TRANSFORMER AND REACTOR PORTFOLIO OVERVIEW	
Name of Scheme/Programme	Transformer and Reactor Portfolio Overview
Primary Investment Driver	Asset Health
Scheme reference/ mechanism or category	N/A
Output references/type	N/A
Cost	N/A
Delivery Year	N/A
Reporting Table	N/A
Outputs included in RIIO T1 Business Plan	N/A

Issue Date	Issue No	Amendment Details
October 2019	Issue 1	First issue of document
December 2019	Issue 2	Updated to reflect final business plan

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1. Introduction

This paper provides an overview of the transformer and reactor assets and its health issues while defining the strategy on how they are prioritised for intervention.

SPT owns 332 transmission transformers and reactors, across different voltages.

Transformers and reactors are maintained, refurbished or have critical components replaced to maintain reliability, operational risk and safety performance at a level which meets defined criteria.

A method has been defined for detailed condition assessment, based upon present condition, known failure mechanisms, technical asset lives for the various transformer and reactor types and their key deterioration patterns, criticality of location in terms of failure consequences, strategic importance, environmental aspects and innovation.

The transformer and reactor refurbishment and replacement strategy is also based upon the NOMS asset risk methodology as implemented with the SPT CBRM tool.

2. Executive Summary

An important aspect of asset management is to understand and quantify the condition of transformers and reactors and assess their remaining lives. This has a significant bearing on the planning of a refurbishment and replacement programme which aims to make maximum use of the remaining life but which avoids failures.

Following the forensic post mortem examinations of transformers replaced in RIIO-T1, enhanced understanding of the nature of the deterioration of transformers and reactors has been gained. To reflect this, the asset strategy has been updated with an updated analysis of Dissolved Gas Analysis (DGA) and condition Assessment which inputs to the CBRM tool. The outputs of the tool are an important factor in the identification and prioritisation of necessary interventions.

This has allowed SPT to develop two workstreams, one for replacement and one for refurbishment to ensure the most effective course of action for each individual transformer and reactor.

3. Overall Strategy

The SPT transformer and reactor fleet was largely installed in the 1950's to `70's as the Transmission during the establishment and growth of the grid and supergrid networks (see figure 1).

