Question No.	From	Proforma section	Criteria	Question	Date question asked	Date response required	Date received	Follow up to Question #	Confidential (y/n)
1	CO	n/a	g) Robust methodology/ready to implement	This project aims "to provide additional services and help the System Operator to reduce voltage fluctuations at the point where the transmission network supplies the distribution network, both short-term fluctuations and longer duration voltage dips". WPD states separately that it worked closely with National Grid to develop future plans etc. There were several references to the provision of reactive power sources to the System Operator in the project proposal and yet there was no letter of support from National Grid. This may call into question the robustness of the project methodology. For example, on page 26, the proposal states: "There is a commercial risk associated with whether the device can be used to provide reactive power to the System Operator (National Grid), for what duration and availability, and for what level of income.". Is National Grid a project partner and, if not, why has it not committed to the project?	22 August 2017	24 August 2017	24 August 2017		
2	CO	n/a	g) Robust methodology/ready to implement	Has the safety implications of using these devices in the system been considered in full and have bodies such as the HSE been consulted?	22 August 2017	24 August 2017	24 August 2017		
3	NC	n/a	a) Enviro+consumer bens	Your submission shows the financial benefits of the proposed trial method versus conventional reinforcement. Please explain why conventional reinforcement is the most efficient method in use today. Have you considered other methods to address the problem, eg ANM or DSR. Within the Poyry report (which accompanied the Innovation Review) you contributed data to indicates 37% of the methods trialled under the LCN Fund are ready for use in business as usual and a further 41% are ready for use in the right circumstances. This would imply that there are more efficient methods available to licensees than traditional reinforcement.	24 August 2017	29 August 2017	29 August 2017		
4	NC	n/a	d) Is innovative	With specific reference to the TRL definition in the governance document please justify the stated TRLs within the submission.	31 August 2017	05 September 2017	05 September 2017		y
5	EP	n/a	a) Enviro+consumer bens	We note your response to question 3. Please provide more information on why you have not considered 'quad-boosters' to be the counterfactual technology?	05 September 2017	07 September 2017	07 September 2017		
6	EP	n/a	d) Is innovative	For the six overseas deployments outlined within the submission, where known please outline why this option has been selected over a quad-booster.	05 September 2017	07 September 2017	07 September 2017		
7	EP	n/a	d) Is innovative	Please provide a comparison table showing the capabilities for the device compared to a quad-booster.	05 September 2017	07 September 2017	07 September 2017		
8	EP	n/a	g) Robust methodology/ready to implement	How do you propose to control this device if it is established on the network?	05 September 2017	07 September 2017	07 September 2017		
9	EP	n/a	a) Enviro+consumer bens	Please clarify why the NPV for GB is positive but the use case/ licensee scale benefits are negative?	05 September 2017	07 September 2017	07 September 2017		
10	EP	3	a) Enviro+consumer bens	Please outline how the benefits in Table 3.3 link to those in the Benefits Tables in the Appendix?	05 September 2017	07 September 2017	07 September 2017		
11	EP	n/a	Multiple	How much appetite have other DNOs shown in using this technology if it is proved to be effective?	05 September 2017	07 September 2017	07 September 2017		
12	EP	n/a	Multiple	We note the proposed device is rather large and likely to meet opposition from nearby residents. Please provide more information on the customer engagement steps you will take to overcome any issues caused by this.	05 September 2017	07 September 2017	07 September 2017		
13	EP	n/a	e) Partners and ext. funding	Please outline the steps you have already taken to identify likely suppliers of the device.	05 September 2017	07 September 2017	07 September 2017		y
14	EP	n/a	a) Enviro+consumer bens	We note your response to question three. Please provide a calculation of the benefits of UPFC technology where other individual devices could be used instead, eg 'quad-boosters'.	05 September 2017	07 September 2017	07 September 2017		
15	NC	Appendices	a) Enviro+consumer bens	Please explain why the capacity 'benefits' are negative?	05 September 2017	07 September 2017	07 September 2017		
16	NC	Appendices	a) Enviro+consumer bens	Please explain whether there are carbon/environmental benefits associated with building a UPFC compared to current business as usual approaches or indeed whether current methods have lower levels of embedded carbon associated with their manufacture and construction.	05 September 2017	07 September 2017	07 September 2017		
17	NC	Appendices	b) Value for money	How likely is it that enough UPFCs will be rolled out to deliver a financial benefit to customers, UPFCs only appear to deliver a benefit based on a GB rollout.	05 September 2017	07 September 2017	07 September 2017		
18	CO	n/a	b) Value for money	Can you please provide the day rates used and the estimated hours for this project for the WPD team and all the Partners / Contractors participating in the project?	05 September 2017	07 September 2017	07 September 2017		
19	EP	n/a	b) Value for money	Please confirm how much money the project will have spent by the point where it would have to be stopped if a provider of the technology cannot be found?	12 September 2017	14 September 2017	14 September 2017		
20	EP	n/a	a) Enviro+consumer bens	Please confirm whether the Carbon Figures solely relate to CO2. If not, please list the other Greenhouse Gasses included within the figure.	12 September 2017	14 September 2017	14 September 2017		
21	EP	n/a	a) Enviro+consumer bens	Please could you also confirm how much Carbon is embedded within the technological solution?	12 September 2017	14 September 2017	14 September 2017		
22	EP	n/a	g) Robust methodology/ready to implement	What risks are there to the delivery of the project/ the GB roll-out by issues relating to planning permission? How are you intending to mitigate these/ is there any budget assigned?	12 September 2017	14 September 2017	14 September 2017		
23	EP	n/a	b) Value for money	Please could you confirm whether your agreement with Mott Macdonald/ the provider of the UPFC technology will include any royalty mechanism to ensure GB Consumers receive good value for the trial?	12 September 2017	14 September 2017	14 September 2017		
24	EP	n/a	b) Value for money	Please outline how you have ensured the contribution from Mott Macdonald represents good value for money to GB consumers when balanced against the financial benefits on offer if they can market this solution abroad?	12 September 2017	14 September 2017	14 September 2017		
25	EP	n/a	a) Enviro+consumer bens	details on the content of this report and whether it identifies any required interactions with the Environment Agency?	12 September 2017	14 September 2017	14 September 2017		
26	EP	n/a	b) Value for money	Please provide a comparison of the benefits offered by the UPFC compared to other similar alternative technologies	12 September 2017	14 September 2017	14 September 2017		
27	EP	n/a	c) Generates new knowledge	solution on their network if it is proven to be successful	12 September 2017	14 September 2017	14 September 2017		
28	NC	9	Multiple	The design of the UPFC is an important output from the project. Please provide a justification that the proposed percentage of funding associated with deliverable one is appropriate.	14 September 2017	19 September 2017	19 September 2017		
29	NC	9	Multiple	Please explain what is innovative and what new learning is associated with project deliverable two. Please provide a justification that the proposed percentage of funding associated with this deliverable is appropriate.	14 September 2017	19 September 2017	19 September 2017		

30	NC	9	Multiple	The proposed funding allocated to Project Deliverable 3 appears high given these are business as usual processes that are undertaken when commissioning new equipment and are not directly linked to project learning. Please provide a justification that the proposed percentage of funding associated with this deliverable is appropriate.	14 September 2017	19 September 2017	19 September 2017		
31	NC	9	Multiple	Project deliverables 4-10 appear to be associated with the outputs of the project and the learning that will be shared. Please provide a justification that the proposed percentage of funding associated with these deliverables is appropriate.	14 September 2017	19 September 2017	19 September 2017		
32	NC	N/A	b) Value for money	Please explain in more detail (with reasons) how you think the royalty arrangements proposed comply with Chapter 10 of the Governance Document.	21 September 2017	26 September 2017	26 September 2017	23	
33	EP	Appendices	a) Enviro+consumer bens	Please comment on the carbon benefits of capacity released with current business-as-usual approaches and their comparison with those of the proposed method (440,000 tCO2e by 2040). Please clarify which scenario from FES was used to derive the estimate of carbon benefits.	21 September 2017	26 September 2017	26 September 2017	16	
34	EP	n/a	Mulitple	In various responses to the Q&A the use of quadrature boosters (QBs) as the counterfactual have been explored, either alone or in combination with other devices depending on the constraint being relieved. Together with the clarification that QBs are available at 132kV and based on relieving (real) constraints currently considered present on the 132kV and 66kV systems (please justify whether the "fast" response of UPFCs are required), do your original CBA and NPV calculations still hold? If not can you please revise your estimates.	05 October 2017	10 October 2017	10 October 2017		
35	EP	n/a	Mulitple	During the 2nd Bi-lateral Meeting you presented a table (page 6 of your notes) showing the networks in the WPD licence areas where UPFCs may be the best solution to relieve network constraints. Can you please clarify how many UPFCs per network (GSP) are required. For example, in the Cardiff East – Aberthaw network only one may be needed but the table suggests two.	05 October 2017	10 October 2017	10 October 2017		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: ___WPD HARP_____

