Question No.	Proforma section	Criteria	Topic	Question	Date question asked	Date response required	Date received	Follow up to Question #	Confidential (Y/N)
1	(b) Benefits section 3.5 and Appendix D	NA	Method for calculating benefits	Number of figures are given for various different benefits throughout the document. This makes it difficult to verify the methods used and assumptions made in calculating the benefits. Please could SPM provide a short method statement (or demonstrate the calculation) for the financial benefits claimed in the text and in table 3-1 (replicated in table D-2)?	18 August 2015	25 August 2015	24 August 2015	NA	
2	Various	NA	Base case	With regard to base case costs, there appears to be a multitude of different figures given, although the ball-park figures seem grossly similar. The methods (as mentioned - Qu 1) are unclear. More specifically, however, the term 'base case' is used to mean both no investment and also conventional reinforcement. Furthermore, the amount for conventional reinforcement is [redacted] in the spreadsheet and Appendix 4, [redacted] on Pg. 53, and a number is given for conventional reinforcement of [redacted] in the TNEI report (due to need for a 132 kV part of the system). Please could we get these figures checked (possibly simplified) and clearly explained?	18 August 2015	25 August 2015	24 August 2015	NA	
3	Various	D	Costs	Costs include [redacted] for an additional 33kV circuit to provide security of supply during the trial. Please explain why these costs couldn't be set against the RIIO-ED1 load-related allowances given the forecast thermal and voltage issues for this network during RIIO-ED1.	01 September 2015	03 September 2015	03 September 2015	NA	
4	Various	F	Business planning	You estimate that up to 25 sites could benefit from, the deployment of this technology. Please can you provide more information on the scope for wider roll out within your networks.	01 September 2015	03 September 2015	03 September 2015	NA	
5	Appendix D	(a)	Rollout	Please list the 25 applications where the project could be replicated. Have the 25 sites throughout GB that are deemed suitable replication been discussed in detail and upfront with the other DNOs? Is it likely that these sites (or their surrounding regions) are already counted in previous LCNF projects or the 2015 NIC, and/or are due for conventional reinforcement in shorter timescales than the next five years (the length of this project)?	08 September 2015	14 September 2015	14 September 2015		
6	Appendix D	(a)	Rollout	A release of 30.5MVA of capacity is assumed for 25 other sites in GB. This would suggest these sites are all currently unable to be used in normal conditions, but alternative operating conditions are not ruled out . In the trial case an AC cable mitigates risk that the current circuit might fail upon conversion to DC, leading to unavailability of the link. It appears that the presented benefits will depend upon the capital expenditure being on the converter system only: how will circuit redundancy during the commissioning of the GB roll-out circuits be avoided? Has this been discussed with other DNOs?	08 September 2015	14 September 2015	14 September 2015		
7	Appendix D	(a)	Rollout	Please provide the assumptions you used regarding installation times and dates for GB rollout.	08 September 2015	14 September 2015	14 September 2015		
8		(a)	Losses	Have you quantified losses within the converters?	08 September 2015	14 September 2015	14 September 2015		

9		(g)	Risks	Do you have any concerns about receiving planning permission for the new line in a timely way?	08 September 2015	14 September 2015	14 September 2015		
10		(a)	Risks	We are to assume that the circuit does not play a role in increasing capacity from the benefits case presented; however, is there, for example, a risk to future operation should the replacement link not operate as expected?	08 September 2015	14 September 2015	14 September 2015		
11		(a)	Control system	What confidence does SPM have that the control system is achievable technically, as well as being delivered within time and budget?	08 September 2015	14 September 2015	14 September 2015		
12		(a)	Environmental benefits	It appears that the 45.4 GWh figure for environmental benefits (through the connection of LCTs) assumes that full capacity (30.5 MVA) is used 24/7 (see Section 3.5.6, Appendix A Section A.2). The 2014 Manweb Long Term Development Statement (LTDS)* shows the typical daily load profile hovering at 70% for most of the day with a long dip at night and a shorter peak (towards 100%) in the late afternoon. Therefore the 45.4 GWh figure seems optimistic. *http://www.spenergynetworks.co.uk/pages/long_term_development_statement.asp Can you confirm that this interpretation is correct? Is utilisation factor considered when calculating losses?	08 September 2015	14 September 2015	14 September 2015		
13	p25	(b)	Procurement	Please provide more detail of your procurement process.	08 September 2015	14 September 2015	14 September 2015		
14	5.2, p32	(c)	Learning	As DNOs are the primary focus for learning, do you have confidence that all DNOs will see the full benefits of the project and are prepared to apply the relevant learning?	08 September 2015	14 September 2015	14 September 2015		
15		(c)	Learning	Have you considered regular meetings with other DNOs involved in similar projects?	08 September 2015	14 September 2015	14 September 2015		
16	9, p48	(c)	Learning	Do you have any plans for sharing, during the project, how the many technical challenges have been tackled and resolved?	08 September 2015	14 September 2015	14 September 2015		
17	p25, Appendix E	(e)	Partners	It is noted that the MVDC link supplier will be tendered separately under acceptable timescales. Furthermore, the letters of support demonstrate that you have entered into significant communication with stakeholders and interested parties already. However, can you provide confidence that it will be possible to secure project partners in tight timescales?	08 September 2015	14 September 2015	14 September 2015		
18		(e)	Partners	Can you provide confidence that the MVDC link can be successfully procured within this budget [redacted]? Can you confirm that processes will be put in place to ensure that technology development that would be funded by this project remains freely available to the industry?	08 September 2015	14 September 2015	14 September 2015		
19	Section on WP3, p12	(g)	AC cable	Please provide further details about the AC cable, including where it will be fitted.	08 September 2015	14 September 2015	14 September 2015		
20	p31	(g)	Safety	Can you provide a detailed overview of the safety aspects to show that the issues have been fully identified? Are SPM procedures already in place that deal, or can be easily adapted to deal, with the potential safety issues of MVDC distribution?	08 September 2015	14 September 2015	14 September 2015		

21		(g)	Modelling	Could up-front modelling and simulation be used to provide assurance that the solution is technically robust? For a project of such a large scale and high risk, modelling and simulation would not be unusual, but does not appear to have been considered.	08 September 2015	14 September 2015	14 September 2015		
22	Appendix J	(g)	OHLs	Are the overhead lines equally suitable (as the underground cables) for DC distribution given the likelihood of them having a ferrite core? Has the makeup of the cables been accounted for when calculating DC capacity?	08 September 2015	14 September 2015	14 September 2015		
23		(g)	EMC	Please explain why you have not discussed the effects of EMC?	08 September 2015	14 September 2015	14 September 2015		
24		(g)	Magnetic fields	The system proposed is a double monopole – can we assume that the cables (which are at +/-27 kV) will be physically close enough and balanced (i.e. equal and opposite current) such that fields will not occur that could potentially affect nearby metallic equipment or AC system assets?	08 September 2015	14 September 2015	14 September 2015		
25	p46	(g)	Power quality	a. What is the evidence that harmonic distortion will not exceed G5/4 levels? b. This limit will presumably be passed on to the MVDC link supplier with which they must comply; however, does the potential for harmonic distortion issues still carry the risk of extra cost should the technical challenge be greater than expected (Risk No. 1.03 is applicable)?	08 September 2015	14 September 2015	14 September 2015		
26		(g)	Network risks	The proposal does not appear to have considered risks, with a converter station at each end, to protect internal and external network. a. It might be the case that the existing protection is sufficient; however, is this going to be tested? b. As a specific example, can the converters help with the static switching from lightning strikes?	08 September 2015	14 September 2015	14 September 2015		
27	p46		Customer impacts	You refer to a standard procedure for scheduling outages to ensure risk to customers is minimised. Can you quantify the risk of outages for this project?	10 September 2015	15 September 2015	15 September 2015		
28	p94	(d)	Innovation	[redacted]	10 September 2015	15 September 2015	15 September 2015		
29	p19	(a)	Benefits	Please explain how you calculated the £1.7bn reduction in capital costs of Scottish offshore projects using direct to MVDC solutions.	10 September 2015	15 September 2015	15 September 2015		
30	p22	(a)	Benefits	Can you quantify the reduced/avoided associated environmental impact and damage to nature from avoiding building an additional circuit?	10 September 2015	15 September 2015	15 September 2015		
31		(a)	Losses	Please provide a breakdown of the losses impact, both gross and net of the DC convertors. Please explain how you have calculated these figures.	17 September 2015	22 September 2015	22 September 2015		
32		(b)	Business case	What are the operational reasons for installing this MVDC link in the proposed location? If this project were not funded, how would you tackle these issues?	17 September 2015	22 September 2015	22 September 2015		
33		(a)	Benefits	The Panel is concerned that the benefits from reduced capital costs and reduced losses may not be realised. What are the other operational benefits of DC that have made other DNOs interested in this project?	17 September 2015	22 September 2015	22 September 2015		

