Question No.	Proforma section	Criteria	Topic	Question	Date question asked	Date response required	Date received	Follow up to Question #	Confidential (Y/N)
1	N/A	b) Value for money		Please provide a table with a breakdown of indicative day rates and person days for SPEN and each project partner. This should be based on the amount of person days required and proposed labour costs.	16 August 2016	18 August 2016	17 August 2016		
2	N/A	g) Robust methodology/ready to implement		How does the project plan to engage with other GB licencees and service providers on potential impacts to the NETS SQSS?	16 August 2016	18 August 2016	17 August 2016		
3	N/A	g) Robust methodology/ready to implement		Please confirm whether the new system stability (with a minimum voltage after t-event + 1.2s reaching 0.883/0.866 pu) has been checked against existing requirements in the GB Grid Code.	18 August 2016	22 August 2016	22 August 2016		
4	N/A	b) Value for money		Please provide a description of how the travel and expenses budget has been determined. Please provide a breakdown of these costs if available.	18 August 2016	22 August 2016	22 August 2016		
5	3.3.1	g) Robust methodology/ready to implement		It is indicated in your proposal (p.15) that the falling short circuit levels causes an "Increased risk of failure of key protection systems". Which systems are referred to and do H-SC reduce or completely mitigate the risk?	23 August 2016	25 August 2016	25 August 2016		
6	N/A	b) Value for money		The Full Submission Guidance states 'Enough information should be included in this [NPV] summary so that it can be used in conjunction with the data in the Full Submission Spreadsheet to enable the Panel to independently calculate the Net Present Value of each Method.' Please direct us to where you have provided this information in your submission.	25 August 2016	30 August 2016	30 August 2016		
7	N/A	a) Enviro+consumer bens		In the bilateral we asked about the NPV analysis and the counterfactual(s). Please can you breakdown the NPV analysis for each service that the H-SC provides relative to each relevant counterfactual (the counterfactual may be different depending on the service).	08 September 2016	13 September 2016	13 September 2016		
8	N/A	d) Is innovative		Please explain how the project would be unique and develop additional knowledge compared to other demonstrations (eg those in Denmark, Germany, California and Texas): o By illustrating the differences between those networks and that in Scotland and GB in general o By clarifying to what extent SCs have been applied with STATCOMs	08 September 2016	13 September 2016	13 September 2016		
9	N/A	d) Is innovative		Please provide the full list of reference papers considered when developing the project and in particular any "historical" papers that address the impact of traditional SCs on stability and fault level rather than or in addition to reactive power.	08 September 2016	13 September 2016	13 September 2016		
10	N/A	e) Partners and ext. funding		Please provide further details of the process taken to identify and recruit project partners. This should include an indication of the number of providers approached (academic and OEMs) and whether aspects of competitive processes were employed (eg were costed proposals received and compared?).	08 September 2016	13 September 2016	13 September 2016		
11	N/A	Mulitple		Are other providers of the Hybrid SC available? If so were these costed during partner selection?	08 September 2016	13 September 2016	13 September 2016		
12	N/A	e) Partners and ext. funding		Please provide an estimation of potential benefits to project partners in the event of rollout on the GB scale as presented in the benefits estimation in appendix A.	08 September 2016	15 September 2016	13 September 2016		
13	N/A	e) Partners and ext. funding		Please confirm the value of funding that will be spent on each project partner (incl labour and equipment costs).	08 September 2016	15 September 2016	13 September 2016		
14	N/A	e) Partners and ext. funding		Please provide a justification of the level of contribution to the project from each project partner. The response should consider partner cost to the project and the potential to benefit post project.	08 September 2016	15 September 2016	13 September 2016		
15	N/A	e) Partners and ext. funding		The project involves a significant element of academic support. Please explain why this level of academic involvement has been included and the value it adds to the project.	08 September 2016	15 September 2016	13 September 2016		
16	N/A	g) Robust methodology/ready to implement		The bid says there will be financial value analysis for SCs/H-SCs and potential development of new commercial mechanisms to financially incentivise such installations? Can you explain a bit in detail how you'll develop these mechanisms and what is the common process followed for the same?	n/a	n/a	13 September 2016		
17	N/A	e) Partners and ext. funding		How will other service providers be encouraged to participate at the end of the project if such a framework is developed? Are we open to the concept of others (other than TOs/SO) tendering for installation?	n/a	n/a	13 September 2016		
18	N/A	b) Value for money		Please explain why you have not identified any Direct Benefits from the project.	20 September 2016	22 September 2016	22 September 2016		
19	N/A	a) Enviro+consumer bens		How much of the capacity and carbon savings are truly NET ADDITIONAL to GB?	20 September 2016	22 September 2016	22 September 2016		
20	p.13	f) Relevance and timing		The Phoenix proposal seems to be a "transmission based investment" solution (p. 13). Please explain how this is taking a more holistic approach (across all industry participants) to resolve the future problems identified (eg with voltage).	29 September 2016	04 October 2016	03 October 2016		
21	5	c) Generates new knowledge	IPR	We note that the project intends to conform to the default IPR arrangements. As per the governance document and full submission guidance, in your resubmission, please explain: - how the project intends to conform to the default IPR arrangements; and - your approach to agree fair and reasonable terms for the future use of any Background IPR and Commercial Products needed for other Licensees to reproduce the Project outcomes.	13 October 2016	N/A - resubmission	N/A - resubmission		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	1
Question date	16/08/2016	Answer date	18/08/2016
Submission section question relates to	N/A		
Topic	N/A		
Question	Please provide a table with a breakdown of indicative day rates and person days for SPEN and each project partner. This should be based on the amount of person days required and proposed labour costs.		
Notes on question	N/A		
Answer	[redacted]		

	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

	[redacted] [redacted] [redacted] [redacted] [redacted]
Attachments	Phoenix_Person_Days_Calculation.xlsx

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	2
Question date	16/08/2016	Answer date	18/08/2016
Submission section question relates to	N/A		
Topic	N/A		
Question	How does the project plan to engage with other GB licensees and service providers on potential impacts to the NETS SQSS?		
Notes on question	N/A		
Answer	Phoenix will engage with other network licensees and service providers in the following ways 1. Working Groups Phoenix will create two working groups during the project with SP Transmission, NGET SO and the market specialist (to be tendered for after the bid process) as lead and NGET TO, SHETL as advisors. The working groups will be the following • WG1 Market Initiatives • WG2 Regulatory Recommendations The detailed nature of the working groups and potential study streams will be decided during the project during the conceptualisation phase. This will require considerable stakeholder engagement and detailed market review. [redacted]		

	[redacted] Working group meetings will be held every six months to share findings and gather feedback among all advisors (other TO network licensees). The leads will work throughout the project feeding information into the working group and recording findings. The successful delivery reward criteria (SDRC) evidence "1. Report summarizing findings of TO SO working groups WP6" will summarize all outcomes of the working groups. This report will be revised after each working group six monthly meeting and will be made available to wider group of service providers for gathering feedback. 2. Website, publications and external stakeholder engagement Phoenix plans to set up a web-page to publish its working group findings and also other reports for SDRC evidences such as: • "Report on international application of SCs and benefit analysis WP3" • "Report on impact of SCs/H-SCs on existing balancing schemes and markets WP3" • "Report on value analysis from roll out of SCs/H-SCs in GB in future potential sites WP3" • "Report on regulatory considerations and recommendations for future roll-out of SCs and H-SCs WP3" These reports will be thus readily available to service providers for review and feedback. Papers will be published during the project and presentations will be conducted at targeted conferences to raise awareness about the potential impacts of project Phoenix. An annual external stakeholder event will be held each year. All service providers, market specialists and network licensees in GB will be invited to this event to share the learnings of project Phoenix. Phoenix will also be presented at the annual LCNI conference each year during the duration of the project. 3. SPEN network planning and regulation group and NGET Compliance Group SP Transmission has identified business champions within its network planning and regulation group who on a daily basis deal with changes and progress of NETS SQSS. These champions are also well engaged with other network licensees. Phoenix has also engaged experts from NGET SO who are keen on this technology and deal on a daily basis with service providers and other network licensees. Together these experts will share the findings of Phoenix with the relevant audience and also ensure Phoenix remains on track and within its scope to deliver the desired outcomes. The experts will also

	critically analyse any impacts on NETS SQSS and provide necessary recommendations to the regulator based on the findings of the project.
Attachments	

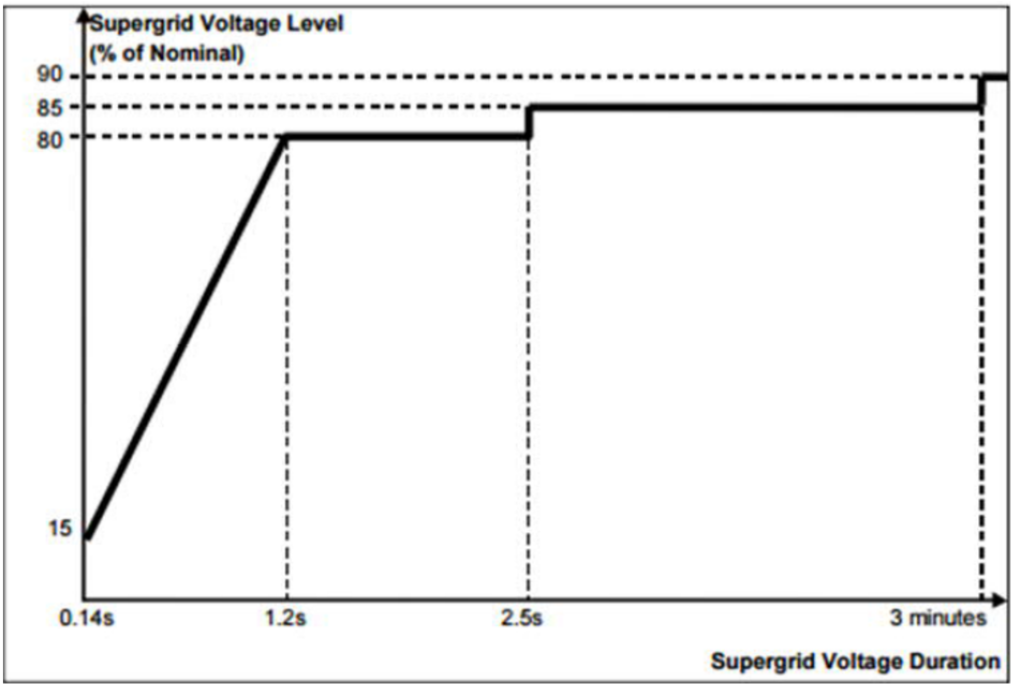
Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	3
Question date	18/08/2016	Answer date	22/08/2016
Submission section question relates to	N/A		
Topic	N/A		
Question	Please confirm whether the new system stability (with a minimum voltage after t-event + 1.2s reaching 0.883/0.866 pu) has been checked against existing requirements in the GB Grid Code.		
Notes on question	N/A		
Answer	Yes, it can be confirmed that the new system stability (with a minimum voltage after t-event + 1.2s reaching 0.883/0.866 pu) has been checked against existing requirements in the GB Grid Code. The Grid Code requires that the voltage on the supergrid (275 and 400kV) network nodes is maintained within a time-dependent limit. Monitored 275 and 400kV bus voltage profiles for system studies purposes for Phoenix bid were assessed against those limits specified in the Grid Code (Section CC.6.3.15.1) as shown in Figure 1.		