Tick if this answer has been provided verbally: ☐

Project code	**WPD/EN/NIC/04**	**Question Number**	**1**
Question date	**22/08/17**	**Answer date**	**24/08/17**
Submission section question relates to	**n/a**		
Topic	**g) Robust methodology/ready to implement**		
Question	**This project aims "to provide additional services and help the System Operator to reduce voltage fluctuations at the point where the transmission network supplies the distribution network, both short-term fluctuations and longer duration voltage dips". WPD states separately that it worked closely with National Grid to develop future plans etc. There were several references to the provision of reactive power sources to the System Operator in the project proposal and yet there was no letter of support from National Grid. This may call into question the robustness of the project methodology. For example, on page 26, the proposal states: "There is a commercial risk associated with whether the device can be used to provide reactive power to the System Operator (National Grid), for what duration and availability, and for what level of income.". Is National Grid a project partner and, if not, why has it not committed to the project?**		
Notes on question			
Answer	The Project Team has not requested National Grid to become either a formal Project Partner or formal Project Supporter at this time. We held discussions with Graham Stein of the GB System Operator function within National Grid on 30 May 2017. This was an in-principle discussion around provision of reactive power support from devices on the distribution network, prior to receiving responses from UPFC manufacturers to our Request for Information (RFI). We received the manufacturer responses on 21 June 2017. We have also subsequently provided a redacted copy of the full bid submission to Graham Stein for awareness. The comment which we made on page 8 of the submission "WPD works closely with National Grid to develop		

	future plans" relates specifically to the work which WPD have carried out to forecast reinforcement needs on their 132kV networks between now and 2030, rather than the discussion around reactive power provision. The reason that we chose not to ask National Grid to formally support the project was two-fold. Firstly, during the development of our bid, National Grid had launched its consultation "System Needs and Product Strategy", and which closed on 18th July. The scope of this consultation is all of the ancillary services procured by the System Operator including reactive power; National Grid are currently considering the responses from that consultation. Within the consultation document (page 21) National Grid state that "We must create a market that values reactive power in a transparent manner and aim to do this by the end of 2018/19. This design will begin following consultation and will use the results of Power Potential and Project Phoenix." This position was also confirmed by Graham Stein during our discussions. This gave us confidence that there is likely to be a means for distribution network assets to offer reactive power as a service alongside other competing providers, but that it was unlikely that National Grid could be seen to endorse further projects or initiatives during this consultation period. The System Operability Framework (SOF) published in 2016 by National Grid also states (page 102) that "Of the growing requirement for voltage control resources, a greater proportion must be dynamic in order to follow the daily reactive load profile and ensure voltage containment and recovery after a disturbance." This is to the advantage of UPFCs which can provide both static and dynamic reactive power. Secondly, we would expect any future arrangements to be on a commercial arms-length basis and not necessarily as a project "sponsor" or Project Partner as defined by the Network Innovation Competition Governance Document. No contract is in place with National Grid regarding this project at this time. **The scope of the HARP project** Our intention set out in Section 7 (page 44) of the Full Submission is not to carry out any activity within the HARP project on the commercial arrangements for providing reactive power, but to rely on the existing activity between National Grid and the projects Power Potential (also known as "Transmission and Distribution Interface 2.0") and Project Phoenix as stated in their consultation document and which are compatible with the timescales of HARP set out in our project plan. The scope of the project will include: 1. Confirmation of R017 in the project risk register in Appendix 10.5 (page 69 of the PDF Full Submission) whether there is indeed any conflict between a typical operating regime for the UPFC (such as that shown on page 12 of our submission) to serve both longer duration voltage dips and the needs of the distribution network. This risk was also referred to on page 26 of our submission. This will be confirmed by discussion with National Grid with respect to their service requirements; confirmation of the distribution network needs through

	trials; confirmation that a compatible operating regime exists; and confirmation through trials that the UPFC can carry out the operating regime. This will be reported as part of the project deliverables 4 through 7 listed in Section 9 (page 47). 2. Confirmation of the extent to which the UPFC, at the size installed, can contribute to attenuating a short-term voltage fluctuation. This will be reported as Project Deliverable 9 listed in Section 9 (page 48).		
Attachments	-		
Project code	**WPD/EN/NIC/04**	**Question Number**	**2**
Question date	**22/08/2017**	**Answer date**	**24/08/2017**
Submission section question relates to	**N/A**		
Topic	**g) Robust methodology/ready to implement**		
Question	**Has the safety implications of using these devices in the system been considered in full and have bodies such as the HSE been consulted?**		
Notes on question			
Answer	The Project Team has not consulted with HSE or similar bodies during development of these proposals. This was not considered necessary since the UPFC can be broken down into a series of major sub-assemblies, each of which has previously been deployed in the UK and has been demonstrated to be compliant with UK Health & Safety legislation and good industry practice. The main requirements to achieve safety of electrical systems within the Electricity Supply Industry are set out in the following legislation: • Electricity at Work Regulations 1989 • Electricity Safety, Quality & Continuity Regulations (ESQCR) 2002 (as amended in 2006 & 2009) Compliance with the WPD Safety Rules and associated procedures will also be essential. We are familiar with the requirements of these Regulations/Safety Rules and are confident that, in all respects, a UPFC can be designed to be fully compliant with them. Compliance with this legislation (and all other relevant		

	UK legislation) will be a condition of Contract and we will be ensuring conformity through a comprehensive technical review of the manufacturer's design proposals by experienced professional staff. We have already included several normative standards and legislation within our Request for Information (RFI) against which manufacturers have provided indicative prices. It is proposed that the Principal Designer role is held by Mott MacDonald Ltd, who have extensive experience of managing power sector construction projects in the UK. We will follow established procedures for identifying risks, including comprehensive Hazard Reviews with input from both the Contractor and WPD operational staff. As will all WPD innovation technology projects, detailed design, type testing and routine testing will take place - witnessed by WPD's or Mott MacDonald's engineers. The full life cycle of the project will be managed in accordance with the Construction (Design & Management) Regulations (CDM) 2015. Mott MacDonald as Principal Designer will ensure that detailed maintenance recommendations are developed and documented in coordination with the equipment manufacturer, as well as other information that could be pertinent to the safe operation of the UPFC.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**3**
Question date	**24/08/2017**	**Answer date**	**29/08/2017**
Submission section question relates to	**N/A**		
Topic	**a) Enviro+consumer bens**		
Question	**Your submission shows the financial benefits of the proposed trial method versus conventional reinforcement. Please explain why conventional reinforcement is the most efficient method in use today. Have you considered other methods to address the problem, eg ANM or DSR. Within the Poyry report (which accompanied the Innovation Review) you contributed data to indicates 37% of the methods trialled under the LCN Fund are ready for use in business as usual and a further 41% are ready for use in the right circumstances. This would imply that there are more efficient methods available to licensees than traditional reinforcement.**		
Notes on question			
Answer	We agree that ANM and DSR are indeed examples of the methods trialled under the LCN Fund which are ready for use in business as usual. Alongside other alternative arrangements for connecting distributed generation, ANM is already being considered by Western Power Distribution first as an alternative to traditional network reinforcement. Western Power Distribution has published its current plan for ANM deployment on its website and which currently lists 20 locations at which ANM is being considered[1]. Our bid however reflects that ANM and DSR are ready for use "in the right circumstances". WPD's series of reports "Shaping subtransmission to		

[1] https://www.westernpower.co.uk/Connections/Generation/Alternative-Connections/ANM-Further-Info.aspx

	2030"[2,3,4] which carried out comprehensive analysis of the South West, South Wales and West Midlands licence areas concluded that a blend of ANM and conventional reinforcement is required. Both ANM and DSR require either generation or demand customers to be flexible with their network capacity and change their operational behaviour. This by nature relies on the customers wanting to participate in a DSR programme or accepting curtailment. There is a finite limit to the flexilibility which customers can provide – either because there is a finite limit to the amount of industrial and commercial demand which can be shifted within a geographic region without disrupting a customer's business activities, or because distributed generators who join later may see an increasing and eventually uneconomic level of curtailment. The UPFC increases the flexibility of the distribution network itself and is therefore most comparable with conventional reinforcement. It is a complementary technology which can be rolled out alongside either ANM or DSR. Importantly, our analysis of applicability to Great Britain set out in Appendix 10.10, section 10.10.5, indicated that 23 sites had constraints which would eventually surpass the capabilities of ANM or DSR and would have to choose between conventional reinforcement or an alternative such as a UPFC in order to continue to accommodate generation and demand growth.
Attachments	

[2] https://www.westernpower.co.uk/docs/About-us/Our-business/Our-network/Strategic-network-investment/East-Midlands/Shaping-subtransmission-to-2030-East-Midlands-2017.aspx
[3] https://www.westernpower.co.uk/docs/About-us/Our-business/Our-network/Strategic-network-investment/Shaping-Subtransmission-to-2030-(South-Wales-2016).aspx
[4] https://www.westernpower.co.uk/docs/About-us/Our-business/Our-network/Strategic-network-investment/Shaping-Subtransmission-to-2030-South-West-2016-v1.aspx

Project code	**WPD/EN/NIC/04**	**Question Number**	**4**
Question date	**31/08/17**	**Answer date**	**05/09/17**
Submission section question relates to	**n/a**		
Topic	**d) is innovative**		
Question	**With specific reference to the TRL definition in the governance document please justify the stated TRLs within the submission.**		
Notes on question			
Answer	***Marked as confidential***		
Attachments			
Project code	**WPD/EN/NIC/04**	**Question Number**	**5**
Question date	**05/09/2017**	**Answer date**	**07/09/2017**

Submission section question relates to	**N/A**
Topic	**a) Enviro+consumer bens**
Question	**We note your response to question 3. Please provide more information on why you have not considered 'quad-boosters' to be the counterfactual technology?**
Notes on question	
Answer	Our response to question 3 concentrated on the two specific technologies which were mentioned, Active Network Management (ANM) and Demand Side Response (DSR). We provided further detail in Appendix 10.9 on pages 77-79 of the bid how we chose the counterfactual, and referenced it in Section 3.1. Appendix 10.9 specifically discusses Thyristor-Switched Series Capacitors, quadrature boosters and STATCOMs as potential counterfactuals. In the case of the quadrature booster we presented the results of some comparative simulations between phase-shifting transformers and the UPFC. Three considerations were involved in our decision to use conventional reinforcement as the counterfactual for the DNO, and procuring reactive power services from alternative sources as the counterfactual for the GB System Operator: 1. the range of control required 2. the dynamic response in the event of an outage 3. the dynamic response in the event of voltage disturbance. Further details can be found in Appendix 10.9.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**6**
Question date	**05/09/17**	**Answer date**	**07/09/17**
Submission section question relates to	**n/a**		
Topic	**d) Is innovative**		
Question	**For the six overseas deployments outlined within the submission, where known please outline why this option has been selected over a quad-booster.**		
Notes on question			
Answer	In all three cases which we could review based on public information, the UPFC is preferred to a quad booster (QB) as the QB is only capable of controlling real power flow on the line and is not capable of providing voltage support however the UPFC is capable of controlling real power flow control and reactive power compensation. One of the six examples of a UPFC being deployed was the application at the American Electric Power Inez Station (Kentucky). The 'CIGRE – TB 160 Unified Power Factor Controller (UPFC) Task Force 14.27' document explains that contingency analysis of the Inez power station identified several single contingency outages could result in a depressed voltage and/or a thermal overload condition. It was identified that the requirement to support increased losses in the event of a single outage would result in area voltage levels being reduced to unacceptable levels and a second contingency was intolerable. Section 3.2.4 of the CIGRE document states after extensive analysis, that constructing a high capacity 138 kV line with thermal capabilities nearing a 345 kV line would provide an economical solution to adding thermal capacity to the area however such a line would not be capable of sharing its line loading based on the high thermal capacity alone and power flow would still be governed by the line impedance and other AC network parameters. As well as the thermal capacity issue, the Inez area required improvements in voltage performance during peak and off peak conditions therefore dynamic voltage support was also required in conjuction with increased thermal capacity. Korea (Mokpo & Gwangju) – to overcome problems of low voltages and overloads for severe contingencies. (Ref: CIGRE paper B4-306 Control		

