SP Energy Networks 2015–2023 Business Plan

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Annex

Black Start Capability

SP Energy Networks

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SP ENERGY NETWORKS

Black Start Capability

Ensuring Network Resilience

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1. Scope

This annex details our plans for ensuring that our network is black start resilient through the ED1 period.

2. Table of linkages

Document	Chapter / Section
SP Energy Networks Business Plan 2015-2023	Chapter 5 – Outputs and Incentives c. Reliability and Availability
SP Energy Networks Business Plan 2015-2023	Chapter C6 – Expenditure b. Asset Stewardship e. Non Load Related Investment
SP Energy Networks Business Plan 2015-2023 Annexes	Annex C6 – 132kV Substation Plant Strategy – SPEN
SP Energy Networks Business Plan 2015-2023 Annexes	Annex C6 – 33kV Substation Plant Strategy – SPEN
SP Energy Networks Business Plan 2015-2023 Annexes	Annex C6 – Expenditure Supplementary Annex – SPEN
SP Energy Networks Business Plan 2015-2023 Annexes	Annex C6-BT21CN Strategy-SPEN
SP Energy Networks Business Plan 2015-2023 Annexes	Annex C6 – SP Manweb Company Specific Factors – SPEN Section B3

3. Introduction

The GB Power Network is normally operated in a state of dynamic equilibrium between connected load and available generation. In the rare event that this equilibrium is disturbed then the result could result in total or widespread loss of the power network. The shutdown of the entire power network is identified as a risk on the National Risk Register.

Recovery from this situation is termed ‘Black Start’.

Traditionally the timescale required to implement a Black Start recovery has been considered to be 18 to 24 hours however the Government and the UK Electricity Industry now consider that full restoration of the network to its normal operating state could take up to 72 hours. It is therefore a key requirement that all equipment on which the recovery process relies is made resilient for such a period, with the main considerations being remote control facilities, voice and data communications, and protection systems.

In 2008, OFGEM and DECC asked the Energy Emergencies Executive Committee (E3C) to look into substation resilience in relation to a Black Start event. The Electricity Task Group (ETG) of the E3C submitted their final report to OFGEM in July 2010. The report recommended that all Grid and Primary substations are equipped with batteries capable of providing SCADA control and tripping functionality for at least 72 hours following a Black Start event. OFGEM accepted this report and has asked the DNOs to plan to implement this requirement.

This step change increase in recovery timescales requires an upgrade to the resilience of the auxiliary systems that support the primary and secondary equipment at our substations, as the majority of our substations are resilient for a maximum of 18-24 hours. It is also essential that SCADA systems and communications are also resilient as otherwise the ability to control a substation remotely from our control centres will be impaired or lost, requiring visits to check systems and undertake manual switching with the subsequent delay to the Black Start recovery process.

In order to accommodate the required level of Black Start resilience, we will invest to upgrade the battery systems or install back-up generation at our major sub stations to deliver meet this resilience requirement during ED1 at our Grid and Primary substations in SPM and Primary substations in SPD.

The expenditure to deliver our RIIO ED1 plan, and ensure Network Resilience through a Black Start event is:

Black start resilience Expenditure in RIIO-ED1 (£m)			
	SPD	**SPM**	**SPEN**
RIIO-ED1 Annual Average	0.2	0.9	1.1
RIIO-ED1 Total (8 years)	**1.6**	**7.5**	**9.0**

Black Start expenditure in the SPD area is less than SPM, due to the 132kV network in Scotland being covered by the SP Transmission (SPT) licence.

The additional volumes required in SPM over SPD is a reflection of the larger number of substations on the SPM interconnected network as identified and discussed in more detail in Annex C6 – SP Manweb Company Specific Factors – SPEN (Section B3)

4. Background

4.1. What is Black Start & how is it implemented?

As detailed above Black Start is the term given to the recovery phase from a total or widespread loss of the GB power network, caused by either a shortage in generation available to meet demand, technical failure, or potentially due to severe weather situations, or any combination of these conditions.

There are comprehensive operational and automatic protection arrangements in place across the GB power industry specifically designed to minimise the opportunity of such a condition occurring, ranging from commercial arrangements in the generation market, operating reserve above forecasted maximum demand, demand reduction, and automatic under frequency controls.

Ultimately if all these preventative arrangements were to fail then all, or a significant proportion of the GB power network will be lost, and the network is likely to become fragmented in the process.

Comprehensive plans are in place to initiate and progress restoration or ‘restarting’ of the power network which require the co-operation of generators, transmission operators and network operators.

