

Protection Modernisation Engineering Justification Paper

Confidential





Engineering Justification Paper Protection Modernisation

1 Executive Summary

This Engineering Justification paper sets out the proposed upgrade to our Protection Systems in line with modern technology, whilst maintaining compliance with Electricity Safety, Quality and Continuity Regulations (ESQCR) and STCP 27-01.

Support for these proposals exists in the form of a response by stakeholders at an engagement session that took place on the 5th of March 2019 at the Edinburgh International Conference Centre. Stakeholders required that SHE Transmission took a forward-thinking approach to the project's execution.

SHE Transmission has outlined the following deliverables for this approach;

- Complete refurbishment of bay protection at 23 sites including auxiliary tripping and supervision relays.
- Enhance 41 bays with post-event and real time monitoring in accordance with IEEE C37.118

The cost to deliver the preferred option stands at £22.00m. This cost is based on previous expenditure for similar tasks and would be delivered as an ongoing roll-out of project works throughout the RIIO-T2 period (2021 to 2026).

Upon delivery, several benefits relating to the RIIO-T2 business goals will be realised:

- Bay enhancements allow for more renewable generation to be connected to the network and contribute to the goal of "Transporting renewable electricity that powers 10 million homes" set out in the "Network for Net Zero" business plan.
- Protection enhancements from bay refurbishment reduces the likelihood of a disconnection and contributes towards the SHE-Transmission goal to aim for "100% Transmission network reliability for homes and businesses"
- Fully embraces the Digital substation concept and contributes to our goal of "£100 million in efficiency savings from innovation" outlined in the "Network for Net Zero" business plan.

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





**Engineering Justification Paper
Protection Modernisation**

| | |
|--|--------------------------|
| Name of Scheme/Programme | Protection Modernisation |
| Primary Investment Driver | Resilience |
| Scheme reference/ mechanism or category | SHNLT2039 |
| Output references/type | NLRT2SH2039 |
| Cost | £22.00m |
| Delivery Year | RIIO-T2 |
| Reporting Table | C2.25 |
| Outputs included in RIIO T1 Business Plan | No |

Highly Confidential

**Engineering Justification Paper
Protection Modernisation****2 Introduction**

This Engineering Justification Paper sets out our plans to undertake protection modernisation works during the RIIO-T2 period (April 2021 to March 2026).

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.

Section 9: References

**Engineering Justification Paper
Protection Modernisation**

3 Need

The management of legacy microprocessor-based relays continues to be a theme for RIIO-T2, much as it was in RIIO-T1. This methodology has been expanded to include the additional themes of:

- relay hardware and firmware management,
- circuit performance and
- the requirement for post-event and real time monitoring pursuant to STCP 27-01.

These themes are developed against the backdrop of the decarbonisation agenda, by ensuring that the protection offering is both compliant and agile enough to accommodate future generation connections.

3.1 Legacy Replacements

Our previous approach to upgrading our protection has been based around replacing time-expired assets on a “like-for-like” basis and was targeted only at principal protection relays. However, this approach did not address the associated auxiliary tripping and supervision relays. It also results in increasing fault rates towards asset end-of-life.

These assets are at an age where some platforms are obsolete or approaching obsolescence. If type faults occur, spares cannot be easily sourced, and this is likely to lead to circuit unavailability. These replacements are time consuming and can cause a business risk if not proactively managed.

3.2 Relay hardware/firmware management

Relays have previously been considered as “fit-and-forget” assets, only to be supported by periodic maintenance. However, microprocessor-based protection relays are subject to software and firmware “bugs” like any other electronic device, and proactive management is required to mitigate the risk of relay maloperation.

3.3 Circuit Performance

Poorly performing circuits having been identified throughout RIIO-T1. Previously, generators have been teed into Major Interconnected Transmission System (MITS) circuits, with the main circuit ends left with a distance protection relay to cover the circuit. Where distance protection has been applied or historically retained due to telecommunications constraints, the relays at the circuit ends are not capable of measuring contributions from the generator and this erodes the effectiveness of the line protection.



**Engineering Justification Paper
Protection Modernisation**

3.4 Post-Event and Real-Time Monitoring

STC Procedure 27-01 was passed by the STC Panel in 2018, placing a set of requirements on SHE Transmission for the provision of appropriate and accurate synchronised data to monitor asset and overall system performance. Essentially this places a requirement on SHE Transmission to provide the System Operator (NGESO) with live data streams in accordance with IEEE C37.118 and suitable synchronised data to facilitate post event analysis.

