Document 13
Asset Category – Protection and Control (Capex and Opex)
SPN

Asset Stewardship Report 2014

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Document History

Version	Date	Details	Originator	Revision Class	Section Update
1		Baselined July 2013 Submission	Kevin Burt		
1.1	21/02/2014	Updated mapping table with NAMP lines and RIGs mapping	David Jeyakumar	Major	1.1
		Included cost and volume tables and graphs for all lines, excluding Protection Enhancement and Low Frequency Protection Comp as these do not report volumes.			7.4 Appendix 5
		Updated ED1 figures to align with RIGs.			7.4 Appendix 5
1.2	21/02/2014	Created Appendix 8 – RIGs mapping to show comparison of ASRs and RIGs	David Jeyakumar	Major	Appendix 8
1.3	24/02/2014	Amended document formatting	David Jeyakumar	Minor	Whole Document
		Split Pilot Cable I&M table into constituent lines, in order to align with the table in Appendix 8.			Appendix 5
1.4	24/02/14	Addition of Glossary and reformatting	Tomas Mazeika	Major	1
1.5	27/02/14	Addition of example for strategic spares and protection enhancement/ Reformatting	Kevin Burt/Tomas Mazeika	Major	8 Whole Document

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1.0 Glossary

AR	Automatic reclosing
AVC	Automatic Voltage Control
Capex	Capital Expenditure
CI	Customer Interuptions
Cigré	The International Council on Large Electric Systems (in French: Conseil international des grands réseaux électriques)
CML	Customer Minutes Lost
CoF	Cause of failure
DAR	Delayed automatic reclose
EHV	Extremely high voltage (22kV up to, but not including 132 kV)
ESQCR	Electricity Supply, Quality and Continuity Regulations
FBPQ	Financial Business Plan Questionaire
Grid Code	Specification of technical requirements for connection to, and use of, the National Electricity Transmission System (NETS)
IEEE	Institute of Electrical and Electronics Engineers
MST	Maintenance schedule task
NAMP	Network Asset Management Plan
NEDeRS	National Equipment Defect Reporting Scheme
NLRE	Non Load Related Expenditure
Opex	Operational Expenditure
PAPM	Protection Asset Prioritisation Model
PoF	Probability of failure

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2.0 Executive Summary SPN Protection and Control Assets

2.1 Scope

This document details UK Power Networks' non-load related expenditure (NLRE) proposals for protection and control assets (excluding SCADA) during the RIIO-ED1 period in SPN. Indicative proposals for the ED2 period are also included. These assets include protective devices (measuring, key auxiliary and control) and pilot cables. It also includes the proposals for inspection and maintenance activities of protection assets, based on the number of protection maintenance groups associated with primary plant.

The totals of each type known to be in service as of April 2013 are as follows:

- Protection and control assets in the SPN area – 19,152 (excluding selector switches, ammeters, transducers and simple auxiliary relays).
- Pilot cables – 807.

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Replacement and refurbishment costs for these assets are held in the Ofgem and UK Power Networks' investment planning documents in the locations outlined in Table 1.

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Sub Programme	Project Name	UK Power Networks NAMP location	RIGs mapping
Protection enhancement	Enhance Grid and Primary Protection	1.05.01.6726	CV106 row 50
Low-frequency protection compliance	Low-Frequency Protection Compliance	1.26.01.8212	CV5 row 37
Protection replacement	Targetted Transformer Differential Protection Replacement	1.26.01.8364	CV5 row 57
	Targetted Distance Protection Replacement	1.26.01.8365	CV5 row 57
	Protection Asset Replacement to Release Strategic Spares	1.26.01.8366	CV5 row 57
	Major Protection Asset Replacement	1.26.01.8367	CV5 row 57
	Minor Protection Asset Replacement	1.26.01.8368	CV5 row 57
	Replacement of AVC Relays or Schemes	1.26.07.6136	CV5 row 37
	Replace Unreliable AVC Schemes	1.26.07.9493	CV5 row 37
Protection inspection and maintenance	132kV CB Feeder Including BS	2.25.02.9395	CV13 row 74
	Grid Transformer Protection	2.25.03.6570	CV13 row 75
	33kV Feeder Protection	2.25.04.6571	CV13 row 47
	System Transformer Protection	2.25.05.6436	CV13 row 47
	11kV Feeder Protection	2.25.06.6437	CV13 row 31
	AVC checks at Grids & Primaries	2.25.07.9396	CV13 row 72
	Low Frequency - 132kV Injection Test	2.25.09.8357	CV13 row 75
	132kV Bus Zone	2.25.10.9397	CV13 row 75
	Trip Testing 132kV DAR	2.25.11.8358	CV13 row 75
	Trip Testing 33kV AR	2.25.12.8359	CV13 row 47
	Trip Testing 11kV Sequence Closing	2.25.13.8360	CV13 row 31
	Single Transformer Auto Changer Scheme Proving	2.25.14.6438	CV13 row 75
	NVD Function Test	2.25.16.9398	CV13 row 75
	Defect Repair - EHV Protection	2.26.01.6467	CV13 row 47
	Defect Repair - 11 kV Protection	2.26.03.6468	CV13 row 31
Pilot cable survey and replacement	Pilot Cable Survey & Replacement - EHV	1.26.02.3196	CV3 row 104
Pilot cable inspection and maintenance	Pilot Cable Repairs	2.01.14.8958	CV15b row 17
	Pilots and Multicores Test Insulation and Continuity	2.25.15.6439	CV13 row 75

Table 1 – Mapping of refurbishment and replacement costs

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2.2 Investment Strategy

Options for refurbishment of protection and control assets are limited, and can only relate to the older electromechanical devices, where component replacement or adjustment is possible. Modern protection devices are of a modular design and do not lend themselves to any form of meaningful refurbishment. In the event of failure or unexpected operation, replacement is the only option. Therefore, the strategy adopted in this document is based around replacement.

This investment strategy is carried through ED1 and ED2 for the replacement of protection assets, It is based around targeting devices with a known history of failure or poor performance and an ongoing replacement plan for other protection assets based on age, criticality of failure (i.e. impact) and probability of failure (likelihood).

The budget forecast for protection and control relays replacement in ED1 allows for the replacement of less than 2% of the known asset base population. While this is a low level of replacement and the total asset replacement would take approximately 400 years, this is a realistic level of work that can be delivered. The risk of this low level of replacement will be quantified using the Protection Asset Prioritisation Model (PAPM) currently in final development and verification.

Protection enhancement involves the addition of new devices, or the replacement of existing ones, with devices that have the additional functionality required to meet the needs of the network; therefore, refurbishment does not apply.

Where network reinforcement or major asset replacement is planned in the ED1 and ED2 periods, protection and control asset replacement will be aligned to optimise opportunities and reduce costs wherever possible. Where asset replacement is driven by changes to the network this will be treated in accordance with Ofgem reporting rules.

Protection enhancement is linked to network changes and will only become clear as additional projects and network needs are identified. Therefore, only a low-level provision is included.

Interventions for pilot cable replacement are, where appropriate and feasible, generally limited to repair after fault, as other interventions are limited to general maintenance or replacement once the pilot cable is no longer fit for service.

The investment is constrained at the same level as DPCR5 to continue the programme of surveying and refurbishment. The completion of the surveying work will provide a more accurate view of future requirements into ED2. However, the replacement of pilots is a costly exercise and could require a

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more substantial allowance. This is a risk that the company is carrying until detailed asset and condition data is available.

2.3 ED1 Proposals

Sub-programme	Investment (£k)	Volume	RIGs table
Protection enhancement	565	n/a	CV106
Low-frequency protection compliance	581	n/a	CV5
Protection replacement	7,101	309	CV5
Protection inspection and maintenance	1,811	7,835 units / tasks	CV13
Pilot cable survey and replacement	726	11.3km	CV3
Pilot cable inspection and maintenance	1,207	776 Units/tasks	CV13
Total	**11,991**	**n/a**	

Table 2 – Investment and volumes in ED1 sub-programmes

2.4 Innovation

Innovation in protection replacement presents itself in a number of forms. Where multiple relays require replacement on a particular circuit, the opportunity will be taken to combine the functionality of these into a single device to reduce work and cost, provided it does not affect the resilience of the network or impose an unacceptable risk to staff, contractors or the general public.

The development of PAPM for UK Power Networks (currently in final development and verification) – it has only been used for data cleansing so far, and full functionality is expected end Q1 2014.) will enable us to better understand the impact of varying criteria, such as design life, maximum life, criticality and likelihood of failure. For example, by varying the volume of assets planned for replacement prior to design life and maximum life, we can better understand the level of risk exposure.