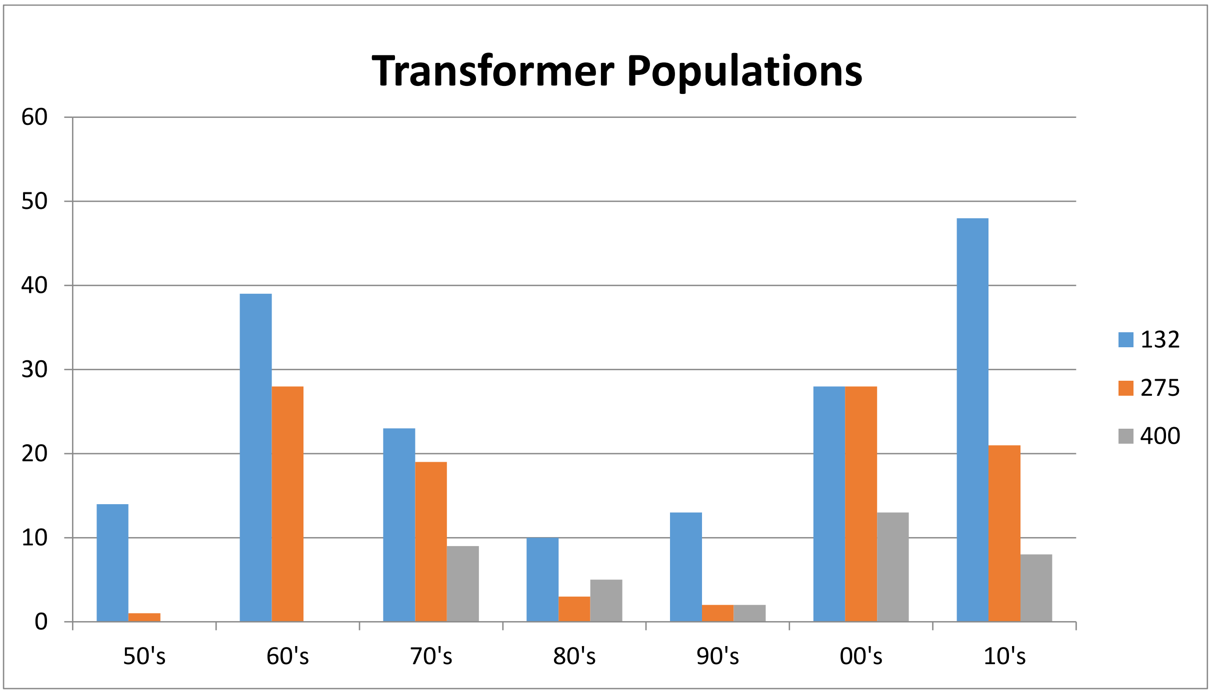


Figure 1: Transformer Overview at 2021in SPT Transmission Network.

The overall strategy for transformers is to maximise the economic lives of transformers but to replace before failure due to the consequences on the operation of the transmission system.

The main exceptional factor is the acknowledged Bruce Peebles design defect within a batch of already identified transformers. Following the post mortem review of the transformers replaced in RIIO-T1, it has been confirmed that all the units demonstrated signs of failure at the known defect location. Based on this finding and along with technical understanding that remaining units that are of an identical design, these transformers were considered high risk and were replaced within RIIO-T1.

Following the decommissioning of the T1 programme of assets (outside the Bruce Peebles type defect fleet), the forensic analysis has found that, in some cases, the active part of the transformer or reactor was in better than anticipated condition when being replaced. This is due to several issues including, but not limited to, design characteristics, lifetime loading and maintenance regimes.

Outside of these, the determination of transformer or reactor intervention is based on condition and risk, built up from multiple factors including oil condition and external condition assessment.

The approach of a holistic review based on condition of the component parts of the transformer and reactor system has been refined by the increase in available condition information. This allows improved identification of when a transformer requires intervention. The application of the NOMS models is central to this review.

As well as age, the NOMS inputs include, but are not limited to, design characteristics, lifetime loading, oil analysis, operational adequacy and maintenance regimes.

This approach allows SPT to examine the scoring of transformers and reactors to identify when an intervention is required. Review of the individual inputs then allows detailed consideration of the scope of the intervention required.

3.1 DGA scoring

DGA analysis is an industry accepted methodology to determine transformer and reactor health. The oil analysis results provide the ability to determine the intervention required. In the instance of FFA results or the presence of high acetylene then it is acknowledged that these are effective indicators that a transformer is approaching end of life and requires to be replaced.

3.2 Oil Leak issues

As well as the environmental issue of oil leaks, they are also an indication of metal corrosion and gasket failures which can lead to the onset of transformer or reactor failure. In this instance individual assessment of the plant will be taken to determine the cause and level of leakage to determine the most economic course of action which may be refurbishment or replacement.

3.3 Operational Adequacy / General Reliability

This is an approach to transformer assessment that allows SPT to quantitatively evaluate the non-numerical elements of transformer assessment such as type defects, OEM support and equipment performance. Depending of the cause of high scores, individual solutions to improve the assets' condition and risk will be determined.

For example, in the area of active part type defects (such as that which affects Bruce Peebles transformers) the main course of action will be to replace as these type defects have been identified on transformers that no longer have original manufacturers support and the failure mode has occurred on other units in the system. Where support is available, efforts will be made with the manufacturer to undertake remedial works on the defect to resolve as long as it is deemed as economically efficient.

SPT have developed a methodology for transformers developed with external experts in the industry to provide an effective means of managing the SPT transformer and reactor fleet. This methodology has also been issued to a further 3rd party for review and challenge to ensure its adequacy.

3.4 End of Life Transformers.

All transformers have been assessed, all additional NOMS model input data evaluated and those that have been identified as end of life are proposed for replacement. The resultant volumes and the network access requirements have determined the time period over which the interventions have been planned.

