<table>
<tr><th colspan="5">Engineering Justification Paper – Synchronous Compensators</th></tr>
<tr><td>Name of Scheme/Programme</td><td colspan="4">Synchronous Compensators</td></tr>
<tr><td>Primary Investment Driver</td><td colspan="4">Load: Operational costs, Low-carbon network operation, System strength, Black start.</td></tr>
<tr><td>Scheme reference/ mechanism or category</td><td colspan="4">SPT200137
SPT200138
SPT200139
SPT200140
SPT200141
SPT200142</td></tr>
<tr><td>Output references/type</td><td colspan="4">Synchronous Compensators</td></tr>
<tr><td>Cost</td><td colspan="4">£154.860m (These costs will be subject to an uncertainty mechanism)</td></tr>
<tr><td>Delivery Year</td><td colspan="4">2022 - 2026</td></tr>
<tr><td>Reporting Table</td><td colspan="4">B0.7 Load Master Data
B4.2a Scheme Summary
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<tr><td>Outputs included in RIIO T1 Business Plan</td><td colspan="4">No</td></tr>
<tr><td rowspan="2">Spend apportionment</td><td>Scheme</td><td>T1</td><td>T2</td><td>T3</td></tr>
<tr><td>SPT200137-42</td><td>£0.000m</td><td>£154.86m</td><td>£0.000m</td></tr>
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Issue Date	Issue No	Amendment Details
June 2019	Issue 1	First issue of document
December 2019	Issue 2	Updated for removal from baseline to uncertainty mechanism. Updated with FES 2019 data. Costing and RFI updates. Section 7 added.

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1 Introduction

Large synchronous generators in the SPT area are closing, while renewables are growing rapidly. This leads to a reduction in system strength over the RIIO-T2 and RIIO-T3 periods (2021 – 2031) to below a level where significant operational difficulties can be expected. This paper supports a proposal to maintain an acceptable minimum level of system strength by installing three synchronous compensators on the SPT system in the RIIO-T2 period:

1. Strathaven 400 kV
2. Hunterston 400 kV
3. Kincardine 275 kV

Synchronous compensation is also proposed as part of the ECVC NOA project at Eccles 400 kV (SPT200121/2), which means that a total of four synchronous compensator installations are recommended for delivery during RIIO-T2.

It is important to note that the synchronous compensator installations proposed in this paper are subject to the outcome of National Grid ESO's Stability Pathfinder project[1]. In the draft versions of our RIIO-T2 business plan, these installations appeared in the baseline. Given that there is uncertainty about the capacity and timing of stability services procured by the Pathfinder project, the SPT synchronous compensators are now proposed to be funded by an uncertainty mechanism, should they be required to make up any shortfall in commercial services or if the services offered prove uneconomic. We are working closely with the ESO and are planning to submit our synchronous compensator projects to future pathfinder tender phases (phase 1[2] is currently tendering for solutions that can be in service by April 2021). Also note that separate funding has been included in our business plan as per-construction funding (see EJP_SPT_SPT200136) to allow us to continue developing these projects so that they can be delivered in the necessary timescales, should they be required to proceed.

The locations of the proposed synchronous compensators are shown in Appendix A.

This paper should also be read in conjunction with Annex 21 – Strategic Investment Plan for Load which explains the interaction of this scheme with others in the load related plan.

2 System Strength Strategy

The closure of synchronous plant and an increasing penetration of renewable generation are leading to a decline in system strength in the SPT area and the wider GB transmission system. In the long term, it is expected that system strength will be addressed by a combination of generation connections, commercial services and the deployment of new technologies. We have engaged with the ESO on their thinking about market arrangements for this type of system support and are collaborating extensively with the ESO on their Stability Pathfinder project. However, the development of a commercial framework is still in progress. There is considerable uncertainty around when "system strength"-type services and new technologies will emerge and if sufficient system strength can be secured in this way.

To ensure that an acceptable minimum level of system strength is available as and when it is required, four synchronous compensator installations are proposed for the RIIO-T2 period. Unless

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[1] See https://www.nationalgrideso.com/publications/network-options-assessment-noa/network-development-roadmap

[2] Opened 5 November 2019, closing 17 January 2020

credible commercial alternatives emerge, these installations will be vital to the operability of the transmission system.

Following the closure of Longannet power station in 2016, restoration of the SPT network has become reliant on connections to the SHET and NGET transmission networks. To achieve restoration of [redacted] demand within [redacted] requires frequency and voltage support from six synchronous compensators rated at 250 MVA. The synchronous compensators proposed in this paper contribute to achieving this restoration time, noting that at least four units are required to reduce the [redacted] restoration time to below [redacted].

It is expected that competitively tendered solutions will start to supplement or replace the proposed synchronous compensator installations in the longer term. However, should such solutions not become available on the network, a further three synchronous compensator installations will be required during RIIO-T3 to ensure that minimum system strength and black start requirements can be met. The following sites have been identified for RIIO-T3:

1. Cockenzie 275 kV
2. Denny 400 kV
3. Neilston 275 kV

3 Background Information

3.1 System Strength

System strength is the ability of the electricity system to resist disturbances. The ideal electricity system always provides all customers with a perfectly constant voltage and frequency and is immune to any disturbance. A system with infinite strength is impractical and uneconomic. Instead, the system has evolved to provide an economic and efficient compromise between the impact of disturbances and the ability of customers and all connected equipment to withstand that impact.

