Protection modernisation project - OFGEM justification paper	
Name of Scheme/Programme	Protection modernisation
Primary Investment Driver	Asset Health
Scheme reference/ mechanism or category	SPNLT2048 Non-Lead Asset – Protection, Control, Telecoms and Metering
Output references/type	NLRT2SP2048 / Non Lead
Cost	£ 11.9 m
Delivery Year	2026
Reporting Table	C0.7, C2.2a
Outputs included in RIIO T1 Business Plan	Yes

Issue Date	Issue No	Amendment Details
July 2019	Issue 1	First issue of document
December 2019	Issue 2	Cost updated

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1 Introduction

Maintaining a healthy protection asset base, which meets modern standards that are based on best practice and experience, is essential to retaining the integrity of the network and reducing the likelihood of substantial losses in the event of network faults.

The principal driver for the proposal is the replacement of types of protection and control relays identified as having significant defects appearing as a trend across the installed population, and therefore considered prone to failure. The following relays have been identified as meeting the criteria:

- [redacted]transformer protections
- [redacted] back-up protections
- [redacted]feeder intertrips and protection signalling devices
- [redacted]mesh corner DAR
- [redacted]capacitor protections

An additional driver is the replacement of legacy protection schemes with outdated relays which are non-compliant with technical policy, and so have limited support and do not provide adequate protection coverage in line with modern standards. Schemes that meet the criteria have been identified within the following categories:

- Double wound transformer protections
- Autotransformer protections
- Breaker fail
- Busbar and mesh corner protections

Throughout these works, secondary drivers have been the rationalisation of works to avoid repeated outages at short intervals and provide more efficient delivery, and the consideration of older installations of obsolete relays that may be most at risk. These drivers have led to the measured extension of the works identified above, and additionally the development of the following proposed programme:

- 132kV feeder protection

It has been considered that investment is required during this price control period as potentially defective relays or inadequate schemes pose an immediate risk to the assets they are supposed to protect, and the ability to keep these assets safely in operation. Some proactive investment is necessary to avoid future trends of relay failures at volumes that are unmanageable.

The project is characterised by the delivery of high volumes of individual relay replacements mixed with a smaller volume of full-scheme replacements. The multiple programmes of work to cover these feature different delivery models dependent on scale and together run for the length of the price control period.

2 Background Information

2.1 Defective relays

The population of protection and control relays installed on the network ranges from electromechanical relays installed in the 1960s, through static electronic relays installed in the 1980s, to processor-based relays installed from the 1990s onwards. New installations primarily use

modern numeric processor-based relays which allow rationalisation of functions, more flexible fault detection, increased monitoring and self-diagnostic capability and greater supplier development and availability compared to the other options.

Due to the timeline of their development, support for electromechanical and static relays is limited or unavailable, with the exception of some particular static devices which are still relatively widely installed. Older processor-based relays have the same obsolescence problems, with parts unavailable and devices now reaching beyond their design life. The actual in-service life of a particular relay varies between models, with RIIO-T1 seeing investment to replace particular models that had exhibited trends of failure that were not apparent in some older devices.

Significant volumes of relays were replaced in RIIO-T1 on this basis, with priority given to protection devices that had been assessed as Health Index 5 (in accordance with asset health methodology ASSET-01-025) due to significant defects, all of which will have been replaced by the end of the period. [redacted] relays were assessed as Health Index 4, and were also the subject of a replacement programme. Associated [redacted] delayed auto-reclose (DAR) relays were also replaced as they belong to the same series of relays, and in modern installations the DAR function can be accommodated within the same device as the backup protection. For these devices, priority was given to main protections, with only 5 [redacted] transformer main protections to be left in service. The remaining population of [redacted] relays are backup protections, used in a number of different protection schemes. There was an expectation that these relays would deteriorate to Health Index 5 during RIIO-T1, which has been shown to be accurate as defects continue to occur.

Additional relay types have begun to show trends of failure during the period. For the older version of the [redacted] intertripping and protection signalling device, installed on the network from the 1990s up until the adoption of a newer model in the 2000s, 20% of the current population suffer from repeated lockouts which render them inoperable until they are manually reset. The devices are also susceptible to power supply failure.

Of the 14 mesh substations that have [redacted] relays installed for auto-reclosing (DAR), 6 sites have had problems with inter-relay communications that have left DAR out of service, slowing circuit restoration times following faults. This particularly affects schemes that were installed in the early 2000s. Since the failure of a single device means that the entire mesh corner DAR scheme requires replacement, relying on reactive replacement can lead to long-term loss of the function until it is possible to carry out extensive site works. The most recent version of the relay, still commercially available, has not been upgraded in line with modern communications standards, or to include functionality that would now be considered as standard within a DAR relay, such as voltage selection.