34		(g)	Rollout	Do you plan to retain the DC link permanently after the project conclusion?	17 September 2015	22 September 2015	22 September 2015		
35		(a)	Business case	Please provide three diagrams of the circuits: 1) one of the current situation highlighting the constraints; 2) the convetional solution to the problem; 3) the proposed solution with the MVDC link.	17 September 2015	22 September 2015	22 September 2015		
36			Business case	The ED1 settlement provided funding for reinforcement works on Anglesey. We understand that these works are not proceeding as planned and that the Angle DC project is instead providing more AC and DC capacity to the island. Please explain why SP is seeing no Direct Benefit from the Angle DC project.	29 September 2015	30 September 2015	30 September 2015		
37		(g)	EMC	Please provide assurance that the trial will include appropriate design consideration and an EMC measurement study to inform future design requirements of the EMC effect associated with the application of this type of technology.	06 October 2015	09 October 2015	09 October 2015		
38			Business case	The Full Submission text states (end of Appendix C) – “The method will provide an efficient and enduring reinforcement solution to meet the long term energy needs of the island”. If this is the case why is no Direct Benefit shown?	06 October 2015	07 October 2015	09 October 2015		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q1
Question date	18/08/2015	Answer date	24/08/2015
Submission section question relates to	(b) Benefits section 3.5 and Appendix D		
Topic	Method for calculating benefits		
Question	Number of figures are given for various different benefits throughout the document. This makes it difficult to verify the methods used and assumptions made in calculating the benefits. Please could SPM provide a short method statement (or demonstrate the calculation) for the financial benefits claimed in the text and in table 3-1 (replicated in table D-2)?		
Notes on question	Not applicable.		
Answer	Statement of costs and benefits: • The capital investement requirement for the MVDC solution is estimated at [redacted] based on the latest stakeholder engagement. • <u>Loss reduction</u> Network losses will be reduced by enhancing voltage and reactive power controllability at both ends of the link. Network studies have demonstrated a loss reduction of 20% is achievable, [redacted]. In accordance with the project programme in Appendix E the MVDC link will be commissioned by 2019, therefore it will provide 12 years of benefits by the end of the 2030 regulatory year and 25 years of benefits by the end of 2050. [redacted]. • <u>Environmental benefits</u> The no investment option would operate the Bangor – Llanfair PG circuit normally open. Given the controllability introduced by the ANGLE-DC solution the circuit can be operated closed and consequently the DC option will secure a power transfer corridor of 30.5MW (in accordance with section 2.3.3) between the Bangor and		

	Llanfair PG sites which could be utilised to export renewable generation from Anglesey. A load factor of 17% has been assumed considering the renewable generation portfolio of Anglesey, resulting in up to 45.4GWh of low carbon energy being transported across the link annually - 30.5MW x 8760hr x 17% = 45.4GWh The social benefits resulting from the avoided CO2 emissions are calculated using the GHG conversion factors and traded carbon price in Ofgem CBA template spreadhseet. The monetised values of the benefits by 2030 and 2050 are £8.12m and £22.73m respectively. • <u>Capital benefits</u> The ANGLE-DC solution will allow 30.5MW of power transfer between Bangor and Llanfair PG. The capacity is equivalent to a [redacted] saving in capital investment corresponding to the cost of laying a circuit of similar characteristics.
Attachments	Not applicable.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q2
Question date	18/08/2015	Answer date	24/08/2015
Submission section question relates to	Various		
Topic	Base case		
Question	With regard to base case costs, there appears to be a multitude of different figures given, although the ball-park figures seem grossly similar. The methods (as mentioned - Qu 1) are unclear. More specifically, however, the term 'base case' is used to mean both no investment and also conventional reinforcement. Furthermore, the amount for conventional reinforcement is [redacted] in the spreadsheet and Appendix 4, [redacted] on Pg 53, and a number is given for conventional reinforcement of [redacted] in the TNEI report (due to need for a 132 kV part of the system). Please could we get these figures checked (possibly simplified) and clearly explained?		
Notes on question	Not applicable.		
Answer	Yes, there are two base cases in the proposal document. 1. 'Base Case' which is specific to the Anglesey area and described in the Project Business Case - Section 3 2. 'Base Case' which is relevant to the roll-out phase and described in the Benefit Tables – Appendix A 1. The business case presented in section 3 compares the proposed MVDC link solution illustrated in Figure C-4 against the submitted RIIO-ED1 proposal, base case illustrated in Figure C-3. In this 'base case' Bangor-Llanfair PG circuit will be open in normal operation at no cost, hence no investment is considered. 2. In line with the Electricity NIC Governance Document the 'base case' costs in the benefits tables are defined as the costs of delivering the **same network benefits** through the most efficient method **currently in use** on the distribution system. A theoretical conventional reinforcement base case was therefore designed to deliver comparable benefits to the MVDC link. We have assumed using a MVDC link provides a 30.5MVA power transfer capability between two distribution systems. The alternative solution to the		

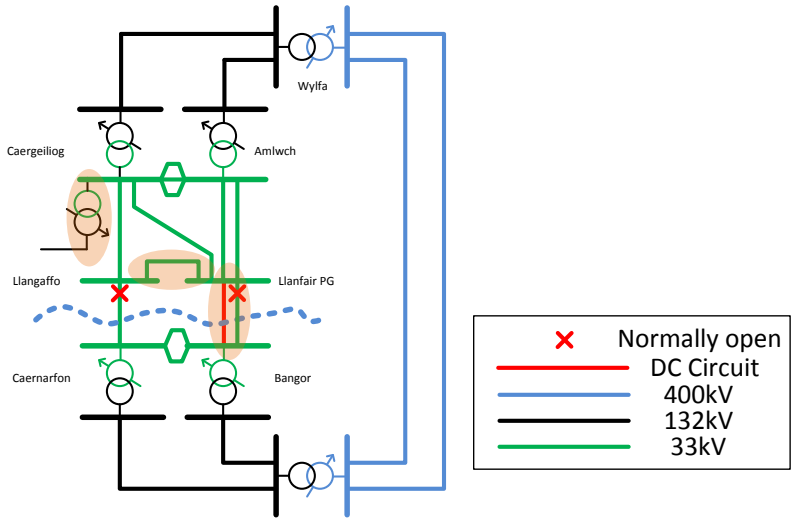
	MVDC link includes the addition of one new grid transformer at each end of the MVDC link. Costs have been prorated to the level of capacity released by the DC link and estimated at [redacted]. Regarding the differences in the amounts for conventional reinforcements: Theoretic cost estimations for the 'base case' in the Benefit Tables have been developed and estimated at [redacted] (as mentioned above). This 'base case' where a high aluminium, steel or copper content is assumed to follow a type 1 cost curve as per Figure D-3 (according to the Work Stream 3 report, issued on behalf of ENA in 2012). With regards to the discrepancy in 'base case' costs between [redacted] and [redacted], these have been calculated at different points [in the type 1 cost curve] in time considering [redacted] as the cost of delivering the scheme at present. The costs in page 53 have been calculated for a Post-Trial replication upon completion of the ANLGE-DC project in 2021: [redacted] x 109.6% = [redacted] The costs in the spreadsheet have been calculated for a replication in 2030 : [redacted] x 115.5% = [redacted]. The [redacted] figure given at the TNEI report is independent from the business case and benefits calculations and shows the total reinforcement cost for the wider Anglesey reinforcement as per figure C-3, including 33kV circuit works, 132kV circuit works and the addition of a new grid transformer in Anglesey.
Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q3
Question date	01/09/2015	Answer date	03/09/2015
Submission section question relates to	Various		
Topic	Costs		
Question	Costs include [redacted] for an additional 33kV circuit to provide security of supply during the trial. Please explain why these costs couldn't be set against the RIIO-ED1 load-related allowances given the forecast thermal and voltage issues for this network during RIIO-ED1.		
Notes on question	Not applicable.		
Answer	The 33kV circuit creates a parallel path to the transmission network at distribution level, which creates an inherent risk of overloading distribution circuits.  In particular, the circuit between Bangor and Llanfair PG constitutes an interconnection between the island and mainland groups and could overload when the anticipated distributed and nuclear generation are commissioned		

	during the first half of the 2020s. Hence there are scenarios where the circuit could not be closed and therefore cannot be treated as an enduring solution to resolve any thermal or voltage issues. The new 33kV circuit is only required as part of the ANGLE-DC project for the purpose of ensuring that security of supply is not compromised as a result of the trial and will not provide any added capacity to the network. Additionally the circuit enables: • DC circuit outages during commissioning and testing • Testing of optimal power flow control between AC and DC The optimum strategy for the operation of the AC link will be considered during the development of the project.
Attachments	Not applicable.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

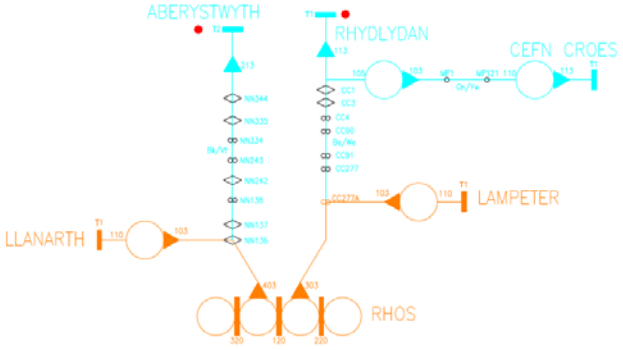
Project code	SPMEN01	Question Number	Q4
Question date	01/09/2015	Answer date	03/09/2015
Submission section question relates to	Various		
Topic	Business planning		
Question	You estimate that up to 25 sites could benefit from, the deployment of this technology. Please can you provide more information on the scope for wider roll out within your networks.		
Notes on question	Not applicable.		
Answer	A study was undertaken to understand the wider benefits medium-voltage DC (MVDC) technology could bring for Distribution Network Operators (DNOs). Critical to this was an understanding of the volume of potential MVDC projects across the UK, to understand both the market size and the level of benefits from a demonstration project, which will directly impact DNOs and electricity customers. It should be noted that DC technology is not a ubiquitous solution. The potential of DC reinforcement was considered for boundaries between different areas of the networks where control of power flow is a problem and areas with a combination of voltage/thermal/fault level issues, an increasingly common scenario in the transition towards a low carbon economy. An independent desktop analysis was carried out in May 2015 using published heat map data from two sample licence areas – assumptions are detailed under the 'Additional Potentials' section below. Results suggest there could be in the region of 35 - 40 potential opportunities for MVDC at distribution level across the UK, with approximately 60% of these showing a case for the operation of a distribution circuit at DC.		