System strength is provided by generators. Large synchronous generators, such as those usually found in coal, nuclear or gas power stations are much better at providing system strength than renewable generators such as wind turbines or solar panels. Therefore, as large synchronous generation plant is closed, system strength reduces.

Low system strength makes it difficult to control voltages and frequency, which reduces the quality of the supply provided to customers. At the transmission system level this means that additional capital investment will be required, e.g. in reactive compensation equipment. Also, operational costs related to frequency control and network access for maintenance or construction works will increase.

3.2 SPT System Strength

3.2.1 Inertia

The closure of Hunterston and Torness nuclear power stations in 2022/23 and 2030/31 would remove the last large synchronous generation plant from the SPT network and leads to a significant reduction in system strength. Unless a new large synchronous machine connects to the SPT network, the total inertia in the SPT area reduces as shown in Figure 1. Note that there is little sensitivity to the FES scenarios and the long-term outcome is the same. Following the closure of Torness, the total inertia of the SPT system reduces to less than 15% of what it was before Cockenzie power station closed in 2012.

The synchronous compensators proposed for the SPT system improve this situation considerably, by increasing the total inertia to about 30% of its value before 2012. This is broadly in line with system inertia before the closure of Torness. Note that this assumes the installation of seven synchronous compensators in the SPT network by 2030[3], or an equivalent provision of regional inertia from commercial services totalling 6.3 GJ.

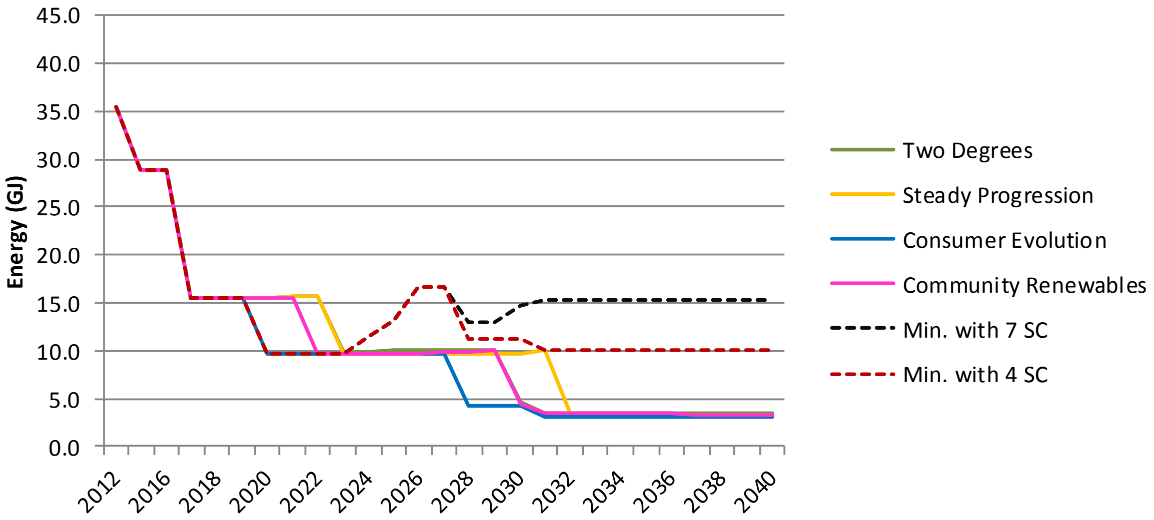

Figure 1. Maximum rotating kinetic energy storage by generators in the SPT area and the impact of 4 or 7 synchronous compensators on the lowest inertia scenario (FES 2019 data).

The situation for the whole of Scotland is similar, as shown in Figure 2. By the early 2030's, total Scottish inertia reduces to about 30% of what it was in 2012 (before the closure of Cockenzie). The value would be increased to 36% by the seven proposed synchronous compensation installations.

Note that at any given time, the inertia actually available on the SPT or Scottish systems is going to be lower than shown in Figure 1 and Figure 2, as not all synchronous plant will be running all the time due to plant unavailability or market position.

Analysis by the ESO suggests that a practical minimum inertia for the GB system is around 130 – 140 GJ[4]. The proposed SPT synchronous compensators could provide upwards of 6.3 GJ, i.e. 5% or more of the required national minimum amount.

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[3] Assuming seven installations of a 300 MVA machine with H = 3.0 s. Also see the discussion in section 5.1.