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2.5 Risks and Opportunities

	Description of similarly likely opportunities or risks arising in ED1 period	**Level of (uncertainties)/ cost growth**
Opportunity	Protection replacement: Combining functionality when replacement is taking place	10%
Risk	Protection replacement: Assumed age-based analysis is too pessimistic, leading to replacing assets too early	Further analysis is needed through the PAPM to define risk level. However, the risk of over-investment in ED1 is low because only 3% of assets will have an intervention in ED1.
Risk	Protection replacement: Assumed age-based analysis is too optimistic, leading to increased network risk	Further analysis is needed through the PAPM to define risk level. Therefore there is the risk of under-investment in ED1 due to only 3% of assets having an intervention in ED1.
Risk	Protection replacement, protection inspection and maintenance (I&M), pilot cable replacement and pilot cables I&M: Significant number of protection assets not captured during data-collection process – key assets may not have been captured, leading to a potential increase of risk to the network due to asset failure	Assumed 10%

Table 3 – Risks and opportunities

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3.0 Description of Protection and Control Equipment Population

The assets considered here are protection and control relays, and pilot cables, each of which is discussed separately.

3.1 Protection and Control Relays

There are 19,152 protection and control relays recorded in SPN in the Ellipse database. These relays are installed in the grid and primary substations across the network. There are three distinct technologies associated with computational and measurement techniques in relays: electromechanical, static and numerical.

Nameplate data on relays do not show the year of manufacture. We have determined the likely year of manufacture based on the primary plant date or a mid-point date in the period during which the product was manufactured. Data quality has been further checked and improved through comparison with the year the site was established. This selected year will be further refined using PAPM; however, this was not available at this stage. The PAPM will compare the selected year in the data, where available, against the manufacturing period of each of the asset types as entered by the user.

Figure 1 shows the age profile of the relays, based on the cleansed data from the PAPM, but not the post-processed data output. At this stage, the graph shows the profile of the 20% of the assets – 3,741 out of 19,152 records – that have a year available against them. As discussed earlier, the PAPM will address the blank years at the same time as the selected year in the data is confirmed.

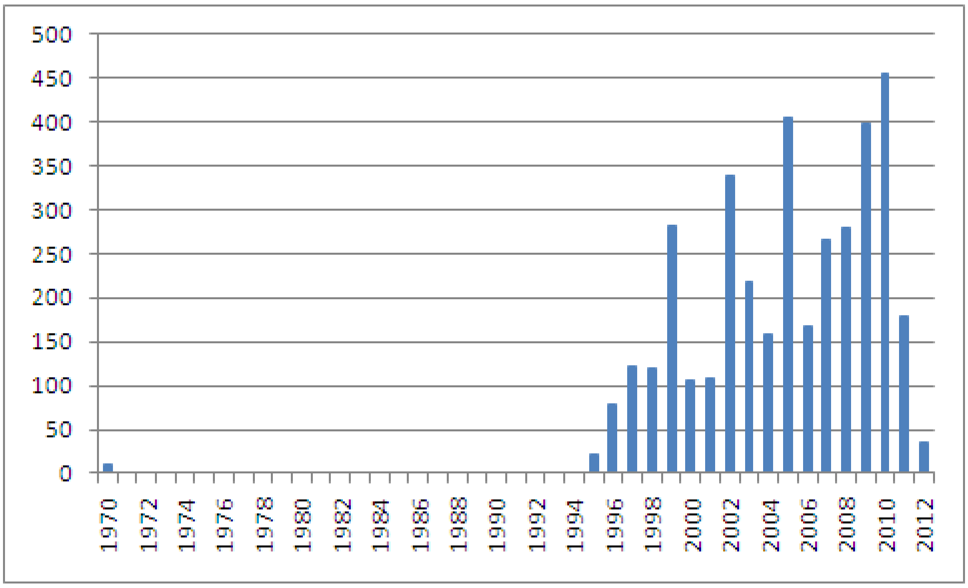

Figure 1 – Age profile of relays

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The following NAMP lines relate to the Capex of protection and control relays:

- Protection enhancement.
- Low-frequency protection compliance.
- Protection replacement.
  - Targeted transformer differential protection replacement.
  - Targeted distance protection replacement.
  - Replacement of AVC relays or schemes.
  - Protection asset replacement to release strategic spares.
  - Major protection asset replacement.
  - Minor protection asset replacement.

The following NAMP lines relate to the Opex of protection and control relays:

- Protection inspection and maintenance.
  - 132kV CB feeder including Bus Section.
  - Grid transformer protection.
  - 33kV feeder protection.
  - System transformer protection.
  - 11kV feeder protection.
  - AVC checks at grids and primaries.
  - Low frequency – 132kV injection test.
  - 132kV bus zone.
  - Trip testing 132kV DAR.
  - Trip testing 33kV AR.
  - Trip testing 11kV sequence closing.
  - Single transformer auto-changer scheme proving.
  - NVD function test.
  - Defect repair – EHV protection.
  - Defect repair – 11kV protection.

3.2 Pilot Cables

Pilot cables provide the necessary 'substation-to-substation' communications paths required by protection signalling schemes, such as intertripping and unit protection. These pilot cables provide the communication necessary to operate the network and ensure its safety, security and integrity.

There are 807 known pilot cables in SPN. The Ellipse database is currently being modified to allow for their recording.

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The following NAMP line relates to the Capex of pilot cables:

- Pilot cable survey and replacement.

The following NAMP lines relate to the Opex of pilot cables:

- Pilot cable inspection and maintenance.
  - Pilot cable repairs.
  - Pilots and multicores test insulation and continuity.

4.0 Investment Drivers

4.1 Investment Drivers

4.1.1 Protection enhancement

Activities within the protection enhancement programme cover future opportunities to improve fault detection, discrimination and network restoration performance.

As a result of future changes to network configuration and/or requirements, this programme is expected to address the specific challenges of reducing outage measures – Customer Interruptions (CIs) and Customer Minutes Lost (CMLs) – and ensuring continued compliance with the Grid Code and Electricity Supply, Quality and Continuity Regulations 2002 (ESQCR) requirements.

This programme provides for the enhancement of grid and primary protection in the following areas:

- Provision of auto-reclose systems.
- Provision of auto-switching schemes.

4.1.2 Low-frequency protection compliance

Low-frequency protection is a Grid Code requirement; this programme covers activities to ensure continued compliance.

This type of protection addresses the possibility of generator volatility due to excessive loading by ensuring that the associated symptoms are detected and the appropriate targeted and controlled load-shedding occurs to ease network loading. Low-frequency protection, therefore, mitigates the risk of network instability as a result of sustained overload conditions and is obligatory as part of licence, statutory and operational requirements.

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This programme is a new activity to comply with the low-frequency protection requirements within the Grid Code. Previously, low-frequency compliance was only covered for installation of new schemes and within the project costs for Grid Site work – there was no separate budget for addressing existing schemes. With the growing increase in the connections of distributed generation, and with the grid requiring these generators to ride through system disturbances, the settings on a large proportion of the existing schemes need to be readdressed.

This programme covers the following tasks to ensure compliance:

- Installation of new equipment.
- Relocation of existing equipment.
- Adjustment of existing equipment.

4.1.3 Protection replacement

The protection replacement programme covers the replacement of protection or control relays and schemes where the requirement for replacement is not driven by the need for additional protection or control functions (enhancement) or as a consequence of network reinforcement. This programme is principally driven by:

- The legislative and licence requirements to protect the network.
- The need to replace relays with known problems.
- Obsolescence of certain types of technology, especially on multi-ended schemes.
- The ageing profile of electromechanical relays.
- The predicted failure of electronic relays as per information from manufacturers.

The company has always based its programme of protection replacement on field experience, targeting select activities and relay types. Until recently, the complete asset base was not being recorded. Therefore, it was difficult to have a complete picture of the population. The recent collection and recording of protection and control relays into the Ellipse database has enabled the complete known asset base to be analysed. Furthermore, the development of PAPM was an innovative approach that has enabled risk analysis to be applied against the asset base. It has also enabled the impact of various replacement policies against the asset group and network risks to be assessed.

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4.1.4 Protection inspection and maintenance

Activities within this programme involve the periodic maintenance of protection assets to ensure that relays and associated equipment are fully functional and able to detect faults on the network. Moreover, asset condition reports are produced, which form an essential part of the required data to optimise and refine future maintenance programmes and/or asset replacement projects.

While this programme ensures continued compliance with legislative requirements, the inspection and maintenance of protection assets should also result in a lower number of unforeseen asset failures, which, correspondingly, leads to reduced CIs and CMLs.

This programme covers maintenance on the following protection assets:

- 132kV circuit breaker feeder protection (including bus sections).
- 132kV bus zone protection.
- Grid transformer protection.
- System (primary) transformer protection.
- 33kV feeder protection.
- 11kV feeder protection.
- Low-frequency protection (132kV injection testing).