[redacted] relays have been installed relatively recently on the network, and in small volumes, acting as a capacitor protection for the MSCDN installations. Of the six MSCDNs, two have been affected by failures of these protections.

2.2 Legacy schemes

In addition to faulty relays, there are a number of legacy protection schemes installed on the network which no longer meet current standards. As these schemes are amongst the oldest installed on the network, associated backup protections, auxiliary items and panels are also aging assets.

Older double-wound transformer protection schemes used only restricted earth fault type relays for the main protections. This is now considered to provide insufficient coverage for all fault types, and

current policy requires an overall differential protection. A number of transformers were highlighted as requiring protection modernisation on this basis and a programme of works to address this was commenced during RIIO-T1. The remaining four schemes having only restricted earth fault protection are proposed to be replaced in the RIIO-T2 period.

Some older autotransformers have only a single main protection installed as these pre-date the now standard practice of two main protections being applied to 275kV and 400kV systems. Due to the criticality of these assets, it is considered that a single main protection is not sufficiently dependable and current policy is to install duplicate main protections. Two autotransformers have been identified for this proposal as requiring a second main protection to be installed outwith the major switchgear replacement projects.

Incorrect operation of breaker fail or busbar protection can have cascading effects and it is proposed to address the population of devices presenting a high risk of this event. On sites where protection modifications have been undertaken in response to feeder or transformer changes rather than a full switchgear change, this has led to breaker fail or busbar protections not being part of the scope of work. This can be seen at some of the sites where major switchgear works are planned during RIIO-T2, with these protections often dating from the original installation. Older installations of these types often rely on a single protection relay, when duplicate protections are required by current policy for these critical functions (with the exception of 132kV busbar protection). The majority of schemes that do not meet current policy or use older electromechanical relays are being replaced under the major switchgear replacement projects. In addition to the legacy electromechanical installations, a number of the first breaker fail and busbar protection schemes installed using processor-based relays are nearing end-of-life, and often there are limited volumes of relays of those types left on the network. This means that expertise and availability of spares is poor, and they often do not have a supervision function.

2.3 Circuits at risk

Following the completion of the RIIO-T1 works, it is expected that over 700 relays will remain on the network of a type that were assessed as Health Index 3 at the start of that period, on the basis of obsolescence or minor defects. There is an expectation that the condition of this population of relays will continue to deteriorate, that external support will decrease, and that internal provision of spare parts will become unsustainable.

Failures of a number of transformer and backup protection relays, as described in previous sections, have led to large replacement programmes. At a number of 132kV sites with grid transformers, extensive relay replacements are being carried out on this basis during RIIO-T1, with further works proposed for RIIO-T2, leaving only a small number of relays unchanged. Often these are obsolete and unsupported intertrips, or feeder main protections which were classified as Health Index 3 going into RIIO-T1. In some cases there are remaining legacy electromechanical backup protections. As 132kV feeders generally have only a single main protection, these are considered the most at risk in event of a single relay failure.

3 Optioneering

The following is a summary of the options considered for this project.

	Option	Status	Reason for rejection
1	No intervention: Reactive replacement only, to replace only failed relays/schemes.	Rejected	Rejected on the basis that system security would be too compromised by this approach.
2	Minimal intervention: Replacement of [redacted] relays. Replacement of only known faulty [redacted]. Single additional relay to bring high impedance auto transformer protection in line with policy for duplicate systems.	Rejected	Rejected on basis that many solutions would in effect be temporary, with future works required to replace the newly installed relays in order to do full protection refresh. Not appropriate in cases where T2 works will already be complex with significant outage requirements. More efficient to carry out further works at the same time. Would likely result in higher fault costs.
3	Balanced intervention: Replacement of [redacted] relays, faulty [redacted] and older models, and two major mesh corner DAR sites per year. Full panel replacement of high impedance schemes outwith policy, plus older installations with non-standard relays.	Proposed	-
4	Balanced intervention + (enhanced option): As per balanced intervention, with additional scope to include [redacted] relays, and HI3 main protections and older relays at sites already having extensive works.	Proposed	-
5	Full panel intervention: Where modifications are required, modernise all of the bay protection should be at the same time.	Rejected	Rejected on the basis that the increased scope would be unjustified. Benefits considered more significant for busbar and transformer protection, so adopted into balanced intervention option.
6	Age-based intervention: Replace all electromechanical and non-complex static relays >60 years old. Replace all complex static and processor-based relays >25 years old.	Rejected	Rejected on the basis that argument for age-based replacement does not have sufficient evidence to proceed, except in cases where known defects exist in earlier models, and where relays are only ones of their type remaining leading to reduced spares and no internal/external technical support. Approach considered more appropriate in major switchgear works, and for efficient use of outages and alignment works.
7	Digitisation preparation at intervention: For new relays being installed, make ready for wider IEC 61850 use by installing appropriate relay and returning alarms via MMS.	Rejected	Rejected on basis of increased complexity for this programme of works. Installation of Merging Units for IEC 61850 preparedness considered as a separate programme.
8	Digitisation at intervention:	Rejected	Rejected on the basis of significant increase in