License Area	MVDC opportunities	With DC circuit	Proportion of UK customers
1	6	3 (out of 6)	9%
2	2	2 (out of 2)	8%
UK	**35-40**	**20-25**	**100%**

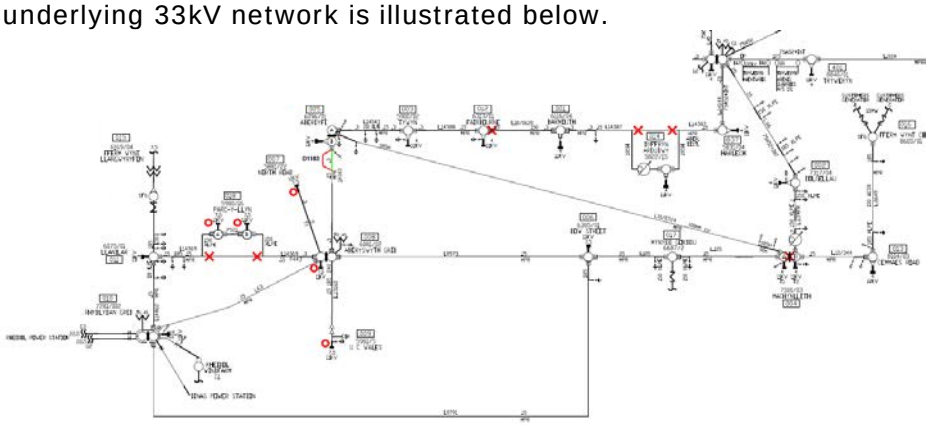
This result can be confirmed by the letters of support from other DNOs. If the ANGLE-DC project is successful, SP Manweb and SP Distribution could benefit from the application of medium-voltage power electronics at distribution level.

SP Manweb Network

The Aberystwyth-Rhydlydan group in SP Manweb does not have a dedicated grid infeed from National Grid but relies on a 132kV infeed from neighbouring Western Power Distribution from their Rhos substation via two 132kV circuits.



The underlying 33kV network is illustrated below.



The network is required to run in island mode due to excessive power flows through the network when the split points are closed.

The high level of connected generation in this group results in both Rhydlydan and Aberystwyth 132/33kV grid transformers experiencing reverse power. Outages of either of these transformers result in the remaining connected unit operating at its reverse power capability. The connection of any further generation could push the transformers beyond their reverse power capability.

If successfully demonstrated MVDC technology could in the future be used to control power flows across currently normally open points while improving the circuit ratings and maintaining electrical separation between adjacent groups.

	This potential opportunity aligns with one replication noted in Appendix A. SP Distribution Network There are a number of locations in the SP Distribution network where remote rural substations fed by long 33kV circuits experience a combination of thermal and voltage constraints, such as Lockerbie. If successfully demonstrated MVDC technology could be used to convert the existing circuits to DC operation as a means of releasing thermal capacity and alleviating voltage constraints. The level of capacity release will be better understood after completing the ANGLE-DC trial. [redacted]
Attachments	Not applicable.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q5
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Appendix D		
Topic	Rollout		
Question	Please list the 25 applications where the project could be replicated. Have the 25 sites throughout GB that are deemed suitable replication been discussed in detail and upfront with the other DNOs? Is it likely that these sites (or their surrounding regions) are already counted in previous LCNF projects or the 2015 NIC, and/or are due for conventional reinforcement in shorter timescales than the next five years (the length of this project)?		
Notes on question	Not applicable.		
Answer	We believe MVDC technology has the potential to play an important role in the transition towards a low carbon economy for DNOs and could compete with alternative conventional and innnovative solutions being trialled under different mechanisms. However we do not have access to other DNO's reinforcement plans or rollout assumptions for LCNF and NIC projects. After actively engaging with DNO colleagues, as reflected in their letters of support, we are convinced that the 25 applications quoted in the document are practical – see Question 4. Such a view has been further supported by our own license areas. We identified remote 33kV circuits in the SP Distribution area, for example Lockerbie and Berwick. We also identified additional sites within the SP Manweb area, for example Aberystwyth. We are confident that the excercise will be repeated and benefit the different DNOs. From the timescale perspective, ANGLE-DC will deliver useful learnings/criteria for consideration during RIIO-ED2 and beyond. The sites/circuits identified above have no immediate plans to reinforce to our best knowledge to date.		

Attachments	Not applicable.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q6
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Appendix D		
Topic	Rollout		
Question	A release of 30.5MVA of capacity is assumed for 25 other sites in GB. This would suggest these sites are all currently unable to be used in normal conditions, but alternative operating conditions are not ruled out . In the trial case an AC cable mitigates risk that the current circuit might fail upon conversion to DC, leading to unavailability of the link. It appears that the presented benefits will depend upon the capital expenditure being on the converter system only: how will circuit redundancy during the commissioning of the GB roll-out circuits be avoided? Has this been discussed with other DNOs?		
Notes on question	Not applicable.		
Answer	The AC cable will not only ensure the security of supply during the ANGLE-DC trial but will also act as part of the testing system to demonstrate the optimal load flow control, and facilitate the understanding of the thermal limit of the converted circuit. The successful trial in ANGLE-DC will prove the reliability of the technology as a means to demonstrate security of supply will not be compromised in future projects, even in the absence of an AC cable. It is not expected that parallel AC circuits will be required for future rollout. During commissioning of future rollout projects an outage of the circuit to be converted will need to be scheduled. The outage will be planned in advance to minimise disturbance on the newtork. This is standard practice in the operation of the electrical network. The duration of the outage could be minimised with the site preparation and installation works of the DC converters taking place with the circuit is still in AC operation. The outage would only be required to transfer the circuits		

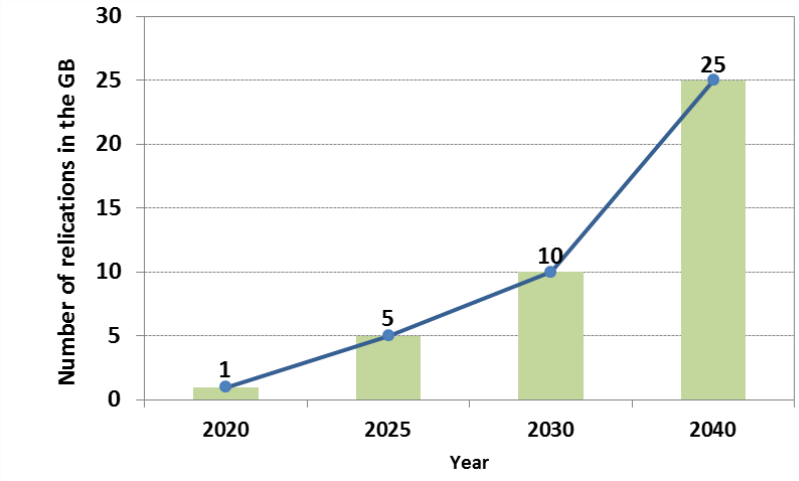
	immediately before conversion to DC.
Attachments	Not applicable.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q7
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Appendix D		
Topic	Rollout		
Question	Please provide the assumptions you used regarding installation times and dates for GB rollout.		
Notes on question	Not applicable.		
Answer	From the analysis of published heat maps it has been assumed that 20-25 sites could benefit from MVDC technology by 2040 during the rollout phase. One of these sites would be the ANGLE-DC trial site. Four more replications have been assumed by 2025, 5 more by 2030 and 15 more by 2040.  In line with the project programme in Appendix E it has been assumed that MVDC reinforcement can be completed in a period of two years, in the post-trial phase. Conventional reinforcements are completed on average in three years time. MVDC can therefore release the capacity at least one year faster than alternative conventional methods.		