	Strategies Study for KEPCO UPFC Operation Automation in Korean Sub-Transmission System, 2006) Korea (KangJin) – solution to under voltage and overload issues during system faults, UPFC was preferred over conventional reinforcement due to risk of delay or cancellation of reinforcement project due to environmental contraints or legal matters such as compensating land owners. (Ref: CIGRE paper B4-211 Commissioning and Testing of the KangJin UPFC in Korea, 2004)		
Attachments			
Project code	**WPD/EN/NIC/04**	**Question Number**	**7**
Question date	**05/09/2017**	**Answer date**	**07/09/2017**
Submission section question relates to	**N/A**		
Topic	**d) Is innovative**		
Question	**Please provide a comparison table showing the capabilities for the device compared to a quad-booster.**		
Notes on question			

Answer

We have summarised the capabilities of each device below against the various functions which are discussed in the HARP submission. We have provided further commentary in the form of footnotes:

Function	Capabilities with respect to this function	
	Quadrature booster	UPFC
Re-direct power away from constrained sections of a ring (Case Study 2 or Case Study 3)	Quadrature boosters have a coarser degree of control based upon discrete tap settings and a fixed phase relationship between the shunt and series windings[5] It is generally not possible to select the most effective phase relationship (which is not necessarily 90 degrees) between the shunt and series windings. The line compensation cannot, therefore, be optimised.	Fine degree of control capable through adjusting the output voltage of the 'Series' VSC bridge. As the coupling between the shunt and seies elements is through a DC link, the phase relationship between system voltage and the injected voltage can be adjusted in real time to optimise line compensation
Reduce "reverse" power being presented to Super-Grid Transformers on the transmission network (Case Study 3)	Same as line above	Same as line above
Re-direct power to avoid overloads in the event of a system fault or outage (Case Study 1)	Same as line above	Same as line above
Control both real and reactive power flows in the circuit in which the unit is connected	The QB cannot control real and reactive power flows independently. In general, a QB is used to control MVA transfers (i.e. real + reactive current combined).	The UPFC allows the phase relationship between the system voltage and the injected voltage to be adjusted over a wide range. This allows real power flows and reactive power flows to be independently controlled. The benefit of this is that a circuit can be operated with an optimised reactive transfer, minimising the thermal capacity of the circuit that is 'wasted' transferring reactive power. For example, a cable generates

[5] We quantified in Appendix 10.9, page 78, that this coarse control may amount to around 10-20MW less capacity able to connect at each 132kV/33V or 66kV/11kV substation around a ring than if a UPFC was used.

		reactive power along its length and its rating can be optimised if 50% of the reactive power generated is transferred into the network at each end of the circuit (i.e. no more than 50% flows in any part of the cable). A UPFC allows this transfer to be controlled whilst still permitting flexible control of real power flows. A further benefit of managing reactive power flows is that transmission losses can be minimised through limiting the total current flowing in the circuit (real + reactive).
Provide reactive power compensation to the upstream 66kV or 132kV busbar and the 275kV or 400kV busbar from which these are fed	Cannot directly provide reactive power compensation (any compensation achieved is a secondary effect and unctrolled).	Able to provide both inductive or capacity compensation from the shunt section.
Reduce voltage fluctuations by injecting a voltage which seeks to damp the fluctuation	A 'classic' quadrature booster relies on operation of a mechanical tapchanger to adjust the power flow in the circuit to which it is connected. Tapchangers are designed to operate step by step through their range, and each step will typically take 0.1 - 0.2s to complete. Thus a QB may require several minutes to achieve a significant change.[6] During this time the circuit or other assets would be exposed to the overload. As such, other faster-acting arrangements may be required such as inter-trip arrangements with generators.	A UPFC is able to alter its operating point rapidly (typically 20-40ms response time) to any point in its operating range. This allows the UPFC to respond to, and assist in managing, transient events on the network. This dynamic response allows the network to be operated closer to its thermal limits whilst still remaining stable during contingency events (typically system faults).

[6] To improve the flexibility of the QB, the mechanical tapchanger can be replaced with a power electronic current controller (based on thyristor technology). Although these units are capable of providing fast-acting response, they have the disadvantage that harmonics generated by the thyristor controller are injected directly into the line. Harmonic control measures may thus be required at additional cost.

Project code	**WPD/EN/NIC/04**	**Question Number**	**8**
Question date	**05/09/17**	**Answer date**	**07/09/17**
Submission section question relates to	**n/a**		
Topic	**g) Robust methodology/ready to implement**		
Question	**How do you propose to control this device if it is established on the network?**		
Notes on question			
Answer	In a similar manner to previous innovation projects led by Western Power Distribution such as Active Network Management (ANM) and System Voltage Optimisation (SVO) the UPFC will integrate with the PowerOn Fusion control system (WPD's standard network management systems) either directly or through an Inter-Control Room Communications Protocol (ICCP) link. We propose to control this device in a 24 hour operating regime that will set the control objectives of the UPFC for each hour of the day. The control objectives for the UPFC will be established during the trials design period of the programme in conjuction with WPD engineers and National Grid to explore the benefits of income from UPFC services to National Grid. For each control objective the UPFC will be required to to direct real power flow (Static Synchronous Series Compensator, SSSC action), provide reactive power compensation (STATCOM action) or provide a combination of real power control and reactive power compensation (SSSC and STATCOM action). Examples of control objectives are provided in Table 2.1 of the full submission document such as reduce energy lost to heat, protect against voltage disturbances, control power supplying demand, optimise power factor, control of active power flow from solar PV. Prior to each control objective being set, the UPFC will establish the existing network conditions using SCADA input and real time measurements and then, using its own software, iteratively perform future load flow assessments of the network offline to determine the required operating voltage and phase angle set points of the SSSC and STATCOM that will permit the UPFC to meet its control objective. The individual hardware controllers within each device will then control the firing angles of the Insulated Gate Bipolar Transistors (IGBTs) to meet the control objectives.		
Attachments			

Project code	**WPD/EN/NIC/04**	**Question Number**	**9**
Question date	**05/09/2017**	**Answer date**	**07/09/2017**
Submission section question relates to	**n/a**		
Topic	**a) Enviro+consumer bens**		
Question	**Please clarify why the NPV for GB is positive but the use case/ licensee scale benefits are negative?**		
Notes on question			
Answer	The NPV was built up from an assumed roll-out of UPFCs to address individual instances of Case Study 1, Case Study 2, and Case Study 3. Overall we believe that Case Study 1 and Case Study 3 will be more common than Case Study 2. Within Western Power Distribution currently, there are examples of Case Study 1 (at [redacted]) but not examples of Case Study 3. The most realistic case on which to base our post-trial or use-case scale benefits is Case Study 1 and a first installation in 2022. The most realistic case on which to base our licencee scale solution is one installation of Case Study 1 in 2022 followed by a second installation of Case Study 3 in 2026. We added some notes to this effect in the column "Cross-references" in the table on page 51 in Appendix 10.1. **Post-trial or use-case scale** The conservative assumptions we have used in Appendix 10.1 are that: - the higher of the [redacted] manufacturer's prices that we have received at RFI is achieved, not the lowest price; - the device does not earn reactive power income; - installations subsequent to the project would be containerised and not require a building. If we apply similar break-even analysis as we carried out in Table 3.5 to the GB and licence-area scale benefits, we find that our existing post-trial case is net positive over timescales to 2040 and 2040 if the lower of the two manufacturer's prices that we have received at RFI is achieved, and the device earns income from delivering reactive power.		

	Licensee scale We have found a formula error in the spreadsheet which we used to calculate the NPV benefits. We were calculating the NPV benefit at licensee scale correctly for 2030, and 2040, but incorrectly for 2050. The formula was calculating gross expenditure on the UPFC installation, not net benefit based on comparing it with gross expenditure on the counterfactual. The correct value is for the NPV at licencee scale in 2050 is £2.45m. As such, the licensee scale shows a positive NPV on timescales measured to 2030, 2040 and 2050. We will correct this in our re-submission.
Attachments	

<table>
<tr><td>Project code</td><td>WPD/EN/NIC/04</td><td>Question Number</td><td>10</td></tr>
<tr><td>Question date</td><td>05/09/2017</td><td>Answer date</td><td>07/09/2017</td></tr>
<tr><td>Submission section question relates to</td><td colspan="3">3</td></tr>
<tr><td>Topic</td><td colspan="3">a) Enviro+consumer bens</td></tr>
<tr><td>Question</td><td colspan="3">Please outline how the benefits in Table 3.3 link to those in the Benefits Tables in the Appendix?</td></tr>
<tr><td>Notes on question</td><td colspan="3"></td></tr>
<tr><td>Answer</td><td colspan="3">
The summary in table 3.3 was presented in a simplified format, based only on the quantity of each Case Study which was included in the GB roll-out. It did not take into account the timing of the expenditure.

The financial figures presented in the table in Appendix 10.1 is based on a fuller calculation which takes into account:

• The year in which each subsequent installation is rolled out, using the profile presented in Appendix 10.10, Section 10.10.6.
• The time value of money, using the parameters set out in Appendix 10.10, Section 10.10.4
• Effects of capitalisation of expenditure, using the paramaters set out in Appendix 10.10, Section 10.10.4
• The effect of future cost reductions in the technology, based on the analysis presented in Appendix 10.10, Section 10.10.7
• Maintenance costs.