	 **Figure 1 Supergrid Voltage Dip Limits Reproduced from Figure 5b in Grid Code CC.6.3.15.1 © National Grid**
Attachments	

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	4
Question date	18/08/2016	Answer date	22/08/2016
Submission section question relates to	N/A		
Topic	N/A		
Question	Please provide a description of how the travel and expenses budget has been determined. Please provide a breakdown of these costs if available.		
Notes on question	N/A		
Answer	The travel and expenses budget for project Phoenix has been calculated using a travel and expense calculator (see attached). The calculator is created based on experience from previous NIC projects and broken down into critical time periods of the project and the activities to be undertaken for knowledge dissemination and project management. In a typical 12 month period of the project following activities will be undertaken:		

2	Stakeholder training / workshops
12	Regular PDT meetings
4	Quarterly internal and external marketing material
2	Attendance to industry conferences
2	Presenting at industry conference
1	Annual review of knowledge activities (Continuous improvement)
2	Stakeholder training / workshops

The typical (averaged) cost for each activity was estimated on basis of costs and expenses from pervious NIC projects:

Type	**Cost(£)**	**Total #**	**Total spend (£)**
PDT	400	58	23200
Kick-Off Close Down event	2500	2	5000
Literature	2800	1	2800
Website	4000	1	4000
Flyers/Update material	1500	22	33000
Attend Conf	1000	12	12000
Present Conf	1000	10	10000
Annual Review	0	5	0
Workshops/Training	10000	11	110000
		Total	200000

The most significant expenses are workshops and trainings which also include an annual stakeholder event. These are of utmost significance for engagement with internal and external stakeholders. However may require a choice of location near to London and/or Manchester and have significant costs associated with them.

Attachments	Phoenix_Travel_Expense_calculator.xlsx

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	5
Question date	23rd August 2016	Answer date	24th August 2016
Submission section question relates to	3.3.1		
Topic	Failure of power system protection due to decreasing fault levels.		
Question	It is indicated in your proposal (p.15) that the falling short circuit levels causes an "Increased risk of failure of key protection systems". Which systems are referred to and do H-SC reduce or completely mitigate the risk?		
Notes on question	N/A		
Answer	On-going research work has already demonstrated (through laboratory testing and injection of actual distance protection relay devices) that reducing fault levels, and delays in the provision of fault current (as will be the case with converter-interfaced sources and interconnectors), can compromise the performance of distance protection in the form of delayed responses or, in some cases, non-operation of the protection for certain fault scenarios. It is also suspected that reduced fault levels may also cause lack-of-sensitivity issues with biased differential protection (particularly when the bias setting is high and the fault resistance is high), and, finally, the operation of backup overcurrent protection will clearly be compromised if fault current levels reduce. Future projects with National Grid are in the process of being arranged to investigate this more thoroughly for a full range of protection relay types. H-SC cannot be guaranteed to completely mitigate this risk of failure to operate – the level of risk mitigation or risk elimination is dependent on the		

	number, capacity and location of H-SC devices in the power system, but the H-SCs will certainly act to reduce the risks through providing increased short circuit levels and, equally importantly, providing fault current instantaneously, as opposed to providing it with a delay (recent ENTSO-E RfG documents mention "fast fault current", but fast is not defined – H-SC will provide fault current with essentially zero delay). Finally, H-SC will readily provide negative sequence currents, which several protection systems rely on in order to detect the presence of certain types of fault. Converter-interfaced sources are sometimes only designed to provide balanced output currents, which is a further risk to the secure operation of protection systems in the future. This paper, authored at Strathclyde, provides more information and results: http://digital-library.theiet.org/content/conferences/10.1049/cp.2016.0063
Attachments	

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix_______________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	6
Question date	25/08/2016	Answer date	29/08/2016
Submission section question relates to	N/A		
Topic	b) Value for money		
Question	The Full Submission Guidance states 'Enough information should be included in this [NPV] summary so that it can be used in conjunction with the data in the Full Submission Spreadsheet to enable the Panel to independently calculate the Net Present Value of each Method.' Please direct us to where you have provided this information in your submission.		
Notes on question	N/A		
Answer	In the past there has been a net benefits section in the full submission spreadsheet submitted with the full proposal. This section appears to have been removed from the 2016 version of the full submission spreadsheet. Hence it is unclear how the submission is supposed to show the extrapolation over the 30+ years in the full submission spreadsheet as was done in past years. Phoenix has carried out a detailed cost benefit analysis determining the NPV of the project and the analysis summary has been detailed in "**Appendix B Cost Benefit Analysis**" of the project. The section details • Extrapolation/Roll-Out Assumptions • Lifecycle Costs • Assumptions made for the market costs, avoided storage costs • Other CAPEX/OPEX costs used to determine the NPV As Phoenix proposes a solution that delivers benefits that are		

	• dependant on the location and size of implementation of the Phoenix Solution • require detailed calculation of system benefits using power system modelling and system studies. This has been carried out for project Phoenix as detailed in "**Section 3 Business Case"** The results provided in section 3 and the assumptions detailed in Appendix B can be used together to determine the NPV for project Phoenix. For the ease of independent assessment please find attached the CBA spreadsheet created for project Phoenix. The extrapolation of the methods has been also described in "**Appendix A Benefits Table Table A.1 Electricity NIC – financial benefits**" and linked to appropriated sections in Appendix B.
Attachments	CBA Phoenix FINAL.xlsx

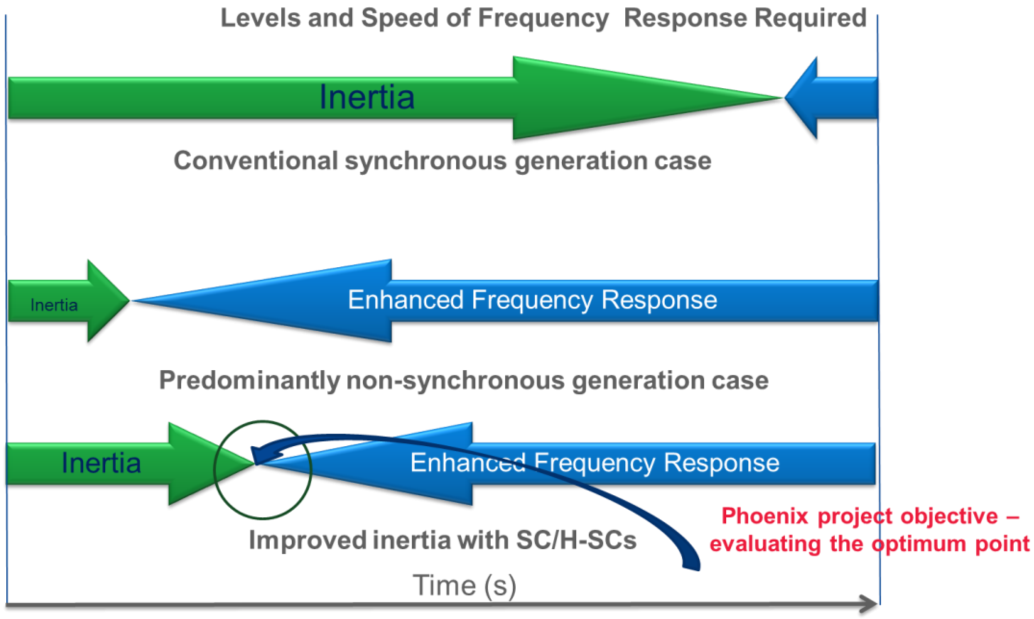
Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix________________________

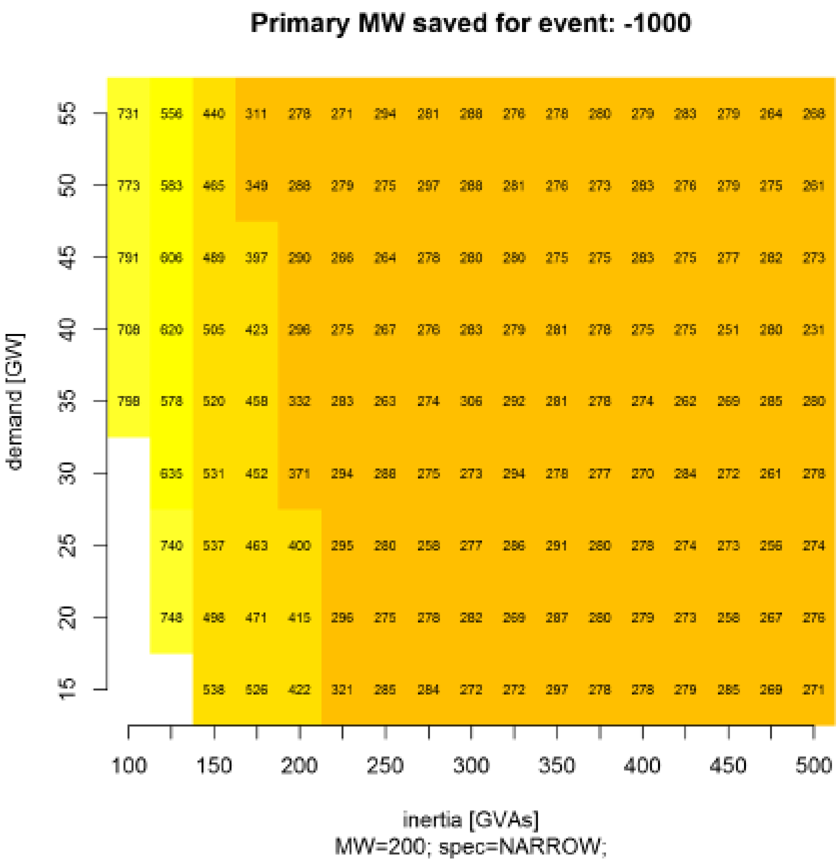
Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	7
Question date	08/09/2016	Answer date	13/09/2016
Submission section question relates to	N/A		
Topic	a) Enviro+consumer bens		
Question	In the bilateral we asked about the NPV analysis and the counterfactual(s). Please can you breakdown the NPV analysis for each service that the H-SC provides relative to each relevant counterfactual (the counterfactual may be different depending on the service).		
Notes on question	N/A		
Answer	The NPV analysis for SC/H-SC was originally conducted taking into account combined benefits from roll-out of this technology at strategic locations in GB system. The breakdown of the NPV analysis to be compared on basis of individual services provided against counterfactuals does reduce the impact of the SC/H-SC as a single technology providing multiple benefits. Thus, it is to be noted the results presented have limitations and for indicative purpose only. Furthermore such analysis repeats the capital investment for each benefit case and thus negatively affects the NPV analysis. The metrics used for the NPV analysis in terms of roll-out of SC/H-SC technology in SP Transmission is shown in attachment (Metrix.docx). The following analysis continues to use the SPT system as a benchmark. NPV analysis of SC/H-SC for each service against counterfactuals **1. Frequency Response** SC/H-SC technology provides an "inertia" response because of the inherent kinetic energy stored in it just as in case of a synchronous generator. The		

	level of inertial response a SC/H-SC can provide can be varied by increasing the rotating mass of the machine (a feasible technique offered by all manufacturers). Synchronous generators/compensators have a store of kinetic energy due to the rotational momentum in their rotors. As these machines are directly coupled with the electricity grid, a change in the grid frequency results in a change in their rotor speeds, which is opposed by rotational inertia. This inertia response acts to dampen the rate of change of frequency ('RoCoF'). In this manner, inertia acts as an enhanced frequency response ('EFR'), due to its immediate and inherent nature (EirGrid and SONI, 2011). Non-synchronous generators, such as solar PV and wind turbines exhibit insignificant or no inertia response. The progressive decline in synchronous generation anticipated in all Future Energy Scenarions [FES 2016] will lead to a decrease in inertia within the GB power system and the provision of frequency response over shorter timeframes i.e. Enhanced Freqquncy Response [EFR] will become more and more necessary. The EFR in GB system is currently mostly procured through battery storage services (BESS). The following diagram attempts to explain this concept in a simplistic way (the actual dynamics are more complex). The diagram indicates that SC/H-SC technology can restore some system inertia (depending on number and size of installation) thus a) Reducing amount/level of EFR required from non-synchronous sources such as BESS b) Protecting the system from a large-scale blackout due to cascading tripping by reducing Rate of Change of Frequency (RoCoF) and providing more improved time for EFR services to start providing a response upon loss of infeed/generation event. 

