these requirements, these assets would be treated as other long-life transmission assets. The costs of the SC or H-SC would be recovered through the TO's allowed revenues as set through their price control processes.

GB Context	Pros	Cons
The Security and Quality of Supply Standards (SQSS)[10] requires TOs to deliver minimum levels of network performance. Further requirements could be put in place relating to system strength, local inertia. TO owned assets, including SC and H-SC, would provide a base line level of inertia / system strength. Where additional inertia / system strength services are required, NGESO could tender for these. As part of its RIIO-T2 investment plan, SPT proposed installation of two H-SC at Eccles to improve boundary transfers and to maintain future system strength. SPT also proposed SC at three sites to address net-zero operability challenges. RIIO-T2	Adequate system strength & system inertia would be ensured over time through the connection of equipment such as SC or H-SC. Wider system benefits that the SC / H-SC can provide can be considered when comparing potential asset solutions. Assets can be deployed quickly as TOs can act quickly to implement the reinforcement without a process to describe and contract for a commercial service. If potential connection sites are available at existing TO sites, then TOs would be able to locate the assets at sites where the connection works are straightforward, and where the assets can be effective.	If SC or H-SC are provided only in this way, parties other than TOs don't compete to provide the capability. It may be that the provision of capability is not the most economically efficient. SC / H-SC assets are likely to be remunerated over their technical asset lives (>20 years). If network requirements change over time, the assets may no longer be required. Whilst TOs seek to provide high levels of asset availability and have reporting requirements in place for asset availability, defined requirements for asset availability are not currently in place for regulated assets. If SC / H-SC assets are out of service when needed (e.g. due to

[8] https://www.nationalgrideso.com/research-publications/network-options-assessment-noa
[9] https://www.nationalgrideso.com/future-of-energy/projects/pathfinders/stability
[10] https://www.nationalgrideso.com/industry-information/codes/security-and-quality-supply-standards

baseline funding was agreed by Ofgem for the two Eccles H-SC.	Use of the TO's SC and H-SC assets would be available to NGESO at no further cost.	breakdown), the ESO may need to procure additional services.

Further discussion of Regulated Asset Deployment

The deployment of H-SC and SC by TOs provides a means to address system stability limitations that can be implemented relatively quickly. A well developed H-SC solution that can be deployed quickly would be a useful tool to address stability challenges in some instances. However, the widescale deployment of assets in this way would not allow the benefits of competition in the provision of solutions.

In its RIIO-T2 determinations, Ofgem were satisfied that the need for SPT's proposed H-SC at Eccles was clear, in part because this solution had been compared with other options through the NOA process. In respect of the proposed SC installations at three sites to address net-zero operability challenges, Ofgem acknowledged the need for intervention but raised concerns on the impacts of the proposals on other markets including Stability Pathfinder. Ofgem did not allow baseline funding for the SC but noted that SPT could bring forward funding requests for SC through the Medium Sized Investment Project (MSIP) re-opener.

As well as losing the opportunity for competition in the provision of stability solutions, concerns have been raised that the wide-scale provision of H-SC or SC as regulated assets would commit GB to a long term solution that may not allow other more efficient solutions to be developed and implemented.

ii) Deployment through independent comparison of options and recommendation (e.g. NOA)

Identify Needs, Review Options, Select Preferred Options (e.g. NOA)

In GB, the NOA process has been developed by NGESO to compare network owner and Third Party options for boundary transfer requirements. Similar processes are used elsewhere. For example - In the USA, regional ISOs operate planning processes that compare options and take forward solutions. This model has resulted in the delivery of transmission reinforcement including SC in California and in Texas. In theory, the provider of the transmission reinforcement could be a Network Company or another party. In GB, whilst the NOA process allows Third Party options to be proposed, the funding of these options requires confirmation.

