Document 18
Asset Category – Black Start (Capex & Opex)
EPN

Asset Stewardship Report 2014

David Jeyakumar / Kevin Burt

Document History

Version	Date	Details	Originator	Revision Class	Section Update
1		Baselined July 2013 submission	Damien Delea		
1.1	12/02/2014	Updated data tables and figures to match RIGs (minor variances) Amended the figures and graphs to show volumes as 'number of sites', as reported in RIGs. Battery installation numbers retained in the document as a new table in Appendix 5.	David Jeyakumar	Major	1.1.1 7.1 Appendix 5
1.2	12/02/2014	Clarified number of grid and primary sites to be covered in the programme. Also clarified that each site may have more than one battery installation Added section 2.3 with updated battery population data.	David Jeyakumar	Major	1.1.2 2.1 2.2 2.3
1.3	14/02/2014	Added Appendix 8: mapping table showing RIGs mapping for ED1 expenditure and volume, using template tables.	David Jeyakumar	Major	Appendix 8
1.4	20/02/2014	Minor formatting changes. Submitted to Steve Mockford for approval	David Jeyakumar	Minor	
1.5	24/02/2014	Clarified the details of the levels of uncertainty/cost growth in risk table	David Jeyakumar	Major	1.4
		Clarified that 10 year asset life applied to VRLA batteries, whilst Planté units are expected to last longer. Also stated that battery population data includes both.			3.1
		Updated the estimated cost of renewables options, following new calculations			5.1
		Listed sites with ABCBs			Appendix 4
		Minor corrections following feedback from Barry Hatton		Minor	1.1.2, 1.2, 1.3 4.6 Deleted 7.4.3, 7.4.4,

Version	Date	Details	Originator	Revision Class	Section Update
					7.4.5
1.6	27/02/2014	Clarified that second string added where there is only one battery string	David Jeyakumar	Minor	1.2
		Added reference to Planté wet cells		Minor	2.0
		Provided named examples of batteries per site		Minor	2.1, 2.2
		Updated battery volumes based on Ellipse extract of 25/02/14. Retained original age profile		Major	2.3, 3.1
		Amended narrative to align with the update to battery volumes, sourced solely from Ellipse extract of 25/02/14.		Major	4.5, 4.5, 4.6
		Amended to refer to unit cost per site in Appendix 4		Minor	5.2
		Amended approach of document to work on the basis of sites rather than batteries, in order to align with RIGs reporting approach.		Major	7.4 Appendix 4 Appendix 5
		Formatting updates		Minor	Whole Document
1.7	27/02/2014	Minor corrections following review by Kevin Burt	David Jeyakumar	Minor	Whole Document
1.8	26/03/2014	Removed references to NAMP and minor formatting updates	David Jeyakumar	Minor	Whole Document
2.0	27/03/2014	Final for publication	Regulations	Minor	All

Contents

1.0 Executive Summary EPN Black Start Mitigation

1.1 Scope

1.1.1 This document details UK Power Network's NLRE roll-out of Black Start mitigation devices across UK Power Network's EPN area. All Grid and Primary installations will be effected at a cost of £6,144,491. £1,677,941 will be allocated for DPCR5 and £4,466,550 will be needed for ED1.

1.1.2 There are 484 primary sites and 160 grid sites impacted by the programme. Each site comprises a minimum of one SCADA battery and one trip battery. Depending on the number of circuit breakers and other ancillary equipment, there may be multiple batteries and chargers of each type at a site. Costs incurred in DPCR5 will be collected and recovery sought from Ofgem in accordance with the agreed approach (Ofgem letter dated 18 October 2010). Expenditure in ED1 will be ex-ante.

1.1.3 Black Start Mitigation costs and volumes are held in the following locations in OFGEM and UK Power Networks investment planning documents:

Sub Programme	**NAMP line**	**RIGS**		
		Programme site volumes and costs	**Outstanding sites to be resolved**	**Battery charger additions and disposals**
Primary (EHV) substation protection/tripping battery modifications (Black Start)	1.13.25.6931	CV11 74	CV11 89	V4a 85
SCADA Primary (EHV) substation battery modifications (Black Start)	1.13.27.6932	CV11 75	CV11 90	V4a 85
Grid (132kV)substation protection/tripping battery modifications (Black Start)	1.13.26.6933	CV11 76	CV11 91	V4a 102
SCADA Grid (132kV) substation battery modifications (Black Start)	1.13.28.6934	CV11 77	CV11 92	V4a 102

Table 1 – Mapping of Black Start battery modifications

A full list of abbreviations is included in Section 6.0 of Document 20: Capex Opex overview.

1.2 Investment strategy

In the event that a large scale loss of local and national generation occurs, OFGEM, in addition with the Energy Emergencies Executive Committee (E3C), requires each DNO to ensure SCADA control and tripping batteries (including intertripping systems, 50V and 60V) in all Grid and Primary substations are serviceable after a period of Black Start recovery.

Each DNO has approached this in a number of ways and UK Power Networks proposed compliance with this requirement is to develop and install a Black Start controller unit to isolate/reduce the standing load on the Grid and Primary substation battery charger systems for both SCADA and tripping functions. Additionally, where a battery/charger installation has a single battery string, a second string will be added to facilitate the installation and functionality of the Black Start controller.

The Black Start controller unit has been developed by UK Power Networks in conjunction with battery and charger suppliers and complies with ENA Recommendation (ENA ER G91), approved by OFGEM.

A company-wide standard has been written to detail the requirements for a Black Start controller and this has also been incorporated into a wider specification for grid and primary battery installations. Discussions have taken place with approved suppliers capable of providing the required equipment and this has helped to ensure the specification meets the needs of the network.

