SP Energy Networks 2015–2023 Business Plan

Updated March 2014

Annex

132kV Substation Plant Strategy

SP Energy Networks

March 2014

SP ENERGY NETWORKS

132kV Substation Plant

March 2014

Issue Date	Issue No.	Document Owner	Amendment Details
17th March 2014	1.0	David Neilson	First Issue

1. Scope

This Annex covers our strategy for the replacement and refurbishment of 132kV 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 C6 – Asset Health and Criticality Strategy – SPEN
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C6 – 132kV Substation Heat Maps – 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 – Cost Benefit Analysis – SPEN

3. Executive Summary

Please note that all 132kV assets in Scotland are owned by our Transmission business.

Switchgear and transformers in 132kV substations are critical assets and the consequences of failure can be significant in terms of safety, reliability and availability of supply.

Our 132kV plan ensures the long-term stewardship and management of the risk of failure through these key deliverables:

Asset	SPM	
	Volume	£m
132kV Circuit Breakers Replacement	50	29.4
132kV Switchgear	71	4.4
132kV Transformer Replacement	21	27.8
132kV Transformer Refurbishment	16	1.5
Total expenditure	**-**	**63.1**

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

Our investment plan for RIIO-ED 1 involves replacement or refurbishment of assets which are in a critical or poor condition. The investment plan has been developed in accordance with our Asset Risk Management procedures which are described in our internal asset management standard ASSET-01-019 (Asset Health, Criticality & Outputs Methodology). Available asset condition information combined with age based modelling, as a proxy for condition where necessary, has determined the intervention volumes.

This document details the Non Load Network Investment Strategy for 132kV substation assets. It explains:

- *The use of condition information together with age-based modelling to derive a health index*
- *The application of a criticality index on each site*
- *The cost benefit analysis for the main asset categories*
- *Our plans for ED1*
- *The process for delivering risk based, prioritised asset interventions.*

5. Network Strategy

The investment strategy for the 132kV network aims to ensure an optimum level of investment by adopting 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 and support network growth.*
- *To intervene prior to asset failure: When asset performance and reliability fall below acceptable operational limits and cannot be restored without an unacceptable financial risk and / or system risk exposure.*
- *Minimise failures, through interventions targeted on assets at or approaching critical condition (Health Index 5): Utilising engineering condition or type information, as appropriate.*
- *Target investment based on an assessment of the consequences of failure using probability of failure (Asset Health) 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 132kV plant utilises our Asset Health Methodology ASSET 01 019 and Assessment of Operational Adequacy detailed in SPEN's policy document SWG-02-008 and TRAN-02-002. 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 than100 and less than 200	3
Total Score is greater than10 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 132kV 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 our Civil strategy (**Annex C6 – Civil Strategy and Plans – SPEN**) and informed by foundation document Civil Asset Inspection Specification SUB 03 025.

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.

