Scottish & Southern Electricity Networks

SSEN Transmission

RIIO-T2 Business Plan T2BP-EJP-0008

# Substation Resilience – Low Voltage Supplies Engineering Justification Paper

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# 1 Executive Summary

The "Substation Resilience – Low Voltage Supplies" project will ensure that SHE Transmission substations have LV supplies – both AC and DC – which are sufficiently resilient both in terms of autonomy and diversity of supply. This project has been primarily driven by the need to ensure the ongoing resilience of the SHE Transmission Network.

SHE-Transmission will carry out the following works to ensure LV systems resilience:

| Achieving Resilience of LV Supplies at Core Substations | Number of sites |
|---|---|
| **Work required due to LV Supply Autonomy** | 70 |
| **Work required due to LV Supply Diversity** | 5 |
| **Work required due to LV Supply Autonomy & Diversity** | 17 |
| **TOTAL SITES REQUIRING RESILIENCE IMPROVEMENTS** | **92** |
| **Total Core Sites** | **116** |

Table 1 - Summary of Proposals

This will be achieved through the diverse replacement, upgrade, and addition of batteries, chargers, LVAC boards, and standby generators.

The cost to deliver the above option is £48.93M. These costs have been derived through Supply Chain engagement and utilising rates from previous tenders.

Upon completion, this project will deliver several benefits relating to the RIIO-T2 business goals and other standards as follows:

- 120 hours of resilience as standard, meeting the minimum required 72-hour reliance as stipulated in the ENA ER G91 guidance and proposed BEIS and Scottish Government recommendations.
- Increased security of supply due to a diverse mix of LV supply options. Capitalising on SHE Transmission's goal to aim for 100% network reliability for homes and businesses
- Allowance for auxiliary load growth due to added Protection and Communications projects allowing these projects to deliver their benefits.

This scheme is not flagged as eligible for early or late competition due to it being under Ofgem's £50m and £100m thresholds respectively.

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| | |
|---|---|
| **Name of Scheme/Programme** | Substation Resilience – Low Voltage Supplies |
| **Primary Investment Driver** | Resilience |
| **Scheme reference/ mechanism or category** | SHNLT2041 |
| **Output references/type** | NLRT2SH2041 |
| **Cost** | £48.93m |
| **Delivery Year** | 2021-2026 |
| **Reporting Table** | C2.12_Black_Start |
| **Outputs included in RIIO T1 Business Plan** | No |

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## 2 Introduction

This Engineering Justification Paper sets out our plans to undertake substation LV supply upgrade work during the RIIO-T2 period (April 2021 to March 2026).

**3** The Engineering Justification Paper is structured as follows:

**Section 3: Need**

This section provides an explanation of the need for the planned works. It provides evidence of the primary and, where applicable, secondary drivers for undertaking the planned works. Where appropriate it provides background information and/or process outputs that generate or support the need.

**Section 4: Optioneering**

This section presents all the options considered to address the need that is described in Section 3. Each option considered here is either discounted at this Optioneering stage with supporting reasoning provided or is taken forward for Detailed Analysis in Section 5.

**Section 5: Detailed Analysis**

This section considers in more detail each of the options taken forward from the Optioneering section. Where appropriate the results of Cost Benefit Analysis are discussed and together with supporting objective and engineering judgement contribute toward the identification of a selected option. The section continues by setting out the costs for the selected option.

**Section 6: Conclusion**

This section provides summary detail of the selected option. It sets out the scope and outputs, costs and timing of investment and where applicable other key supporting information.

**Section 7: Price Control Deliverables and Ring Fencing**

This section provides a view of whether the proposed scheme should be ring-fenced or subject to other funding mechanisms.

**Section 8: Outputs included in RIIO-T1 Business Plan**

This section identifies if some or all the outputs were included in the RIIO-T1 Business Plan and provides explanation and justification as to why such outputs are planned to be undertaken in the RIIO-T2 period.