GB Context	Pros	Cons
In NOA, NGESO identifies requirements for further network capacity to increase boundary transfers. TOs and other parties can then bring forward options to provide this capacity. For the 2020/21 NOA, the Interested Persons' Options process was introduced to enable non-TO options to be assessed. NGESO is also developing an Early Competition Plan to identify those projects that can be competed for by other parties as well as TOs. In the 2019/20 NOA process, installation of an H-SC based solution at Eccles (proposed by Scottish Power Transmission) was recommended as a solution to increase Anglo-Scottish	The NOA model already allows implementation of H-SC solutions by TOs. The process is being developed to enable other parties to bring forward proposals for assessment. The solutions recommended through the NOA process should be relatively efficient as the requirements for additional capacity are being centrally assessed, and proposed options are being compared by NGESO. In assessing options, H-SC and SC solutions can be compared to other options and the longer-term costs and benefits can be considered.	To date, NOA has addressed system boundary transfer requirements rather than inertia and system strength. The NOA assessment would not factor in the benefits of any inertia or system strength provided by a solution. NOA and similar processes are complex and time consuming relying on the annual identification, scoping and assessment of ongoing requirements. In addition, a NOA recommendation does not provide certainty that a solution is progressed as requirements are reviewed year on year. As yet, there are no mechanisms for Third Parties to deliver and be funded for proposed options. NGESO and Ofgem are

boundary capability. The Eccles proposal was revaluated as part the 2020/21 NOA process and continues to be recommended for installation by 2026.		considering how Third Party options might be funded. In the medium term, Early Competition arrangements may establish the future mechanism.

Further discussion of Network Options Assessment

The NOA process provides a means for TOs and other parties to propose solutions to increase transmission boundary capabilities. As evidenced by the assessment and recommendation of the proposed Eccles H-SC, NOA provides a route for H-SC to be deployed on the GB network.

One limitation of the NOA process is that it is focussed on boundary capability and so it does not take account of other benefits that solutions might deliver. For example, the H-SC at Eccles will increase transmission boundary transfer capability by addressing voltage stability limitations, but the full potential of the solution to improve system stability through the provision of increased system inertia or short circuit infeed is not valued.

Another limitation of NOA is that currently there are no established mechanisms for funding Third Party solutions. 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 MSIP mechanism in the case of SPT or SHET (and also NGET where the IWW does not apply). However, if other industry parties bring forward options to meet NOA requirements, and these options are recommended, there is no mechanism in place to fund the recommended options. Going forward, the Early Competition Plan[11] being developed by NGESO may provide a means for funding such works when this is finalised.

iii) Deployment as solutions for Commercial Tendered Services (e.g. Stability Pathfinder)

Identify Requirements and Tender for Services

In GB, specific, time limited requirements for inertia and system strength have been identified by NGESO and solutions have been sought through the Stability Pathfinder. This is seen as a development of the NOA process to provide solutions to address system strength and system inertia. The Stability Pathfinder Phase 1 and Phase 2 processes have involved technical and commercial phases to identify effective solutions.

GB Context	Pros	Cons
In Stability Pathfinder Phase 1, requirements were identified for a five year period beginning in April 2021. Successful tenders have included existing generators adapted for SC use and new SC. For Stability Pathfinder Phase 2, further requirements for Scotland have been identified. The service would begin in April 2022 and would continue for eight years until March 2030. The requirements are being set to enable the participation of different technology solutions.	SC were successfully tendered for Stability Pathfinder Phase 1. Different technical and commercial solutions can be compared, and the most cost effective can be taken forward. Third Party providers are able to compete to provide solutions. The contract period can be matched to the period for which the service is required. This can help avoid particular solutions becoming outdated over time.	The need for new connections to transmission networks may limit tendered solutions. Improved information on connection sites could improve the effectiveness of Third Party tenders. Potential conflicts of interest can arise for Network Companies with regard to information and connections. Existing generators are not eligible to provide services through Stability Pathfinder. The tender processes for Stability Pathfinder Phase 1 and Phase 2

[11] https://www.nationalgrideso.com/future-energy/projects/early-competition-plan

	Availability requirements for the services are set in the contracts and payments are linked to this.	have taken time to be established. The technical lives of new assets are likely to be longer than contract periods.

