Strategy for losses

January 2016, version 1.2

Guidance for the reader

The purpose of this document

This document describes the processes, technologies and engineering solutions that we are adopting in the 2015-23 period to ensure electrical losses on our system are as low as reasonably practicable, since losses are a source of inefficiency and waste. We also set out the range of alternative options that we have considered to reduce losses, and our assessment of which options deliver the best value for money for customers.

The document covers both electrical losses and electricity theft.

It includes as appendices:

- A history of the updates and the reasons that drove them, and
- The proposed action plan through which this strategy will be implemented

Future versions will include a commentary on our success in achieving the action plan.

Our target audience for this document

This document can be used to help guide any interested reader or stakeholder through our strategy for ensuring losses are as low as is reasonably practicable.

It represents a summary of internal working documents that are continually reviewed and updated by our staff. In order to provide full information for stakeholders we have inevitably included in the document some concepts and terminology that may not be familiar to the general reader.

We have included at annex GL.1 of our published RIIO-ED1 business plan a glossary that explains the key technical terms and abbreviations used in our business plan. This may also assist in reading this document.

Mapping this document to our published RIIO-ED1 business plan

The relevant sections in the core narrative that relate to this document are:

- Outputs: section 2.7.1
- Innovation strategy: section 5
- Expenditure: section 1.2
- Strategy for technical losses: annex 1.4

Contents

1 Summary

We have been fully engaged in ensuring appropriate development of the regulatory framework to tackle losses. We contributed to the wording of a new licence condition on minimising losses including those due to theft (SLC 49).

Our strategy

Our strategy for the 2015-23 period can be summarised as follows:

- To seek loses reduction through the selection of equipment and installation designs across the full range of our engineering activity. We are not bringing forward work programmes solely to target losses reduction since we do not believe it is justified by the cost/benefit analysis we have undertaken.
- To use the information flows from smart meters as they become available to better understand and measure losses and to target both the use of DSR to reduce peak loads and existing reinforcement programmes thereby reducing losses.
- To review network configuration, both in design and operation, to establish whether the network can be configured to reduce losses and when necessary make these changes.
- To work within our relevant powers with suppliers and police forces in our region to disconnect illegal and/or unsafe connections.

Electrical losses

Electrical (or technical) losses from our network are the natural effect of wires heating up when they conduct electricity. It is not possible to distribute electricity without this effect and it is reasonable to consider losses as the energy required to transport electricity. However, just as road vehicles can be more or less efficient, so electricity networks can use more or less energy in transporting electricity.

Our forecast, shown over page in Table 1, is that losses from our electricity network will reduce in the 2015-23 period by 230GWh (based on the benefits of all investment including customer driven) from an estimated opening level of 2,369GWh (a 9% reduction). The forecast profile of losses across the period initially rises slightly with load growth, before falling from 2018 driven mainly by our strategy for reducing technical losses and our expectation that the roll-out of smart meters will affect system losses by changing consumer behaviour to reduce load on the system at peak times. This projection is subject to significant uncertainty since it is highly sensitive to variables that are outside our control. In particular, we do not know how quickly, if at all, energy suppliers will implement time of use tariffs that send strong signals to customers, how customers will respond to those signals and how reported losses under the industry's billing and settlement arrangements will be impacted by the advent of smart meters.

The expected uptake of low-carbon technology may increase losses from the network in some situations, due to the heavier loading it causes and lower operating voltages that will be required to accommodate it. Throughout 2015-23 we will continue to look for innovative ways of minimising electrical losses, and we will implement them where there is a clear benefit to our customers from doing so.

	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23
	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh
Opening balance	2,368,517	2,374,046	2,374,017	2,368,727	2,353,929	2,330,452	2,290,663	2,227,455
Background changes								
Load growth	11,843	11,870	11,870	11,844	11,770	11,652	11,453	6,785
General historical rate of reduction	-1,184	-1,187	-1,187	-1,184	-1,177	-1,165	-1,145	-679
Smart grids & LCTs	253	-1	207	-3,805	-6,942	-337	-764	507
Smart meters	-	-	-	-	-	-17,333	-34,667	-52,000
Technical losses strategy								
GM Transformer	-3,873	-7,833	-11,840	-15,848	-19,855	-23,863	-27,871	-31,878
PM Transformer	-161	-214	-366	-518	-671	-825	-979	-1,134
HV cables	-178	-372	-557	-743	-929	-1,117	-1,306	-1,496
LV cables	-1,170	-2,292	-3,416	-4,544	-5,673	-6,801	-7,929	-9,057
Closing balance	2,374,046	2,374,017	2,368,727	2,353,929	2,330,452	2,290,663	2,227,455	2,138,503

Table 1- Forecast losses movements

In particular, we will ensure that electrical losses feature in our investment decisions. Losses are built into our procurement and policy decisions alongside safety and reliability considerations, so that we systematically consider the costs and benefits of investing in new low-loss technology when we replace our assets. This assessment means that we install assets (such as low-loss transformers) that are more efficient at conducting electricity, and therefore result in lower losses. However, we will not do this regardless of cost, bearing in mind that our customers want us to keep their costs down. As a result, we are not proposing work programmes in our current business plan solely to target loss reduction (such as the premature replacement of assets).

Electricity Theft

We consider electricity theft to be an important issue, as it is linked to organised crime and the production and distribution of illegal drugs. For example, cannabis is very often farmed in houses filled with lights to stimulate growth of the plants. The drugs gangs often take the dangerous step of bypassing the electricity meter in order to draw power directly from the network without it being measured or paid for.

We take our responsibilities in this regard very seriously and we maintain a 24-hour fast-response service to support the police when they need technical help in their investigations.