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# 3 Need

SHE Transmission currently owns and operates 146 substations. Our substations have Low Voltage (LV) systems to provide the auxiliary power necessary to run the network. These supplies are brought in as an alternating current (AC) supply, from a range of different sources depending on the location and nature of the site. These are supported by provision of direct current (DC) systems, which ensure supply continuity through both short-duration disturbances as well as prolonged supply interruptions such as a Black Start event. A simplified diagram of the LV auxiliary systems in a typical substation is shown in Appendix A.

SHE Transmission define a "Resilient" or "Core" substation as one where any of the below are true:

- Substations that form part of the Main Interconnected Transmission System (MITS)
- Substations that provide connection to domestic load customers
- Substations feeding a single customer via more than one radial feeder
- Substations at all ends of a multi-ended circuit, other than two-ended circuits
- Substations providing a connection to a generator which provides Black Start services
- [redacted]
- Substations which carry communications traffic for other Core Substations

SHE Transmission has 116 substations which meet our definition as a "Core Substation".

## 3.1 Resilience

Following a UK government and UK electricity industry review of the ability of the UK to respond to a Black Start event (Exercise Phoenix, 2006) the Energy Emergencies Executive Committee (E3C) recommended in 2010 that 'core' substations should be resilient against loss of system supplies for a period of 72 hours, which was formalised in the Energy Networks Association Engineering Recommendation (ENA ER) G91. This was deemed to be the duration that may be required to achieve a full system restoration following a Black Start event.

## 3.2 Levels of Autonomy

In 2018, the Scottish Government commissioned a report looking at the impact of a Black Start event[1]. It considered that the "economically efficient recovery standard" in the event of a Black Start was 120 hours (5 days). This was determined using central assumptions of Value of Lost Load (VoLL) and event likelihood, and assuming least cost measures are used. It was delivered through a combination of

[1] Black Start Event – Assessment of the Socio-Economic Costs and Recovery Standards for Scotland. E&Y, 2018

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retro-fitting black start capability to existing thermal generation at Peterhead and installing new reactive compensation at strategic points on the network.

The geography of the SHE Transmission network area is a diverse one, with many substations being in isolated and difficult-to-reach locations. Changing weather events can also cause access difficulties in emergency situations. We have previously experienced significant network events whose duration has been extended because of geographical issues.

Recently, the Department for Business, Energy and Industrial Strategy (BEIS) have issued a revised standard which recommends "the introduction of a Standard that will set a maximum restoration timeframe of 24 hours for the restoration of 60% of regional electricity demand and; 5 days for the restoration of 100% of electricity demand, at all times"[2]. Indeed, the Black Start Task Group has also stated that recent modelling has suggested that restoration can take up to 8 days.

Recognising all of these factors, the updated edition of the SHE Transmission LVAC specification goes beyond the ENA ER G91 recommendation of 72 hours, stipulating any new "Core Substation" on the SHE Transmission system shall achieve 120 hours of autonomy. This increased autonomy was supported by our Stakeholders during a March 2019 Stakeholder Workshop.

### 3.3 Legacy Sites

Under previous engineering specifications and design standards, any new SHE Transmission substation built during the RIIO-T1 period achieved 72 hours of autonomy in line with ENA ER G91. However, the SHE Transmission network still contains a number of sites constructed prior to the application of these standards. These legacy sites generally contain batteries designed for a much shorter autonomy period, often without standby generation, and were also designed around legacy substation auxiliary loads. As such, many older DC auxiliary systems are now under-sized for the required level of autonomy.

### 3.4 Interdependencies

The works identified in this paper are interlinked with and will support the following programmes of work:

- Protection Modernisation (T2BP-EJP-0005), required to meet STCP 27-01 implementation which will allow the substation to provide real-time and post-event monitoring for the System operator.
- Transmission Communications Upgrades (T2BP-JPS-0006), which outlines out intention to upgrade our communications network, including the integration of secure data network connections into all substations.

[2] BEIS BSTC/0219/03 Black Start Standard

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- SCADA Upgrades (T2BP-JPS-0007), which intends to develop each substation in its target list to become enhanced with the latest cyber security and operate in line with the IEC 61850 Standard, a communications protocol for intelligent electronic devices that requires fibre network connections inside substations.