Further discussion of Stability Pathfinder

Stability Pathfinder has been effective at sourcing additional stability services from commercial providers. A wide range of providers tendered solutions for Stability Pathfinder Phase 1 and different technical solutions are being provided including new SC and the conversion of previously retired generation plant to SC operation. For Stability Pathfinder Phase 2 to procure short circuit level, inertia and dynamic voltage services in Scotland, the Expressions of Interest phase closed on 8th January 2021. Twenty-nine different parties offered over 1500 different options for assessment including solutions based on synchronous machines, grid forming converters and hybrid arrangements including SC and battery storage systems[12].

Going forward, Stability Pathfinder appears to offer an effective means to address network requirements for system inertia and system strength services. However, some concerns have been raised around Stability Pathfinder including potential conflicts of interest for TOs, the eligibility of existing in-service assets to provide services, the time taken to source services and the mismatch of technical asset lives to contract periods. These are further discussed below.

On potential conflicts of interest, there are concerns that TOs will have better information than Third Party providers on where to connect assets most cost effectively. In addition, both TOs and Third-Party providers may be seeking to provide solutions at locations where there are limited connection opportunities. From the TO perspective, there are already licence obligations to help manage conflicts of interest. TOs have existing obligations to facilitate competition and not to discriminate in the provision of new connections. However, if TOs are competing directly with commercial providers to provide Stability Pathfinder services through the provision of further assets, then additional steps should be taken to ensure that potential conflicts of interest are seen to be managed. For example, more suitable connection sites for new stability assets could be identified as part of the Stability Pathfinder information process, and network connection aspects could be considered outside the tender assessment. Another option would be for the TOs to separate the teams that review connection options from the teams that will participate in the tender process.

On the eligibility of assets to provide services, Stability Pathfinder is a service that is seeking to provide additional capability over that which is already being provided by existing assets. To determine eligibility for the Stability Pathfinder service, the service includes an "additionality" criterion which excludes existing assets that are not able to increase their SCL and/or Inertia capability from the levels they currently provide. The use of Stability Pathfinder as a "top-up" service for inertia and short circuit infeed has been criticised by parties that are not eligible to provide the service through existing assets due to the "additionality" criterion. These parties contend that they are providing equally valuable inertia and short circuit infeed without direct remuneration. In the medium term, parties with existing assets feel that the failure to access the Stability Pathfinder revenue stream could affect longer term operation of these assets.

On the lead time for accessing services, it has been argued that the provision of services through the Stability Pathfinder process will take longer than the provision of an assets by a Network Company. The information and tender processes for Stability Pathfinder are taking around 9 to 12 months to carry out and it is only after this period that a firm commitment is made to a service provider. In practice, after the award of Stability Pathfinder contracts in January 2019, new SC assets are being installed and should be operational by April 2021 such that the overall lead time for service provision is likely to be around 3 years. From the ESO perspective, so long as system requirements are identified well in advance, then the stability services should be available when required. Going forward, it is also anticipated that the

[12] https://www.nationalgrideso.com/document/187371/download

information and tender processes for future Stability Pathfinders will take less time as NGESO and participants become more familiar with the steps involved. Furthermore, the ESO is looking at developing a Stability Market whereby short-term requirements could be procured to compliment the longer term contracts under the Pathfinders.

On the mismatch of asset lives to Stability Pathfinder contract periods, this is likely to be managed by service providers in different ways. In setting their costs for providing the service, some service providers may seek to recover the full costs of new assets through the contract period. Other providers may assume that the asset will be able to provide further services after the contract period and so should have some residual value. However, in the latter case, providers are likely to recognise the risk that the residual value is not recovered. In either case, the costs tendered for Stability Pathfinder services are likely to be greater than would be the case if contract periods were more closely aligned to asset lives.