In essence the process requires the starting up of designated (contracted) Black Start Power Stations which have a self start capability. These power stations will require their generators to be run up against predefined load blocks provided by DNO’s to achieve a position of stability with the subsequent creation of a local Power Island. Local Power islands are then joined together in order to re-energise the entire national grid, and provide opportunities for non Black Start power stations to start up and synchronise onto the network, extending the opportunity to recover additional load and customers. It is anticipated t it could take up to 72 hours before the full transmission and distribution networks are restored.

5. Technical requirements

Implementing a Black Start recovery is likely to be the severest challenge placed on the GB power Industry.

In the first instance it will be desirable if not essential, to attempt the majority of, if not all operations in the Black Start recovery plans via remote means from Control Centres across the GB power Industry.

It is also essential that in the Black Start recovery process provision is made to re-energise the electricity network in such a manner as to safeguard the integrity of the power network, and prevent danger to staff, the general public and property.

To support these requirements, over the likely timescales to achieve them, it is necessary to ensure that we have robust plans and resilient systems in place to support operational staff and the primary equipment on the power network, covering control centres, SCADA/voice communication, and substation equipment.

The SPEN Black Start resilience strategy based on compliance with the ENA Engineering Recommendation G91[1] summarised in the sections below and collated in tabular form in Appendix A.

5.1. Substation Resilience Requirements

It is essential that provision is made to safely re-energise the electricity network following a black start. In particular the protection and tripping systems at substations, which disconnect supplies in the event of a local network fault, need to be functional upon re-energisation.

Over the past decade or more DNO's including SPEN have replaced large numbers of low burden electro-mechanical protection relays with more sophisticated equipment to enhance network performance. However these replacement relays are typically micro-processor based with increased power consumption than the traditional electro-mechanical units and therefore place a higher continuous demand on the Substation DC battery supply, therefore once mains (external) power supplies are lost to the substation, the relays will drain the tripping /protection battery more quickly than earlier scheme designs.

Failure of the battery systems will place risks and delays to the overall Black Start process.

Within SPEN a portfolio of solutions has been developed to equip substation auxiliary AC and DC supply systems with a minimum resilience of 72 hours. It is intended to deploy one or more of these solutions to the required Transmission and Distribution substation estate during RIIO T1 and RIIO ED1 price review periods. This portfolio of solutions follows the guidance and Substation Resilience Decision Chart included in Engineering Recommendations G91 (issue 1 2012).

Generators

Local self contained generators, with appropriate housing and wiring into LVAC boards/panels will be located at Transmission substations in Scotland and Grid substations in England & Wales where there is an LVAC dependency for motive power to Circuit Breakers (and where applicable associated motorised disconnector equipment) The generator will be sized sufficiently to meet this demand, in addition it will cater for DC battery charging system(s) and any air conditioning equipment for communication equipment hosted at the site. The generator will be sized to meet a run time in excess of 72 hrs at site load conditions.

[1] ENA Engineering Recommendation G91 Issue 1 2012 – Substation Black Start Resilience

Battery and Charger enhancement

Grid substations without an AC motive power dependency for circuit breakers and associated disconnector's and all Primary Substations wherever possible will be fitted with an enhanced battery and charger unit. The battery will be sized for 72 hours resilience based on standing substation DC load. The housing of the new battery and charger unit may require site work to enable the larger unit to be accommodated; in some case this may require civil works or installation of suitable external cabinets

Consideration will be given to provide battery load disconnection facility with any new chargers as part of the overall resilience arrangement.

Battery Load Disconnection

At Primary substations where physical accommodation does not allow for accommodation of replacement battery and charger units, or where the current standing load provides for marginal resilience in the order of 48 hours, a battery load disconnection solution (will be implemented.

Load disconnection schemes whilst effective in prolonging the resilience of the site battery; do however introduce the risk of failure to the electronic relays for which the battery provides the DC source. SPEN estimate that the mortality rate of between 1:100 to 1:200 is considered likely which when applied across the primary substations in SPD & SPM could conservatively impact in excess of 500 relays with consequential impact on the integrity of the power network, danger to staff, the general public and property. Failures of relays during the initial phase of Black Start restoration process will also introduce doubt, and consequential delays into the restoration process.

Where such arrangements are implemented then amendments will be required to modify the Primary transformer 'Back up' protection supply arrangements such that it remains continually connected to the site protection battery. This will ensure that upon re-energisation of the Power Network under Black Start conditions there will be a required level of protection in place to clear any local network faults which have occurred in the down time.