- Personnel Communications (T2BP-JPS-0009), which outlines the requirement for the implementation of a Voice over Operational Technology Network (VoTN).

- Integrated Condition & Performance Monitoring (T2BP-JPS-0012), which outlines the work required to allow real time monitoring of asset condition and performance to enable improved decision making and investment planning.

### 3.5 Diversity of Supply

SHE Transmission also designs its substations to have diverse sources of LV auxiliary supplies. These are typically derived from either auxiliary transformers within SHE Transmission substations or in-feeds from the local Distribution Network Operator (DNO). Diversity of these supplies is important to ensure that substation auxiliaries are still supplied even when one supply is unavailable, both for planned and unplanned events (maintenance or faults). SHE Transmission specifications require two diverse supplies for a Core substation, over and above a standby generator installed locally to maintain supply to non-essential systems and to avoid unnecessary running of standby generation.

The source of these supplies is important during a Black Start event. Although SHE Transmission specifications stipulate designing for 120 hours resilience, it is preferable for a normal auxiliary supply to be restored quickly as this prevents excessive battery discharging as well as restoring non-essential systems and functionality to the substation. Minimising the running time of standby generators is also aligned with SHE Transmission's strategic theme of "Leadership in Sustainability", and feedback from stakeholders on the importance of considering the environmental impact of any work. For this reason, these supplies shall be derived from the transmission network where possible, as this will be rebuilt most quickly following a Black Start event. The new edition of the SHE Transmission LVAC specification mandates this requirement and gives an order of preference for all auxiliary supplies as indicated in [redacted]

Substations which are dependent wholly on DNO supplies may be without an auxiliary supply for some time as DNO restoration will naturally take longer and, based on the supply restoration plan for a Black Start, much of the DNO networks in rural areas covered by SHE Transmission where the local DNO will be a lower priority for re-energisation.

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| Hierarchy of Options | First Supply | Second Supply | Standby Supply |
|---|---|---|---|
| **1** | GT-ET | GT-ET | Standby Generator |
| **2** | SGT-ET | SGT-ET | Standby Generator |
| **3** | GT-ET | SGT-ET | Standby Generator |
| **4** | GT-ET | DNO | Standby Generator |
| **5** | SGT-ET | DNO | Standby Generator |
| **6** | PVT | DNO | Standby Generator |

Table 2 - Hierarchy of Options for LV Supplies at Core Substations

(GT-ET – Grid Transformer Earthing Transformer, SGT-ET – Super-Grid Transformer Earthing Transformer, PVT – Power VT, DNO – Infeed from Distribution Network Operator)

While most SHE Transmission substations already have this supply diversity, some legacy sites either have no supply diversity at all or are dependent on DNO in-feeds for auxiliary power. Many remote sites had limited scope for supply diversity with the technology that was available, where LV supplies could generally only be derived from a DNO rather than directly from transmission voltages. New technology such as Power Voltage Transformers (PVTs) give opportunities to achieve supply diversity locally at site rather than procuring long & expensive distribution connections. Other sites where supplies have historically been taken from the DNO network can be made more resilient by transferring away from that DNO connection onto a supply provided from the SHE Transmission system, where a suitable supply can be made available.

A review of the auxiliary equipment installed at these sites indicates that, under current business practices, by the end of the RIIO-T2 price control period SHE Transmission compliance with ENA ER G91 will be as indicated in Table 3 below.

| ENA ER G91 Compliance | Sites |
|---|---|
| **Compliant** | 29 |
| **Non-Compliant** | 87 |

Table 3 - SHE Transmission Core Substation Compliance with ENA ER G91

### 3.6 Diversity at Core Substations

SHE Transmission have also reviewed the auxiliary supply diversity of Core Substations against internal specifications, as indicated in Table 4 below. Whilst this diversity is not explicitly commented on by

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the ENA ER G91 guidance, SHE Transmission considers the diversity of supplies to these sites to be important for Core Substations for the following reasons:

- To ensure that for routine operations and local unplanned faults & events even non-essential systems remain operational.
- To avoid unnecessary operation of standby generation units at a relatively high financial and environmental cost. This is in line with our strategic theme of Leadership in Sustainability.
- To ensure that during a wider-area event including a Black Start event, Core Substations can be brought back to full operation on their normal auxiliary supplies early during system restoration, which brings substations back to full capability and avoids reliance on battery systems for longer than necessary. This maintains system availability which is of key importance for achieving a full and fast restoration and helps to mitigate against any further interruptions or events in the period immediately following a Black Start event. This is in line with our clear goal to aim for 100% transmission network reliability for homes and businesses and our strategic theme of Safe and Secure Network Operation.

| Supply Diversity | Sites |
|---|---|
| **Diverse Supplies** | 94 |
| **Non-Diverse Supplies** | 22 |

Table 4 - SHE Transmission Core Substation LVAC Diversity

Prolonged Black Start would be of huge economic impact to the country; it has been estimated that the cost to the Scottish economy alone would be approximately £913 million per day[3], with other societal impacts that would be far reaching. Whilst this scenario might be considered low likelihood, the extremely high severity deems it necessary to take steps to ensure a quick and effective restoration.

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[3] Black Start Event – Assessment of the Socio-Economic Costs and Recovery Standards for Scotland. E&Y, 2018

# 4 Optioneering

When reviewing our options in this area, we produced a three-tier approach to our development (in addition to a "Do Nothing" option:

**Minimum Requirements**

- The bare minimum required to "keep the lights on" & maintain legal/regulatory compliance

- **Responsible Operator**
  - A more resilient network for longer term customer benefit

- **Progressive Network Enabler**
  - An adaptable, sustainable and flexible network providing enhanced value to current and future customers

In this workstream, "Do Nothing", "Minimum Requirements", and "Responsible Operator" options are considered.

## 4.1 Do Nothing

The consequence of this is that during a Black Start event or prolonged network fault, SHE Transmission may lose essential systems at substations prior to supply restoration. This could prevent access to the associated transmission circuits and the restoration of customer supplies. Batteries which are deep-discharged in this worst-case scenario may be beyond repair and would have to be replaced. At a minimum manual intervention would be required prior to a supply restoration. As such, the time to restore the network would increase dramatically with consequential knock on impact to customers.

Ensuring SHE Transmission meet or exceed the Engineering Recommendation is therefore appropriate, and so to do nothing is considered not to be a viable option. This view is supported by stakeholders, who have confirmed through engagement events support for work to meet industry guidance and recommendations on Black Start contingency.

Whilst a 'do nothing' approach would be the least cost option, it does not address the following concerns:

- Compliance with ENA ER G91,
- Compliance with SHE Transmission specifications.

On this basis, this option has not been progressed to detailed analysis.

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**NOT PROGRESSED TO DETAILED ANALYSIS**

### 4.2 Minimum Requirements

Under this option, SHE Transmission would determine the existing autonomy of core substations and, where this does not meet the ENA ER G91 guidance of 72 hours, would carry out work to meet this guidance. Typically, this could be achieved by installing a small battery (12 hours capacity) supplemented by a standby generator (72 hours).

However, the 120 hours substation autonomy will not be achieved through this option.

On this basis, this option has not been progressed to detailed analysis.

**NOT PROGRESSED TO DETAILED ANALYSIS**

### 4.3 Responsible Operator

This option involves SHE Transmission carrying out works to meet 120 hours of autonomy as dictated by our LVAC specification at sites which do not meet the ENA ER G91 guidance of 72 hours. This option does not propose to upgrade sites which already comply with the ENA ER G91 guidance of 72 hours at this time.

