Phoenix - System Security and Synchronous Compensators

In collaboration with

Project Progress Report

[Public]

June 2017

For enquiries please contact:

Priyanka Mohapatra
Phoenix Project Manager
SP Energy Networks

SP Power Systems Limited Registered Office: 1 Atlantic Quay Glasgow G2 8SP
Registered in Scotland No. 215841 Vat No. GB 659 3720 08

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1 Executive Summary

SP Transmission (SPT), supported by project partners National Grid, the University of Strathclyde and Technical University of Denmark, made a full proposal submission for the project, *Phoenix – System Security and Synchronous Compensators,* under the Network Innovation Competition (NIC) mechanism in 2016. Ofgem approved the proposal and issued the Project Direction on the 16th of December 2016. The awarded project budget is £17.64m with a duration to 31st March 2021.

Phoenix will demonstrate a sustainable design, deployment and operational control of a Synchronous Compensator (SC) with innovative hybrid co-ordinated control system combined with a static compensator (STATCOM) flexible AC transmission system (FACTS) device, referred to in the project as a Hybrid Synchronous Compensator (H-SC).The use of these devices is expected to mitigate serious system issues that are being encountered on the GB Transmission network as a result of the progressive closure of synchronous generation plants. This will enable future installations and essential network services to be provided for GB Transmission Owners and Operator, including Distribution and Offshore network operators.

The project will enable an efficient and composite solution that will enhance system stability and security while maintaining power quality resulting in reducing risks of blackouts and delivering significant benefits to GB customers.

1.1 Project Highlights

This is the first in the series of biannual progress reports for the Phoenix project, covering the project delivery period January 2017 – June 2017, “the reporting period”. The most significant developments during the period are listed below:

- Contracts signing nearing completion with all Project Partners, detailing project deliverables, deadlines and payment schedules:
    - National Grid, contract terms agreed, signature expected early June 2017
    - University of Strathclyde, contract terms agreed, signature expected early June 2017
    - Technical University of Denmark, contract terms agreed, signature expected early June 2017
    - ABB, contract negotiation nearing completion, expected late June 2017.
- Agreement of each parties’ modelling requirements and responsibilities, including modelling software format, intended use and delivery date, for example, ABB to provide SC model in PSCADX4 to DTU for detailed protection studies by October 2017.
- Technical visit to ABB manufacturing facilities, attended by SPEN and NG technical lead, and SPEN engineers.

- Installation site chosen to be Neilston 275kV substation.
- Kick-off meeting scheduled for July 2017.
- First knowledge dissemination event arranged for 6 July 2017, hosted by SPEN at the Technology and Innovation Centre, Glasgow.

1.2 Project Risks

There are currently no uncontrolled risks that could impede the achievement of any of the SDRCs outlined in the Project Direction, or which could cause the Project to deviate from the Full Submission. We monitor risks on a continuous basis with regular review at monthly progress meetings. The key risks are summarised below, with more details in Section 4.

1.2.1 Technical Risks

The following technical risks have been identified:

- Outage Window overrun. On-site implementation of a large scale transmission infrastructure project. Phoenix on-site work time extends beyond the outage window
- Limited specialist commercial expertise. Limited specialist market expertise within SPEN to support development. Effective commercial mechanisms required to enable deployment of technology
- Lack of operational experience. Unproven hybrid technologies with no live network experience of the control interactions between a SC and a STATCOM
- Lack of installation experience. New technology will require new training and procedures to be followed which introduces risk of overrun during installation

1.2.2 Project Management Risks

The follow project management risks that have been encountered during the reporting period are listed below. Project Managers at each of the project partners have ensured that these risks are continuously monitored and actively managed to ensure the project milestones are not jeopardised:

- Contractual negotiation hindering wider project plan

Further details of Risk Management including Technical Risk and Project Management Risk can be found in Section 4 of this document.

1.2.3 Summary of Learning Outcomes

At this early stage of the project, there are no major learning outcomes of note other than that preliminary studies, reported in the proposal, have outlined and quantified initially various benefits that the technology may bring to the GB power system.

2 Project Manager's Report

This section highlights the projects' key activities, milestones, risks and learning over the first reporting period (January 2017 – June 2017).

2.1 Project Progress Summary

In the first months of the project, the significant achievements during the period are:

- Contractual meetings held independently between SPEN and each Project Partner to finalise detailed deliverables and project plans for each partner.
- Contracts signing nearing completion with all Project Partners, detailing project deliverables, deadlines and payment schedules:
  - National Grid, contract terms agreed, signature expected early June 2017
  - University of Strathclyde, contract terms agreed, signature expected early June 2017
  - Technical University of Denmark, contract terms agreed, signature expected early June 2017
  - ABB, contract negotiation nearing completion, expected late June 2017.
- Modelling requirements and responsibilities matrix agreed between all Project Partners.
- Technical visit to ABB manufacturing facilities, attended by SPEN and NG technical lead, and SPEN protection engineers.
- National Grid appointed two members of staff to the Project Delivery Team (PDT).
- Installation site chosen to be Neilston 275kV substation
- System Description report submitted to SPEN by ABB
- Technical compliance report submitted to SPEN by ABB
- Action Register created to track deliverables, responsibilities and key deadlines, such as IEC tendering deadline

In the coming months, Phoenix will be presented at the following noteworthy events:

- First knowledge dissemination event arranged for 6 July 2017, hosted by SPEN at the Technology and Innovation Centre, Glasgow.
- Low Carbon Innovation Conference 6-7 December 2017, Telford.

2.2 Project kick-off and administration

During the initial months of the project, the focus has been on agreeing contractual terms between all parties ahead of the official kick-off meeting (scheduled for July 2017).

During the period, technical meetings have significantly progressed the important aspects of design and modelling responsibilities and requirements from each party in determining deliverable specifics and dates.

With regards to project resourcing, the following progress has been made:

- The structure of the Project Team has been agreed between all Project Partners.
- Key internal stakeholders within SP Energy Networks have had early involvement with the project by providing input into technical design requirements and attending meetings including the manufacturing site visit
- In SP Energy Networks Phoenix has currently 1FTE equivalent representation from Engineering Design and Standards, Network Planning and Regulation and Transmission Operations team
- National Grid have made new appointments for the role of Project Engineer and Project Management Officer
- Recruitment of an Independent Market Specialist will begin in summer 2017, to support in the commercial model development and roll-out recommendations.