The programme also covers the following specific tasks:

- Automatic voltage control scheme checks at grids and primaries.
- 132kV circuit breaker trip testing.
- 33kV circuit breaker trip testing.
- 11kV circuit breaker trip testing.
- Single transformer auto-changer scheme proving.
- Neutral voltage displacement protection functional test.

4.1.5 Pilot cables

Faulty pilot cables have been implicated in a number of protection failures. The programme provides for the replacement of faulty pilots where necessary. Many of the circuits comprise decades-old pilot cables and their repeated failure results in the time-consuming and costly activities of identifying healthy cores and re-routing the circuit.

Progressive deterioration can result in pilot cables being rendered unserviceable with no healthy alternative cores remaining; therefore, replacement becomes the only solution. This programme will identify and prioritise these and propose remedial actions.

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As well as the replacement of already identified critical pilot cables, activities will include surveys to identify the condition of other pilot cables on the network, and insulation and continuity testing.

4.2 Condition Measurements

4.2.1 Protection and control relays condition

Relay condition data is now being collected and recorded in the Ellipse database, making the informed management of these assets more effective. However, this is a complex process, as the condition data relating to protection and control relays cannot be assessed from a basic inspection of the site. Other than signs of physical damage, relays do not readily offer an inspector any information about their condition. Detailed maintenance can measure key health indicators:

- Accuracy test – This can offer a pass/fail comparison of accuracy against manufacturer tolerance, as well as drift of accuracy over time.
- Inputs/Outputs tests – This also offers a pass/fail measure against the condition of the contacts.

Self-monitoring functions are generally available in modern numerical relays. Research has shown that these functions offer a pass/fail assessment against 75-85% of the failure modes.

The main measure of relay condition presently available is the field experience of certain relay types and families. However, this is not fully comprehensive for reasons discussed in section 5.1. Although this does not offer the exact condition of a singular unit, it gives a good indication of the general asset type condition and the direction of the intervention to be applied. For example, the C21 transformer protection relay has been identified as no longer reliable due to history of failure in its operation mechanism. Therefore, due to the criticality of such relay and the lack of warning before or on failure, the complete population is to be replaced, regardless of the individual unit condition.

In PAPM, relay unit condition will be combined with the family condition to produce a likelihood of failure, that is then combined with the consequence of failure to produce a criticality of failure. This is discussed further in section 6.2.1.

4.2.2 Pilot cables condition

Cable insulation tests offer a reasonable degree of confidence with regard to the condition of pilot cables. However, until recently, these were not recorded in Ellipse.

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By looking at the presently recorded assets, the conditions available for pilot cables are shown in Table 4.

Condition	
1 (As new)	56%
2 (Good)	26%
3 (Poor)	6%
4 (Unusable)	12%

Table 4 – Condition ratings for pilot cables

It can be seen that around 18% of the pilot cables are in poor or unusable condition. This information was not available at an early enough stage to enable detailed analysis of the pilot requirements. However, future risk-based analysis can calculate the budget forecast requirements.

Condition data will be used to prioritise the replacement of pilot cables throughout the ED1 and ED2 periods and as more detailed information becomes available about pilot cable condition this will be used to prioritise our replacement strategy.

5.0 Asset Assessment

5.1 Asset Health

It is difficult to establish the health of protection assets for the following reasons:

- Until recently, individual protection asset condition was not being recorded centrally.
- There are many variants affecting the failure mode of protection and control assets, such as the technology, type, model, manufacturing batch, etc. Therefore, it is often impractical to establish trend information.
- Most protection and control assets and their components have a simple pass/fail mode, therefore, there are no means of predicting the occurrence of a failure.
- Many upgrades are driven by technology obsolescence, primary plant replacement and network configuration changes. These replacements mask the true failure rates of protection and control assets.

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Therefore, the asset health measure is based on field experience, both locally within the company and nationally through the National Equipment Defect Reporting Scheme (NEDeRS). This will be used as an input to PAPM to assign the relay probability of failure (PoF), which is a combination of the relay type history and, where available, the individual asset condition.

5.1.1 Asset life expectancy

Following interrogation of the limited protection failure records in UK Power Networks and the NEDeRs, it was not possible to establish an asset life expectancy. This was due to:

- The relatively small number of failed units recorded.
- The majority of failures recorded being from ‘infancy’ rather than the ‘end of life’ stage.
- A large percentage of assets having a cause of failure as ‘unknown’ or ‘under investigation’.

The experience of distribution and transmission companies outside of the UK was investigated and found to be similar to UK Power Networks’ experience. One manufacturer agreed to issue a life expectancy statement, indicating that static and numerical relay life should be greater than or equal to 20 years. Previous communication with manufacturers has also indicated that electromechanical relays have design lives similar to that of the primary plant, which was previously assumed to be 40 years.

International research into area of protection asset life expectancy is inadequate. Researched publications – of and through the IEEE and Cigré – revealed only two papers with reference to age profiles. One of these papers has given a 90% confidence that 50% of the relays under investigation will fail between 14 and 36.5 years. The paper did not specify the technology being used.

It was decided that UK Power Networks will take the following initial stance on life expectancy:

- Electromechanical relays: 40 years’ design life, 60 years’ maximum life.
- Static and numerical relays: 20 years’ design life, 30 years’ maximum life.

The impact of the above will be quantified through sensitivity analysis in the PAPM.

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5.2 Asset Criticality

Protection systems are critical and relatively low-cost assets that enable the safe operation of the network. Their provision and maintenance are a legislative requirement and licence condition. The consequence of failure of protection assets can be disastrous, leading to increased risk to the public, staff and plant, as well as impacting CIs and CMLs.

The criticality of the protection asset is based on its function and the associated voltage level. For example, a unit protection scheme is deemed to be more critical than a voltage control scheme, as a failed protection system has greater potential to cause harm. Similarly, an auto-switching scheme at 132kV is more critical than one at 33kV due to the wider impact of the network. The PAPM uses the two discussed measures to assign the criticality of failure for each protection and control relay.

5.3 Network Risk

Using the PAPM, the network risk will be calculated on the basis of the residual life of the protection and control relays in relation to their design and maximum expected life.

5.4 Data Validation

All data used in the PAPM is subject to validation against a set of minimum requirements. The model will ensure that the data received is in the right format and with the prerequisite fields filled. It will also cleanse it of duplicates of the same relays. The PAPM creates two lists of data – cleansed data for use in the model and rejected data – allowing continued improvement of data quality.

5.5 Data Verification

After each data upload, a sampling approach to data verification is taken to ensure accurate transfer into the models.

5.6 Data Completeness

The programme of work is based on the known data. Any errors caused by data quality or missing data have not been accounted for and will be carried by the company at its own risk.

5.6.1 Protection and control relays

As part of the data cleanse routine in the PAPM, the relay data is assessed for completeness and to detect duplication. Duplication in the data is predominantly caused by one of two factors:

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- The older three or more element relays are recorded in Ellipse as their separate elements; however, in terms of replacements, more often than not, these relays would be replaced with single multi-function relays.
- Multi-function relays, which share a unique identifier, are shown as multiple lines within the database for each of the functions.

The PAPM cleanse routine is based on the following set of criteria:

1. Unique asset identifier not available.
2. Associated voltage not available.
3. Relay type or model not available.
4. Relay function not available.
5. Duplication – looking at the availability of year and relay condition, picking the most populated line and rejecting the rest.

The data is assessed on the above criteria in sequence and is rejected as soon as meeting the first of these. Table 5 shows the level of accepted and rejected data after the cleanse routine is completed.

Original lines	**32,595**	
Unique asset identifier not available	1,418	4%
Associated voltage not available	-	0%
Relay type or model not available	1,020	3%
Relay function not available	1,160	4%
Rejected duplicates	9,845	30%
Total accepted	19,152	59%
Total rejected	13,443	41%

Table 5 – Accepted and rejected data after the cleanse routine

It can be seen from Table 5 that, as expected, a large proportion of the rejected data is caused by duplication, leaving only 11% rejected due to data quality.

5.6.2 Protection inspection and maintenance

This programme of works was based on the number of protected assets recorded in Ellipse after application of the routine inspection and maintenance cycles as set in EMS 10-0002. These were compared against the smoothed profile for the maintenance schedule tasks (MSTs) for the ED1 period and found to be comparable. Therefore, it is believed there are no significant issues with the data used in the development of this programme of work.

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5.6.3 Pilot cables

Table 6 shows the legacy cable records, with some significant gaps in the recorded information. With the aim of improving this situation, the company has created a structure within the Ellipse database to record pilot-related data.

End-to-end	**807**
Function recorded	35%
Type	–
Number of cores	19%
Used cores	–
Spare cores	–
Defective cores	–

Table 6 – Legacy cable record

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6.0 Intervention Policies

6.1 Interventions: Description of Intervention Options

The intervention policies considered are as follows:

- Do nothing.
- Inspect, maintain and repair.
- Refurbish existing assets.
- Replace on failure.
- Replace assets on risk basis.
- Replace assets on age basis.