	Where works are required, implement full digital substation solution.		disruption for this programme of works, but to be considered for major switchgear works and sites with significant intervention.
9	Increased automation: Implementation of protection and control logic in SCADA systems.	Rejected	Rejected as unproven, and reduces reliability due to dependence on remote communications.
10	New algorithms: Replacement of relays on the basis of unsuitability in future network scenarios	Rejected	Current Indications are that such changes would align with the end of life of replacement relays and can be addressed at that time.

4 Detailed analysis

Both of the options considered achieve the principal objectives of replacing defective relay types and legacy out-of-policy protection schemes. The secondary objective of rationalising work to avoid repeat interventions and outages is exercised to varying degrees in the two options. An assessment has been made for each of the proposed individual programmes of work as to the most appropriate implementation of the options. In all cases it is expected that options not progressed at this time would be reviewed and considered again for the protection modernisation plan for the following price control period.

Where possible, the required protection and control modernisations have been incorporated into the major switchgear or transformer replacement works, and so the analysis below applies only to relays expected to be unaffected by the projects proposed elsewhere in the overall RIIO-T2 plan. This is detailed in the cost sheets for this project, to clarify the volumes and costs that have been assumed to be covered elsewhere in the RIIO-T2 plan.

4.1 Relay replacement

The base option for [redacted] and associated [redacted] relays is to carry out a full replacement, given the expectation for continued failure of the devices. All of the [redacted] transformer main protections require their HV and LV backup protections and DAR relays to be changed as they are of type [redacted]

The base option for the [redacted] devices is to replace only the intertrip relays with known defects. Where associated main protection relays are nearing end of life, and the [redacted] is providing a protection signalling function, it has been considered appropriate to change these main protections at the same time and move to integral signalling. This is now the standard solution, removing the need for a separate device and hence a potential point of failure, with lower overall costs. The enhanced option is to replace older [redacted] relays, since they have shown a trend of major defects. Given the problems that have been experienced with [redacted]intertrips, their extensive installation on the network, and that most will be reaching end-of-life during T2, it is proposed to carry out the enhanced works. This would leave around 45% of devices still on the network, with the expectation of these requiring to be replaced during the following price control period.

Again for the mesh corner DAR relays, the base option is to replace only systems with known problems. The enhanced option would be to extend this to cover all legacy [redacted]installations, and an additional [redacted] installation. As there is less evidence of defects within the older [redacted] installations and more recent [redacted] installations, the proposal is to maintain the baseline option but to include provision in direct Opex fault costs in anticipation of future failures informed by historical trends. Known problems with [redacted] relays are due to the inability to extend the system to cover new mesh corners. A direct replacement for the [redacted] that resolves the issues with redundant communications protocols and integration of additional functions in line with modern standards is not currently available off-the-shelf, and work is ongoing with manufacturers to develop alternative solutions, taking into account the requirement for ferro-resonance detection at some sites.

For the [redacted] relay, replacement of all relays was considered as an option, but was judged to be unnecessary due to the small number of relays involved and the expectation that half of the relays would be replaced under planned major switchgear replacement works, allowing a suitable provision of spare devices in event of failure.

4.2 Scheme modernisation

The transformers without differential protection are old installations with obsolete and unsupported backup protections, and so full panel replacements are also proposed for these under both options. The enhanced option for the proposal would be to include for feeder protection replacement, to allow for more co-ordinated design and installation works. This option has not currently been proposed on the basis that it would disproportionately increase the scope of the works.

For the two auto-transformer protection schemes which are non-compliant with the policy requiring two main protections, only one of the affected bays has legacy electromechanical LV protection as well. The base option considered was therefore for HV replacement for both, and LV replacement for one. The proposed option is the enhanced version which includes LV protection changes for both transformers, as the second bay has older processor-based relays, and it is expected that the works can be rationalised with some of the load-related projects. This has been considered as more efficient than requiring a second outage to carry out the same works within a relatively short timescale.