Attachments	Not applicable.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q8
Question date	08/09/2015	Answer date	14/09/215
Submission section question relates to	Not applicable.		
Topic	Losses		
Question	Have you quantified losses within the converters?		
Notes on question	Not applicable.		
Answer	Yes, losses have been quantified. These will be largely dependent on the converter design and specification. Manufacturers indicated that losses can be as low as 1% per converter station by scaling down HVDC technology and around 2% by scaling up STATCOM techology. For the purposes of the Financial Analysis the conservative value of 2% per converter station was assumed. The acceptable level of losses will be evaluated as part of technical specification development which will be carried out in Work Package 1.		
Attachments	Not applicable.		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q9
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	Risks		
Question	Do you have any concerns about receiving planning permission for the new line in a timely way?		
Notes on question	Not applicable.		
Answer	It has been confirmed that there is sufficient land available at the exisitng sites to accommodate MVDC equipment. An enquiry has been made to the local authority during the proposal development stage and it has been confirmed that this can be implemented under permitted development and no planning permission is required. With regards to the circuit, wayleaves were identified as a risk (2.04) in the risk register. As a mitigation measure we will perform pre-engineering studies before defining the detailed cable route and liaise closely with planning authorities. SP Manweb and its contractors have extensive experience and dedicated resources in performing wayleave application to safeguard the project delivery in the area.		
Attachments	Not applicable.		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q10
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	Risks.		
Question	We are to assume that the circuit does not play a role in increasing capacity from the benefits case presented; however, is there, for example, a risk to future operation should the replacement link not operate as expected?		
Notes on question	Not applicable.		
Answer	The replacement link will provide security of supply during the trial i.e. will be connected for outages of the DC link. In those instances the OCC (Operational Control Centre) will evaluate the suitability of connecting the circuit. If the link does not operate as expected the network would be subject to N-1 conditions while corrective action is taken. This is within standard operational practice and does not pose a risk to the operation of the network.		
Attachments	Not applicable.		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q11
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	Control system.		
Question	What confidence does SPM have that the control system is achievable technically, as well as being delivered within time and budget?		
Notes on question	Not applicable.		
Answer	We have already undertaken due diligence on the supply chain and potential technology vendors to get an initial understanding of the technology which is best suited for MVDC applications. One solution described in Appendix H is based on a Modular Multi-level Converter topology, which has been used for STATCOM and HVDC applications. One possible solution is to "up-scale" STATCOM converter technology, which better matches the power requirements of MVDC, rather than "down-scale" HVDC converter technology, which may carry a high price base. However, the control system will be derived from HVDC experience, to ensure that the functionality, in terms of power flow, reactive power flow, dynamic response, and transient response is suitable for the application. Digital studies will be conducted by SP Energy Networks to define the functional requirements in these areas. The equipment supplier will perform digital studies in all of these areas to confirm the design of the control algorithms, which will be implemented in the MVDC controllers. These control algorithms will be subject to rigorous testing, witnessed by SP Energy Networks, typically using a Real Time Simulator, which models the AC networks on both sides of the link, plus the complete DC link, allowing the hardware controllers to be tested against multiple operating scenarios, prior to implementation in the field. This is normal practice for suppliers of STATCOM and HVDC equipment and can be achieved within the normal time and costs of such a project. During the formal engagement with suppliers to prepare the proposal, the cost indication from vendors has included the control element.		

Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q12
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	Environmental benefits.		
Question	It appears that the 45.4 GWh figure for environmental benefits (through the connection of LCTs) assumes that full capacity (30.5 MVA) is used 24/7 (see Section 3.5.6, Appendix A Section A.2). The 2014 Manweb Long Term Development Statement (LTDS)* shows the typical daily load profile hovering at 70% for most of the day with a long dip at night and a shorter peak (towards 100%) in the late afternoon. Therefore the 45.4 GWh figure seems optimistic. *http://www.spenergynetworks.co.uk/pages/long_term_development_statement.asp Can you confirm that this interpretation is correct? Is utilisation factor considered when calculating losses?		
Notes on question	Not applicable.		
Answer	[Answer 1]: Yes, it is reasonable to assume and take into account seasonal and daily variations on the power flowing across the network. For the purposes of environmental benefits calculation a prudent assumption for a load factor of 17% for renewable generation was made, resulting in up to 30.5 x 24 x 365 x 0.17 = 45.4GWh of low carbon energy transfer per annum. The full capacity of the link provides an annual capacity of 30.5 x 24 x 365 = 267.2GWh. This loading factor (17%) was developed based on the DECC generation loading factors for the different renewable technologies in the area. *https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes		

<table>
<tr><td></td><td>[Answer 2]: For the losses calculation we undertook detailed network studies for representative points in the annual load curve including the winter maximum, winter minimum, summer maximum and summer minimum demand scenarios. A utilisation factor was assumed for each of the study cases as well as a specific duration for each case.

The hours per year for each of the four periods considered in the losses calculation came from the Indicative LLF (load loss factors) Time Periods, published in the Manweb Use of System Charging Statement.

<table>
<tr><th></th><th>Demand</th><th>Export</th><th>Hours per Year</th></tr>
<tr><td>P1</td><td>Summer Minimum</td><td>Maximum Generation</td><td>2920</td></tr>
<tr><td>P2</td><td>Summer Maximum</td><td>No Generation</td><td>4765</td></tr>
<tr><td>P3</td><td>Winter Maximum</td><td>Maximum Generation</td><td>817</td></tr>
<tr><td>P4</td><td>Winter Maximum</td><td>No Generation</td><td>258</td></tr>
</table>
</td></tr>
<tr><td>Attachments</td><td>Not applicable.</td></tr>
</table>

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q13
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	p25		
Topic	Procurement		
Question	Please provide more detail of your procurement process.		
Notes on question	Not applicable.		
Answer	**During the proposal preparation phase** we extensively and actively engaged with the supply chain. We produced a functional specification for the procurement of the MVDC link – see Appendix I. This was utilised as the basis for the funding request and to enable us to have an early visibility of potential competing MVDC solutions. Back in May 2015, we circulated and shared the ISP proposal and a high level functional specifications to [redacted]. This engagement and extensive support from the supply industry continued during the full proposal development phase and is still being maintained. The NIC process helped us to raise the profile of the project and awareness across the industry. Following the publication of the ISP on Ofgem's website, we have been also approached by local SMEs such as [redacted], to express their strong support to our procurement engagements. **During the delivery of the project** we will conduct a more detailed MVDC market research as a fundamental activity in Work Package 1. The objective of this Work Package is to develop a fit-for-purpose functional specification for the procurement of the MVDC link. The functional specification must deliver a solution that is adequately future-proofed in order to deal with uncertainty in the precise nature of the development of the distribution systems. It will not presuppose choices of particular technologies or suppliers. Because we have identified a number of companies capable of delivering the solution, the final choice of technology will be the outcome of a competitive tender process, which will stimulate the supply chain and deliver the best		

	value solution for the customer for future MVDC applications. This will be done as part of Work Package 2 between April and August 2017.
Attachments	Not applicable.

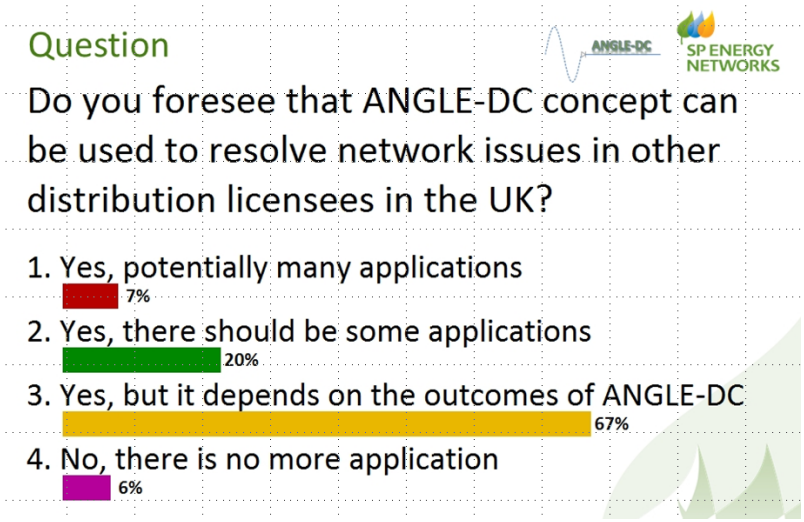
Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q14
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	5.2, p32		
Topic	Learning		
Question	As DNOs are the primary focus for learning, do you have confidence that all DNOs will see the full benefits of the project and are prepared to apply the relevant learning?		
Notes on question	Not applicable.		
Answer	Extensive stakeholder engagement activities were undertaken during the proposal preparation phase over the past 18 months including engagement with academic parties, research consortiums, consulting professional bodies, and DNOs in particular. We received a consistent and overwhelming message which convinced us that the ANGLE-DC trial will provide added value to address the genuine challenges distribution networks will face (and are facing) in the transition towards a low carbon economy. This is reflected in the letters of support in Appendix N as well as in the response to the following question raised during a stakeholder engagement session in Glasgow with industry representatives, including DNOs among others:		