The STCP requires SHE Transmission to provide devices for the measurement of said data:

- at or near each agreed Grid Supply Point; and
- where and to the extent agreed between NGET and the relevant TO, at each point where an Interconnector or Generator is directly connected to the National Electricity Transmission System.

This will enable both post-event and real-time monitoring to understand asset performance for SHE Transmission and to facilitate dynamic/transient modelling and oscillatory stability analysis for the System Operator. The STCP mandates that the instrumentation necessary to facilitate this monitoring shall be installed throughout the RIIO-T2 time frame.

Highly Confidential

**Engineering Justification Paper
Protection Modernisation**

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

4.1 Do Nothing

This option would entail carrying out no works on protection over the course of RIIO-T2. However, it fails to address the following concerns:

- Obsolescence, with no plan to proactively address assets heading towards end-of-life,
- Bay refurbishment requirements
- Firmware management, with no proactive management to address hardware/firmware bugs,
- Circuit performance, leaving levels of line protection at less than optimum,
- Post-fault and real-time monitoring, rendering us unable to comply with STCP 27-01.

Doing nothing would also add additional risk as primary relays would no longer be replaced.

On this basis, this option is not taken forward to detailed analysis.

NOT PROGRESSED TO DETAILED ANALYSIS

4.2 Minimum Requirements

The Minimum Requirements for Protection would be to replace the time expired assets on a “like-for-like” basis (insofar as is practical). Steps would have to be taken to enhance protection schemes to maintain compliance with legislation and codes. This would entail a restricted adoption of the relay



Engineering Justification Paper Protection Modernisation

hardware / firmware management theme, abandoning the circuit performance theme and a heavily restricted adoption of the monitoring theme.

However, it fails to address the following concerns:

- Obsolescence, with no plan to proactively address assets heading towards end-of-life,
- Bay refurbishment, continuing to focus only on primary relays; obsolete or poorly performing auxiliary relays will not be addressed
- Firmware management, with a restricted approach to addressing hardware/firmware bugs,
- Circuit Performance, leaving levels of line protection at less than optimum.
- Post-Fault and Real-time Monitoring, rendering us unable to comply with STCP 27-01.

It also fails to take account of future network risks such as reduced fault levels and system inertia, perhaps leading to regret cost arising from retro-fitting current differential protection where distance relaying is used at present.

On this basis, this option is not taken forward to detailed analysis.

NOT PROGRESSED TO DETAILED ANALYSIS

4.3 Responsible Operator

In addition to the proposals under Minimum Requirements, this option includes system monitoring to meet STCP 27-01 requirements, and enhanced protection schemes able to take advantage of new telecommunications infrastructure, as well as the proactive management of relay firmware and hardware changes using enhanced data management systems. It would also provide improved circuit protection for those circuits with performance issues and an enhanced adoption of the post-event and real time monitoring theme.

This would require the modernisation of 22 feeder protection bays which have reached end-of-life. In addition to the forgoing works, an additional six circuits that previously have not had intertripping have been identified with the associated requirement for 12 intertrip panels. Plant protection replacements have been identified at three 275kV sites and thirteen 132kV sites. This work also enables compliance with STCP 27-01. More information can be found in Appendices A & B.



**Engineering Justification Paper
Protection Modernisation**

However, this option fails to suitably protect SHE Transmission against protection relay market developments, specifically the new protocols regarding “digital substations”.

On this basis, this option is taken forward to detailed analysis.

PROGRESSED TO DETAILED ANALYSIS

Highly Confidential

**Engineering Justification Paper
 Protection Modernisation**
4.4 Progressive Network Enabler

This option expands on that outlined in Section 4.3 above through the inclusion of works required to align with IEC 61850, the international standard defining communications protocols for intelligent electronic devices at electrical substations – or “digital substations”.

This would entail an enhanced adoption of the relay hardware/firmware management theme including the adoption of the digital substation in the retro-fit environment, developing circuit protection for those circuits with performance issues and an enhanced adoption of the post-event and real time monitoring theme.

This option has the additional benefit of bringing existing assets into line with the digital substation. However, by progressing to this standard, it is possible in the retro-fit environment that networking switches and such like may result in stranded assets.