[4] System Operability Framework (SOF), November 2016, Chapter 3: Frequency management. Available: https://www.nationalgrideso.com/insights/system-operability-framework-sof

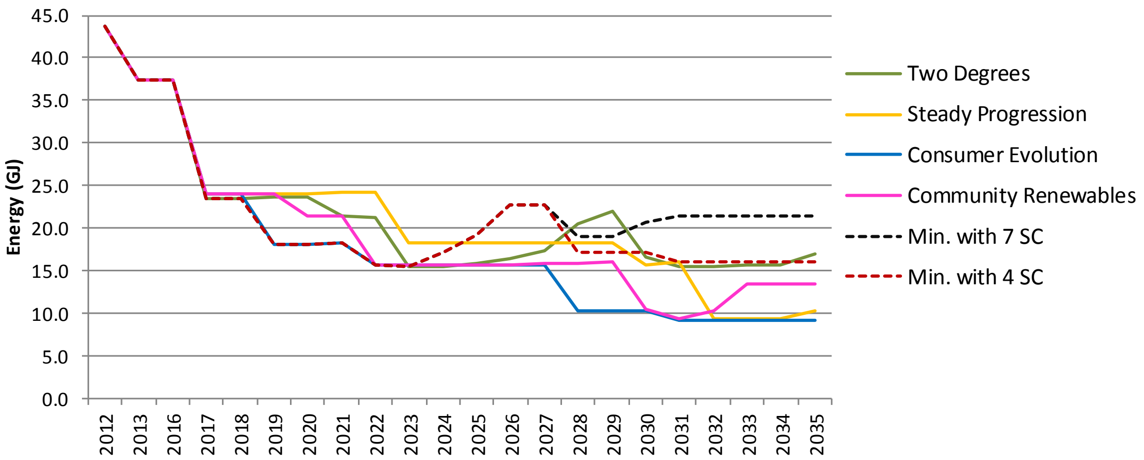

Figure 2. Maximum rotating kinetic energy storage by generators in Scotland and the impact of 4 or 7 synchronous compensators on the lowest inertia scenario (FES 2019 data).

3.2.2 Fault Level

The impact of large synchronous plant closures on average system fault levels is shown in Figure 3[5]. It can be seen that the proposed installation of synchronous compensators restores a substantial portion of the fault level reduction that results from the closure of coal and nuclear power stations in the SPT area.

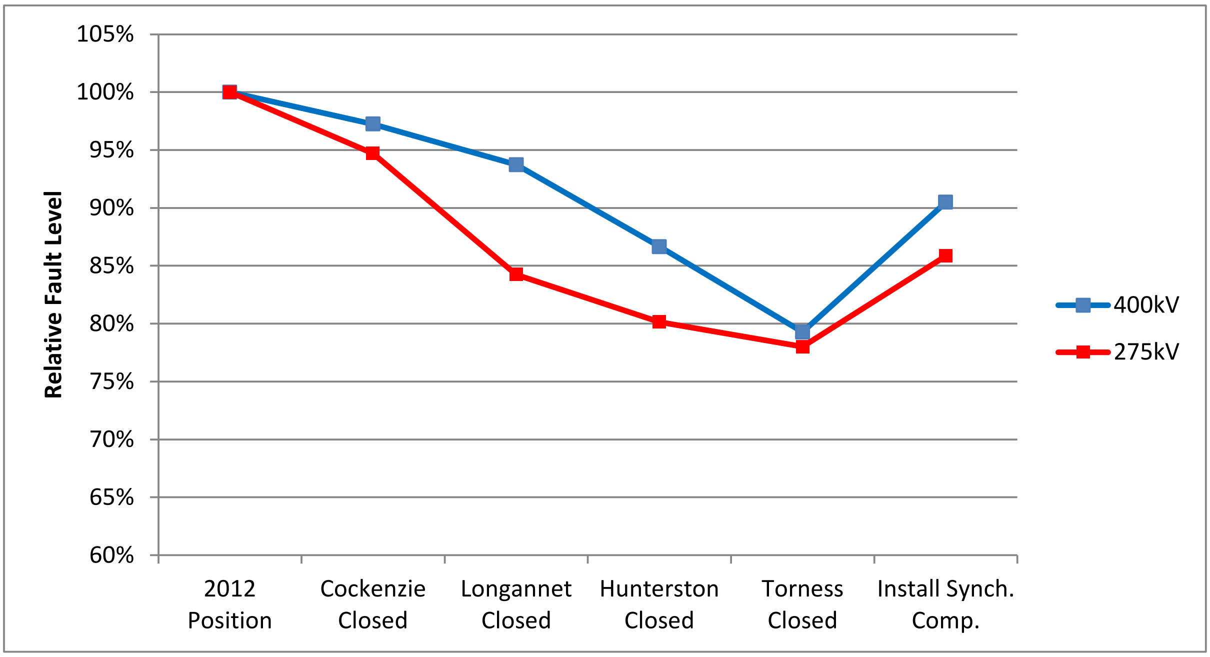

Figure 3. Reduction in average fault level due to large synchronous plant closure.

A minimum fault level is required to ensure acceptable power quality; a very low fault level would lead to e.g. poor voltage control, excessive voltage steps and increased problems with flicker, harmonics and waveform distortion in general.

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[5] The reference (100%) fault level is 18.8 kA at 400 kV and 21.7 kA at 275 kV (sub-transient values).