This fuller calculation could also take into account income from providing services to National Grid, and was used for the break-even analysis in Table 3.5.

The conventional costs used in both Table 3.3 and in the fuller calculation which informed Appendix 10.1 are explained in Appendix 10.10, section 10.10.4.

The "UPFC unit cost" in Table 3.3 was derived in accordance with Figure 3.3 and Table 3.4. In fuller detail, this included:

<table>
<tr><td>Front-end Engineering Design (FEED) activities at a reduced cost of 50% compared to the trial</td><td>£0.10m</td></tr>
<tr><td>Site surveys and Detailed Design at the same cost as the trial</td><td>£0.44m</td></tr>
</table>
</td></tr>
</table>

	<table><tr><td>Land Purchase, cSite learance and preparation (incl. earthing grid) at the same cost as the trial</td><td>£1.53m</td></tr><tr><td>UPFC cost</td><td>£10.40m</td></tr><tr><td>Ancillary equipment at 32% of £2.10m required in the trial</td><td>£0.47m</td></tr><tr><td>Telecomms and SCADA equipment at the same cost as the trial</td><td>£0.20m</td></tr><tr><td>Installation at the same cost as the trial</td><td>£0.42m</td></tr><tr><td>Construction oversight and commissioning at 50% of the trials</td><td>£0.15m</td></tr><tr><td>[No requirement for programme management or learning and dissemination]</td><td>-</td></tr><tr><td>[No requirement for contingency]</td><td>-</td></tr><tr><td>Total</td><td>£13.71m</td></tr></table> Finally, the figures in red on the right in Table 3.3 provided totals for capital expenditure based on multiplying these costs through by the number of installations.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**11**
Question date	**05/09/2017**	**Answer date**	**07/09/2017**
Submission section question relates to	**N/A**		
Topic	**Multiple**		
Question	**How much appetite have other DNOs shown in using this technology if it is proved to be effective?**		
Notes on question			
Answer	Neither Mott MacDonald or Western Power Distribution has at this time formally asked the other DNOs about their appetite to replicate the solution if proven successful. However, we would note that there is increasing interest in power electronic solutions as represented by the following recent projects: • Western Power Distribution's Low Carbon Network Fund (LCNF) project "Network Equilibrium" (operating at 33kV) • ScottishPower Energy Networks' project Network Innovation Competition (NIC) project ANGLE-DC (operating at 33kV) • ScottishPower Energy Networks' Network Innovation Allowance (NIA) project "11kV power electronics providing reactive compensation for voltage control" • ScottishPower Energy Networks' Network Innovation Allowance (NIA) project "Technical Review of Non-conventional Statcom Applications" which is looking particularly at the 11kV network.		
Attachments			

Project code	**WPD/EN/NIC/04**	**Question Number**	**12**
Question date	**5 Sep 2017**	**Answer date**	**7 Sep 2017**
Submission section question relates to	**n/a**		
Topic	**Multiple**		
Question	**We note the proposed device is rather large and likely to meet opposition from nearby residents. Please provide more information on the customer engagement steps you will take to overcome any issues caused by this.**		
Notes on question			
Answer	One of the trial sites identified in Appendix 10.2 will be on land immediately adjacent to an existing sub-station. The other trial site would require establishing a new substation site. Both sites are bounded by farm land or other open areas and main roads. Neither of these sites has a boundary to residential or business areas. We had discounted trial sites where the location would have been directly next to or within residential areas (for example Stratford upon Avon, located opposite a residential area and with planned residential development around the existing sub-station). Nevertheless we envisage the following engagement with local residents: 1. Compliance with all statutory planning communications requirements. 2. General project information in existing WPD customer information publications. 3. Follow Western Power Distribution's existing engagement strategy for similar new-build projects, where required providing specific project information, plans and impacts, and the measures to minimse any impacts during construction and operations. 4. Ongoing project updates through in WPD customer publications and website, and progress updates in targeted publicity to local residents. The communications materials and planning application will address likely questions on disruption and routing of construction traffic, site construction noise, safety issues and supply interruptions as well as the project objectives and intended benefits. Specific publicity will be issued to warn of major equipment delivery.		
Attachments			

Project code	**WPD/EN/NIC/04**	**Question Number**	**13**
Question date	**05/09/2017**	**Answer date**	**07/09/2017**
Submission section question relates to	**N/A**		
Topic	**(e) Partners and external funding**		
Question	**Please outline the steps you have already taken to identify likely suppliers of the device.**		
Notes on question			
Answer	***Marked as confidential***		
Attachments			

Project code	**WPD/EN/NIC/04**	**Question Number**	**14**
Question date	**05/09/2017**	**Answer date**	**07/09/2017**
Submission section question relates to	**N/A**		
Topic	**a) Enviro+consumer bens**		
Question	**We note your response to question three. Please provide a calculation of the benefits of UPFC technology where other individual devices could be used instead, eg 'quad-boosters'**		
Notes on question			
Answer	Our business case is focussed on rolling out UPFCs in locations which exhibit multiple challenges. We built our roll-out estimate to 23 locations by searching for signs of multiple different challenges which could not be solved by a single individual device (such as a quad-booster). The process by which we carried out this search is explained in the Appendix 10.10, section 10.10.5, pages 83-88. Western Power Distribution would not typically roll out the UPFC to solve only one specific issue. A number of our calculations presented in the bid can be used to draw conclusions as follows. 1. Within our break-even analysis on page 20, table 3.3, we demonstrated that the added value of providing reactive power to the GB System Operator National Grid is 6.2m in NPV terms, over the timescale from now to 2040. This is calculcated from the difference between a scenario in which the UPFC earns reactive power income (£33.5m) and our base benefits case (£27.3m). A STATCOM, switched shunt reactor or capacitor bank are all examples of individual devices which could capture this £6.2m of value but which would not be able to capture the underlying £27.3m since they are not able to direct power to support the distribution network. By contrast, a quad-booster is able to capture most of the benefits associated with £27.3m but is not able to capture this additional £6.2m of benefits. 2. In Appendix 10.9, we provided calculations on the capacity benefits of a UPFC against a phase shift transformer (PST) and shown that the UPFC is able to release more line capacity than the PST due to its finer control of the phase angle. We calculate this as increasing capacity which can join by 10-20MW, and which may be the difference		

	between an additional distributed generator being able to join the network or not being able to join the network. The unit cost of a UPFC is provided in Table 3.3 at £13.7m in 2018 prices, and prior to any discounts which may be achieved in future. The estimated cost of a 132 kV rated PST is provided in Appendix 10.9 at £3.5-4.5m (2015 prices). These costs are not comparable as the UPFC technology provides the additional benefit of reactive power control. To achieve the same control objectives of the UPFC technology would require a STATCOM as well as a PST. The estimated cost of a STATCOM is provided in Appendix 10.9 at £3.5-5m. This equates to a total estimated cost of £7-9.5m for a STATCOM and PST however this does not include any costs for the control and communication requirements of integrating both devices as a joint solution. Further work would be required to ensure that our data sources for the cost of PST and STATCOM are comparable "turn-key" costs including all associated switchgear, land purchase etc. and therefore comparable with our £13.7m turn-key cost of the UPFC.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**15**
Question date	**05/09/2017**	**Answer date**	**07/09/2017**
Submission section question relates to	**Appendices**		
Topic	**a) Enviro+consumer bens**		
Question	**Please explain why the capacity 'benefits' are negative?**		
Notes on question			
Answer	We calculated the capacity benefits as net benefits: Net capacity released = Capacity released by the UPFC (Method Case) – Capacity released by conventional reinforcement (Base Case) The capacity released by the UPFC was based on simulations carried out at [redacted] for Case Study 1, and simulations carried out at [redacted] for Case Study 2. The capacity released by conventional reinforcement was calculated from equipment ratings supplied by Western Power Distribution. The capacity released in each Case Study for both the Method Case and Counterfactual is summarised in Table 3.3 in Section 3, on page 19. We wanted to be open and transparent that conventional reinforcement creates more capacity; but can only be purchased in large quantities, some of which may in fact be stranded capacity. Because we had no firm assumption that we could provide for the proportion of capacity which might be unused or "stranded", we did not discount any of the capacity created by conventional reinforcement. As such, the net amount of capacity created by the UPFC is lower than conventional reinforcement in each Case Study, and the overall net benefit is negative when calculated in MVA terms under these assumptions.		
Attachments			

Project code	**WPD/EN/NIC/04**	**Question Number**	**16**
Question date	**5 Sep 2017**	**Answer date**	**7 Sep 2017**
Submission section question relates to	**Appendices**		
Topic	**a) Enviro+consumer bens**		
Question	**Please explain whether there are carbon/environmental benefits associated with building a UPFC compared to current business as usual approaches or indeed whether current methods have lower levels of embedded carbon associated with their manufacture and construction.**		
Notes on question			
Answer	We have not quantified the carbon or environmental benefits of a UPFC or other current methods (line reinforcement) within a distribution network. With Ofgem interest in quantified embedded carbon costs, it would be possible to create data sets for the UPFC installation as part of the project – suggested to be conducted in Work Package 3 (Studies) - assuming sufficient asset specification and material content information is provided by the manufacturer and DNO. Such data capture would demonstrate the viability and utility of the carbon capture tool for wider application for DNOs and Ofgem. Mott MacDonald has developed a mature carbon calculation tool that could perform such calculations, but does not possess any data sets for network assets within a distribution network. National Grid have developed data sets for transmission network assets, including for 132kV transmission lines. Whilst these data sets are proprietary to National Grid, indicative figures are that the carbon cost for a transformer installation is roughly equivalent to the carbon cost for 4km of overhead line. A sub-station circuit breaker bay is roughly equivalent to 0.5km of overhead line. A UPFC installation requires 2 transformers, 3 to 4 circuit breakers and the UPFC equipment itself. However, the carbon cost for the civil works required for a containerised UPFC solution and the carbon cost required for a UPFC housed in a building would create a significant variance in any cost/benefit calculation. The other environmental benefits for a UPFC solution centre on the avoidance of the cumulative disruption associated with line reinforcement. The level of disruption is driven by actual line routing, and includes disturbance to		

	ecology along the lines, access to agricultural land over which lines are routed, noise and road restrictions for communities and business along the line route, the complexity of planning and community engagement along a route and the impact of network interruptions for consumers during reinforcement. These costs would need to be compared to the localised disturbance and disruption resulting from the UPFC site works.
Attachments	

