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RESPOND

Cost Benefit Analysis and Buy Order of Respond Fault Mitigation Solutions – Final Report

18 January 2018

1 RESPOND PROJECT SUMMARY

1.1 Project objective and background

The Respond project is seeking to demonstrate that a network's fault level can be estimated in near real time, and in responding to that estimation a series of innovative technical and commercial techniques can be initiated to reduce the fault level without the need for expensive and time consuming asset replacement. As this approach could maximise the use of existing assets and minimise the need for capital investment, Respond has the potential to realise significant cost savings to customers and improve the connection of generation to the network Fault Level Assessment Tool.

The WPD FlexDGrid project looked at using enhanced data to improve the accuracy of the calculation of system fault level together with real time fault level monitoring to allow the network to be actively managed. Fault level mitigation was undertaken by installing pre-saturated core or resistive superconducting fault current limiters at a number of substation sites.

One of the Respond project's success criteria is to produce cost benefit analysis figures based on actual installed costs and derive a buy order of Respond, FlexDGrid and traditional reinforcement fault level mitigation solutions.

The Respond project is trialling three fault level mitigation techniques to manage fault current on the distribution network namely:

- **Adaptive Protection** is also known as sequential tripping and is retrofitted to existing substations to re-sequence the operation of circuit breakers
- **Fault Current Limiting (FCL) service** is a commercial solution whereby industrial, commercial and generation customers agree to disconnect their equipment to provide a fault level management service
- **I_S-limiters** are devices which use electronics to detect the rate of rise in fault current to calculate the peak value and if it is higher than a predetermined level the device operates in less than one millisecond.

The WPD FlexDGrid project is also investigating system fault levels and fault level mitigation techniques on an existing network with fault level issues as follows:

- **Enhanced fault level assessment** uses enhanced data to improve the accuracy of the calculation system fault level while the second technique
- **Real time fault level management** monitors system fault level to allow control engineers to actively manage the network
- **Fault level mitigation technologies** use fault current limiters to restrict the passage of fault current.

2 BUY ORDER

Adaptive Protection and I_S-limiters have been installed as part of the Respond trial and the costs of the installation are summarised in Figure 1. The operating and maintenance costs for I_S-limiters have been based upon the experience in the trial to date whereas in the absence of any other data those for the procurement of a Fault Current Limiting service are those used in the project submission document.

The capital cost of installing fault current limiters for the FlexDGrid project together with the ongoing operational costs were obtained from WPD and they are also summarised in Figure 1.

Figure 1: Summary of costs

Equipment	Capital Cost	Additional O&M costs	Advantages compared to traditional reinforcement	Disadvantages compared to traditional reinforcement
Traditional reinforcement (replace HV cables at primary substation)	£1,115k	None	N/A	N/A
Traditional reinforcement (change primary HV switchgear)	£442k	None	N/A	N/A
Traditional reinforcement (WPD primary substation)	£9,700	None	N/A	N/A
Adaptive Protection HV	£43k	None	• Lower capital cost • Reduced design and installation times	• Reduced network security • Operational failure could cause existing equipment to exceed rating
Fault Current Limiting service	£10k	£30k-£540k	• Low capital cost	• Ongoing annual payments required • Service could easily be terminated
I_S-limiter (protecting primary switchgear)	£402k	£12k pa refurbishment of inserts	• Reduced capital cost • Ability to relocate I_S-limiter to other sites	• Additional space required • Additional civil costs • Ongoing operating costs
I_S-limiter (protecting HV cables)	£402k	£12k pa refurbishment of inserts	• Reduced capital cost • Ability to relocate I_S-limiter to other sites	• Additional space required • Additional civil costs • Ongoing operating costs
Pre-saturated core FCL (protecting HV cables)	£1,906k	£6k pa electricity for DC bias	• Lower capital cost • Reduced design and installation times	• Additional space required • Additional civil costs • Ongoing operating costs
Resistive superconducting FCL (protecting HV cables)	£1,730k	£36k pa electricity for cooling	• Lower capital cost • Reduced design and installation times	• Additional space required • Additional civil costs • Ongoing operating costs
Network modelling (WPD method alpha)	Time based	Time based updating	• Low costs • Reduced design and installation times	None

3 COST BENEFIT ANALYSIS

There are a number of considerations to be taken into account when determining a 'buy order' for fault level mitigation techniques.

- The capital cost of the fault current limiting solution.
    - For Adaptive Protection this will include the costs of remote terminal units for communications, replacement relays and associated installation costs
    - For an I_S-limiter the costs will include the purchase of the unit together with the housing, civil works plus HV switchgear and cabling to connect to the existing network
    - For a pre-saturated fault current limiter the civil costs and ongoing electricity costs to provide the DC bias are included
    - For a resistive superconducting fault current limiter the costs include civils and the costs of electricity for cooling
- Any ongoing costs for the solution such as equipment maintenance, replacement parts and availability payments to customers
- The length of time remaining until the programmed replacement date of the asset with the fault level restriction when it would be replaced with a modern unit having sufficient capability
- The costs of removal of the fault level mitigation solution following the eventual replacement of the asset causing the fault level restriction.

Consequently there isn't a 'one size fits all' solution and in order to determine the buy order for a particular scenario it is necessary to undertake a cost benefit analysis (CBA).

