SP Energy Networks 2015–2023 Business Plan

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Annex

132kV Cable Strategy

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17th March 2014	1.0	Jane Wilkie	First Issue

1. Scope

This Annex covers our strategy for the replacement and refurbishment of 132kV cable 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
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C6 – Expenditure Supplementary Annex – SPEN
SP Energy Networks Business Plan 2015-2023 - Annexes	Annex C6 – Asset Health and Criticality Strategy – SPEN

3. Executive Summary

Our 132kV cable is a critical asset and essential to provide our customers with reliable electricity supplies. We only invest in proactive 132kV cable replacement when the cable condition and performance result in unacceptable risk to reliability or the environment.

Replacing 132kV cable in city centres is a significant undertaking requiring road closures with disruption to residents and commuters and requires careful management. We therefore only replace it when absolutely necessary.

For the ED1 period we have only two Health Index 5 cable circuits in Merseyside which require replacement.

1. *132kV Gas compression cable: We plan to replace 5.0 km of gas compression cable between Lister Drive and Wavertree, with a modern XLPE equivalent.*

2. *132kV Oil Filled cable: We plan to replace 10.9 km of oil filled cable between Kirkby and Bootle, with a modern XLPE equivalent.*

Delivery of our cable programme is essential to delivering reliable network performance and is fundamental to delivering our stated output to reduce oil leaks by 50% through the replacement of poorly performing 132kV cable in SPM.

Asset Replacement, Refurbishment		DPRC5			RIIO-ED1			% change
		Total length	D5 pa	Total	Total length	ED1 pa	Total	
		Km	£m	£m	Km	£m	£m	
132kV Cable	SPM	23.6	3.8	19.0	19.4	2.3	18.6	-39%

4. Introduction

132kV cable assets in SPM are one of three types:-

- *Gas compression cables*
- *Oil filled cables*
- *XLPE cables*

Gas compression cables were generally installed from the early 1950s to the mid 1960s and oil filled cables were installed from the 1950s through to the late 1990s. From the late 1990s onwards a new type of non-pressurised XLPE cable was installed.

It is not possible to ascertain the actual condition of cable buried underground, so as a proxy for condition we use fault rates and oil leakage rates to determine the health index of our cable assets.

Our investment plan for RIIO-ED 1 involves replacement of assets which are Health index 5.

The delivery of our key outputs and value for money for the customer is central to our plan.

- *Environment - to reduce oil leaks by 50% through the replacement of poorly performing 132kV cable in SPM*
- *Performance – to manage the risk associated with failure of critical 132kV cable circuits through removal of poorly performing cable*

5. Network Strategy

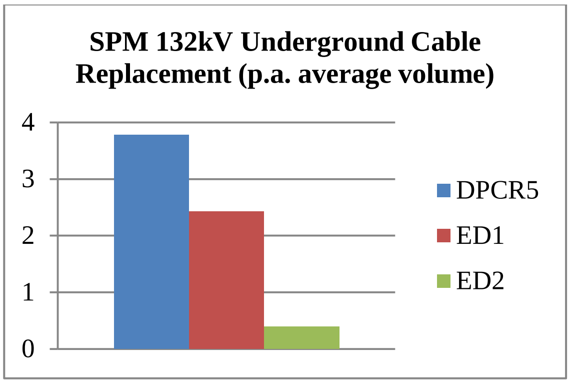
The investment strategy for the 132kV network aims to ensure an optimum level of investment by adopting a prioritised and targeted project specific approach. This is necessary to effectively manage the business risk and ensure long term sustainability, utilising appropriate engineering interventions and risk management. Specifically our strategy aims to:

- *Maintain safety, integrity and performance of the network as its age increases 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 of end of life (Health Index 5): Utilising engineering condition or type information, as appropriate.*
- *Target investment based on an assessment of risk through probability (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. Investment Strategy and Plans

6.1. 132kV Cable Investment Strategy and Plans

We have a total population of 246km of 132kV cable and we plan to replace 6% in RIIO ED1. We plan to address the age and risk through the replacement of two poorly performing Health Index 5 cables.



Based on our analysis, the following numbers of units are planned for replacement during ED1 as they are currently in critical condition and approaching end of life.