3.5 Transformers approaching End of life

Transformers that have been assessed, have had all NOMS model input data evaluated and are categorised as approaching end of life will have further additional in-depth assessment to determine the most appropriate course of action applicable to the asset. This can be replacement or refurbishment which will be determined upon the assessment of the asset. The determination of refurbishment or replacement will be assessed taking into account the outcome of a CBA and review of the individual elements of the condition factors.

3.6 Transformers considered mid-life

Transformers that have been assessed, have had all additional NOMS model input data evaluated and are categorised as mid-life will be assessed to determine if an intervention is required. The intervention strategy is likely to be minor (painting / leak repairs etc.) to maintain nominal standards and ensure environmental and electrical performance and compliance. At this stage in the assets' lives, the bushings and tap changers will be assessed to determine whether these also require intervention.

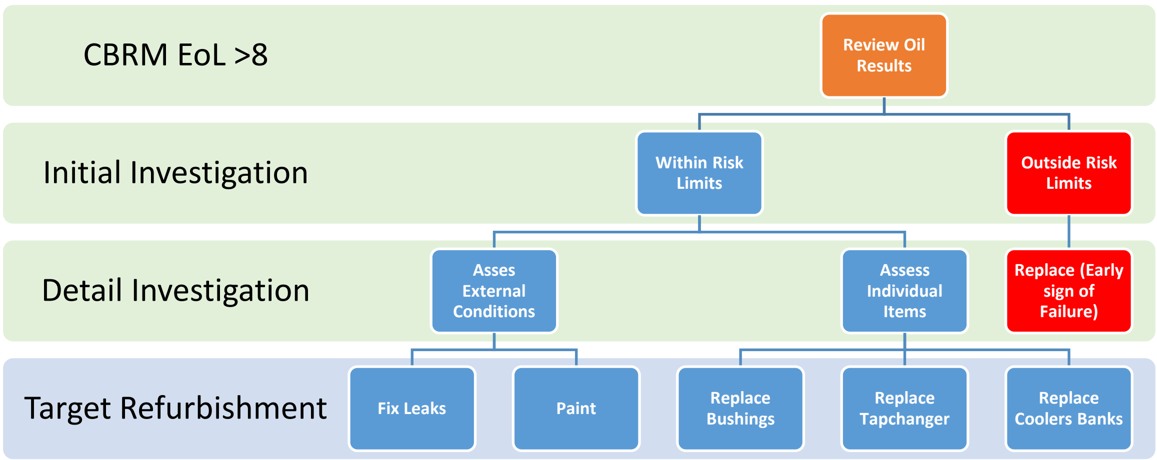
3.7 Transformers assessed as new or early life

Transformer assessed as new or early life will be subject to no intervention. All works will comply with SPT maintenance policy with regular inspection, maintenance and DGA.

4. Programme Development

The NOMS model outputs were reviewed to determine the main driver for the EOL score. From this there was a process applied to determine the best and most appropriate course of intervention.

The figure below illustrates the process



4.1 Replacement

The main drivers of transformer and reactor replacements are the conditions identified by the analysis of DGA results. The gas content of oil provides an indication of the onset of failure within transformers and reactors. These industry standard tests allow the identification of transformers and reactors that are in the early stages of deterioration towards end of life and allow intervention before failure.

SPT has developed a two price control investment strategy to manage the risk associated with end of life transformers and provide deliverable plans that removes the highest risk and end of life assets.

OFGEM Scheme Reference (OSR)	Scheme Name	RIIO	EOL Band	Risk Band
SPNLT2043	Shrubhill SGT1 replacement	T2	10	10
SPNLT2064	Devol Moor T2A replacement	T2	10	10
SPNLT2065	Neilston SGT1 Transformer Replacement	T2	10	7
SPNLT2066	Giffnock SGT1 Transformer Replacement	T2	10	6
SPNLT20139	Giffnock SGT2 Transformer Replacement*	T3	10	6
SPNLT2042	Cockenzie SGT1 Transformer Replacement	T3	8	4
SPNLT2044	Strathaven SGT1 Transformer Replacement	T3	8	4
SPNLT2045	Kaimes SGT2 Transformer Replacement	T3	8	6

* Giffnock SGT2 is planned for completion early in year 1 of RIIO-T3.