This work will include:

- Replacing DC auxiliary systems at substations with new equipment, and provision or enhancement of standby generation.
- Civil works as required where existing control buildings are not large enough to accommodate the larger proposed systems, and to accommodate a standby generator.
- Provision of diverse main LV supplies for routine operation at Core substations, in line with updated SHE Transmission LVAC specifications. The use of innovative techniques such as Power VTs will be explored where appropriate, in line with our ambitions to bring innovation into business as usual.
- Replacement or adaptation of LVAC switchboards is required to accommodate the new incoming supply from a standby generator or other auxiliary supply where one does not exist currently.

SHE Transmission has reviewed the 86 sites noted in Table 3 as being non-compliant with ENA ER G91 by the end of the RIIO-T2 price control period, and have identified the required mitigating work noted in Table 5 below.

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| Work Required | Quantity |
|---|---|
| **Protection Battery System (110V) – New** | 43 |
| **Telecontrol Battery System (48V) – New** | 63 |
| **Standby Generator – Enhanced Fuel Capacity** | 12 |
| **Standby Generator – New** | 56 |
| **LVAC Works (generator driven)** | 55 |
| **LVAC Works (non-generator driven)** | 21 |
| **Third-Party Sites – Enhanced Autonomy** | 14 |

Table 5 - Proposed Work for ENA ER G91 Compliance

Core Substations which do not have the required level of supply diversity will be resolved by the provision of an additional incoming supply, from the most economically feasible source which meets the SHE Transmission specification. Work will include:

- Provision of the required new incoming supply at these substations,
- Modification or replacement of LVAC switchboards at the substations to integrate that new supply with existing auxiliary systems.

SHE Transmission identified 21 Core Substations as having insufficient diversity of supply in Table 4, and have identified the work noted below in Table 6 to bring these in-line with specifications.

| Work Required | Quantity |
|---|---|
| **Power VT – New** | 14 |
| **DNO Infeed – New** | 3 |
| **Rearrangement of Existing Supplies** | 3 |
| **LV Automatic Voltage Regulator - New** | 17 |
| **LVAC Switchboard – New** | 15 |

Table 6 - Proposed Works for Supply Diversity

The work across supply autonomy and diversity are not mutually exclusive and would be combined as a single work package for each site. For example, although there is an identified requirement for 55 LVAC switchboards for autonomy and 15 for supply diversity the total number required across the

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entire SHE Transmission network would be 65. The total number of sites requiring work relating to either autonomy and/or diversity is 92.

On this basis, this option has been progressed to Detailed Analysis.

**PROGRESSED TO DETAILED ANALYSIS**

A summary of the above optioneering is shown in Table 7, below.

| | Do Nothing | Minimum Requirements | Responsible Operator |
|---|---|---|---|
| **Resilience – 72hrs at all core substations** | ✗ | ✓ | ✓ |
| **Resilience – 120hrs at non G91 core substations** | ✗ | ✗ | ✓ |
| **Supports project Interdependencies** | ✗ | ✓ | ✓ |
| **Diversity of LV supply at Core Substations** | ✗ | ✓ | ✓ |

Table 7 - Optioneering Summary

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# 5 Detailed Analysis

This section considers in more detail each of the options taken forward from the Optioneering section. It examines three comparative factors in order to determine the preferred option:

- Risk,
- Stakeholder Requirements, and
- Cost.

## 5.1 Risk & Benefit Analysis

Due to the nature of this project, risks and benefits involved are not easily quantifiable and are not suitable for traditional Cost Benefit Analysis.

In order to demonstrate the benefits of delivering this project, we have carried out a Risk and Benefit Analysis. It looks at the existing risks, the likelihood of these risks being realised, and the severity should that happen. The likelihood and severity combine to give an overall Unmitigated Risk Rating. Mitigation actions are then identified, and the likelihood and severity are reappraised, resulting in a Mitigated Risk Rating.