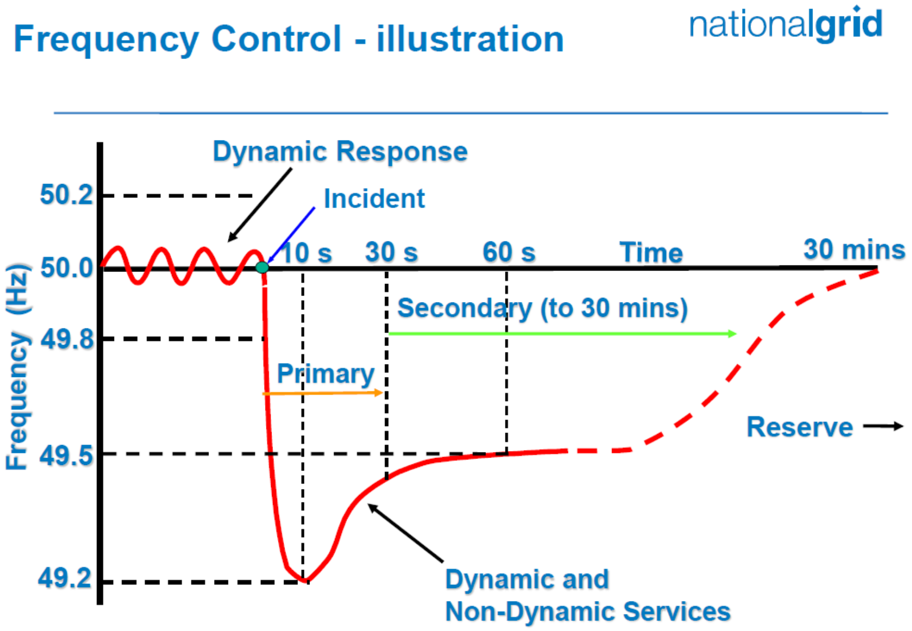
The diagram below is taken from NGET EFR slide share from July 2016, which shows that if levels of inertia in the system are high such as a case in winter, the level of EFR required is considerably lower. The slide concludes that the ±0.05Hz EFR service has

- More value (than the ±0.015Hz service) at times of low demand/inertia
- No value at times of very high demand/inertia



The challenge is to procure the right levels of inertia and EFR service in future maximising system stability and minimising cost to GB customers. An independent study conducted by research institute in Australia **(Fast Frequency Markets under High Penetrations of Renewable Energy in the Australian National Electricity Market, 2015, see attached)** estimated the cost of frequency response services provided by **SCs to be $0.3095/ MWh s as compared to BESS $3.3830/ MWh s.**

The main difference between SC and synchronous generation is it does not produce active power however in current market scenarios it can displace some of the spinning reserve requirements (large synchronous generators operated at reduced levels of output) to maintain system stability and also displace the levels of MW required from BESS.



For the NPV analysis of this service the benefits for primary frequency response have been split in to two categories; the first is the benefits associated with the market cost of peak active power response (MW), and the second is the avoided asset cost of installing and operating an energy storage device (e.g. battery) that would be displaced or reduced frequency response as SCs. The benefits of the increased active power response are based on a market cost for Mandatory Frequency Response (MFR) (average £160k/MW/year). The second quantifiable benefit for the case of frequency response is the cost of a battery that would be displaced by SCs. The asset and O&M costs of an equivalent sized battery required across the same roll-out period has been calculated, assuming a battery cost of £1.84m/MW, and a fixed annual O&M cost of the first MW installed of £0.5m, with each subsequent MW costing £0.05m.

Counterfactual: The counterfactual to the inertia service provided by SC/H-SC is a synchronous generator. The option chosen for this analysis is a CCGT plant (cheapest in terms of levelised cost after nuclear, source Electricity Generation Costs 2013, DECC). The cost profile for installation of CCGT and multiple SCs taking SP Transmission system as an example is installation of capacity (300 MW) in year 2022 and 2042 with CAPEX investment of £190m and subsequent O&M costs of £2m (based on comparison of generation market prices and experience).

The NPV analysis comparing SC/H-SC to this counterfactual is shown below:

Term (Baseline 2022)	NPV - SC/H-SC (£m)	NPV - CCGT (£m)
-2	0.00	0.00
8	30.90	-11.92
18	82.61	32.85
28	235.68	150.06

It should be noted that it is only an indicative summary based on one service, CCGT equally as SC provides other services. For simplicity the fuel costs were not taken into account for CCGT operation.

2. Short Circuit Level (SCL)

The reduction in SCL has the following effects on the power system, which can be mitigated by improving SCL with addition of SCs/H-SCs:

- Challenges to maintain system voltage during short-circuit faults.
- Increased risk of failure of key protection systems
- **Increased risk of commutation failures in LCC HVDC links e.g. the Western link caused by disturbances on the AC side of the converter. (Only case studied for NPV analysis)**
- Adverse effect on power quality, such as increasing levels of harmonics, flicker and voltage and current distortion.

It should be noted that the following NPV analysis only highlights the effect of reduced SCL on operation of western HVDC link only. The assumptions do not include LCC commutation failure only constraints on the link 10% of the operational time in a year. The constant decline of SCL in the Scottish system is assumed to be 5% per year.

The following benefits are equally important, but the occurrence with which they occur is difficult to predict, so they have not been taken into account in the commercial/financial analysis:

- The added benefits of improved SCL such as improvement of power quality especially by use of H-SCs which is crucial for protection of critical transmission and distribution connected assets and connected generation services (VISOR project case)
- SCL is very important in fault situations in order for key protection systems to operate efficiently and accurately. Counterfactual to this could be theoretically complete re-design of protection systems, which will require further research and work with vendors to design such systems. It will also involve significant investment to install and test such systems and building of this skillset within the industry.
- Starting the SC/H-SC system by use of a small gas turbine or battery system will provide SCL and voltage regulation in a black start situation. This will enable the use during a black start of associated LCC interconnected HVDC links that could start transferring power between two different regions such as England and Scotland, enhancing UK recovery from this scenario.

Counterfactual: The counterfactual to provide SCL can only be met by a synchronous generator. Hence the same analogy as in case of frequency response by installing CCGT in SPT area was applied and the NPV analysis is shown below:

Term (Baseline 2022)	NPV - SC/H-SC (£m)	NPV - CCGT (£m)
-2	0.00	0.00
8	12.60	-39.27
18	65.84	13.69
28	233.67	169.51

3. B6 Boundary Transfer Capability

The B6 Boundary capability increase has been calculated from the system studies for each additional SC added to the network. The required transfer shortfall between the base capability of the boundary and the projected transfer requirement of the boundary for each FES has been calculated using B6 boundary flow data from ETYS 2015. The same shortfall has been derived using a revised base capability including SCs.The boundary shortfall represents the requirement for additional network reinforcement across the boundary. The inclusion of SCs defers the shortfall across the boundary; hence deferring the requirement for additional network reinforcement.

<u>Counterfactual:</u> The benefit is then calculated as the difference between the NPV of the network reinforcement investment without SCs and the NPV of the network reinforcement investment being deferred due to SC installation. For the Slow Progression scenario additional network investment has been deferred by 7 years.

Scenario	First Year Netwo	Network Investment deferred (years)
Gone Green	2027	5
Slow Progression	2029	7
Consumer Power	2029	7
No Progression	2042	20

The cost of the reinforcement estimated as follows

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

NPV W/O SC Installed(£m)	548.22
NPV with SC Installed(£m)	459.13
Total Benefit of deferred investment by (£m)	89.10

4. Losses

The following real situation was not included in NPV analysis due to difficulty in predicting the probability of occurrences. Controlling the voltage on the

SPT network is becoming ever more challenging. The closure of Cockenzie in 2013 and Longannet in 2016 has diminished the amount of available voltage control. The H-SC solution can act faster than conventional solutions to limit over voltage after fault clearances and switching transients. When there is little or no wind generation on the system and the system is lightly loaded, there are issues controlling high system voltages. This can and has resulted in circuits being switched out of service most of the day to control high system voltages. SCs and especially H-SCs provide improved dynamic voltage control, thus allowing use of these circuits and reducing constraints amunting to savings of **£6-12m every year from 2016 onwards (based on recent operational experience)**.

The NPV analysis of SC/H-SC purely on calculation of benefits of reduction in losses (not including all of the above benefit cases) and improved voltage control are shown below.

The counterfactual to this would be STATCOMS however SCs have a larger overload capacity and thus there is no direct comparison between the both. Phoenix proposes a hybrid-SC building on the strengths of each tehnology.

Term (years from first out flow)	NPV (£m)
-2	0.00
8	7.27
18	24.38
28	125.42

.

Attachments

Metrics.pdf

Fast Frequency Markets under High P

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	8
Question date	08/09/2016	Answer date	13/09/2016
Submission section question relates to	N/A		
Topic	d) Is innovative		
Question	"Please explain how the project would be unique and develop additional knowledge compared to other demonstrations (eg those in Denmark, Germany, California and Texas): o By illustrating the differences between those networks and that in Scotland and GB in general o By clarifying to what extent SCs have been applied with STATCOMs		
Notes on question	N/A		
Answer	**<u>Differences between international networks and that in Scotland and GB in general</u>** • **Network and operational strategy of Denmark TSO** The current network of Denmark is well connected to the neighbouring countries Germany, Norway and Sweden. The west Danish Power system is in the synchronous area of Central European system while the east Danish system is synchronized with the Nordic system. The Danish power system has a long history of deployment of HVDC. In the west Danish system, there are 4 HVDC lines to Norway, 1 connected to Sweden, whilst an ongoing HVDC project COBRAcable connects to Holland. The capacity of the HVDC links is close to the maximum demand in west Denmark. The Danish power system has a high penetration of wind power, comprising both offshore and onshore installations. The Danish TSO also plans to change the sub-transmission level overhead lines into underground cables		

that presents further challenges to voltage regulation.

The operational strategy of Danish power system, besides security of supply for the local demand, is facilitation of the power and energy exchange between the Nordic system and the central European system. For example, the total capacity of the interconnectors in the west Danish system is well above the maximum demand in that area.