An important consequence of low fault levels is a potential reduction in the performance of protection systems. E.g. protection relays could fail to detect a fault condition or take longer than expected to clear a fault. By ensuring a minimum level of system strength, unreliable and variable protection system performance can be avoided. It would generally be possible to change the protection technology to achieve reliable protection operation when system strength is reduced. However, this would require an extensive and lengthy programme of protection upgrades, requiring an outage programme that would itself compromise the power transfer capability of the system and resulting in higher constraints.

3.2.3 Renewables Penetration

Increased penetration of renewables has led to operational problems in a number of networks across the world, e.g. Ireland[6] , South Australia[7] and Denmark[8] . The maximum penetration level, beyond which operational problems and costs increase significantly, will be system-specific. However, SPEN experience[9] and experience from other networks indicates a maximum penetration of non-synchronous generation around 70%. Figure 4 shows that the penetration of non-synchronous generation will exceed this limit during the RIIO-T2 period, following the closure of Hunterston power station, although there is some scenario dependency on the year within this is projected to happen.

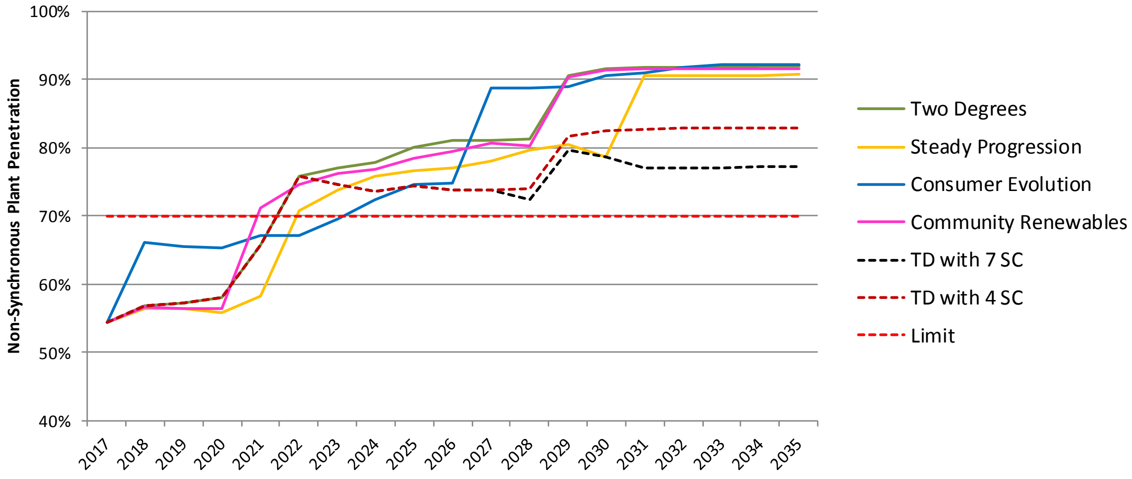

Figure 4. Renewables penetration in the SPT area and the impact of 4 and 7 synchronous compensators on Two Degrees (FES 2019 data).

The proposed synchronous compensator installations aim to maintain a non-synchronous penetration of around 70% in the SPT network as also shown in Figure 4. The timing of the seven proposed synchronous compensator installations has been established to achieve this, given the projected connection dates for new generation and the expected closure dates for synchronous generators. Without additional synchronous compensators or suitable alternative technologies, the three installations proposed in this paper will not reduce the penetration of non-synchronous plant sufficiently (see Figure 4).

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[6] See: http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/

[7] See: https://www.electranet.com.au/what-we-do/projects/power-system-strength/

[8] See e.g. research carried out by DTU: http://www.scapp.dk/ (DTU are also partners in the Phoenix project).

[9] During 2018, generator outages at Hunterston and Torness led to problems. E.g. on 04/09/2018 outages were cancelled with total outage change costs of £2.6m when both Hunterston units and one Torness unit were out of service.

3.3 System Strength during a Black Start

In the past, plans to black start the Scottish network have relied on using large pumped storage stations to start a large coal-fired power station unit. Following the closure of coal-fired generation plant in Scotland, the SPT area is reliant on a connection being established from the SHET or NGET areas before demand can be picked up in any significant quantity. A recent review by SPEN of options to improve system recovery after a black start has estimated that to achieve restoration of [redacted] of demand in [redacted] ([redacted]), the installation of 6 synchronous compensators in the SPT network is required.

During a system restoration, synchronous compensators would provide a significant amount of system strength. This makes it easier to energise transmission equipment and larger blocks of demand, speeding up the restoration process and reducing the risk of operational issues, such as tripping of recently re-energised parts of the network.

Importantly, this may make it possible for smaller and/or renewable plant to contribute to the black start process. SPEN are working with National Grid and others to investigate these alternatives[10].

Achieving a [redacted] demand restoration in [redacted] aligns closely with the strategy of ensuring a minimum level of system strength as provided by seven synchronous compensators or equivalent commercial services. Three of the six required units are proposed in this paper and are planned to be available by the end of the RIIO-T2 period.