As per this document, a Black Start Controller is defined as follows:

Black Start controller in this document refers to the proposed unit which will be incorporated into UK Power Network’s Grid and Primary substation tripping battery charger systems to reduce the effect of the standing load and hence the DC drain on the batteries in the event of a battery system power supply loss. The driver behind the development of this solution is to meet the requirement with regard to substation protection battery resilience in Black Start situations as specified by OFGEM.

SCADA batteries will not be fitted with the Black Start controller unit as they are required to remain serviceable for the whole of the black start period. Therefore they will be assessed for 72 hour compliance and where necessary, enhanced with additional capacity or replaced.

1.3 ED1 Proposals

In the short term, as per an OFGEM recommendation from the established Electricity Task Group, it is proposed that the supply to substation auxiliary supplies/battery chargers be connected more quickly by reconnecting substations as soon as generation becomes available, but not reconnecting customers other than those associated with circuits feeding auxiliary supplies.

This option will be proposed by Network Control & Operations as a short term solution to aid restoration in the event of a Black Start situation.

In order to provide the resilience needed to meet the recommendation for 72 hour resilience, it is proposed that each Grid and Primary be equipped with dual string 110V tripping battery supplies, each string being rated for 6 hours use at rated output. In conjunction with the Black Start controller unit this will ensure that dc supplies to substation equipment during and after a period of Black Start outage is available. The SCADA monitoring battery supply will be sized for the full 72 hours, the maximum period a Black Start recovery is expected to last according to the report published by OFGEM in 2010. These proposals will meet the requirement to have serviceable SCADA and tripping batteries available after a period of 72 hours.

It is estimated that this roll-out will take 8 years, the associated expenditure of which will be undertaken by UK Power Networks and will be recovered in the next distribution price control review.

The delivery of this programme will be based on the successful contractor initially conducting on-site surveys to determine what type of work is needed for each installation.

1.4 Risks and Opportunities

	Description of similarly likely opportunities or risks arising in Ed1 period	**Level of (uncertainties)/cost growth(£'m)**
Opportunity	Greater resilience of battery and charger capability across the network, reducing risk of future failures	
Opportunity	More accurate monitoring capability of batteries from new units	
Opportunity	Change to get accurate data of what is currently installed throughout network with individual surveys. Change for database completeness	
Opportunity	Standardisation of equipment across the network	
Risk	Civil works may be needed to accommodate new strings of battery and Black Start unit.	£20,000 per site on average, based on estimated cost of heated Glass-Reinforced Plastic containment unit.
Risk	Accuracy of information, variance in number of sites to be completed	
Risk	Air-Blast Sites requiring generators	£12,000 per site extra, for generator units
Risk	Loss of SCADA control despite battery resilience, meaning Black Start functionality would be lost	
Risk	Change in policy due to better methods of Black Start mitigation	

Table 2 – Risks and opportunities

2.0 Black Start Population

Across UK Power Networks, each substation employs a group of batteries in conjunction with a battery charger or chargers. The charger, which derives its power from local LVAC supplies, keeps the batteries at full capacity. These battery units provide power to fundamentally important units within substations, namely trip and close supply of circuit breakers, inter-tripping supplies, SCADA monitoring facilities, emergency lighting and also to power numerical protection devices.

Across EPN, a wide variety of capacity sizes exists based on an applied version of IEEE 485 document for battery sizing within substations. In this document, the battery installation was determined by the size of the standing load, calculated from manufacturer's datasheets. The manufacturers informed UK Power Networks that the life-span of a Valve-Regulated Lead Acid (VRLA) battery installation would be in the region of 10 years if kept at temperatures close to those specified in the datasheets and in a clean environment. Based on this, the refurbishment period was set at 8 years. Therefore, each installation was sized for a particular site and was due to last for this period. The life-span of Planté wet cells is anticipated to be longer than that of VRLA based on design life.

There was however no provision provided for a Black Start scenario. This term refers to a large scale loss and subsequent re-starting of local and national generating power. This scenario would lead to a loss of AC mains, affecting the charging facilities of substations resulting in a loss of battery power. Due to high profile incidents of this nature in large cities, combined with the urgent need for National Grid infrastructure refurbishment, this became a concern for the UK and in 2010, OFGEM in conjunction with the Energy Emergencies Executive Committee (E3C) published a report *("Black Start Recovery – Substation and SCADA Resilience" - June 2010)* stating that all DNO grid and Primary substations be available after a black start period, calculated to take up to 72 hours to resolve.

UK Power Networks' proposal was to ensure that SCADA batteries be sized for this 72 hour period to ensure network visibility throughout a Black Start period. Substation batteries for tripping, closing and protection devices are to be designed to "shed load" during this period with the aid of double strings of batteries. One string would be disconnected after a certain time period after a Black Start recovery begins, leaving Control the option of switching in the a reserve battery when AC mains is being restored. A more detailed description can be found in section 5.2.

2.1 Grid Sites

Battery installations at 160 grid sites are to be made resilient by the Black Start Mitigation programme. Each site comprises a minimum of one SCADA battery and one trip battery. Depending on the number of circuit breakers and other ancillary equipment, there may be multiple batteries of each type at a site.

For example, Ilmer Grid has one SCADA and one Protection trip/close battery, whereas Trowse Grid has one SCADA battery and four Protection batteries (three trip/close and one intertrip).

Bury Grid has been made into a Black Start resilient site with the scheme outlined above. It was included as a trial site and carried out by the battery manufacturer PE Systems in 2012. Following the trial, the specification was varied slightly to the current standard. For further information, please see Appendix 7.

