

SP Energy Networks 2015–2023 Business Plan

Updated March 2014

Annex

33kV Substation Plant Strategy

SP Energy Networks

March 2014

33kV Substation Plant

March 2014

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1. Scope

This Annex covers our strategy for the replacement and refurbishment of 33kV substation plant assets through the ED1 period.

2. Table of linkages

This strategy supports our ED1 Business Plan. For ease of navigation, the following table links this strategy to other relevant parts of our plan.

Document	Chapter / Section
SP Energy Networks Business Plan 2015-2023	Chapter C6 – Expenditure b. Asset Stewardship c. SP Manweb Company Specific Factors e. Non Load Related Investment
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C6 – Civil Strategy and Plans – SPEN
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C5 – Losses Strategy – SPEN
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C6 – Asset Health and Criticality Strategy – SPEN
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C6 – Cost Benefit Analysis – SPEN
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C6 – TRAN-02-002 Assessment of the Operational Adequacy of Transformers and Reactors 33kV and Above – SPEN
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C6 – SWG-02-007 Switchgear Assessment 6kV, 11kV and 33kV – SPEN

3. Executive Summary

Our 33kV asset replacement programme is built up from individually detailed plans using on-site condition surveys, technical reports, condition-based modelling and operational adequacy information. This is coordinated with other asset replacement and reinforcement plans to minimise costs across our 33kV programmes.

Our Grid substations contain 33kV circuit breakers and switches and Primary substations contain transformers with associated 33kV switches to manage power flow to the local area, and provide interconnection for security of supply. We will maintain the overall condition of these assets to meet our obligations in providing a safe and reliable service to our customers over the ED1 period.

Our 33kV plan ensures the long term stewardship and management of risk through the following deliverables:

Asset	SPM		SPD	
	Volume	£m	Volume	£m
33kV Circuit Breaker Replacement	251	24.2	119	12.4
33kV Switches	202	5	34	0.9
33kV Transformer Replacement	89	15.4	61	15.6
33kV Transformer Refurbishment	48	1.7	85	3.7
Total expenditure	-	46.3	-	32.6

Delivery of our substation programme is essential to delivering a number of our primary outputs, particularly public and employee safety, reliable network performance for our customers and reduced environmental impact. The programme also allows us to manage the overall health Index and risk for our assets, a key secondary deliverable.

4. Introduction

The replacement and refurbishment strategy for our existing 33kV substation plant aims to ensure an optimum level of investment through a targeted, project specific, approach. To ensure we appropriately prioritise our investment we have used performance data, detailed technical reports and specialist surveys to determine the condition and criticality of our plant.

The investment plan has been developed using our risk based approach to asset intervention, driven by our Asset Management Policy ASSET 01 019.

This document details the Non Load Network Investment for 33kV network assets, including:

- *our risk management and process methodology*
- *the use of condition information*
- *the application of age based modelling as a proxy for condition assessment in some circumstances*
- *the results from the application of these approach on switchgear and transformers*
- *the cost benefit analysis for the main asset categories*
- *the outputs delivered by the programme*
- *the process for delivering risk based, prioritised asset interventions*

The overall programme includes the two key deliverables:

- *The planned replacement and refurbishment of 33kV transformers*
- *The planned replacement of 33kV circuit breakers and Ring Main Units*

5. Network Strategy

The investment strategy for our 33kV network is directed at maintaining overall network risk experienced by our customers. This will be achieved via a prioritised and targeted project specific approach. This is necessary to effectively manage the business risk and ensure long term sustainability, utilising appropriate engineering interventions and risk management. Specifically our strategy aims to:

- *Maintain safety, integrity and performance of the network whilst ensuring long-term sustainability.*
- *To intervene prior to asset failure: Replace or refurbish equipment before asset performance and reliability fall below acceptable operational limits and failure may incur unacceptable system or financial risk exposure.*
- *Minimise failures, through interventions targeted on assets at or approaching end of life (Health Index 5): Utilising a combination of engineering condition, age and type information, as appropriate.*
- *Target investment based on an assessment of risk through probability of failure, Health Index and criticality: Taking account of factors such as public and staff safety, strategic importance, customer sensitivity to supply disturbances, asset performance and environmental considerations.*

6. Assessment of Condition and Operational Adequacy

The investment plans for 33kV circuit breakers, switches and transformers utilises our Asset Health Methodology ASSET 01 019 and Assessment of Operational Adequacy detailed in SPEN's policy documents **Annex C6 – SWG-02-007 Switchgear Assessment 6kV, 11kV and 33kV – SPEN** and **Annex C6 – TRAN-02-002 Assessment of the Operational Adequacy of Transformers and Reactors 33kV and Above – SPEN**. Our Operational Adequacy document provides the scoring assessment that enables us to determine interventions according to asset health.