Potential Improvements to existing Routes to Markets

Potential improvements to the processes already used to deploy SC and H-SC assets are identified in Section 4 - Conclusions and Recommendations of this report. Before this, some wider aspects relating the accountabilities and ownership of stability assets are considered in Section 3.3, and possible alternative approaches to the deployment of SC and H-SC assets are considered in Section 3.4.

3.3. Further Issues in relation to Ownership

If H-SC (or SC) are being deployed, either through the NOA process or through a commercial tender such as Stability Pathfinder, they might be owned by either Network Companies or Third Parties. The ownership of H-SC (or SC) assets can result in differences as to how the costs of the assets are recovered and this makes direct comparisons between assets provided by Network Companies and by Third Parties more difficult. There are pros and cons of Network Company and Third Party ownership and these are summarised in the table below. The table also includes steps that might be taken to mitigate difficulties with the different models.

Attribute	Regulated Model (e.g. TO ownership)	Merchant Model (e.g. contracted services via Third Party)	Mitigation to improve Regulated or Merchant Models
Investment & Risk / Returns	• Regulatory returns help address future uncertainty and support investments. • Network owner decisions may be driven by short term regulatory targets. • For assets that are being remunerated over longer term timescales, there are risks of asset stranding if future conditions change. • End-consumers carry some risk of assets being ineffective.	• Merchant model introduces greater competition between options to meet specific requirements. • Size of investment and duration may mean that higher returns are necessary. • Stability contracts may be time limited and so carry less risk of ongoing costs for consumers. • Project developers and Investors carry greater risk.	Comparisons of regulated and merchant solutions are difficult given differences in i) how assets are remunerated, and ii) the length of regulatory asset lives compared to commercial contracts. Mitigation includes: • Longer term contracts for commercial services. • Depreciate regulatory assets more quickly. • Remunerate TO & Third Party assets in the same way.
Running Costs	• Additional costs could be incurred over time to repair or upgrade assets. • There may be potential for economies of scale through wider TO asset base (e.g. maintenance). • Energy losses are socialised.	• Running costs are part of tender assessment. • The need to run tenders and put in place contracts introduces some costs. • Energy losses are factored into contracts.	Ways to mitigate differences in how ongoing costs are incurred include: • Factor costs including energy losses into comparisons. • Consider whether some cost elements (e.g. charges) should be applied.
Accessing H-SC & SC Benefits	• When making investment decisions, the wider system benefits that the SC / H-SC can provide can be considered when comparing potential asset solutions. • Multiple benefits may be more accessible to ESO. (E.g. voltage, inertia don't require separate contracts.) • Asset availability is not set in a contract although regulatory reporting is in place to highlight poor availability. • If assets are needed outside normal system conditions, existing TO obligations would ensure they are made available for system support.	• Specific services may not utilise all the capabilities of H-SC / SC. • Different services can be stacked. • Asset availability levels are set in contracts. • The contract requirements for Third Party service providers ensure that assets will be made available. • Providers must also accede to the BSC and CUSC.	Ways to mitigate include: • Design services so that these can be stacked to access multiple system benefits and commercial opportunities. • Set availability requirements for regulated assets. • Monitor contract performance and if necessary, include further provisions in contracts to ensure that stability assets are made available.
Information	• Perception that Network Companies have access to additional information. (E.g. where to locate assets for increased system benefits.)	• Connection opportunities may be limited for Third Parties.	Ways to mitigate differences in information and connection opportunities include: • Make complete information available to all parties. • Look to separate connection aspects from comparisons.

Innovation	• Licence obligations & regulatory contracts can lead to more cautious approach?	• May be quicker to adopt new technologies and new approaches from different markets.	• Regulatory mechanisms support new approaches. For example, NIC funding has enabled early deployment of H-SC technology.