This exercise was carried out for the LV Supplies proposals. As can be seen in Table 8, the Unmitigated Risk Rating is "Severe". Once all the mitigations are taken into account, the Mitigated Risk Rating falls to "Medium". The full Risk & Benefit Analysis is contained within Appendix C.

| | | | | Responsible Operator |
|---|---|---|---|---|
| **Risk ID** | **Risk Title** | **Risk** | **Unmitigated Overall Risk Rating** | **Mitigated Overall Risk Rating** |
| 1 | Resilience – 72 hours at all core substations | Compliance with ER G91 may not be met for all sites | Severe | Medium |
| 2 | Resilience – 120hrs at non G91 core substations | 120hr autonomy will not be met for Core sites | Severe | Low |
| 3 | Project Interdependencies | Unable to support dependent projects, may result in non-compliance with STCP 27-01 | Severe | Medium |
| 4 | Diversity of LV supply at Core Substations | No Diverse supplies, may result in non-compliance with ER G91 | Severe | Medium |
| | | **OVERALL** | **Severe** | **Medium** |

Table 8 - Risk and Benefit Analysis Results

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### 5.2 Stakeholder Engagement

On 5 March 2019, SHE Transmission hosted a stakeholder workshop, facilitated by consultancy EQ Communications, aimed at gathering feedback from its stakeholders on its approach to network resilience and reliability for the RIIO-T2 plan in line with our strategic theme of having a Stakeholder Led Strategy.

The need for LV supplies was outlined including the impact of "do nothing" in a Black Start situation, as well as options for achieving autonomy, and the approach SHE Transmission were proposing, namely, the use of battery technology with standby generation. Stakeholders supported SHE Transmission's proposed prioritisation for the rollout of the battery / generator upgrade. One stakeholder urged the company to prioritise parts of the network that support major urban centres in Scotland.

More information can be found in our Stakeholder Engagement Workshop Report.

### 5.3 Costs – Responsible Operator

Costs for this option are laid out in Table 9 below.

| Work Required | Number of Sites | Costs (£k) |
|---|---|---|
| **Protection DC** | 43 | [redacted] |
| **Telecontrol DC** | 62 | |
| **LVAC** | 68 | |
| **Standby Gen** | 68 | |
| **Civils** | 66 | |
| **Other** | 26 | |
| **On Costs** | | |
| **Risk & Contingency** | | |
| **TOTAL** | | |

Table 9 - Cost Breakdown

These costs have been derived through Supply Chain engagement and utilising rates from previous tenders.

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### 5.4 Proposed Solution

We have examined each of the options in terms of three comparative factors:

- Cost
- Risk Reduction
- Stakeholder Requirements

and have determined through this analysis which is the preferred option.

Therefore, the Responsible Operator option is selected, given that is was the only option taken forward for detailed analysis and it aligns with Stakeholder Requirements.

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# 6 Conclusion

SHE Transmission recognises that the growth of our network and auxiliary components such as communications has increased the demand on our LV supplies to levels where a suitable resilience level is not always met. Additionally, an expected improvement in requirements from 72 to 120-hour capability at core substations requires upgrades to many of our LV supplies in substations.

An optioneering assessment took place which investigated three options, only one of which was taken forward for detailed analysis.

Given the preceding information, a decision has been made to deploy the "Responsible Operator" option. The cost forecast for the project is £48.93m.

The scope of the selected option is as outlined in Table 10 below.

| Achieving Resilience of LV Supplies at Core Substations | Number of sites |
|---|---|
| **Work required due to LV Supply Autonomy** | 70 |
| **Work required due to LV Supply Diversity** | 5 |
| **Work required due to LV Supply Autonomy & Diversity** | 17 |
| **TOTAL SITES REQUIRING RESILIENCE IMPROVEMENTS** | **92** |
| **Total Core Sites** | **116** |

Table 10 - SHE Transmission LV Supply Projects

The project will be completed by 2026 following a 5-year construction period.

This scheme is not flagged as eligible for early or late competition due to it being under Ofgem's £50m and £100m thresholds respectively.