2.3 Project Plan

The project comprises of six core work packages. A brief outline of these work packages is provided below:

Workpackage 1: Hybrid Synchronous Compensator Installation

- Pre-Site Planning and Design
- On-Site Deployment and Commissioning

Following the finalisation of the design of the pilot H-SC installation, including detailed engineering, civil and operational requirements, the plant will be installed and commissioned. Learning generated through this stage will be documented to inform future installations.

Workpackage 2: Live Trial

SC and H-SC Performance Monitoring

- SC and H-SC Output Monitoring
- System/Operational Performance Monitoring
- Extended Live Performance Trials Report and Recommendations

The operational performance of plant will be extensively monitored for evaluation against forecasts, in both standalone SC and H-SC modes. Voltage support, short-circuit level and inertia contribution will be validated and fed into financial cost benefit modelling. This stage will also provide feedback to refine system/component models, where appropriate.

Workpackage 3: Commercial Model Development and Roll out Recommendation

- Development of Cost Benefit Analysis (CBA) model for SCs and H-SCs
- Financial evaluation based on economic and emerging energy policies
- Validation of the CBA against actual utilization and value addition of pilot H-SC on the system.
- Regulatory recommendations for future roll-out of SCs and H-SCs

An independent Market Specialist will be employed and work closely with the PDT to develop a CBA model to assess the potential services and commercial opportunities available to SC/H-SCs in today's electricity markets and highlight potential regulatory requirements or frameworks required to ensure the GB network can access such services. For example, studies will examine if the application of SCs and H-SCs in different parts of GB system results in similar or increasingly variable benefits for investment considerations.

Workpackage 4: Hybrid Co-ordinated Control and Integration

- Hybrid coordinated control to maximize benefits from different technology solutions
- Lab Simulation of Control Methods
- Hybrid Control method Site Deployment and Testing

Workpackage 4 will demonstrate the innovative control strategies made possible by new hybrid coordinated control methods that maximise different outputs from SC/H-SCs, allowing assessment on the optimum level and variant type (see Section 2.5) to provide necessary system support to inform overall GB roll-out roadmap.

Workpackage 5: Component and System Studies

- **Component Level Studies**
- **System Level Studies**

Component models of SC and H-SC will be provided by ABB and investigated by DTU and UoS through a series of case studies, and building upon previous DTU experience. System level studies, using models supplied by NG, will analyse the application of SCs and H-SCs at different locations of the GB network and will directly feed into National Grid's FES and SOF studies. Detailed analysis will be performed for specific use cases such as role of SCs/H-SCs in frequency response market in conjunction with fast frequency solution developed through EFCC and potential constraint of western HVDC link in low SCL conditions after planned closure of Hunterston in 2023. The research component of this project will result in GB roadmap for future rollout of SCs/H-SCs and will aid RIIO T2 planning for GB TOs and SO.

Workpackage 6: Knowledge Dissemination

- Dissemination in GB and international conferences and paper submissions
- Quarterly Internal stakeholder events - WebEx and Focus Group Meetings
- Annual External stakeholder events
- Engagement with technical standard bodies and working groups
- Engagement with GB SO for development of commercial mechanisms and participation in working group

Knowledge generated will be disseminated through a variety of channels to all stakeholders to ensure the knowledge generated is shared and considered from a range of perspectives beyond the core project team. Feedback will ensure that any hidden dependencies, flaws or opportunities can be identified and the maximum benefit can thus be extracted from the knowledge generated.

The figure below illustrates the overall project timeline with respect to the workpackages.