2.2 Primary Sites

Battery installations at 484 primary sites are to be made resilient by the Black Start Mitigation programme. Each site comprises a minimum of one SCADA battery and one trip battery. Depending on the number of circuit breakers and other ancillary equipment, there may be multiple batteries of each type at a site.

For example, Shefford Primary has one SCADA and one Protection trip/close battery, whereas Durham Road Primary has one SCADA battery and two Protection trip/close batteries.

Bury Primary has been made into a Black Start resilient site with the scheme outlined above. It was included as a trial site and carried out by the battery manufacturer PB Design in 2012. Following the trial, the specification was varied slightly to the current standard. For further information, please see Appendix 7.

2.3 Battery Units

The following table presents the recorded population of SCADA (telecontrol) and Protection (trip) battery units. As stated above, it must be noted that some sites have multiple batteries of each type.

Installation Type	Units
Grid Telecontrol	99
Primary Telecontrol	383
Grid Trip/ Close	213
Primary Trip/ Close	624
Grid Inter-trip	56
Primary Inter-trip	7

Table 3 – Battery Population

3.0 Investment Drivers

OFGEM Guidance

The Electricity Task Group (ETG) of the Energy Emergencies Executive Committee (E3C) were tasked by OFGEM to look into substation resilience in relation to Black Start and established an ENA working group in 2008 to identify solutions to the issue. The ENA working group submitted their final report to the ETG in 2009 and in turn the ETG submitted their final report to OFGEM in July 2010.The ETG recommended that all DNO's ensure that SCADA control and tripping batteries in all Grid and Primary substations be available after a period of Black Start recovery. The battery resilience to cover this period is aimed to be 72 hours minimum and the tripping and closing supplies are to be available after the Black Start outage period.

As the impact of large scale loss of AC mains is identified as a possible scenario, the impact this would have on Grid and Primary substations needed to be identified. In this case, all LVAC/ auxiliary supplies to substation operations would be lost for the duration of the black-out period. In the event that no dc-delayed restoration was available, the batteries supplying the load would drop-off and eventually fail as the units would drop below a voltage sustainable for re-charging. During a Black Start scenario, it is also assumed that field staff resources would be extremely stretched and generator connections could not be carried out in a suitable time period to prevent this from happening. Adding to this, it is anticipated the transport infrastructure may not be able to operate normally in these circumstances and road networks may become quickly congested thereby preventing access to key Grid and Primary sites. The combination of this would mean that after a Black Start recovery, the vast majority of substations would have AC mains restored without any monitoring or protection facilities available. This could lead to a situation where faults occurring on the network would not be detected and therefore no effective fault clearance.. This could lead to catastrophic damage to existing equipment and pose a severe risk to staff and the public. It has been decided from this potential scenario that Black Start mitigation is needed.

OFGEM wrote to UK Power Networks in September 2010 asking for the company's view on this recommendation and for detailed plans and spending profiles. UK Power Networks responded by saying the company agreed to the recommendation, and that it would take 8 years to make the required changes. Spending profiles were subsequently compiled and are available in the appendix of this report.

3.1 Condition Measurements

The following table describes the age profile of the battery installations in EPN. The manufacturers informed UK Power Networks that the life-span of a valve-regulated lead acid (VRLA) battery installation would be in the region of 10 years if kept at temperatures close to those specified in the datasheets and in a clean environment. Based on this, the refurbishment period was set at 8 years. Therefore, each installation was sized for a particular site and was due to last for this period. However, due to variances in temperature owing to locations of assets, batteries have been known to fail after 5 years. Table 4 below shows battery populations comprising of VRLA, and Planté Wet Cells whose anticipated life-span is longer than that of VRLA.

Installation Type	**Units**	**>5 yrs old**	**> 10 yrs old**	**% >5yrs old**	**%> 10 yrs old**
Grid Telecontrol	99	23	16	23	16
Primary Telecontrol	383	84	73	22	19
Grid Trip/ Close	213	136	47	64	22
Primary Trip/ Close	624	343	168	55	27
Grid Inter-trip	56	20	3	35	6
Primary Inter-trip	7	4	4	54	58

Table 4 – Age profile of grid and primary tripping and SCADA batteries

4.0 Asset Assessment

4.1 Asset Health

Not Applicable. Health Indices data does not apply to Black Start equipment as only one unit is currently installed.

4.2 Asset Criticality

All Black Start equipment is of the highest criticality as it will be the only mitigation in place for UK Power Networks Black Start situation.

4.3 Network Risk

Any risk to the network which could be caused by the Black Start units has been mitigated as much as possible by implementing various controls which would allow all monitoring and control equipment to function as normal should the unit fail.

The risk to the network if the work is not completed could result in restoration of AC mains supply to the distribution network without any form of control or protection over the substation.

4.4 Data Validation

The total recorded number of installed batteries is obtained from UK Power Networks' database which has been populated with data following consultation with battery system surveyors and maintained through updating following regular maintenance and refurbishments.

The estimations calculated in this document are dependent on the accuracy of the UK Power Networks asset register.

4.5 Data Verification

The programme costs are highly sensitive to the accuracy of the recorded data. Individual site surveys will be required prior to implementation of solutions to ensure all affected battery units are catered for.

4.6 Data Completeness

Programme costs are based on all grid and primary sites being upgraded. The Grid/Primary numbers breakdown is taken from Ellipse records.