The investment strategy aims to refurbish Health Index 4 and replace Health Index 5 assets in line with the operational adequacy scoring;

- *The operational adequacy of all plant is assessed on an annual basis by Lead Technical Engineers within Asset Management, utilising standardised templates to score plant components*
- *Site condition inspections are conducted by staff trained in this activity.*
- *The results are augmented to include any reports of plant defects, including a reduction in operational performance and asset condition from operational staff.*
- *The items within the assessment are categorised as Critical, Major, Significant or Minor with scores assigned to each category within the operational adequacy document.*
- *The score of each plant type accumulates to derive the overall asset Health Index table.*
- *The plant incurring the highest score moves towards the top of the table indicating the higher priority for replacement.*

An example of how the scoring relates to HI is shown in the example table below.

Scoring Criteria	Health Index
Total Score is greater than 300 points or any end of life criteria have been met	5
Total Score is greater than 200 and is less than 300	4
Total Score is greater than 100 and less than 200	3
Total Score is greater than 10 and less than 100	2
Total Score is less than 10	1

Our plant and civil condition assessments consider the detailed condition and technical assessments available for each Grid and Primary substation. These sites were assessed using the templates published in our Specification for Primary Substation Audit SUB 03 030 and Civil and Asset Health Methodology detailed in **Annex C6 – Civil Strategy and Plans – SPEN** and informed by foundation document Civil Asset Inspection Specification SUB 03 025.

The prioritised interventions look to exploit advances in new technology, where appropriate, to assess alternative solutions over simply replacing assets on a like for like basis.

In the case of transformers our risk based strategy to ensure staff and public safety from HV Transformers is based on;

- *Ground Mounted (GM) transformers are replaced as determined through condition assessment on reaching HI5 or on failure;*
- *RMU replacement in SPM may require refurbishment of the associated transformer;*
- *Pole Mounted (PM) transformers are only replaced on failure, normally using a recovered unit or during 11kV overhead line replacement work.*

In addition to the ground mounted replacement volumes identified, SP Energy Networks has embarked on the pro-active replacement of high loss pre-1962 transformers. This programme of work is driven and justified by the value of reduced losses and is detailed in **Annex C5 – Losses Strategy – SPEN**.

6.1. Deterioration

An assessment of the length of time it takes for a typical asset to deteriorate is based on experience and engineering knowledge of the increasing probability of failure for each asset health category. This provides the expected rate of deterioration over the assets life. Current Health Indices then form the base to develop forward looking health indices with and without intervention. The difference between with and without intervention HI profiles is indicative of the risk mitigated by the proposed asset specific interventions.

6.2. Criticality Index

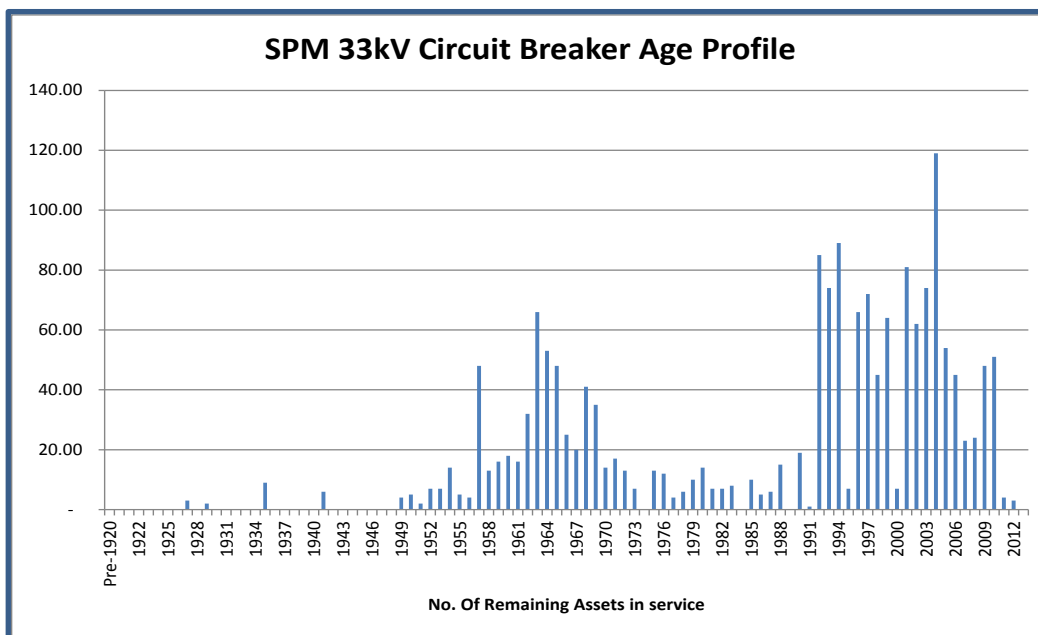
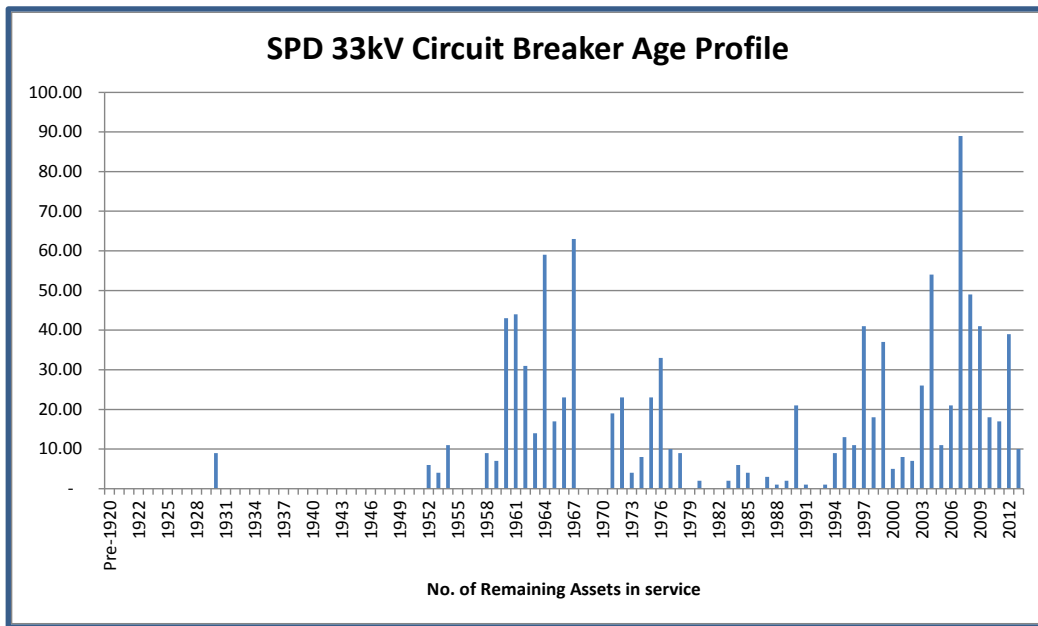
SP Energy Networks quantifies asset criticality in accordance with our internal asset management standard, ASSET-01-019 (Asset Health, Criticality & Outputs Methodology). Our criticality measure takes into account the impact on safety, environment, system reliability and cost that would occur as a consequence of the failure of the asset. The asset Criticality Index (CI) is used to prioritise replacement of HI5 assets.