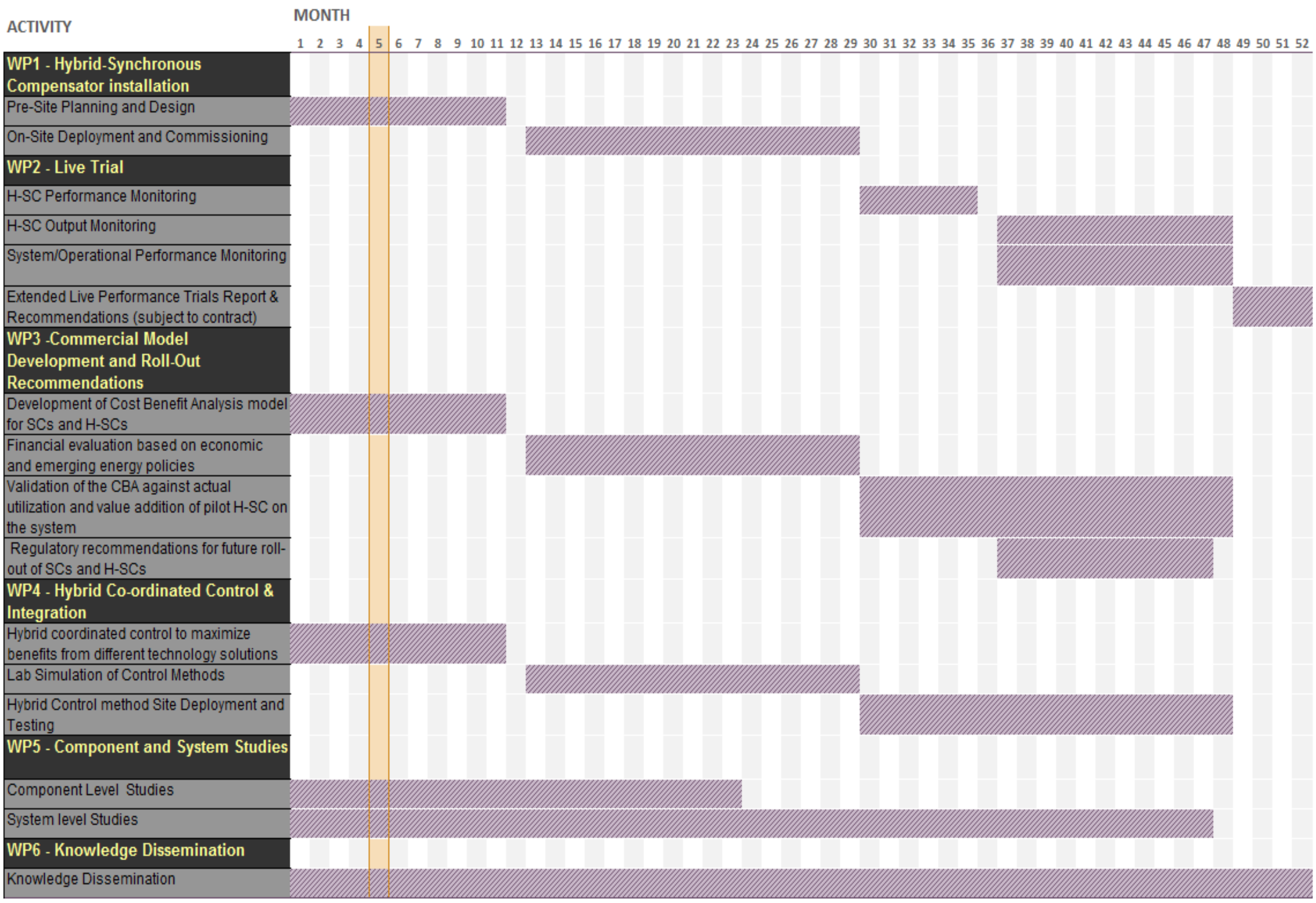

Figure 1. Project timeline

2.4 Team Structure

The team structure of the project is depicted in the figure below.

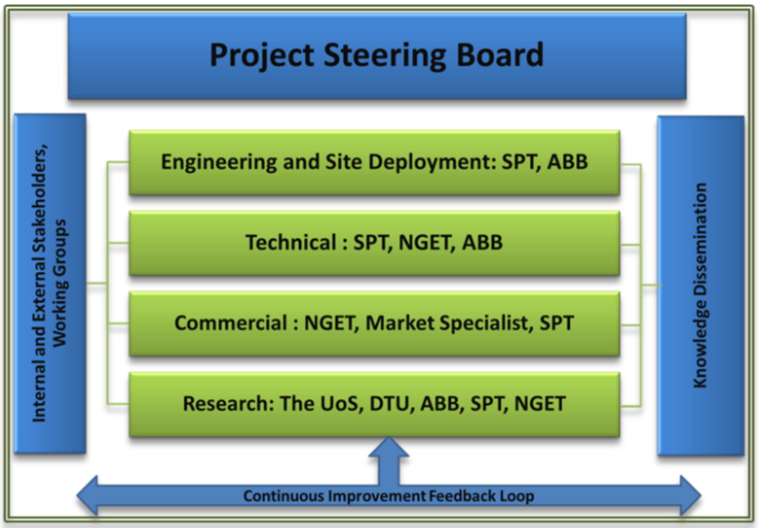

Figure 2. Team structure for project Phoenix

2.5 The Phoenix Solution

2.5.1 Overview

A high-level outline of the Phoenix solution was identified as part of the project design and scoping stage submitted to Ofgem in the project proposal in 2016. In order to ensure the most efficient and cost effective recommendations for the future use of Synchronous Compensators in GB, four design variants will be investigated by this project; variant 2 by deployment and variants 1,3, and 4, through modelling and case studies:

- Variant 1: Standalone SC
- **Variant 2: Hybrid SC (Phoenix solution to be installed)**
- Variant 3: Hybrid SC + self-start + Black Start
- Variant 4: Hybrid SC + Battery Energy Storage System (BESS)

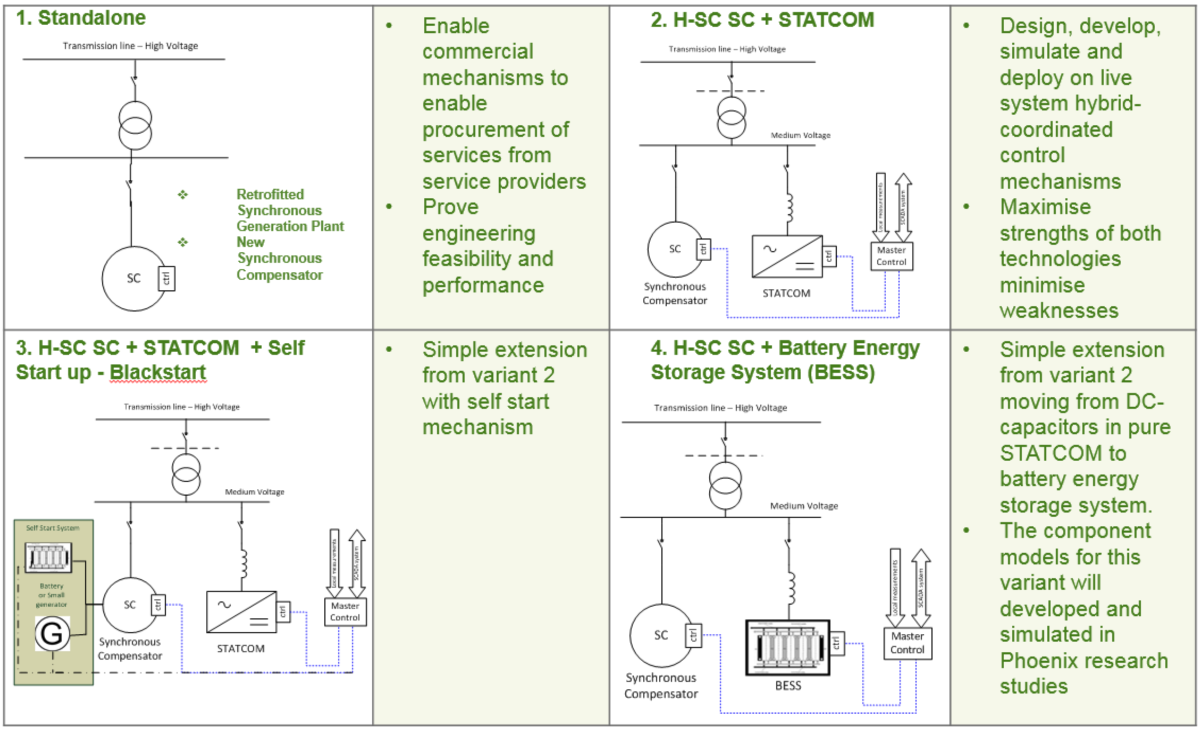

Figure 3. Synchronous Compensator design variants

By considering multiple variants of SC designs, Phoenix aims to cover the necessary technical and commercial challenges for each design so that the findings and final recommendations are both robust and viable. In addition, detailed system studies and financial value analysis across all potential system support services will be performed to estimate the number and type of SC/H-SC units to provide necessary level of support to the GB system; all of which work toward the project achieving a fundamental objective - to inform future investment decision making regarding roll-out.