5.0 Intervention policies

5.1 Interventions: Description of intervention options

The ENA working group investigated the various options available to the DNOs in meeting with the 72 hour resilience goal. The options examined were:

- Self powered relays
- Using renewable sources to charge batteries
- Install extra batteries to raise the resilience to 72 hours.
- Reducing the standing load on batteries by disconnecting the batteries

The option of expanding the resilience by installing extra batteries was not examined in much detail in the ENA report, but is examined in this paper in terms of estimated costs. The conclusions of the ENA working group from a UK Power Networks perspective are set out below

Self-Powered Relays

Self-powered relays would in some circumstances require battery supplies. On top of this, it is not seen as a practical solution because trip coils would need changed on most circuit breakers at an estimated cost of £8,000 per panel (every panel in the substation would require this retrofit). Assuming an average of 12 panels per site:

EPN - £68m

Conclusion – Not practical and too expensive

Renewable Energy Sources

Using PV and wind sources was examined, and it was determined that to supply sufficient current to the batteries in a typical substation would require 8 kWh per day. A PV system to deliver this would require 100m^2 at an estimated cost of £30,000 per site. Wind was considered to be unreliable.

EPN – £19.3m

Conclusion – Not practical and too expensive

Install extra batteries to raise resilience to 72 hours

This approach could be appropriate in older sites which have very little standing load. However, where there is significant standing load, installing a battery system which is 6 times the size (when compared to the standard 12 hour standard batteries) would be difficult, impractical and expensive. In SPN, there may be room in the substations to house the batteries, but in many cases switch houses would require alterations. A typical cost based quote from two current battery systems suppliers to UK Power Networks for a system with 72 hours resilience is £16k - £23k per site. This excludes any civil costs associated with the much larger space requirement for larger battery banks. From discussion with internal discussions a modification would cost approximately £90k per site. Assuming an average system cost of £18k per site and civil modification requirement for approx. 50% of the sites:

EPN - £45m

In addition to the high initial cost, there would be a high on-going cost resulting from the regular replacement of the battery cells.

Conclusion – Too expensive and impractical

5.2 Policies: selecting preferred interventions

Rejected Options	Cost	Reason for rejection
Self-Powered Relays	£68m	Not practical and too expensive
Renewable Energy Sources	£19.3m	Not practical and too expensive
Install extra batteries to raise resilience to 72 hours	£45m	Too expensive and impractical
Reducing load on batteries	£6m	cost effective solution

Table 5 – Intervention options

Preferred Option: Reducing load on batteries (ENA Recommendation)

This report has assumed that under Black Start conditions, DNO's may not be able to get staff to site. Also, it is assumed that Network Control will be busy with the Local Joint Restoration Plan amongst other things. Therefore any scheme to disconnect the standing load was required to be automatic and not require staff to attend site. The scheme proposed (and recommended) by the ENA working group involved fitting a DC contactor between the batteries and the DC distribution board. The scheme operates as follows:

- Supplies fail to the substation, detected by Voltage Transformers on the switchgear
- A timer starts a count
- After one hour, the timer times out and sends an alarm to control and starts the disconnection process
- The DC contactor opens, isolated the batteries from the standing load, except for the transformer back-up protection, indication is sent to control
- When the DC supplies are required to energise the site, the contactor is closed from control via SCADA
- Scheme returns to normal when supplies are restored

In order to allow the remote control of the contactor, the SCADA batteries require upgrading to 72 hour resilience so that they are available at all times.

Also recommended in this report is to install standby generation at high priority sites as well as at sites which require AC dependant switchgear (such as air-blast circuit breakers, of which 172 units exist across UK Power networks)..

The cost for generation is estimated to be £3,500 to £5,000 per Primary site, excluding labour and £10,000 to 12,900 per Grid site including generation and excluding labour.

Conclusion – The most cost effective solution

Following consultation with battery suppliers and after conducting trial sites throughout the three network areas of UK Power Networks, the following description of the innovative approach was devised and made company standard.

Description of Black Start Units

To meet OFGEM's proposals as stated, the term Black Start refers to:

The proposed unit which will be incorporated into UK Power Network's Grid and Primary substation battery charger systems to reduce the effect of the standing load and hence the DC drain on the batteries in the event of a battery system power supply loss. The driver behind the development of this solution is to meet the requirement with regard to substation protection battery resilience in Black Start situations as specified by OFGEM.

Black Start Controller Function

The Black Start Controller will have multiple functions:

- Each Trip/ Close installation will have two battery strings
- Disconnect battery string 2 due to loss of AC supply
- Disconnect either battery strings due to low voltage
- Carry out routine automatic battery discharge test
- Interface with SCADA and manual controls

In Normal Condition Prior to Outage.

- The chargers supply the load and keep the batteries charged up.
- The battery discharge test function will discharge each string of batteries every 45 days, with the strings alternating the test sequence every 22.5 days.

After Charger System Supply Failure.

- In the event of a loss of AC power supply to battery charger system, the batteries will continue to supply the load.
- If the loss of AC is sustained, battery string 2 will be isolated from the standing load.
- Battery string 1 remains in service.
- When the battery string 1 is drained, the voltage will fall below a configurable predetermined level. A contactor will open to prevent irreparable damage to the batteries.
- All power to the load will be lost.

Restoration of DC Power Prior to Network Supply Restoration.

Presuming battery string 1 is drained and is disconnected from the load, the Control Engineer will issue a command to close battery string 2 contactor. The units have been installed as shown in EPN:

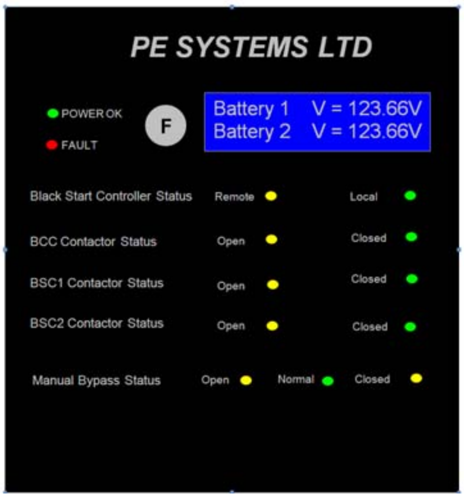

Figure 1 – Black start controller unit

A number of alarms will also be available to allow for any issues to be highlighted and monitoring will also be available through the Black Start unit.