<table>
<tr><td>Project code</td><td>WPD/EN/NIC/04</td><td>Question Number</td><td>17</td></tr>
<tr><td>Question date</td><td>05/09/2017</td><td>Answer date</td><td>07/09/2017</td></tr>
<tr><td>Submission section question relates to</td><td colspan="3">Appendices</td></tr>
<tr><td>Topic</td><td colspan="3">b) Value for money</td></tr>
<tr><td>Question</td><td colspan="3">How likely is it that enough UPFCs will be rolled out to deliver a financial benefit to customers, UPFCs only appear to deliver a benefit based on a GB rollout.</td></tr>
<tr><td>Notes on question</td><td colspan="3"></td></tr>
<tr><td>Answer</td><td colspan="3">We established the potential for 23 units to be rolled out from the methodology set out in Appendix 10.10, section 10.10.5, on pages 83-86 of the submission. We established the roll-out profile using the methodology set out section 10.10.6, on pages 88-89 of the submission. Based on this we had the following roll-out assumptions in the early years:

<table>
<tr><td>2022</td><td>1x installation to address Case study 1</td></tr>
<tr><td>2023</td><td>[No additional installs]</td></tr>
<tr><td>2024</td><td>[No additional installs]</td></tr>
<tr><td>2025</td><td>1x installation to address Case study 3</td></tr>
<tr><td>2026</td><td>2x installation to address Case study 1
1x installation to address Case study 2
2x installations to address Case study 3</td></tr>
<tr><td>2027</td><td>1x installation to address Case study 3</td></tr>
<tr><td>2028</td><td>1x installation to address Case study 1</td></tr>
<tr><td>2029</td><td>1x installation to address Case study 3</td></tr>
</table>

At the end of this period a total of 10 installations have taken place. All of our break-even analyses shown in table 3.5 on page 20 of the submission and which carried out NPV analysis of costs and benefits up to 2040 demonstrated that the project had paid back the initial contribution from the Network Innovation Competition on or before 2029.

As such, the likelihood of the project paying itself back is only dependent on a roll-out to other DNOs reaching 10 units, or less than one per licence area. Our choice of case studies 1 and 3 as being dominant is reflective of the situation experienced by the DNOs.

There is an increasing certainty that ancillary services will be required by the GB System Operator (National Grid) from a variety of sources including non-</td></tr>
</table>

	conventional sources and which strengthens the case for devices such as a UPFC which can provide these services.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**18**
Question date	**5 Sep 2017**	**Answer date**	**7 Sep 2017**
Submission section question relates to	**n/a**		
Topic	**Value for Money**		
Question	**Can you please provide the day rates used and the estimated hours for this project for the WPD team and all the Partners / Contractors participating in the project?**		
Notes on question			
Answer	Please see attachment with requested information for WPD and Partner : • WPD effort and day rates • Mott MacDonald effort and day rates For the other costs not included in the WPD, the Mott MacDonald or the manfuacturer's lump sum estimate provide in the Request for Information, we used unit costs drawn from industry standard or previous project data. Unfortunately we are not able to break the labour contribution within these unit costs down into day-rates: • Building costs were estimated using industry-standard data book "SPONS" against each manufacturer's site requirements. Site set-up and ongoing costs were estimated at 15% of net contract value. Professional fees were estimated at 10% of net contract value • Civil works site preparation, site survey requirements, and civils works themselves (earthing, foundations, fencing, etc) were priced using Mott MacDonald's project experience and then validated with WPD's construction team. Site set-up and ongoing costs were estimated at 20% of net contract value. Professional fees were estimated at 10% of net contract value • Additional electrical equipment for connection to the distribution network, protection and control systems and telecoms with reference to actual data from previous UK substation projects for which Mott MacDonald has been the principal designer (primarily from National Grid South East Substation alliance where we were also the cost management lead). Site costs were already within the civil works estimate. Design costs were within the Contractor's indicative estimate.		

Attachments	Clarification Response to Question 18 - ***marked as confidential***

Project code	**WPD/EN/NIC/04**	**Question Number**	**19**
Question date	**12/09/17**	**Answer date**	**14/09/17**
Submission section question relates to	**N/A**		
Topic	**b) value for money**		
Question	**Please confirm how much money the project will have spent by the point where it would have to be stopped if a provider of the technology cannot be found?**		
Notes on question			
Answer	Based on the submitted project plan (Appendix 10.4) and cost spreadsheet (Appendix A), the project spend at the point where the project would have to be stopped due to lack of technology provider would be in August 2018 (H1 Year 1) with a Total Cost of £1,222k. The Outstanding Funding Required at this stage is £1,059k. This equates to 7.2% of the Total Cost (or 7% of the NIC Funding Request). The costs incurred include all work package (WP) costs in financial year 2017/18, WP1/2/3 costs in year 2018/19 and a 75% reduction applied to WP5 (Procurement) costs in year 2018/19 as it is expected that Mott MacDonald and WPD will spend some time and effort attempting to overcome any concerns that manufacturers may have. These figures exclude the construction and installation costs (WP6) in year 2018/19. We have already taken steps to mitigate this risk by issuing an RFI to manufacturers with an indicative quote and received two responses and one note of interest from manufacturers. We plan to further mitigate this risk by requesting an expression of interest from manufacturers at the prequalification process (beginning of WP5, March 2018). Based on responses to the RFI, we do not envisage a lack of response at this stage however if this was to occur then the project may be halted prior to August 2018. On review of the submitted plan and cost sheet, we propose to reduce the project spend at this potential stopping point by delaying the land purchase until a successful tenderer has been identified. The planning application requires official engagement with the land owner however land acquisition is not required. The revised Total Cost at this point with land purchase delayed would be £714.95k (equivalent to £602.56k of Outstanding Funding		

	required). This equates to 4.21% of Total Costs (4.02% of the NIC Funding Request). Included in the existing and revised total spend figures is £30.31k of learning activities where knowledge obtained from the UPFC model development, equipment specification and lessons learned from the tendering process would be captured and disseminated to industry and academia through technical papers and presentation at the LCNI 2018 conference.

Project code	**WPD/EN/NIC/04**	**Question Number**	**20**
Question date	**12/09/17**	**Answer date**	**14/09/17**
Submission section question relates to	**n/a**		
Topic	**a) Enviro+consumer bens**		
Question	**Please confirm whether the Carbon Figures solely relate to CO2. If not, please list the other Greenhouse Gasses included within the figure.**		
Notes on question			
Answer	The carbon figures quoted throughout the submission document are solely related to CO2. These figures have been calculated assuming that the capacity created by the UPFC is taken up by commercial solar PV (a zero carbon source of generation) and displaces other high-carbon sources of generation. Other greenhouse gases that could be considered in the carbon figures for the UPFC project is the use of Sulphur Hexafluoride (SF6). Our design includes 6 no. of 66kV or 132kV circuit breakers containing a volume of 10kg (216 l) or 59 kg (1374 l) of SF6 per circuit breaker, or equivalent to 228 to 1277 tonnes CO2, depending on the type of circuit breaker to be used. Typical leak rate is 0.5% a year although a leak rate of 0.1% has been claimed by one manufacturer. SF6-free equivalents are already installed in utilities for gaining experience under actual operational conditions. As such, these figures of additional SF6 have a very small impact when compared with our calculation of carbon saved by displacing other high-carbon sources of generation.		
Attachments			

<table>
<tr><td>Project code</td><td>WPD/EN/NIC/04</td><td>Question Number</td><td>21</td></tr>
<tr><td>Question date</td><td>12/09/17</td><td>Answer date</td><td>14/09/17</td></tr>
<tr><td>Submission section question relates to</td><td colspan="3">N/A</td></tr>
<tr><td>Topic</td><td colspan="3">a) Enviro+consumer bens</td></tr>
<tr><td>Question</td><td colspan="3">Please could you also confirm how much Carbon is embedded within the technological solution?</td></tr>
<tr><td>Notes on question</td><td colspan="3"></td></tr>
<tr><td>Answer</td><td colspan="3">
At this stage in the project we have not received detailed technical proposals from the manufacturers. In the absence of detailed technical data on the main components, there is little benefit in undertaking a detailed evaluation of embedded carbon.

To answer this question we have taken a qualitative view of the project and considered the potential embedded carbon of its main components. We have concluded that, since the mass of the power electronic converters and HV switchgear is relatively small compared with the transformers, the main impact on embedded carbon will be the series and shunt transformers.

The main materials used in transformer construction are:
• Steel (used for tank and magnetic core).
• Copper (used for windings).
• Mineral oil (used for insulation).

The mass of all these materials increases with increasing power rating, thus we have sought to identify assessments of embedded carbon from units of a similar electrical capacity.