We are in the minority of DNOs that provide a revenue protection service to suppliers on an optional and commercial basis. This service provides investigation and analysis of unusual activity on our network. Where we find that electricity theft has taken place, we will work with suppliers and within our relevant powers to disconnect illegal and/or unsafe connections. In order to perform these disconnections, we work closely with the police forces in our region.

We have been a key player in increasing the focus on electricity theft within our industry and will continue our active engagement on this issue. For example, we have representatives on the Home Office's Cannabis Cultivation and Power Companies Working Group, and we worked with industry colleagues to develop the National Electricity Revenue Protection Code of Practice.

Electrical loss reduction as part of our wider carbon footprint reduction

We have been monitoring our carbon footprint since 2007 and have successfully achieved a 5% year-on-year reduction in carbon emissions over the past three years.[1] In 2015-23, we are aiming to reduce our carbon emissions by 10%. Alongside non-electrical measures such as speed limiters on our operational vehicle fleet, electrical loss reduction is part of this. In particular we are assessing energy use in our operational buildings (which is classed as electrical losses) seeking to reduce usage with solutions such as innovative humidistats to reduce the temperature (and hence electricity consumption) at our substations (see section 1.3.2 and annex 1.6 of our published business plan).

Smart Meters

The roll-out of smart meters will provide us with an opportunity to access network data at lower voltage levels of our network than ever before. In the 2015-23 period we will use the new smart meter data to understand how best to measure losses on networks where LCTs are becoming more commonplace. As a result, we will be able to make more targeted investments to reduce electrical losses. And in the future, the more accurate measurement of losses would enable our regulator to re-establish a financial incentive on us to reduce losses further. (For more information, see annex 1.4 of our published business plan).

We will continue to develop our own processes, and help to develop the processes for the industry as a whole, to ensure that we are well positioned to collect data from smart meters as soon as they are installed.

In 2015-23 we intend to use smart meter demand data to more effectively plan and develop our network to meet the future challenges from the connection of LCTs, targeting the use of DSR and investment in reinforcement.

It should be noted that the benefits in this area are dependent on the availability of both data for decision making and, in the DSR area, agreements on how decisions might be implemented. For this reason loss reductions are subject to:

- A swift and successful roll out of smart meters;
- Availability of consumption data are a sufficiently granular level at a reasonable cost - this may depend on suppliers being minded to facilitate this; and
- Methods of passing cost signals or device management signals to customers at a reasonable cost - this will depend on suppliers being minded to facilitate this.

2 Scope

Energy is lost on the distribution network whenever power is transported from the Grid Supply Points or embedded generators to the end customer. The energy lost is driven by the following general mechanisms:

- Inaccuracies in metered and unmetered data;
- Theft from the system;

[1] We publish our carbon footprint reporting in the sustainability section of our website, on http://www.northernpowergrid.com/downloads/usefulinfo/sustainability.cfm . The information is also available on annex 2.11 of our published RIIO-ED1 business plan

- Electrical energy loss from network asset components due to the passage of current through a resistance;
- Electrical energy consumed in the course of network operation and control; and
- For the purposes of this document, electrical losses are characterised by the latter two mechanisms.

This document details our approach to electrical loss reduction and to electricity theft reduction. It considers:

- Electrical energy losses;
- Electrical energy consumed by network operations;
- Electricity theft; and
- The possibilities raised by and expected benefits from smart meters.

It details the approaches we will pursue including existing strategies and initiatives for new techniques. These initiatives will drive changes to our design and to a lesser extent operational policies which will ensure that development and operation of our network and specification of assets minimise technical losses within the context of designing an economic, efficient and co-ordinated network.

The document does not cover inaccuracies in metered and unmetered data, although it may be noted that the smart metering roll out will have an impact upon this.

3 Electrical losses

Electrical losses occur when energy is transferred across electrical networks, the magnitude of which defines the total network efficiency. Losses are well understood process and the economic reduction of losses is embedded within Northern Powergrid historical and existing design codes and procurement policies.

There are two areas of electrical losses:

- Electrical energy losses associated with the passage of current through a resistance, and
- Electrical energy consumed by network operations, for example heating and lighting at a substation.

The picture for losses going forward is mixed. However the future predicted changes in the nature of electrical demand, primarily through Low carbon technologies (LCTs), are likely to lead to increased networks losses but an overall carbon reduction for the economy. Furthermore as the cost of wholesale energy and price of carbon are factored into loss reduction cost benefit analysis, there is a greater incentive to reduce losses than would otherwise be the case.

Around two thirds of total system losses are on the LV and HV network and solutions are introduced on an incremental basis to manage volume and cost in a proactive manner. This paper details our approach to technical loss reduction, through existing strategies and new initiatives. These initiatives will drive changes to our design policies which will ensure that development of our network and selection of plant and cable, minimise technical losses within the context of designing an economic, efficient and co-ordinated network. These changes were put in place by the end of the 2010-15 period wherever possible. We are also looking to implement new technologies such as power factor correction and carbon neutral substations as part of business as usual in future.

We will continue to develop and update the actions proposed in this document to reflect European developments, learning from industry projects and progress on our initiatives, so that our losses strategy remains calculated to ensure losses are as low as reasonably practicable, and based on up-to-date cost-benefit analysis.

3.1 Electrical energy losses

The energy lost in this manner can be normally characterised as either:

- Fixed losses; or
- Variable losses.

Fixed losses are incurred on an electrical system by virtue of it being energised and are independent of the loading conditions.

- Cables incur these losses in the form of dielectric losses which are most significant at 33kV and above, at 11kV these losses are considered negligible.
- Overhead lines incur these losses in the form of corona discharge, both audible and visible, but this is considered negligible in terms of network voltages used by Northern Powergrid.
- Transformers incur these losses in the form of iron losses within the transformer core and are significant at all voltage levels.