2.5.2 Hybrid Synchronous Compensator Technical Details

The hybrid synchronous compensator solution to be installed as a part of project Phoenix is a hybrid system combining a synchronous compensator with a STATCOM FACTS devices designed to support the network by offering the following services:

- Boost system inertia;
- Increase the system short circuit level and system total strength;
- Provide dynamic voltage regulation;
- Reactive power injection support to alleviate voltage dip conditions;
- Reactive power absorption to mitigate the risk of potential overvoltage scenario in light load conditions;
- Enhance the oscillation damping capability;
- Aid in maintaining power quality of the network.

The detailed design of the H-SC to be installed through Phoenix is nearing completion and, as such, the design is yet to be finalised. A single line diagram of the draft H-SC is provided below, and a site layout diagram in Appendix 1 (confidential).

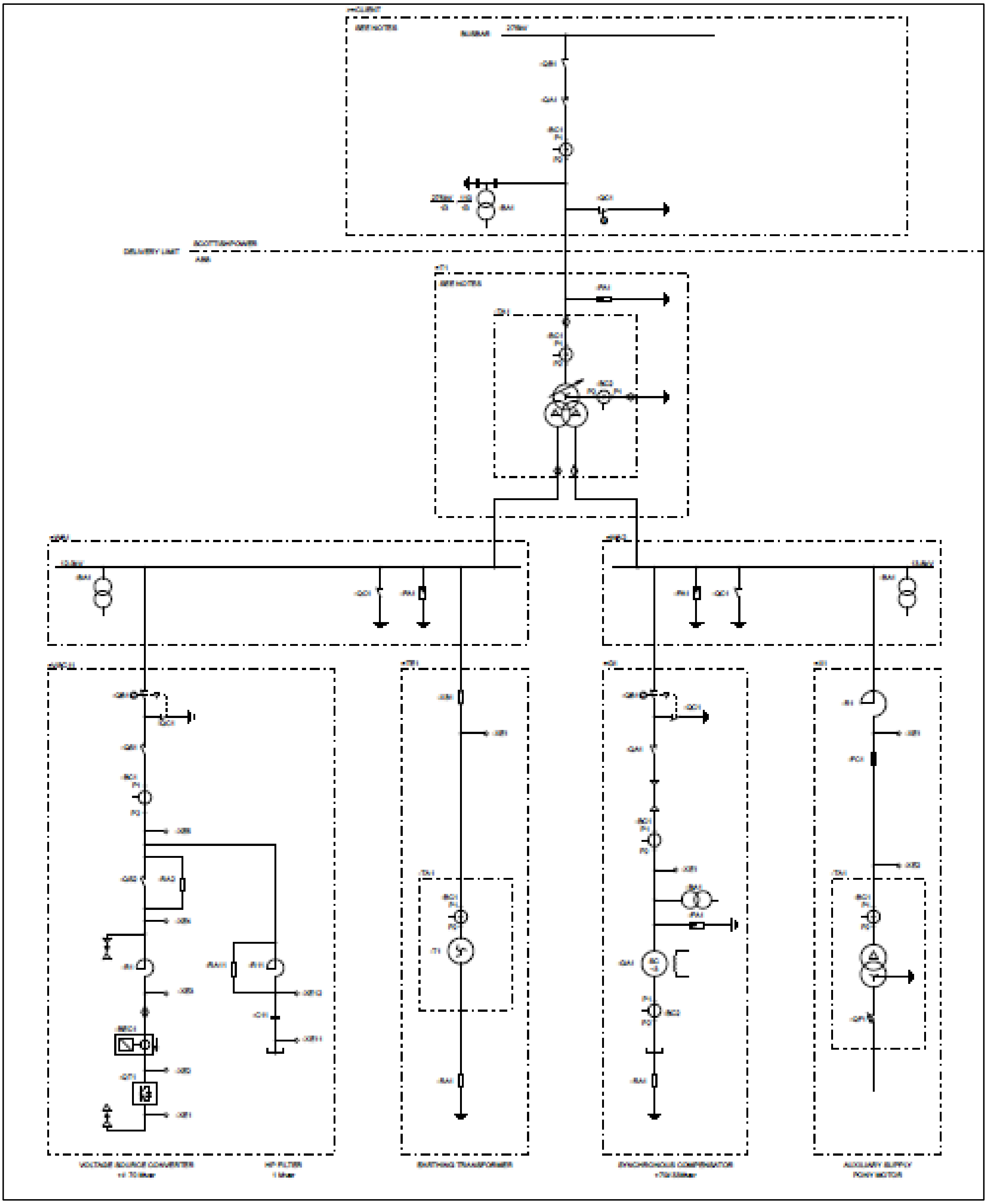

Figure 4. Single line diagram of the H-SC

The H-SC utilises a fast switching Voltage-Source Converter (VSC) for its fast response and high controllability in combination with the SC with its ability to support the network with system inertia and short-circuit power, and its high overload capability. These two branches of the H-SC are discussed below.

