Investment Decision Pack NGET_A10.07_Black Start December 2019

As a part of the NGET Business Plan Submission

nationalgrid

Engineering Justification Paper Black Start			
Asset Family	Auxiliary Systems		
Primary Investment Driver	Enhanced network resilience in anticipation of a Black Start restoration standard		
Reference	A10.07 – Black Start		
Output Asset Types	- DC Supply & Distribution Systems (Batteries, Chargers etc.) - AC Supply & Distribution Systems (LVAC switchboards) - Standby Diesel Generator Systems - HV Disconnectors - Metering - HV Circuit Breakers		
Cost	£22.19m		
Delivery Year(s)	RIIO ET2		
Reporting Table	C2.12		
Outputs included in RIIO T1 Business Plan	No		
Spend Apportionment	**T1**	**T2**	**T3**
	N/A	£22.19	£2.35m

Contents

1. Executive Summary

Our stakeholders have told us that they want us to protect the electricity transmission network from external threats such as cyber-attacks, physical attacks and extreme weather, and they want us to be able to quickly recover from incidents if they happen.

This justification paper details our proposed incremental investments of £22.19m (beyond those delivered via our reliability plan) required to create an effective **Black Start Restoration** capability in direct response to our current understanding of the performance requirements identified in the proposed Black Start restoration standard currently being developed by BEIS. This standard is being introduced due to recognition by the government of the increasing reliance of consumers and the whole UK economy upon resilient electricity supplies, and the growing dependence upon electricity for transport and heat through T2 and beyond. Given that the specific details of the standard, and how these obligations will be applied to Transmission companies, have not been defined in detail at the time of this submission, there is a likelihood for further investment beyond the level proposed in this paper, and this risk should be managed through the introduction of an appropriate uncertainty arrangement to provide the necessary funding if and when required.

We do, however, fully expect the new BEIS Black Start restoration standard (based on our involvement with the Black Start Task Group which was tasked by BEIS with developing the parameters for the new standard) to define new, specific, and more stringent requirements with respect to both speed of restoration [redacted] and confidence of an effective restoration of supply, following a Black Start event. We also understand that these requirements will be underpinned with specific new obligations placed on electricity and network companies via the Grid Code, STCs, and where appropriate licenses. It is expected that companies will be expected to sign off their ability to comply with the standard by a specific date (potentially 2022, although this will be dependent upon the level of investment required to meet the requirements of the standard) therefore preparing now for the investment needed is required.

The success of Black Start restoration relies on many participants in the energy sector, working collaboratively in a coordinated effort to restore supplies as directed by the Electricity System Operator (ESO). To effectively meet expected restoration timescales each participant must carry out their Black Start activities in line with the joint plans that they have pre-agreed with the ESO. If they do not, then the whole process may fail.

National Grid Electricity Transmission (NGET), as a participant of the energy sector, has an extremely significant role to play in the event of a Black Start, using its interconnected system to connect generation to demand and support an overall restoration of supplies across England and Wales, and potentially into Scotland. To carry out this role with a high level of confidence during a black start event requires that :

a) each substation that is required to facilitate Black Start recovery must have resilient site electricity supplies that are designed, managed and maintained to provide the capability to remain in service with no external infeed for a defined period of time, so that the site and communication assets continue to operate during a Black Start event and are able to be remotely monitored and controlled to implement the Black Start restoration plans in line with the standards required,
b) the network needs to be capable of meeting the demands of the restoration plans that are required and enacted by the ESO, and must be either configured, or be quickly reconfigurable, to allow the connection of generation and demand within the timescales that are defined within the standard that is applicable at the time

c) control and data centres, with their associated control and communication systems must remain operating, without external electrical infeed, to monitor the network, communicate/coordinate with other Local Joint Restoration Plan (LJRP) participants (including the ESO), emergency services, public bodies, etc, and implement control actions to deliver the Black Start restoration plans sufficient trained staff must be in place within the control centres, and across the transmission network, to carry out the Black Start restoration plans, resolve network issues, coordinate with other participants, and respond to unexpected events that occur during the restoration process.

We consider that the capability we need to meet our existing Black Start obligations is delivered through the investments defined within our Safe and Reliable and Protection from External Threats key stakeholder priorities (eg asset replacement of substation Low Voltage Alternating Current (LVAC) and auxiliary plant, OPTEL communications infrastructure, IT systems, primary and secondary asset management investment, critical staffing etc) – and this is consistent with the submission we made for RIIO-T1. However, to provide the network capability required to comply with the new BEIS standard for Black Start restoration, we will need to invest, as a minimum given the definition of the standard to date, in the following key areas specifically for Black Start during RIIO-2:

i) Robust, high performance assets – through targeted use of higher specification products, (e.g. batteries and associated systems, to give higher performance and a longer service life), and potentially the introduction of auxiliary system redundancy at critical substation sites, and
ii) Enhanced operability - through remediation of technical limitations on existing assets at critical Black Start sites to ensure operability at the enhanced level required to meet the new stringent Black Start restoration obligations.
iii) Enhanced maintenance regime – increased servicing and functional testing (compared to standard policy) of substation auxiliary/LVAC systems and communication systems and associated integrated processes
iv) Preparedness – enhanced training and Black Start simulation exercising for our Transmission Network Control Centre (TNCC) and Operations staff, together with increased switching capacity in the TNCC required to comply with more stringent regional restoration time requirements