A full description of our approach to the assessment and management of asset health, criticality and network risk is provided in **Annex C6 – Asset Health and Criticality Strategy – SPEN**.

7. 33kV Circuit Breaker Investment Plan

Currently, there is a population of 1,784 33kV circuit breakers in SPM and 1,036 in SPD of which we plan to replace 8.5% and 11.4% respectively during ED1.

The age profile of our 33kV circuit breakers is shown below;



An age based model is utilised to predict high level, long-term asset replacement volumes for each asset category and provides early identification of potential peaks in future workload. Our approach to determining the contribution to network risk, based on asset health and criticality indices, from each of the major asset categories forms the basis of the intervention volumes proposed in our business plan.

There are no economic life extension techniques for oil circuit breaker mechanisms although we recover the bushings, which can then be considered for use as strategic spares.

The 33kV bulk oil units have several replacement drivers;

- *Bushing degradation and failure*
- *Solenoid mechanism – closing coil fails to de-energise after operation*
- *Failures of latch mechanism*
- *Corrosion of the main tank, mechanism housing and metal structures*
- *Broken trip latch springs*



Associated equipment intervention drivers;

- *ABSW drive rod deterioration*
- *ABSW contact and mechanism deterioration*

Our site surveys have identified other issues associated with the circuit breaker population including widespread plinth degradation, addressed in our civil works strategy in **Annex C6 – Civil Strategy and Plans – SPEN**, and metallic structure corrosion.

The 33kV circuit breaker population will continue to deteriorate and we will address the rate of deterioration to manage the increasing network risk contribution from the large population of 1950s and 60s bulk oil circuit breakers. This risk mitigation will be achieved with the replacement of HI4 and HI5 units through our long term replacement programme.

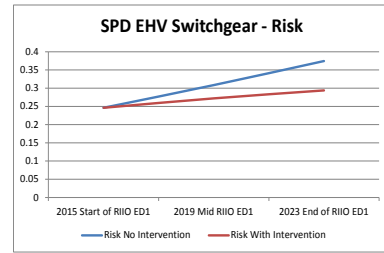
Targeted replacement is therefore the only option to improve the performance and reliability of these network assets. The accompanying Cost Benefit Analysis (**Annex C6 – Cost Benefit Analysis – SPEN**, reference 59) has been used to verify this strategy.