Some of the key challenges in respect of ownership arrangements are further discussed below.

- Regulated Asset Lives v Fixed Contract Periods

  Given that regulatory assets are typically remunerated over a much longer period compared to a contract for commercial services, direct comparisons of the costs and benefits of regulated and merchant solutions are not straightforward. If regulatory asset lives and contract periods are made similar in duration then comparisons are improved but, in practice, there is much less confidence in service requirements after 5-10 years in the future as other changes are likely to affect networks and/or system requirements.

  If H-SC or SC are installed by network owners as regulated assets, there is a risk of asset stranding given that the assets will normally be remunerated over a 20-40-year lifespan. Under the current GB regulatory model, this risk is shared by network owners and consumers through the Totex incentive mechanism. In some cases, this risk of asset stranding may be acceptable as the short to medium term benefits of securing a base level of system strength in an area might outweigh the longer-term risks of the asset not being required in the future. However, in other cases, if system conditions change, the H-SC or SC benefits may turn out to have been overestimated.

  Where a Third Party provides an asset for a fixed contract term, the risk of asset stranding is less as the contract period has been matched to the expected period over which the need for the service is more certain. The risk that the asset will not be required in the future is carried by the commercial service provider. However, where Third Parties provide assets for a commercial contract period (say 5-10 years), the full asset cost, or the risk that the assets will not be usable beyond the contract period, is likely to be priced into the contract cost in some way. It may be that the full cost of the asset is recovered over the contract period such that the service costs are increased. Alternatively, it may be that the service provider assumes that the asset will have some residual value following the contract period but factors in a risk premium to cover this.

  One way to mitigate longer term asset stranding risks is to utilise assets that are capable of being relocated in the future if system conditions change. If assets are relocatable then it is more likely that they would be able to be used elsewhere if future system conditions change.

- Comparing the Costs of Network (Regulated) and Third Party (Merchant) Solutions

  There are different exposures to costs (e.g. equipment energy losses, some elements of commercial charges, treatment of Final Consumption Levies) when a network solution is compared to a Third Party tendered solution. For Third Party solutions, costs also differ depending on whether a solution is classified as demand or generation and further clarity is required to understand the appropriate classification for H-SC and SC.

  To some extent these differences can be mitigated. For example, some costs such as losses can be factored into the tender assessment and the evaluation process to create a level playing field. For other costs, changes to charges might be considered. (These costs have been considered in the Mersey Voltage pathfinder. Regulatory/charging changes have been proposed for reactive services but do not currently apply to stability services.)

- Potential Conflicts of Interest for Network Owners

  If regulated network solutions are directly compared with Third Party solutions, then this can lead to conflicts of interest if the network owner is proposing a solution. For example, Network Owners will be to some extent involved in the facilitation of network connections for the Third Party solutions (e.g. the connection process). Whilst TOs already have licence obligations in place not to discriminate when providing connections, Third Party service providers perceive that they are at a disadvantage when putting forward solutions.

As it is in the overall consumer interest to locate solutions at the most effective sites, if Network Owner and Third Party solutions are being compared directly, it would be best to separate the connections aspects from the comparison process. One way to do this would be to identify and describe potential connection sites as part of the commercial tender process.

- Optimal siting of SC and H-SC

  Network Owners may be better placed to locate H-SC and SC more optimally as they may be able to identify those sites where H-SC and SC can be connected more cost-effectively whereas third parties may be limited in knowing what potential sites are available. Third party providers perceive that Network Companies have better information in respect of where to site assets to maximise value.

  A key challenge here may be how to make suitable connection sites and related information available to Third Party developers. (CWG members have highlighted information availability as a key factor). As in the discussion of Potential Conflicts of Interest above, if connection aspects can be separated from the comparison of Network Owner and Third Party solutions, this will help ensure that solutions are sited effectively as well as mitigating concerns about information disparities.