These investments are incremental to planned non-load, non-lead investments in primary and auxiliary systems and will be delivered across the RIIO T2 period at a total cost of £22.19m. They provide a step change in capability over RIIO T1, in response to the BEIS sponsored Black Start standard, and we consider these investments to be the minimum ‘no-regrets’ base line level to comply with the standard

There are a number of potential incremental investment areas that we have not included within our business plan at this time, due to uncertainty of the specifics of how the standard will be applied to network companies, which will need further review either in the run up to RIIO-2 or during the period, once we have clarity on the specific requirements and obligations of the new standard and the resultant requirements of the ESO to comply with the standard. These will include, but not potentially be limited to :

- introducing increased redundancy of substation LVAC/auxiliary equipment and systems at sites critical to meeting the black start standard
- implementation of hot-standby control room capability for NGET,
- enhanced contractual relationships/SLAs with third party providers of critical services (such as telecoms) to ensure resilience and support arrangements align with delivery of standards.
- development of primary and secondary network assets (such as synchronous compensation, protection systems, etc) to specifically support the new regional obligations in areas of the network where voltage control, inertia and other challenges may prevent the new standard being met due to lack of availability of appropriate generation.

These remain under review, and in our list of options considered (see section 4. Optioneering) pending further clarity around the obligations to be delivered through the proposed new standard. We will engage further with BEIS and ESO to gain further clarity on these requirements in the coming months, and we therefore believe that an appropriate funding mechanism should be put in place as part of the T2 arrangements to recognise the uncertainty on these elements. In particular, any need for transmission system network development (including introduction of compensation plant) identified by the ESO specifically to support the regional black start standard would need both a new mechanism for triggering the investment and an associated funding mechanism.

Whilst we recognise that the new standard has not yet been formalised, our latest updates from the Black Start Task Group / BEIS is that the new standard is being progressed and that this is still expected to be brought forward by the government following the general election process.

Figure 1 below highlights the Black Start resilience investment defined within this paper in comparison with the other investment areas that are critical for Black Start compliance that are included within other parts of our plan. Investment is required in all areas to enable an effective Black Start restoration.

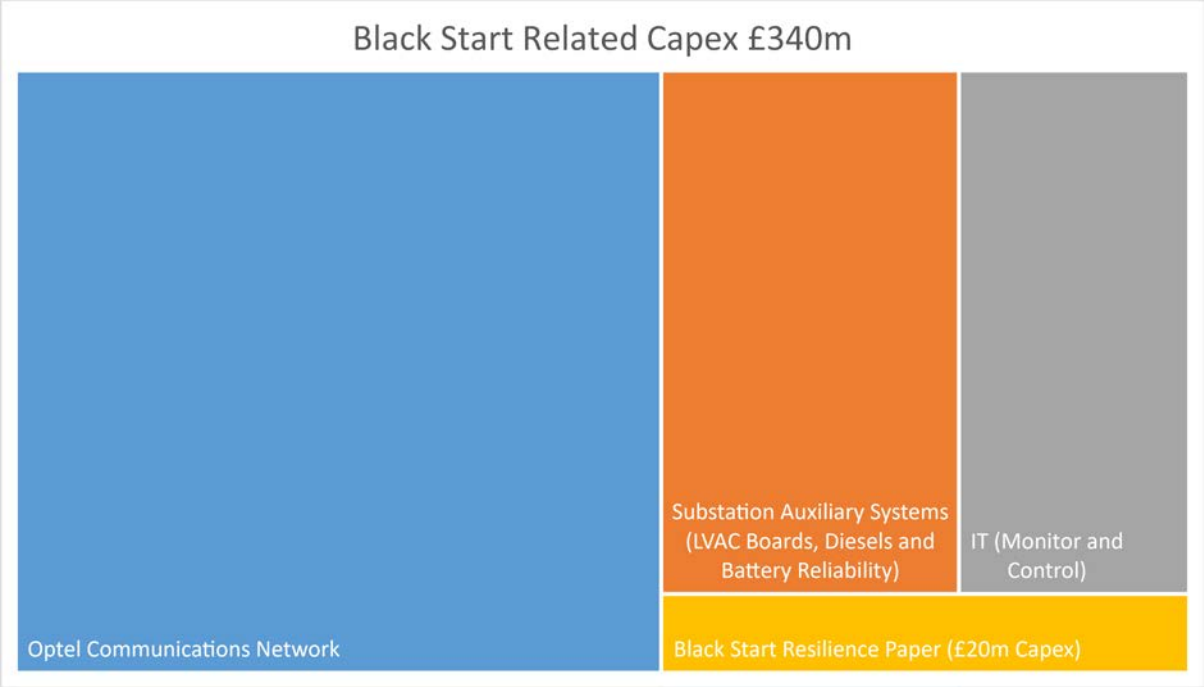

Fig. 1 Black Start related capex. This paper covers £22.19m in additional spend on Black Start resilience. It is part of a wider reliability and resilience investment in systems that enable the day to day function of the transmission network as well as its recovery following loss of regular site supplies.