2.5.3 The Synchronous Compensator branch

The SC branch comprises of the compensator connected via a cable to the branch power switch along with measurement devices and protection components. The SC will be a three phase, synchronous, four pole 50 Hz type with a synchronous speed of 1500 RPM and shall be designed to:

- be capable of contributing to system recovery under emergency conditions with transient frequency excursions from 47.0 to 52.0Hz
- withstand 1.3 times the rated voltage over a period of up to 30 seconds on the occurrence of sudden load rejection or similar event
- ensure that no critical speed occurs in the range of 80-120% of normal rated speed with the Pony Motor attached

The SC supplied will also achieve the following performance requirements, as a minimum:

- Capable of continuous parallel operation with the UK Grid and contribute towards a stable operation of the Grid
- Remain connected to the Grid over the frequency range of 47.5 Hz to 52 Hz and shall disconnect from the Grid after twenty seconds when the frequency falls below 47.5 Hz and stays above 47 Hz
- The synchronous compensator shall be capable of remaining in synchronism and operating without damage for the above frequency conditions within the power factor range 0.85 lagging to 0.95 leading at maximum continuous rating
- Fully comply with the requirements of the UK Grid Code, generating reactive power with the required voltage stability and with harmonics below the limits
- Capable of rapid disconnection from the Grid without damage under severe Grid disturbance and fault conditions

2.5.4 The STATCOM branch

The following components are the major part of the STATCOM:

- Modular Multi-Level Converter (MMC) based on IGBT valves
- Air-core design phase reactor
- Electronic Current Transducer with fast response, large bandwidth and capable of measuring DC components
- Charging resistor circuit used for limit the current at energization
- Small high-pass filter in order to mitigate any switching harmonics generated by the converter

The STATCOM consists of a delta connected single block MMC Voltage Sourced Converter (VSC) rated at 70 MVA. The VSC is controlled to produce a sinusoidal voltage on the converter terminals. The reactive current injected in the power system is controlled by adjusting the converter voltage magnitude in relation to the actual MV system voltage magnitude. The required converter current is controlled by adjusting the voltage drop across the total phase reactance connected to the converter terminals, where the total phase reactance seen by the converter is the sum of the voltage drop across the phase reactor and the step-up transformer reactance.

The output current from the VSC is limited by the semiconductor current rating with applicable design margins included. This fact, in combination with the operating principle of the VSC, ensures the device will work as a voltage source when operating within limits and as a constant current source when operating at its limits, providing a reactive output that varies linearly with system voltage.

The VSC branch includes a high-pass harmonic filter. The purpose of the harmonic filter is to minimize the harmonic generation impact from the VSC. The proposed topology consists of one 1Mvar high-pass filter tuned to the 35th harmonic. A damped-filter topology is chosen giving the filter a wider frequency characteristic.

2.5.5 The hybrid co-ordinated control system - MACH

The fully redundant MACH™ control system is a microprocessor-based system with a Windows platform that will be responsible for the main functions in the coordinated control of the H-SC. The computing capacity and speed fulfils all requirements for the control and monitoring, and has facilities for remote operation.

It will be possible to run the Hybrid-SC with either the STATCOM or SC out of service and isolated from the system through 13.8 kV and 12kV disconnectors. In such case, the control system will automatically adapt to the H-SC system configuration.

The coordination and monitoring capabilities have the following challenges to be studied during the project.

- Normally a synchronous compensator works also in voltage control mode. ABB will change the SC normal control so that there is only one overall voltage controller for the H-SC, establishing the correct orders to the STATCOM and synchronous compensator control loops.
- Conventional FACTS installations like SVC´s and pure STATCOM´s do not employ transformers with tap-changers and the whole equipment installed at secondary side is designed to withstand large voltage variations. The synchronous compensator is however designed for lower continuous voltage variations (+/-10%). Taking also into account normal voltage excursions at primary voltage (247 to 303 kV) and its reflection on the secondary side for different H-SC operating points, a tap-changer control needs to be implemented for keeping the secondary bus voltage within +/-10% of the nominal voltage.

- Synchronous compensators reactive power x field current curves are given assuming 1.0 per-unit voltage at machine connecting point. Due to STATCOM operation, this voltage will constantly change, which will cause small deviations on the machine operating point. The effect on the closed loop response will be analysed.
- Since each equipment has its own controller, ABB will put lots of effort on sending relevant and available monitoring/parameters of the machine to the MACH system so that the H-SC monitoring system is implemented at the MACH system (transient fault records, events, alarms, etc), taking also into account that Neilston substation is unmanned. For this purpose, the communication protocol between MACH system and GCP has been stablished for the signals that do not require fast communications between the control platforms. For signals requiring faster communication, hardwiring will be used.

2.5.6 Chosen installation site

The site to install the H-SC has been chosen to be Neilston 275kV substation, highlighted below.