Battery & Charger Currently Resilient

At Primary substations equipped with electro-mechanical relays only there is no immediate requirement to increase the resilience of the site battery or charger. However battery systems at these substations which incorporate Valve Regulated Lead Acid (VRLA) batteries will have additional SCADA facilities' added to allow monitoring of battery output/resilience, to allow monitoring of battery performance, VRLA batteries are known to have a 'cliff face' fall off on discharge and are not re-generable.

Systems incorporating Planté battery units will not require this additional monitoring, as Planté cells are known to be resilient to slow discharge and are re-generable.

5.2. Securing the Telecoms Infrastructure

Currently there is no Electricity Industry recommended minimum standard for Voice or Data communication resilience. Following the industry Exercise White Noise (November 2009) and recent E3C work, the industry is preparing an Engineering Recommendation that defines these requirements. Our plans are to meet most of the requirements of this draft recommendation during RIIO-ED1 with, where necessary, some work deferred into ED2.

To improve the resilience of fixed path voice and data communication routes to our Grid and Primary substations, our plans include:-

The provision of dual communication routes to all Grid substations, one of which will be borne on SPEN owned and operated infrastructure guaranteed 72 hours resilient, the alternate route will where economically viable will be 72 hours resilient

Improving the fixed path communications routes which serve greater than 2 primary substations, In general this will require the modification of current radial communications infrastructure, using SPEN or in some cases third party communications paths. Resilience will be 72hrs where SPEN owned and operated assets are used for the communication route.

Where we do not already meet the recommended standards SPEN will work towards the indicated levels of resilience as laid down in the draft Engineering Recommendation during ED1, with where necessary some work being deferred into ED2.

To improve the resilience of mobile path voice communications between our 24hr Operational Control Centres, our resource centres and operational resources essential to the Black Start recovery process, our plans include:-

The expansion of robust mobile communications, through the Airwave UK platform during the first year of ED1 by providing a further 30 hand portable units distributed at operational locations throughout Central & Southern Scotland and 3 additional fixed terminals at operational muster locations (NB In Scotland where SPEN are the Transmission Network Operator as well as the Distribution Network Operator (DNO) we have implemented Airwave solutions as a previous requirement to replace the Grid System Radio, our RIIO ED1 plan is to enhance this to encompass our DNO responsibilities) We will also introduce Airwave voice communications across the SPM licence area, providing 53 hand portable units, and 11 fixed terminals at operational locations comprising control centres and staff muster locations.

6. Expenditure and Delivery

For efficiency, our substation resilience improvement programme will be delivered in conjunction with our Load and Non Load investment plans. Our telecoms infrastructure programme will be delivered in conjunction with our plans to deliver BT21CN compliant communications and through our SCADA RTU replacement programme. Budgets for these activities are separately accounted for in worksheets CV10 and CV105.

The CV11 worksheet tables include:

Expenditure for substation resilience through enhancement of Protection and SCADA battery systems at SPM Grid and SPD& SPM Primary substations to provide 72 hr resilience using a combination of generators, hi capacity battery chargers and cells, or battery DC Load disconnection schemes, as follows:

Black start resilience of SCADA batteries at 132kV sites in RIIO-ED1			
	SPD	SPM	SPEN
Number of 132kV sites requiring work		99	99
Total (£m)		1.4	1.4

Black start resilience of protection batteries at 132kV sites in RIIO-ED1			
	SPD	SPM	SPEN
Number of 132kV sites requiring work		99	99
Total (£m)		3.5	3.5

Black start resilience of protection batteries at EHV sites in RIIO-ED1			
	SPD	SPM	SPEN
Number of 132kV sites requiring work	255	414	669
Total (£m)	1.5	2.5	4.0

The additional volumes required in SPM over SPD is a reflection of the larger number of substations on the SPM interconnected network as identified and discussed in more detail in our Annex C6 – SP Manweb Company Specific Factors - SPEN

Expenditure for voice communication enhancement to strategic operational locations in SPD & SPM through the deployment of Airwave communication services, as follows:

Black start resilience of Mobile Voice Communications in RIIO-ED1			
	SPD	SPM	SPEN
Number of sites	3	11	14
Total (£m)	0.06	0.09	0.1

*The provision of 83 mobile airwave radio handsets is not shown in the table above, but they will be co-located at the sites where we have existing fixed airwave units in SPT/SPD or at the locations where we are installing additional fixed airwave units in SPD and SPM as per the above table

These planned activities summate to:

Black start resilience Expenditure in RIIO-ED1 (£m)			
	SPD	SPM	SPEN
RIIO-ED1 Annual Average	0.2	0.9	1.1
RIIO-ED1 Total (8 years)	**1.6**	**7.5**	**9.0**

To assist us in our plan development and cost assessment a detailed CBA was carried out. The CBA summarised below can be found in **Annex C6 – Cost Benefit Analysis – SPEN** Black Start CBA No.3.