2. Introduction

'Black Start' is the condition where some, or all, of the power system has lost electricity supply and there is no 'mains' electricity available to consumers, potentially resulting in serious detrimental social and economic impacts if the restoration is not swift enough. Potential causes of a Black Start event include significant generation loss, network fault conditions that exceed normal network security levels, weather related events, or, increasingly, cyber-attack. It is the worst-case scenario for the UK electricity supply industry; the probability of occurrence is low, but the potential consequence is severe. Black Start restoration is the process whereby the electricity system is restarted following such an event, with restoration of the electricity transmission system being a critical component of this process.

The success of Black Start restoration relies on many participants in the energy sector, working collaboratively in a coordinated effort to restore supplies to consumers. National Grid Electricity Transmission has a significant role to play in the event of a Black Start, using its interconnected system to connect generation to demand and support a coordinated restoration of supplies. With Great Britain being an island we are totally reliant on our own processes and capabilities to deliver a Black Start restoration, and cannot rely on the use of interconnection from other countries or regions to support a restart (as has been seen with other international Black Start events).

This justification paper details our minimum planned investment to enhance the resilience of our assets required in a Black Start event to meet new standards being introduced by BEIS and the additional investments that may also be required once the further details of the definition and application of the standard become available. This new standard aims to improve the resilience of the electricity network to ensure timely restoration of supply [redacted] to minimise impact on end consumers.

Our Approach

To meet the requirements of the proposed new BlackStart restoration standard, we are currently proposing to invest (beyond those investments that support our Black Start capability defined within the Safe and Reliable key stakeholder priority) to provide 'a high degree of confidence' in achieving the expected BEIS standard. Further investment (eg in substation and control centre redundancy) may also be justified once the full requirements of the new standard are known.

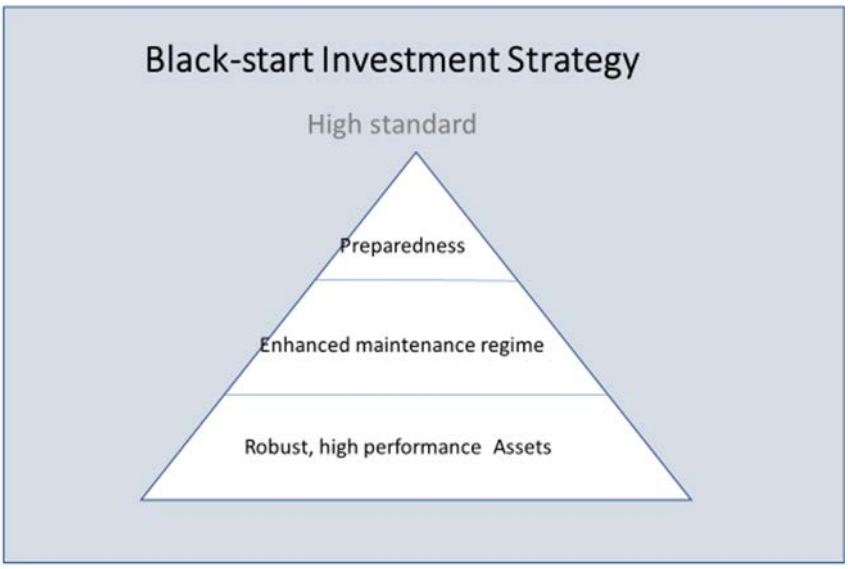

Fig 2: Black Start Investment Strategy

Should a Black Start situation occur, the overall management and coordination of the restoration is carried out by the Electricity System Operator (ESO), and enacted through a number of LJRPs that are pre-agreed with the relevant Transmission Owners, Generators and Distribution Network Operators within each LJRP zone. There are currently 15 LJRPs defined for England and Wales, and a further 2 for Scotland, but the number, location and defined processes may vary over time. As the Transmission Owner for England and Wales our focus areas to ensure we comply with the proposed obligations during a restoration are:

i) equipment at each substation site within each LJRP (and where appropriate on the wider network) is scoped, managed and maintained to meet a level of resilience that aligns with our Black Start restoration obligations. Generally, this means that each substation must have resilient site electricity supplies that are capable of remaining in service with no external infeed for a defined period of time. This ensures that the site and communication assets continue to work correctly and are able to be remotely monitored and controlled to implement the restoration plan