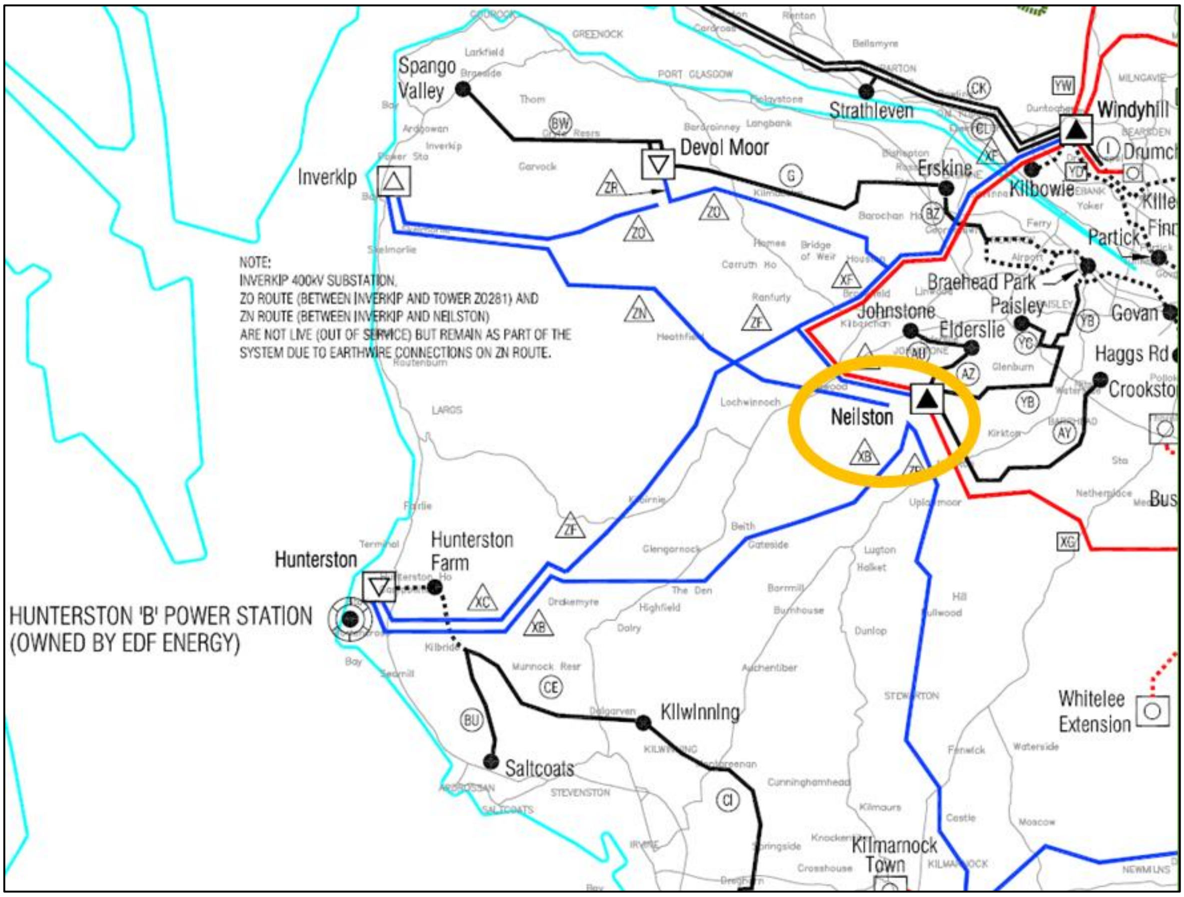

Figure 5. Installation site: Neilston 275kV Substation

2.6 Modelling requirements

The following modelling requirements matrix has been jointly developed between all parties to clearly specify each parties' modelling requirements and responsibilities to be delivered in Phoenix:

No	Model	Use	Platform	Req. Date
1	Synchronous compensator (Neilston)	Detailed protection studies (DTU)	PSCAD X4	Oct-17
2	Synchronous compensator (Generic)	System studies (SPEN/UoS)	PowerFactory 15.2.5	Dec-17
3	Statcom (Generic)	System studies (SPEN/UoS)	PowerFactory 15.2.5	Sep-17
4	Type 2 variant for phasor studies (Neilston)	SSTI (SPEN/UoS), System studies (UoS), Control interaction with nearby HVDC/STATCOM (SPEN/UoS)	PowerFactory 15.2.5	Sep-18
5	Type 2 variant for EMT studies (Neilston)	Control development (ABB), System studies (ABB), Protection studies (DTU)	PSCAD X4	Jul-18
6	Type 2 variant for phasor studies (generic/scalable)	System studies (SPEN/UoS)	PowerFactory 15.2.5	Mar-19
7	Battery Energy Storage	System studies (SPEN/UoS)	PowerFactory 15.2.5	Mar-18
8	Type 4 variant for EMT studies	Control studies (DTU)	PSCAD X4	Dec-18
9	Type 4 variant for phasor studies	Control studies (DTU), System studies (UoS)	PowerFactory 15.2.5	Dec-18
10	GB Dynamic system model (full model) - present state	System studies (SPEN/UoS)	PowerFactory 15.2.5	Jan-18
11	GB Dynamic system model (full model) - future state(s)	System studies (SPEN/UoS)	PowerFactory 15.2.5	Jan-18
12	GB Dynamic system model (reduced local equivalent) - present state	Dynamic performance studies in PSCAD (ABB), RTDS studies (ABB)	PowerFactory 15.2.5	Jan-18
13	GB Dynamic system model (reduced equivalent) - for type 4	System studies (DTU)	PowerFactory 15.2.5	Jan-18
14	EFCC reduced model for studies with EFCC models	UoS studies in conjunction with provided ABB model	PowerFactory 15.2.5	
15	HVDC model for Western Link	UoS studies	PowerFactory 15.2.5	Dec-17

Figure 6. Modelling requirements matrix

2.7 Knowledge Sharing and Stakeholder Engagement

The Phoenix dissemination strategy has been developed to ensure robust mechanisms are in place throughout the project to ensure relevant learning and knowledge is identified and shared effectively to key stakeholders and interested parties.

In the coming months the project team will:

- Establish a visual identity for Phoenix that allows any dissemination material produced by Phoenix to be immediately recognisable. This identity will also extend to establishing a pack of materials that include other aspects, e.g. identifying the project partners (names/logos) and the funding source;
- Establish a knowledge dissemination coordinator who will refine and update the dissemination strategy throughout the course of the project to maximise the benefits of Phoenix for all stakeholders. They will be responsible for identifying dissemination opportunities, ensuring all dissemination is consistent with the Phoenix identity, liaising with other relevant projects, maintaining an up to date list of stakeholders and establish contacts within them;
- Identify project champions within each relevant department who ensure the project remains visible and relevant to their department. These project champions need not be a part of the core project team;
- Prepare a range of materials (e.g. posters, presentations, leaflets and videos) that clearly define what Phoenix is and what the goals and benefits are. These materials will include different versions; each of which are tailored for audiences with a different level of technical and commercial knowledge;
- Establish an online portal to serve as the hub for conference papers, journals etc.

The following knowledge dissemination matrix is used to support knowledge dissemination activities by ensuring important stakeholders are identified and engaged effectively through the course of the project.

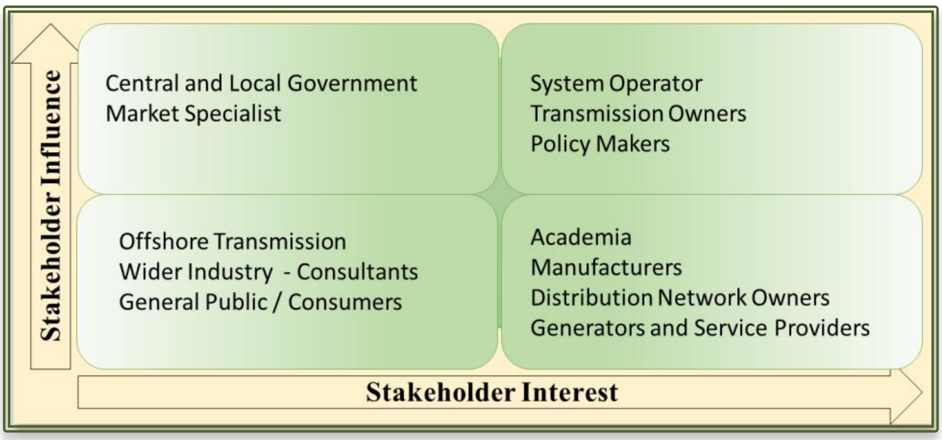

Figure 7. Phoenix Stakeholder Matrix

In order to ensure the stakeholders remain engaged and informed a number of key activities have been identified that will be conducted and assessed on an annual cycle, including:

- Biannual stakeholder events to notify and educate stakeholders;
- Biannual progress reports and marketing material to be circulated amongst stakeholders;
- Provisions for attendance and presentations at key industry innovation events;
- Continuous improvement of dissemination effectiveness.