With the retirement plan of coal-fired power plants, the system has faced challenges in the operation of HVDC links associated with power ramping and load rejection. The operator needs to purchase costly services from the retired conventional plants for reactive power support. Further having those generators online jeopardizes the optimal efficiency of market operation leading the system cost deviate from the marginal cost. The grid operator therefore introduced synchronous compensators [compensators] to the system to maintain a minimum short circuit power level which could only otherwise be provided by the conventional plant. So far, all the synchronous compensators recently installed by Danish TSO are at the terminal of line commutated converter based HVDC links to provide local voltage support and fault level infeed which would otherwise require conventional plant to run.

- **German system**

The German transmission network is in a very different situation. The country has closed down eight of its 17 nuclear power reactors and will retire the rest by 2022. At the same time it has set very ambitious renewable energy targets. Germany is well known for its solar PV power deployment in the distribution grids, however, the wind power installation is also at a high pace. For example, over 65% of 2015 worldwide offshore wind farm capacity was installed in Germany. The renewable generation once reached 95% of the demand of the whole country, which is the highest record in history.

The fluctuations of renewables result highly variable load flow within the grid leads to voltage fluctuations and the need for enhanced reactive power control. Like the Danish system, the German system is well connected to other systems and frequency stability is not a major issue. However, German TSOs need to purchase services from conventional power plants to provide reactive power support and power imbalances. Germany has recently started installing SCs for improving frequency and voltage stability to backfill those services left by conventional synchronous plant (nuclear, coal)

- **Synchronous Compensators in US**

North America is the largest market by size and there is a high demand for synchronous compensators from Canada and the U.S..

Canada has seen a steadily rising demand for synchronous compensators, especially new installations, whereas in the U.S., the more prevalent trend is to convert the retired power stations to synchronous compensators. As in Europe, thermal power plants are being shut down or are planned to shut down in the U.S. to curb pollution and promote renewable power generation. This is also likely to increase demand for synchronous compensators in the region.

The synchronous condenser market is expected to grow at a moderate rate of 2.4% from 2015 to 2020. It is projected to reach USD 532.6 Million by 2020. The growth of is attributed to the requirement to compensate for the large influx of power from renewable sources into the transmission and distribution grid.

- **California systems**

The system in South California has high percentage of installed PV capacity. Similar to the German network, the system operator has experienced challenges in voltage regulation after retirement of nuclear power plants and other conventional power plant in the area. The retirement of local plant has led to high imports in certain situations that stresses the local grids. In order to facilitate the power transmission from external grids and relieve the stress of local transmission, a number of synchronous compensators were installed or retired generators converted.

- **Texas system**

Texas has high levels of wind generation in an area with no local synchronous generation or loads. The wind capacity is over 5 GW with signed interconnection agreement. To stabilize the voltage and enhance the fault ride through capability of the area, synchronous compensators were introduced into the system, with ongoing plans for additional installations/conversions.

Worldwide –

Existing and planned upgrades and expansion of High-Voltage Direct Current (HVDC) interconnection worldwide is expected to increase demand for power factor correction equipment such as synchronous compensators. Developed countries are expanding their power grid network to accommodate power generated through renewable and conventional sources. With a rising contribution of renewable energy in the grid, power factor correction becomes unavoidable to stabilize the grid and for voltage regulation.

These devices are a key component of many HV transmission substations. They deliver enhanced voltage regulation and stability by providing continuously adjustable reactive power and improved short-circuit strength.

- **Scotland and GB network**

The Scotland and GB network, seen from a global perspective, faces similar challenges as other systems due to the transition to a renewable energy based system. One of the less common challenges is frequency stability since the UK it is a smaller than for example, highly interconnected Danish system. Furthermore, the wind penetration is similar to the Danish power system and this presents similar challenges in voltage control when conventional power plants are phased out.

Project VISOR system studies has also highlighted emerging issues with

	oscillations and power quality specific to GB. The constant decline of Short circuit level [SCL] in GB system poses challenges to the operation of LCC HVDC links. Further studies are being undertaken to analyse the effect of decreasing SCL on key protection systems. Details of the GB and SPT business case are provided in Section 3 and Section 4 (Relevance and Timing Section). The main differences between the international applications of SC/H-SC and GB system are • NG Future Energy Scenarios all indicate decreasing levels of synchronous generation in Scotland • The UK is predicted in all scenarios to increase its use of HVDC interconnection which depends on maintaining a certain level of short circuit level. This can only be provided by synchronous plant. • Issues with frequency stability are predicted to be more prevelant in GB in all scenarios and can be reduced using SC / H-SC by amounts that the project will analyse. • The UK is facing increasing challenges to maintain power quality e.g. sub-synchronous oscillations as a result of the high proportion of non-synchronous plant • Challenges with black start strategies and increasing costs for maintain black start services could be alleviated using Synchronous Compensators The additional knowledge that Phoenix will deliver when compared with international applications of SCs are following: **Technical and Research** **The unique combination of an integrated synchronous compensator and Statcom will:** • Demonstrate the improved system benefits expected of hybrid-SC over standalone SC through advanced control methodolology • Provide performance analysis of a hybrid-SC solution over standalone SC. • Develop the novel control systems that will fully optimise the benefits of both components (SC and Statcom) whilst reducing the risk of independent control systems compromising performance of each other. • Provide an optimum cost vs benefit profile for SC and STATCOM sizing for future applications (sizes kept similar for ease of analysis in Phoenix project) • Develop system models that enable and support evaluation of the concept in different GB Grid scenarios and investigate effects of different equipment sizes and control strategies at strategic sites across GB network • Enable the study of innovative control strategies to optimise network parameters such as system strength (SCL), stability (voltage and frequency) transmission losses and inertia by including compensation plant contributions to efficiency. • Inform current and future network analysis to understand the technical limits of renewable generation penetration and interconnection and study how H-SC technology can benefit commercial and technical operation of future grid operation.

	• Lead to increased confidence in accepting high levels of renewable plant on the UK network, with subsequent benefits to environmental and commercial performance. • Test and evaluate the hybrid innovative control strategies and their effect in lab simulation environment, and the university provides testing with hardware in the loop arrangements • Having the plant actually installed will enable us to validate models, control strategies and results in a field application in GB system • This will lead to a proposal for a GB roll-out roadmap with recommendations and results for optimal placement, size and type for future installations **Commercial** There are only limited established commercial mechanisms to incentivise ownership and operation of SCs/H-SCs in GB or worldwide. Globally such SCs are mostly owned by TOs and SOs. As the paradigm shifts from measuring levels of inertia and SCL to defining the minimum levels of inertia and SCL services required to maintain security and stability of power system such value analysis will become increasingly important to allow participation of independent service providers in this market. Phoenix will set precedents and create recommendations for development of such marketswe – we will work closely with the GB SO in this respect . In GB there is a reluctance to invest in and implement SC/H-SC technology without a thorough demonstration and establishment of Return On Investment. This was a question posed by generation owners while investigating the option of converting closed or planned for closure synchronous generators to synchronous compensators. The commercial innovation of Phoenix is essential to maximise the chance of a future roll out by minimizing financial risks and will include GB specific: • Valuation of services, cost of operation and business case • Change in market dynamics and rules for roll out of competitive tendering • Analysis of asset owners' financial expectations and requirements • Assessment of impact on ancillary services markets and other existing contracts **Regulatory** The demonstration and research in project Phoenix will generate regulatory recommendations regarding incentivising procurement of such services in future and the role of GB TOs and DNOs to maintain minimum levels for ensuring security and reliability of supply to GB customers. **o What extent SCs have been applied with STATCOMs** A Hybrid system based on synchronous compensators is globally innovative in nature. The two technologies were developed and applied in different periods in the history of power industry. SC is an older technology while STATCOM is a newer counterpart. The combination, however, is perceived to be optimal in a sense that SC can provide short circuit level and inertia while

	STATCOMs can provide fast reactive power support as well as load following capability if equipped with battery. The hybrid-SC concept minimises the limitations of each technology and maximises system benefits. To the best of our knowledge and knowledge of our OEM partner there is no international example of such H-SC implementation and this is why this project is truly innovative in our opinion.
Attachments	

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Supplementary Answer Form

Project: Phoenix________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	9
Question date	08/09/2016	Answer date	13/09/2016
Submission section question relates to	N/A		
Topic	d) Is innovative		
Question	Please provide the full list of reference papers considered when developing the project and in particular any "historical" papers that address the impact of traditional SCs on stability and fault level rather than or in addition to reactive power.		
Notes on question	N/A		
Answer	Multiple relevant research papers, OEM specifications, TO/SO reports and thesis analysed and used for development of this proposal. The ones listed below and few attached were the most relevant for the direct analysis of SCs on stability and security of power system with declining levels of synchronous generations and increasing levels of non-synchronous renewable generation. Papers primarily describing voltage stability and transfer capability improvements through SCs though relevant are not listed here for distinction as requested in the question. NB: Historically due to presence of large scale thermal and nuclear power plants power system stability (affected by inertia) and fault level were not a challenge for power systems worldwide. Thus SCs were mostly used for voltage regulation. As in the past SCs were poorly designed and old hydrogen cooling systems, they were prone to high losses and required regular maintenance. They were gradually replaced by power electronics. As post 2008 the interest in SCs was renewed internationally analysing its effects on stability and short circuit levels manufacturers re-designed and launched state-of-the art SCs with minimal losses and almost no		

	maintenance requirements. This new technology remains to be proven in GB system and demonstrated live through project Phoenix. Thus there are no relevant "historical" papers regarding stability and SCL benefits of SCL. The papers describing this new role of new and improved SCs in recent fast evolving power system were published from year 2006 onwards. News article: http://www.think-grid.org/node/135717/pdf [1] Paul E. Marken, Arthur C. Depoian, John Skliutas, and Michael Verrier. "Modern Synchronous Condenser Performance Considerations", 978-1-4577-1002-5/11©2011 IEEE [2] A. Glaninger-Katschnig "Contribution of synchronous condensers for the energy transition", Elektrotechnik & Informationstechnik (2013) 130/1: 28–32. DOI 10.1007/s00502-013-0119-3 [3] Ori Agranat, Iain MacGill, Anna Bruce "Fast Frequency Markets under High Penetrations of Renewable Energy in the Australian National Electricity Market", presented, 2015 Asia-Pacific, Solar Research Conference [4] P. Hsu, E. Muljadi, Z. Wu, W. Gao "Permanent Magnet Synchronous Condenser with Solid State Excitation", presented at the 2015 IEEE Power and Energy Society General Meeting Denver, Colorado, July 26–30, 2015 [5] H T Nguyen et al. (2016). "Frequency Stability Improvement of Low Inertia Systems Using Synchronous Condensers", DTU, Siemens, Copenhagen [6] H Abildgaard, N Qin. "Synchronous Condensers for reliable HVDC operation and bulk power transfer", presented, IEEE PES General Meeting, Denver, Colorado, 2015 [7] Synchronous Condenser Market - By Cooling Type (Hydrogen Cooled, Air & Water Cooled and Others); By Components (Stator, Cooling System, Exciter and Others); By Industry (Wind / Solar, Oil & Gas and Others); By Geography Forecast (2016-2021) – Report not available however impacts discussed with vendors, international TOs and in Cigre working groups. Summary and brochure attached [8] Karlsson, K. B., Kitzing, L., Katz, J., Sørensen, P. E., Cutululis, N. A., & Hansen, A. D. (2014). Challenges and solutions for energy systems with high shares of wind energy. In H. Hvidtfeldt Larsen, & L. Sønderberg Petersen (Eds.), DTU International Energy Report 2014: Wind energy — drivers and barriers for higher shares of wind in the global power generation mix. (pp. 63-71). Technical University of Denmark. [9] J. O'Sullivan, A. Rogers, D. Flynn, Senior Member, P. Smith, A. Mullane, M. O'Malley, "Studying the maximum instantaneous non-sunchronous generation in an island system –frequency stability challeges in Ireland", IEEE Transactions on Power Systems (Volume: 29, Issue: 6, Nov. 2014) [10] Michael Schmidt Nielsen "Allocation of Synchronous Condensers for Low Inertia Systems", DTU, Siemens, Copenhagen [11] Emanuel Marazzi "Short circuit power planning for renewable energy

	systems via synchronous condensers", DTU, Siemens, Copenhagen The additional publications studied for development of business case are as follows:

[1] National Grid. (2016 July 26). Future Energy Scenarios 2016. [Online]. Available: http://fes.nationalgrid.com/fes-document/

[2] National Grid. (2016 July 26). System Operability Framework 2015. [Online]. Available: http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/System-Operability-Framework/

[3] SQSS Panel. (2016 July 26). NETS Security and Quality of Supply Standard. [Online]. Available: http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/SQSS/The-SQSS/

[4] J Burr, S Finney, C Booth, "Comparison of Different Technologies for Improving Commutation Failure Immunity Index for LCC HVDC in Weak AC Systems", presented IET ACDC conference, Birmingham, 2015

[5] P Wall et al. (2016). "Assessing the Smart Frequency Control Resources in the Future GB Power System", University of Manchester, National Grid, GE Grid Solutions, University of Strathclyde, Manchester

[6] National Grid. (2016 July 26). Transmission Entry Capacity (TEC) Register. [Online]. Available: http://www2.nationalgrid.com/UK/Services/Electricity-connections/Industry-products/TEC-Register/

[7] Scottish Government. (2016 July 26). "Energy Statistics for Scotland". [Online]. Available: http://www.gov.scot/Resource/0049/00498583.pdf

[8] GE Digital Energy. (2016 July 26). Synchronous Condenser Systems. [Online]. Available: https://www.gegridsolutions.com/PowerD/catalog/synch_cond.htm

[9] Siemens AG. (2016 July 26). The stable way - Synchronous condenser solutions. [Online]. Available: http://www.energy.siemens.com/br/pool/hq/power-transmission/FACTS/Synchronous%20Condenser/Synchronous_Condenser.pdf

[10] National Grid, Code Administrator. (2016 July 26) System Operator Transmission Owner Code (STC). [Online]. Available: http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/System-Operator-Transmission-Owner-Code/

[11] T Ackermann, R Kuwahata. (2011). "Lessons Learned from International Wind Integration Studies", Energynautics GmbH, Langen

[12] HM Government. (2016 July 26). Carbon Plan: Delivering our low carbon future. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47613/3702-the-carbon-plan-delivering-our-low-carbon-future.pdf

[13] J Bömer et al. (2010). "All Island TSO Facilitation of Renewables Studies", Ecofys prepared for EirGrid Plc, Dublin

[14] National Grid. (2016 July 26). March 2016 Monthly Balancing Services Summary 2015/16. [Online]. Available: http://www2.nationalgrid.com/UK/Industry-information/Electricity-transmission-operational-data/Report-explorer/Services-Reports/

[15] Ofgem. (2016 July 26). Electricity Interconnectors. [Online]. Available: https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors

[16] National Grid. (2016 July 26). 2015 Electricity Ten Year Statement. [Online]. Available: http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-Ten-Year-Statement/

[17] International Renewable Energy Agency. (2016 July 26). Battery Storage for Renewables: Market Status and Technology Outlook. [Online]. Achieved: http://www.irena.org/documentdownloads/publications/irena_battery_storage_report_2015.pdf

[18] C Davidson, W Wirta. (2016 July 26). AES Uses Synchronous Condensers for Grid Balancing. [Online]. Available: http://www.powermag.com/aes-uses-synchronous-condensers-for-grid-balancing/

Attachments	Contribution of synchronous condens Modern synchronous condenser performan Fast Frequency Markets under High P A parametric investigation on the e synchronous-condenser-market-report-br Think Grid - Synchronous condens Denmark_Integrating _Wind.pdf Ireland ERC Max Instant Non synch ge MSc_Short circuit power planning for re

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Supplementary Answer Form

Project: Phoenix_________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	10
Question date	08/09/2016	Answer date	13/09/2016
Submission section question relates to	N/A		
Topic	e) Partners and ext. funding		
Question	Please provide further details of the process taken to identify and recruit project partners. This should include an indication of the number of providers approached (academic and OEMs) and whether aspects of competitive processes were employed (eg were costed proposals received and compared?).		
Notes on question	N/A		
Answer	The scope and innovation components were verified by engaging with academic bodies, generation companies (EDF, SP Generation), potential investors and GB SO, National Grid. A brief scope was sent to suppliers to gauge interest in the supply chain for innovation in Synchronous Compensators. The major global suppliers were identified as ABB, GE Grid Solutions and Siemens. All three suppliers proved willing to participate in the project and offered support in identifying key innovation components. Individual meetings were carried out with all 3 suppliers, academic bodies, generation companies and international stakeholders. SP Transmission approached SP Generation regarding potential conversion of Longannet to SC, however due to lack of defined return on investment and impact on delivery on project due to on-going de-commissioning plan this approach was considered of extreme risk to the successful delivery of the project as a NIC project. Conversion does remain a viable option in future as discussed with EDF.		

OEM Partner Selection

Phoenix proposal team engaged will 3 main vendors during the proposal preparation phase GE, Siemens and ABB. All vendors proposed different solutions and showed interest to partner should the project be successful. SCs by nature require higher capital investment and it was not considered value for money for GB customers for a larger SC to be funded through this mechanism. A concept of 3rd party ownership or leasing was also discussed with OEMs and 3rd party owners however due to lack of clear ROI such concept was perceived unfeasible in all discussions.

For proof of concept and to demonstrate innovation, vendors were requested to add value to the project by contributing through globally innovative control strategies, contributing to project through R&D and accepting certain risks involved. [redacted]

[redacted]

[redacted]

ABB were selected as project partners because the ABB solution proposed for this project is globally innovative with its hybrid SC concept. ABB is a leader in power technologies with proven experience in SCs and FACTS devices. ABB has a great commitment to innovation in GB. ABB also pledged a substantial contribution to the project of the order of £1.95m through R&D and discounted equipment costs.

Academic Partner Selection

Academic partners were selected by their virtue of level of research already conducted/undertaken relevant to project Phoenix. They were also assessed on technical expertise, availability of laboratory facilities, experienced resources and component & system models that can form a solid base for further research to be carried out in Phoenix.

During the literature review in preparation for Phoenix, it became apparent to the project proposal team who the global leaders in SC academic research were. Technical university of Denmark (DTU) has substantial experience in SC/H-SC

	modelling/control and world-leading academic knowledge and hardware in loop testing facilities. DTU started the Synchronous Condensers APPlication in Low Inertia Systems (SCAPP) http://www.scapp.dk/ project in 2014 along with Danish System Operator, Energinet and Siemens. DTU were identified to provide expertise in SC/H-SC modelling/control and inform on SC applications in the Danish system. Partnering with DTU also enables a detailed knowledge transfer between Phoenix and the SCAPP project; ensuring Europe's best practise for Synchronous Compensator deployment is integrated into the GB wide roll out. Through Phoenix, the project proposal team planned to initiate a knowledge transfer between DTU and a GB university to ensure the post-project knowledge and expertise would remain in GB. SPT was contacted by University of Strathclyde (UoS) after the Phoenix ISP was published on the internet. UoS presented the case with relevant research recently carried out by their department of Electronic and Electrical Engineering. UoS also made a very compelling case for undertaking the GB wide system studies, building on previous innovation projects and integrating SC (modelling and control) into dynamic studies to measure whole system response (building on their ongoing work in SMART Frequency Control, NGET SO project) and benefits on the GB network. University of Strathclyde has a proven track record of excellent research for SPEN. UoS will also aid the Phoenix delivery team in knowledge capturing and dissemination activities including through national and international working groups. Details of project and partner selection are described in **Appendix D** of full submission. **Market Specialist** SP Transmission will tender for services of a market specialist as a part of the project for independent assessment of the financial value analysis and enagagement with wider range of stakeholders. The role of the market specialist will be to participate in working groups and create independent reports informing service providers, TOs, OFTOs and DNOs regarding role and potential of SC/H-SC techology in future GB power system. This will be a key element of the knowledge dissemination strategy of the project. [redacted]
Attachments	

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Supplementary Answer Form

Project: Phoenix

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	11
Question date	08/09/2016	Answer date	13/09/2016
Submission section question relates to	N/A		
Topic	Mulitple		
Question	Are other providers of the Hybrid SC available? If so were these costed during partner selection?		
Notes on question	N/A		
Answer	During the OEM partner selection process of ABB was the only supplier with a well-developed concept for hybrid-SC concept based on their R&D research and product protfolio development plan for finding technical solutions to meet future power system challenges with higher levels of renewable generation. [redacted] The concept of hybrid-SC can be deployed with any vendor's devices in future. The underlying firmware and software development for the master control system will be ABB specific in this project however the component, system models and objective functions will be made available for further research and implementation for GB wide roll-out.		

Attachments	

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Supplementary Answer Form

Project: Phoenix____________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	12
Question date	08/09/2016	Answer date	15/09/2016
Submission section question relates to	N/A		
Topic	e) Partners and ext. funding		
Question	Please provide an estimation of potential benefits to project partners in the event of rollout on the GB scale as presented in the benefits estimation in appendix A.		
Notes on question	N/A		

Answer

The potential benefits listed in Appendix A will be accrued to GB TOs, SO and service providers with the potential roll-out of Phoenix solution after successful demonstration.

Network Licensee Partners

The potential benefit breakdown among project partners and stakeholders based on Appendix A is shown in table below

The primary benefit for GB TOs is reduced risk on security of supply to customers and for GB SO is increased level of services for maintaining system operability.

Benefit Scenario Slow Progression (NPV)		2030 (£m)	2040 (£m)	2050 (£m)	% Benefits
GB TO (SP Transmission)		18.36	50.48	130.15	15.18
GB SO (NGET)	SO Partner	38.71	106.41	274.37	32
Non-Partners					
GB TOs	Project Advisor	37.28	102.48	264.25	30.82
Service Providers	Stakeholder	26.61	73.15	188.63	22

	It should be noted that all GB TO and SO benefits will be ultimately translate into end consumer benefits for GB customers. The benefits to service providers will potentially raise interest in SC/H-SC technology and accelerate roll-out of this technology across GB power system. The socio-economic benefit of retaining interest in large capacity synchronous machines will also benefit GB industry and future markets. **Academic Partners** The academic partners DTU and UoS do not directly benefit from roll-out of this technology. However they benefit indirectly from: • Renewed and retained interest in SC technology. There has been concerns regarding loss of knowledge regarding large electrical machines on the event of progressive closure of large scale generation plants • Improvement in research models and knowledge in hybrid-SC systems and hybrid co-ordinated controls strategies best depicting future technical solutions and state of power system • Transfer of knowledge and skills between GB and Denmark • Recognition in international working groups • Participation in development of FES and SOF with GB SO and TO • Foundation building for future innovation of Phoenix solution **OEM Partner** The OEM partner and other OEMS will directly benefit from roll-out of this technology through increased sales of H-SC technology in GB and worldwide. However the % share of GB sales in worldwide sales is difficult to predict at this stage. Due to rising issues with stability and security of supply within GB power system and potential roll-out metrics predicted during benefit calculation OEMs could benefit from sales at 6-9 different sites across GB. The exact nature, type and size of installation is can not be predicted without proper system studies and engineering feasibility analysis. Additionally the profit margins of OEMs are confidential information and won't be available to TOs/SO. On that basis the exact value of OEM benefit is unavailable at this moment. It is to be noted as before retaining the skills in SC technology and renewed interest from GB power industry will indirectly benefit GB industry and future economics. It may also encourage OEMs to retain manufacturing within GB to reduce transport costs and import taxes. **Market Specialist** The market specialist to be tendered for through project Phoenix will not directly benefit from the project. The indirect benefits are difficult to predict without knowing the person or institution at this moment.
Attachments	

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Supplementary Answer Form

Project:Phoenix

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	13
Question date	08/09/16	Answer date	13/09/16
Submission section question relates to	n/a		
Topic	e) Partners and ext. funding		
Question	Please confirm the value of funding that will be spent on each project partner (incl labour and equipment costs).		
Notes on question			
Answer	The project costs are distributed across each project partner as below.		