As part of their ‘Capacity to Customers’ project, ENW commissioned a Carbon Impact Assessment report from Tyndall Manchester. This work established the following embedded carbon values for 132/11kV distribution transformers:
<table>
<tr><td></td><td colspan="2">Transformer Capacity</td></tr>
<tr><td></td><td>23 MVA</td><td>38MVA</td></tr>
<tr><td>Copper and Steel (tCO2e)</td><td>57.0</td><td>75.8</td></tr>
<tr><td>Oil (tCO2e)</td><td>8.50</td><td>15.6</td></tr>
<tr><td>Transportation (tCO2e)</td><td>0.90</td><td>1.30</td></tr>
<tr><td>Total (tCO2e)</td><td>66.3</td><td>92.7</td></tr>
</table>
</td></tr>
</table>

	Based on these figures, we would make a preliminary estimate that the 25MVA rated shunt transformer for the UPFC would have a total embedded carbon of 72 tCO2e. The sizing of the series transformer will largely be based on the compensation rating (rather than its series rating) and again will be based on 25MVA. However, on the basis of the non-standard configuration, we would propose an estimate of 108 tCO2e for this unit (i.e. 50% more than the shunt unit). This gives a total estimate for the two transformers of 180 tonnes of CO2 equivalent (tCO2e. It should be noted that the carbon-intensive materials (steel, copper, oil) can largely be recycled at end of life. Assuming that the transformers represent 75% of the embedded carbon, we would make a preliminary estimate that the total embedded carbon in the UPFC will be 240 tCO2e. As such, these figures of embedded carbon have a very small impact when compared with our calculation of carbon saved by displacing other high-carbon sources of generation.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**22**
Question date	**12/09/17**	**Answer date**	**14/09/17**
Submission section question relates to	**n/a**		
Topic	**g) Robust methodology/ready to implement**		
Question	**What risks are there to the delivery of the project/ the GB roll-out by issues relating to planning permission? How are you intending to mitigate these/ is there any budget assigned?**		
Notes on question			
Answer	The primary risk is that planning permission is not achieved for the preferred site. The subsequent two main risks are that the process takes longer than scheduled due to additional conditions being imposed, and that additional surveys/stakeholder engagement is required, both delaying the securing of planning consent. All three risks are recorded in the project risk register (R012, R018, R019). The consequence for the project is a potential delay in issuing the Request for Quotation (RFQ) for firm prices from manufacturers, since this will rely on site information to complete the RFQ documentation. A delay is likely to impact installation and subsequent trial activity. For roll-out the main risk at this time is identifying suitable sites for UPFC installation on the network, with sites close to urban areas being at higher risk of not securing permission. The project risk mitigations are: 1. The project site required for the UPFC requires a minor planning application due to being below 1 hectare in size and for operation below 220kV. 2. Two candidate sites have been identified to provide an option if planning refused at the other site. 3. An initial environmental review has been conducted for each candidate site to eliminate any special conditions or likely barriers to securing planning consent. 4. Engagement with planning authorities and stakeholders will start during project mobilisation, with actions and responsibilities identified in the Communication Plan. 5. The Mott MacDonald project team includes a town planning specialist and environmental specialist both with significant experience in preparing planning applications for UK sub-stations to advise and		

	guide on specific local authority requirements and help address likely issues early. There is specific budget under Work Package 3 and Work Package 6 for both WPD and Mott MacDonald to specifically prepare and submit the outline and detailed planning application and engage with planning authorities. We have included contingency against WP3 (Studies) and WP6 (Construction and installation) and in each year to address the potential for delay in securing planning permission and additional work required.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**23**
Question date	**12/09/2017**	**Answer date**	**14/09/2017**
Submission section question relates to	**n/a**		
Topic	**b) Value for money**		
Question	**Please could you confirm whether your agreement with Mott Macdonald/ the provider of the UPFC technology will include any royalty mechanism to ensure GB Consumers receive good value for the trial?**		
Notes on question			
Answer	***Marked as confidential***		
Attachments			

Project code	**WPD/EN/NIC/04**	**Question Number**	**24**
Question date	**12/09/17**	**Answer date**	**14/09/17**
Submission section question relates to	**n/a**		
Topic	**b) Value for money**		
Question	**Please outline how you have ensured the contribution from Mott Macdonald represents good value for money to GB consumers when balanced against the financial benefits on offer if they can market this solution abroad?**		
Notes on question			
Answer	The primary responsibility for marketing the UPFC as a solution will lie with the manufacturer in competition with other manufacturers and other solutions. Mott MacDonald recognise and hope that overseas network operators may continue to need support as they design and implement UPFCs following a further successful trial in the GB. Mott MacDonald will need to continue to win this advisory work through competitive tenders. Framework contracts which we currently have with overseas network operators will typically be re-let and competitively tendered over the timeframe of the HARP project. As such, Mott MacDonald's discounts and contribution in-kind has not, up to this point, been able to factor in a firm view of overseas revenues which it may earn. Mott MacDonald has offered a package of in-kind contributions set out in Appendix 10.8, pages 75-76 of our submission. Part of this package was the discounted rates which we have evidenced on 76 of our submission alongside rates at which we work with other clients. We will within our re-submission add to this package the royalties arrangement set out in our response to question 23 in order to address this point.		
Attachments			

Project code	**WPD/EN/NIC/04**	**Question Number**	**25**
Question date	**12/09/17**	**Answer date**	**14/09/17**
Submission section question relates to	**n/a**		
Topic	**a) Enviro+consumer bens**		
Question	**Within the Expert Panel bilateral you referred to a desktop environmental report for this solution - please provide details on the content of this report and whether it identifies any required interactions with the Environment Agency?**		
Notes on question			
Answer	***Marked as confidential***		

Project code	WPD/EN/NIC/04	Question Number	26
Question date	12/09/17	Answer date	14/09/17
Submission section question relates to	N/A		
Topic	b) value for money		
Question	Please provide a comparison of the benefits offered by the UPFC compared to other similar alternative technologies.		
Notes on question			

Answer

We have provided a comparison of the benefits offered by the UPFC compared to other technologies in the table below:

Function	Capabilities with respect to this function				
	UPFC	Quad Booster	Line/Cable	STATCOM	Commercial (ANM or DSR)
Re-direct power away from constrained sections of a ring	✓(**fast acting and fine degree** of line power flow control)	✓(Control of line power flow)	✓	-	✓(subject to availability of flexible resources)
Reduce "reverse" power being presented to Super-Grid Transformers on the transmission network	✓	✓	✓ (if it sufficiently alters power flows)	-	✓
Re-direct power to avoid overloads in the event of a system fault or outage	✓(**Fast acting** in order of milliseconds)	✓(Slow acting but acceptable)	-	-	✓(subject to availability of flexible resources)
Control both real and reactive power flows	✓(**Independent** control of MW and MVAr)	✓(MVA control only)	-	-	-
Provide reactive power compensation	✓(**Full** MVAr output control)	-	-	✓(Full MVAr output control)	To be trialled within NIC project Power Potential
Damping of voltage fluctuations	✓(**Fast acting** in order of milliseconds)	-	-	✓(Fast acting in order of milliseconds)	To be trialled within NIC project Power Potential
No build solution	-	-	-	-	✓

Project code	**WPD/EN/NIC/04**	**Question Number**	**27**
Question date	**12/09/17**	**Answer date**	**14/09/17**
Submission section question relates to	**n/a**		
Topic	**c) Generates new knowledge**		
Question	**Please also provide written evidence to show there is an appetite amongst other network licensees to use this solution on their network if it is proven to be successful**		
Notes on question			
Answer	Please find attached letters of support from other licencees or trade associations. We will include any further letters of support in our re-submission.		
Attachments	"Letter of support WPD 140917" "WPD HARP project – 14 09 17" "Unified Power Flow Controller"		

Project code	**WPD/EN/NIC/04**	**Question Number**	**28**
Question date	**14/09/17**	**Answer date**	**19/09/17**
Submission section question relates to	**Section 9**		
Topic	**Multiple**		
Question	**The design of the UPFC is an important output from the project. Please provide a justification that the proposed percentage of funding associated with deliverable one is appropriate.**		
Notes on question			
Answer	In the first instance, the NIC Funding Request percentages have been aligned to the level of expenditure for each Project Deliverable. The Total Costs associated with achieving Project Deliverable 1 (Project design and study information for installation & commissioning) is £510.14k, this equates to 3% of the Total Costs for the project. The NIC Funding Request at this stage is £471.99k, this equates to 3.15% of the total NIC Funding Request. The 'Design documentation' deliverable in milestone 1 will consist of the design work achieved in developing the UPFC model for network modelling and defining its specification for suppliers at the tender stage, this is a preliminary design prior to the successful manufacturer carrying out the detailed design. The design of the UPFC will be progressively refined during the tendering process, during the contractor design period (line 140 in our project plan), during detailed design reviews (line 128/129 in our project plan) and later in the trials period. The refined model at the end of the project will be incorporated into the DNO Toolset to be delivered as part of Project Deliverable 10. Project Deliverable 1 does not contain all of the deign activities within the project and these activities will be spread across Deliverables 1,2,3,9 and 10. Project Deliverable 1 will also include the Knowledge Management and Communications Plan which will set out the planned learning throughout the project, how this learning will be captured and disseminated, who the stakeholders/beneficiaries of this learning are and how any unplanned learning will be captured.		
Attachments			

Project code	**WPD/EN/NIC/04**	**Question Number**	**29**
Question date	**14/09/17**	**Answer date**	**19/09/17**
Submission section question relates to	**Section 9**		
Topic	**Multiple**		
Question	**Please explain what is innovative and what new learning is associated with project deliverable two. Please provide a justification that the proposed percentage of funding associated with this deliverable is appropriate.**		
Notes on question			
Answer	The learning and innovation associated with Project Deliverable 2 (Tender process completed with supplier under contract) is detailed in Table 5.1 of the submission document. The evidence for this deliverable is the Tender documentation and Agreed contract. The Tender documentation will include the Tender assessment report and the Tender evaluation report. These reports will include a summary of the manufacturers' anonymised submissions covering their scope of work, equipment specifications, detailed costs and delivery programme. The Agreed contract will provide detail on the agreed performance bonds, milestones and liquidated damages and a summary will be made available to other DNOs excluding any commercially sensitive information. Both the Tender documentation and Agreed contract will contain valuable information and learning from the design and tendering stage of a UPFC project. The UPFC will be a first-of-a-kind project in the UK therefore learning and innovation at this stage of the project will also be realised from the modelling procedures and techniques used to develop the UPFC in the detailed design period, the methodology for site selection and the work associated with outlining the planning application for the UPFC project. The proposed percentage of NIC Funding Request associated with Project Deliverable 2 is 12%. This has been aligned to the expenditure in financial year 2018/19 which equates to £2,042k (12% of Total Costs). These costs include the work associated with the tender assessment, selecting a preferred supplier for contract award and a 10% up front payment to the preferred supplier which we will aim to protect through performance bonds. Based on the work required to achieve the milestone deliverables and the learning to be obtained at this stage of the project we believe 12% of NIC Funding Request for Project Deliverable 2 is appropriate.		