In addition to the works listed under 4.3, we have identified 71 sites on our network which will require improvements to align with IEC 61850. Of these, 30 sites are addressed under our Non-Load Related Intervention portfolio so are not considered here. The remaining 41 sites contain a total of 68 bays, and the requirements consist of varying scopes of work, as shown in Table 1 . Some sites require only upgraded licenses, while others need wholesale replacement of the existing protection. It is anticipated that the site end design will be such that these works can be done without need for an outage.

| Category | No of sites | No of Bays |
|--|-------------|------------|
| Wholesale Replacement | 24 | 41 |
| Replacement measuring device | 4 | 5 |
| Measuring device requires hardware upgrade | 6 | 12 |
| License upgrade required | 7 | 10 |

Table 1 – STCP Driven Requirements

On this basis, this option is taken forward to detailed analysis.

PROGRESSED TO DETAILED ANALYSIS



**Engineering Justification Paper
Protection Modernisation**

A summary of the above optioneering is shown in Table 2, below.

| | Do Nothing | Minimum Requirements | Responsible Operator | Progressive Network Enabler |
|--|------------|----------------------|----------------------|-----------------------------|
| Legacy Replacements | ✗ | ✓ | ✓ | ✓ |
| Relay Hardware/ Firmware Management | ✗ | ✗ | ✓ | ✓ |
| Circuit Performance | ✗ | ✗ | ✓ | ✓ |
| Post Event & Real-Time Monitoring | ✗ | ✗ | ✓ | ✓ |
| Alignment with IEC 61850 | ✗ | ✗ | ✗ | ✓ |

Table 2 - Optioneering Summary

Highly Confidential



**Engineering Justification Paper
Protection Modernisation**

5 Detailed Analysis

5.1 Risk and Benefit Analysis

Due to the nature of this project, risks and benefits involved are not easily quantifiable and, as agreed with Ofgem, 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. For each option taken forward to Detailed 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 delivered by each option are then identified, and the likelihood and severity are reappraised, resulting in a Mitigated Risk Rating.

Highly Confidential

**Engineering Justification Paper
Protection Modernisation**

This exercise was carried out for the Protection Modernisation proposals. As can be seen in [REDACTED], the Unmitigated Risk Rating sits at "Severe". Once all the mitigations are taken into account, the Mitigated Risk Rating falls to "Medium" for both options. Both potential options derive similar amounts of improvement to the risk rating. The full Risk & Benefit Analysis is contained within Appendix C.

| Risk ID | Risk Title | Risk | Unmitigated Overall Risk Rating | Responsible Operator | Progressive Network Enabler |
|----------------|----------------------|---|---------------------------------|-------------------------------|-------------------------------|
| | | | | Mitigated Overall Risk Rating | Mitigated Overall Risk Rating |
| 1 | Age and Obsolescence | Assets are at an age where some platforms are obsolete or approaching obsolescence. If type faults occur, spares cannot be easily sourced, and this is likely to lead to circuit unavailability. These replacements are time consuming and can cause a business risk if not proactively managed | High | Medium | Medium |
| 2 | Relay Management | Relays can maloperate if software and firmware are not periodically maintained | High | Medium | Medium |
| 3 | Circuit Performance | Protection effectiveness is eroded where generators have been teed into MITS on distance protection only | Severe | Medium | Medium |
| 4 | STCP 27-01 | Measurement devices required for STCP are not in place so SHE Transmission is non-compliant | Severe | Medium | Medium |
| 5 | New Technology | Technology is developing quickly and we are not in sync with modern technologies in this area. Risk is that we are left reliant on obsolete equipment | Severe | Severe | Medium |
| OVERALL | | | Severe | Medium | Medium |

Table 3 - Risk and Benefit Analysis Results

5.2 Stakeholder Engagement

On 5 March 2019, SHE Transmission hosted a stakeholder workshop, aimed at gathering feedback from its stakeholders on its approach to network resilience and reliability for the RIIO-T2 plan. A total of 46 stakeholders attended the workshop, representing 31 organisations.

Stakeholders supported the Progressive Network Enabler option when it was first presented to them, though it was only marginally more favoured than the Responsible Operator option. However, once costs had been discussed, the support for the Progressive Network Enabler option increased significantly. Stakeholders felt that the cost differential between the two options was negligible and the more ambitious option offered better value.