3.4 Flexibility

Our proposal does not make provision for an increase in synchronous compensator inertia above what would be provided by the synchronous machine and any equipment like a start-up motor. However, it is possible to increase the inertia provided by the installation by adding rotating mass. This increases the cost of the installation, but is likely be justifiable based on operational cost savings in the frequency response and balancing markets.

3.5 Uncertainty

It is clear that economic operation of the future electricity system will require improvements in system strength, particularly at times when not many synchronous generator units are running. These improvements are likely to be met by a combination of investment in new equipment like synchronous compensators (by TOs or others) and a range of commercial services from providers connected to the transmission and distribution networks. Although the ESO is working on developing a range of system strength-related services[11] and the Stability Pathfinder project, there is uncertainty around when and how these will emerge and if they will emerge in suitable locations. The SPEN strategy is to continue to work with the ESO on solutions to system strength problems and to review and adjust our investment proposal to accommodate:

- Changes in the closure dates of Hunterston and Torness nuclear power stations
- The emergence of commercial service solutions
- Possible future connections of large synchronous plant in the SPT area
- The emergence of new technologies that improve the operability of networks with a high penetration of non-synchronous plant.

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[10] See https://www.nationalgrideso.com/project-black-start-from-der
and https://www.smarternetworks.org/project/nia_ngso0022.

[11] National Grid ESO, Operability Strategy Report, November 2018.

3.6 Regulatory Position

There is significant uncertainty about the capacity and timing of stability services procured by the ESO via the Stability Pathfinder project or e.g. the connection of new large synchronous generation or the emergence of new technologies to enhance system strength. We therefore propose to fund the SPT synchronous compensators by an uncertainty mechanism, should they be required to make up any shortfall in commercial services or if the services offered prove uneconomic.

Details of the proposed uncertainty mechanism are discussed in Annex 20 - Uncertainty Mechanisms in RIIO-T2.

4 Technology Options

The inherent characteristics of synchronous machines have underpinned the design and operation of power systems for many years. As such, they are also the proven and established technology to provide system strength to networks with increasing renewables penetration such as the SPT system, as discussed in section 3.2.3. Synchronous compensators are therefore the “standard” solution. However, alternatives to synchronous machines are emerging and various research and development projects are ongoing in this area.

Synthetic inertial response can be provided by converter-driven plant in combination with an energy-storage mechanism and a suitable control system. However, inertial response is only one aspect of system strength. Unlike synchronous machines, converters have a limited overload capability and would need to be over-sized considerably to provide the same fault infeed as a synchronous machine. At this time, cost-competitive converter-based alternatives to synchronous machines are not available.

By using converter control technologies like virtual synchronous machines (VSM) on renewables and batteries, converter-driven plant can be designed to behave in the same way as a synchronous machine. More generally, converters with a “grid-forming” capability could be used instead of “grid-following” converters to improve the characteristics of the network. At this time, this type of technology is being developed and trialled and not generally used in generator installations. A significant design, testing and manufacturing lag is expected before VSM or similar technology becomes widely available. It is also not yet clear if a substantial improvement in system strength would be achieved. Limited overload capability would also be a problem.

VSM requires application of the technology on new plant as well as retrofitting existing plant to achieve the minimum penetration required to achieve a minimum level of system strength and operability. From the point of view of owners of renewable plant, retrofitting existing plant would require a revenue stream to justify the additional investment, assuming that the plant is suitable for retro-fitting. Further, this could require plant to run at an operating point below maximum output, leading to reduced revenues and requiring additional compensation to be considered economic.

Given the lack of technology availability and a commercial framework to support it, there are delays and considerable uncertainty around the widespread use of alternative technologies to improve system strength. At this time, alternatives like VSM are not yet suitable to be widely deployed in acceptable timescales.

5 Scheme Design

5.1 Synchronous Compensator Specification

Although this paper supports the installation of synchronous compensators, we intend to use a technology-neutral specification if we are required to procure any synchronous compensator installations and will consider viable, practical alternatives.

The synchronous compensator requirements are outlined in Table 1 below.

Table 1. Synchronous compensator requirements

Item	Units	Value
Rating	MVA	Not specified – to be selected by Contractor
Inertia – stored rotating energy at rated speed	MJ	≥ 900 MJ (E.g. a 300MVA synchronous compensator with H ≥ 3.0s)
Rated voltage at connection point	kV	400 or 275
Sub-transient fault infeed at the transmission (high-voltage) connection point	MVA	≥1000
Minimum reactive power (underexcited)	Mvar	-140.0
Maximum reactive power (over-excited)	Mvar	+250.0

It is a requirement that all synchronous compensator installations can be used during black start conditions. This does not mean that each installation needs to be capable of black starting itself, but that all auxiliaries must be supplied from its own transmission connection, rather than a remote source that is unlikely to be available during a black start. The practical implication of this is that the auxiliaries must be supplied by a separate unit transformer winding or an auxiliary transformer connected to the unit transformer low-voltage winding as shown e.g. in Figure 4. This also means that the high-voltage breaker cannot be used for synchronisation; a low-voltage generator breaker is required instead (a load switch could be considered if all faults are cleared by the high-voltage breaker). The high-voltage circuit breaker must be equipped with point-on-wave switching to minimise the energisation transient during system restoration.