Variable losses are incurred due to the load on a system and are proportional to the load squared.

- Cables and overhead lines incur these losses due to the resistance of the conductor cores and the energy is lost as heat. The calculation of the loss is given by the formula $P = I^2R$.
- Transformers also incur losses due to the resistance of the copper HV and LV windings and the energy is again lost as heat.

3.2 Electrical energy consumed by network operations

The auxiliary transformers at our major substations provide power supplies to support the command and control and general substation facilities on site. The demand on site typically comprises of:

- Battery charging;
- Opening and closing of switchgear;
- Transformer cooling fans and pumps;
- Heating & lighting;
- Security lighting, alarm systems, CCTV and power fence;
- Supervisory Control And Data Acquisition (SCADA) telemetry and supervision Remote terminal Unit (RTU) consumption including communications;
- Protection and intertripping pilot schemes; and
- Voltage control relays e.g. AVCs, and tap changer operation.

For example, an EA technology report carried out to study the power consumption at our major substations suggests that the annual consumption of the primary distribution network substations for a single licence area may be in excess of 11 000 MWh for the Yorkshire license area alone. Of the energy consumed, the largest consumption is from space heating of the substation buildings.[2] A more detailed assessment of the unmetered electricity consumption has been undertaken and will be impact over the short term by installation of substation dehumidifiers.

3.3 Calculation of electrical losses

Fixed losses are calculated by using manufacturers or standard loss data on a per asset basis for transformers or on a per km basis for cables and overhead lines. This type of loss can therefore be robustly assessed either on an individual asset or total network basis without the need for onerous detailed calculation.

Variable losses have a complex relationship to customer demand, the customer maximum demand, the customer load profile and the load profile of system load. Since all four of these vary with time of day and time of year, it is only possible to predict how losses will change with any one parameter by considering all four.

At the total network level it is therefore not possible to calculate losses to within an accuracy level that will facilitate the measurement or monitoring of improvement in electrical losses as a result of an efficiency initiative. Accurate measurement of real time electrical losses on the distribution system is not and may not be achievable for many years to come, and will depend on the eventual profile and final extent of the smart meter roll out programme. Current methods of calculating losses are based upon crude models that simply allocate the difference between energy purchased and distributed across the network assets in an educated way. Having long recognised that that movement in this loss figure is very insensitive to investment that Northern Powergrid make but very sensitive to the data accuracy and the behaviour / efficiency of customers; we cannot influence it significantly and demonstrably. We will investigate how the future smart metering infrastructure for domestic customers, covering 50% electrical demand, can be used to improve our understanding of network electrical losses. This will enable us to better target improvements in loss performance.

3.4 Overall distribution of electrical losses

Figure 1 below gives an indication of how the total system losses are distributed across the network assets. These figures are based on the Northern Powergrid Yorkshire license area, but the distribution of losses is similar to that of the Northern license area. It can be that over two thirds of the energy lost on the system is at 11kV and below.

[2] EA Technology - Andrew Bower et al (2013). S5195_2 - "Energy Efficient Substation".

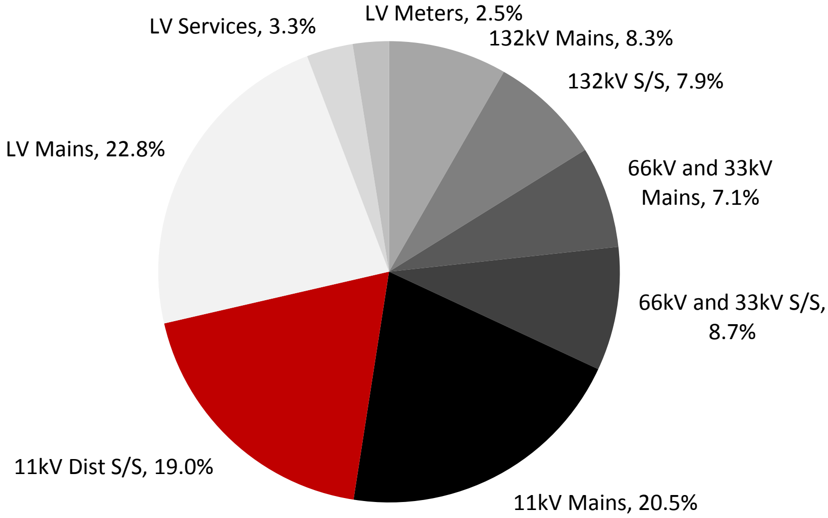

Figure 1: Overall distribution of percentage losses (adding up to 100%)

3.5 Wider environment

Figures on losses over the DNOs' networks in Great Britain are thought to be around 5-6% of total electricity generated[3]. This represents the largest component of the DNOs Carbon footprint, for example this represents 96% of Northern Powergrid's carbon footprint[4] . Broadly this translates to around 2.7 MTonnes of CO2 emitted due to losses on the Northern Powergrid network.

Reducing losses on distribution networks can have a significant effect on overall CO2 emissions for the country. For example electrical losses on distribution networks are estimated to contribute approximately 1.5% of GB's overall greenhouse gas emissions[5] , and although reducing losses to zero is not possible, any significant reduction in losses will make an important impact on the overall emissions of the UK.

3.5.1 EU targets and directives

2020 targets

One of the five 2020 headline targets agreed across the EU relates to Climate Change and Energy. These are split into an overall reduction in greenhouse gas emissions of 20% from 1990 levels; 20% of energy from renewables; and 20% increase in energy efficiency.

These targets have been translated into national targets by the EU which takes into account the different situations and circumstances of each member state. The UK has been set a target of a reduction in greenhouse gas emissions of 16% from 1990 levels and 15% of energy from renewables (no level of energy efficiency has been mandated for the UK at this time).