6.2 Policies: Selecting Preferred Interventions

The choice of intervention policy differs depending on asset type and each is discussed in detail separately. In general, due to the criticality of the protection asset, the 'do nothing' option is considered to be too high risk. Inspection is deemed important to reduce that risk, as is maintenance and repair where possible. Refurbishment is generally not a suitable option due to the construction of the equipment or the obsolescence of the technology.

6.2.1 Protection and control relays

The following types of policies are applied to protection and control relays:

- Inspection.
- Maintenance/repairs, where possible.
- Replacement.

Due to the lack of availability of components relating to older relays and the complexity of modern relays, most relay faults can only be rectified by replacement. Inspection, however, does allow for the condition data to be collected and improves the likelihood of failures being detected.

Therefore, there is not much choice in intervention methodology. However, UK Power Networks can make an assessment based on the cost and the network risk associated with various replacement programmes. The PAPM will enable UK Power Networks to quantify the effect of various replacement options for the first time.

The ED1 expenditure for replacement was based on the following sub-programmes using Ellipse, as well as some legacy asset records:

- Complete replacement of high-risk assets with known issues.
- Replacement of AVC relays and schemes that are faulty or no longer suitable for the network requirements.

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- Managed replacement of certain assets to release strategic spares.
- Limited replacement of major protection assets.
- Limited replacement of minor protection assets.

The PAPM will be used to work out a similar programme of work and calculate the associated risks. In future, the PAPM will form an integral part of decision-making from the outset, significantly reducing the time and resource requirement for the production of replacement programmes, and creating a means of calculating and understanding the impact of such programmes on the carried level of risk.

The PAPM offers a choice of replacement policies that can be applied to different asset groups:

- Forced (F-type) – Applied to the relay type, without consideration of other factors, in the form of a cumulative percentage of relays to be replaced within a specified period of an input start year.
- Prioritised (P-type) – Applied in the form of a cumulative percentage of relays to be replaced within a specified period of an input start year. This is similar to the Forced policy; but whereas that is assigned on the asset-type basis, the Prioritised policy is assigned on account of probability and criticality of failure.
- Age (A-type) – Applied in the form of a cumulative percentage of relays to be replaced within a specified window before design life; a cumulative percentage of relays between design life and maximum life; and a cumulative percentage of relays to be replaced by the end of a replacement window as specified after maximum life.

6.2.2 Pilot cables

This part of the programme is based on the following pilot related activities:

- Survey of pilot cable circuits to identify the most at-risk systems for prioritisation.
- Pilot and multicore cables insulation and continuity testing.
- Replacement of pilot cables.

The choice of intervention for pilot cables is based on the following:

- If damage or severe deterioration is detected on one or more of the used cores and there are a number of healthy spare cores: re-terminate the pilot using the spare cores and attempt to repair the damaged ones.
- If no spare cores are available and repairs are not possible: attempt to reroute the signal through other pilot(s).
- If no alternatives are available: the pilot has to be repaired or replaced (not necessarily with the same technology).

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7.0 Innovation

UK Power Networks has taken an innovative approach to enable the calculation of the protection replacement programmes by developing the Protection Assets Prioritisation Model (PAPM). This will enable a more inclusive and accurate calculation of the programme based on the risk of failure of a particular asset. As PAPM calculates the residual risk on the asset base, it enables, through sensitivity analysis, a robust understanding of the impact by selecting various design parameters and replacement policies.

Furthermore, where modern technology allows and network risk is not increased, existing functionality provided through discrete relays will be combined into fewer units to reduce cost and space requirements.

8.0 ED1 Expenditure Requirements

8.1 Method

The way each plan was constructed is different for each sub-programme and is dependent on data availability. This is discussed individually in 7.2.

8.2 Constructing the Plan

The protection and control asset NLRE programme consists of six sub-programmes:

1. Protection enhancements.
2. Low-frequency protection compliance.
3. Protection replacement.
4. Protection inspection and maintenance.
5. Pilot cable survey and replacement.
6. Pilot cable inspection and maintenance.

These are discussed further below.

8.2.1 Protection enhancements

Protection enhancement is an ongoing programme, anticipated to be completed in-house. The expected costs are based on a technical assessment of the design team's forecasts and analysis of present and historical spending. However, since activities with this programme are contingent on changes to the network configuration and/or requirements, the actual protection enhancement needs may not be as foreseen, and so costs may vary.

Smart grid and Future Network needs have not been accounted for within this budget, as these requirements will be managed on a project-specific basis within the ED1 period. However, the replacement of older technology with

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modern devices will provide additional functionality which will support smarter network management and analysis of system performance.

8.2.2 Low-frequency protection compliance

The programme was derived by analysing the settings and location of the existing low-frequency schemes against the projected targets using the most up-to-date peak demand values and estimates compiled from the relevant workgroups for rectification works. The analysis has identified the need to modify some low frequency demand disconnection block configurations to ensure the required levels of disconnection continue to be met. The increasing level of distributed generation (DG) will impact on the extent of demand disconnected under low frequency conditions and this will be included in the assessments for modifications to existing settings. r.
The programme will install approximately 12 new schemes and adjust the setting on approximately 40 others. This is a generic programme based on the assumption that each grid site is estimated to have a 45MW load on average. Further analyses are needed to fine-tune this programme on an annual basis, and this shall take into account the network loading, emergency restoration plans and availability of generation.

8.2.3 Protection replacement

The technical team has assembled the protection replacement programme using the available condition information, equipment availability and obsolescence, and volumes and age profiles. The PAPM has been developed to enable the analysis of the complete asset base and the quantification of network risk brought about by different replacement strategies. Through the sensitivity analysis, the PAPM will be used to assess the suitability of the proposed programme, which was based on what is believed to be realistically deliverable. Through the sensitivity analysis, the details of this programme could change through optimising the budget to manage a different level of network risk at the various voltage levels.

The protection replacement programme presently features the following sub programmes:

1. Replacement of assets with known issues.
2. Replacement of AVC relays or schemes.
3. Replacement of certain assets to release strategic spares.
4. Replacement of major protection assets.
5. Replacement of minor protection assets.

Table 7 shows the recorded population of assets with known issues and defects. These are to be replaced before the end of ED1.

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Type	Function	Number
C21	Transformer differential protection	24
DT2	Transformer differential protection	3
H Type	Distance protection	2
SSM3V	Distance protection	1

Table 7 – Assets with defects and issues

The above will form the basis of the Forced policy within the PAPM environment.

The release strategic spares programme features the replacement of critical multi-ended schemes, such as inter-tripping and unit protection, where the relays are obsolete and no longer supported by suitable equivalents from the manufacturers. The programme plans to replace a number of these critical relays with modern equivalents, releasing the replaced relays to become spares for like-for-like replacements on failure. The opportunities will be taken to do this in conjunction with non-load related or load-related major works, where network changes dictate the replacement of protection and control assets to ensure continued network reliability.

An example of releasing strategic spares is the estimated population of 286 Telecode 80 voice frequency based intertripping equipment (first installed in the 1980s/early 1990s). These continue to give good service but are no longer supported and spares are difficult to obtain. Rather than replace the whole population it is proposed that a low level replacement programme is put in place to release units as strategic spares over time. This is seen as a more cost effective approach and a quicker solution to resolving protection depletion which may otherwise place the network at risk. Should significant failures start to occur then these will be re-evaluated for a targeted replacement programme.

The major asset replacement programme covers replacements that affect the whole panel or its front sheet and/or the replacement of schemes that span multiple panels. The volumes show the anticipated requirements within this programme. Typical examples can be distance-protection schemes, where the older technology required a complete panel to accommodate all components.

The minor asset replacement programme is used to reduce the population of assets that have large volumes of a specific relay or manufacturer type anticipated to fail within ED1. This programme also provides allowance for expected requirements for replacements on failure. Table 8 shows the known volumes for some assets targeted in this low-level programme. These asset types are a combination of either old electromechanical relays or modern numerical relays with failures expected to start occurring beyond a 20-year service life.

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Type	Number
TJX	183
TJV	892
TJM	647
CDG	569
PBO	28
K relays	176
Argus relays	65

Table 8 – Known volumes for assets in the minor asset replacement programme

8.2.4 Protection inspection and maintenance

The inspection and maintenance of protection equipment was based on the number of protected assets and the associated scheme. The even profile of work is prepared for all protection equipment recorded on Ellipse in accordance with the inspection and maintenance cycles, as set out in EMS 10-0002 *Inspection and Maintenance Frequency Schedule*.