Project code	**WPD/EN/NIC/04**	**Question Number**	**30**
Question date	**14/09/17**	**Answer date**	**19/09/17**
Submission section question relates to	**Section 9**		
Topic	**Multiple**		
Question	**The proposed funding allocated to Project Deliverable 3 appears high given these are business as usual processes that are undertaken when commissioning new equipment and are not directly linked to project learning. Please provide a justification that the proposed percentage of funding associated with this deliverable is appropriate.**		
Notes on question			
Answer	The percentage of NIC Funding Request for Project Deliverable 3 is 60% and has a deadline of 31/08/20. The evidence for Project Deliverable 3 is the Factory Acceptance Test (FAT) report, Site Installation report and Site Acceptance Test (SAT). The proposed percentage of 60% is aligned to the costs associated with Work Packages (WP) WP5 (Procurement) and WP6 (Construction & Installation) incurred in financial year 2019/20, this equates £10,860k or 64% of the Total Costs. These costs include the manufacturing and shipping fees for the UPFC, site preparation costs and third party civil and structural works. It does not include the commissioning costs that will be incurred in financial year 2020/21 to achieve the SAT report. The Total Costs to achieve Project Deliverable 3 exceed the NIC Funding Request at this stage of the project, as such this shows Mott MacDonald and WPD taking on a level of risk and commitment to the project. In order to reach the FAT and SAT reports, we will have created and set the methodologies for the testing procedures of the UPFC, the performance requirements to be met and the verification of the devices performance. The site installation report will include the manufacturers design review reports, the detailed planning application and site survey reports, all of which will provide substantial learning for the manufacturing, construction and installation of a UPFC. A detailed trials strategy report and trials instruction document for the UPFC will be developed during this phase of the project. These have not been included as evidence for Project Deliverable 3 however we believe this is another vital part of learning on the project and propose to include both documents as evidence for Project Deliverable 3 in the re-submission.		

Project code	**WPD/EN/NIC/04**	**Question Number**	**31**
Question date	**14/09/17**	**Answer date**	**19/09/17**
Submission section question relates to	**Section 9**		
Topic	**Multiple**		
Question	**Project deliverables 4-10 appear to be associated with the outputs of the project and the learning that will be shared. Please provide a justification that the proposed percentage of funding associated with these deliverables is appropriate.**		
Notes on question			
Answer	The total percentage of NIC Funding Request for Project Deliverables 4 through to 10 is 25%. Prior to commissioning, the project expenditure exceeds the level of NIC Funding Request as stated in our response to Question 30. The project expenditure after commissioning and prior to Work Package 9 (Trial execution) is 94.3% of the Total Costs (£15,995k) with only 77% of NIC Funding Request received (£11,519.2k). This was intentional and provides an incentive to Mott MacDonald and WPD to deliver the project in full. The costs associated with achieving Project Deliverables 4,5,6,7,9 and 10 equate to 5.7% of the Total Costs against 23% of NIC Funding Request remaining therefore the proposed percentages against the Deliverables is more aligned to the amount of learning to be obtained rather than the associated expenditure. At this stage of the project, Deliverable 8 with 2% of NIC Funding Request is already achieved. The NIC Funding request for Project Deliverable 4 (Trials Report 1) is 5% with Trials Report 2, 3 and 4 (Deliverables 5, 6 and 7) requesting 4%. The Trials Reports will provide valuable learning for the deployment of the UPFC, its setup and configuration and analysis of its performance against set objectives. This equates to a total NIC Funding Request of 17% for the Trails Reports. The remaining percentage of NIC Funding Request is 8% and has been for distributed across Project Deliverables 8, 9 and 10 in proportion with the learning outcomes of each milestone. The Replicability report (Project Deliverable 8) requests 2%, the dynamic model and report of findings in response to network issues/voltage disturbances (Project Deliverable 9)		

	requests 3% and the DNO Toolset including demonstration and summary report (Project Deliverable 10) requests 3%.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**32**
Question date	**21/09/2017**	**Answer date**	**25/09/2017**
Submission section question relates to	**N/A**		
Topic	**b) Value for money**		
Question	**Please explain in more detail (with reasons) how you think the royalty arrangements proposed comply with Chapter 10 of the Governance Document.**		
Notes on question			
Answer	Our response on royalties concerned both the manufacturer and Mott MacDonald. **Manufacturer** We did not make a commitment to a royalties arrangement as a pre-condition within our Request for Information (RFI) issued to manufacturers or test their appetite around royalties. We did ensure that respondees stated that they had read and agreed to comply with the intellectual property provisions of the NIC. We will test at the tender stage the manufacturers' proposals to protect GB customers both at delivery and around future revenues and this may include an offer from manufacturers in the form of a royalties arrangement. **Mott MacDonald** For clarity, Mott MacDonald is a person-hours driven business; whilst we occasionally sell access to IT platforms which we have developed, there are otherwise no products which we sell. As such, there are no Commercial Products. The Background IPR consists, among other items, of a simulation model which we developed. We have made clear on page 34 of our submission that we will make this available as part of our dissemination to other GB DNOs. This will be free of charge and therefore we count the engineering time associated with this on page 75 as part of Mott MacDonald's financial contribution to the project. The Foreground IPR and the Relevant Foreground IPR will be contained in the form of written reports, specifications, calculations or simulations,		

	commercial pricing information, schedule information (i.e. how long things took to build), and in the form of the know-how of Mott MacDonald staff. We currently envisage with Western Power Distribution to carry out public dissemination and which goes beyond the minimum requirements in clause 9.13 of the NIC Governance Document. Relevant Foreground IPR will in most cases be available beyond other Network Licensees, and available to the supply chain, other manufacturers, other consultants and overseas DNOs. The only effective alternative mechanism would be to run smaller dissemination events only open to the Network Licensees and to attempt to charge other entities for copies of reports and documents. Judging from other precedents (such as Energy Networks Association (ENA) documents and the Strategic Technology Programme (STP) which ran for a number of years under the Innovation Funding Incentive) the price at which these can be sold is relatively low, of the order of tens or low hundreds of pounds. Our royalties mechanism is intended to therefore provide a return for GB customers on the know-how of Mott MacDonald staff, since this is likely to the determining factor by which we earn overseas revenues on other UPFC projects. That know-how will only reasonably be exploited on dedicated UPFC projects rather than wide-ranging optioneering or feasibility studies considering many options. We have made a number of reasonable exclusions or caveats to protect against, for example, not being paid by the client and fluctuations in exchange rates. If these are not enacted, we realistically have to price for these items within our price to the client at the outset, reducing the likelihood of winning the work at all and generating any revenues for GB customers. As such our proposal complies with Section 10 of the NIC Governance document as follows: 1. Mott MacDonald will pay royalties to WPD on receipt of the final payment from the client on a UPFC project which meets the criteria set out in question 23. This will occur throughout the year. 2. WPD will at the end of the year collate the royalties which it has received from Mott MacDonald. 3. This equates to RRk,y in paragraph 10.6 where y refers to WPD and k to the current year. 4. WPD will deduct Directly Attributable costs, if applicable, and report the net value to the Authority. 5. NLCCk, NLECk, and RAk will be the values from the Licence Direction for HARP, if awarded. 6. The Authority will carry out the calculation in paragraph 10.6 in order to derive APk,y and instruct WPD to return this amount to consumers by means of the NIC Funding Direction.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**33**
Question date	**21/09/2017**	**Answer date**	**25/09/2017**
Submission section question relates to	**Appendices**		
Topic	**a) Enviro+consumer bens**		
Question	**Please comment on the carbon benefits of capacity released with current business-as-usual approaches and their comparison with those of the proposed method (440,000 tCO2e by 2040).** **Please clarify which scenario from FES was used to derive the estimate of carbon benefits.**		
Notes on question			
Answer	These figures have been calculated assuming that the capacity created by the UPFC is taken up by commercial solar PV (a zero carbon source of generation) and displaces other high-carbon sources of generation. We confirmed in our answer to question 20 that carbon, and this way of offsetting carbon used in power generation, was the only factor in our carbon benefits calculation. We clarified in our response to question 15 that business-as-usual reinforcement of lines and/or cables creates more capacity; but can only be purchased in large quantities, some of which may in fact be stranded capacity. Because we had no firm assumption that we could provide for the proportion of capacity which might be unused or "stranded", we did not discount any of the capacity created by conventional reinforcement. In the same way, if all of the capacity which it creates is indeed used by new renewable generation and not stranded, conventional reinforcement can save more carbon than the 440,000 tCO2e by 2040 calculated for our Method. It is important context that if renewables are put off from constructing due to high grid connection costs, then no carbon is offset or saved at all. This has already been the experience for some periods of time, on some parts of the GB distribution network. This is the driving motivation to find alternative means to release capacity on the network with devices such as the UFPC.		

	We used the "Slow Progression" scenario from the Future Energy Scenarios (FES) as the source of grid carbon intensitity which could be offset by renewables.
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**34**
Question date	**05/10/2017**	**Answer date**	**10/10/2017**
Submission section question relates to	**n/a**		
Topic	**Multiple**		
Question	**In various responses to the Q&A the use of quadrature boosters (QBs) as the counterfactual have been explored, either alone or in combination with other devices depending on the constraint being relieved. Together with the clarification that QBs are available at 132kV and based on relieving (real) constraints currently considered present on the 132kV and 66kV systems (please justify whether the "fast" response of UPFCs are required), do your original CBA and NPV calculations still hold? If not can you please revise your estimates.**		
Notes on question			
Answer	We will distinguish between responses which are required: 1. Throughout the day, and from day-to-day, but not faster than from one half hour to the next 2. Over the timescale of a few minutes up to 30 minutes 3. Over the timescale of sub-second through to several seconds. The first of these is typically experienced during a "normal running" situation where the system is intact but system requirements may be changing due to variations in renewable output, or due to changes in power factor throughout the day leading to different requirements for reactive power. This was illustrated by Table 2.1 on page 12 of our submission. The second of these is typically experienced following a fault on the distribution network and can be utilised to relieve post-fault overloading of circuits. The third of these is typically experienced following a fault on the transmission network (including outages of large transmission-connected generators) and/or distribution network which has caused a temporary voltage disturbance and is used to mitigate this disturbance. We will compare the functions of the Unified Power Flow Controller (UPFC) and a quadrature booster in each case. **Variations throughout the day and from day-to-day** There is little difference between the capabilities of a quadrature booster and a UPFC to adjust power flow on a 132kV or 66kV ring on these timescales.		