[3] Ofgem (2010). Factsheet "Electricity Distribution Units and Loss Percentages Summary"

[4] NPg (2012). DPCR5 – Ofgem Reporting "Business Carbon Footprint"

[5] http://www.ofgem.gov.uk/Networks/ElecDist/Policy/losses-incentive-mechanism/Pages/index.aspx

DECC carbon budget

To meet the European targets, the UK has placed a legally binding restriction on the total amount of greenhouse gases the UK can emit over a five year 'carbon budget' period. Under each budget every tonne of greenhouse gas emitted will count towards the overall restriction up to 2050. Total emissions are capped using the EU Emissions Trading System, with any rises in one sector, meaning another sector will have to reduce emissions.

Losses on the electrical distribution system are not directly stated within the budget; however they have an indirect effect on the targets for the UK. This is because as losses are reduced, less input from generators is required, and overall carbon emissions are lowered.

Ecodesign and energy labelling policies

The Ecodesign Directive (2009/125/EC) establishes a framework to set ecological requirements for energy-using and energy-related products sold in all 27 EU Member States.

The requirements to be introduced in three tiers: 2015; 2020 (and 2025 for larger pole mounted transformers) and include:

- minimum energy performance requirements for medium power transformers,
- peak efficiency requirements for large power transformers, and
- product information requirements.

As of early 2013 the Northern Powergrid transformers could be split into four Ecodesign categories as shown in table:

Ecodesign Category	Equivalent Northern Powergrid Category	Method of losses measurement	Expected impact on Northern Powergrid
Medium Pole Mounted Transformers ≥160kVA & ≤315kVA	'Large' Pole Mounted Transformers (200kVA and 315kVA)	Maximum load and no load loss level specified (more lenient and increased timescale due to weight limitation of poles)	Tier 1 are similar in terms of total losses as existing capitalised cost. Tiers 2 & 3 more stringent, however cost increase uncertain.
Medium Power Transformer <4MVA; HV ≤24kV; LV≤1.1kV	Ground Mounted Distribution Transformer (315kVA, 500kVA, 800kVA & 1000kVA)	Maximum load and no load loss level specified.	Tier 1 are similar in terms of total losses as existing capitalised cost. Schneider Electric estimate to increase the efficiency of their standard distribution transformer offering to Tier 2 the price would increase by 85% (see diagram overleaf).
	'Small' Pole Mounted Transformers (25kVA, 50kVA & 100kVA)		Tiers 1 are similar in terms of total losses as existing capitalised cost. Tier 2 more stringent, however cost increase uncertain.

Ecodesign Category	Equivalent Northern Powergrid Category	Method of losses measurement	Expected impact on Northern Powergrid
Medium Power Transformer Rated > 4MVA; 24kV < HV ≤ 36kV; 1.1kV < LV ≤ 24kV	33kV CER Primary Transformer (i.e. 33/11kV)	Maximum load and no load loss level specified.	Tier 1 & 2 perform slightly worse given Northern Powergrid's estimated load loss factors and utilisation rates. Existing stock has better iron losses, but worse copper losses than both Ecodesign tiers. Ecodesign minimum performance appears to be optimised for highly loaded transformers.
Large Power Transformer Rated > 5MVA; HV > 36kV;	66kV CER Primary Transformer (i.e. 66/11kV) & CMR System Transformers	Chosen on calculation of peak efficiency.	Similar methodology to existing practices.

Table 2 : Transformer Ecodesign categories

The directive references the performance categories described in EN50464-1:2007. Figure 2 below shows how existing ground mounted distribution transformers compare against the expected minimum requirements for the Ecodesign directive.

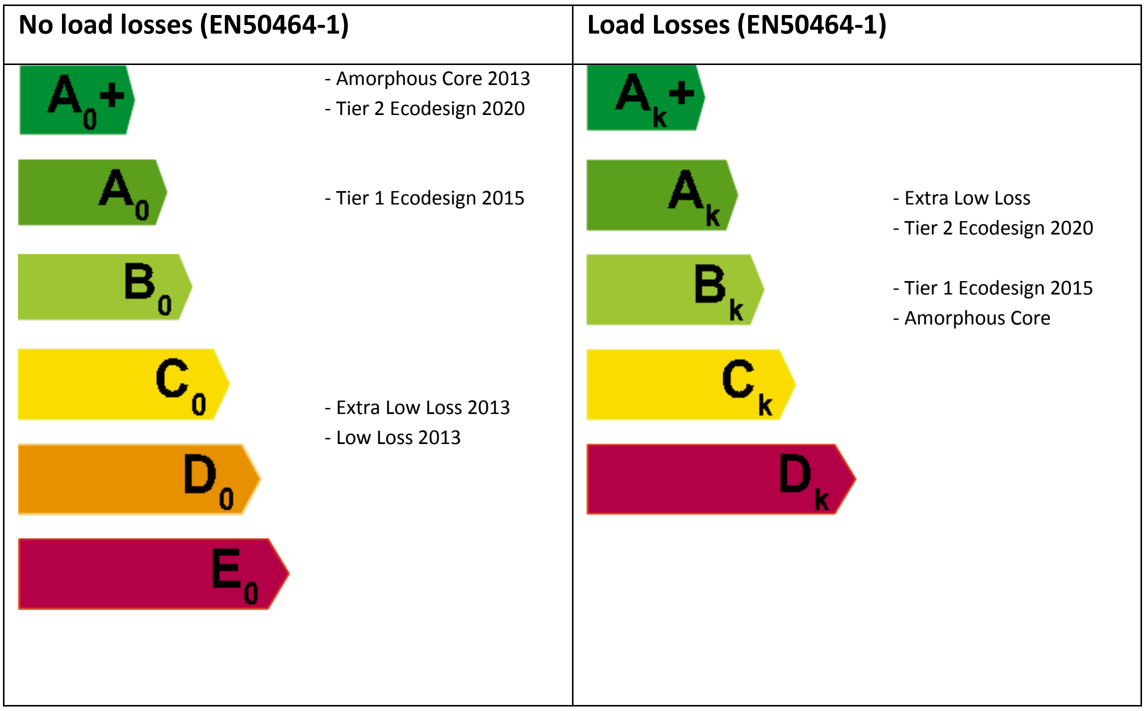

Figure 2: Existing ground mounted distribution transformers

EU network codes

The European Network of Transmission System Operators for Electricity (ENTSO-E) represents 41 transmission system operators (TSOs) from 34 European countries.