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## 7 Price Control Deliverables and Ring Fencing

As set out in our Regulatory Framework paper (section 1.12 and Appendix 3) we support a key principle from Citizens Advice – one that guarantees delivery of outcomes equivalent to the funding received - to ensure that RIIO-T2 really deliver for consumers. At the project level this means that if we don't deliver the output, or a materially equivalent outputs, we commit to returning the ex-ante allowance for the output not delivered.••

This means that if the funding for Substation Resilience – Low Voltage Supplies should be ring-fenced and if it does not go ahead, we will return the allowances of £48.93m in full (minus any justified preconstruction expenditure).•

It also means that we commit to delivering the output specified above for the costs of £48.93m. If we do not deliver the output, or a materially equivalent output, we commit to returning a proportion of the ex-ante allowance. The detailed methodology should be decided at when developing the Close Out methodologies but should apply the same principles of uncertainty mechanisms - that any under delivery should be material.•

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## 8. Outputs included in RIIO-T1 Plans

There are no outputs associated with this scheme included in our RIIO-T1 plans.

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## 9. References

- Resilience Policy
- Energy Networks Association Engineering Recommendation (ENA ER) G91
- SHE Transmission LVAC specification
- SHE Transmission Innovation Strategy
- BEIS BSTC/0219/03 Black Start Standard

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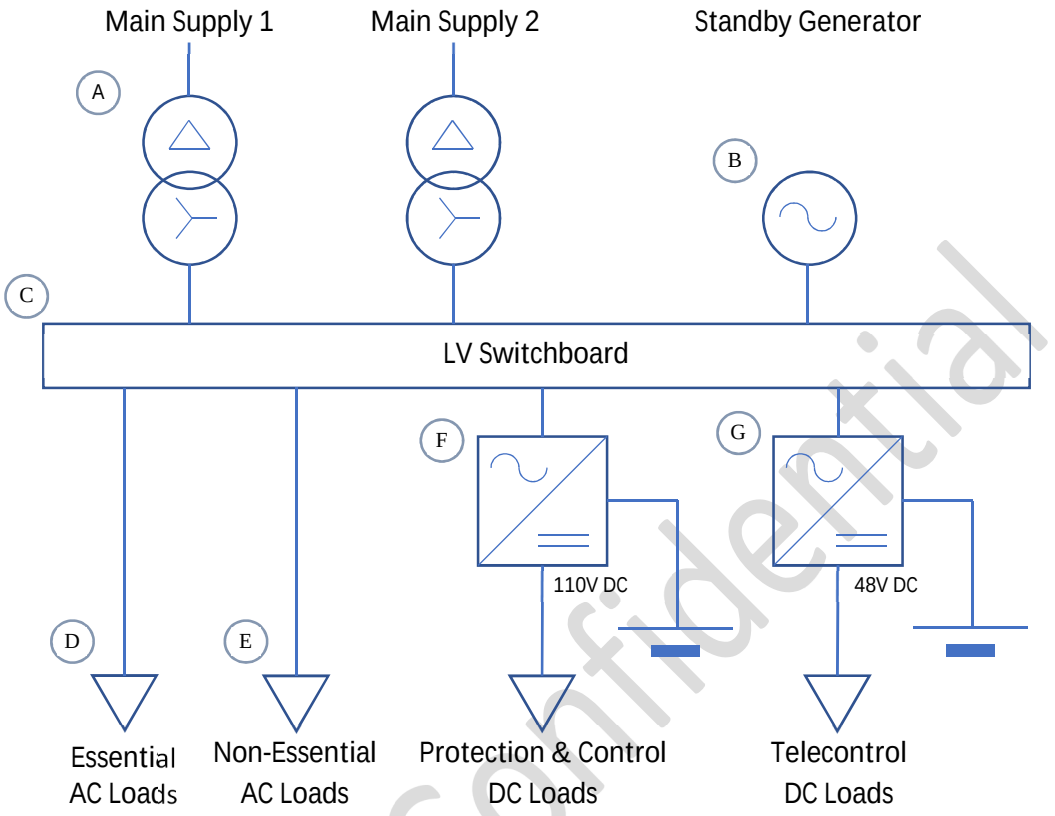
## Appendix A – Simplified Diagram of LV Auxiliary Systems in a Core Substation

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A – Main LV Supply: This is the normal source of supply for the substation. SHE Transmission normally install two auxiliary supplies from diverse sources to avoid interruption due to planned or unplanned outages. This supply is typically derived from a dedicated auxiliary transformer on either the SHE Transmission network or from the local DNO.