The noise emission from a synchronous compensator installation is likely to be very high and mitigation will almost certainly be required at all locations. It must be a requirement that, by design, the synchronous compensator installation or any associated assets do not increase noise levels at the site and surrounding areas against the existing background noise levels.

It is expected that each installation will have an overall availability (i.e. including maintenance outages) of around 95%. Note, however, that this could be improved by installing multiple smaller units. This also introduces the possibility of reducing operational losses by running part of an installation when the full capability is not required. In this paper it has been assumed that each installation will consist of two half-size units. However, it is recommended that the selection of machine size and number is left to suppliers to achieve specific availability and loss requirements.

Synchronous compensators are usually started by means of an induction motor and a variable-speed drive or directly via a drive. The start-up drive can also be used to slow down the synchronous compensator. The choice of start-up arrangement will be left to suppliers. However, it must be noted that increased inertia will also increase the start-up time and/or the rating of the start-up drive. Therefore, any option to increase the inertia of the installation in future has to be included in the tender and a maximum value should be stated.

Aspects like flood risk, sustainability, fire, security will be considered further during the detailed design stage.

5.2 Locations

The location of synchronous compensators has to be considered carefully, to maximise their impact on the wider network and to be close to a main route that will be energised during system restoration. Both of these aims are achieved by placing them at central, well-connected nodes and preferably connected to the highest voltage level at such sites.

From an overall system frequency control point of view, the exact location of inertia is not critical. The total inertial response available is more important in limiting the system rate of change of frequency (RoCoF) following e.g. a generator trip. However, during a network disturbance, the local RoCoF could differ significantly from the system average and more localised inertial response assists in maintaining local stability of converters and prevents e.g. unwanted tripping of plant. It is therefore important to have sources of inertial response strategically placed across the network to support renewable generation.

Strathaven and Eccles are important from a black start point of view, as both sites are reached by main transmission corridors that would be energised from the NGET area. Further, shunt compensation at these sites is critical to maintaining transfer capability across the B6 interconnector circuits, particularly following the closure of Hunterston and Torness. Both sites are well connected the rest of the network, which means that improvements in system strength can be seen across much of the network.

The installation at Hunterston partially replaces the support provided by Hunterston power station and is important for maximising the capability of the Western Link. Further, this site has 400 kV connections to Strathaven via Kilmarnock South, which places it within reach during a black start, potentially enabling the use of renewable generation in South West Scotland.

Kincardine is centrally located in the northern part of the SPT network and electrically close to a number of circuits that provide interconnection to the SHET area. It is therefore close to a number of routes that could be used to energise the SPT network during a system restoration. Further, a synchronous compensator located at Kincardine provides system strength and support to the area, partially replacing support that was previously provided by Longannet. It could be argued that Denny is a better location for a synchronous compensator. However, this site has severe space limitations which would increase the project cost and risks, leading to the selection of Kincardine. As noted in section 2, an installation at Denny may be required in RIIO-T3.

Details of the installation proposed for each site are provided in the following sections.

5.2.1 Hunterston 400 kV

The layout of the proposed Hunterston synchronous compensator installation is shown in Figure 5 (note that the ratings are indicative; each installation is expected to have a rating of 250 MVA – 300 MVA). To limit costs, a single 400 kV connection is used, potentially with multiple machines sharing a unit transformer. Although the transformer is a common point of failure, this is no worse than a single machine and transformer combination and therefore deemed acceptable.

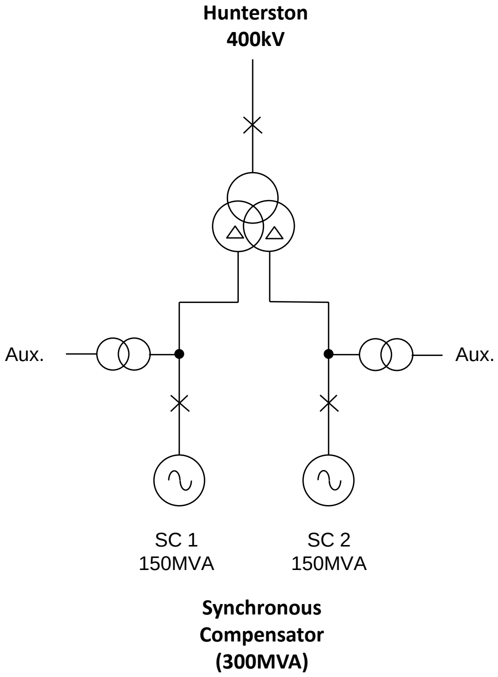

Figure 5. Hunterston synchronous compensator installation (indicative ratings and layout).

5.2.2 Kincardine 275 kV

The Kincardine 275 kV installation is identical to that proposed for Hunterston and is shown in Figure 6.