Alarms shall also have adjustable threshold limits. The settings and range of the above shall take account of hysteresis, maximum and minimum conditions. Alarm levels shall be in line with battery and charger recommendations.

All alarm and indications shall be monitored both locally and remotely.

The interface between the charger alarms and the UK Power Networks SCADA/ Telecontrol (Communication) systems shall be fail-safe volt-free contacts.

Below are the different types of installations found across the network and the units which the Black Start battery suppliers will be modifying/ replacing:

Existing sites with PB Design N+1 hybrid 110V battery charging systems

At these sites the existing unit would be modified by the manufacturers to replicate the scheme described above.

Existing sites with 2 or more separate battery charging systems

At these sites one of the complete charging units would be fitted with a contactor between the common bus and battery output. This would open in the event of a supply failure, leaving one of the units supplying the standing load with the other unit in reserve. When required, the contactor would be closed via SCADA to restore supplies.

Existing sites with only one battery charger system

This is the most basic method in which one charger is used to maintain an individual battery bank in the substations. At these sites a dual string of batteries would be fitted to the existing charger unit and the Black Start functionality added as outlined above.

SCADA/Telecontrol Resilience

It will be necessary to increase the resilience of SCADA systems to 72 hours. From consultation with the supplier, it is assumed that each increase will cost in the range of a £1000.

For a summary of the cost per site of the works associated with the modifications, please see Appendix 4.

6.0 Innovation

The process of Black Start Mitigation as outlined in this document is a novel approach to the issue of a lack of resilience of battery to sustain an outage in the event of a large scale loss of AC mains power. The approach has considered the use of large scale roll-out of new battery units across the region and other sources of power. The innovation of this project lies in the manipulation and refurbishment of current assets related to batteries in order to achieve OFGEM targets with the most robust solution with minimum spend.

7.0 ED1 Expenditure Requirements for Black Start Mitigation

7.1 Method

The method of rolling out the work will be done on a basis of the last site to be reconnected will be the first site to be installed with a Black Start controller. UK Power Networks confirmed to OFGEM that the roll out of this project would take 8 years based on current volume and an analysis of the work load. The following graph indicates how this will be delivered across this period. Appendix 5 details the volumes and expenditure.

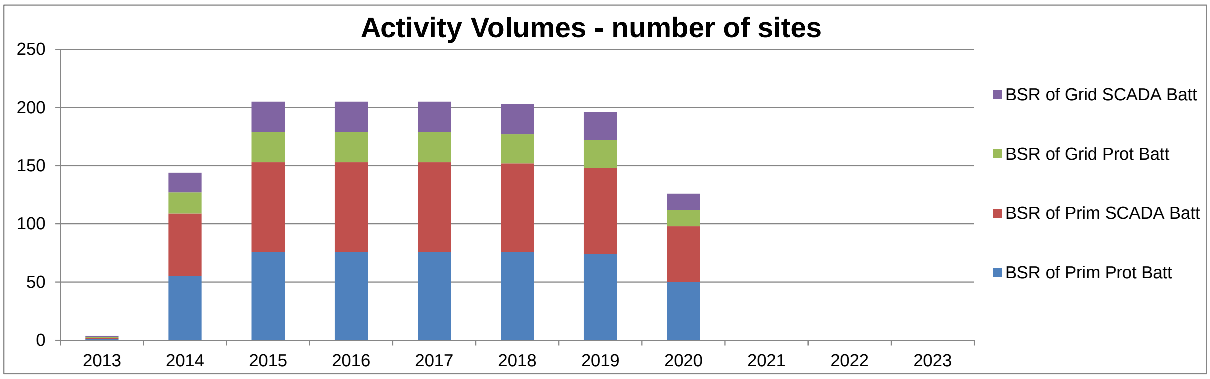

Figure 2 –Delivery Volumes of Black Start Mitigation

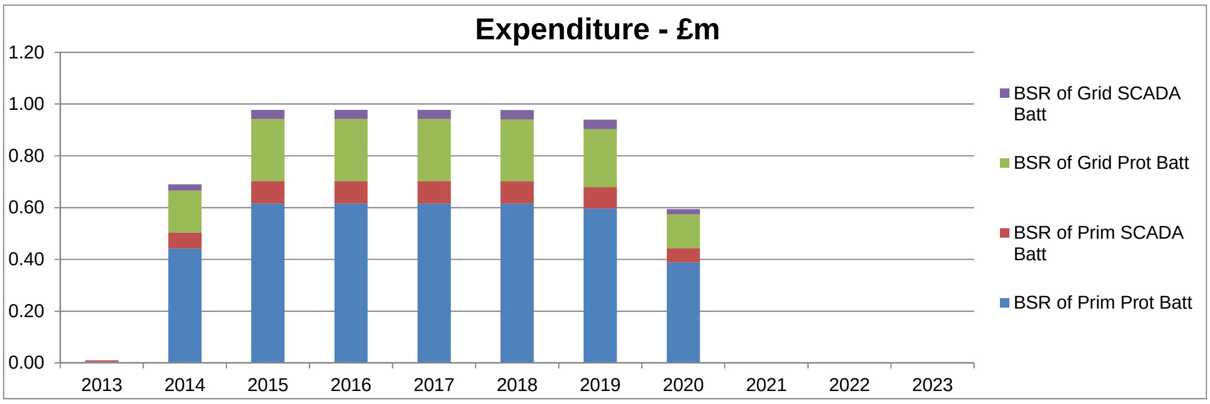

Figure 3 – Expenditure requirements of Black Start programme

7.2 Constructing the Plan

Construction of the planned roll out will be in conjunction with how National Grid will be re-installing supplies after a Black Start period. A detailed analysis will be completed for EPN.