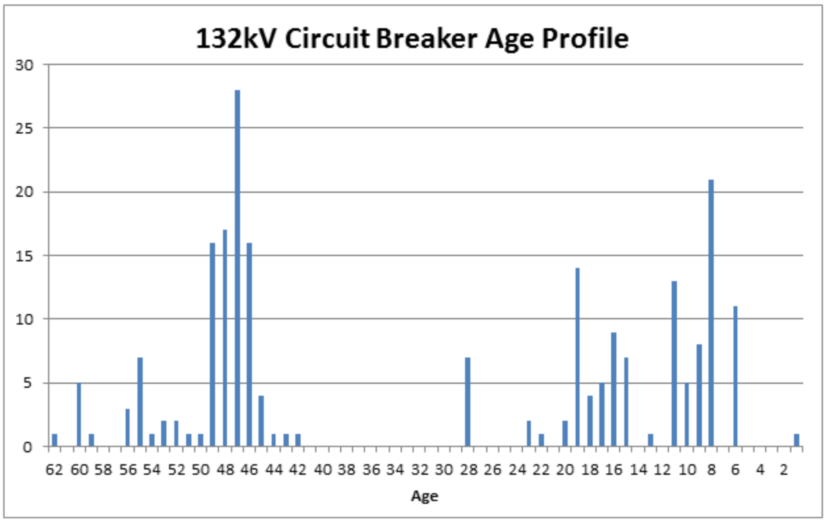
6.2. Criticality Index

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. 132kV CB Investment Plans

SP Energy Networks has a total population of 219 132kV circuit breakers comprising GIS, AIS and OCB designs, of which we plan to replace 22% during RIIO-ED1.We plan to replace all of our remaining OCB and AIS circuit breakers by 2031 (end RIIO-ED2).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 heath and criticality indices, from each of the major asset categories forms the basis of the intervention volumes proposed in our



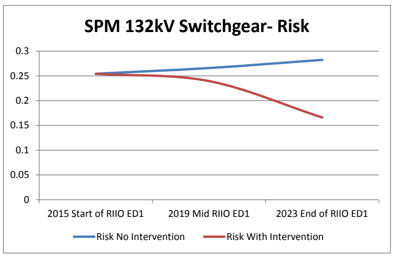
business plan.

7.1. 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.

SPM	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	12	0	0	0	-12	0
CI2	24	0	0	0	-24	0
CI3	14	-2	0	0	-12	0
CI4	0	0	0	0	0	0
Total HI	50	-2	0	0	-48	0



7.2. Circuit Breaker Heat maps

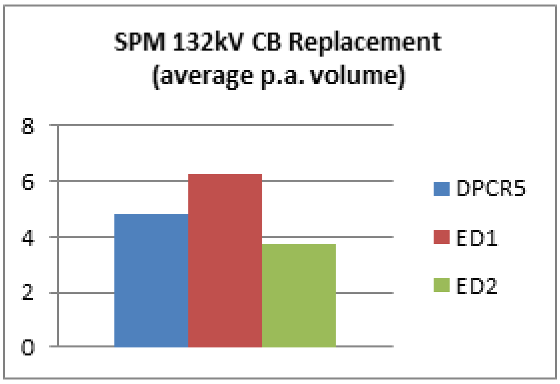
The results from all the 132kV switchgear condition analyses are merged to produce a site specific heat map to inform replacement prioritisation, part of which is shown below. The complete 132kV heat map has been attached as an annex to the submission (**Annex C6 – 132kV Substation Heat Maps – SPEN**).

Substation	Switchgear Operational Adequacy SWG-02-008	Switchgear (site condition)	Ancillaries
BIRKENHEAD GRID	5	5	5
CREWE	5	5	3
GATEACRE GRID	5	5	5
LISTER DRIVE GRID	5	5	5
RAINHILL GRID	5	5	4
SPEKE GRID	5	5	5

7.3. Circuit Breaker Volumes

The optimised interventions look to exploit advances in new technology, where appropriate and avoid replacing assets on a like for like basis, focussing on value by delivering outputs in an efficient manner. We seek to utilise air insulated switchgear (AIS), and gas insulated switchgear (GIS), where appropriate.

Our long-term investment plan spans two price review periods, targeting the highest criticality sites on a prioritised basis, and those associated with a 132kV transformer replacement.



Our plan for switchgear replacement during DR5 will peak in 2015, we remain on target to complete 100% of this programme during DR5. The proposed average annual replacement rate during ED1 is broadly consistent with that for DPCR5.

Based on our analysis, the following numbers of units are planned for replacement during ED1.

Asset	SPM	
	Volume	£m
132kV Circuit Breakers Replacement	50	29.4

7.4. Air Blast Circuit Breakers Condition

We plan to remove twelve AEI GA6 circuit breakers at Rainhill. These circuit breakers are in a critical condition, and our technical assessment document, SWG-05-096, details the operational and system issues around this type of circuit breaker.

They have no manufacturer support, available parts are limited to spares cannibalised from recovered units from our asset replacement programme which is all but exhausted. Therefore it is not considered economic to endeavour to refurbish this type of circuit breaker.