- Asset Utilisation (Flexibility & Availability)

  Whereas regulated assets can be fully utilised by the ESO for services, it may be that Third Party assets can only be used within the defined contract terms. To some extent, this can be addressed in the contract form by ensuring that the contract covers the range of services that are likely to be required. In the case of Stability Pathfinder Phase 2, several services are being sought including short circuit infeed, inertia and dynamic voltage support.

  In respect of availability, there are different exposures to non-delivery of services from regulated assets as compared to Third Party assets. TOs are financially incentivised to minimise levels of energy not supplied to customers and have regulatory reporting requirements in place for asset availability. However, specific requirements for asset availability are not in place for regulated assets and Network Owners are not normally subject to penalties for non-availability of assets. For a commercially tendered service such as Stability Pathfinder, penalties for poor availability form part of the contract terms. For Stability Pathfinder Phase 2 for example, there is a requirement for the service (specifically Short Circuit Level) to be made available 90% of the time. If in any month, the actual level is less, then a rebate is applied in that month.

  There is a concern that assets provided by Third Parties to deliver commercial services may be less accessible to NGESO at times. With respect to TO owned assets, existing licence and code obligations would ensure that these assets are made available for system support even under conditions of system distress. Whilst the Stability Pathfinder contract does incentivise a high level of service availability, it does not ensure that assets are made available at certain times. Nor are service providers necessarily obligated to provide broader support to NGESO through licence or network code obligations. This issue will be considered further and, if necessary, additional obligations would be included in future commercial service contracts.

3.4. Alternative Approaches to Deployment

Three further ways in which SC and H-SC might be deployed have been considered in addition to regulated ownership, NOA and Stability Pathfinder. These approaches include the following:

- A local compliance based approach with requirements placed on connectees.
- Provision of H-SC and SC through "Early Competition" Arrangements.
- Use network owners as a fall-back provider of inertia / system strength where there are no viable offers to provide commercial services.

i) Local Compliance Based Approach

New Connection Assets to meet Standards

Place requirements on new connectees to ensure that minimum levels of system capability and performance (e.g. voltage limits, system strength) would continue to be met locally when their generation is operating. This approach has been used in Australia.

GB Context	Pros	Cons
Where new generation connects to the transmission network, local system strength levels are tested, and additional requirements are included in connection agreements if needed to maintain minimum levels of system strength.	Adequate system strength & system inertia would be ensured over time through the connection of equipment such as SC or H-SC. Minimises the need for additional connection infrastructure elsewhere on the Network. Incentivises generators to roll out solutions that reduce the requirement -for additional system strength. Use of the assets would be available to NGESO at no further cost.	The provision of capability may not be the most economically efficient as assets may not be located at sites where they can be most effective. If network conditions change over time, the assets may no longer be required. A requirement to provide further assets as part of the connection process would introduce additional complexity for new generation projects and could slow down the connection of new renewables.

Further discussion of Local Compliance Based Approach

This approach requires further consideration as to where the obligation to maintain system strength resides. New connections may be less effective at optimising the location of new stability assets than alternative approaches.

However, this approach may be the most cost efficient when considering system costs in their entirety.

ii) Provision of H-SC & SC through Early Competition Arrangements

Provision through Early Competition Arrangements		
Alongside RIIO-2, Ofgem have proposed that Early Competition arrangements are established to identify transmission requirements that might be competed for and delivered by other parties as well as TOs.		
GB Context	**Pros**	**Cons**
The ESO has consulted on an Early Competition Plan. Projects that are sufficiently certain, new and separable (from other transmission network assets) might be identified and procured through a tender process open to TOs and other parties. The successful party would enter into a contract or licence arrangement and would be remunerated through a "Tender Revenue Stream". The contract or licence period could be up to 45 years.	The process would allow different parties to compete to meet transmission requirements. Options proposed by Network Companies and Third Parties would be directly compared. Transmission requirements might be highlighted through the NOA process. Requirements driven by new connections, wider network compliance and network stability could be identified as well as boundary limitations. The arrangements could establish longer term revenue streams to support investments such as SC and H-SC.	The Early Competition process may only be cost effective to operate for larger, more costly transmission requirements. (A cost benefit assessment would be used to ensure that the potential savings through wider competition would outweigh any costs resulting through applying the process such as shorter term network constraints.) In practice, the number of projects that meet the process criteria may be few. The Early Competition Plan requires further development and Ofgem review. It may take some time to implement.