7.1. Circuit Breaker Health Index

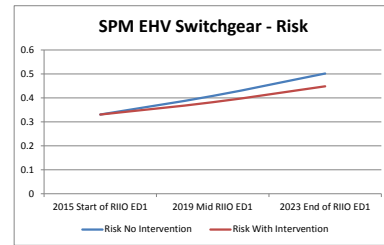
The approach and policy outlined in section 6 provides a mapping of our condition and operational adequacy assessment scores to Health Indices. Combining Criticality Indices with our HI outputs, along with probability and consequence of failure, provides a measure of network risk. Refer to **Annex C6 – Asset Health and Criticality Strategy – SPEN** for a detailed description of our methodology. Our approach to managing overall network risk during ED1 is to maintain a similar level of risk at the end of the ED1 period as experienced at the start. Whilst the overall level of network risk across all asset categories is broadly constant there can be some variation within each asset category. The relative risk measures for each asset category with and without investment are profiled in the graphs below.

A matrix of HI and CI interventions indicating the movement in HI and CI volumes between the start and end of ED1 is also provided.

SPD	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	68	0	0	-4	-64	0
CI2	36	-2	-4	0	-30	0
CI3	15	-6	-1	-1	-7	0
CI4	0	0	0	0	0	0
Total HI	119	-8	-5	-5	-101	0



	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	204	-2	-1	-20	-127	54
CI2	16	0	0	-3	-9	4
CI3	11	0	0	-1	-7	3
CI4	20	0	0	0	-15	5
Total HI	251	-2	-1	-24	-158	66

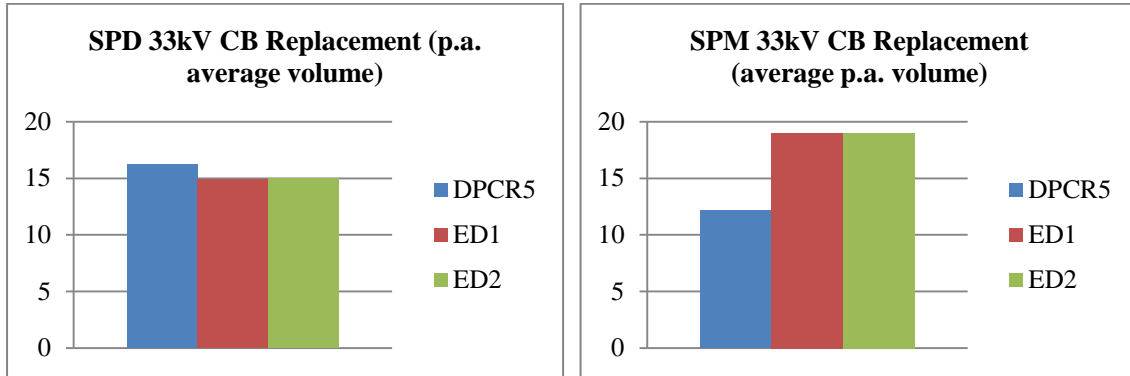


The results from all the 33kV switchgear condition analysis is merged to produce a substation site specific heat map used to inform intervention prioritisation, part of which is shown.

SPD / SPM	Location	Voltage	Arc	Manufacturer			OP AD	Plant Condition		Overall HI	Worst Components
				Type	Model	Year		CB	Isol		
SPD	Saltcoats	33kV	CB OD	Reyrolle	OMT4	1970	4	5	3	3	5
SPD	Broxburn	33kV	Bulk Oil CB	AEI	JB424	1966	4	4	3	3	5
SPD	Cumbernauld	33kV	Bulk Oil CB	AEI	JB424	1971	4	3	3	3	5
SPD	Glenniston	33kV	Bulk Oil CB	EE	OKM4	1959	4	4	3	3	4
SPD	Linnmill	33kV	Bulk Oil CB	SWS	E01	1973	4	2	3	3	4
SPM	Caergeiliog Grid	33kV	Bulk Oil CB	EE	OKM4	1963	4	4	5	3	4
SPD	Bartiebeith	33kV	Bulk Oil CB	SWS	E01	1965	4	3	5	3	4

7.2. Circuit Breaker Volumes

Our condition assessment and replacement prioritisation results in the replacement of 251 circuit breakers in SPM and 119 circuit breakers in SPD with average annual delivery indicated in the graphs below.



The variation in assets replaced or refurbished each year over DR5 and ED1 is driven by our continuing assessment of asset health. Volumes proposed are aligned to current delivery achievement in DPCR5.

We plan to deliver the total volumes indicated below.

Asset	SPM		SPD	
	Volume	£m	Volume	£m
33kV Circuit Breaker Replacement	251	24.2	119	12.4

8. EHV Switches

EHV switch replacements are associated with our circuit breaker replacement programme and consist of line and busbar disconnectors on either side of the circuit breaker.

Fault thrower switches have historically been installed on 33kV OHL transformer feeders in SPD to provide crude inter-tripping during fault clearance. Potential consequences of the non-operation of these ageing devices include disruptive transformer failures and proactive investment is required to mitigate the associated risk.