The periodic maintenance cost for a legacy air blast circuit breaker, is circa £40k, which can takes up to six weeks to complete while maintenance on modern GIS switchgear is typically limited to testing and condition assessment over longer maintenance periods.

The 132kV air blast investment drivers include:

- *Failure of interrupter head*
- *Unacceptable blast tube insulation resistance*
- *Poor conditioning air flow*
- *Failure of interrupter to re-close*
- *Damage to isolator arm during fault clearance*
- *Additional restrictions during maintenance to*
- *facilitate working at height regulations*

7.5. Oil Circuit Breakers Condition

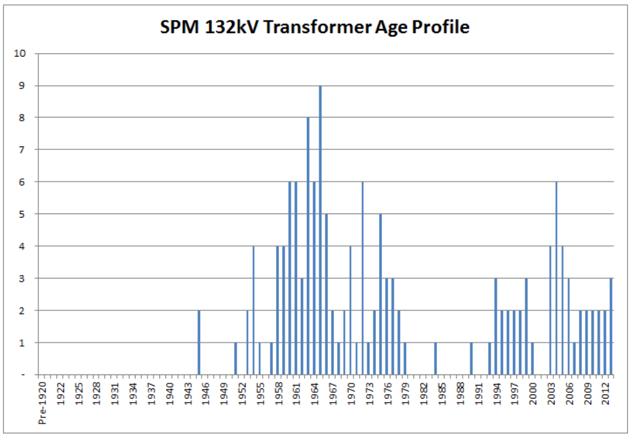
As detailed in SWG-05-091, OW410 132kV Bulk Oil Circuit Breakers: There are no economic life extension techniques for oil circuit breakers other than replacement/refurbishment of the bushings. Therefore any recovered bushings as part of the switchgear replacement programme are considered for use as strategic spares. Maintenance of a legacy oil circuit breaker, costs about £15k and can take up to two weeks. Relative replacement costs for 132kV circuit breakers are circa £1m for a new switchgear bay.

132kV bulk oil units investment drivers include:

- *Bushing failures due to water ingress,*
- *Solenoid mechanism – closing coil fails to*
- *de-energise after operation*
- *Failures of latch checking pressure relay,*
- *Corrosion causing oil leaks*
- *Failure of bellows and pressure switches,*
- *Failures to latch,*
- *Broken trip latch springs*
- *Confined space working.*

8. Transformer Investment Plans

Currently we have 144 132kV transformers in SPM and we plan to replace 21 units and refurbish 16 units during ED1.

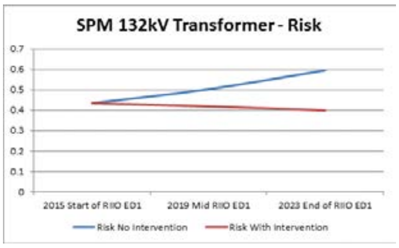


8.1. Health Index

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 ASSET 01 019 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.

	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	10	5	0	-6	-9	0
CI2	7	6	0	-6	-7	0
CI3	4	2	0	-2	-4	0
CI4	0	3	0	-3	0	0
Total HI	21	16	0	-17	-20	0