[redacted]

Attachments	

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Supplementary Answer Form

Project:Phoenix________________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	14
Question date	08/09/16	Answer date	13/09/16
Submission section question relates to	n/a		
Topic	e) Partners and ext. funding		
Question	Please provide a justification of the level of contribution to the project from each project partner. The response should consider partner cost to the project and the potential to benefit post project.		
Notes on question			
Answer	Each project partner plays a vital and contributing role in the successful undertaking of this project. [redacted] [redacted] SPT PM have the overall responsibility for leading the project, including managing the overall project programme, budget, and reporting. In managing innovation projects such as this, input is required from various areas of the businesses at various times throughout the project (e.g. engineering design, system planning, and regulation/commercial, finance) to assist the overall project delivery. SPT will also be responsible for the overall co-ordination between all collaboration partners and reporting to Ofgem during the project. The importance of role of SPT in Phoenix is to ensure that it can in future maintain security of supply for its customers as required by NETS SQSS and protect its assets against issues with power quality and increased levels of system dynamics in light of progressive closure of large scale generation in Scotland.		

Potential roll-out benefit: 15% of potential roll-out benefits may accrue to SPT

[redacted] [redacted]

As System Operator, NGET will play a pivotal role in ensuring the project addresses the key current and future issues faced by the GB system as a whole whilst also ensuring that the solutions proposed align with ongoing system modelling studies to determine optimal investment requirements and opportunities. In addition, NGET will provide valuable input into the assessment and recommendation of potential future market mechanisms and facilitator measures, as required. NGET will also be responsible for informing and introducing project Phoenix results into future system operability framework and network options assessment. The input from NGET SO will be valuable towards generating recommendations for regulatory and market changes in future.

Potential Benefits to GB SO: 32% of the roll-out benefits may accrue to GB SO.

[redacted] [redacted] [redacted]
[redacted] [redacted] [redacted]

The two academic partners were chosen based on their experience of similar and relevant study in the subject field, in particular DTU's existing SCAPP project and UoS's recent studies into GB inertia and synthetic inertia.

The contribution from UoS is through use of lab facilities (RTDS and RTDS specialist) of the order of £150k. The contribution from DTU includes use of lab facilities (£64.5k) and discounted overheads of the order of £85,5 k.

Potential Roll-Out benefits: No direct benefits

[redacted] [redacted]

The contractor costs are provided as a 'turnkey' solution, with costs associated to the major project areas rather than resource allocation. For the purposes of this submission, the civil works and materials & equipment costs have been categorised as equipment, with the remaining costs categorised as contractor and extrapolated across the work packages. The "contractor" costs therefore encompasses PM, detailed design, engineering, installation and commissioning.

Furthermore, the manufacturer has committed to contributing £1.9m, largely related to R&D resources, as set out below:

- £373k R&D specialists in project
- £321k Utilisation of ABBs RTDS facilities for offline testing
- £146k SC manufacturer financial contribution to the project
- £1,114k Through ABB's deployment of resource and equipment ABB expects to recover operational costs and overhead only - this equates to £1114k in kind contribution

[redacted]
[redacted] [redacted]

To support the development and assessment of the potential commercial mechanism, a market specialist(s) will be utilised through work package 3. This additional resource will support the project progress the development of new robust commercial service or framework by which H-SC can operate, based on the learnings from the project. The role(s) of Market Specialist will

	be tendered during the project to ensure the necessary expertise that may bring maximum value for money. A provision [redacted] has been made for these services. [redacted] To facilitate the primary asset installation, additional site works are required at the substation to establish a point of connection, which will be the HV turrets of the transformer. In undertaking our RIIO-T1 Business Plan SPT established an optimal operating model working alongside Iberdrola Engineering and Construction (IEC) to deliver cost effective EPC across all operational projects. IEC's involvement with this project necessary to align with SPT's current operational practices for site installation & commissioning and, furthermore, to ensure learning from the project is incorporated into future practices.

Attachments	

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Supplementary Answer Form

Project: Phoenix_______________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	15
Question date	08/09/2016	Answer date	13/09/2016
Submission section question relates to	N/A		
Topic	Multiple		
Question	The project involves a significant element of academic support. Please explain why this level of academic involvement has been included and the value it adds to the project.		
Notes on question	N/A		
Answer	There is a significant element of research in project Phoenix, and the academic partners have been selected for their proven track record in a number of very relevant project – the SCAPP project in Denmark (DTU) and the Enhanced Frequeency Control Capability (EFCC) project in GB (University of Strathclyde). The principal investigators on both of these other projects will lead the contrinution of the respective institutions. The research element is crucial for successful roll-out of the SC/H-SC technology in the post-demonstration phase. WP 5 Component and System Studies will deliver following key deliverables of the project: • Study and laboratory simulation testing of innovative control strategies in various grid scenarios with appropriate component and system models. • Optimal hybrid co-ordinate control strategies depending on site and context to maximise both regional and system benefits. • The optimal size, type and site considerations for future installations across GB power system through detailed analysis of GB power system model.		

- Analysis and valuation of levels of inertia, short circuit level and voltage control services SC/H-SC technology can provide – this will build upon GB models and studies already carried out under the EFCC project.
- GB roadmap for roll-out of SC/H-SC technology.
- Case studies:
    - Define role of SC/H-SC technology in enhanced frequency control schemes – building on EFCC experience and resources.
    - Impact of SC/H-SC installation on future operation of Western HVDC link.
- Comparison of international TO/SO business cases for investment in SC/H-SC technology to that of the GB system.
- Knowledge Dissemination through publication of papers and participation in established working groups for system operation – academics are highly-motivated to publish and this is positive for this project.

The following work streams will be covered as a part of WP5 in Phoenix.

- **Component Level Studies (led by Technical University of Denmark (DTU))**
    - Analysis of SC model from the SCAPP project.
    - Development of the new H-SC model in the RTDS environment.
    - Co-Simulation platform for faster prototyping for new designs and hybrid co-ordinated control schemes.
    - Agreement and Validation of representative GB system model – real-time and non-real-time reusing GB models from FES, EFCC and SOF (in conjunction with Strathclyde).
    - Integration of SC/H-SC model to GB network model (in conjunction with Strathclyde).
    - Performance analysis of the H-SC based on monitoring the output and performance from live operation on site.
- **System Level Studies (led by University of Strathclyde (UoS))**
    - Analysis of the system findings from SCAPP project.
    - System Studies and Quantification of overall benefits to be fed into the financial analysis of SCs in GB system.
        - Dynamic Voltage Response
        - Short-Circuit Capacity
        - Frequency response characterisation
        - All of the above will build on experience and models used in EFCC
    - Further to the above points, exchange of models and system characteristics with EFCC and use of EFCC scenarios to show positive influence that SCs will have in conjunction with other new forms of frequency response. Overlaying SCs on EFCC scenarios.
        - Optimised benefit calculation from SCs and EFR.
    - Studies on value addition of SCs with respect to interconnectors (HVDC links) in a weak AC system
        - Case study: Western HVDC Link and analysis of LCC – again building on work previously carried out by Strathclyde with NG.
    - Research review Optimal Placement and Capacity evaluation of SCs in GB.
    - GB roadmap and roll-out recommendations.

This research element in project Phoenix will bridge the gap between past

	and future system studies regarding system operations and role of SC/H-SC in different energy scenarios. The system studies will start begin with analysis of results and findings from SCAPP, EFCC and other projects (**detailed in Appendix H of the full submission**). The models developed through previous projects will be used to conduct different streams of studies at both component and system level. The component-level studies will be extended from the existing studies regarding SC inertial and fault level performance in SCAPP project to include AVR tuning and new hybrid co-ordinated control strategies developed through this project. The existing laboratory facilities at both institutions will be used to conduct real time and hardware-in-the-loop demonstrations of SCs embedded within modelled grid systems. The system level studies will analyse the application of SC/H-SCs at different locations within the GB network and will directly feed into FES and SOF studies conducted by the GB System Operator. The system studies will also provide different methods for analysis of the financial value analysis model developed in work package 3 and help validate the outcomes of the financial evaluation. System studies will be created that are influenced by future energy scenarios, energy policies and they will also analyse in detail specific use cases such as the role of SC/H-SCs in frequency response markets in conjunction with other fast frequency solutions developed through EFCC and potential constraints upon the operation of the western HVDC link in low fault level conditions after the planned closure of Hunterston in 2023. The research component of this project will result in GB roadmap for future rollout of SCs and aid in RIIO T2 planning for GB transmission owners. Dissemination and demonstration, and building upon extensive experience in other related projects, will also be positive outcomes of using the academic partners.
Attachments	

Additional questions from 1st Bilateral

16. **The bid says there will be financial value analysis for SCs/H-SCs and potential development of new commercial mechanisms to financially incentivise such installations? Can you explain a bit in detail how you'll develop these mechanisms and what is the common process followed for the same?**

Answer: The important objective for project Phoenix is to identify "essential security" requirements of inertia and SCL services in future from "incremental value" by which it could be possible to determine which of the benefits from the SC/H-SC solution are necessary for security and stability compliance (which are may be funded or enabled through an essential financial mechanism) and which additional services (not essential to security, but still important for system operability) could be funded via other possible means.

The processes followed in this project will be in line with and inspired by past and present examples of commercial arrangements existing with GB SO and will include considerations from other streams of commercial developments within GB and in international energy markets. The results of work package 3 will be disseminated through SDRC 2 (financial value evaluation and regulatory recommendations) and SDRC 8 (knowledge dissemination) as described in full submission.