8.2.5 Pilot cable survey and replacement

This part of the programme is based on historical allowances and profiles of spend. Data recorded to date (see section 4.2.2) will be used to prioritise pilot cable replacement to ensure worst condition pilot circuits are addressed first. As more detailed data becomes available this will enable a more robust analysis and prioritisation of the programme.

8.3 Additional Considerations

Where possible and appropriate, asset replacement and maintenance will be aligned with load-related and non-load-related reinforcement projects, and strategic asset replacements of major plant. This will reduce the burden on resources, outage requirements, and network risk.

8.4 Asset Volumes and Expenditure

Figures 2–11 show the actual achievement for all programmes during the first three years of DPCR5 (with the third year shown as pro rata of the first nine months) and the forecast for the last two years of DPCR5. These are shown against the DPCR5 allowance as set in the FBPQ. The graphs also show the ED1 and ED2 forecast of requirements.

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8.4.1 Protection enhancements

As this programme is a low-level budgetary allowance, there are no associated volumes. For a similar reason, the expenditure has actually been below the allowance. However, it is important to have this small level of investment available to allow enhancing protection and control schemes when required.

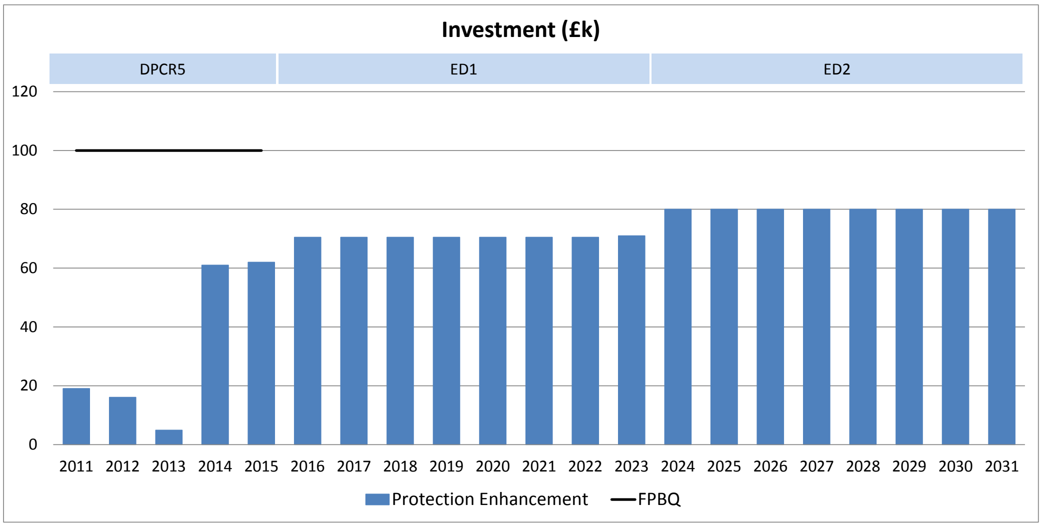

Figure 2 – Investment and predicted investment for protection enhancement programme

Examples of protection enhancement are installation of Canterbury Rapid intertripping system in 2012-2013 and the installation of additional Bolney/ Three Bridges/ Horsham intertripping systems in 2011-2012.

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8.4.2 Low-frequency protection compliance

This programme did not have an allowance in DPCR5. The programme of work aims to install, relocate and adjust settings of low-frequency schemes, and is set to maintain low-frequency compliance as soon as possible. This programme starts in 2013 and follows through to ED2.

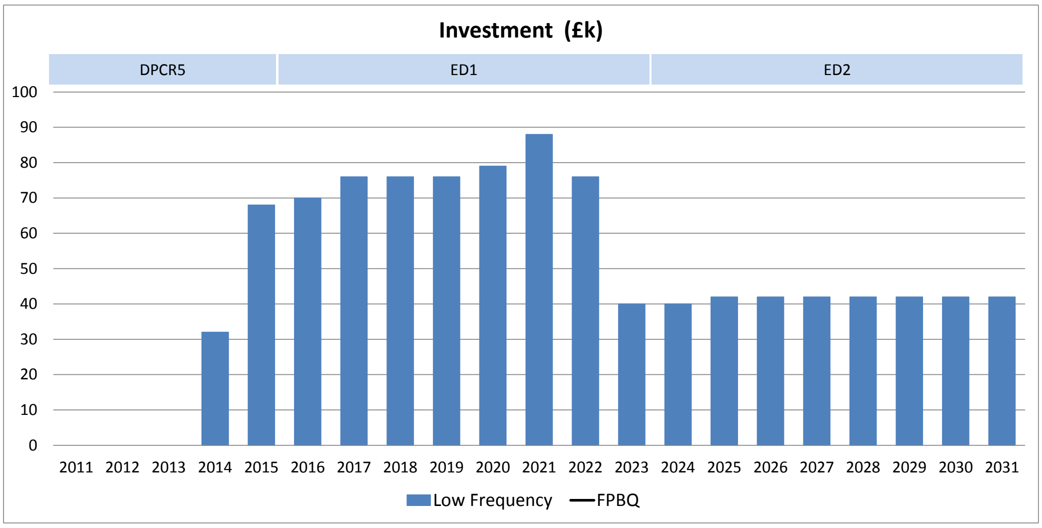

Figure 3 – Investment and predicted investment for low-frequency protection compliance programme

8.4.3 Protection replacement

In ED1, this programme will be based on volumes with unit costs. Furthermore, the spend levels presently recorded do not represent the actual spend level associated with protection replacement, as many are incorporated into reinforcement and replacement schemes and not uniquely identified. As the proposed programme represents the replacement of a small fraction of the ageing asset base, the risks associated with the failure of these assets is continuously increasing. The activity in this area in ED2 and beyond will require further increases, striving to bring back a manageable level of risk.

Figures 4 and 5 show the details of volumes and expenditure, including the sub-programmes for this category.

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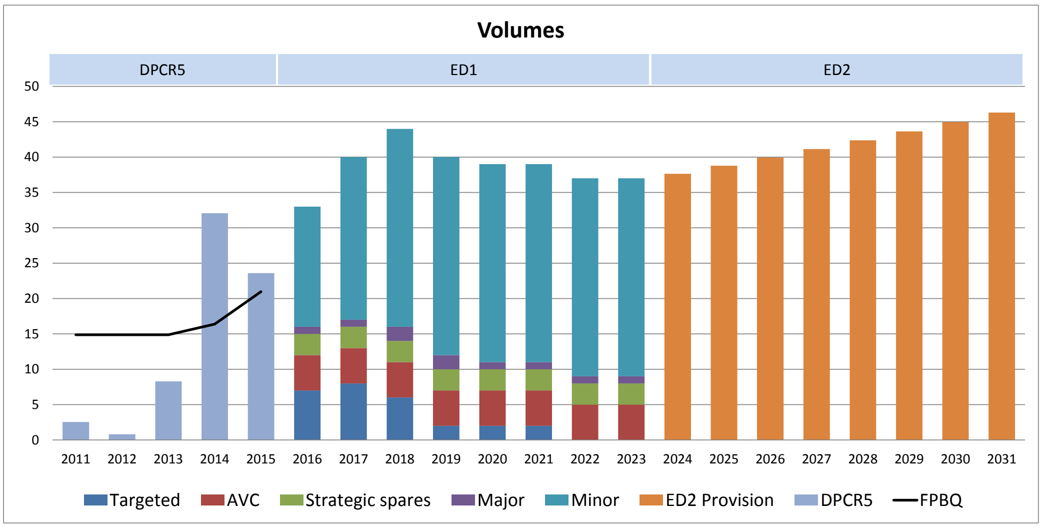

Figure 4 – Volume and predicted volume for protection replacement and compliance programme

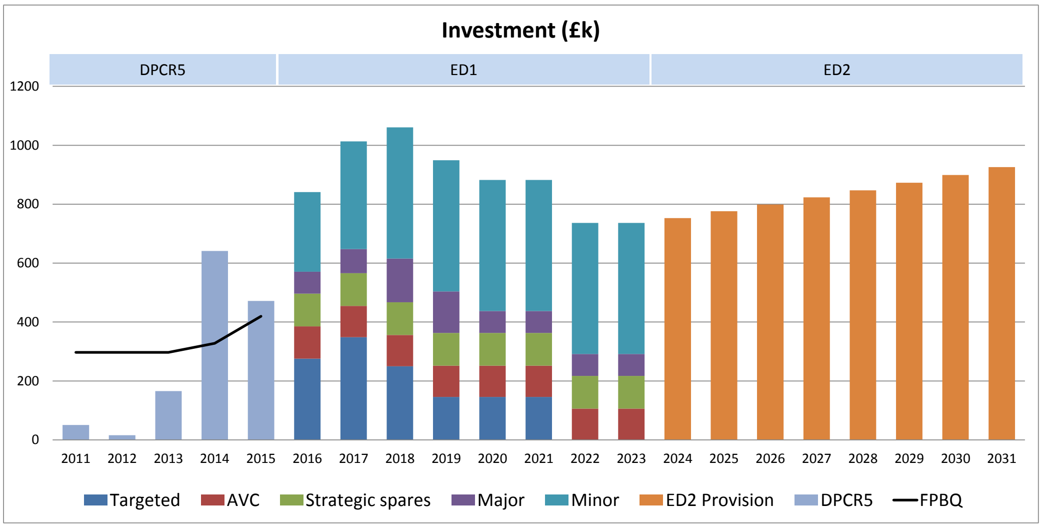

Figure 5 – Investment and predicted investment for protection replacement and compliance programme

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8.4.4 Protection inspection and maintenance

The increase in volumes in this programme is attributed to the clarity gained from the collected protection asset data. This has allowed a more targeted and accurate programme to be created. Although previous programmes aimed towards the same targets, they did not have sufficient data to achieve this programme's level of granularity.