7.3 Additional Considerations

It may be found that during the detailed surveying of assets by the installer, that assets not due for replacement will need to be changed in order to meet the company's new battery specifications for Black Start compliance. This replacement will be in conjunction with UK Power Networks current battery replacement programme. This will be taken into consideration when rolling out the Black Start project.

7.4 Commentary

All grid and primary substations need this type of work to ensure that the substation is ready for Black Start resilience. A total of £6,144,491is a figure based on unit cost estimates per site (see Appendix 4). Data will be collected and stored on the company's database to ensure that full visibility of all battery related assets be available in the future. This will lead to robust figures which will allow UK Power Networks to ensure these assets are maintained to the highest quality in the future.

7.5 Sensitivity Analysis and Plan Validation

7.5.1 Average Life Sensitivity

It is envisaged that the replacement of the units will coincide with the current battery maintenance schedule already in place for batteries and chargers where they exist and are planned for the future. The current maintenance schedule details the following:

Plant Type	Minor Inspection	Major Inspection	Maintenance	Comments
Batteries at Grid/Primary substations (maintenance free type)	4 months		1 year	Inspection carried out during routine Grid/Primary Inspections.
				Battery replacement at:
				• Cyclon cells six years.
				• All other cells eight years.
Batteries at Grid/Primary substations (traditional wet cell)	4 months	1 year	N/A	Inspection carried out during routine Grid/Primary Inspections.
				Replace battery if Condition 4.

Table 6 – Inspection frequencies

7.5.2 Network Risk Sensitivity

Risk to the network caused by the units has been mitigated.

8.0 Deliverability

8.1 Network Access and Outage Availability

From the roll out expectancy rate detailed in Appendix 5, the requirements for network outages and access will be detailed in the survey period before installation of the units. It will be a requirement of the contractor to detail the arrangements required in order to carry out to the relevant UK Power Network's project manager to allow for any deviations from the initial plan.

8.2 Consistency Of Delivery Volumes and Explanations Of How Increases Will Be Managed.

The roll out will start with a delivery target agreed with contractor availability in the first year. This will increase until year 3 at which point the process will plateau in terms of product deliverability for the remaining period that the units are to be installed. The figures, detailed in Appendix 5, are a best assessment of contractor's ability to carry out the modification works.
UK Power Networks delivery teams are aware of this programme of work and have confirmed the programme is deliverable.

To date, OFGEM has not set a specific completion date for this programme other than to require DNOs to ensure projects for the establishment of new grid or primary sites, or reinforcement at existing locations incorporates Black Start battery mitigation. The remaining sites are to be addressed over time. The proposal in the document will ensure all UK Power Networks grid and primary sites are addressed in a timely manner over an 8 year period to provide the required mitigation.

8.3 Implications of Standards, Specifications

A new engineering standard has been written to cover Grid and Primary sites and the impact of Black Start mitigation on secondary sites, including customer sites where appropriate. The standard will be referred to by any contractor or member of staff undertaking work in regard to Black Start mitigation and will be adhered to for as long the current standard remains applicable.

Appendices

Appendix 1 Age Profiles

As this is a new asset to be introduced across each Grid and Primary substation, there is currently no Age Profiles available.

Appendix 2 HI Profiles

As this is a new asset to be introduced across each Grid and Primary substation, there is currently no HI Profiles available.

Appendix 3 Fault Data

Not Applicable to Black Start Units.

Appendix 4 WLC case studies:
Risk, Cost, Performance, condition profiles for various options

Risk

SCADA/ Telecontrol Communications

Whilst the battery upgrade of SCADA units will ensure that 72 hours of continuous monitoring will be available, this is still dependant on the Control Centre being able to communicate with the RTUs in Primary and Grid substations.

Air Blast Switchgear

The function of Air Blast Switchgear depends on the availability of a compressed air supply on site.

There are currently 95 Air Blast Circuit Breakers in 11 Grid and Primary Substations in EPN. Sites containing this type of switchgear at present are not equipped with a means of powering the compressors in a Black Start situation and these will be dealt with on a case by case basis. These sites are listed below:

Site	No. of recorded ABCBs
BARKING 132	2
ELSTREE 132KV	8
LAWFORD GRID	8
LITTLE BARFORD 132	15
PELHAM GRID	7
RAYLEIGH LOCAL GRID	13
RYE HOUSE 132	8
TOTTENHAM 132	9
WALPOLE GRID	6
WARLEY GRID 132KV	9
WATFORD SOUTH 132	10
TOTAL	95

Sourcing Ability

The success of this project is subject to the ability of the business to source, install and commission the necessary equipment to provide Black Start resilience.

Suppliers have indicated an eight to ten week lead time on all Black Start equipment and this factor must be considered when delivering the project. External contractors will require the appropriate authorisations to carry out the work and the need for internal workforce support is not completely mitigated in using external contractors.

Wherever interaction of the UK Power Network staff is required there is a risk to the company's ability to carry out the business as usual functions. This may incur additional project costs and may require special consideration.

Network Security

A major risk to network security lies in the implementation of the Black Start function and the upgrade of SCADA/ Telecontrol systems for UK Power Networks. As the majority of the work is expected to be carried out in live substations there is a risk that switchgear communication to the Control Centre may be lost, hence effecting automation schemes which are enabled.