Cable Voltage	SPM
132kV	15.9km

Within the additions planned for ED1 there is 3.5 km of new cable required as a consequence of 132kV substation plant replacement. Our most critical cable circuits will be addressed during ED1 resulting in a reduction of forecast ED2 interventions.

6.2. Gas compression cable

By the end of DPCR5 we will have 5.0 km of British manufactured gas compression cable remaining, which is classed as a Health Index 5. We will continue to have 6.4km of German manufactured gas compression cable which was installed in the 1990s which is performing reliably and is currently classed as a Health Index 2.

Within our two license areas over the last 15 years we have progressively been removing unreliable Enfield type gas compression cable. The design, construction and installation of this type of cable in the 1950s and 60s has been found to be prone to failure and has been recognised as a problem across the industry.

This type of cable system relies on gas pressure in the pipeline in which it is laid being maintained. It suffers faults in both the cable itself due to depressurisation of the pipeline and the terminations which have porcelain sealing ends which have a risk of failing explosively. More detail on the failure mechanism of this cable type is provided in an Appendix to this annex. The SPM cables have had rating restrictions applied to reduce the risk of failures. Of this type of cable remaining in SPM, two of the circuits are being removed in DPCR5 and Lister Drive – Wavertree will be removed in ED1.

6.3. Pressurised Oil Filled Cable

We use a five year moving average leakage rate as a proxy for oil cable condition and assign a health index relative to this.

In general, those cables with minimal leakage only require maintenance to ensure that degradation is minimised and that they continue to operate safely and reliably. As part of our management of the environment, we have a well-established programme of use of PFT (PerFluoroCarbon) tracers to expedite oil leakage fault repairs, on a targeted basis. Cables which are exhibiting a random cumulative leakage rate, consistent with an end of life characteristic, will be targeted for replacement. The insulation within oil filled cables (unlike paper insulated cables), does not deteriorate over time as long as the hydraulic system maintains its capability to retain pressure. Condition assessments therefore focus, on the components of the system which ensure that oil pressure is maintained within design limits. The necessary maintenance procedures can be summarised as follows:

- *Sheath tests to confirm the integrity of the anti-corrosion serving.*
- *Tests to confirm the functionality of the pressure monitoring equipment and alarms.*
- *Tests to confirm the integrity and functionality of the earthing and bonding system.*
- *Regular pressure gauge checks to identify deviations from normal pressure.*

6.4. Health Index Outputs Deterioration and Criticality

6.4.1. Health Index Outputs

Considering the 5 year average oil leakage rate results in 16.8km being classed as Health Index 5. The 16.8 km of category 5 circuits comprises of three circuits:

- *Rainhill to St Helens – 5.2 km*
- *Capenhurst A to Hooton Park 1 – 0.7 km*
- *Kirkby to Gillmoss T1 to Fazakerley to Bootle – 10.9 km*

While the Capenhurst A to Hooton Park 1 circuit is a category 5 due to the oil leakages looking at the last five years, repairs have been carried out on this cable and there have been no leakages in the last two years. This indicates that oil leaks have been localised and have now been repaired, rather than a general deterioration of the cable insulation.

The Kirkby/Gillmoss/Fazakerley/Bootle circuit has an oil leakage rate that is 10 times worse than the average in SPM and accounts for 50% of the total oil leakage from all our 132kV cables.

The Rainhill to St Helens circuit is being replaced in DPCR5 and the Kirkby-Gillmoss- Fazakerley-Bootle circuit is planned for RIIO-ED1.

6.4.2. Criticality Index

Asset criticality is measured in terms of the stakeholder impact resulting from a failure of asset function. There are three elements to criticality:

- *Safety – based on the exposure and proximity to the public and personnel*

- *Environment – based on the environmental exposure from the asset and the sensitivity of the geographical area local to the asset.*

- *System – based on the impact of the distribution system not delivering services to stakeholders or the smooth operation of the UK services and economy*

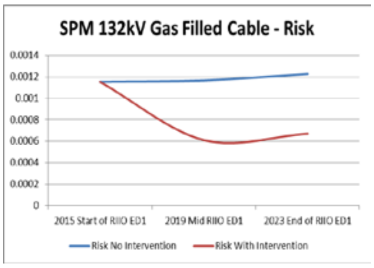
- *Financial – based on e.g. the cost to repair/ replace or public relations*

The criticality in each element is assigned a level of Very High, High, Medium or Low. The overall asset criticality is based on the highest of the 3 assessments. The criticality, or site 'importance', of each cable is assessed first.