This proposed investment over the RIIO-T2 and T3 periods changes the profile of the population as illustrate in figure 2 (end of RIIO-T2) and figure 3 (end of RIIO-T3) below. It can be seen that there is still a large volume of transformers installed in the period 1950-1970. However, through the analysis of failures, and improved monitoring, the opportunity to refurbish transformers to maximise and extend life allows the deferral of investment in replacements to allow a more manageable population profile.

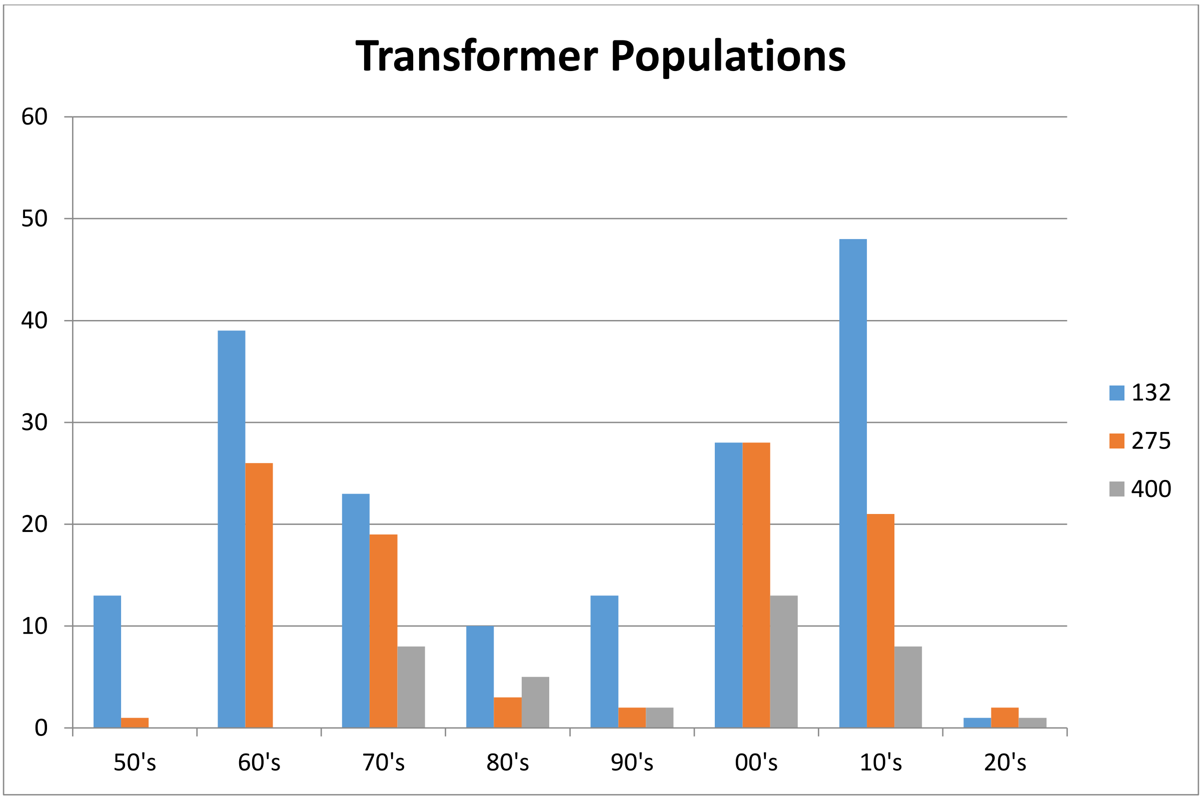


Figure 2: Transformer Overview at 2026 in SPT Transmission Network

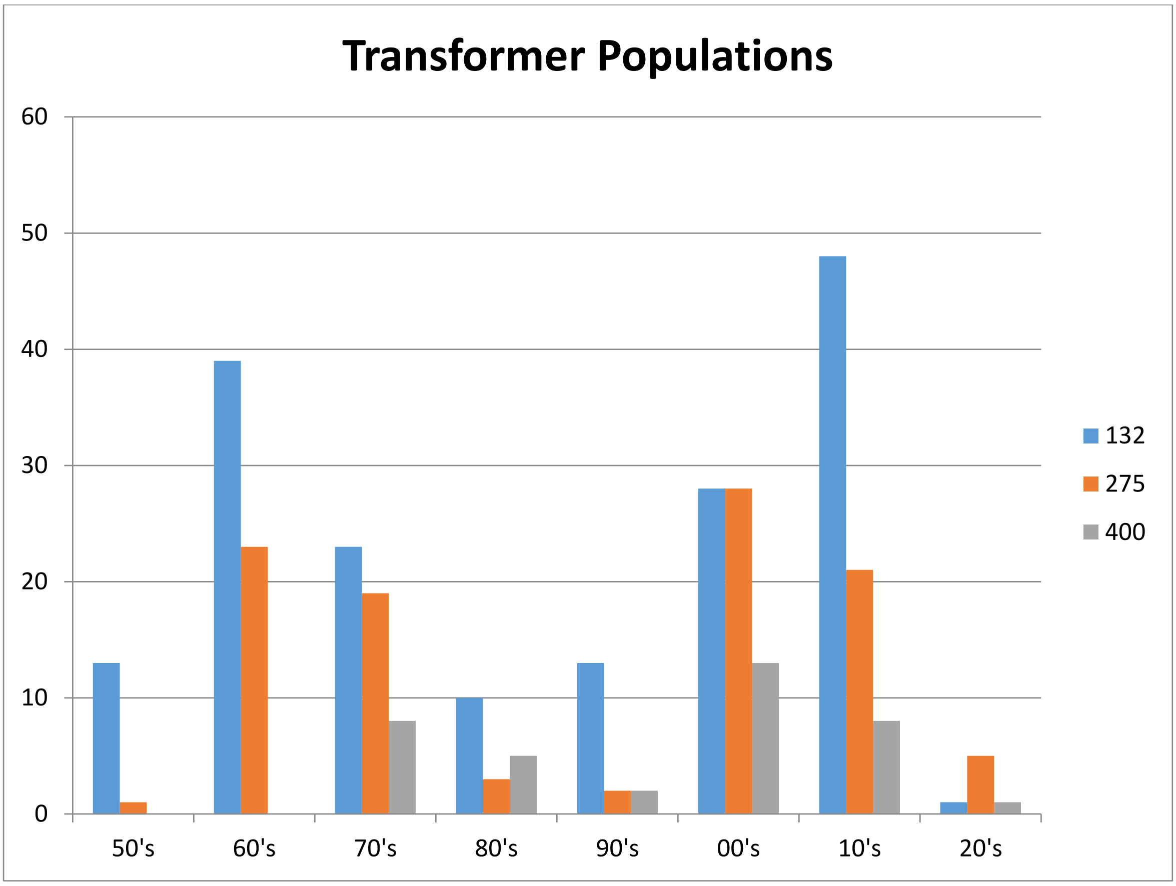


Figure 3: Transformer Overview at 2031 in SPT Transmission Network

4.1.1 RIIO T3 Forward View

All schemes were reviewed and their forecast end of life determined based on the NOMS models. This allowed the units whose condition is expected to be sufficiently poor that the risk of failure would be intolerable within the RIIO-T2 period to be prioritised for replacement. Where the condition data and model outputs provided sufficient confidence in the ongoing operability of the units, they have been proposed for intervention in RIIO-T3.

4.2 Refurbishment

The detailed assessment has identified other units that require intervention but where the condition data does not indicate that the transformer or reactor is at or approaching end of life. These condition factors are primarily tap changer condition, bushings issues, oil leaks and general condition. While these result in an EOL from the NOMS models that may be indicative of end of life, a refurbishment intervention can sufficiently improve the condition of the ancillary equipment and to maximise the life of the transformer or reactor.

Therefore, RIIO-T2 and RIIO-T3 programmes for refurbishment are proposed.