For breaker fail, the base option considered is to replace all schemes which are non-compliant with the policy requiring two main protections, and the [redacted] and [redacted] installations. The enhanced option considered is to additionally begin replacement of the older [redacted] installations on the network, which will be reaching the end of their design life in the period. None of these relay types are supported by the manufacturer. In the case of the [redacted] and [redacted] relays, very few are installed and expertise and internal spares are limited, whereas the [redacted] is more widely installed. Therefore, the proposed option is the base option, with the addition of one of the older [redacted]T schemes to allow the breaker fail and busbar protection replacements for that site to be aligned, allowing rationalisation of devices and outages.

Busbar protection replacements have been considered on a like-for-like basis: installing high impedance protections and utilising the existing CT wiring. Numerical schemes have been considered, as the adoption of such schemes in RIIO-T1 showed potential benefits in reduced panel footprint and easier staged commissioning, although this would require additional cabling/equipment to collect switchgear indications. The base option proposed for the busbar protection modernisation covers the oldest electromechanical and processor-based relays at key sites. The enhanced option covers 132kV sites – both legacy electromechanical schemes and one of the oldest processor-based schemes. The proposal is a mix of the two options, allowing for replacement of the legacy electromechanical scheme at 275/400kV in RIIO-T2, and the most vulnerable of the 132kV electromechanical and 275/400kV processor-based sites highlighted for replacement in the following price control period.

4.3 Site refresh

A number of 132kV sites were surveyed in order to determine the scope and costs required to replace remaining obsolete and unsupported protections at each site. Substations were grouped together where they would have connecting circuits affected by the proposed works. Seven options were examined in total, based on over two thirds of the relays at the sites already being replaced by other programmes of work in RIIO-T1 or RIIO-T2. The selected option allowed the best co-ordination with existing outages due to major switchgear works proposed in the same area. A further option was highlighted for work early in the following price control period, to allow the replacement of some of the highest risk obsolete and unsupported processor-based relays on the network.

4.4 Selected option

Please find below a direct cost summary of all the options reviewed:

	Balanced intervention (Base option)	Proposed option	Balanced intervention + (Enhanced option)
Cost	**£ 10.2 m**	**£ 11.9 m**	**£ 18.2 m**

Reasons for the recommended options are laid out in the previous sections (and represent a balance between the proposed Options 3 and 4). In general, it is considered that the base case represents a higher risk scenario, leading to greater numbers of anticipated future failures and resulting in the requirement for much larger replacement programmes, with associated system access challenges, in later investment periods.

It is likely that the majority of works identified as options but not progressed at this stage will require review and intervention during the next price control period.

5 Conclusion

A number of programmes of work have been proposed within the scope of this project, to deal with types of relays with known defects and legacy protection schemes that present significant network risk and do not meet current standards. For these installations, works to proactively deal with obsolete installations and rationalise works have been considered. The final proposal is a balance of these approaches, providing greater security of the protections and their associated assets. The volumes of relays and schemes involved means that investment will be required throughout the RIIO-T2 period, with priority given to faulty devices, and coordination with other major works and outages wherever possible.

- Costs: £ 11.9 m
- Timing of investment: RIIO-T2 period
- Declared outputs: N/A

6 Future Pathways – Net Zero

We have reviewed this project against the criteria set out within the business plan guidance and have assessed that it does not prevent achievement of our Net Zero plans or lead to stranded assets.

7 Outputs included in RIIO T1 Plans

The protection modernisation plan for RIIO-T1 included replacement of all Health Index 4 relays acting as main protections, with some replacement of backup protections, during a wider programme of works which included the replacement of all Health Index 5 relays. For this, [redacted] type transformer main protection relays were identified as Health Index 5 due to significant defects, but because of the volume of these relays installed on the network it was anticipated that 20 of these relays would need to be carried over for replacement in the RIIO-T2 period. During RIIO-T1, it was decided that it would be possible to replace all of the [redacted] relays, which was preferable due to the increased failures compared to the Health Index 4 [redacted].

As a result of this, no [redacted] relays are left on the network, and so the 20 anticipated relays are not included in this proposal. However, the remaining 5 [redacted] relays that were initially included in

the RIIO-T1 plan are now proposed for replacement under this project. Due to the increased volume of main protection changes to manage the issues associated with the [redacted] in RIIO-T1, Health Index 4 backup protections originally planned to complete in RIIO-T1 have in some cases been deferred, leading to the volumes proposed for replacement in RIIO-T2 being higher than had been planned. The risk associated with these devices are considered more manageable than for main protections and the deliverability of the changes is simplified due to the availability of withdrawable case replacements for most models, meaning minimal wiring work on site. The development of standardised replacement configurations in RIIO-T1 will further improve the replacement process.