Further discussion of Early Competition Arrangements

In the medium term, Early Competition could provide a mechanism to fund SC or H-SC based solutions proposed by Third Parties through the NOA process.

iii) TOs as Fall-back Providers of System Stability Services

TOs as Fallback Providers of Services		
Where Third Party providers do not offer commercial services, or where the offers are above a threshold price, the services could be sought through TO assets.		
GB Context	**Pros**	**Cons**
This could provide a fall-back source of system strength and system inertia where commercial providers are not able to provide services at an acceptable price.	This could place a maximum cost to consumers on the services. Use of the assets would be available to NGESO at no further cost.	TOs may be placed in the position of owning and maintaining a small number of assets.

Further discussion of TOs as Fall-back Providers of System Stability Services

This differs from the TO asset deployment described in section 3.2 above in that TOs would only deploy assets when a commercial tender process has failed to deliver stability solutions at a reasonable cost. By having the TO as a fall-back provider of stability services, NGESO and consumers would have some protection against having overpay for commercial services. Ceiling costs for services could be identified and if commercial parties don't offer options below this cost, TOs would be asked to provide the service.

4. Conclusions & Recommendations

From the work carried out to date, including the feedback provided by the Commercial Working Group, the conclusions and recommendations are as follows.

H-SC Use and Performance

NGESO has an ambition to operate Great Britain's electricity system at net zero carbon emission by 2025[13], having innovative systems, products and services in place. With declining traditional synchronous generation and increasing distributed generation and low-carbon technologies, the requirements for assets and services to meet voltage, system strength and inertia challenges are changing. There are several different options available to address GB voltage, system strength and inertia challenges. From international solutions, from the solutions already proposed to address GB stability challenges and from the work carried out in the Phoenix project to date, it is evident that SC and H-SC are valuable technical options to provide stability services.

From the studies carried out as part of Phoenix, H-SC can provide cost savings compared to other technical options where there are system requirements to co-locate a SC and a STATCOM.

The H-SC master controller FTC function improves the response of the H-SC. With the FTC function, the H-SC achieves faster dynamic voltage support than a standalone SC though slower than a standalone STATCOM. The H-SC can also provide higher SCL and inertia support compared with a standalone STATCOM though this will be lower than the standalone SC.

The H-SC master controller PLM function reduces H-SC power losses. For the H-SC configuration used in the Phoenix project, there is no significant reduction in power loss with PLM function. For other H-SC configurations, with higher ratings of STATCOM than SC, the PLM function could provide more benefit in reducing the power loss incurred by the device. However, for H-SC with higher ratings of STATCOM than SC, inertia and SCL would be lower. These aspects have not been analysed in the Phoenix project.

The H-SC master controller ISM function maximises the inertial contribution by blocking or deblocking the STATCOM device. To date, there is no evidence to conclude that the ISM function could provide material benefits to the system operation.

Further operational experience through the ongoing Neilston trial will help understand the extent to which H-SC control flexibility is of particular value. The recommended technical specifications of a H-SC device are being developed and will be reported in SDRC 8.2 (Report on emerging technical standards for SC).

Routes to Market for H-SC and SC

There are already routes to market in place in GB to deliver system stability requirements and these should be applicable for SC and H-SC solutions. These routes to market should enable the ESO to access SC, H-SC and similar solutions at the pace required to meet system changes. No further bespoke commercial framework is required.