**Engineering Justification Paper
Protection Modernisation**

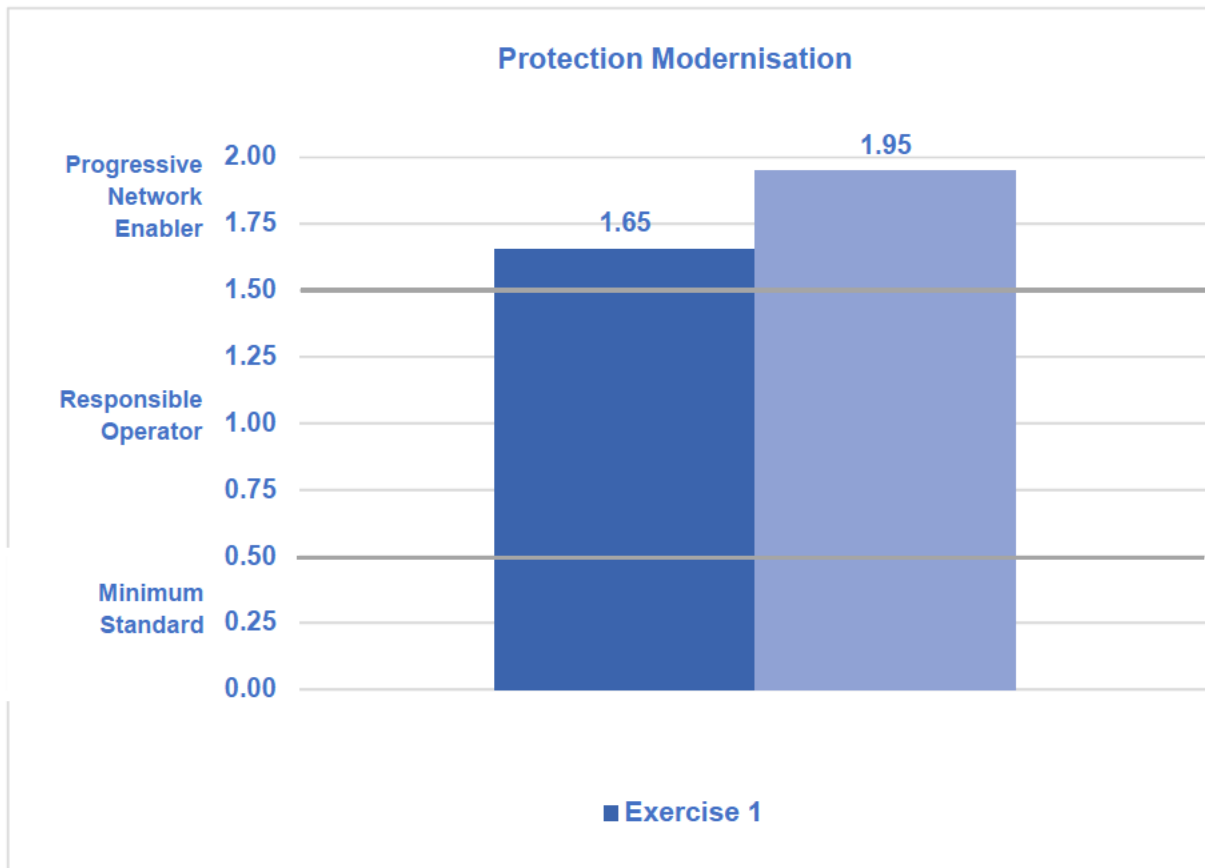


Figure 1 - Stakeholder Feedback

There are a number of factors driving stakeholder support in this area. Stakeholders recognised that investment is required to keep up-to-date with changes in technology, that latest technologies likely offer a lower whole-life cost than their predecessors, and that digitising protection offered health and safety benefits. Stakeholders did express their concerns that this modernisation be mindful of cyber security risks and did not result in technologies being installed which become quickly obsolete.

5.3 Costs – Responsible Operator

These works have been estimated at £20.27m over the RIIO-T2 period. A breakdown of these costs is shown in Table 4 and requirements can be found in Appendix A.

5.4 Costs – Progressive Network Enabler

In total, this work is estimated at £22.00m and is required to be completed over the RIIO-T2 period, not including internal staff costs. A breakdown of these costs is shown in Table 4 and requirements can be found in Appendix A.



**Engineering Justification Paper
Protection Modernisation**

| | Responsible Operator (£M) | Progressive Network Enabler (£M) |
|--------------------------|---------------------------|----------------------------------|
| Circuit Protection Works | | |
| Plant Protection Works | | |
| STCP 27-01 Works | | |
| On Costs | | |
| Risk & Contingency | | |
| TOTAL | | |

Table 4 – Options Cost

5.5 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 that the “Progressive Network Enabler” option is be preferred, as it is delivers equal risk reduction to the “Responsible Operator” option for a very small additional cost. Finally, it aligns with Stakeholder Requirements.