ENTSO-E's Network Code on Demand Connection will help to facilitate cross-border network issues and market integration issues across the EU. The code helps to establish a secure interconnected transmission system through close co-operation between generators, transmission network operators and distribution network operators.

Article 16 of the code places a restriction on Reactive Power of not wider than 0.9 power factor of the maximum import (or export) capability for transmission connected distribution networks. The existing reactive power range is not specified by the Grid Code. These limits have been implemented primarily from a stability perspective; however they will inevitably have a positive effect on system losses.

Within this code it places an emphasis on the cost benefit analysis to justify the savings. If this was installed at the GSP with National Grid, the only cost savings would be on National Grid's transmission system but paid for by Northern Powergrid, so this not justifiable. However power factor correction on the lower voltage networks would have benefits for NPg and National Grid.

3.5.2 BHE environmental policy

As part of Berkshire Hathaway Energy (BHE), Northern Powergrid's environmental policy supports and upholds the principles and objectives of BHE's global environmental policy (known as "Environmental RESPECT").

Specifically under 'Efficiency', the RESPECT policy states: -

"We will responsibly use natural resources and pursue increased efficiencies that reduce waste and emissions at their source.

We will develop sustainable operations and implement environmental projects designed to leave a clean, healthy environment for our children and future generations".

As losses are the largest component of Northern Powergrid's carbon footprint, losses are should continue to be actively reduced to lower overall emissions to uphold and support the RESPECT principles.

3.5.3 Historical performance

Due to the inherent difficulties in comparing losses between the different DNO license areas due to differences in geography, methodology and settlements, the graph below should be used for illustrative purposes only. Nevertheless, there is little overall downward trend across all of the DNOs, and the losses picture looks relatively stationary. Northern Powergrid, have similar losses as most of the other DNOs, with an overall losses trend over time similar to the industry average. This graph highlights how inaccuracies in settlement can have a significant effect on measured losses. It is envisaged that in terms of actual losses, there is less variance between the years. Year 2009-10 shows an example of how metered data inaccuracies can skew the measured losses significantly.

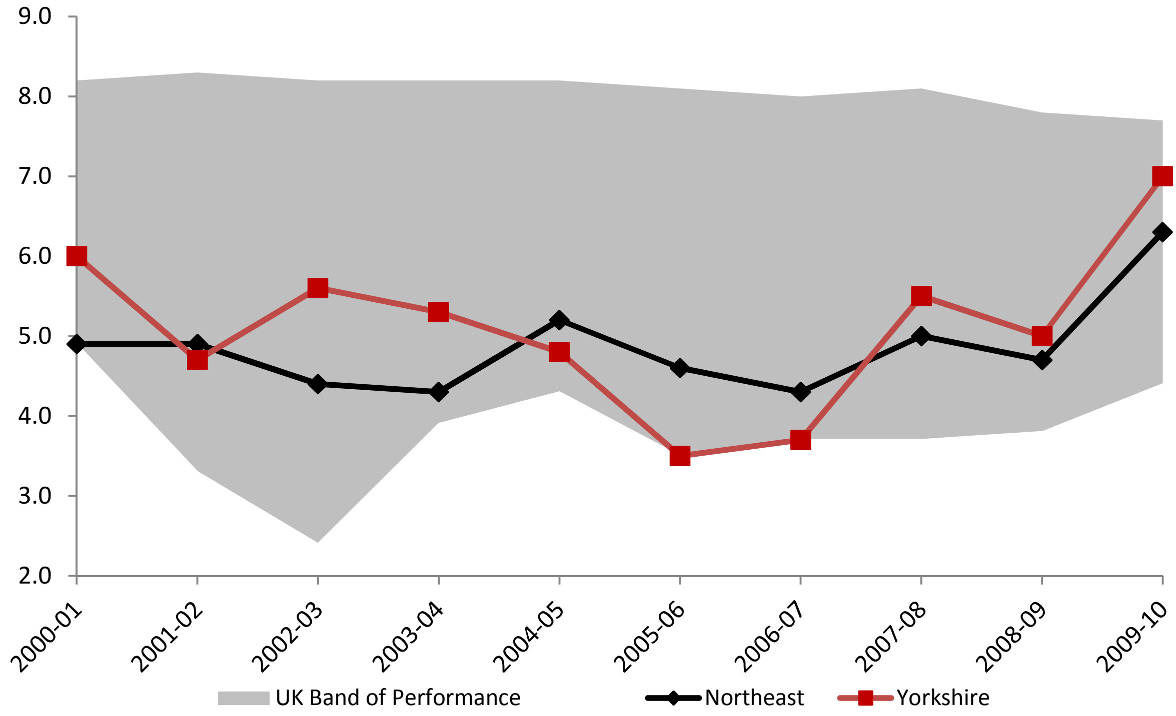

Figure 3: Comparison of DNO percentage losses with Northern Powergrid

3.6 Present policy on managing and reducing losses

This section captures the present policies that underpin our business plan assumptions. The various elements of product specification and product application embedded in our design policies have been justified using cost benefit analysis. More recently these cost benefit analyses have been reviewed and updated using the Ofgem CBA framework for the WJBP.