A matrix of HI and CI interventions indicating oil and gas cable disposals in HI and CI volumes between the start and end of ED1 is also provided. The relative risk measures for each asset category with and without investment are also profiled in the graphs below.

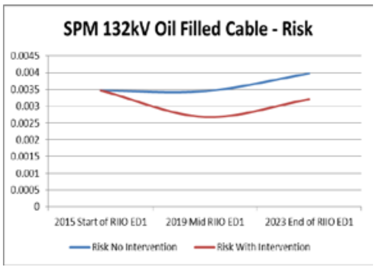
132kV Gas cable HI and CI movement

	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	0	0	0	0	0	0
CI2	0	0	0	0	-5	-5
CI3	0	0	0	0	0	0
CI4	0	0	0	0	0	0
Total HI	0	0	0	0	-5	-5



132kV Oil cable HI and CI movement

	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	0	0	0	0	0	0
CI2	0	0	0	0	-8.3	-8.3
CI3	0	0	0	0	0.0	0.0
CI4	0	0	0	0	-2.6	-2.6
Total HI	0	0	0	0	-10.9	-10.9



6.4.3. Cable Heat maps

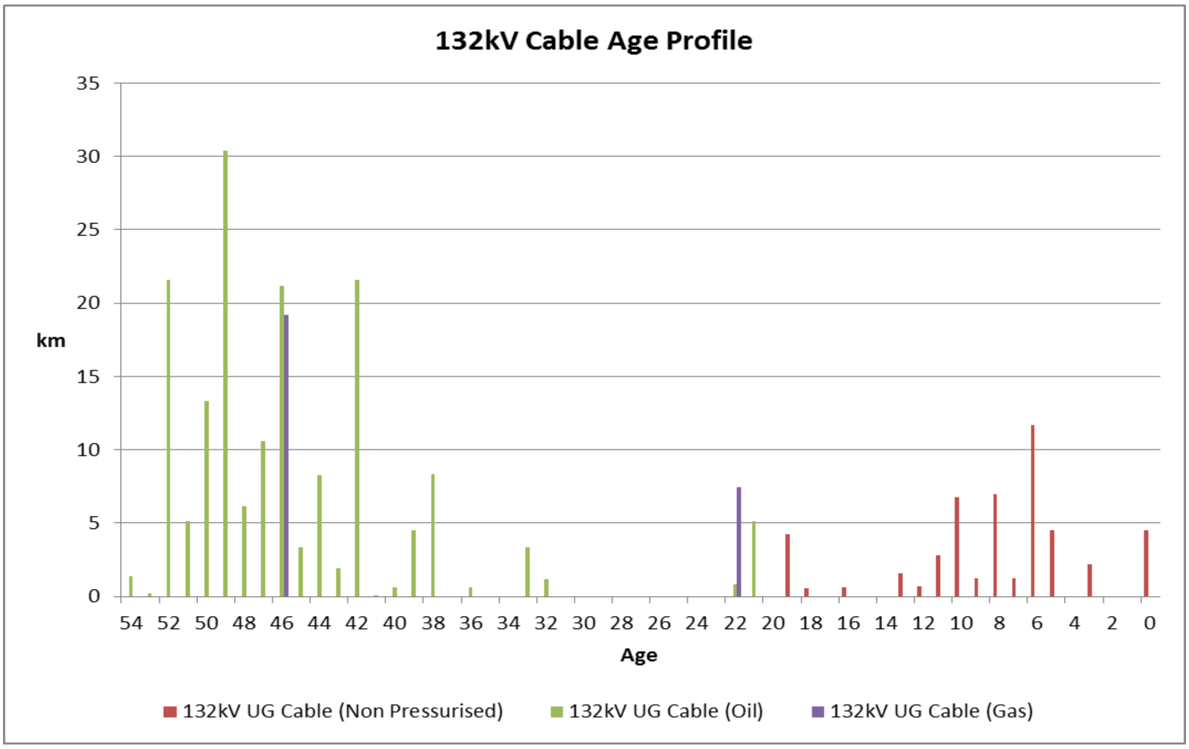
The results from all the 132kV oil filled cable leakage rates is used to compile a cable heat map to inform replacement prioritisation, part of which is shown below.