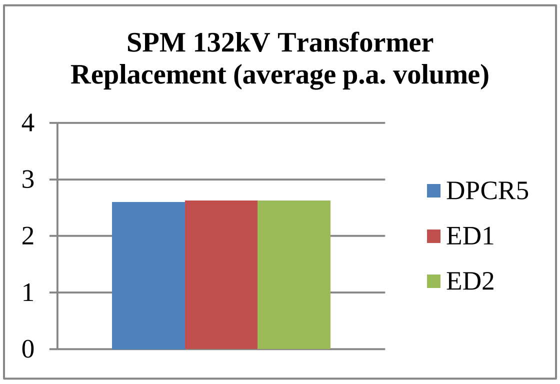
8.2. Transformer Heat maps

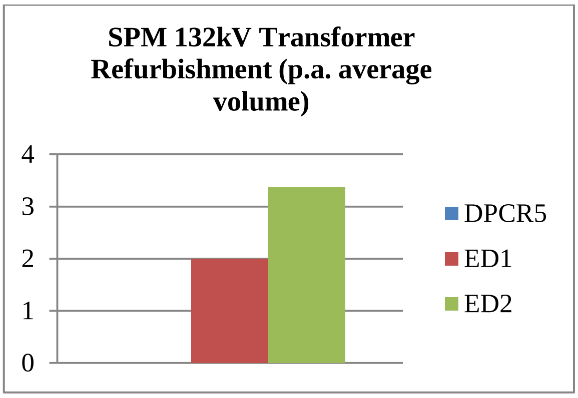
The results from all the 132kV transformer condition analysis is merged to produce a site specific heat map to further inform prioritisation, part of which is shown. The complete 132kV heat map has been attached as an annex to our submission - **Annex C6 – 132kV Substation Heat Maps – SPEN.**

Substation	Unit	Transformers Operational Adequacy TRAN-02-002	Transformers (site condition)	Switchgear	Ancillaries	Civils
ABERYSTWYTH GRID	T2	5	4	4	4	4
AINTREE GRID	T1	3	4	5	4	5
AINTREE GRID	T2	4	4	5	4	5
BIRKENHEAD GRID				5	5	5
BOLD GRID				5	5	5
BOLD GRID	T2	2	5	1	5	5
BOOTLE GRID	T1	2	3	4	1	3
BOOTLE GRID	T2A	3	3	4	4	4
CONNAHS QUAY A				3	3	3
COPPENHALL GRID	T1	5	5	4	3	3
CRANE BANK	T1	2	3	2	2	3
CREWE	T1	4	5	5	3	5
CREWE	T2A	2	2	5	3	5
CREWE	T2B	2	2	5	3	5
CREWE	T4A	2	2	5	3	5
CREWE	T4B	2	3	5	3	5
DALLAM GRID	T1	2	3	4	4	5
DEESIDE PARK	T1	2	3	2	2	2
DOLGARROG	T2	2	2	2	2	2
DUTTON GRID	T2	3	4	4	4	3
ELLESMERE PORT GRID	T1	5	5	5	5	5
ELLESMERE PORT GRID	T2	5	5	5	5	5
ELLESMERE PORT GRID	T3	3	5	5	5	5
ELLESMERE PORT GRID	T4	2	4	5	5	5

8.3. Transformer Volumes

Our condition assessment and replacement prioritisation results in our planned delivery profiles shown below.





Our plan for 132kV transformer replacement during DR5 remains on target for completion. The proposed average annual replacement rate during ED1 is broadly consistent with that for DPCR5. Based on our analysis, the following numbers of units are planned for replacement and refurbishment during ED1 as they are currently approaching critical condition (HI5) or are suitable for refurbishment and life extension (HI4).

Asset	SPM	
	Volume	£m
133kV Transformer Replacement	21	27.8
132kV Transformer Refurbishment	16	1.5

We have included a full CBA Reference number 63 for transformer refurbishment that presents a positive outcome for the proposed refurbishment. The scope of this work is critical to realise the full life extension benefits.

8.4. Transformer Condition

Our plans are condition based, informed by individual asset condition reports. Long term age based modelling is undertaken to provide strategic context for asset replacement volumes and future capital expenditure needs and is utilised to refine the Investment plan. The model is also utilised to predict long-term asset replacement volumes for each asset category and thus enable early identification of potential peaks in future workload. The age based modelling methodology complements the bottom up condition assessment process, enabling immediate and longer term risks to be adequately managed. The asset replacement model records information relating to age, voltage and circuit parameters for the different categories of assets employed on distribution networks, including transformers.