2.8 Outlook to the Next Reporting Period

Looking ahead to the next six months, the following activities are expected:

- Agree terms and complete contractual negotiations with ABB
- The design teams will continue to develop the final detailed design
- A project collaboration portal is required to enable secure sharing and version tracking of documents throughout the project, such as design documents, project reports, and minutes of meetings, and will be procured in the coming months.
- Forthcoming Project Delivery Team meetings to be organised and attended in accordance to workpackage requirements.
- Detailed Knowledge Dissemination plan and training programme to be developed and agreed between all parties, defining the roles and responsibilities for annual participation and contribution of all project partners.

In terms of knowledge dissemination activities, Phoenix will engage with the key internal stakeholders through the following activities during the forthcoming period:

1. Technical workshops covering the operating principles of the H-SC, hosted by the PDT
2. Site visit to DTU testing and simulation facilities, to be arranged

And in order to engage with the wider industry and international stakeholders, Phoenix will be presented at the following noteworthy international events:

3. First knowledge dissemination event arranged for 6 July 2017, hosted by SPEN at Technology and Innovation Centre, Glasgow.
4. Low Carbon and Innovation Conference 2017

3 Consistency with full submission

At this early stage of the project deliver, Phoenix remains consistent with the original Full Project Submission with regards to project schedule, budget, resource allocation and programme.

4 Risk Management [CONFIDENTIAL]

[redacted]

[redacted]

5 Successful Delivery Reward Criteria (SDRC)

The Successful Delivery Reward Criteria set out in the Project Direction links with the Project Milestones and the identified targets directly. This SDRC can be used to check the progress of the project delivery and position the progress against the original proposal. A full list of the SDRC is provided in Appendix 2 for reference.

Table 3 lists all the required evidences in line with project direction for reporting period.

Table 3. Achieved SDRC in reporting period

Successful Delivery Reward criterion	Evidence
1) Architecture, Design and Engineering feasibility Engineering design and feasibility analysis for pilot H-SC deployment and demonstration. Site selection and planning consent for H-SC installation. Detailed layout, civil designs and approval through system review group for finalising tender for site works and ordering equipment.	**SDRC 1.2.** Report on environmental studies and life cycle analysis. WP1 (01/06/2017).
3) Control Methods Development and Testing Innovative control methods to maximize benefits of SC/H-SC installations in different network conditions and different locations across GB. Simulation of co-ordinated control schemes with other network components such as SVCs, STATCOMS and battery storage. Development and on-site testing of hybrid control scheme for H-SC.	**SDRC 3.1.** Report on methods and functional specifications of hybrid control mechanisms developed and trialled in pilot demonstration. WP4 (01/06/2017).

The following SDRC are due for completion in the forthcoming period:

Table 4. SDRC due in forthcoming period, in accordance with original Full Project Submission

Successful Delivery Reward criterion	Evidence
1) Architecture, Design and Engineering feasibility Engineering design and feasibility analysis for pilot H-SC deployment and demonstration. Site selection and planning consent for H-SC installation. Detailed layout, civil designs and approval through system review group for finalising tender for site works and ordering equipment.	1. Report on engineering and design feasibility analysis. WP1 (01/12/2017). 2. Report on environmental studies and life cycle analysis. WP1 (01/06/2017). 3. Report on detailed installation diagrams and site layouts. WP1 (01/08/2017). 4. Report on routine and type testing procedure and results. WP1 (01/12/2017).

2) Financial Value Evaluation and Regulatory Recommendations Develop and demonstrate a commercial framework to financially incentivise services provided by synchronous compensators. Enable service providers to participate in a new market for inertia and other ancillary services provided by SCs. Create recommendations for regulatory considerations for future roll-out of SCs/H-SCs.	1. Cost benefit analysis model for SCs and H-SCs. WP3 (01/12/2017).
3) Control Methods Development and Testing Innovative control methods to maximize benefits of SC/H-SC installations in different network conditions and different locations across GB. Simulation of co-ordinated control schemes with other network components such as SVCs, STATCOMS and battery storage. Development and on-site testing of hybrid control scheme for H-SC.	1. Report on methods and functional specifications of hybrid control mechanisms developed and trialled in pilot demonstration. WP4 (01/06/2017). 4. Report on methods and functional specifications of innovative control schemes for future roll-out. WP4 (01/12/2017).
4) Lab Functionality and Component Model Testing Testing of different operational scenarios in laboratory environment to generate results to better understand performance of SC/H-SCs under various limits and constraint conditions. Lab testing will test different operational parameters of SC/H-SCs. Use of RTDS to facilitate simulation of technical models and control algorithms.	1. Component model adapted to pilot demonstration and for further system studies. WP5 (01/12/2017). 3. Report on co-simulation for faster prototyping for new designs and controls. WP5 (01/12/2017).

6 Learning Outcomes

During the reporting period, the contract negotiations have formed the largest part of the project and, as such, there have been no substantial learning outcomes to date however, with the detailed design and model development now underway, we anticipate key learning related to final design and operation during the forthcoming period.

7 Business Case Update

We are not aware of any developments that have taken place since the issue of the Project Direction that affect the business case for the Project.

8 Bank Account [CONFIDENTIAL]

[redacted]

9 Intellectual Property Rights (IPR) [CONFIDENTIAL]

[redacted]

10 Other

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11 Accuracy Assurance Statement

I therefore confirm that processes in place and steps taken to prepare the PPR are sufficiently robust and that the information provided is accurate and complete.