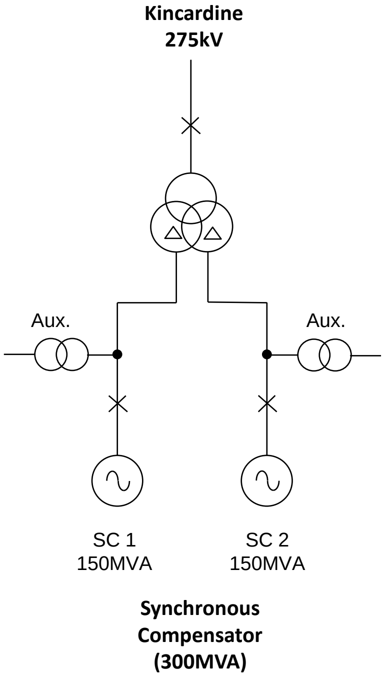

Figure 6. Kincardine synchronous compensator installation (indicative ratings and layout).

5.2.3 Strathaven 400 kV

At Strathaven, the 400 kV busbars are often run in a split configuration. Therefore the synchronous compensator installation has been split into (at least) two smaller units, each with its own unit transformer as shown in Figure 7.

The Strathaven 275 kV busbars are likely to be a more cost-effective connection point for the synchronous compensator installation. However, it is important that the synchronous compensators are installed at the highest voltage in the substation to maximise the system strength improvement obtained. Further, during a black start the 400 kV system is likely to be energised first from Harker and a 275 kV connection would increase the number of switching operations required before the synchronous compensators can be utilised.

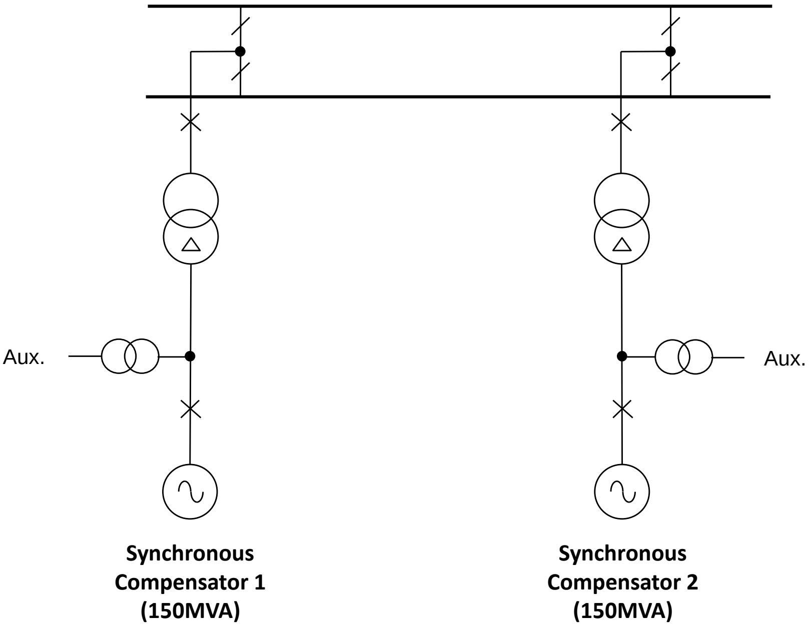

Figure 7. Strathaven 400 kV synchronous compensator installation (indicative ratings and layout).

5.2.4 Eccles 400 kV

A hybrid synchronous compensator and STATCOM arrangement, similar to the Phoenix project at Neilston, is proposed for Eccles 400 kV as shown in Figure 8. A hybrid device is proposed to provide enhanced dynamic response. The Eccles installation is shown in this justification paper because it is part of the overall synchronous compensator strategy for RIIO-T2. Note that this paper does not aim to provide justification for this installation. Instead, the Eccles hybrid compensator is being put forward as part of NOA project ECVC (SPT200120/1) and is presented in a separate justification paper.

As shown in Figure 8, the Eccles installation provides the same total synchronous compensator rating as the other installations, supplemented by two 150 Mvar STATCOMs, increasing the reactive power rating to 2 x -220 Mvar to +300 Mvar. The STATCOMs increase the total reactive range and provide faster response to voltage disturbances.