	Whilst the quadrature booster is based upon a mechanical tap changer which may take several minutes to make multiple taps, it is able to act sufficiently fast to maintain overhead lines and other network equipment within their ratings when the system is intact and continues to have redundancy. **Over the timescales of a few minutes** Each of our case studies discussed in the Full Submission at Evesham and at Walpole concerned rings on the 132kV or 66kV network formed of overhead lines (at Walpole) or both overhead lines and cable (at Evesham). The convention amongst the UK Distribution Network Operators (DNOs) is that distributed generation is able to be accommodated to the full (duplicate) capacity of the circuit. In the case of rings, this means that generation can be added to the extent that both directions around the ring are fully loaded. In the case of demand, each side of the ring is only loaded to half of its capacity to ensure that demand can be fed from the other side of the ring in the event of a fault. As such, the capacity of the overhead lines forming the ring or parts of the ring directly impact: 1. The amount of distributed generation that would potentially have to be removed (tripped) following a fault on the ring; 2. The amount of demand which can be supported by the ring. Overhead lines when fully loaded heat up over a timeframe of tens of minutes, during which they expand and sag, meaning that they are closer to the ground. For the rare occasions on which a fault occurs, a level of risk that the weather is also adverse and preventing the line from cooling, and that a sufficiently tall vehicle, or a person carrying implements, is passing underneath and could come close enough to the (now lower hanging) line to cause a flash-over is agreed in the industry to be acceptable. Western Power Distribution is thus able to operate 132kV and 66kV overhead lines with a higher capacity or "rating" following a fault. In the case of a typical construction (175mm^2 Lynx ACSR) operating in the summer, this rating is 7% higher than the intact rating and is 465A. Western Power Distribution stipulate the additional load on the line should be reduced "as soon as practicable" and in any circumstance within 24hours. This is documented within the Company Directive "Standard Technique SD8A/2: Relating to revision of overhead line ratings", and goes some way to minimising the amount of generation which would have to be removed, and increasing the amount of demand which can be supported. National Grid (the transmission operator) go one step further and point out that if the line is not running at full capacity prior to the fault, it is therefore not operating at its full design temperature. It will therefore take longer before the heating effect has caused the line to sag. This is documented in Technical Guidance Note TGN(E) 26 "Current ratings for overhead lines". To give an example from this document, the same conductor (1x175mm^2 Lynx operating at 132kV) line will have a post-fault continuous rating which of 465A, identical to the WPD calculation. Loads of up to 625A can be place upon the line if the line was running at only 84% of its original capacity

	before the fault, and if the load can be certain to be removed within 3 mins. Loads of up to 495A can be placed upon the line if the load can only be certain to be removed within 10 mins. Loads up to 470A can be placed upon the line if the load can only be certain to be removed within 20 mins. A quadrature booster, even with automated control, cannot guarantee to operate within 3 minutes, since the number of taps required will depend on the tap setting in which the device finds itself when the fault occurs. As such it is likely to be limited to a 10 minute rating. A quadrature booster without automated control and relying on manual control via SCADA from the control room could only be expected to operate within 20 mins. A UPFC could be guaranteed to operate within 3mins. It therefore is able to support greater amounts of renewable generation and demand, knowing that a fast-acting method is available to reduced load on overhead lines following a fault and ensuring that the line can be brought back within its post-fault continuous rating. In the example above, the difference between a 3 minute rating of 625A and a 10 minute rating of 495A is equivalent to 30MVA of generation or demand which can be supported. The cable sections within a ring will have a slower thermal time constant and as such are unlikely to benefit in the same way. The exception is where cables have been deliberately designed to run closer to their maximum load during normal operation than the associated overhead lines on the ring, in which case their time to reach critical temperature may also need to be considered. **Variations over the timescale of sub-second through to several seconds** National Grid in their 2017 System Operability Framework (Section 4.5.3) describe the action which we intend for the UPFC to provide: "The retained voltage during a fault affects the ability of a generator to ride through the disturbance. It is supported by fast fault current injection (FFCI), reactive current which arrests the voltage dip during a disturbance. This helps to reduce the risk of generation failing to ride through a fault and also facilitates protection operation. Currently, synchronous generators are the predominant source of fast fault current injection due to their characteristic immediate fault current injection." The SOF also identifies that generation technologies dependent on PLL controllers, such as wind and PV, are more vulnerable to voltage disturbance than conventional synchronous machines. With less conventional plant to control disturbances and increasing reliance on embedded wind/PV, the ability to manage transient events to avoid cascade tripping will be critical. Because a quadrature booster is controlled mechanically, and because its controllable element is in series rather than parallel, it is not able to provide the fast fault current injection described by National Grid over the timescale of sub-second through to several seconds. Only the addition of a STATCOM would achieve this function.

	It is interesting to note that several academic papers ([1][2]) show that a UPFC is able to provide a higher contribution to voltage stability than a STATCOM by reducing the amplitude of voltage variations faster or by increasing the voltage stability margin. The HARP project will allow this effect to be investigated further and practically demonstrated. **Conclusion** Our NPV calculations were based on case studies at Evesham and Walpole and which benefit not only from managing power flow variations throughout the day and from day-to-day but also from managing variations over several minutes post-fault. Since the UPFC provides better performance in the latter case, and can provide value-adding services equivalent if not better than a STATCOM, we continue to believe that a quadrature booster is not a reasonable comparison. We have selected conventional reinforcement as the alternative which creates sufficient capacity as to wholly remove the concerns about capacity over the timescales of a few minutes following a fault, and to wholly remove concerns about capacity in the intact state. We have not at this stage included in our NPV calculation, or relied upon, income from providing fast fault current injection to National Grid when making our business case but will seek to demonstrate the technical capability to deliver this service. [1] "Effects of STATCOM, TCSC, SSSC and UPFC on static voltage stability", M.A. Kamarposhti & H. Lesani, Electrical Engineering, Volume 93, pages 33-42, 2011 [2] "Unified Power Flow Controller in Alleviation of Voltage Stability Problem", N. Dizdarević, Doctoral Thesis, University of Zagreb, 2001
Attachments	

Project code	**WPD/EN/NIC/04**	**Question Number**	**35**
Question date	**05/10/2017**	**Answer date**	**10/10/2017**
Submission section question relates to	**N/A**		
Topic	**Multiple**		
Question	**During the 2nd Bi-lateral Meeting you presented a table (page 6 of your notes) showing the networks in the WPD licence areas where UPFCs may be the best solution to relieve network constraints. Can you please clarify how many UPFCs per network (GSP) are required. For example, in the Cardiff East – Aberthaw network only one may be needed but the table suggests two.**		
Notes on question			
Answer	In the bid we identified several areas of Grid Supply Point (GSP) networks within WPD's four licence areas that were stressed and in which a UPFC could be used. Some of these GSP networks run in parallel therefore in some cases only a single UPFC can be used to alleviate on the interconnected network if the constraint being managed is related to the power flow between the GSPs. In some cases there are meshed networks in parallel running GSP groups where they do not straddle the GSPs; in this case multiple UPFCs would be needed, although in the cases we have identified this is not the case. Please see below for the number of UPFCs required in the GSP networks we identified in the bid. **West Midlands (total of 2)** Feckenham – 1 UPFC Shrewsbury – 1 UPFC **East Midlands (total of 1)** Walpole – 1 UPFC **South Wales (total of 2)** Pembroke – 1 UPFC Swansea North – 1 UPFC **South West (total of 4)** Indian Queens/Alverdicott group – 1 UPFC Bridgewater (runs in parallel with Taunton) – 1 UPFC Abham/Landulph/Exeter group – 2 UPFCs We have therefore revised 11 sites in WPD down to 9.		

	We do not believe that this change is material and, as such, we continue to see a roll-out potential of 23 sites.
Attachments	

Intervention	After Diversity Peak reduction (kW)	Gross Peak Reduction (kW)	Assumed running hours/year	kWh/year reduction	£/kWh benefit (retail electricity price if we are considering the reduction on customer energy bills)	£/ year benefit (on customer energy bills)	£/kWh benefit (40% of retail electricity price [i.e. the cost of generating electricity] if we are considering the avoided cost of generation)	£/ year benefit (avoided cost of generation)	Life of measure years (appliance life)	£ benefit over life of measure (on customer energy bills)	£ benefit over life of measure (avoided cost of generaiton)	Cost of measure (Appliance cost)(£)	£/year saving in distribution UoS costs	£/year savings in DNO's network reinforcement costs (from deployment of EE measure)	£/year savings in DNO's network reinforcement costs (over lifetime of EE measure)
Appliances	0.14	0.212	627	133	£ 0.14	£ 19.11	£ 0.057	£ 7.64	10	£ 191.12	£ 76.45	£ 345.00	£ 1.91	£ 1,858.00	£ 186.00
Heating	0.385	0.453	542	983	£ 0.14	£ 141.26	£ 0.057	£ 56.50	20	£ 2,825.14	£ 1,130.06	£ 750.00	£ 14.13	£ 5,110.00	£ 255.00
Lighting	0.27	0.54	185	100	£ 0.14	£ 14.37	£ 0.057	£ 5.75	30	£ 431.10	£ 172.44	£ 50.00	£ 1.44	£ 3,583.00	£ 119.00
Behaviour	0.072	0.085	N/A	50	£ 0.14	£ 7.19	£ 0.057	£ 2.87	5	£ 35.93	£ 14.37	£ 70.00	£ 0.72	£ 956.00	£ 191.00
Solar PV	18.75	37.5	425	15938	£ 0.14	£ 2,290.22	£ 0.057	£ 916.09	30	£ -	£ 27,482.63	£ 23,756.25	£ 229.02	£ 610,000.00	£ 20,333.33
Combined Measures	0.357	0.51	549	280	£ 0.14	£ 40.24	£ 0.057	£ 16.09	10	£ 402.36	£ 160.94	£ 425.00	£ 4.02	£ 4,738.00	£ 474.00