	 Consequently we do believe that DNOs will see the benefits of the project even if the rollout will largely depend on the learning of ANGLE-DC. It is one of the main motivations for ANGLE DC that it will unlock the supplier chain and facilitate competition, which in turn benefits all the DNOs and our customers. In the meantime, measures are in place to comply with the default IPR policy under NIC. DNOs will directly benefit by: 1. Joining our project steering board to influence the scope/design 2. Joining the regular knowledge dissemination events 3. Joining/subscribing the webinars 4. Sharing the data from ANGLE DC In addition, we have been working closely with ENA (Energy Network Association) and its R&D workstreams (where all DNOs have senior representation) and will report project findings regularly. Annual industry events, such as the Low Carbon Network Conference, will be the appropriate platform to disseminate knowledge to the wider industry. Due to importance of learning dessimmination to other UK DNOs, we have considered a separate Work Package for knowledge sharing activities as described in detail in Section 5 of full submission pro-forma. One major outcome of the project is to produce a simple checklist for all DNOs to use and check the applicability of DC projects on an individual basis.
Attachments	Not applicable.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q15
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	Learning.		
Question	Have you considered regular meetings with other DNOs involved in similar projects?		
Notes on question	Not applicable.		
Answer	Yes, it's one of our aims to share the learning with other DNOs, especially those involved in similar projects in order to ensure the learning is complemented. Engagement with some of the UK DNOs was initiated during the proposal preparation phase and will be continued during the delivery phase in the form of workshops, seminars and and meetings. ANGLE DC will trigger market competition in MVDC technology and will provide technical guidance for building future MVDC links which in turn benefits all the DNOs and our customers. We can only achieve this by transparently delivering ANGLE-DC, and sharing the technical/non technical considerations/lessons learnt across the DNOs. Measures are in place to share the knowledge with the relevant stakeholders, including DNOs by: 1. Joining our project steering board to influence the scope/design 2. Joining the regular knowledge dissemination events, including workshops and LCNI conferences 3. Joining/subscribing the webinars 4. Sharing the data from ANGLE DC In addition, we have been working closely with ENA (Energy Network Association) and its R&D workstreams (where all DNOs have senior		

	representation) and will report project findings regularly.
Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q16
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	9, p48		
Topic	Learning.		
Question	Do you have any plans for sharing, during the project, how the many technical challenges have been tackled and resolved?		
Notes on question	Not applicable.		
Answer	Yes, facilitating knowledge transfer is one of the key principles of the Network Innovation Competition. As such we have developed a detailed learning dissemination strategy as described in Section 5 of the full submission proposal including regular progress reports, internal and external workshops, webinars, presentations at innovation conferences - such as the Low Carbon Network Conference where the knowledge will be disseminated to the wider industry – a project website and a close-down report. Additionally DNOs will have access to the knowledge directly by: 1. Joining our project steering board to influence the scope/design 2. Visiting the site during different stages of the project 3. Sharing the data from ANGLE DC The technical challenges will be specifically addressed and discussed at the workshops where the focus will be on both the technical and non-technical aspects of the project. In addition, we will work closely with ENA (Energy Network Association) and its R&D working streams (where all DNOs have senior representation) and will report project findings regularly.		
Attachments	Not applicable		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q17
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	p25, Apendix E		
Topic	Partners		
Question	It is noted that the MVDC link supplier will be tendered separately under acceptable timescales. Furthermore, the letters of support demonstrate that you have entered into significant communication with stakeholders and interested parties already. However, can you provide confidence that it will be possible to secure project partners in tight timescales?		
Notes on question	Not applicable.		
Answer	We have already undertaken initial discussions and pre-selection of potential partners for the project and are maintaining this engagement to ensure project partners can be selected in the proposed timescales. Additionally prior to final procurement it is within the scope of Work Package 1 to conduct a MVDC market research update to identify qualified partners. The procurement process is detailed below: During the course of Work Package 1 a detailed viable technical specification will be developed to inform the procurement of the MVDC link. This activity will be completed over a 10 month period. Note we have already developed a high level fit-for-purpose functional specification (see Appendix I), which will accelerate the procurement process. Once the technical specification has been completed there is provision within the project programme for the preparation of the procurement documents during one month. Upon completion of the above, we are confident that our standard procurement process can be completed within the four month period allocated in Work Package 2.		

Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q18
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	Partners.		
Question	Can you provide confidence that the MVDC link can be successfully procured within this budget [redacted]? Can you confirm that processes will be put in place to ensure that technology development that would be funded by this project remains freely available to the industry?		
Notes on question	Not applicable.		
Answer	[Answer 1]: We have estimated a total of [redacted] for the MVDC equipment production and optimisation including Factory and Site Acceptance tests - in accordance with the full submission spreadsheet. We have confidence that the MVDC link can be successfully procured within the budget because: 1. The estimated cost is the outcome of active engagement with suppliers 2. The estimated cost has been sense-checked with other DNO colleagues who have experience in the power electronic sector We have also considered an overall contingency of 8% to mitigate any potential risks. Additionally we have designed another procurement exercise as part of Work Packages 1 and 2, in the hope to safeguard the value for money of our customers. In the event that we can achieve a better price, we will return the funding in due course. In the unlikely event that we expect to exceed the funding, we will ask for the permission from the Authority in line with the NIC governace prior to any advancement. [Anwer 2]: Yes, ANGLE-DC will be funded by electricity customers and as such all the learning will be shared with other DNOs and relevant		

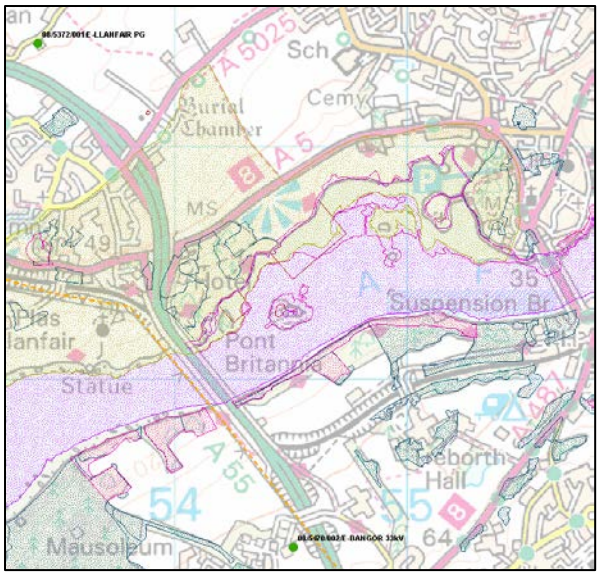
	stakeholders. SP Manweb will establish this link and has developed a comprehensive knowledge dissemination strategy to ensure learning is accessible to all interested parties. Additionally, we will put all the processes in place to comply with the default NIC IPR conditions.
Attachments	Not applicable.

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q19
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Section on WP3, p12		
Topic	AC cable		
Question	Please provide further details about the AC cable, including where it will be fitted.		
Notes on question	Not applicable.		
Answer	The AC cable will be fitted between two dedicated circuit breakers at the Bangor and Llanfair PG substations.  The detailed circuit route is not defined yet and will be designed as part of Work Package 3 in Q1 2017. Our initial site inspection confirmed that there is enough space in the aforementioned substations for building new bays for the new AC circuit.		

	With regards to the circuit, wayleaves were identified as a risk (2.04) in the risk register. As a mitigation measure we will perform pre-engineering studies before defining the detailed cable route and liaise closely with planning authorities. SP Manweb and its contractors have extensive experience and dedicated resources in performing wayleave application to safeguard the project delivery in that area. It was confirmed that there is sufficient land available at the exisitng sites to accommodate MVDC equipment. An enquiry was made to the local authority during the proposal development stage and it was confirmed that this can be implemented under permitted development and no planning permission is required.
Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q20
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	p31		
Topic	Safety		
Question	Can you provide a detailed overview of the safety aspects to show that the issues have been fully identified? Are SPM procedures already in place that deal, or can be easily adapted to deal, with the potential safety issues of MVDC distribution?		
Notes on question	Not applicable.		
Answer	The MVDC converter stations, which are identical at both ends of the link, consist of the following main items of plant: - Interface transformers, which are similar in design and construction to any distribution transformer and represent no added safety hazard or require any special operating or maintenance procedure from any other transformer on the SP Energy Networks distribution network. - The Power Electronic Converters consist of multiple sub-modules, each operating at low voltage (<1000V) and housed within a metallic cubicle. Multiple modules are connected in series to achieve the desired operating voltage. Each cubicle is protected by mechanical and electrical interlocks, such that access to the equipment is only possible when the complete MVDC link is de-energised, i.e. the main AC circuit breakers are open and ground switches have been closed, which connect all live parts of the circuit to earth. Individual sub-modules cannot be inspected or maintained while the converter is in service. - There is no oil-filled equipment within the converter sub-modules, which can ignite in the event of an electrical flash-over. All non-metallic materials are fire-retardant, i.e. they will not continue to burn once the source of any flash-over is remover, e.g. by operation of the primary protection provided by the main AC circuit breakers.		

	- The cooling system for the power electronic converters contains a mixture of water and ethylene glycol (“anti-freeze”). This needs handling according to the suppliers instructions, during the first fill, by the supplier, and any top-up by the owner. - The control and protection cubicles contain low voltage terminals, typically 230Vac, 110Vac and 110Vdc, which are shrouded to avoid possible contact during inspection. This represents the same safety issues as a conventional distribution substation. - The DC voltage on the distribution circuit (overhead line and cable sections) has been chosen to be at the peak of the AC voltage of the existing circuit and thus is considered to represent no additional safety hazard to the existing system operation. Procedures will be adapted as part of this project to deal with any potential issues of MVDC distribution which are identified during the delivery of the project.
Attachments	

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q21
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	Modelling		
Question	Could up-front modelling and simulation be used to provide assurance that the solution is technically robust? For a project of such a large scale and high risk, modelling and simulation would not be unusual, but does not appear to have been considered.		
Notes on question	Not applicable.		
Answer	Yes, up-front modelling and simulation is very important for the proposed solution. So far a detailed distribution network simulation study was completed by TNEI to understand: 1. Constraints of the existing network 2. Benefits of ANGLE-DC on various aspects such as voltage optimisation and power flow control 3. Reduced system losses The outcomes fed into the business case, as well as the technical specifications: for example, providing the optimal sizing for the converter design. Regarding the converter technology itself, both off-line digital studies and real time simulation studies will be performed to develop the control and protection algorithms of the MVDC controllers and to prove their functionality. The latter is particularly important as it provides the closest approximation to the "reality" of distribution networks on both sides of the proposed link. This will test the control software as will be implemented in the actual hardware to be installed in the field, as against the "ideal" controls implemented in the fully digital studies. The functional specification for the MVDC equipment will specify the range of digital studies required to determine the interaction between the DC and AC systems, which will be performed by the supplier. This will also include the requirement to perform tests of the controllers on a Real Time Simulator. The details of these proving tests, e.g. operating scenarios, faults conditions, etc., will be		

	revisited and further defined during the development of the project (WP 1).
Attachments	Not applicable.