For the purpose of this document a number of options have been considered using the CBA model that was developed for the RIIO-ED1 submission and excerpts from these are shown in Appendix A.

APPENDIX A: EXCERPTS FROM CBA MODELS

Summary sheet showing the cost benefit of installing Adaptive Protection to defer changing primary HV switchboard

Purpose of CBA: describe the stated aim of the investment decision

To investigate the cost benefits of installing adaptive protection to defer changing the HV switchgear at a primary substation

If investment is to replace an existing asset / asset class, please state the condition of the asset / asset class (HI / CI etc.)

List below all options considered to meet the stated aim

Options considered	Comment
"do minimum" option	Change primary switchboard in year1
Adaptive protection 2 years	Change primary switchboard in year 2
Adaptive protection 3 years	Change primary switchboard in year 3
Adaptive protection 4 years	Change primary switchboard in year 4
Adaptive protection 5 years	Change primary switchboard in year 5

List below the short list of those options which have been costed within this CBA workbook

Option no.	Options considered	Decision	Comment	Spend area (from Table C1) (relevant only to adopted option)	NPVs based on payback periods				
					16 years	24 years	32 years	45 years	DNO view
1	Adaptive protection 2 year		No cost benefit		-£4.38	-£12.82	-£18.61	-£24.84	
2	Adaptive protection 3 year				£21.00	£10.85	£3.72	-£4.29	
3	Adaptive protection 4 year				£45.76	£33.90	£25.43	£15.64	
4	Adaptive protection 5 year				£69.92	£56.36	£46.54	£34.98	
5									

Summary sheet showing the cost benefit of installing an I_S-limiter to defer replacing the HV cables feeding from a primary substation

Purpose of CBA: describe the stated aim of the investment decision

To investigate the cost benefits of installing an Is-limiter to defer replacing HV cables feeding from a primary substation

If investment is to replace an existing asset / asset class, please state the condition of the asset / asset class (HI / CI etc.)

List below all options considered to meet the stated aim

Options considered	Comment
Replace HV Cables	Traditional reinforcement solution
Install Is-Limter to defer reinforcement by 5 ye	Includes installation and removal plus costs of replacing/refurbishing inserts
Install Is-Limter to defer reinforcement by 10 y	Includes installation and removal plus costs of replacing/refurbishing inserts
Install Is-Limter to defer reinforcement by 20 y	Includes installation and removal plus costs of replacing/refurbishing inserts
Install Is-Limter to defer reinforcement by 30 y	Includes installation and removal plus costs of replacing/refurbishing inserts
Install Is-Limter to defer reinforcement by 40 y	Includes installation and removal plus costs of replacing/refurbishing inserts

List below the short list of those options which have been costed within this CBA workbook

Option no.	Options considered	Decision	Comment	Spend area (from Table C1) (relevant only to adopted option)	NPVs based on payback periods				
					2 years	5 years	10 years	20 years	DNO view
1	Is-limiter 5 year		Cable replacement should be deferred longervthan 5 years to achieve a cost benefit		£147.49	£79.83	-£18.12	-£18.12	
2	Is-limiter 10 year		Positive benefit		£147.49	£235.77	£210.33	£19.62	
3	Is-Limiter 20 year		Positive benefit		£147.49	£235.77	£345.38	£366.81	
4	Is-Limiter 30 year		Positive benefit		£147.49	£235.77	£345.38	£462.56	
5	Is-limiter 40 year		Positive benefit		£147.49	£235.77	£345.38	£462.56	

Summary sheet showing the cost benefit of installing an I_S-limiter to defer replacing the HV cables feeding from a primary substation

Purpose of CBA: describe the stated aim of the investment decision

To investigate the cost benefits of installing an Is-limiter to defer replacing the HV switchboard at a primary substation

If investment is to replace an existing asset / asset class, please state the condition of the asset / asset class (HI / CI etc.)

List below all options considered to meet the stated aim

Options considered	Comment
Replace primary switchboard	Traditional reinforcement solution
Install Is-Limter to defer reinforcement by 5 ye	Includes installation and removal plus costs of replacing/refurbishing inserts
Install Is-Limter to defer reinforcement by 10 y	Includes installation and removal plus costs of replacing/refurbishing inserts
Install Is-Limter to defer reinforcement by 20 y	Includes installation and removal plus costs of replacing/refurbishing inserts
Install Is-Limter to defer reinforcement by 30 y	Includes installation and removal plus costs of replacing/refurbishing inserts
Install Is-Limter to defer reinforcement by 40 y	Includes installation and removal plus costs of replacing/refurbishing inserts

List below the short list of those options which have been costed within this CBA workbook

Option no.	Options considered	Decision	Comment	Spend area (from Table C1) (relevant only to adopted option)	NPVs based on payback periods				
					2 years	5 years	10 years	20 years	DNO view
1	Is-limiter 5 year		No benefit		£4.35	-£60.83	-£150.66	-£150.66	
2	Is-limiter 10 year		No benefit		£4.35	£0.02	-£71.93	-£234.31	
3	Is-Limiter 20 year		No benefit		£4.35	£0.02	-£16.93	-£112.11	
4	Is-Limiter 30 year		No benefit		£4.35	£0.02	-£16.93	-£73.12	
5	Is-limiter 40 year		No benefit		£4.35	£0.02	-£16.93	-£73.12	