List below all options considered to meet the stated aim

Options considered	Comment
Upgrade equipment in line with normal attrition rate	Fails to meet expected requirements or timeline for full 'blackstart' resilience
Global upgrade of batteries to 72 hr capacity	Fails to cover AC motive power requirements and has incumbent accommodation issues
Operational response	Would fail to meet expected restoration strategy/requirements or timescales
Global Battery DC supply disconnection units	Fails to cover AC motive power requirements and has incumbent accommodation issues
Base Case - Global LV generator installation	Considered too expensive and over complicated for all substation configurations
OPTION 1 - Combination of solutions portfolio	Generation applied to all Grid Sites consistent with SPT, 6 operational sites, plus 72hr battery capacity batteries in Primaries with Significant DC loading
OPTION 2 - Combination of solutions portfolio	Generation/72 hr battery capacity at Grids, generation at 6 operational sites, plus 72hr capacity battery capacity/dc load disconnection scheme applied to primary sites - Electronic relay mortality rates due to loss of DC raises risk of Safety
OPTION3 - Combination of solutions portfolio var2	Generation/72 hr battery capacity at Grids requiring ac, Generation at 6 operational locations and battery load disconnection schemes applied at all other sites (assume 40% of sites need new batteries in line with 20 year asset replacement policy) - Re-balanced portfolio of solutions and balanced engineering/societal risk
OPTION 4 - Re-balanced portfolio of solutions and balanced engineering/societal risk	Fit standby generation to all Grid Sites with multiple Transformers/ or AC dependent CB's and Fit 72hr capacity battery units to all simple GT site installations (Single/dual Tx No AC dependent CB's etc).
Operational response	Would fail to meet expected restoration strategy/requirements or timescales
Global Battery DC supply disconnection units to all sites Grid & Primary	Fails to cover AC motive power requirements and has incumbent accommodation issues
Upgrade equipment in line with normal attrition rate	Fails to meet expected requirements or timeline for full 'blackstart' resilience

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
Baseline	Install generators at all locations	Rejected							
1	Generation applied to all Grid Sites consistent with SPT, 6 operational sites,	Rejected	Least economic option		£19.63	£26.89	£32.74	£40.17	
2	As option 1 plus 72hr capacity battery capacity/dc load disconnection scheme	Rejected	Least economic option		£22.45	£30.57	£37.04	£45.15	
3	Generation/72 hr battery capacity at Grids requiring ac, Generation at 6	Rejected	Least economic option		£23.81	£32.30	£39.02	£47.40	
4	Re-balanced portfolio of solutions and balanced engineering/societal risk	Adopted	Most economic option		£24.06	£32.62	£39.38	£47.81	

Substations where there is no immediate requirement to enhance Black Start resilience will be continually assessed, with resilience upgrades applied as required, based on the criteria outlined in this document.

7. Appendix A - Black Start Resilience Strategy -Technical Requirements Summary

Location	Responsibility for Resilience	Substation Site Resilience	Data Comms	Voice Comms
Control Centres (inc DRS sites)	SPM/SPT/SPD	Generator	Dual routes, both resilient	SPEN Strategic Network/ Airwave solution
Grid with SGT	SPT & NGT (for SPM area)	NGT Generator	Dual routes, one resilient	SPEN Strategic Network/ NGT Optel Airwave solution
Grid with minimal SPM equipment	Site owner	Generator/Increased Battery Capacity	Dual routes, one resilient Solution developed in partnership with Host DNO	SPEN Strategic Network developed in partnership with Host DNO
Grid	SPM/SPT	Generator/Increased Battery Capacity	Dual routes, one resilient.	Dual routes, one over resilient BT31CN.
Primary (no space constraint)	SPM/SPD	Battery	Single Route, Resilience on best endeavours basis	BT21CN where achievable otherwise Airwave handset
Primary (with space constraint)	SPM/SPD	Load Disconnection plus modify Back up protection.	Single Route, Resilience on best endeavours basis	BT21CN where achievable otherwise Airwave handset
Primary (all EM relays)	SPM/SPD	Battery monitoring if VRLA	Single Route, Resilience on reasonable endeavours basis	BT21CN where achievable otherwise Airwave handset

All solutions consistent with the ENA Engineering Recommendation G91 – Page 13 Substation Resilience Decision Chart