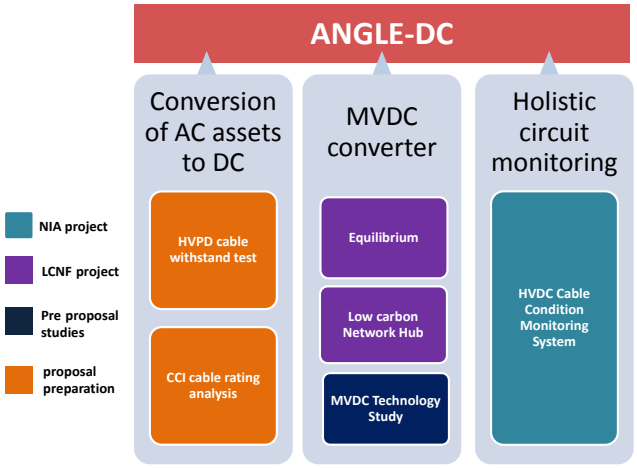
Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q22
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Appendix J		
Topic	OHLs		
Question	Are the overhead lines equally suitable (as the underground cables) for DC distribution given the likelihood of them having a ferrite core? Has the makeup of the cables been accounted for when calculating DC capacity?		
Notes on question	Not applicable.		
Answer	[Answer 1]: There is a short (~400metre, 5 spans) section of overhead line on the Bangor to Llanfair PG circuit. The suitability of the existing overhead line for DC operation has been identified as a risk (1.06) where the possiblity of fashovers across the insulators has been considered. The proposed contingency measure includes performing a study of the insulation requirements as well as to visually inspect the insulators and replace if necessary. [Answer 2]: Yes, the makeup of the cables has been accounted for when calculating DC capacity. Please see also Figure 3-1, page 15, which shows studies conducted during proposal preparation phase for evaluating the cable capability and cable DC rating.		

	 We specifically commissioned an independent study to understand the feasibility of AC to DC conversion of the existing cable circuits. The study was based on the cable records held for the proposed circuit, and showed three types of cable insulation or construction (please see also Appendix K): • Type A using paper and oil rosin insulation • Type B using paper and oil rosin or MIND compound • Type C using XLPE insulation The study recommended a suitable current rating and DC voltage for DC operation of the circuit between Bangor and Llanfair PG based on makeup of cables. Additionally we commisioned diagnostic and withstand tests of the cables between the Bangor and Llanfair PG substations to get more evidence to address this risk. Tests showed that both cables were able to withstand DC voltages of at least 27kV (recommended by the aforementioned report).
Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q23
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	EMC		
Question	Please explain why you have not discussed the effects of EMC?		
Notes on question	Not applicable.		
Answer	EMC is a major field of investigation and in broad terms the use of DC creates a more benign environment than does the use of AC and hence was not given much prominence in the submission. However, there are a few aspects which can be commented upon. - The conversion from AC to DC within the power electronic converters will create electromagnetic “noise” which will both radiate through space and be conducted through the electrical connections on the AC and DC sides. As the low voltage converters are in grounded metallic cubicles, radiated interference to any adjacent communication systems should be minimal from the new station. - Conducted interference through the AC and DC connections will be quantified by the equipment supplier to ensure that any interference from these circuits to adjacent communication systems is within accepted guidelines in this area. - Particular attention will be required on the cables which cross the Britannia bridge and are thus in close proximity to any communication systems installed for the railway system. - DC electric and magnetic fields will be created below the overhead line section in Anglesey, however these are considered to be more benign that the existing AC fields. As DC fields have no time variance there is no induction process which could impact on human health. - A DC magnetic field will exist above the underground DC cables, but typically of the same magnitude as the natural magnetic field generated by the earth’s north and south poles.		

Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q24
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Appendix J		
Topic	Magnetic fields		
Question	The system proposed is a double monopole – can we assume that the cables (which are at +/-27 kV) will be physically close enough and balanced (i.e. equal and opposite current) such that fields will not occur that could potentially affect nearby metallic equipment or AC system assets?		
Notes on question	Not applicable.		
Answer	For clarity the scheme we are proposing is a single symmetrical monopole. The cables already exist and follow the same route - please see Figure I-1. We will have three cables on the positive pole and three cables on the negative pole. Some sections of the cables are bundled. At this stage we cannot guarantee perfect proximity between cables for the whole length. As a consequence of imperfect proximity there is a potential we could have a spill magnetic field around the cables, due to imperfect cancellation of +ve and –ve fields. This should be assessed at surface level. However, this is a DC magnetic field and it cannot couple into anything, hence there is no impact on magnetic structures. For the same reason there is no impact on human health. The only impact will be on compass deflection, but this is not normally an issue on land, only at sea where small vessels may still use magnetic compasses.		
Attachments	Not applicable		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q25
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	P46		
Topic	Power Quality		
Question	a. What is the evidence that harmonic distortion will not exceed G5/4 levels? b. This limit will presumably be passed on to the MVDC link supplier with which they must comply; however, does the potential for harmonic distortion issues still carry the risk of extra cost should the technical challenge be greater than expected (Risk No. 1.03 is applicable)?		
Notes on question	Not applicable.		
Answer	The concept of the converter design is to synthesis a fundamental frequency voltage waveform from multiple steps of voltage. The number of steps is directly related to the DC voltage. For the ±27kV proposed for the ANGLE DC projects, there will be a number of steps in the waveform between zero and the voltage peak. Existing HVDC projects, albeit at much higher voltages, e.g. 230kVac / ±200kVdc / 110kVac (USA) and 110kVac / ±160kVdc / 110kVac (China) have been implemented without AC side harmonic filters. A demonstration project built by Alstom Grid at 11kVac / ±12kVdc / 11kVac has no harmonic filters and operates successfully on the public electricity supply. To be on the prudent side and have more evidence to confirm the theory, a dedicated simulation has been commissioned, Strathclyde University presented a study demonstrating the THD (Total Harmonic Distortion) level will be less than 2% under 33kV. The existing G5/4 specifies the THD of 3%. The 33kVac / ±27kVdc / 33kVac system for ANGLE DC will be specified to meet the requirements of G5/4 or other limits as determined by SP Energy Networks. These will be defined in the functional specification issues to potential suppliers, together with a suitable representation of the AC networks in Anglesey and North Wales. The suppliers will be contractually		

	bound to comply with these limits, which will apply at the 33kV connection to the distribution networks. A detailed harmonic evaluation will be required upon the commencement of the project, either in terms of the harmonic impedance of the AC networks (by SP Energy Networks), or the harmonic emissions for the MVDC converters (by suppliers), we appreciate the risk that a small harmonic filter may need to be installed to ensure compliance with the as yet undefined harmonic limits. The requirement will be passed on to the suppliers. The customers will be protected both financially and technically.
Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q26
Question date	08/09/2015	Answer date	14/09/2015
Submission section question relates to	Not applicable.		
Topic	Networks Risks		
Question	The proposal does not appear to have considered risks, with a converter station at each end, to protect internal and external network. a. It might be the case that the existing protection is sufficient; however, is this going to be tested? b. As a specific example, can the converters help with the static switching from lightning strikes?		
Notes on question	Not applicable.		
Answer	The existing AC network protection system will be integrated into the MVDC link protection system. Full details of this will be developed during the project implementation stage, but an outline of the concept would include, - An extension of the existing AC feeder protection to overlap the first protection zone of the MVDC system, up to the transformer. - The first protection zone will be a differential protection across the interface transformer to detect faults in this major asset - An AC zone will cover the equipment on the secondary side of the transformer, such as pre-insertion resistors, harmonic filter (if required) up to the connections to the power electronic converter. - An AC – DC differential zone will cover the power electronic converters, to detect any faults within this equipment. - A DC protection zone will cover the link between the two converter stations, to detect faults in the overhead line section and the cable section. For the MVDC link any major faults will trip the AC circuit breakers at both ends of the link, isolating the link from the distribution network, to allow remedial actions to be taken.		