SPM 132kV Oil Filled Cables

				Litres per Year											Litres			
Circuit Name	Cable Section	Region	Circuit Length	03/04	04/05	05/06	06/07	07/08	08/09	2010	2011	2012	Total	l/year	l/km	l/m/year	Circuit Length (km)	l/km/year
Rainhill - St Helens	St Helens Substation	Merseyside	5050	772	83	398	490	749		3850	1673	809	7081	1416	1.402178218	0.280435644	5.1	280
Capenhurst A - Hooton Park 1	Isolator 203 - Tower CV1	Cheshire	740						985	35			1020	204	1.378378378	0.275675676	0.7	276
Kirby - Gillmoss T1 - Bootle 305	Kirby Substation	Merseyside	10845	87		360	50	1548	10000	307	963	65	12883	2577	1.187920701	0.23758414	10.8	238
Bold - Kirby - Windle	Kirby - C85A	Merseyside	478	50	50	103	243	165	40	154		14	373	74.6	0.780334728	0.156066946	0.5	156
Bold - Rainhill 2	Rainhill - BZ14	Merseyside	571					234		27			261	52.2	0.45709282	0.091418564	0.6	91
Frodsham - Salt Un - Percival Lne - Ince	Tower Q18A - Tower Q17A	Cheshire	117		5	5			30	20			50	10	0.427350427	0.085470085	0.1	85

6.4.4. Cable Asset Age Profile

Currently SPM has an average age of 38.3 years which is above industry average for 132kV cable.



7. Appendix 1

7.1. Gas Compression Cable Systems – Failure Mechanisms

The behaviour and failure mechanisms of gas compression cable systems have been reported in the past[1,2]. However, investigations of gas compression cable faults in the late 1990s and early 2000s have led to a revised understanding of the failure mechanisms experienced by Gas compression cables which are outlined in detail in a report from Cable Engineering Consultants[3] and can be summarised as follows:-

During normal operation of a gas compression cable system, it has become clear that impregnant moves along the cable cores. This fact was not appreciated during the design, installation and operation of these cables, however, it has now been found to play a significant role in end of life behaviour and failure mechanisms.

Over a period of time, the impregnant can fill and distend the corrugated joint sleeves and the cable diaphragm sheaths so that they come into hard contact with the reinforcing components reducing their capability to accommodate any significant further expansion of the impregnant. If the load on the cable is now increased beyond it's 'historic' level, the increased expansion of the impregnant can produce very high hydraulic pressures in those parts of the system where the expansion accommodation is limited by distension of the diaphragm components. The hydraulic pressure within the cable may then burst the reinforcing tapes, and the diaphragm sheaths, expanded oil will exit the cable via the rupture in the diaphragm sheath. On cooling the remaining impregnant contracts and the lost oil is replaced by nitrogen from the pipeline. As the nitrogen used to fill the pipelines is not specially dried, and it is known that some pipelines contain free water dating from the time of installation, the gas entering the dielectric introduces water into the cable core. Free gas is now present in the cable, along with water, causing the losses in the dielectric to be increased locally so the local temperature of the dielectric becomes higher than that along the general length of the cable. If the load on the cable is increased, the heat generation is increased. If this additional heat generation is sufficient, in conjunction with the increased losses in the dielectric, to raise the dielectric temperature to a critical value the cable may be tripped into localised thermal instability leading to electrical failure.

If a load is supplied by two gas compression cables, and one is removed from service then the load on the remaining cable is increased and the increased temperatures and pressures may result in the second cable bursting with the same results as described above. Changes of load and gas pressure are, therefore, to be avoided wherever possible on these cable systems and this leads to reduced operational flexibility for these network-critical assets. In summary, it is now believed the gas compression cable population has reached an end-of-life situation after 40 to 50 years' service due to the combination of three factors, namely, inconsistent cable build during manufacture, latent installation damage and unforeseen behaviour of the impregnant during operation.

1. *ACE Report No.81 (1981): "132kV Gas Compression Cable sealing end failures".*

2. *"Gas Compression Cable Systems – A Review of the current situation and recommendations for future action a 132kV" (1988) – DJ Skipper.*

3. *Cable Engineering Consults – "Gas Compression Cable Systems – A review of current knowledge with regard to their operating principles, service history and failure mechanisms" (2001) - BJ Harrison.*