ii) the network needs to be capable of meeting the demands of the restoration plans that are required and enacted by the ESO, and must be either configured, or be quickly reconfigurable, to allow the connection of generation and demand within the timescales that are defined within the standard that is applicable at the time. Generally the means that the network design supports the requirements of the black start plans and that the status of site equipment is remotely visible and is remotely operable

iii) IT, control and communications systems, as well as our control and data centres, are specified and managed appropriately; they must remain operational, without external electrical infeed. This enables us to monitor the network, communicate/coordinate with other participants, and implement control actions to deliver the restoration plans during a Black Start event

iv) sufficient trained staff must be in place within the control centres, and across the transmission network. This enables us to execute the Black Start restoration plans, resolve network issues, and respond to unexpected events that occur during the restoration process

v) effective, well understood and tested processes and procedures are in place to allow compliance with our obligations

Following the introduction of the expected Black Start standard, we believe that the level of resilience required to meet the enhanced obligations will be higher than that delivered through the Safe and Reliable plan alone. We are therefore seeking specific targeted incremental Black Start funding to meet this requirement.

A range of options is available to improve confidence around levels of network resilience for Black Start (discussed later in the optionality section) but the proposals below details our current view of the best overall balance between the levels of resilience that consumers have said that they want, and the cost of delivering that resilience (although this may change as we get more clarity on the specific requirements of the standard and how it will be enacted upon network companies).

Robust, high performance assets: -

The specific focus areas for this element of the investment is the resilience and capability of substation LVAC/auxiliary systems, and resolution of existing technical limitations on transmission assets. These can be summarised as:

- Introduction of enhanced battery ‘switch mode’ technology at sites deemed critical for Black Start restoration [redacted] which is robust to higher temperature variations, has an inherently robust design (i.e. less failure modes), which deliver greater performance and a longer service life than standard battery technology, and therefore a greater confidence in resilience to support Black Start restoration process.

- Fuel polishing equipment for diesel generators on critical LJRP sites [redacted] which significantly mitigates the risk of fuel contamination issues preventing the diesel generator from auto-starting during a black start event.
- Resolution of existing technical limitations on NG assets (mainly HV disconnectors, circuit breakers, protection and metering equipment) at sites critical for Black Start Restoration will ensure remote network reconfiguration and switching to meet LJRP processes can be achieved within the timescales required in the new standard. For efficiency reasons, we accept a level of operational limitation caused by minor equipment malfunction and failure, without significant detriment to the levels of operational performance under normal network conditions. In a Black Start situation, however, these technical limitations would lengthen the time required to restore demand as they prevent or slow the required reconfiguration of the network to meet the LJRP. A definite time for restoration being implemented through the new standard, and that also being applied regionally, means that the existing acceptance of a level of technical limitation would not suffice and we will need to ensure that we remove limitations of this nature within LJRP areas, hence the need for a level of investment for managing technical limitations that is higher than that needed to meet normal reliability requirements.

Enhanced maintenance regime: -

The adoption of an ‘enhanced maintenance regime’ for critical LJRP sites, involving an increased quality and frequency of functional testing and servicing (compared to standard policy), will provide the required level of confidence in the resilience of auxiliary systems.

A Black Start restoration is reliant on the successful operation of critical substation systems. Regular maintenance and testing plays a crucial role in ensuring assets are performing at the required level to give necessary confidence that assets will perform effectively under Black Start conditions. Implementing an enhanced testing regime is resource intensive due to the level of preparatory work required to ensure that the testing is valid and that there is no detrimental impact on the live system. It is essential that we exercise critical substation auxiliary systems under simulated Black Start conditions (whilst recognising the need to maintain security of supply) to provide assurance that assets will perform when called upon to do so under Black Start conditions.

An interval based maintenance policy is carried out on auxiliary system assets. For example, a periodic battery inspection is implemented in addition to a major maintenance activity where early indications of potential problems (cell leakage, pillar corrosion) can be identified visually by experienced operatives. More detailed diagnostic testing identifying any excessive variations in cell voltages, temperature and in the case of Planté cells, electrolyte level and specific gravity are all valid warning signals which currently prompt further investigation.

Contracted maintenance is employed on standby diesel generator assets for major and minor maintenance activities. This is supplemented by a routine diesel operational test run at 3 and 6 monthly intervals, off load and on-load respectively. It is desirable to initiate the on-load diesel test run by simulation of loss of incoming supply rather than using load banks.
Key areas of activity include: -

- Greater exercising of diesel generators by the simulation of a ‘loss of supply event’, which will test the execution of the auto-changeover control system and identify any potential ‘single point of failure’. This will enable corrective action to be made in a controlled environment.

- Introduction of controlled battery discharge tests will enable an on-site capacity assessment of each battery system to be performed. This is the only true method of evaluating battery capacity and will provide early identification of issues that require intervention to maintain required resilience levels.