Attachments	Not applicable

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q27
Question date	10/09/2015	Answer date	15/09/2015
Submission section question relates to	p46		
Topic	Customer Impacts.		
Question	You refer to a standard procedure for scheduling outages to ensure risk to customers is minimised. Can you quantify the risk of outages for this project?		
Notes on question	Not applicable.		
Answer	The standard procedure for scheduling outages is mentioned in Section 8. The only outages we forecast are the outages of the Bangor and Llanfair PG busbars while installation and commissioning of the parallel AC circuit. No customers impact is envisaged as this is the standard approach. The outages will be carefully planned in advance, coordinated with the distribution outage maintenance programme and controlled to ensure that operational security standards are not infringed. This is standard SP procedure, and in line with the planning/operational standards of the network. There will be a parallel 33kV AC circuit, as an integrated part of the trial to enable DC circuit commissioning, optimal power flow control, thermal limit testing and data collection. This circuit will be connected when the DC link is out of service. Such a measure will be sufficient to mitigate the risk of any unplanned outages.		
Attachments	Not applicable		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q29
Question date	10/09/2015	Answer date	15/09/2015
Submission section question relates to	p94		
Topic	Benefits		
Question	Please explain how you calculated the £1.7bn reduction in capital costs of Scottish offshore projects using direct to MVDC solutions.		
Notes on question	Not applicable.		
Answer	As highlighted in previous answers, this proposal is the direct outcome and builds upon previous NIA projects. Those NIA projects included one that further assessed the feasibility and perceived worth of MVDC technology for use in DNO and Offshore applications. The outcomes of this project looked to enable SP Energy Networks and key stakeholders to make an informed decision on any future investment and development plans for MVDC. Initial market analysis was conducted which included research and stakeholder engagement activity. This identified feasible applications for MVDC technology. A detailed cost benefit analysis for two case study applications was then carried out as well. In order to give an indication of the size of the potential market for MVDC, the value of Scottish Offshore projects and interconnectors in 2014 was calculated. It was found that there is a significant volume of Scottish offshore projects that will spend a total of £3.3bn on electrical infrastructure. Most of these projects are going ahead with AC transmission solutions; however this figure does indicate the potential scale of the offshore market in Scotland for MVDC, if the technology is matured and de-risked sufficiently for developers to consider it as a transmission solution. If the same projects were to use direct to shore MVDC solutions, the reduction in capital costs could amount to up to £1.7bn. Indicative savings from MVDC applied to current Scottish Offshore Projects are as follows:		

Scottish Offshore Projects					
Project	**Capacity (MW)**	**Transmission Distance**	**TEC Year**	**Estimated HVAC Capex**	**Estimated Direct MVDC Capex**
Moray Firth Eastern Development Area Round 3 Wind Farm Zone	504	85	18/19	£293m	£139m
Moray Firth Eastern Development Area Round 3 Wind Farm Zone	612	85	18/19+	£356m	£169m
Firth of Forth Round 3 Wind Farm Zone Phase 1	1050	70	18/19	£559m	£260m
Firth of Forth Round 3 Wind Farm Zone Phase 2	1820	50	18/19+	£844m	£384m
Firth of Forth Round 3 Wind Farm Zone Phase 3	790	50	18/19+	£367m	£167m
Beatrice	664	85	18/19	£386m	£183m
Inch Cape	784	83	18/19	£452m	£214m
			Total:	£3257 m	£1516 m
			Reduction due to MVDC		£1741 m
					53%

Attachments	Not applicable

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Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q30
Question date	10/09/2015	Answer date	15/09/2015
Submission section question relates to	Can you quantify the reduced/avoided associated environmental impact and damage to nature from avoiding building an additional circuit?		
Topic	p22		
Question	Can you quantify the reduced/avoided associated environmental impact and damage to nature from avoiding building an additional circuit?		
Notes on question	Not applicable.		
Answer	As indicated in the answer to Question 2, the alternative solution to the MVDC link includes the addition of one new grid transformer at each end of the MVDC link – with the associated risk of oil leakage. These transformers are fed using 132kV circuits which combine overhead line and cable sections. For the purposes of this analysis the environmental impact of the cable sections has been neglected. The environmental impact of new overhead lines is primarily associated with the construction of new support structures. However prior to construction, temporary accesses will be constructed, as necessary, and laydown /storage areas established, usually mid-way along the route. Any trees which may impact on safety clearances will be removed or lopped. Following commissioning of the overhead line, all equipment and temporary access of construction areas will be remained with the land being reinstated to the satisfaction of the landowner. There is also an ongoing requirement to ensure that any trees within the wayleave corridor do not impact on safety clearances. An analysis of our internal records revealed that the avoided number of support structures is up to 146 wood poles or 66 towers, depending on the type of construction. Making full use of the exisitng assets can save up to 920Tn of concrete corresponding to 2188m^3. The avoided excavation weight is up to 4000Tn, corresponding to 9524m^3.		

	Additionally, the construction of up to 8km of new access roads can be avoided. Number of support structures | | Worst case | Best case | | Wood Pole | 146 | 106 | | Tower | 66 | 46 | | | Foundation weight (Tn) | | Foundation volume (m3) | | | | Worst case | Best case | Worst case | Best case | | Wood Pole | Not applicable | | Tower | 920 | 700 | 2188 | 1666 | | | Excavation weight (Tn) | | Excavation volume (m3) | | | | Worst case | Best case | Worst case | Best case | | Wood Pole | 920 | 668 | 2190 | 1590 | | Tower | 4000 | 3000 | 9524 | 7142 | | | Length of access (km) | | | | Worst case | Best case | | Wood Pole | 6 | 3 | | Tower | 8 | 4 |
Attachments	Not applicable.

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Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q31
Question date	17/09/2015	Answer date	22/09/2015
Submission section question relates to	Not Applicable.		
Topic	Losses		
Question	Please provide a breakdown of the losses impact, both gross and net of the DC convertors. Please explain how you have calculated these figures.		
Notes on question	Not Applicable.		
Answer	To calculate losses, load flow studies were performed for the network in four operational configurations. After load flows had been performed, the total MW losses in the Bangor/Caernarfon and Caergeilliog/Amlwch groups were determined for the entire year, using the number of hours per year for each period in the table below:		

	Demand	Export	Hours per Year
P1	Summer Minimum	Maximum Generation	2920
P2	Summer Maximum	No Generation	4765
P3	Winter Maximum	Maximum Generation	817
P4	Winter Maximum	No Generation	258

The hours per year for each of the four periods considered in the losses calculation came from the Indicative LLF Time Periods, published in the Manweb Use of System Charging Statement (Annex 5). The time periods are defined in the table below:

SP Manweb - Effective from 1 April 2014 - Indicative LLF Time Periods				
Time periods	Period 1	Period 2	Period 3	Period 4
	Night	Other	Winter Weekday	Winter Peak
Monday to Friday March to October	23:30 – 07:30	07:30 – 23:30		
Monday to Friday November to February	23:30 – 07:30	20:00 – 23:30	07:30 – 16:00 19:00 – 20:00	16:00 – 19:00
Saturday and Sunday All Year	23:30 – 07:30	07:30 – 23:30		
Notes	All the above times are in UK Clock time			

Losses in the MVDC link were not considered in the modelling. Instead, these were calculated separately using an efficiency of 98.0% i.e. 2% lossess per converter, based on stakeholder input.

For each period, the optimum loading of the MVDC link was derived by load flow analysis. For the purposes of the losses calculations, it was assumed that the MVDC link will operate with a fixed real power set point, and the converters will operate in voltage control mode to support system volts at Llanfair PG and Bangor, with reactive power limits set such that the total apparent power does not exceed the rating of the MVDC link.

The table below indicates the network losses (33kV & 132kV network losses) as well as the breakdown of converter losses. It can be seen losses reduce from 65703MWh to 52673MWh i.e. approximately 20% reduction of distribution network losses.

		Conventional		MVDC	
	Hours	**Real Power Losses (MW)**	**Real Power Losses (MWh/yr)**	**Real Power Losses (MW)**	**Real Power Losses (MWh/yr)**
Winter Max	258	9.58	2473	6.33	1633
Winter Min	817	12.67	10347	14.47	11823
Summer Max	2920	9.84	28730	6.07	17767
Summer Min	4765	5.07	24153	3.47	16545
Converter Losses	n/a	n/a	n/a	n/a	4905
Total	**n/a**	**n/a**	**65703**	**n/a**	**52673**

Attachments	Not Applicable.

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Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q32
Question date	17/09/2015	Answer date	22/09/2015
Submission section question relates to	Not Applicable.		
Topic	Business Case		
Question	What are the operational reasons for installing this MVDC link in the proposed location? If this project were not funded, how would you tackle these issues?		
Notes on question	Not Applicable.		
Answer	The 33kV system on the isle of Anglesey is currently approaching both thermal and voltage limits. The demand in Anglesey is anticipated to increase significantly over the next years. The two grid transformers at Amlwch and Caergeiliog operate close to thermal limits during n-1 outage conditions and will exceed thermal limits with forecast demand growth. Because of the extended 33kV circuits on the island the automatic voltage control settings for the group are set to manage lower voltage limits during outage conditions. However, with the current level of generation on Anglesey it is becoming problematic to accommodate further generation without exceeding upper voltage limits and causing voltage control stability issues. Additionally, Horizon Nuclear are progressing their proposals build a new nuclear power station at Wylfa which will impose significant parallel flows on the distribution network in due course. An integrated reinforcement scheme is required to address these challenges. The proposed alternative considers the addtion of a new 132/33kV transformer, 33kV circuit works and opening the interconnectors between Anglesey and the North Wales mainland. ANGLE-DC will demonstrate a novel reinforcement alternative by which the interconnector between Bangor and Llanfair PG will be maintained in operation and instantaneous controllable voltage support provided at both		

	ends of the MVDC link.
Attachments	Not Applicable.