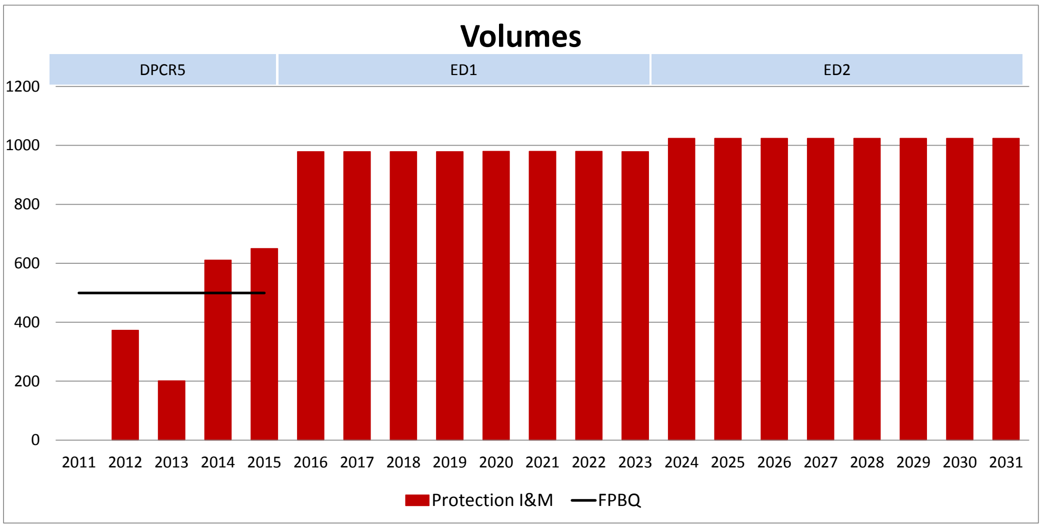

Figure 6 – Volumes and predicted volumes for protection inspection and maintenance programme

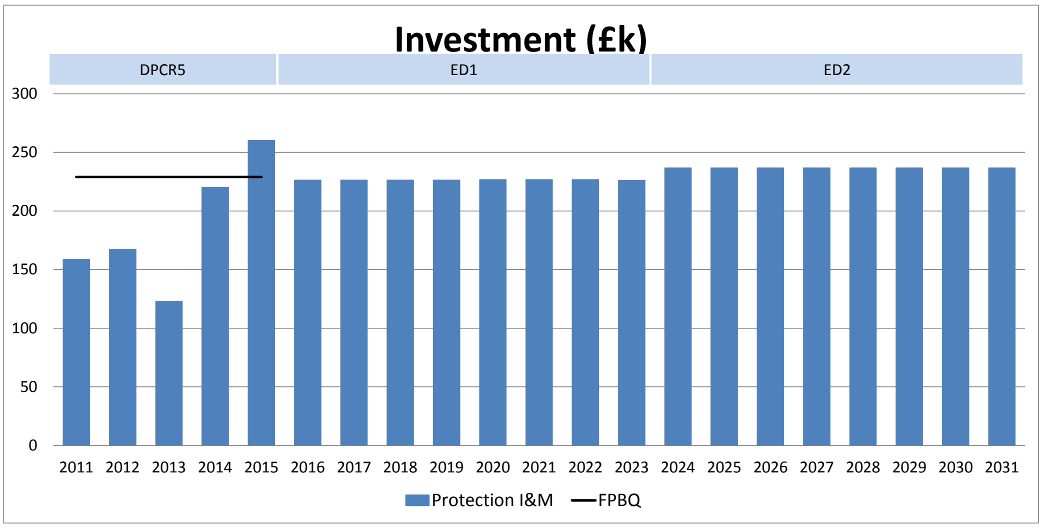

Figure 7 – Investment and predicted investment for protection inspection and maintenance programme

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8.4.5 Pilot cable survey and replacement

ED1 allowances for this small but critical activity have been constrained by DPCR5 regulatory allowances and activity will be taken forward on this basis.

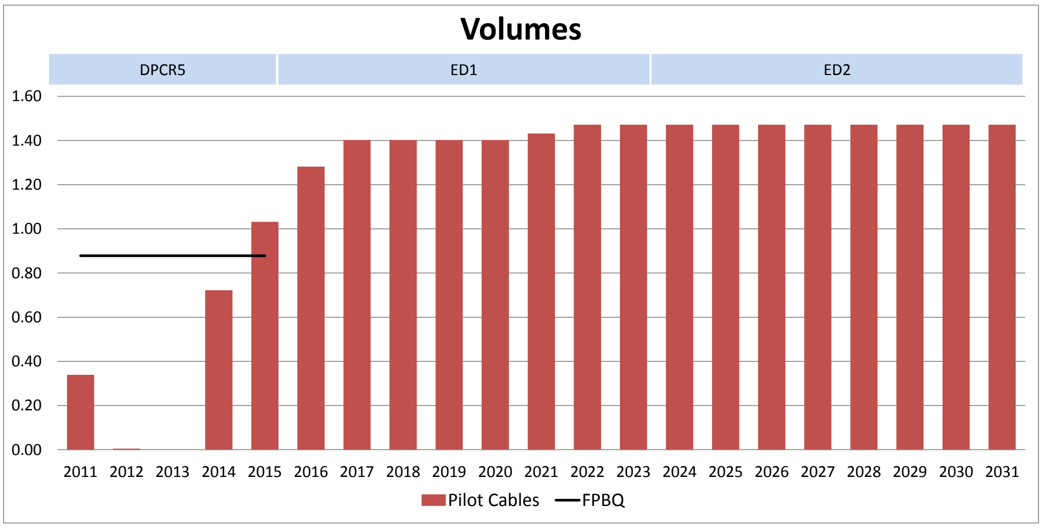

Figure 8 – Investment and predicted investment for pilot cable survey and replacement programme

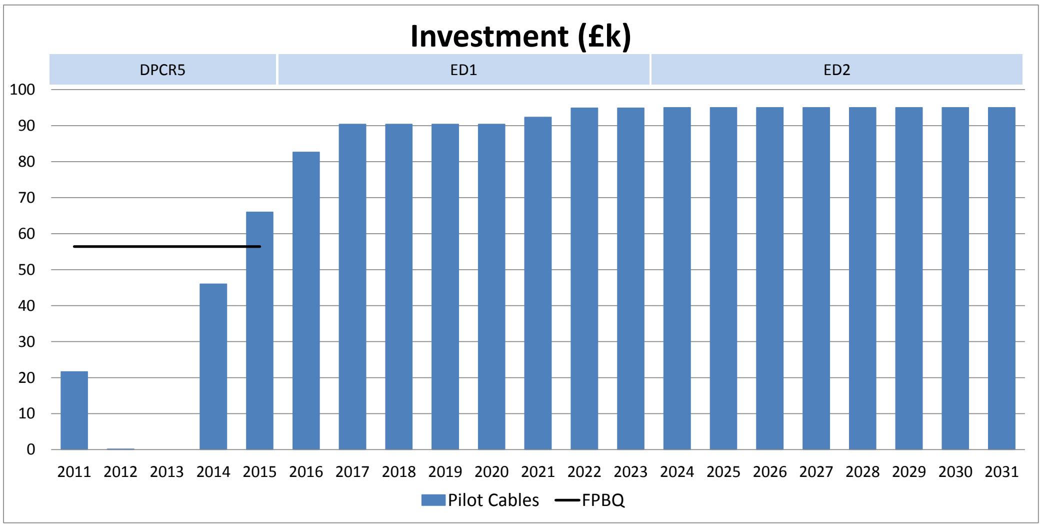

Figure 9 – Investment and predicted investment for pilot cable survey and replacement programme

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8.4.6 Pilot cable inspection and maintenance