The investment strategy for transformers is to replace assets at or approaching end of life, particularly those with high Dissolved Gas Analysis (DGA) readings and/or poor site specific, condition based assessment. Assessment is by means of a scoring system and the results of the assessment are tabulated in the form of a league table. The transformer types with the highest score move towards the top of the table indicating they have the highest priority for replacement.

The strategy for 132kV transformers also considers refurbishment as a mid-life option to extend asset life. Our selection criteria are based on detailed oil and condition assessment.

Our replacement and refurbishment strategy for 132kV 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 8.4.

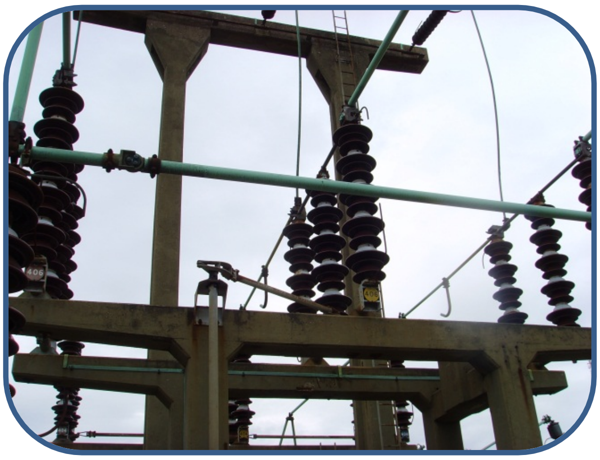
Our intervention strategy for 132kV transformers also considers refurbishment as an option for units assessed to be in poor condition, typically HI4. Refurbishment will only be performed where it is cost-effective to extend asset life by a minimum of ten years.

Transformer refurbishment involves:

- *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*

8.5. Disconnectors

ABSD are essential to the operation of our circuit breakers and transformers. These assets are designed to allow the plant to be isolated and earthed for maintenance and reconfigured during fault activities.



The disconnectors and the civil structures which support them have gradually deteriorated over time. The ongoing costs associated with the repair and maintenance is high, and the condition of this asset has added to the overall justification for 132kV plant replacement. Full site condition details are contained within our 132kV survey reports.

9. Options & Cost Benefit Analysis

A series of scheme CBAs Ref numbers 52, 53 and 54 are provided to justify the use of GIS versus AIS in these instances. Designing out the use of outdoor air break switches, the associated structures and long term maintenance and system access costs preclude AIS solutions. Further to this the substation GIS footprint is approximately 20% of the equivalent AIS solution with the added visual amenity and security benefits.

10. Deliverability & Efficiency

The 132kV network has significant access constraints that require a high level of forward planning. We will ensure that no further major interventions are required at any site in the subsequent price review period.

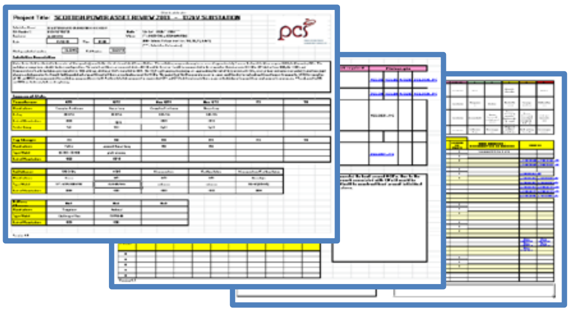
The optimised interventions look to exploit advances in new technology, where appropriate, and avoid replacing assets on a like for like basis, focussing on value by delivering outputs in an efficient manner.

11. Appendix

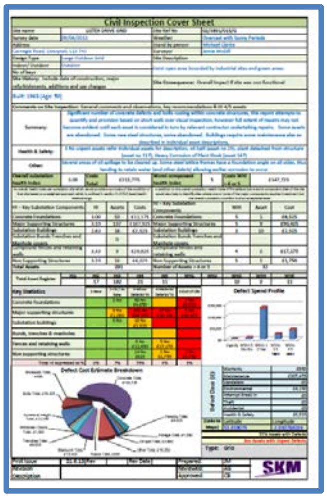
We have extensive reports for our entire 132kV substation to assess the technical capability asset condition, and asset life plans which set our capital and operational funding for our assets. Further to this we have captured our maintenance and defect records, all of which have informed our investment plans.