OFGEM Scheme Reference (OSR)	Scheme Name	RIIO	EOL Band	Risk Band
SPNLT2068	Kendoon T2 refurbishment	T2	10	4
SPNLT2069	Windyhill SGT3 refurbishment	T2	10	7
SPNLT2070	Inverkeithing T2 refurbishment	T2	10	10
SPNLT2071	Torness SGT1 refurbishment	T2	9	10
SPNLT2072	Torness SGT2 refurbishment	T2	9	10
SPNLT2073	CarntyneT2B refurbishment	T2	10	10
SPNLT2074	Carntyne T1B refurbishment	T2	10	10
SPNLT2075	Clydesmill SGT2 refurbishment	T3	9	5
SPNLT2094	Saltcoats T2C refurbishment	T2	10	10
SPNLT2095	Grangemouth SGT1 refurbishment	T2	10	10
SPNLT2096	Partick GT1 refurbishment	T2	10	7
SPNLT2076	Partick GT2 refurbishment	T3	10	7
SPNLT2077	Glenluce T2 refurbishment	T3	9	5
SPNLT2079	Wishaw SGT7 refurbishment	T3	9	4
SPNLT2080	Wishaw SGT6 refurbishment	T3	9	5
SPNLT2081	AYR SGT1 refurbishment	T3	8	8
SPNLT2082	Saltcoats T1A refurbishment	T3	8	8
SPNLT2083	Glenluce T1 refurbishment	T3	8	3
SPNLT2084	Dunfermline T1 refurbishment	T3	8	6

4.2.1 RIIO-T3 Forward View

All schemes were reviewed and their forecast end of life determined based on the NOMS models. This allowed the units whose condition is expected to be sufficiently poor that the risk of accelerated end of life would lead to early replacement to be prioritised for replacement. Where the condition data and model outputs provided sufficient confidence in the ongoing operability of the units, they have been proposed for intervention in RIIO-T3.