Operational preparedness: -

There will be an enhanced requirement for operational expenditure within RIIO T2 which is required to meet the expected standard through training, exercising and development of support systems. For an extreme event, such as Black Start, staff do not gain the experience and skills required to successfully manage an incident through their normal activities. Training and exercising is therefore essential to bridge the gap for staff to gain the necessary skills and confidence to manage a Black Start event.

For TNCC staff, regular training and exercising needs to be carried out in the execution of Black Start plans and in the procedural aspects of managing Black Start restoration.

For Operational teams, there is a need for regular exercises to gain experience of the incident management procedures and functioning of the various response teams.

National Grid plan to recruit an additional [redacted] specialist control room resources, and dual authorise a further [redacted], in the TNCC to allow more simultaneous switching activities which will contribute towards the required regional and national restoration times required under the expected Black Start standard.

All of the additional operational costs will extend beyond the T2 period as the arrangements we are putting in place will be required long term to meet the standard obligations.

The replacement of the monitoring, control and communication IT systems utilised by the TNCC is critical to the safe and effective management of a Black Start event. These investments are planned during the RIIO T2 period and are included in the ET Direct IT investment plan. The costs for these investments are therefore **not** included within this paper.

Summary

The following table shows the proposed volumes and costs of interventions in RIIO-T2 specifically to support the higher confidence levels required to deliver compliance with the proposed expected BEIS Black Start standard. The table is split into the three key investment areas of; robust high performance assets), enhanced maintenance and enhanced preparedness. All other investment that supports NGET in delivering effectively in a Black Start restoration situation is delivered through the Safe and Reliable plan (and noted within the relevant Justification Reports).

Robust, high performance assets (CAPEX)	AC/DC Batteries – High performance technology	[redacted]	Robust design and higher service life mean that 1) assets will be operate more reliably when required, and 2) assets will operate for longer with no external supply	£6m
	LVAC power electronic (SMPS) battery chargers	[redacted]	Robust design and higher service life mean that 1) assets will be operate more reliably when required	£3.6m
	Standby Generator fuel polishing	[redacted]	Minimise risk of standby generator not starting due to fuel contamination under blackstart conditions	£0.8m
	Remediation of TLs - disconnectors	[redacted]	Minimise accepted risk position in critical LJRP areas in order to meet requirements of the standard.	£3.3m

	Remediation of TLs – metering, indication, control	[redacted]	Minimise accepted risk position in critical LJRP areas in order to meet requirements of the standard.	£6.3m
TOTAL				£20.1m

(*Table 1)*

Enhanced Maintenance (OPEX)	Battery discharge testing	£0.3m
	Diesel generation operational testing	£0.5m
Enhanced Preparedness (OPEX)		
	Additional TNCC staffing	£1.38m
TOTAL		£2.18m

(Table 2)

3. Background Information

Criticality of substation auxiliary supplies

Following a major system disturbance, when large parts of the GB electricity system may be without power, the reliability and availability of substation auxiliary supplies play a critical role in the restoration of the network back to a normal state, as the capability to monitor and operate substation equipment without the requirement for a mains supply underpins the delivery of the LJRP. Key auxiliary systems that will be called upon in the event of a Black Start include:

a. *DC Batteries Supply and Distribution Systems* – Substations require DC supplies for powering telecommunications and other light current equipment (48V) and for the operation of protection and control equipment including operation of circuit breakers (110V). These supplies are derived from a battery systems comprising of batteries, battery chargers, and a DC distribution system. In the event of a loss of supply incident, several critical systems will need to continue to operate; 110V & 48V batteries will be required over an extended period of time to provide power for protection, control and communications, in order to monitor the system and initiate switching to reconfiguration the network.

b. *LVAC Batteries Supply and Distribution Systems* – Substation LVAC systems play a critical role in normal transmission operation and in the restoration phase following a system failure. LVAC systems provide substation auxiliary power for equipment such as transformer tap changers and cooling, air compressors, switchgear drive motors, and site battery chargers. Most substations only have one critical LVAC switchboard.

c. *Standby Diesel Generators* – Substation diesel generators are crucial in maintaining LVAC auxiliary power during a supply failure and for maintaining battery charging. An auto-changeover facility will connect the standby generator within minutes to limit the disruption until such time that the supply is restored. In practical terms, the on-site generator can support the site load almost indefinitely, subject to reliability and fuel replenishment. Levels of on-site fuel storage vary depending upon site criticality from an initial period of 52-hours continuous running to 168hrs. Most sites only have 1 standby generator.

d. *Communications* are vital to Black Start restoration. National Grid has its own private communication systems (referred to as Optel), which supports voice communications and the monitoring and remote control of substations. The resilience of key communications circuits, which form part of protection schemes between substations are essential to facilitate the safe re-energisation of the electricity network. The ability to recover successfully from a Black Start event also requires resilient voice communications.

The importance of providing resilient and reliable substation auxiliary systems was highlighted in 2018, when the loss of site LVAC supplies at Chickerell Substation was a contributing factor to the time taken to restore 34MW load to SSE, following the disruptive failure of a 400kV circuit breaker.