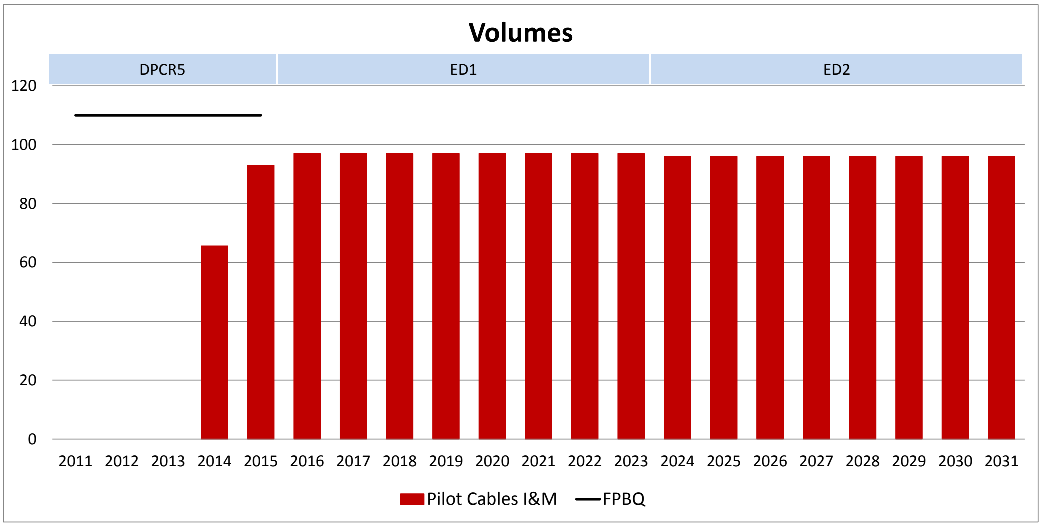

Figure 10 – Predicted volumes for pilot cable inspection and maintenance programme

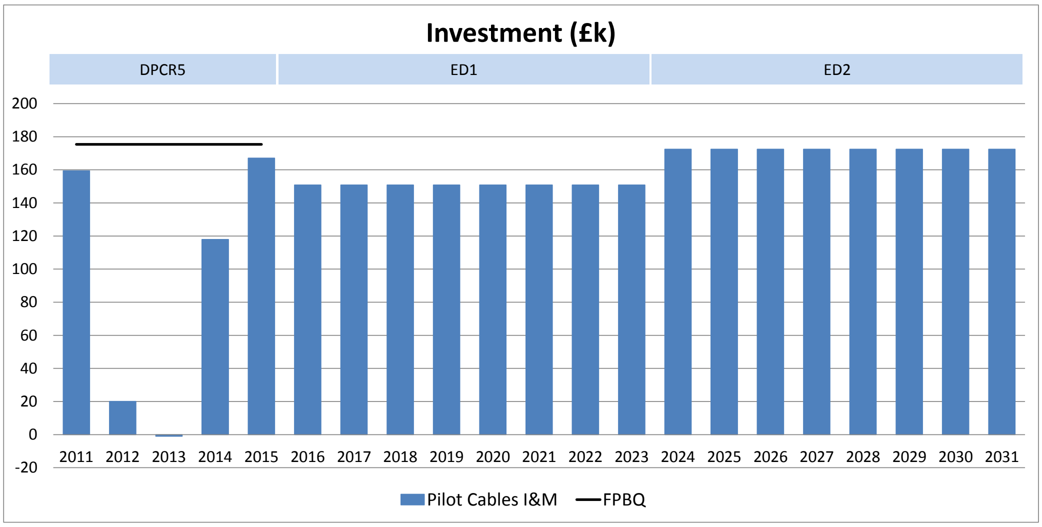

Figure 11 – Predicted costs for pilot cable inspection and maintenance programme

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8.5 Commentary

It should be noted that the budget forecast is predominantly aligned with existing allowances. The main differences are in the protection replacement and the protection inspection and maintenance programmes. These are driven by the higher availability and quality of data following the protection asset data collection exercise.

8.6 Sensitivity Analysis and Plan Validation

As the final development and verification of the PAPM is not completed, it has not been possible to carry out the sensitivity analysis. However, during its early development it was established that the choice of the input parameters (particularly design/maximum lifetimes) would have a significant effect on the output replacement volumes. Hence, sensitivity analysis is required as a method to allow the effects of the PAPM parameter variation to be investigated. The result of this analysis will be used in the development and application of appropriate replacement policies to achieve a suitable programme and an acceptable level of risk.

The simple methodology used for this sensitivity analysis is as follows:

- Establish a base-case scenario, where the best-guess input parameters, determined by research and engineering judgement, are used to produce replacement volumes for the Ellipse data.
- Vary the input parameters, one at a time, producing replacement volumes for comparison to the base-case.
- Establish correlations between input parameters and output replacement volumes.

Not all the input parameters need to be subject to variation; instead, the sensitivity analysis will focus on those parameters that are considered to require further analysis due to a lack of evidence or justification in the adoption of values as input parameters. The parameters that remained fixed are:

- Relay super-type groupings.
- Criticality of failure matrix.
- Likelihood of failure matrix.

The parameter inputs that were varied are:

- Relay super-type design/maximum lifetimes.
- Replacement policies.
- Relay-type replacement cost.

Throughout 2014, the PAPM will be used for programmes of work containing replacement volumes, costs programmes and a network risk profile. The latter will be calculated on the basis of the residual life of the protection and control relays in relation to their design and maximum expected life.

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9.0 Deliverability

Each of the asset categories has been discussed with the key stakeholders across the business to ensure they fully understand the requirements of the ED1 programme and are able to identify key resource requirements. To ensure the ED1 requirements are deliverable expenditure in the latter stages of DPCR5 (2014 and 2015) will be significantly increased compared to the date to deliver improved achievement against allowances. Where possible and appropriate, in both the latter stages of DPCR5 and ED1, asset replacement and refurbishment will be aligned with load-related and non-load-related reinforcement projects and strategic asset replacements of major plant. This will reduce the burden on resources, outage requirements and network risk.

The innovative approach – consolidating some relay functions into fewer devices for a given protection scheme – will reduce not only costs but also overall time and resource commitments.

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Appendices

Appendix 1 – Age Profiles

Not used as section 2.1 sets out the process for deriving relay asset age profiles.

Appendix 2 – HI Profiles

Not used.

Appendix 3 – Fault Data

Not available.

Appendix 4 – WLC Case Studies: Risk, Cost, Performance and Condition Profiles for Various Options

Not available.

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Appendix 5 – NLRE Expenditure Plan

Appendix 5.1 Protection enhancement

ED1

Description	Costs (£k)							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Enhance grid and primary protection	70	70	70	70	70	70	70	71

ED2

Description	Costs (£k)							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Enhance grid and primary protection	80	80	80	80	80	80	80	80

Appendix 5.2 Low-frequency protection compliance

ED1

Description	Costs (£k)							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Low-frequency protection compliance	70	76	76	76	79	88	76	40

ED2

Description	Costs (£k)							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Low-frequency protection compliance	40	42	42	42	42	42	42	42

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Appendix 5.3 Protection replacement

ED1

Description	Costs (£k)							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Targeted transformer differential protection replacement	130	130	104	0	0	0	0	0
Targeted distance protection replacement	146	219	146	146	146	146	0	0
Protection asset replacement to release strategic spares	111	111	111	111	111	111	111	111
Major protection asset replacement	74	82	148	141	74	74	74	74
Minor protection asset replacement	270	366	445	445	445	445	445	445
Replacement of AVC relays or schemes	106	106	106	106	106	106	106	106
Replace Unreliable AVC Schemes	3	0	0	0	0	0	0	0
Total	841	1,013	1,061	949	882	882	736	736

Description	Volume							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Targeted transformer differential protection replacement	5	5	4	0	0	0	0	0
Targeted distance protection replacement	2	3	2	2	2	2	0	0
Protection asset replacement to release strategic spares	3	3	3	3	3	3	3	3
Major protection asset replacement	1	1	2	2	1	1	1	1
Minor protection asset replacement	17	23	28	28	28	28	28	28
Replacement of AVC relays or schemes	5	5	5	5	5	5	5	5
Replace Unreliable AVC Schemes	0	0	0	0	0	0	0	0
Total	33	40	44	40	39	39	37	37

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ED2

Description	Costs (£k)							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
ED2 protection replacement provisions	753	776	799	823	847	873	899	926

Description	Volume							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
ED2 protection replacement provisions	38	39	40	41	42	44	45	46

Appendix 5.4 Protection inspection and maintenance

ED1

Description	Cost (£k)							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Total	226	226	226	226	227	227	227	226

Description	Volumes							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Total	979	979	979	979	980	980	980	979

ED2

Description	Cost (£k)							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Total	237	237	237	237	237	237	237	237

Description	Volumes							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Total	1,024	1,024	1,024	1,024	1,024	1,024	1,024	1,024