4.2.2 RIIO T2 and RIIOT3 Proposed Intervention Graph

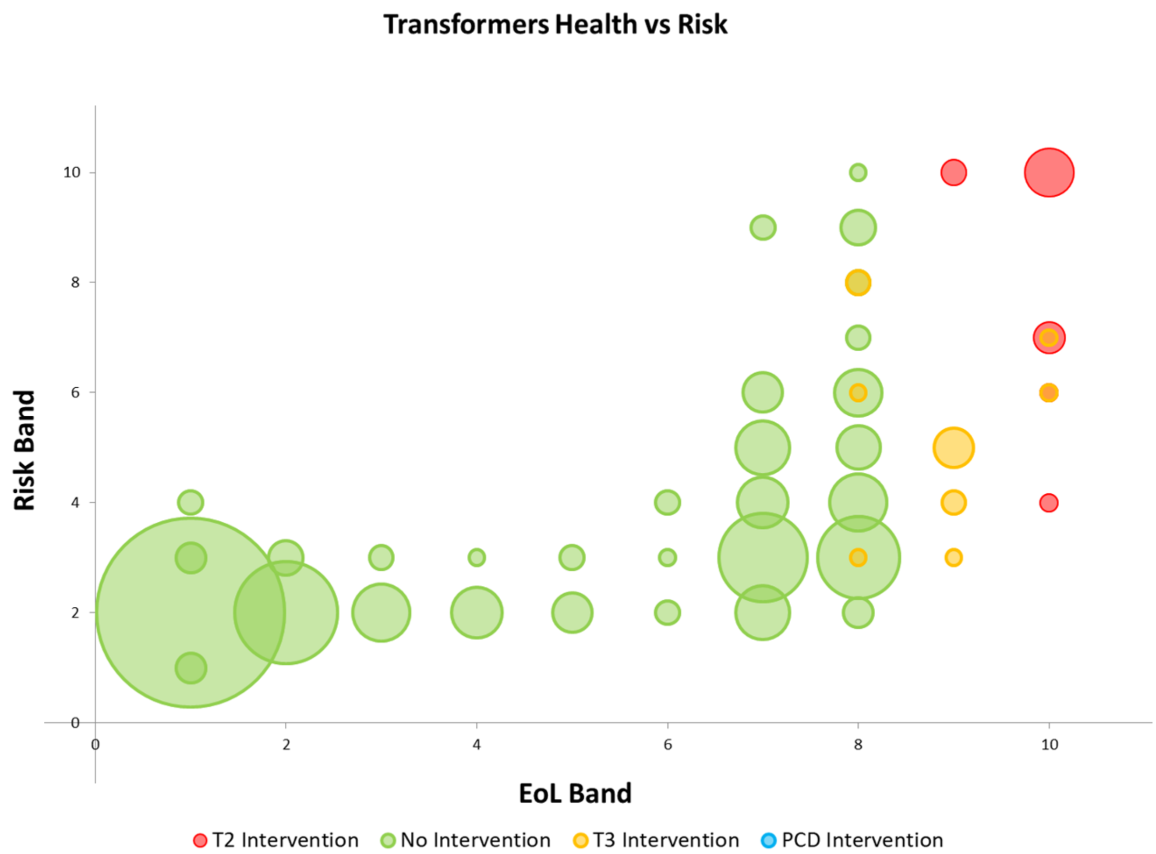


Figure 4: Transformer Overview Investment Strategy to 2031 in SPT Transmission Network

The figure above, where the size of the circle represents the asset count at each point, demonstrates how the proposed investments address the assets that will be at end of life by the end of RIIO-T2 without intervention and an indicative view of the likely RIIO-T3 interventions. It is clear from this chart that the interventions are justified by the condition of the assets and the interventions have been prioritised by risk.

5. Reactors

The process described for transformers has been applied to reactors, with those identified by as either end of life, or approaching end of life subject to a detailed assessment and a programme of interventions developed.

The reactor fleet is considerably smaller and has been the subject of a relatively large intervention programme in RIIO-T1 so only small number of units were identified for intervention. These are detailed below.

OFGEM Scheme Reference (OSR)	Scheme Name	RIIO	Health Score	Risk Score
SPNLT2047	Torness 400kV Shunt reactors replacement	T2	10	8-10
SPNLT2063	Longannet 275kV series reactors refurbishment*	T2	8	10

*Note that the Longannet scheme is proposed as a ring-fenced PCD.