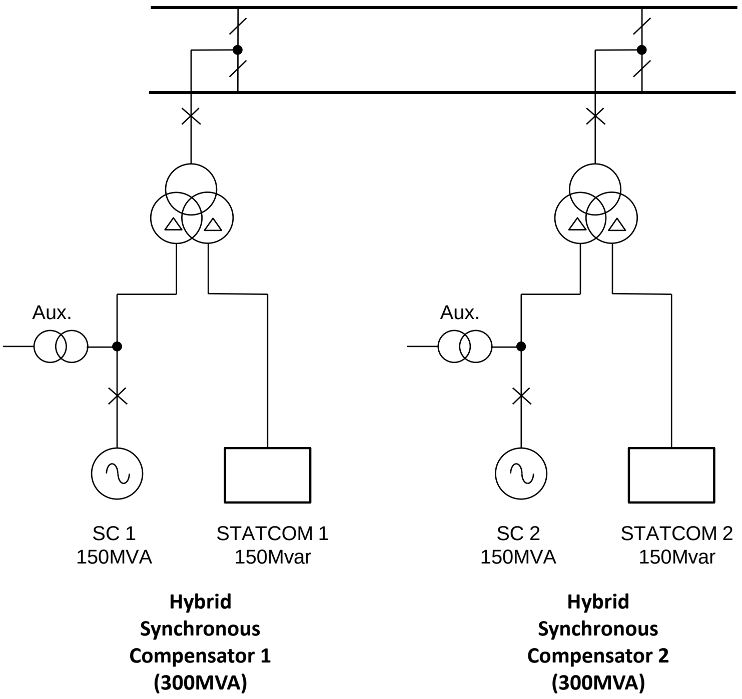

Figure 8. Eccles hybrid compensator.

5.3 Project Costing

We have not installed large synchronous compensation plant before and there is considerable uncertainty over the project costs. We engaged with a number of suppliers and asked them to respond to a request for information (RFI), which is included in appendix B.

Because suppliers were responding to an RFI rather than a full technical specification, it is difficult to assess if they all fully meet the technical requirements of the RFI. In the responses there were differences in terms of fault infeed and inertia offered, as well as e.g. maximum ambient temperature. Other costing risks and uncertainties exist around the cost of any additional noise mitigation that may be required. Five responses to the RFI were received:

- The cost provided by one respondent had many exclusions and does not reflect the full project cost. It was therefore excluded.
- The cost from the most expensive respondent was almost 50% higher than the next-highest cost. Also, very little technical information was provided. Therefore, this cost was excluded.
- The costs provided by the remaining three respondents were broadly consistent, and were +5%, +13% and -18% with respect to the average.

For our project costing, we used the central cost. Using a lower cost would introduce a significant risk of under-estimating the cost, e.g. if lowest-cost respondent did not include all cost components in their RFI response.

The RFI requested full EPC costs for a synchronous compensator up to and including the HV circuit breakers breaker. To ensure some consistency in the costs, respondents were asked to assume that SPT would provide:

i) An earthworks platform to finished compound level

ii) Access road(s) to the location of the compound

iii) Main perimeter security fence

The cost of the above items and the cost of a substation bay has to be added to obtain the total cost. Although the RFI stressed that noise emission would be a significant problem, the full cost of mitigation will not have been included in the budget costs as detailed studies would be required. Some respondents have specifically excluded the cost of noise enclosures for transformers and cooling banks. Therefore, an additional cost allowance for noise mitigation has been made.

5.4 Losses

In our synchronous compensator RFI, we asked suppliers to provide estimates of losses for their equipment. Maximum losses up to 5.4 MW were provided, although values of 2.5 MW – 3.5 MW are expected during normal operation. The losses associated with synchronous compensators are significant and are expected to account for around £1.6m per year[12]. However, this cost has to be weighed against savings in frequency response and other constraint costs that would result from the installation of this equipment. Synchronous compensators or alternative stability and system strength services are indispensable for operating a network with a very high penetration of renewables and therefore an important contributor to achieving Net Zero.

6 Conclusion

The provision of adequate system strength is vital to the continued growth in renewable generation in Scotland and the reliable operation of a transmission system with reducing conventional synchronous plant.

Our synchronous compensator proposals are no longer included in our RIIO-T2 business plan baseline, but are funded by an uncertainty mechanism that will be triggered only when the need has been established. We will continue to work with the ESO on the Stability Pathfinder project to ensure that the most economic and efficient solution is identified and implemented.

7 Future Pathways – Net Zero

Primary Economic Driver

The primary driver for this investment is to ensure economic and efficient operation of a network with a high penetration of renewable, non-synchronous generation. The proposed plant mitigates issues arising from network changes and the closure of large synchronous generation plant and acts as a further enabler of future renewable generation across the SPT network. Synchronous compensators are vital in ensuring a rapid recovery from a black start situation and also enable renewable generation to contribute in the early stages of system restoration.

Payback Periods

This solution is required for technical compliance and therefore a payback period has not been considered.

Pathways and End Points

This solution is justified in all Future Energy Scenarios. We anticipate that system strength will continue to be problematic as the system changes to achieve Net Zero.

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[12] Assuming 3 MW for a whole year (8760 hours) at a cost of £60/MWh.

Asset Stranding Risks

We do not consider there to be a risk of asset stranding in any of the future scenarios. We expect that going forward, further synchronous compensation may be required in the RIIO-T3 period as more issues emerge from changing generation and demand patterns.

Sensitivity to Carbon Prices

This scheme is not sensitive to carbon price changes.

Future Asset Utilisation

It has been assessed that the proposed solution is consistent with the future generation and demand scenarios and that the risk of stranding is very low.

Whole Systems Benefits

This project enables system operation with very high levels of renewable generation, thus contributing directly towards the achievement of Net Zero.

8 Appendix A - Proposed Synchronous Compensator Locations