Looking at each route to market in turn, some specific conclusions and recommendations should be considered to improve deployment.

Deployment by TOs as Regulated Assets

- The classification of SC as generation, storage or demand is being considered as a result of issues raised through the Stability Pathfinder process. If SC (and by extension H-SC) are defined as generation, then Network Companies would not be able to own these assets. Further clarity on this issue is needed.
- The wide scale deployment of SC or H-SC by TOs outside of commercial services (e.g. Stability Pathfinder) would reduce the opportunity for competition in the provision of stability services and could preclude the future deployment of other more efficient technical solutions.
- In some cases, where the need for services has not been identified in advance, the deployment of a SC or H-SC by a TO could provide a solution that can be deployed quickly. A standard "off-the-

[13] https://www.nationalgrideso.com/electricity-explained/zero-carbon-explained

shelf" H-SC solution could be developed so that key elements such as space requirements, lead times and other parameters are well understood.

- Where SC and H-SC are deployed by TOs to support system stability, asset availability requirements should be agreed with NGESO.

Deployment through NOA Process

- Whereas the funding of TO proposed solutions to increase transmission boundary capability is clear, there is no mechanism yet in place to enable Third Parties to be funded to provide solutions. Ongoing work including the establishment of Early Competition arrangements should be followed through to address this.

Deployment through Stability Pathfinder

At present Stability Pathfinder looks to compare TO and Third Party solutions for stability requirements. To enable Network Companies and Third Parties to compete more effectively to provide services, further changes should be introduced to help level the playing field. These include:

- Improved information should be made available on potential connection sites to help optimise SC and H-SC effectiveness and to mitigate perceived conflicts of interest between TOs and Third Party providers. Further clarity on the connection process would better inform participants in their approach to the tender assessment.
- Detaching the connections process from the tender assessment would also be beneficial.
- When comparing Network Company and Third Party commercial ownership, steps can be taken to mitigate the different ways that Network Company and Third Party cost elements are treated to ensure that proposed solutions are compared on an equivalent basis (e.g. energy losses, transmission charges).
- If H-SC (or SC) are proposed by Network Companies or Third Parties, requirements should be considered to ensure that the proposed solutions will provide a comparable level of performance and availability (e.g. asset availability requirements).
- Where assets are deployed through Stability Pathfinder, asset use and availability will be monitored. If necessary, further provisions will be included in contracts to ensure that stability assets are made available when required.
- Further clarity is required on the classification of SC as generation, storage or demand to ensure Third Parties can fully understand the cost associated with their solution and any level playfield issues can be properly considered.
- If TOs are competing to provide commercial services through Stability Pathfinder, consideration could be given to the assets being outside the TO regulated asset base so that TOs are remunerated on the same basis as Third Party service providers. (This would be similar to the position developed by Ofgem for the CLASS service.[14]) The costs of SC or H-SC assets would then be met by the TO and the TO would receive service payments in the same way as Third Party providers. The same contract provisions around service performance and availability could equally apply to TOs and third Party providers.

TOs as Fall-back Providers of Stability Services

If TOs were not competing directly with Third Parties to provide stability services, they could become the fall-back providers of stability assets where commercial tender processes fail to deliver stability solutions at a reasonable cost. For example, the existing Stability Pathfinder approach could be modified so that the costs of providing TO assets are used to set a maximum cost for the service. Where the solutions tendered by Third Parties exceed this maximum cost, then the tender could either be rerun to seek less expensive commercial services, or TOs could be asked to provide the assets.

This approach would reduce level playing field concerns to some extent and would put a ceiling on the costs that would be paid by consumers for the stability services.

[14] This approach reflects Ofgem's "minded to" position for the CLASS service provided using DNO assets. (Regulatory treatment of CLASS as a balancing service in RIIO-ED2 network price control, 10th Feb 2020.) Regulatory treatment of CLASS