The material available for each 132kV substation includes:

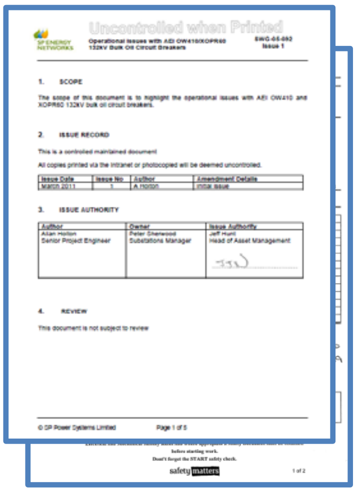
Plant surveys



Civil Surveys

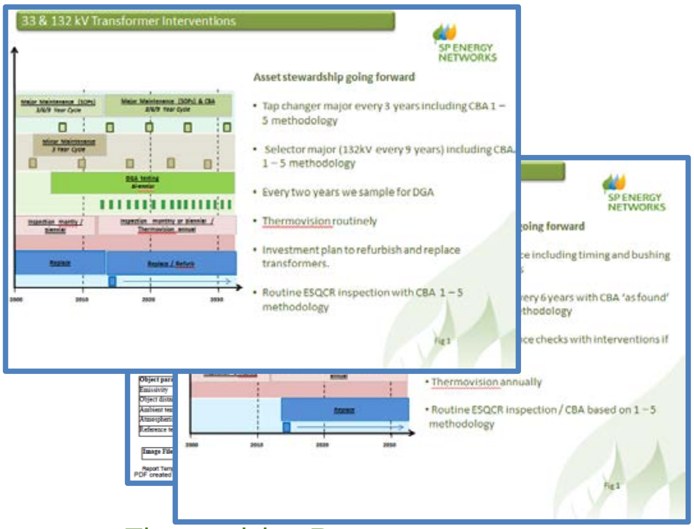


Technical Report



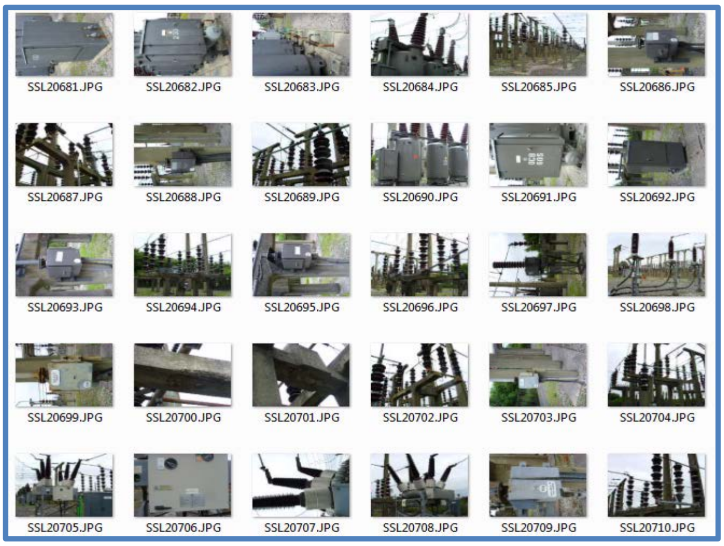
Maintenance records

Asset Life Plan



Thermovision Report

Photographs of each plant and civil item



12. Reference Documentation

- *TRAN 02 002 Assessment of Transformers*
- *SWG 02 008 Assessment of the Operational Adequacy of Switchgear*
- *Asset 01 019 Asset Management Strategy and Plans*
- *Asset 01 021 Asset Inspection and Condition Assessment Policy*
- *Civil Health Index Approach*
- *SWG 03 092 and 091 Circuit Breaker technical report*