Signature: Colin Taylor

Name (Print): COLIN TAYLOR

Title: DIRECTOR ENGINEERING SERVICES

Date: 19/06/2017

Signature: Priyanka Mohapatra

Name (Print): PRIYANKA MOHAPATRA

Title: SENIOR PROJECT MANAGER

Date: 19/06/2017

12 Appendices

12.1 Appendix 1 - Bank Account Statement [CONFIDENTIAL]

[redacted]

12.2 Appendix 2 - Phoenix Successful Delivery Reward Criterion

Successful Delivery Reward criterion	Evidence
1) Architecture, Design and Engineering feasibility Engineering design and feasibility analysis for pilot H-SC deployment and demonstration. Site selection and planning consent for H-SC installation. Detailed layout, civil designs and approval through system review group for finalising tender for site works and ordering equipment.	1. Report on engineering and design feasibility analysis. WP1 (01/12/2017). 2. Report on environmental studies and life cycle analysis. WP1 (01/06/2017). 3. Report on detailed installation diagrams and site layouts. WP1 (01/08/2017). 4. Report on routine and type testing procedure and results. WP1 (01/12/2017).
2) Financial Value Evaluation and Regulatory Recommendations Develop and demonstrate a commercial framework to financially incentive services provided by synchronous compensators. Enable service providers to participate in a new market for inertia and other ancillary services provided by SCs. Create recommendations for regulatory considerations for future roll-out of SCs/H-SCs.	1. Cost benefit analysis model for SCs and H-SCs. WP3 (01/12/2017). 2. Report on cost benefit analysis of SCs and H-SCs based on system studies and FES. WP3 (01/03/2019). 3. Report on international application of SCs and benefit analysis. WP3 (01/06/2019). 4. Report on value evaluation of SCs/H-SCs based on pilot installation and performance. WP3 (01/06/2020). 5. Report on impact of SCs/H-SCs on existing balancing schemes and markets. WP3 (01/01/2021). 6. Report on value analysis from roll out of SCs/H-SCs in GB in future potential sites. WP3 (01/01/2021). 7. Report on regulatory considerations and recommendations for future roll-out of SCs and H-SCs. WP3 (01/12/2020).
3) Control Methods Development and Testing Innovative control methods to maximize benefits of SC/H-SC installations in different network conditions and different locations across GB. Simulation of co-ordinated control schemes with other network components such as SVCs, STATCOMS and battery storage. Development and on-site testing of hybrid control scheme for H-SC.	1. Report on methods and functional specifications of hybrid control mechanisms developed and trialled in pilot demonstration. WP4 (01/06/2017). 2. Report on output of SCAPP project on protection and control of synchronous compensators and simulation results of new control methods. WP4 (01/06/2018). 3. Report on performance of pilot hybrid co-ordinated control system. WP4 (01/03/2020, 01/03/2021). 4. Report on methods and functional specifications of innovative control schemes for future roll-out. WP4 (01/12/2017). 5. Report on FAT test procedure and results of pilot hybrid co-ordinated control system. WP4 (01/06/2019). 6. Report on SAT test procedure and results of pilot hybrid co-ordinated control system. WP4 (01/10/2019).
4) Lab Functionality and Component Model Testing Testing of different operational scenarios in laboratory environment to generate results to better understand performance of SC/H-SCs under various limits and constraint conditions. Lab testing will test different operational parameters of SC/H-SCs. Use of RTDS to facilitate simulation of technical models and control algorithms.	1. Component model adapted to pilot demonstration and for further system studies. WP5 (01/12/2017). 2. Report on component level studies from SCAPP project and relevance to pilot demonstration and future installations. WP5 (01/12/2018). 3. Report on co-simulation for faster prototyping for new designs and controls. WP5 (01/12/2017).

5) Application of synchronous compensators: GB system studies System studies using SC/H-SC component model and GB system model developed through EFCC project and SOF studies to critically analyse impact of future roll-out of SC/H-SCs in GB network. Case studies for specific system cases on GB network.	1. Report on System Studies and Quantification of overall benefits from application of SCs/H-SCs in GB system. WP5 (01/06/2019). 2. Report on case studies on system characteristics of SCs/H-SCs in conjunction with other innovative solutions proposed through EFCC and HVDC converters. WP5 (01/06/2019). 3. Report on optimal placement and capacity evaluation of SCs/H-SCs in GB. WP5 (01/03/2020). 4. GB roadmap for roll-out of SCs/H-SCs. WP5 (01/12/2020).
6) Pilot Installation and Operational Trial On-site installation and commissioning of pilot H-SC demonstration. Civil work and electrical connection of H-SC to the transmission network.	1. Report on site installation process, details and recommendations for future - Civil. WP1 (01/03/2019). 2. Report on site installation process, details and recommendations for future - Electrical. WP1 (01/10/2018). 3. Report on SAT procedure and test results. WP1 (01/06/2019). 4. Report on electrical layout of H-SC design with protection and control architecture. WP1 (01/03/2019). 5. Report on extended live trial and recommendations for future installations (Revision 01/03/2021).
7) Performance Monitoring Monitoring of equipment performance such as losses, vibrations and maintenance requirements of rotating parts of the pilot H-SC. Condition monitoring of the H-SC output and impact on the regional and wider power system.	1. Report on pilot H-SC installation component level SC, STATCOM condition monitoring. WP2 (01/12/2020). 2. Process documentation for SC type testing requirements for future installations. WP2 (01/12/2019). 3. Functional specifications for H-SC output monitoring - Methods and User Interface. WP2 (01/06/2018). 4. Functional specification for H-SC wider system operational performance monitoring WP2 (01/12/2018). 5. Report on pilot H-SC installation output data logging and monitoring WP2 (01/01/2021). 6. Report on H-SC system impact in local and wider system context - Usage, Control methods and Interactions. WP2 (01/01/2021).
8) Knowledge Dissemination Stakeholder engagement and dissemination of learnings and outcomes of the pilot H-SC demonstration through project.	1. Report summarising findings of TO SO working groups. WP6 (01/12/2019) 2. Report on emerging technical standards for synchronous compensators. WP6 (01/06/2020). 3. Project Phoenix Close down report. WP6 (01/06/2021). 4. Project Phoenix regular project progress reports. WP6.

12.3 Appendix 3 - Site Layout of Phoenix H-SC [CONFIDENTIAL]

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12.4 Appendix 4 - Project Risk Register [CONFIDENTIAL]

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