There are now options available to provide this fault clearance function that employ modern communications, or circuit breaker alternatives included in our CB investment plan, eliminating the requirement for fault throwers. It is SP Energy Networks policy not to install fault throwers or to replace existing fault throwers like for like when they reach end of life.

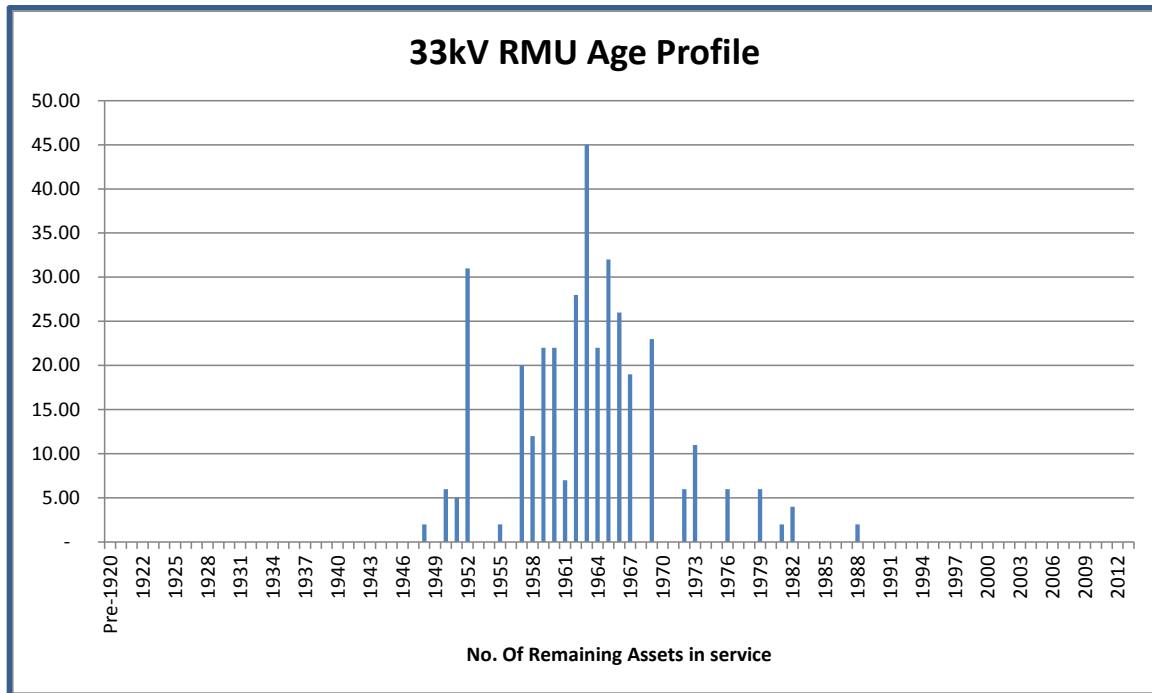
We will reduce the population of fault throwers in SPD over the ED1 period by 38. Due to the difference in network design in SPM the deployment of fault throwers has not been widespread and none have been identified by condition assessment as requiring replacement.

Asset	SPM		SPD	
	Volume	£m	Volume	£m
33kV Switches	202	5	34	0.9

9. RMU Replacement Plan

There are currently 361 ring main units installed in our SPM license area, of which we will replace 9.1 % during ED1. There are no 33kV RMUs in our SPD license area.





An age based model is utilised to predict high level, long-term asset replacement volumes for each asset category and provides early identification of potential peaks in future workload. Our approach to determining the contribution to network risk, based on asset health and criticality indices, from each of the major asset categories forms the basis of the intervention volumes proposed in our business plan.

There are no economic life extension techniques for RMUs. Due to the unique network configuration deployed in SPM, replacement 33kV RMUs offered by manufacturers do not meet SPM requirements. The interconnected network in SPM requires a CB and protection configured on the network ring rather than the CB and trip arrangements offered by manufacturers on the 'T off'. The current equipment rating offered by the manufacturers does not meet the design requirement of the SPM interconnected network.

SP Energy Networks has explored replacement options and concluded that the most effective option is the replacement of this SPM specific asset with modern circuit breakers.

33kV RMU operating mechanisms, bushings and perishable spare parts are now difficult to source and no longer supported by suppliers. There are also operational difficulties, including restrictions which often result in longer customer interruptions, maintenance outages and safety issues.

Our condition assessment programme has identified common investment drivers for 33kV RMUs;

- *Current Suspension of Operational Practice relating to the switch*
- *Unreliable mechanism resulting in operator manual intervention*
- *Trip coil linkage resulting in failure to trip,*
- *S switch auxiliary switch contact switch,*
- *drive linkage rubber perishing resulting in failure to operate of the cb*



Site surveys have also identified other issues associated with the RMU including civil degradation and steelwork corrosion.