The duration of the loss of supply to the Weymouth and Dorchester area was for a period of approximately 70 minutes. This incident was reportable under the 'Energy Not Supplied' Incentive at a loss of 39.7MWh. It is believed that this duration would have been significantly reduced had the LVAC supplies been available through the incident.

Investment during T1

RIIO T1 proposals did not include specific allowances to enhance our resilience or reliability beyond existing accepted Black Start restoration levels. There was no formal requirement to meet specific target restoration targets, however as a responsible Transmission Owner we have invested to ensure we can respond effectively during a Black Start event. National Grid has invested in managing asset health replacement activity within RIIO T1 to maintain an accepted level of reliability of assets and to reduce the risk of loss of supply. Training of TNCC and substation employees has been undertaken to enhance our Black Start capabilities and confidence to respond to an incident. Regular operational test scenarios are conducted to ensure our employees are sufficiently knowledgeable and able to respond.

Criticality of effective Black Start restoration process to the UK

The implications of a Black Start event on UK consumers and the economy are potentially extremely severe, and in response to this BEIS have set up the Black Start Task Group (BSTG) with the aim of

a) building an understanding of the electricity industry's current ability to respond and recover from an incident in which a large-scale loss of supply occurs, and
b) developing a new standard for energy and network companies which will carry firm obligations defined within codes and/or licences to ensure a 'high level of confidence' in meeting specific supply restoration targets.

NGET has been represented on the group and recognises both the desired aims of the standard, and the cost benefit analysis carried out by BEIS which supports the proposed standard outcome. The investments identified within this paper are a direct response to the expected obligations within the standard at the current stage in its development.

The BEIS CBA, and therefore the proposed standard, takes into account the growing reliance on electricity in all aspects of people's lives, with the increasing importance of technology underpinning the economy, and the growth of electrification of transport and in the future potentially heat as well. This has also been highlighted by several other groups and panels, notably the Lancaster Flood Report and the recent Energy Research Partnership document on 'Future Resilience of the UK Electricity System'; the understanding in this area will undoubtedly continue to evolve during the T2 period and beyond.

External Landscape

The energy landscape we are operating in has changed significantly through T1 and will continue and potentially accelerate through T2 and into T3. From a Black Start perspective the critical aspects for NGET are the evolving generation and demand patterns on the network that change the relevant importance and roles of different substations and elements of the network, the evolution of the LJRPs which mean that the processes we need to follow, and therefore preparedness processes, need to be continually updated. The growth of threats such as cyber-attack are driving significant change in the way we prepare for future resilience. With the growing threat of cyber-attack, it becomes increasingly credible that an attack on the transmission system could result in a Black Start event, as seen in Ukraine in 2015.

Recent international incidents highlight the diversity of causation and consequences of a loss of supply and Black Start event:

Ukraine – December 2015. A cyber-attack seized control of SCADA systems, switching out 30 substations, resulting in loss of supply for 230,000 consumers for a period of between 1-6 hours, with a total of 73MWh not supplied.

South Australia - September 2016. A severe storm resulted in damage to transmission infrastructure. The resulting cascade failure of the transmission network, which was also linked to the rapid increase in reliance on wind generation, resulted in almost the entire state losing electricity supply. The restoration was initiated using inter-state interconnectors, with the metropolitan area of Adelaide restored in 3-6 hours, however many areas could not be restored within 24 hours, and overall 1.7m people were impacted.

Venezuela – March 2019. Between 7 - 14 March most of Venezuela's 23 states were without electricity, including the capital Caracas. The incident caused serious problems for hospitals, industry, transport and in water and communications services, resulting in a number of deaths and contributing to further civil unrest. The Venezuelan government cited sabotage as the cause of the incident, although others have attributed the cause to under-investment and a lack of maintenance.

Argentina/Uruguay – June 2019. On 16 June a widespread power outage impacted most or Argentina, Uruguay and parts of Paraguay, resulting in a loss of electricity supply for an estimated 48m people, which is currently believed to have been caused by a combination of transmission system outages and faults. Hospitals, transportation, water and communications services were all adversely impacted. It is reported that supplies were restored to most of Argentina within 12 hours, and that supplies were fully restored within 24 hours.

These and other incidents highlight the significant social and economic impact of a widespread loss of electricity supply, and the knock-on impact to other sectors, including healthcare, transport, water and communication services.

4. Optioneering

To achieve our obligations in the new BEIS Black Start standard, we must ensure we have resilient and fully operable assets with a high confidence that they will work first time, and remain in service, during a Black Start event. We must also have effective management systems and processes, appropriate contractual relationships with suppliers, and competent, trained and well prepared staff in place. Our Black Start investment strategy will ensure that we are investing in the appropriate areas to meet the high confidence levels set by BEIS to allow the target restoration times for the industry to be met, however as the details of the standard, and the obligations proposed for the network companies emerge more clearly over the next 12 months the level and type of investment required may change significantly.