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Appendix 5.5 Pilot cable survey and replacement

ED1

Description	Costs (£k)							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Pilot cable survey and replacement	83	90	90	90	90	92	95	95

Description	Volume							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Pilot cable survey and replacement	1.3	1.4	1.4	1.4	1.4	1.4	1.5	1.5

ED2

Description	Costs (£k)							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Pilot cable survey and replacement	95	95	95	95	95	95	95	95

Description	Volume							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Pilot cable survey and replacement	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5

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Appendix 5.6 Pilot cable inspection and maintenance

ED1

Description	Cost (£k)							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Pilot Cable Repairs	91	91	91	91	91	91	91	91
Pilots and Multicores Test Insulation and Continuity	60	60	60	60	60	60	60	60
Total	151	151	151	151	151	151	151	151

Description	Cost (£k)							
	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
Pilot Cable Repairs	9	9	9	9	9	9	9	9
Pilots and Multicores Test Insulation and Continuity	88	88	88	88	88	88	88	88
Total	97	97	97	97	97	97	97	97

ED2

Description	Cost (£k)							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Total	172	172	172	172	172	172	172	172

Description	Volumes							
	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	2029/ 2030	2030/ 2031
Total	96	96	96	96	96	96	96	96

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Appendix 6 – Sensitivity Analysis

To follow when the PAPM is completed.

Appendix 7 – Named Schemes

Not available.

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Appendix 8 – RIGs mapping for ED1 volumes and expenditure

Volumes		Asset Stewardship reports									RIG Table										
Investment destription	NAMP Line	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total	RIG Table	RIG Row	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total
Enhance Grid and Primary Protection	1.05.01.6726	No Mapping																			
11kV Feeder Protection	2.25.06.6437	199	199	199	199	199	199	199	199	1,592											
Trip Testing 11kV Sequence Closing	2.25.13.8360	416	416	416	416	416	416	416	416	3,328	CV13	31*	1,397	1,418	1,438	1,459	1,471	1,458	1,438	1,418	11,497
Defect Repair - 11 kV Protection	2.26.03.6468	10	10	10	10	10	10	10	10	80											
33kV Feeder Protection	2.25.04.6571	55	55	55	55	55	55	55	55	440											
System Transformer Protection	2.25.05.6436	40	40	40	40	40	40	40	40	320	CV13	47*	237	237	237	237	238	238	238	238	1,900
Trip Testing 33kV AR	2.25.12.8359	113	113	113	113	113	113	113	113	904											
Defect Repair - EHV Protection	2.26.01.6467	3	3	3	3	4	4	4	4	28											
AVC checks at Grids & Primaries	2.25.07.9396	54	54	54	54	54	54	54	54	432	CV13	72*	4,983	4,976	4,977	4,982	4,983	4,976	4,977	4,981	39,835
132kV CB Feeder Including BS	2.25.02.9395	16	16	16	16	16	16	16	16	128	CV13	74*	275	278	296	272	272	273	268	240	2,174
Grid Transformer Protection	2.25.03.6570	14	14	14	14	14	14	14	14	112											
Low Frequency - 132kV Injection Test	2.25.09.8357	4	4	4	4	4	4	4	3	31											
132kV Buz Zone	2.25.10.9397	5	5	5	5	5	5	5	5	40											
Trip Testing 132kV DAR	2.25.11.8358	30	30	30	30	30	30	30	30	240	CV13	75*	419	419	419	421	427	421	419	418	3,363
Single Transformer Auto Changer Scheme Proving	2.25.14.6438	0	0	0	0	0	0	0	0	0											
NVD Function Test	2.25.16.9398	20	20	20	20	20	20	20	20	160											
Pilots and Multicores Test Insulation and Continuity	2.25.15.6439	88	88	88	88	88	88	88	88	704											
Pilot Cable Repairs	2.01.14.8958	9	9	9	9	9	9	9	9	72	CV15b	17	9	9	9	9	9	9	9	9	72
Pilot Cable Survey & Replacement - EHV	1.26.02.3196	1.28	1.4	1.4	1.4	1.4	1.43	1.47	1.47	11	CV3	104	1.28	1.40	1.40	1.40	1.40	1.43	1.47	1.47	11
Low-Frequency Protection Compliance	1.26.01.8212	No Mapping																			
Replacement of AVC Relays or Schemes	1.26.07.6136	5	5	5	5	5	5	5	5	40	CV5	37	5.16	5	5	5	5	5	5	5	40
Replace Unreliable AVC Schemes	1.26.07.9493	0	0	0	0	0	0	0	0	0											
Targetted Transformer Differential Protection Replacement	1.26.01.8364	5	5	4	0	0	0	0	0	14											
Targetted Distance Protection Replacement	1.26.01.8365	2	3	2	2	2	2	0	0	13											
Protection Asset Replacement to Release Strategic Spares	1.26.01.8366	3	3	3	3	3	3	3	3	24	CV5	57	28	35.1	39	34.9	34	34	32	32	269
Major Protection Asset Replacement	1.26.01.8367	1	1	2	2	1	1	1	1	10											
Minor Protection Asset Replacement	1.26.01.8368	17	23	28	28	28	28	28	28	208											
Total		**1,110**	**1,117**	**1,121**	**1,117**	**1,117**	**1,117**	**1,115**	**1,114**	**8,931**			**7,354**	**7,378**	**7,421**	**7,421**	**7,440**	**7,415**	**7,387**	**7,342**	**59,161**

* RIGs rows which contain volumes from other non-protection related projects, hence the higher value in RIGs as compared to ASR

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Expenditure				ASR	RIGs								
Asset Type	**Asset Name**	**RIGs Table**	**RIGs Row**	**Total**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**Total**
Protection enhancement	Enhance Grid and Primary Protection 1.05.01.6726	CV106	50*	0.56	0.42	0.86	0.84	0.36	0.36	0.36	0.36	0.36	**3.90**
Protection inspection and maintenance	11kV Feeder Protection 2.25.06.6437			0.24									
	Trip Testing 11kV Sequence Closing 2.25.13.8360	CV13	31*	0.50	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.21	**1.72**
	Defect Repair - 11 kV Protection 2.26.03.6468			0.01									
	33kV Feeder Protection 2.25.04.6571			0.12									
	System Transformer Protection 2.25.05.6436	CV13	47*	0.09	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	**0.51**
	Trip Testing 33kV AR 2.25.12.8359			0.24									
	Defect Repair - EHV Protection 2.26.01.6467			0.01									
	AVC checks at Grids & Primaries 2.25.07.9396	CV13	72*	0.13	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	**3.58**
	132kV CB Feeder Including BS 2.25.02.9395	CV13	74*	0.08	0.18	0.18	0.19	0.18	0.18	0.18	0.17	0.16	**1.41**
	Grid Transformer Protection 2.25.03.6570			0.08									
	Low Frequency - 132kV Injection Test 2.25.09.8357			0.02									
	132kV Buz Zone 2.25.10.9397			0.03									
	Trip Testing 132kV DAR 2.25.11.8358	CV13	75*	0.16	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	**2.30**
	Single Transformer Auto Changer Scheme Proving 2.25.14.6438			0.00									
	NVD Function Test 2.25.16.9398			0.11									
Pilot cable inspection and maintenance	Pilots and Multicores Test Insulation and Continuity 2.25.15.6439			0.48									
	Pilot Cable Repairs 2.01.14.8958	CV15b	17	0.73	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	**0.73**
Pilot cable survey and replacement	Pilot Cable Survey & Replacement - EHV 1.26.02.3196	CV3	104*	0.73	1.28	1.40	1.40	1.40	1.40	1.43	1.47	1.47	**11.25**
Low-frequency protection compliance	Low-Frequency Protection Compliance 1.26.01.8212			0.58									
Protection replacement	Replacement of AVC Relays or Schemes 1.26.07.6136	CV5	37	0.85	0.18	0.18	0.18	0.18	0.18	0.19	0.18	0.15	**1.43**
	Replace Unreliable AVC Schemes 1.26.07.9493			0.00									
	Targetted Transformer Differential Protection Replacement 1.26.01.8364			0.36									
	Targetted Distance Protection Replacement 1.26.01.8365			0.95									
	Protection Asset Replacement to Release Strategic Spares 1.26.01.8366	CV5	57	0.89	0.73	0.91	0.95	0.84	0.78	0.78	0.63	0.63	**6.25**
	Major Protection Asset Replacement 1.26.01.8367			0.74									
	Minor Protection Asset Replacement 1.26.01.8368			3.31									
Total				**11.99**	**3.89**	**4.63**	**4.67**	**4.07**	**4.01**	**4.04**	**3.92**	**3.86**	**33.08**

* RIGs rows which contain expenditure from other non-protection related projects, hence the higher value in RIGs as compared to ASR

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