**Engineering Justification Paper
Protection Modernisation****6 Conclusion**

This Engineering Justification Paper set out the need for refurbishment of protection systems due to SHE Transmission's commitment to "Electricity Safety, Quality and Continuity Regulation 2002" (ESQCR).

SHE Transmission is required to implement STC Procedure 27-01.

The paper investigated protection modernisation of bays at key sites and determined a need that due to some assets reaching their operational life expectancy and a growing need to upgrade protection systems for future renewable generations connections.

An optioneering assessment took place which investigated 4 options, two of which were taken forward for detailed analysis.

Taking account of that detailed analysis, the preferred option is the Progressive Network Enabler option.

SHE Transmission has outlined the following deliverables for this approach;

- Complete refurbishment of bay protection at 22 sites including auxiliary tripping and supervision relays.
- Enhance 41 bays with post-event and real time monitoring in accordance with IEEE C37.118

The cost analysis for the preferred option stands at £22.00m. This cost is based on previous expenditure for similar tasks. This scheme is not flagged as eligible for early or late competition due to it being under Ofgem's £50m and £100m thresholds respectively.



**Engineering Justification Paper
Protection Modernisation**

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 Protection Modernisation should be ring-fenced and if it does not go ahead, we will return the allowances of £22.0m in full (minus any justified preconstruction expenditure).

It also means that we commit to delivering the output specified above for the costs of £22.0m. 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.

Highly Confidential



**Engineering Justification Paper
Protection Modernisation**

8 Outputs included in RIIO-T1 Plans

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

Highly Confidential



**Engineering Justification Paper
Protection Modernisation**

9 References:

- Electricity Safety, Quality and Continuity Regulations 2002
- STCP 27-01 System Performance Monitoring
- IEEE C37.118

Highly Confidential



Engineering Justification Paper
Protection Modernisation

Appendix A – Circuit Protection Works

Table 5 - 275kV Circuit Protection Works

Table 6 - 132 kV Circuit Protection Works



Engineering Justification Paper
Protection Modernisation

Appendix B – Plant Protection Works

- 275kV Plant Protection Works

Table 8 - 132kV Plant Protection Works

Highly Confidential

**Engineering Justification Paper
 Protection Modernisation**
Appendix C – Risk & Benefit Analysis

| Scottish & Southern Electricity Networks TRANSMISSION | | Project Risk and Benefit Matrix - Responsible Operator | | | | | | | | |
|---|----------------------|--|-----------------------------|-------------------------|---------------------------------|--|---------------------------|-----------------------|-------------------------------|--|
| Risk ID | Risk Title | Risk | Unmitigated Risk Likelihood | Unmitigated Risk Impact | Unmitigated Overall Risk Rating | Mitigation Action | Mitigated Risk Likelihood | Mitigated Risk Impact | Mitigated Overall Risk Rating | Benefits |
| 1 | Age and Obsolescence | assets are at an age where some platforms are obsolete or approaching obsolescence. If type faults occur, spares cannot be easily sourced, and this is likely to lead to circuit unavailability. These replacements are time consuming and can cause a business risk if not proactively managed. | Likely | Serious | High | Modernization of bays which have reached end of life | Hardly Ever | Serious | Medium | Reduces risk of failure. Also provides better value for the consumer as it makes optimal use of outages. |
| 2 | Relay Management | Relays can malfunction if software and firmware are not periodically maintained. | Possible | Serious | High | Enhanced data management systems | Hardly Ever | Serious | Medium | Proactive Management of firmware and hardware |
| 3 | Circuit Performance | Protection effectiveness is eroded where generators have been feed into MTS on distance protection only. | Likely | Major | Severe | Install intertripping on 6 circuits | Almost Never | Major | Medium | Improve circuit protection |
| 4 | STCP 27-01 | Measurement devices required for STCP Compliance are not in place. | Almost Certain | Major | Severe | Install system monitoring devices | Almost Never | Major | Medium | STCP Compliance, post-event and real-time monitoring |
| 5 | New Technology | Technology is developing quickly and we are not in sync with modern technologies in this area. | Almost Certain | Serious | Severe | | Almost Certain | Serious | Severe | |