Targeted replacement is therefore the only option to improve the performance and reliability of these network assets. The accompanying Cost Benefit Analysis (**Annex C6 – Cost Benefit Analysis – SPEN**, reference 60) has been used to identify optimal transition timing from maintenance to asset replacement.

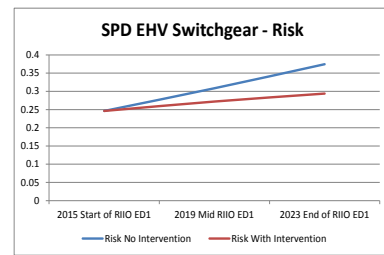
We will continue this programme of work in line with our risk based replacement strategy over ED2 and ED3 price review periods.

9.1. RMU Health Index

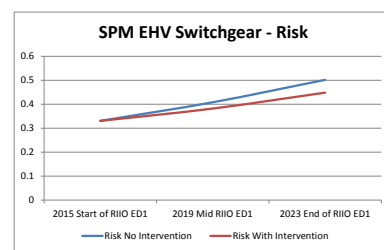
The approach and policy outlined in section 6 provides a mapping of our condition and operational adequacy assessment scores to Health Indices. Combining Criticality Indices with our HI outputs, along with probability and consequence of failure, provides a measure of network risk. Refer to **Annex C6 – Asset Health and Criticality Strategy – SPEN** for a detailed description of our methodology. Our approach to managing overall network risk during ED1 is to maintain a similar level of risk at the end of the ED1 period as experienced at the start. Whilst the overall level of network risk across all asset categories is broadly constant there can be some variation within each asset category. The relative risk measures for each asset category with and without investment are profiled in the graphs below.

A matrix of 33kV switchgear HI and CI interventions indicating the movement in HI and CI volumes between the start and end of ED1 is also provided.

SPD	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	68	0	0	-4	-64	0
CI2	36	-2	-4	0	-30	0
CI3	15	-6	-1	-1	-7	0
CI4	0	0	0	0	0	0
Total HI	119	-8	-5	-5	-101	0

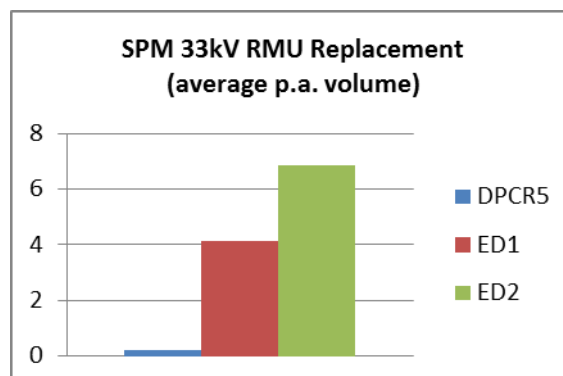


	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	204	-2	-1	-20	-127	54
CI2	16	0	0	-3	-9	4
CI3	11	0	0	-1	-7	3
CI4	20	0	0	0	-15	5
Total HI	251	-2	-1	-24	-158	66



9.2. Ring Main Unit Volumes

Our condition assessment and replacement prioritisation results in the removal of 33 RMUs during ED1 at an average removal rate of 4 per annum, to be ramped up to 7 per annum in ED2 as indicated in the graph below.

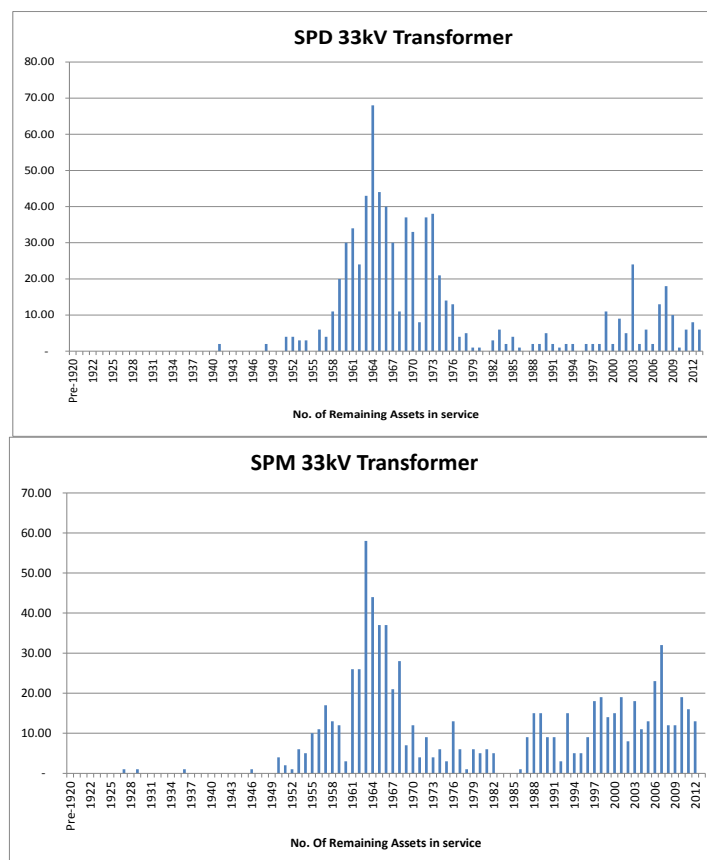


Recent condition surveys of our substations and operational assessment reports have provided enhanced data to better inform our assessment of RMU condition. This reappraisal has resulted in a programme of work to replace these units commencing in ED 1.