3.6.1 Product specifications

Transformers

Northern Powergrid typically specifies four main types of transformer for use on the system (technical specification identifier in parenthesis): -

- CMR Transformers (NPS/003/021);
- CER Transformers (NPS/003/012);
- 11kV & 20kV Ground-Mounted Distribution Transformers (NPS/003/011); and
- 11kV & 20kV Pole-Mounted Distribution Transformers (NPS/003/034).

The specifications for all of these transformer types include a requirement that the manufacturer works out the lifetime cost of the transformer using the following formula: -

Lifetime Cost = Purchase price + (No load loss kW x No load £/kW) + (Load loss kW x Load loss £/kW)

The values for the no load £/kW and load loss £/kW are given in the Code of practice for the assessment of asset-specific losses (IMP/001/103). The latest figures (2011) are shown in the table below:

Transformer Type	No Load (Fe loss) £/kW	Load Loss (Cu loss) £/kW
System Transformers (CER & CMR)	£4,730	£130
Distribution Transformers (Ground and pole mounted)	£4,730	£390

Table 3 : No load £/kW and load loss £/kW

As expected the no load losses on a per kW basis are the same for all transformer types as they are the steady state condition of the network (assuming one week per year being de-energised for maintenance). The difference in load loss values are attributed to differing load loss factors and utilisation factors.

Cables

Cables are procured to Northern Powergrid standards which in-turn reference national standards which specify minimum resistivity of conductors, and variance from nominal conductor size. From a loss reduction perspective, the selection of cable size as dictated by the design policy has a greater impact than the equipment standard.

3.6.2 Design policy

In designing and operating an efficient power network, Northern Powergrid has historically embedded a low loss policy within design practices.

Cable selection

The benefits of low loss design have usually been in the form of oversizing conductors (relative to existing utilisation levels), which can have the added benefit of improving network performance (i.e. voltage drop, current carrying capacity and earth loop impedance).

At low voltage (230/400V), the use of 300mm^2 aluminium cables has been adopted as standard cable size for all mains other than spurs carrying less than 120A per phase[6].

At high voltage (between 1kV and 22kV), the use of 185mm^2 aluminium has been adopted as a standard network feeder size, with 300mm^2 aluminium used for the first leg from the primary substation and highly loaded feeders. The use of 95mm^2 is only recommended in special circumstances, as it becomes uneconomical in terms of lifetime losses at greater than 100A peak loading[7].

For HV overhead lines, the use of 100mm^2 and 175mm^2 AAAC is specified for Main Line circuits and 50mm^2 and 100mm^2 AAAC for tail end circuits are specified. The choice of these conductor sizes is dependent on the load of the circuit.

[6] NPg (2012). IMP 001 911 – “Code of Practice for the Economic Development of Low Voltage Networks”

[7] NPg (2009). IMP 001 912 – “Code of Practice for the Economic Development of the HV System”

Transformer sizing

For distribution transformers, the 'economic' sizing for a transformer is generally based upon not exceeding an initial maximum design loading of 95% of the nameplate rating for typical domestic load curves and transformers up to 1000 kVA.

System transformers are sized to match the load, and that selection of cables and overhead lines shall be based on technical and engineering aspects on System Configuration[8].

3.6.3 Network operations

Optimising customer numbers

Open points on the high-voltage network are positioned to optimise customer numbers and load, but also to reduce switching operations under first circuit outages. Moving an open point to optimise customer numbers between two or more feeders usually results in the optimisation of load, however this is not guaranteed.

Substation ambient temperature

In all major substations (primary substation, supply and grid supply points) indoor equipment rooms are temperature controlled. This is usually in the form of resistive electric heaters, controlled via a thermostat to allow switchgear and associated control equipment to function correctly.

There is an existing initiative being delivered to install dehumidifiers at all major substation sites this will have a variable impact due to present practice in the setting of temperature controls.

3.6.4 Promoting the efficient use of electricity

Power factor correction

For customers connected to the LV network, customers are encouraged to aim for a power factor of between 0.95 lagging and unity on their electrical systems[9]. Northern Powergrid's Statement of Use of System Charging, stipulates that half hourly metered customers are charged for excess reactive power consumption (kVArh)[10].

The excessive reactive power charge was introduced for HV and LV half hourly metered customers in the CDCM in April 2010.

Power quality

The nature of loads over recent decades has changed from passive current using devices (i.e. incandescent lamps and directly connected motors), to switched mode power supply connected devices (Compact Fluorescent Lamp (CFL)/Light Emitting Diode (LED) lamps, and Variable Frequency Drive (VFD) motors). These non-linear connected devices can create non-sinusoidal voltage and currents, which increases the iron losses in the upstream transformer core and eddy current losses in the transformer windings and cables.

[8] NPg (2007). IMP 001 913 – "Code of Practice for the Economic Development of the EHV System"

[9] NPg (2012). IMP 001 010 – "Code of Practice for Standard Arrangements for Customer Connections"

[10] NPg (2013). LC14 – "Statement of Use of System Charging" – NPgN & NPgY.

As such Northern Powergrid stipulates that where this is likely to occur, the connection design should take into consideration the requirements of Engineering Recommendations G5/4 as appropriate to mitigate any issues.

3.7 Impact of future networks on losses

The overall impact of future network uses on losses is mixed. There will be increased pressure from the electrification of heat and transport, but this will be partially offset by distributed generation.

3.7.1 Increased parasitic losses

Between 2014 and 2019 smart meters are expected to replace manually read gas and electricity meters in homes and small businesses. These meters are designed to record consumption of energy (electricity and gas) and relay the information to the energy suppliers automatically. Due to the increasing functionality of the new meters, the parasitic losses from these meters are generally greater than existing metering. The energy supplied to these meters is on the Northern Powergrid side of the meter, (as per existing meters) and hence are classed as a system loss.