WP3 Commercial Model Development and Roll-Out Recommendations of project Phoenix with its work streams will

- deliver the **financial assessment**,
- Generate a potential ROI with **market design arrangements** for future SC/H-SC solutions
- Set precedents for inertia and SCL markets in future
- Deliver recommendations for regulatory changes to enable the financial framework developed

SP Transmission, GB SO, market specialist (to be tendered for during the project) will work in close collaboration and in working groups with other TOs, DNOs, service providers and other stakeholders to deliver the following measurable during the project conceptualisation, implementation and validation phases of project Phoenix:

<u>Financial Assessment principles</u>

Phoenix will adopt the best approach for demonstrating a positive end consumer business case by deriving a forecast of alternative balancing actions against a "do-nothing", "new CCGT" and "alternative technology" case for each of the scenarios in the SOF/FES and for each of the potential locations. In doing this Phoenix would utilise seasonal normal load factors for wind to

- Derive a generation stack from our dispatch model and assess the required utilisation for locational specific actions (e.g., voltage and constraints), and use these underlying assumptions to derive weekday/weekend inertia values and translate this into response requirements. Particularly against the "do-nothing" case we would seek to "price" the benefit of the additional operational flexibility to take outages on units and boundaries.
- Phoenix will also derive an appropriate de-rating or "risk discount factor" to reflect that there may be a fundamental change in the provision of ancillary services etc. which could lead to a reduction in the costs the project offsets. In this method, Phoenix will adopt a punitive or least aggressive discount factor.

<u>Proving a positive end-consumer business case will demonstrate the project is consistent with the aims and aspirations of the regulator and NIC project objectives.</u>

Phoenix will then address the next stage of the framework development: **Funding Mechanics.**

<u>Market Design/Arrangements</u>

Once the need has been justified it becomes a pure funding issue and allows the opportunity to ask "what funding arrangement for this asset provides the greater benefit to the consumer?" Benefit in this context includes exploring the potential consequences of each funding route exploring questions like “does this allow for further completion?”, “are there unintended consequences for creating a monopoly position?”, “how does this interact with existing incentive schemes?”. In effect it asks, what is an appropriate return for the risk of building, owning and maintaining this asset and how can we ensure its continued availability to provide the benefits detailed above.

The potential routes would include:

- **TO asset (included under RIIO and/or future schemes)** providing “free” continuous access to the SO.
    - Independent tenders could still be accepted for the build of such assets in future, or the build of the asset could be separated from the maintain/operate requirements (essentially providing a tendered market).

- **Ancillary service market** - there is some precedent for ancillary services funding in new build assets in the short term (e.g EFR service)

- **Bespoke Solution** – If none of the above routes prove suitable Phoenix with collaboration between TOs, GB SO and market specialists may choose an alternative bespoke route if it delivers maximum end consumer benefits. The exact nature of the bespoke solution is difficult to predict at this moment.

Phoenix will ensures the framework it proposes will be

- Scalable (i.e. that it could be replicated)
- Accessible (i.e that it doesn’t preclude competition).

For each solution proposed Phoenix will detail the forecast return, allocation of risk, accessibility of benefit and regulatory changes required.

Potential Regulatory Changes

Phoenix having created a recommended market arrangement after detailed analysis, will detail recommendations for regulatory developments to accommodate the proposed route.

NB: At Phoenix submission/response stage no parties within the project have a pre-commitment to a particular arrangement.

17. **How will other service providers be encouraged to participate at the end of the project if such a framework is developed? Are we open to the concept of others (other than TOs/SO) tendering for installation?**

Answer: If project Phoenix after the implementation phase of WP3 and after developing recommendations for market design concludes that ancillary service market route (see Q1) is the most suitable arrangement and delivers maximum end consumer benefits: service providers will be provided details of the market requirements (see example EFR) and asked to tender for SC/H-SC installations post project Phoenix.

One of the market design routes as discussed above (see Q1) is the route of ownership, operation, and maintenance of the assets by TO/SO and a tendered market route for installation of the assets to be delivered by independent contractors. This route may be followed in future if ownership of the assets by To/SO will deliver maximum end consumer benefits without affect other market arrangements and service providers.

The bespoke solution and a probable arrangement moving forward could be a combination of both options discussed above and could lead to regulatory changes allowing TOs to participate in service market or be allowed to deliver minimum level of services essential to maintain security of supply to GB customers.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: Phoenix________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	18
Question date	20/09/2016	Answer date	22/09/2016
Submission section question relates to	N/A		
Topic	b) Value for money		
Question	Please explain why you have not identified any Direct Benefits from the project.		
Notes on question	N/A		
Answer	Project Phoenix requires a new transmission infrastructure to be established to accommodate the connection of the hybrid synchronous compensator (H-SC). Thus this transmission infrastructure is additional to any works planned and authorised for the RIIO-T1 price control period. The H-SC itself is innovative and was not planned to be installed in the RIIO-T1 price control period. The nature of the transmission infrastructure required to facilitate connection varies from site to site, as one site requires additional cables (Longannet) and the other requires a new bay (Neilston). The engineering design team calculated the costs of these additional infrastructures and the price quoted in the total project costs is the best case scenario (most economical) to facilitate connection at each of the site. As the transmission infrastructure to be built as a part of the project is purely for connection of the H-SC and is additional to existing works planned in RIIO-T1 period delivering no wider planned benefits in this period; no direct benefits were identified for project Phoenix.		

Attachments	

Electricity Network Innovation Competition Full Submission

<u>*Supplementary Answer Form*</u>

Project: Phoenix________________________

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	19
Question date	20/09/2016	Answer date	22/09/2016
Submission section question relates to	N/A		
Topic	a) Enviro+consumer bens		
Question	How much of the capacity and carbon savings are truly NET ADDITIONAL to GB?		
Notes on question	N/A		
Answer	All the capacity and carbon savings listed in Appendix A of the proposal are truly net additional to GB through roll-out of SC/H-SC technology provided • The roll-out installations are of the size and at the site as simulated in the system studies for SPT Licensee area • The roll-out considerations for GB additional sites match the size of the installations as considered for SP Transmission area and the roll-out scale is as estimated in the benefit calculation case **Net Additional Capacity** The additional capacity quoted in Phoenix bid for SP Transmission area was a sum of capacity increase by: • Increase of AC power flow across B6 boundary		

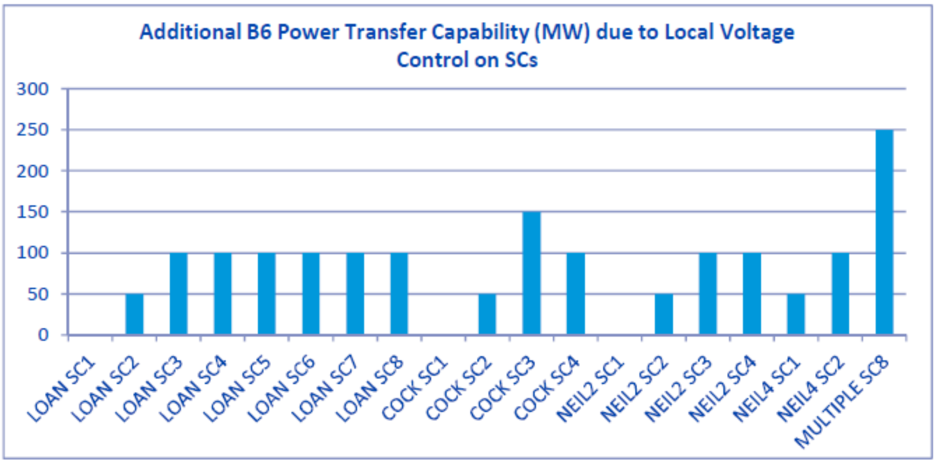


Figure 6-2 - Additional B6 Power Transfer Capability (MW) due to Local Voltage Control on SCs

- Relieving constraints at the DC link
  Figure below shows increase of short circuit level (SCL, also known as fault level) at Hunterston through roll-out of SC/H-SC technology. [redacted]

[redacted]

Figure 5-9 - Minimum Short Circuit at Hunterston

The cumulative sum of the additional capacity released by deploying SC/H-SC technology in SPT area (assuming the roll-out plan described in Appendix A) is 665 MW by 2030 and 887 MW by 2040/2050. The net additional benefit maxes out post 2040 as assuming an asset life of 35-40 years no additional installations may be required post 2040 until 2050.

The capacity release as in case of financial benefits is then multiplied by a factor of 3 for GB roll-out scale. As there are additional interconnectors planned for GB to be connected to the wider European grid and the need for increase in AC transfer capability across power boundaries highlighted in ETYS is progressively increasing in each future energy scenario (except for

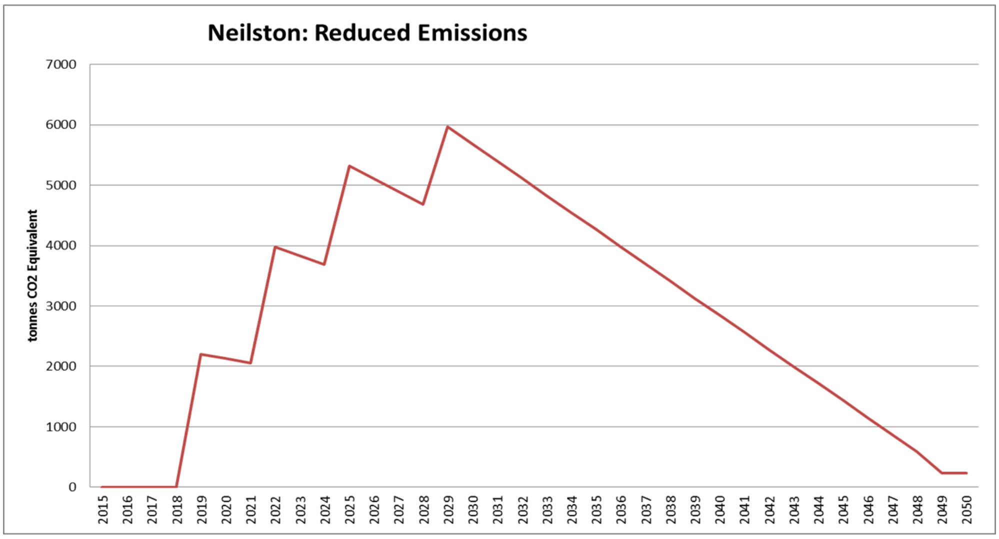
No Progression scenario) the estimate of x3 is conservative and achievable.