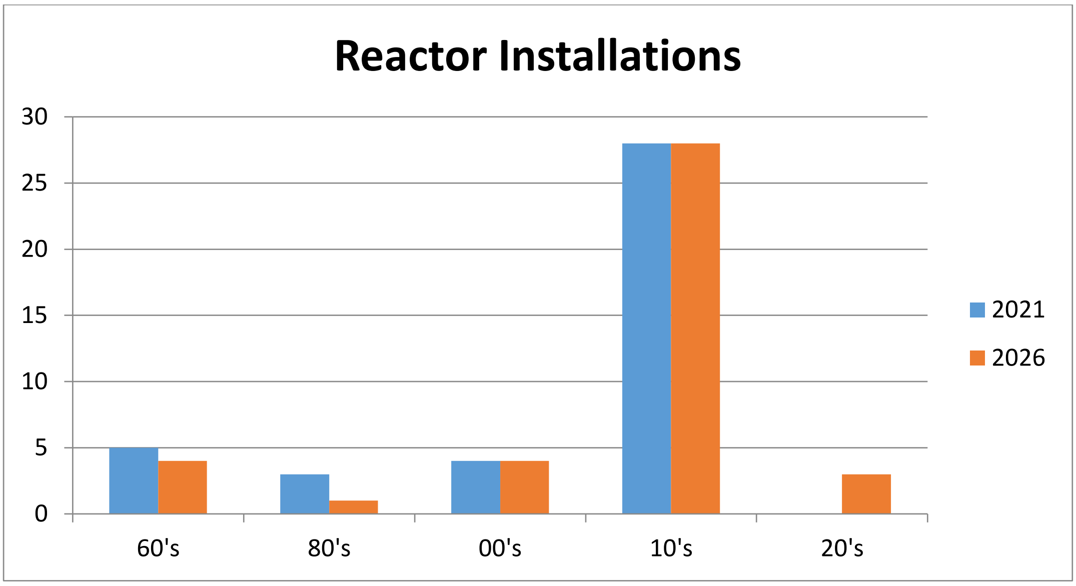


Figure 5: Reactor Overview at 2026

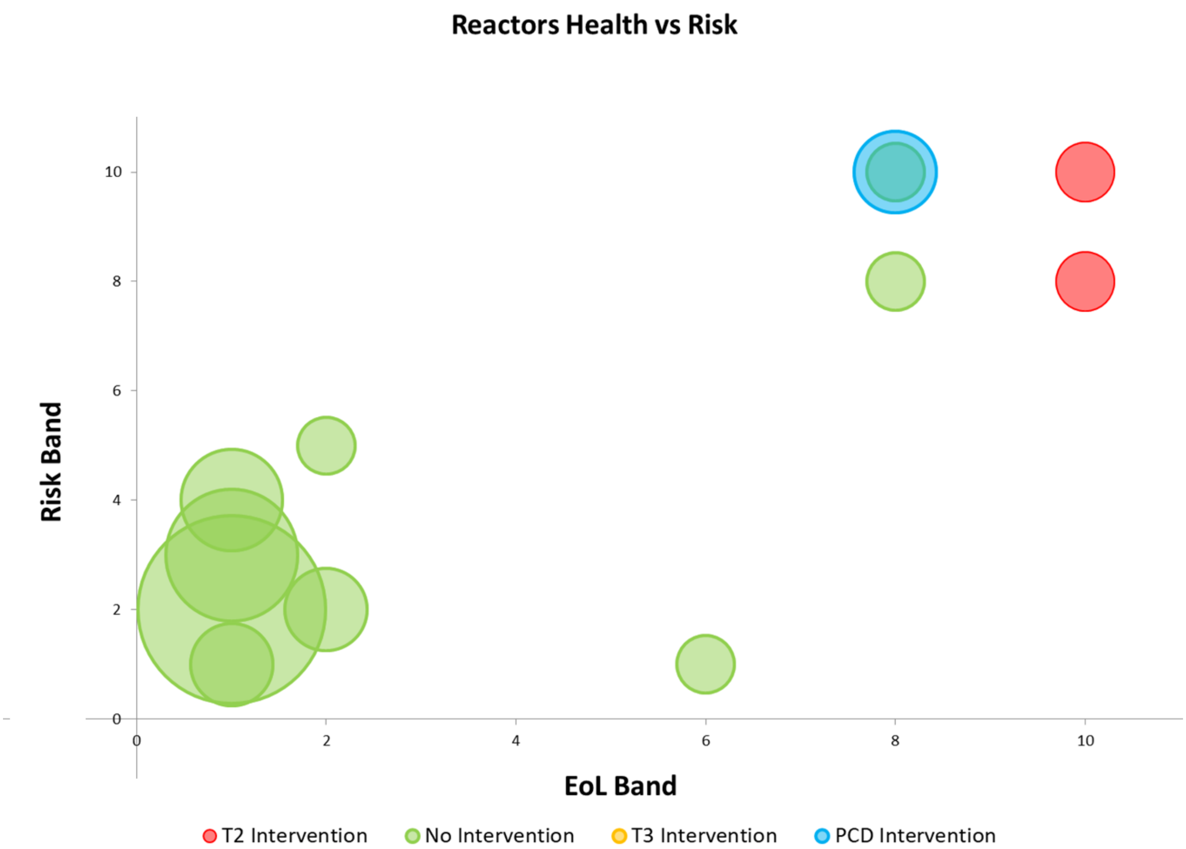


Figure 6: Reactor Overview Investment Strategy to 2031

The figure above, where the size of the circle represents the asset count at each point, demonstrates how the proposed investments address the assets that will be at end of life by the end of RIIO-T2 without intervention. It is clear from this chart that the interventions are justified by the condition of the assets and the interventions have been prioritised by risk.

6. RIIO-T3 Forward View

While there are units identified for intervention in RIIO-T3, it should be noted that this is a best view of the asset base at this moment in time.

7. Conclusion

The proposed circuit breaker programme for RIIO-T2 has been carefully developed to balance the effective management of network risk, system access and deliverability, and costs to current and future consumers.