We have outlined below the cost and benefit detail of various options and the option to do nothing.

1) Do nothing **(REJECTED AS THIS WILL NOT GIVE US CONFIDENCE OF BEING ABLE TO COMPLY WITH THE REQUIREMENTS OF THE STANDARD AS CURRENTLY UNDERSTOOD)**

2) Incremental investment to increase robustness resilience of specific critical assets coupled with an enhanced maintenance and preparedness regime to increase confidence that equipment and processes will work when needed **(PROPOSED IN THIS PAPER AS IT WILL ALLOW A STEP CHANGE IMPROVEMENT TO ALIGN WITH CURRENT UNDERSTANDING OF STANDARD REQUIREMENTS)**

3) As 2, plus introduction of 'plug and play' technologies and strategically located spares, for the situation where Black Start restoration cannot commence within the available 'life' of substation

batteries and diesel generator fuel supplies **(REJECTED DUE TO CONCERNS OVER PRACTICAL APPLICATION DURING BLACK START CONDITIONS)**

4) As 2, plus further review of auxiliary asset redundancy requirement and implementation at all substations deemed critical for black start restoration to enhance confidence of meeting obligations, plus changes to third party contractual relationships for critical services, plus creation of second 'hot' NGET control centre to ensure availability at all times, **(REJECTED AS ADDITIONAL COST NOT CURRENTLY JUSTIFIED FOR INCREASE IN CONFIDENCE DELIVERED)**
5) Modification of primary network, and introduction of primary network assets such as synchronous compensation, to support the delivery of the regional elements of the proposed standard **(REJECTED AS REQUIREMENTS FROM THE ESO HAVE NOT BEEN DEFINED IN APPROPRIATE DETAIL AND EXISTING NOA MECHANISM TO TRIGGER WORKS IS NOT APPLICABLE TO BLACKSTART RELATED INVESTMENT – NOT INCLUDED IN TABLE BELOW AS IT IS A SEPARATE INVESTMENT AREA)**

Option	Cost	Pros	Cons
1. Do nothing	*£0*	*No Cost (above investment level delivered through reliability plan)*	*Uncertainty/ risk over restoration performance*
2. Incremental resilience investments and increased preparedness	*£22.19m*	*Significant increase in confidence on meeting restoration timescales*	*Expenditure required to improve confidence of resilience to align with expected BEIS standard*
3. As above plus plug and play technology	*£30.19m (£22.19m + £8m)*	*Opportunity to provide additional resilience for sites where permanent redundancy not implemented*	*High risk over ability to transport equipment to sites during a black start event*
4. As 2 plus asset redundancy and 2nd hot control centre	*£52.19m (£22.19m + £30m + 2nd control centre cost)*	*Wide implementation of redundancy increases confidence on delivery of 100% commitment beyond LJRPs. Second Hot control centre provides resilience against loss of TNCC due to electricity supply or other failure modes and allows diversity of LJRP delivery to meet timing commitments*	*High cost and timing to deliver 2nd control centre and associated infrastructure both from a CAPEX and ongoing OPEX perspective. Increased site redundancy beyond LJRPs incurs ongoing OPEX commitment.*

5. Detailed Analysis & CBA

The driver of these investments is the Black Start that is being introduced by BEIS and, therefore, as mentioned above a 'do nothing' option will not be acceptable as we currently do not expect to have sufficient confidence in the resilience required to meet the rapid regional restoration target without the asset intervention detailed above as the level of resilience required from the standard, and the confidence of delivery, is higher than that delivered through our normal reliability related investment (which we currently rely on to underpin our Black Start capability).

Through the Black Start Task Group, led by BEIS, a CBA was carried out to help define the level that the new standard should be set at. Once the standard is published, and the application of that standard to the TOs is defined, we will use cost benefit analysis to assist in ongoing prioritisation of work throughout the RIIO T2 period to ensure we are delivering greatest benefit by completing works as soon as possible and we work in efficiencies by combining investments with other work being undertaken on sites.

Prioritisation of LVAC / auxiliaries' investment will be based on:

1. Ensuring all sites comply with minimum policy requirements, taking account of Optel and other dependencies
2. Known implications of a site for LJRPs and/or skeleton network restoration
3. Condition and remaining life assessment of existing assets
4. Interaction with some other schemes, which may require modifications to auxiliaries, and/or provide expedient opportunities to work on certain assets

Prioritisation of technical limitations will be based on:

1. Whether a site is part of an LJRP, or early skeleton network restoration plans
2. An assessment of the probability of a specific TL being an impediment to restoration switching
3. The complexity and feasibility of the technical solution
4. Availability of outages

Our current assumption, underpinning the numbers provided in this paper is that work will encompass activity at [redacted] different sites with the interventions have been selected on the basis of system criticality. The overall level of intervention is our considered view of the minimum level that will be required to align with the expectations of the standard, and further intervention may be required beyond this level should the definition of the standard be more robust that currently envisaged. The most critical sites fall into one or a number of the following categories in the table below. Different activities may occur in different locations depending on the ownership of standby generator supplies and the presence of technical limitations.