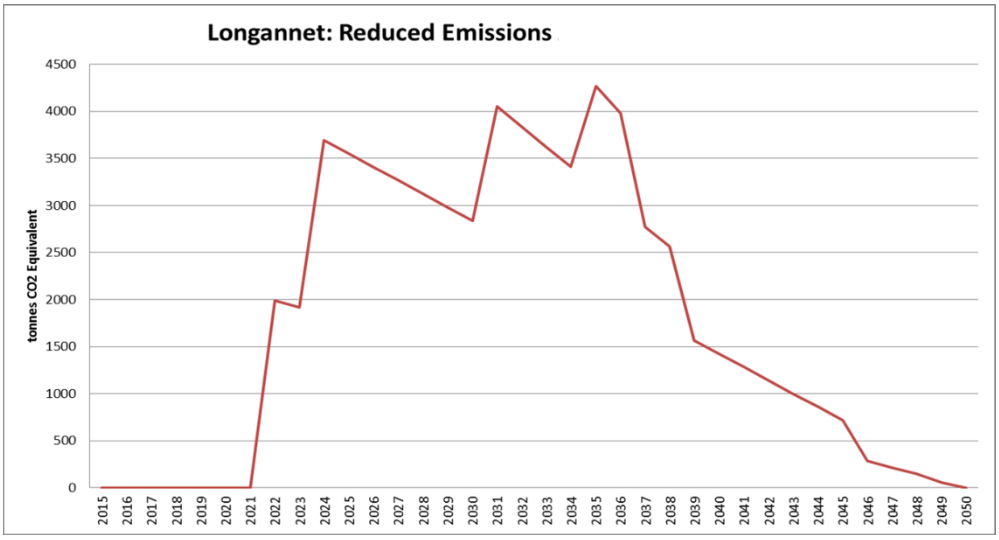
Net Additional Carbon Savings

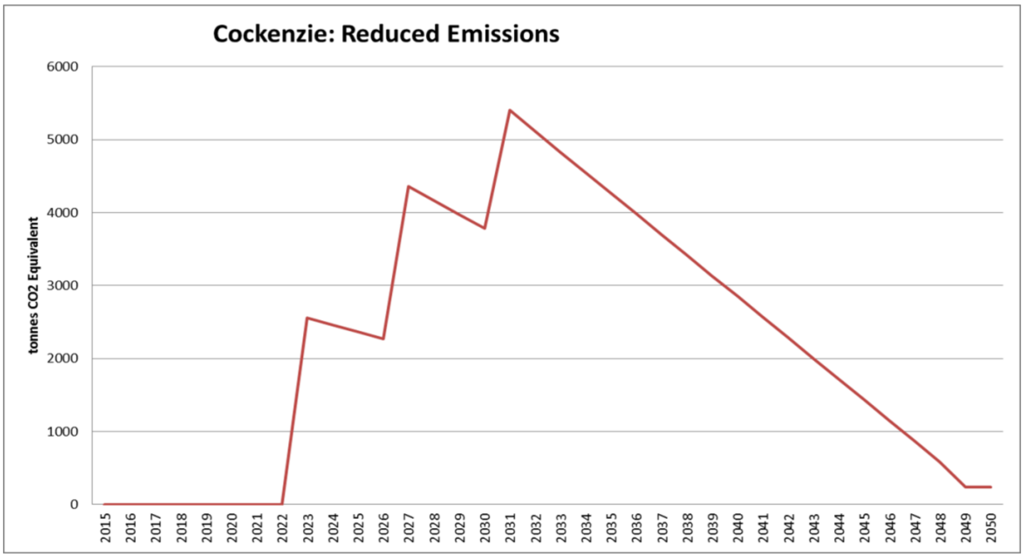
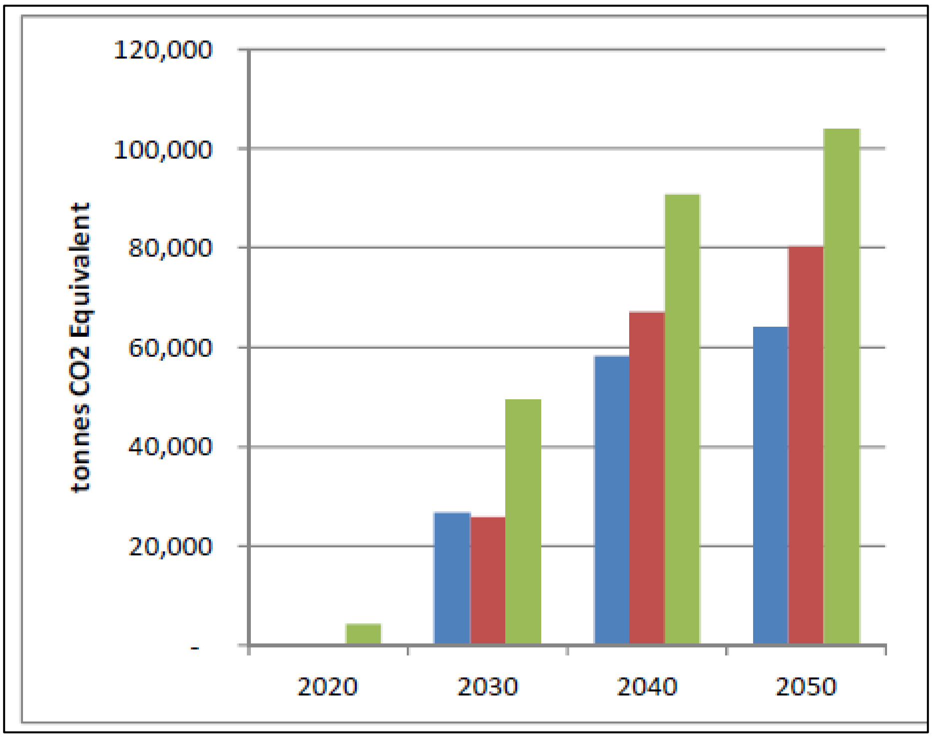
The carbon benefits for optimum SC/H-SC installation at different locations below. The shape of the graphs is representative of the installation profile of SCs, where the spikes occur at dates where a new SC/H-SC is installed at these sites. All benefits quoted below are net additional.

The network losses and constraints relieved due to improved voltage control by implementation of SC/H-SC technology in MWh are multiplied by the Electricity GHG conversion factor in tonnes per MWh for each year.

The conversion factor is based on the assumption that the power sector should target a reduction to 10g CO2 equivalent/KWh by 2050, which translates to a 12.10 annual reduction in carbon intensity. Hence the carbon savings profile is falling year on year post 2030.





	 Cumulative carbon savings  Additional carbon savings not included in the above calculation are • Smaller footprint than similar sized synchronous generation • Faster installation thus lesser time spent on site • Higher percentage of renewable generation penetration (detailed analysis is required to determine approximate rise in percentage outside the scope and time of the bid-studies) A factor of x3 as in all other benefit cases is applied for carbon savings at GB roll-out scale.
Attachments	

Electricity Network Innovation Competition Full Submission

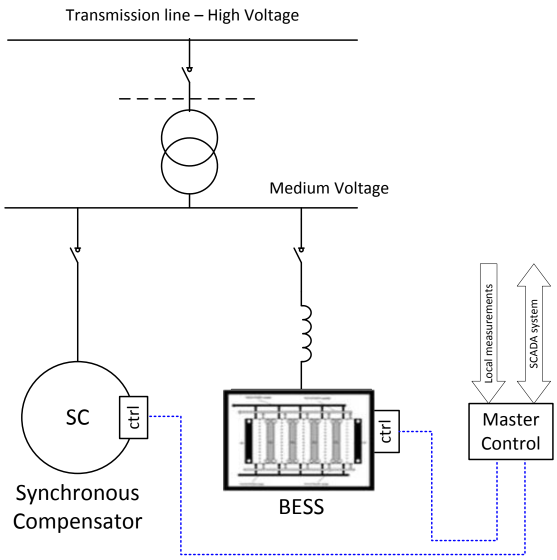
Supplementary Answer Form

Project: Phoenix

Tick if this answer has been provided verbally: ☐

Project code	SPTEN03	Question Number	20
Question date	29/09/2016	Answer date	04/10/2016
Submission section question relates to	p.13		
Topic	f) Relevance and timing		
Question	The Phoenix proposal seems to be a "transmission based investment" solution (p. 13). Please explain how this is taking a more holistic approach (across all industry participants) to resolve the future problems identified (eg with voltage).		
Notes on question	N/A		
Answer	Phoenix proposes a solution to fundamental issue of decreasing system strength in GB power system due to progressive closure of synchronous generation plants. The issues are more pronounced currently in transmission system as the network needs to maintain stability during periods of low demand and high levels of non-synchronous embedded generation. However, it does not exclude use of synchronous compensators in distribution network, and at offshore connection points. Solution for TOs/DNOs/OFTOs Examples from Hydro-Quebec and Denmark highlight use of SC both at large and small scale windfarm connection points. Small scale/Mobile SCs can be used at grid supply points to provide voltage support and short circuit level (SCL) locally. One particular extension of the H-SC solution in future will be to replace the DC capacitors of the STATCOM solution to be tested in Phoenix with battery storage. The hybrid control system to be developed under Phoenix can be applied to this arrangement as well. The system shown below will be		

simulated in project Phoenix.



The above figure combines the voltage control capabilities of a battery energy storage system with SC's dynamic overload/underload voltage control capabilities. It also provides range of inertial, enhanced response and SCL. This and may such future roll-out component models and hybrid control methods will be studied in WP4 "Hybrid co-ordinated control and integration" and WP5 "Component and System Studies".

Phoenix will also study the possible extension of hybrid control strategies to SCs, storage and power electronic converters across the network. This will align with industry's previous efforts with VISOR and EFCC to enable wide area monitoring and control applications.

Phoenix aims to find a suitable alternative solution to backfill the essential services provided by synchronous generation plants. However the solution proposed and to be enabled as future roll-out is

- Scalable (Different sizes and capacities possible)
- Replicable (Simple but effective solution making best use of existing and new technologies)
- Independent of voltage level (Applicable to both transmission and distribution network)
- Accessible (Phoenix encourages an open market concept for backfilling essential services for system security)

The main aim of Phoenix is to empower the network owners and system operators with a solution that provides range of essential services and can potentially resolve a wide range of network issues. It tackles the underlying cause of the network issues and not simply the symptoms. Upon completion of this project TOs, DNOs and SO will have a roadmap to enable to procure the solution through independent tender or from service providers.

Solution that can be enabled by Network Owners, Generation Owners, Service Providers, Independent Market Participants

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Inertia, SCL and reactive power support were main by-products of synchronous generation. In future when the paradigm shifts from measuring the levels of these parameters to defining minimum levels required for maintaining system security and stability, these will need to be procured as services. This may raise the question as to who provides these services?

There are many possible mechanisms, Phoenix proposes an open market

	approach. At this stage Phoenix does not commit to any particular mechanism but rather encourages "an open market" approach. This is unprecedented globally where SCs are largely owned by TSOs. The potential routes would include: • **<u>TO asset (included under RIIO and/or future schemes)</u>** providing "free" continuous access to the SO. o Independent tenders could still be accepted for the build of such assets in future, or the build of the asset could be separated from the maintain/operate requirements (essentially providing a tendered market). It could be encouraged under the Integrated Transmission Planning and Regulation (ITPR) process. • **<u>Ancillary service market</u>** - there is some precedent for ancillary services funding in new build assets in the short term (e.g. EFR service). Generation owners could be encouraged to retrofit synchronous generation plants planned for closure to synchronous compensators thus repurposing existing assets. The driver for generation owners to invest in this technology could be provided through a financial valuation/market mechanism. Through this an established market route service providers can also be encouraged to invest in this technology and provide services as and when required by the system operator. • **<u>Bespoke Solution</u>** – If none of the above routes prove suitable Phoenix with collaboration between TOs, GB SO and market specialists may choose an alternative bespoke route if it delivers maximum end consumer benefits. The exact nature of the bespoke solution is difficult to predict at this moment. The most suitable route will be chosen based on end consumer benefits. Knowledge Dissemination and Working Groups Phoenix under work package 5 "Knowledge Dissemination" will establish working groups with representatives from across to industry to discuss the various market mechanisms that can be developed to enable roll-out of SC/H-SC technology across GB. There will be six monthly working group meetings to share findings from the project and gather industry feedback. The end result of these working groups and the collaborative approach will be a clear direction amongst all industry participants to understand when and how the SC/H-SC solution can be applied and who can enable it. Ultimately, there may be a set of regulatory recommendations to support the necessary approach. This collaborative approach is crucial to the success of Phoenix project and for enabling a solution to the range of issues it addresses. It can be concluded that Phoenix will take a holistic approach across industries participants and network owners for developing a solution that can be rolled-out in future to backfill essential network services such as inertia, SCL and voltage support to ensure security of supply to GB customers.

Attachments	