Figure 2 - Risk & Benefit Matrix – Responsible Operator

| Scottish & Southern Electricity Networks TRANSMISSION | | Project Risk and Benefit Matrix - Progressive Network Enabler | | | | | | | | |
|---|----------------------|--|-----------------------------|-------------------------|---------------------------------|--|---------------------------|-------------------------|-------------------------------|--|
| Risk ID | Risk Title | Risk | Unmitigated Risk Likelihood | Unmitigated Risk Impact | Unmitigated Overall Risk Rating | Mitigation Action | Mitigated Risk Likelihood | Mitigated Risk Severity | Mitigated Overall Risk Rating | Benefits |
| 1 | Age and Obsolescence | assets are at an age where some platforms are obsolete or approaching obsolescence. If type faults occur, spares cannot be easily sourced, and this is likely to lead to circuit unavailability. These replacements are time consuming and can cause a business risk if not proactively managed. | Likely | Serious | High | Modernization of bays which have reached end of life | Hardly Ever | Serious | Medium | Reduces risk of failure. Also provides better value for the consumer as it makes optimal use of outages. |
| 2 | Relay Management | Relays can malfunction if software and firmware are not periodically maintained. | Possible | Serious | High | Enhanced data management systems | Hardly Ever | Serious | Medium | Proactive Management of firmware and hardware |
| 3 | Circuit Performance | Protection effectiveness is eroded where generators have been feed into MTS on distance protection only. | Likely | Major | Severe | Install intertripping on 6 circuits | Almost Never | Major | Medium | Improve circuit protection |
| 4 | STCP 27-01 | Measurement devices required for STCP Compliance are not in place. | Almost Certain | Major | Severe | Install system monitoring devices | Almost Never | Major | Medium | STCP Compliance, post-event and real-time monitoring |
| 5 | New Technology | Technology is developing quickly and we are not in sync with modern technologies in this area. | Almost Certain | Serious | Severe | Enhanced adoption of relay hardware/firmware including | Hardly Ever | Serious | Medium | Alignment with IEC 61850 |

Figure 3 - Risk & Benefit Matrix – Progressive Network Enabler

**Engineering Justification Paper
Protection Modernisation**

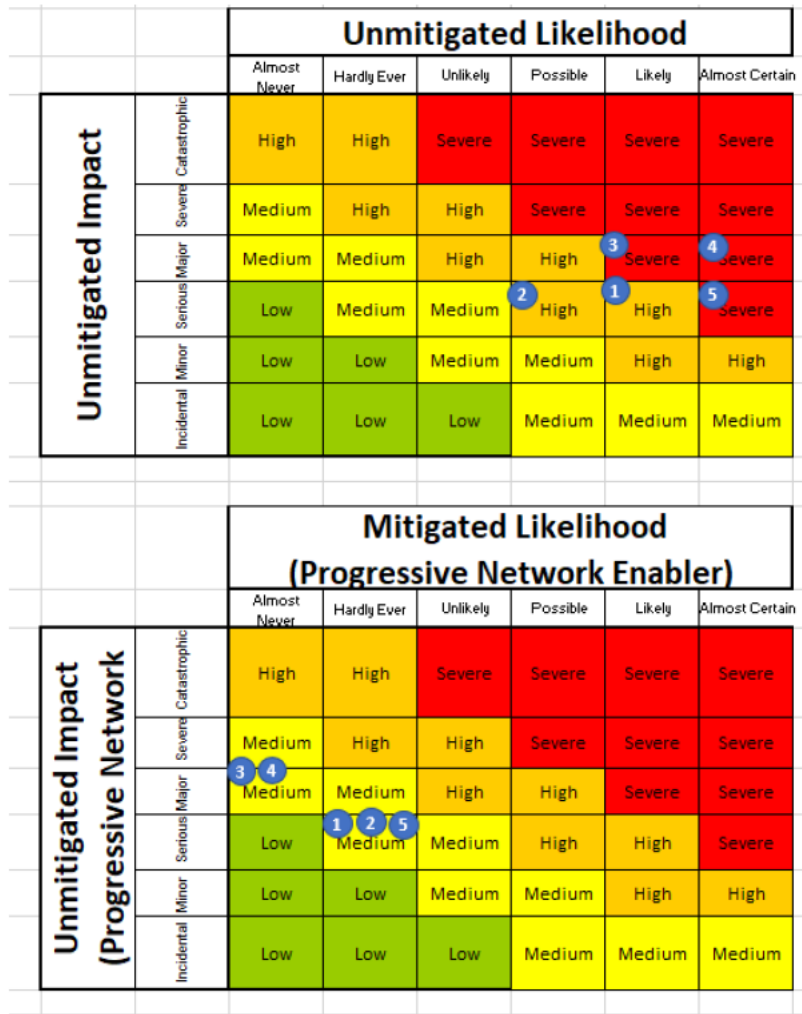


Figure 4 - Risk Heat Maps for Preferred Option