The table 4 shows an estimate of smart meters parasitic (from maximum permitted losses stated in the Metering Instrument Directive) against existing meters: -

Meter Type	Existing Metering Losses	Smart Meter Losses	Increase in Losses
Gas Meter	0W Electrical (Gas pressure driven)	1W	1W
Single Phase Single Element Electricity Meter	2W	3W	1W
Single Phase Twin Element Electricity Meter	2W	3W	1W
Poly Phase Electricity Meter	5W	7W	2W
In Home Display	0W	0.6W	0.6W
Communications Hub	0W	1W	1W

Table 4 : Estimate of smart meters

As can be seen in table 4 the parasitic losses from a typical household will increase from around 2Watts to over 5Watts (Gas meter, Single phase meter, in home display and communications hub).

The existing electricity meters on our network are estimated to contribute to around 2.5% of the overall losses; therefore smart meters could conceivably increase this proportion significantly. Assuming that smart meters do not adjust customers' behaviour and load remains static, smart metering is estimated to add a steady state load of 8MW to system losses in the Yorkshire region alone.

3.7.2 Embedded generation

Small and medium generation on the LV and HV networks is envisaged to be mainly from Photovoltaic (PV) and Wind Generation. There are varying predictions and scenarios from DECC about the future uptake of these technologies, however we currently forecast that across both license regions, the number of PV and Wind installations is expected to increase by around three times the 2012 penetration levels by 2020.

On a network feeder when embedded generation is exporting energy, the load on a feeder will be reduced. As the net power flow on the respective feeder tends to zero (i.e. local generation matches local load), thus the variable losses on the feeder and on the upstream transformer will be also tend to zero. However, these scenarios are unlikely to often coincide with maximum demand on the system, where variable losses on the system are highest.

3.7.3 Electrification of transport and heat

In a similar vein to increased generation, DECC are also predicting an increase in heat pumps and electric vehicles being connected to the network. Northern Powergrid's interpretation of the DECC scenarios indicate that across both license regions, the expected number of installations will rise from a relatively small base to around 50,000 Heat Pump installations and 40,000 EV charger installations. These loads if not properly managed will significantly increase the load on the network and the associated I2R losses will increase quadratically.

3.7.4 Impact of future time of use tariffs

The variable losses are proportional to the square of the load therefore for given amount of energy transferred over a fixed time period; a flatter load profile has fewer losses than the same energy transferred with a 'peakier' load profile.

There are plans to introduce time of use tariffs, which aim to flatten the load profiles by creating real-time charging mechanisms. This will charge customers more for electricity at peak times, and will encourage customers to use electricity at other off-peak times, which will flatten the load profile. The smart metering roll out is key to the introduction of these tariffs for domestic consumers.

Although the aim of the time of use tariffs is not solely for a reduction in variable losses, (primarily to match generation with demand); it should nevertheless help to reduce overall losses on the network.

3.8 Options for further loss reduction

This section describes a range of potential options for reducing technical losses, split into three sections – expand existing loss reduction techniques; new technologies; and changes to network operations.

3.8.1 Expand existing loss reduction techniques

It is important to note that due to the incremental nature of the asset replacement programmes and network reinforcement, any improvement in losses implemented in this manner will be gradual. It is also worth noting that a reduction in losses at lower voltage levels on the network can also have benefits on losses further upstream at higher voltages.

Increasing cable sizes/plant sizing

Cables and overhead lines

Losses in LV and HV circuits represent around half of all system losses on the network. With no real scope in improving cable performance in the short term, the only way to make any significant progress is to review design policies on cable and overhead line selection.

For low voltage distribution, the policy states using 300mm^2 aluminium for all mains except for small tees. To increase the cross sectional area above 300mm^2 is not straight forward or practical as it would involve manufacturers modifying equipment and limitations on bending radius for installation, for example for LV feeder pillars the maximum size is 4c300mm^2 . An alternative may be to change the conductor material from aluminium to copper, however as copper is currently around three times the price of aluminium (kg to kg) this would be unlikely to be recovered in terms of losses over the lifetime of the cable.

For high voltage design, 185mm^2 aluminium is the prominent cable size used for network feeders, except for 300mm^2 for first leg from primary. Analysis of our network has shown the average feeder load on an underground, distribution 11kV feeder is 136A, has a loss load factor of 20% and is 3.9km long. Cost benefit analysis for this average feeder shows it is beneficial to install 300mm^2 over 185mm^2 in losses savings alone. The increased current carrying capacity by upsizing the cable has not been valued, however is an added benefit.

For HV overhead lines, the designer has the choice between 50mm^2, 100mm^2 and 175mm^2. The construction of 50mm^2 and 100mm^2 lines is similar; however there is a step change in construction cost at 175mm^2 to cope with additional weight of conductor.

The policy limits the use of 50mm^2 to tail end spurs with less than 700kVA of load. A cost benefit analysis suggests the figure of 700kVA remains appropriate in terms of losses savings.

At EHV the cable is selected on a more bespoke basis, where the cost of losses is factored in, for the purposes of this review EHV cable size selection are considered appropriate.

Transformers

Oversizing transformers is not guaranteed to reduce losses, as under low load conditions, the fixed iron losses of a large transformer may be greater than the sum of the iron and copper losses of a smaller one. Nevertheless, this scenario is rare for most network load profiles and it is usually beneficial to oversize transformers relative to load.

Figure 4 below shows some typical distribution transformers procured for Northern Powergrid under various loads. When the transformers are lightly loaded the baseline iron losses are dominant in total losses and the smaller rated transformers fair best in terms of efficiency. As the load picks up the copper loss component quickly becomes more dominant in efficiency and using a higher rated transformer reduces losses.