B – Standby Generator: Provides AC power in event of losing both main LV supplies (for example in a Black Start event). These are typically diesel generators, with on-site fuel stored to provide several days uninterrupted running.

C – LV Switchboard: Selects the most appropriate incoming supply and distributes auxiliary power across the site.

D – Essential AC Loads: These AC loads can tolerate a short disruption but are required under prolonged outages; such as transformer control equipment. These loads are supported by the standby generator.

E – Non-Essential AC Loads: Loads such as substation lighting aren't required for the site to operate during an outage. These loads are deliberately disconnected if the standby generator is running to reduce fuel consumption.

F – 110V Battery System: Protection & Control systems, including switchgear operation, are powered at 110V DC via a battery & charger system. Supplies are kept running without interruption using energy stored by batteries. Higher voltage and critical sites may be supported by dual batteries to provide redundancy.

G – 48V Battery System: Telecontrol systems, such as communications and remote-control capability, are powered at 48V DC via a battery & charger system. Supplies are kept running without interruption using energy stored by batteries. Higher voltage and critical sites may be supported by dual batteries to provide redundancy.

Note: Supply system Low Voltage (LV) is defined by the International Electrotechnical Commission (IEC) as Alternating Current (AC) Voltage in the range 50VAC to 1000VAC.

## Appendix B – Work Breakdown by Site

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## Appendix C – Risk and Benefit Matrix

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Project Risk and Benefit Matrix - Responsible Operator

| Risk ID | Risk Title | Risk | Unmitigated Risk Likelihood | Unmitigated Risk Severity | Unmitigated Overall Risk Rating | Mitigation Action | | Mitigated Risk Likelihood | Mitigated Risk Severity | Mitigated Overall Risk Rating | Benefits |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Resilience | Compliance with ER G91 may not be met for all sites | Almost Certain | Severe | Severe | Upgrade identified sites to 120 hours | | Almost Never | Severe | Medium | Provision of supply under a black start event. |
| 2 | Specification | 120hr autonomy will not be met for Core sites | Almost Certain | Serious | Severe | Upgrade identified sites to 120 hours | | Almost Never | Serious | Low | Provision of supply under a black start event. |
| 3 | Interdependencies | Unable to support dependent projects | Almost Certain | Severe | Severe | Upgrade identified sites to 120 hours | | Almost Never | Severe | Medium | Projects supported |
| 4 | Diversity | No Diverse supplies | Almost Certain | Severe | Severe | Ensure diversity of supplies in line with LVAC specification and with a transmission derived supply | | Almost Never | Severe | Medium | Provision of diverse main LV supplies |

Figure 1 - Risk & Benefit Matrix

| Unmitigated Impact | Unmitigated Likelihood: Almost Never | Hardly Ever | Unlikely | Possible | Likely | Almost Certain |
|---|---|---|---|---|---|---|
| Catastrophic | High | High | Severe | Severe | Severe | Severe |
| Severe | Medium | High | High | Severe | Severe | 1 3 4 |
| Major | Medium | Medium | High | High | Severe | Severe |
| Serious | Low | Medium | Medium | High | High | 2 evere |
| Minor | Low | Low | Medium | Medium | High | High |
| Incidental | Low | Low | Low | Medium | Medium | Medium |

| Mitigated Impact | Mitigated Likelihood: Almost Never | Hardly Ever | Unlikely | Possible | Likely | Almost Certain |
|---|---|---|---|---|---|---|
| Catastrophic | High | High | Severe | Severe | Severe | Severe |
| Severe | 1 3 4 | High | High | Severe | Severe | Severe |
| Major | Medium | Medium | High | High | Severe | Severe |
| Serious | 2 Low | Medium | Medium | High | High | Severe |
| Minor | Low | Low | Medium | Medium | High | High |
| Incidental | Low | Low | Low | Medium | Medium | Medium |

Figure 2 - Risk Heat Maps

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