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Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q33
Question date	17/09/2015	Answer date	22/09/2015
Submission section question relates to	Not Applicable.		
Topic	Benefits		
Question	The Panel is concerned that the benefits from reduced capital costs and reduced losses may not be realised. What are the other operational benefits of DC that have made other DNOs interested in this project?		
Notes on question	Not Applicable.		
Answer	We have communicated the ANGLE-DC proposal with colleagues from all GB DNOs. They are convinced and each identified that there are cases in their licensed areas which can benefit from the operational advantages of this technology if competitive costs are achieved. Given the strong interest in the technology and rollout opportunites, it is reasonable to assume that reduced capital costs are achievable. The key operational benefits of AC to DC conversion can be summarised as follows: • Enhanced thermal ratings • Wide area voltage control • Power flow controllability • Fault level separation • Interconnection of different distribution groups • Reduced operational losses Among the numerous operational benefits, the most interesting for other DNOs were the uplift in thermal capacity of existing circuits and full power flow controllability. The next paragraph describes the views of other DNOs. Distribution networks have traditionally been designed for passive operation and consequently have very limited controllability to direct power flows. As such, even where the network has been upgraded with novel components, DNOs remain in a situation where the ability to move load or generation is		

	very limited in many areas. Meanwhile generator footprints are increasing in size and quickly saturating this level of flexibility. There are certain network-wide changes that can assist such as the removal of constraints associated with Directional Over-Current protection, and the introduction of Dynamic Line Ratings to assist wind generators. However there remains a strong need to find ways to **use existing assets** and **create substantial increases in capacity.**
Attachments	Not Applicable.

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Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q34
Question date	17/09/2015	Answer date	22/09/2015
Submission section question relates to	Not Applicable.		
Topic	Rollout		
Question	Do you plan to retain the DC link permanently after the project conclusion?		
Notes on question	Not Applicable.		
Answer	Yes, if successful, the DC link will be retained after the trial and will provide an enduring solution for the local area beyond the ANGLE-DC project. Such an arrangement will enable us to effectively share the experience and knowledge with other DNOs. One of the main outcomes of this project will be the production of a best practice guide for the operation and maintenance of MVDC assets.		
Attachments	Not Applicable.		

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Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q35
Question date	17/09/2015	Answer date	22/09/2015
Submission section question relates to	Not Applicable.		
Topic	Business Case		
Question	Please provide three diagrams of the circuits: 1) one of the current situation highlighting the constraints; 2) the convetional solution to the problem; 3) the proposed solution with the MVDC link.		
Notes on question	Not Applicable.		
Answer	The 33kV system on the isle of Anglesey is approaching thermal and voltage limits. The main constraints associated with the 33kV group relate to transformer and circuit capacity due to the expected demand growth, high levels of generation and the potential for imposed 400kV parallel flows. [redacted] The Base Case considers the conventional option of opening the circuit between Bangor and Llanfair PG substations. [redacted] The proposed MVDC solution proposes to convert the Bangor to Llanfair PG circuit to DC by using MVDC converters at both ends. **This is a double circuit with six cores running between the sites**. It is proposed that three conductors are parallel connected to form each DC pole. [redacted]		
Attachments	Not Applicable.		

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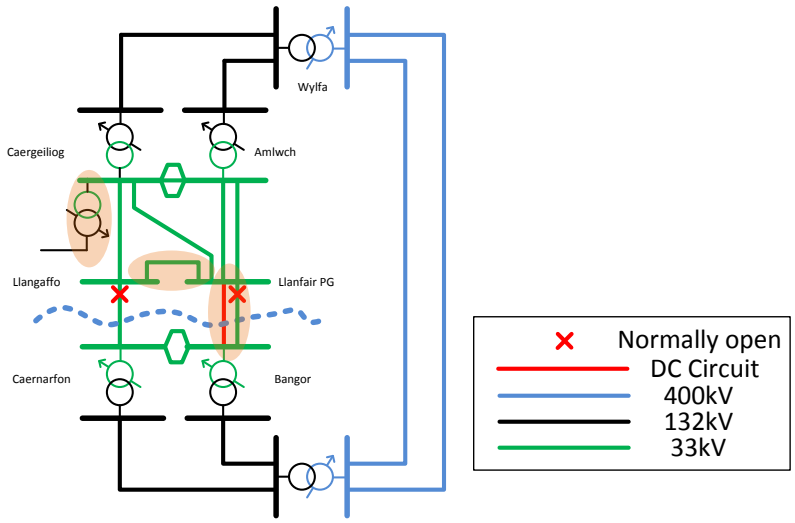
Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q36
Question date	29/09/2015	Answer date	30/09/2015
Submission section question relates to	Not applicable.		
Topic	Business Case		
Question	The ED1 settlement provided funding for reinforcement works on Anglesey. We understand that these works are not proceeding as planned and that the Angle DC project is instead providing more AC and DC capacity to the island. Please explain why SP is seeing no Direct Benefit from the Angle DC project.		
Notes on question	Not applicable.		
Answer	It should be clarified that while the ED1 settlement includes funding for certain reinforcement works on Anglesey, the ANGLE DC project will be an incremental approach and is currently not in a position to replace those conventional reinforcements due to its existing TRL. The works proposed in the ANGLE-DC project are not replacing the need of conventional works but offering improved/additional controllability which enables to maintain an existing circuit in operation and keep the electrical separation between the island and the mainland. Conventional works proposed in ED1 will still proceed on the island (such as construction of a new GSP and construction of a new 33kV overhead line) independently from the ANGLE-DC works. The ANGLE DC trial could provide incremental capacity, which will be considered for conventional network planning upon successful demonstration of the technology. SP Manweb has every reason to believe that Medium Voltage DC technology can be part of our toolbox of reinforcement solutions for future consideration. The details about the Anglesey reinforcement are included in Appendix C. An extract of the Appendix can be found below:		

	A scheme to reinforce the demand group on Anglesey was designed in 2011/12 and submitted as part of the RIIO-ED1 business plan. The proposal was to establish a new grid transformer at Llanfair PG and a new 33kV circuit on the island. The submitted scheme was expected to significantly increase the thermal demand capacity on Anglesey and facilitate the separation of the Anglesey 33kV group from the mainland. In recent years, this area of the network has undergone very high levels of generation and demand connection activity. The requirement for reinforcement of the distribution network on Anglesey has been re-assessed in order to satisfy the existing demand and generation requirements and accommodate future load growth. As a result Caergeiliog has been identified as the optimum location for the proposed grid transformer where most of the activity has been concentrating in recent years. With the generation growth in Anglesey together with the potential for imposed 400kV parallel flows, the power flows between the island and mainland are forecast to exceed the capability of the existing circuits. For this reason, options still need to be considered to separate the 33kV electrical network on the Isle of Anglesey from the mainland. The ANGLE-DC method was identified as a viable solution which maintains the link between Bangor and Llanfair PG in service and at the same time provides an upgraded power corridor between Anglesey and the North Wales mainland. 
Attachments	Not applicable.

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Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q37
Question date	06/10/2015	Answer date	09/10/2015
Submission section question relates to	EMC		
Topic	Not applicable.		
Question	Please provide assurance that the trial will include appropriate design consideration and an EMC measurement study to inform future design requirements of the EMC effect associated with the application of this type of technology.		
Notes on question	Not applicable.		
Answer	A key aspect of the project will be the impact of EMC. Relevant epidemiological and biological studies have been reviewed in reports by the independent Advisory Group on Non-ionising Radiation (AGNIR, 2001a,b, 2003). These conclude that there is no firm evidence of such adverse health effects at the levels of EMC to which people are normally exposed. The ANGLE DC Team considers that guidelines on limiting exposure to electromagnetic fields should be kept under review, and recognises the need to adopt a cautious approach in the interpretation of scientific knowledge and the benefits of common international guidelines. From technology perspective, we will: 1) recognise the need to adopt a cautious approach in the interpretation of scientific knowledge and 2) make full use of the benefits of common international guidelines 3) take on the overall responsibility of controlling the risk due to EMF for customers and third parties, and takes into account the international efforts in the following documents: IEC: 61000-1-2, IEC: 61582 The trial will include consideration of EMC and during the commissioning trials field measurements will confirm compliance with limits defined in WP1.		
Attachments	Not applicable.		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ANGLE-DC

Tick if this answer has been provided verbally: ☐

Project code	SPMEN01	Question Number	Q38
Question date	06/10/2015	Answer date	09/10/2015
Submission section question relates to	Business Case		
Topic	Not applicable.		
Question	The Full Submission text states (end of Appendix C) – "The method will provide an efficient and enduring reinforcement solution to meet the long term energy needs of the island". If this is the case why is no Direct Benefit shown?		
Notes on question	Not applicable.		
Answer	While the ED1 settlement includes funding for certain reinforcement works on Anglesey, the ANGLE DC project will be an incremental approach and is currently not in a position to replace those conventional reinforcements due to its existing TRL. Conventional works proposed in ED1 will still proceed on the island (such as construction of a new GSP and construction of a new 33kV overhead line) independently from the ANGLE-DC works. The works proposed in the ANGLE-DC project are not replacing the need of conventional works but offering improved/additional controllability which enables to maintain an existing circuit in operation and keep the electrical separation between the island and the mainland. ANGLE-DC will convert an existing 33kV AC circuit to DC operation. Permanent monitoring of the DC circuit condition will be used to demonstrate the sucess of the trial. If sucessful the additional capacity and ancillary services offered by the MVDC converters could provide direct benefits during the RIIO-ED2 period. Hence the sentence from Appendix C – "The method will provide an efficient and enduring reinforcement soluiton to meet the long term energy needs of the island".		
Attachments	Not applicable.		