Also working in close proximity to DC Trip/Close wiring may lead to incidents of unexpected switchgear operation and/or loss of protection schemes. Detailed steps will be required to mitigate these issues prior to any work commencing. In some instances dead substation working may be required.

The cost of effected network distribution performance has not been included in this document and may require consideration in particular situations.

Accurate information

The estimations calculated in this document are highly dependent on the accuracy of the UK Power Networks asset register and all other internal information sourced.

Policy and Procedure

While the Black Start resilient battery charger system standards and procedures are completed at the time of writing, it is possible that variations in the design will occur from lessons learnt over the period of installation. If this occurs, the standard will be updated and the new method will be employed on all assets yet to be installed.

Risk and Impact description	**Financial Impact**	**Probability**	**Risk Exposure**
Approval to commence the trial in Jan 2013 and subsequent companywide roll-out in 2013 will be deferred. As a result UK Power Networks commitment to OFGEM for entire Black Start Resilience in 5 to 8 years will not be achieved.	£853,000.00	0.3	£255,900.00
Unsuccessful trial could result in technology re-design	£50,000.00	0.3	£15,000.00
Control Centre not available to facilitate trial, hence delays in 2013 program	£58,516.00	0.25	£14,629.00
Programme Delivery not available to facilitate trial, hence delay to 2013 program	£48,720.00	0.3	£14,616.00
Manufacturers not available to facilitate trial, hence delay to 2013 program	£48,720.00	0.2	£9,744.00

Risk and Impact description	**Financial Impact**	**Probability**	**Risk Exposure**
Unforeseen network operational issues will effect trial locations, therefore trial may have to be postponed	£50,000.00	0.25	£12,500.00
For any reason Ellipse and Business data is not accurate, the cost estimate may be inaccurate	£610,101.00	0.5	£305,050.50
OFGEM may request that the Black Start roll-out timeframe be shortened	£610,101.00	0.2	£122,020.20
Ambitious project roll-out may not be achievable if sufficient resources cannot be dedicated to the project. Equipment would be purchased and not installed	£3,050,000.00	0.25	£762,500.00
Ofgem will decide not to fund entire project	£3,050,000.00	0.05	£152,500.00
Total Exposure to all risks			**£1,664,459.70**

Table 7 – Risks and impact

Risk Response activity

Risk Response Activity	**Risk Response cost**	**Residual Financial Impact**	**Residual Probability**	**Residual Risk Exposure**
Ensure PAIF documents include the appropriate data to allow the project to progress. Ensure the business is aware of this risk.	£0.00	£853,000.00	0.15	£127,950.00
Ensured trial was appropriately scoped and contract issues sorted with the manufacturers	£700.00	£50,000.00	0.05	£2,500.00
Brief control centre in suitable time	£0.00	£58,516.00	0.1	£5,851.60
Programme Delivery in all three areas are already aware of the project. They will be updated on any progress. Additional resources may be required.	£2,500.00	£48,720.00	0.1	£4,872.00
Contracts will be negotiated with the manufacturers subject to the approval of this document	£700.00	£48,470.00	0.05	£2,423.50

Risk Response Activity	Risk Response cost	Residual Financial Impact	Residual Probability	Residual Risk Exposure
Additional contingency has been allowed for in the trial NAMP request to adequately relocate location without any additional costs	£0.00	£50,000.00	0.05	£2,500.00
Any variations will be taken into account while costing. Worst case values were assumed in all cases during the cost estimation.	£30,000.00	£610,101.00	0.1	£61,010.10
Running an effective and efficient roll-out will display UK Power Networks commitment to the project. Cost and quantity estimates will be verified during this trial.	£0.00	£610,101.00	0.05	£30,505.05
Extend roll-out period up to the end of ED1	£50,000.00	£610,000.00	0.05	£30,500.00
Verifying the concept will allow us to demonstrate the technology to OFGEM	£0.00	£610,000.00	0.05	£30,500.00
Total Risk Response cost	**£83,900.00**	**Total Residual Risk Exposure**		**£298,612.25**

Table 8 – Risk response activities

Cost

The table below presents the estimated average unit costs per site for the Black Start Resilience programme. It must be noted that these costs are estimates based on current understanding of the typical scope of work per site. The average unit cost is subject to change following detailed site surveys.

Black Start Resilience at Substations		Estimated Unit Cost per site
Prim (EHV)	BSR of Protection Batteries	£8,053
Prim (EHV)	BSR of SCADA Batteries	£1,128
Grid (132kV)	BSR of Protection Batteries	£9,228
Grid (132kV)	BSR of SCADA Batteries	£1,400

Table 9 Black Start Unit Costs per site

Appendix 5 NLRE Expenditure plan

Below is a list of the associated units and costs in total for the implementation of Black Start Units for EPN for the period of 2013-2023, the full roll-out of the project is expected to finish in 2020.

Activity volumes - no. of sites		DPCR5			ED1								TOTAL	
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	DPCR5	ED1
Prim (EHV)	BSR of Protection Batteries	1	55	76	76	76	76	74	50	-	-	-	**132**	**352**
Prim (EHV)	BSR of SCADA Batteries	1	54	77	77	77	76	74	48	-	-	-	**132**	**352**
Grid (132kV)	BSR of Protection Batteries	1	18	26	26	26	25	24	14	-	-	-	**45**	**115**
Grid (132kV)	BSR of SCADA Batteries	1	17	26	26	26	26	24	14	-	-	-	**44**	**116**

Expenditure - £m		DPCR5			ED1								TOTAL	
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	DPCR5	ED1
Prim (EHV)	BSR of Protection Batteries	0.01	0.44	0.62	0.62	0.62	0.62	0.60	0.39	-	-	-	**1.06**	**2.83**
Prim (EHV)	BSR of SCADA Batteries	0.01	0.06	0.09	0.09	0.09	0.08	0.08	0.05	-	-	-	**0.15**	**0.39**
Grid (132kV)	BSR of Protection Batteries	-	0.16	0.24	0.24	0.24	0.24	0.22	0.13	-	-	-	**0.40**	**1.07**
Grid (132kV)	BSR of SCADA Batteries	-	0.02	0.04	0.04	0.04	0.04	0.04	0.02	-	-	-	**0.06**	**0.16**
												Total	**1.68**	**4.47**
												Overall	**6.14**	

Table 10 Black Start Programme

The volume roll-out of the devices has been planned to be the most achievable over the period it will take to complete the project. The cost associated with each year is the volume to be installed multiplied by the estimated average unit cost.