Activity	Designated Black Start Sites – locations that are critical to the restoration of the wider system	Sites with key national infrastructure (Nuclear, Traffic Hub, COMAH Site, Economic Key Point)	Sites with high criticality to System Security	Total
Batteries – High Performance Technology and LVAC Power Electronic Chargers	[redacted]	[redacted]	[redacted]	[redacted]
Standby Generator Fuel Polishing	[redacted]	[redacted]	[redacted]	[redacted]
Technical Limitations	[redacted]	[redacted]	[redacted]	[redacted]
All Activities split across…	[redacted]	[redacted]	[redacted]	[redacted]

Note: A detailed list of sites is available upon request via a secure source. These have not been provided in the paper due to the security sensitive nature of these investments

Unit costs have been taken from the National Grid Cost Book (based on work delivered) for technical limitations (disconnector refurbishment and metering replacement). For batteries and chargers, unit costs have been based on a reasonable assumption of incremental unit cost as the technologies will be more expensive than the current unit cost of [redacted] (which includes battery room refurbishment to bring these into line with modern standards).

Costs in the Business Plan Data Table C2.12 include all direct capex costs at [redacted] of the amount declared within this paper. Also included is the incremental opex only which includes

- Battery discharge and diesel generator testing
- Training and retention of new full time employees in the Transmission Network Control Centre to increase switching capability

6. Key Assumptions, Risk and Contingency

- Following an event that leads to the initiation of the Black Start restoration plan,
  - the transmission system is in a physical condition that allows immediate re-energisation, i.e. no, or only minimal, remedial action is required to repair faults or disruption on the network that prevent implementation of our Black Start restoration plans.
  - The IT, communication systems and control centres remain available and operating normally to allow immediate re-energisation, and if the event is caused by a cyber-attack, this does not delay our implementation of the black start restoration strategy.
- The new BEIS Black Start Standard, and any other relevant legislation, aligns with our current understanding of the approach (and remains like that for whole of T2). For example, shorter or significantly longer obligatory restoration times would require alternative investments and preparedness processes.
- The number (15 within E&W, and 2 in Scotland) and location of LJRPs are broadly aligned with current definition. It would change the investments we need to make if these changed significantly.
- The ESO approach to Black Start restoration remains broadly consistent with current strategy throughout T2.
- Events do not occur, either in UK or elsewhere, that significantly change our/customers/stakeholders risk appetite, and therefore the capabilities and level of investment required to respond to that.
- The developing cyber landscape doesn't require a fundamental rethink of our approach for managing Black Start events through T2.
- The UK Energy landscape remains broadly as it is now, or as currently forecast (evolution of generation background, company ownership, customer requirements, interface with EU, etc).
- The development of the NGET transmission system and the systems we interact with align with current forecasts for T2 period.
- No significant equipment issues occur through the T2 period (OESBs, legal obligations, etc) that impact how we use our equipment.
- Other critical equipment investments and interventions that are required to meet our Black Start obligations are delivered as proposed in our Safe and Reliable priority (notably substation auxiliary interventions for LVAC, batteries, diesels, etc, communication systems, IT systems, security, weather protection, cyber enhancements).
- No specific primary transmission network interventions are required by ESO to allow the regional obligations to be achieved (for example. the SO does not require us to construct synchronous compensation or other equipment to specifically meet the needs of Black Start restoration in a particular region due to lack of available or appropriate generating plant).

7. Conclusion

Threats against our network are growing and it is becoming evident that there is an increasing reliance on a reliable and resilient electricity network. This is driven, in part, by the growing interdependence between networks and other sectors including, water, communications, and transport. This interdependence will increase in the future as we seek to decarbonise heat and migrate to electric vehicles.

BEIS recognise the increasing socio-economic impact of a widespread and prolonged loss of electricity supply incident, and are moving to introduce a new Black Start standard. This will introduce a new target restoration time, and accompanying audit and monitoring regime, to provide 'a high level of confidence' that the standard can be achieved.

To achieve a 'high degree of confidence' of meeting these target restoration times, we propose the following deliverables within RIIO T2;

- 30% reduction of technical limitations on assets critical to Black Start restoration
- Replacement of existing substation battery and charger systems with more advanced technology and diversity of types to improve resilience at critical sites
- Introduction of fuel polishing technology at critical sites
- Enhanced maintenance and testing at critical sites
- Enhanced Black Start training and exercising of site and control room engineers

These investments will be delivered over the five year RIIO T2 period at a cost of £22.19m.

High level costs for the proposed investments are set out in the table below. This includes both Capex and Opex.

		2021/22	2022/23	2023/24	2024/25	2025/26
BLACK START PREPAREDNESS	TOTEX	4.3**9**	4.3**9**	4.4**7**	4.4**7**	4.4**7**

8. Outputs included in RIIO T1 Plans

N/A