Expenditure associated with replacing these units with circuit breakers is captured within our 33kV circuit breaker investment plan.

10. Transformer Investment Plan

SP Energy Networks has 809 33kV Primary transformers in SPM and 756 in SPD of which we plan to replace 7.5% and 8% respectively. The age profiles of the population of primary substation transformers is shown below;



An age based model is utilised to predict high level, long-term asset replacement volumes for each asset category and provides early identification of potential peaks in future workload. Our approach to determining the contribution to network risk, based on asset health and criticality indices, from each of the major asset categories forms the basis of the intervention volumes proposed in our business plan.

Our replacement and refurbishment strategy for 33kV transformers is detailed in **Annex C6 – TRAN-02-002 Assessment of the Operational Adequacy of Transformers and Reactors 33kV and Above – SPEN**. The investment strategy for transformers is to replace assets assessed to be in critical condition (HI5), particularly those with consistent or rising high Dissolved Gas Analysis (DGA) readings. Oil tests are also carried out to measure the level of acidity, moisture and furans, the latter indicating electrical ageing of the transformer windings. The testing frequency is increased if the level of gases starts to rise indicating a potential problem. These tests are incorporated into our prioritised condition assessment methodology previously outlined in section 6.

Our intervention programme for 33kV transformers also considers refurbishment as an option for units assessed to be in poor condition, typically HI4. Refurbishment will only be performed where it is cost-effective to extend

asset life by a minimum of ten years. This programme has been successfully rolled out in both distribution Licence areas during DPCR 5, and we will continue with this strategy into RIIO-ED1.

Our plans for ED1 have identified transformers suitable for refurbishment. These have been selected on the basis that the test results indicate no serious acetylene or acidic values, the exterior condition can be improved and the tap change voltage unit can be refurbished with life extension of 15 to 20 years.

The scope of work included within our refurbishment plans and reflected in TRAN-03-031 includes:

- replacement or repair of cooling fins,
- oil regeneration,
- sealing of leaks through gasket replacement,
- refurbishment of the voltage tap changer
- upgrading of the civils associated with the transformer which may include the noise enclosure.

We will regularly perform oil tests and condition assessment to ensure that we have selected the correct candidates through the RIIO ED 1 period, updating and prioritising as required.

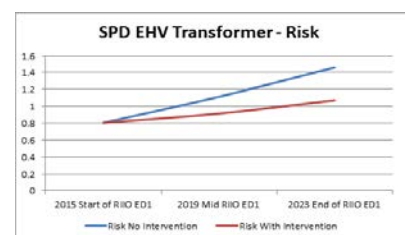
10.1. Impact on Health and Criticality Indices

The approach and policy outlined in section 6 provides a mapping of our condition and operational adequacy assessment scores to Health Indices. Combining Criticality Indices with our HI outputs, along with probability and consequence of failure, provides a measure of network risk. Refer to **Annex C6 – Asset Health and Criticality Strategy – SPEN** for a detailed description of our methodology. Our approach to managing overall network risk during ED1 is to maintain a similar level of risk at the end of the ED1 period as experienced at the start. Whilst the overall level of network risk across all asset categories is broadly constant there can be some variation within each asset category. The relative risk measures for each asset category with and without investment are profiled in the graphs below.

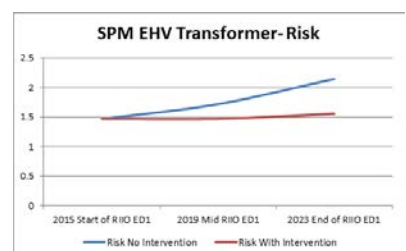
A matrix of HI and CI interventions indicating the movement in HI and CI volumes between the start and end of ED1 is also provided.