The units will be installed as per the distribution plan based on the most urgent sites. This plan will be optimised after the detailed site surveys have taken place. The plan will be to award the project to the most successful candidate(s) in order to initially carry out a site survey for the first sites of each year and then to carry out the works. As was mentioned, the roll out of the units will be prioritised on the basis that the sites which National Grid have specified as the last to be re-instated will get the units first. After the initial site surveys have been carried out, the units can be manufactured and the equipment ordered to complete the work. While the rest of the surveys are then being completed, work can then begin on the initial sites. It is also envisaged that the asset detail can be populated into the database in order to provide an accurate idea of what will and is installed on the network.

Appendix 6 Sensitivity analysis

If any of the risks mentioned are to materialise, it is expected that the costs associated with the project could vary as much as 10%.

Appendix 7 Named Schemes

In EPN, Bury Grid substation was chosen for the trial. On the Grid site the Trip/Close function is provided by a recently installed PB Design PSR19-110-010-41 dual N+1 10A battery charger with a dual string of 110V 37A SBS40 Powersafe batteries. The standing load has been assumed in the region of 1.2A. The Telecontrol battery charger on the Grid site comprises of a recently installed PB Design dual N+1 24A battery charger system with a dual string of 48V 50A SBS60 Powersafe batteries. The standing load has been assumed to be 0.6A. (Information assumed from Ellipse site asset information and verified through EPN Programme Delivery).

Bury Grid also contains a Primary 33/11kV compound with 33kV distribution. The relay room contains a 2008 PE Systems WCVF110/15 15A Trip/Close battery charger and a single string of 12V62F Enersys batteries configured to give 110V and a capacity of 62Ah. The standing load is 3A as indicated in Ellipse. The Telecontrol battery system is a 48V dual N+1 PB Design system installed in 2008. This is a 24A charger connected to a dual string of SBS60 Hawker Energy 60Ah batteries and a standing load of 0.6A. (Information assumed from Ellipse site asset information and verified through EPN Programme Delivery).

The trial at Bury Grid involved the upgrade of both the 132kV and 33/11kV battery systems. The Grid system required a Black Start controller installed adjacent to the PB Design battery system. A voltage analogue indication will also be provided on the Telecontrol battery charger system.

In relation to the 33/11kV site at Bury Grid the trial process involved a Black Start controller being installed adjacent to the existing PE Systems battery charger. A second string of identical 110V 62Ah batteries was also required in parallel with the existing battery bank. A voltage analogue indication was provided on the Telecontrol battery charger system.

PE Systems carried out the work which cost £10k.

Appendix 8 RIGs mapping for ED1 volumes and expenditure

Expenditure				ASR	RIGs								
Asset Type	Asset Name	RIGs Table	RIGs Row	Total	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total
Black Start	EHV BSR of Protection Batteries	CV11	74	2.83	0.62	0.62	0.62	0.60	0.39	0.00	0.00	0.00	**2.83**
Black Start	EHV BSR of SCADA Batteries	CV11	75	0.39	0.09	0.09	0.08	0.08	0.05	0.00	0.00	0.00	**0.39**
Black Start	132 BSR of Protection Batteries	CV11	76	1.07	0.24	0.24	0.24	0.22	0.13	0.00	0.00	0.00	**1.07**
Black Start	132 BSR of SCADA Batteries	CV11	77	0.16	0.04	0.04	0.04	0.04	0.02	0.00	0.00	0.00	**0.16**
Total				**4.46**	**0.98**	**0.98**	**0.98**	**0.94**	**0.59**	**0.00**	**0.00**	**0.00**	**4.47**

Table 11 Expenditure RIGs mapping

Volumes	Asset Stewardship reports										RIG Table										
Investment description	NAMP Line	2015 /16	2016 /17	2017 /18	2018 /19	2019 /20	2020 /21	2021 /22	2022 /23	Total	RIG Table	RIG Row	2015 /16	2016 /17	2017 /18	2018 /19	2019 /20	2020 /21	2021 /22	2022 /23	Total
EHV BSR of Protection Batteries	1.13.25.6931	76	76	76	74	50	0	0	0	352	CV11	74	76	76	76	74	50	0	0	0	**352**
EHV BSR of SCADA Batteries	1.13.27.6932	77	77	76	74	48	0	0	0	352	CV11	75	77	77	76	74	48	0	0	0	**352**
132 BSR of Protection Batteries	1.13.26.6933	26	26	25	24	14	0	0	0	115	CV11	76	26	26	25	24	14	0	0	0	**115**
132 BSR of SCADA Batteries	1.13.28.6934	26	26	26	24	14	0	0	0	116	CV11	77	26	26	26	24	14	0	0	0	**116**
Total		**205**	**205**	**203**	**196**	**126**	**0**	**0**	**0**	**935**			**205**	**205**	**203**	**196**	**126**	**0**	**0**	**0**	**935**

Table 12 Volume RIGs mapping