SPD 33kV transformer – HI/CI ED1 movements

	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	26	31	0	-31	-26	0
CI2	25	32	0	-32	-25	0
CI3	6	18	0	-18	-6	0
CI4	4	4	0	-4	-4	0
Total HI	61	85	0	-85	-61	0



SPM	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	45	22	0	-22	-45	0
CI2	29	19	0	-19	-29	0
CI3	15	7	0	-7	-15	0
CI4	0	0	0	0	0	0
Total HI	89	48	0	-48	-89	0



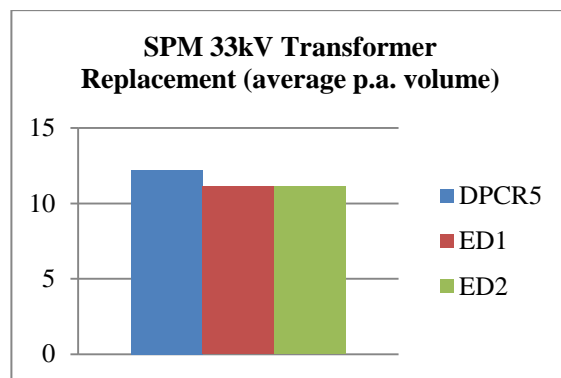
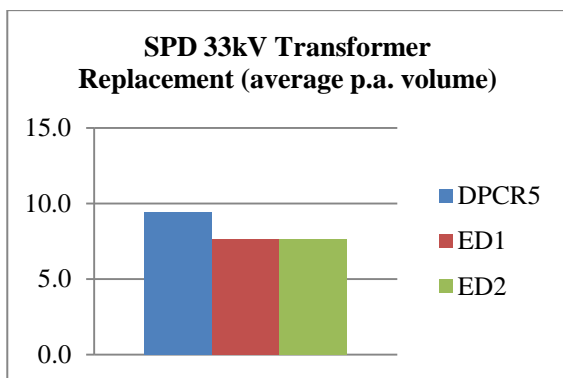
10.2. Transformer Heat Map

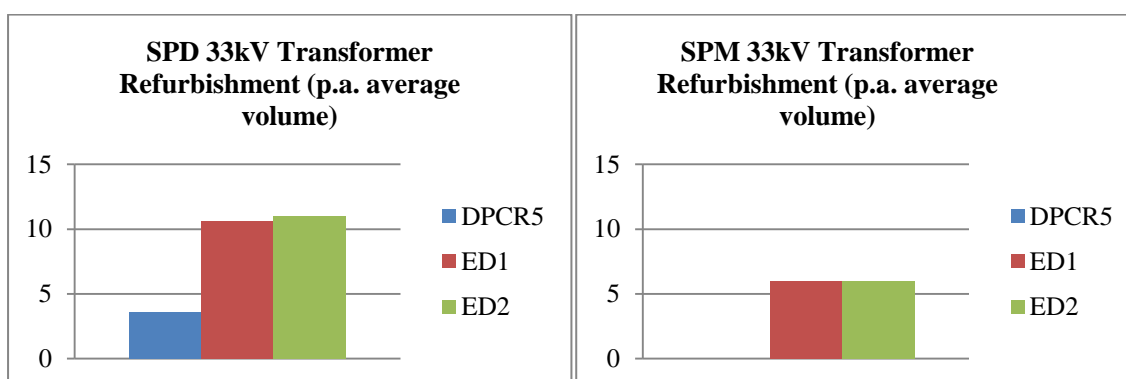
The results from all the 33kV transformer analysis provide data by which we can select and prioritise the transformers for replacement or refurbishment.

Substation Name	Transformer	HI
NEWBURGH PRIMARY-TRX	T01	4
NEWBURGH PRIMARY-TRX	T02	4
QUEENSWAY PRIMARY-TRX	T01	4
CUPAR PRIMARY-TRX	T01	5
CUPAR PRIMARY-TRX	T02	4
KILLOCH COLLIERY-TRX	T01	4
DURIE HOUSE PRIM-TRX	T01	4
NEW CUMNOCK TEMP-TRX	T01	5
NEW CUMNOCK TEMP-TRX	T02	4
SHERWOOD PRIMARY-TRX	T02	4
DUNDAS ST PRIMARY-TRX	T01	4
DUNDAS ST PRIMARY-TRX	T02	4
BALMORE B/VILLAGE-TRX	T01	5
HUNTER STREET PRIMARY-TRX	T01	4
FLEMINGTON ST PRIMARY-TRX	T02	4
CROOKSTON 33/11-TRX	T02	4
SALTCOATS MAIN-TRX	T01	4
WHITLAWBURN PRIMARY-TRX	T01	4
TROON 33KV-TRX	T01	5
TROON 33KV-TRX	T02	4
CRONBERRY-TRX	T01	4

10.3. Transformer Volumes

Our condition assessment and replacement prioritisation results in the interventions with the average annual delivery indicated in the graphs below.





The combination of replacement and refurbishment plans allows us to effectively manage network risk and smooth the profile of transformer investment over ED1 and ED2 periods. Our transformer replacement and refurbishment plan is broadly consistent with delivery volumes achieved during DPCR5.

Asset	SPM		SPD	
	Volume	£m	Volume	£m
33kV Transformer Replacement	89	15.4	61	15.6
33kV Transformer Refurbishment	48	1.7	85	3.7

Cost benefit analysis documentation is available for 33kV transformer refurbishment which shows a positive outcome, and is contained within **Annex C6 – Cost Benefit Analysis – SPEN**, Assessments 64.1 and 64.2.