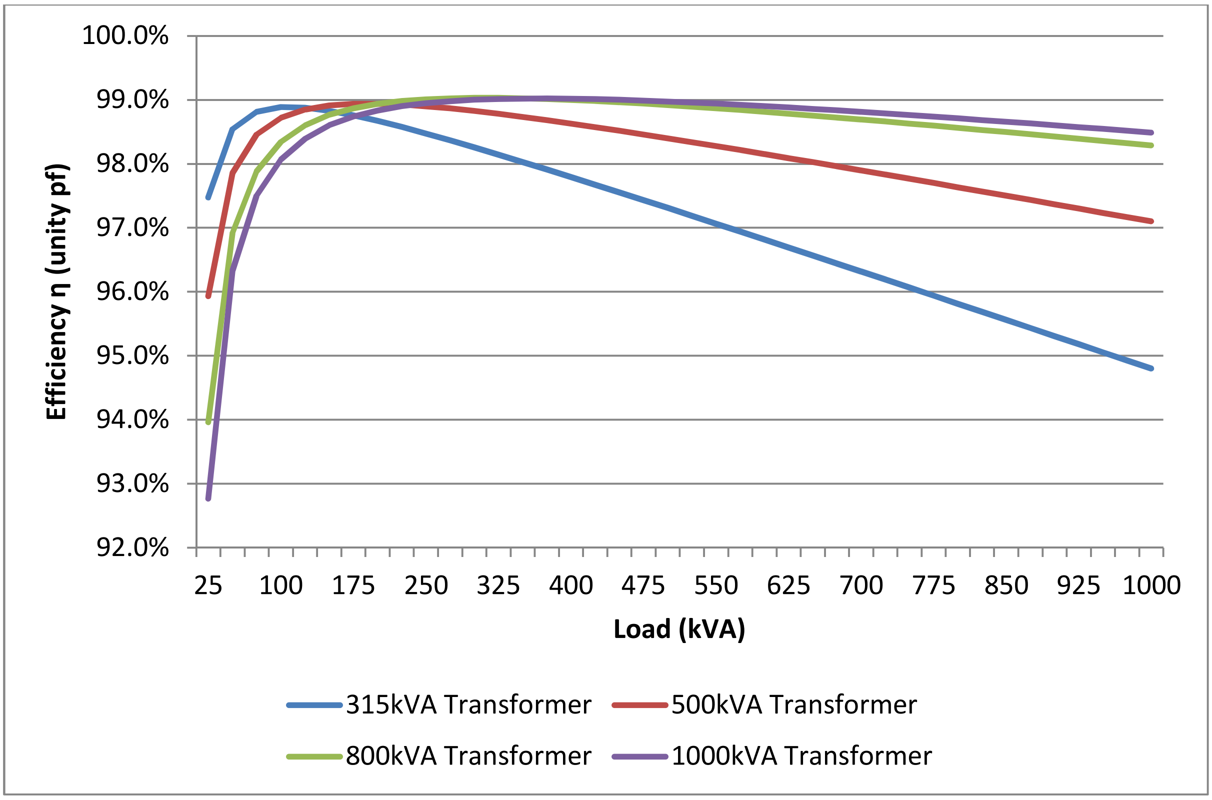

Figure 4: Approximate efficiencies against load for typical Northern Powergrid transformers

Therefore our current policy of oversizing distribution transformers (at a minimum of 105% of the forecast initial maximum demand) is beneficial from the point of view of reducing losses. Since transformers are only purchased in a small number of discrete sizes this policy can lead to oversizing to a maximum of 68% in certain circumstances e.g. installation of an 800kVA unit to supply an initial 475kVA demand. If anything the 5% lower threshold is possibly conservative and a more optimal position might be reached with a lower threshold of 40%. Of course this is not necessarily the *economic optimum* once the higher capital cost of the larger capacity units has been taken into account. We will be carrying out an economic loading assessment of these new Ecodesign directive compliant transformers against design load based on pricing information from manufacturers.

Network configuration

There has been a drive within the business to reduce customer numbers on LV and HV feeders to reduce the respective CIs and CMLs. The knock on effect of this is that the load on these circuits is also reduced, as fewer customers are connected. The existing guidance states there should be no more than 120 customers on an LV feeder and 2,000 on an HV feeder.

Ultimately, reducing load on feeders by splitting customers will reduce variable losses. We will review the customer numbers figures on the each feeder to factor in likely losses, or specifically limit design load on feeder at HV and LV, and the influence of ED1 IIS regime.

Power factor correction

The most efficient power transfer takes place when the power factor of the demand on the network operates at unity.

The general benefits of installing PFC would be: -

- Overall network power consumption reduced (kVA)

- Electrical energy transmission efficiency maximised
- Transformer and distribution equipment losses reduced
  - Circuit fixed losses & transformers iron losses remain same
  - Upstream circuit variable losses reduced
  - Transformer copper losses reduced
- Higher utilisation of existing equipment capacity
  - Potential reduction in reinforcement needed
- Network voltage conditions improved
- Potential future ENTSO-E compliance

Possible draw backs on a case by case basis could be:

- Capacitor banks are resonant with the system at harmonic frequencies;
- Pre-existing harmonic conditions on the network are magnified or exacerbated;
- Transient in-rush currents and voltages occur; and
- Reliability of equipment and consequence of failure on voltage, max demand and harmonics.

Power factor correction could be installed at various points of the system. The most efficient use of power factor correction is at the load. Traditionally for bulk customers this is often at the customer's switchboard and at the consumer level within certain devices (such adding a capacitor in parallel with the magnetic choke in fluorescent light fittings).

The use of PFC in residential installations is unlikely to be technically or financially feasible, except as required within manufacturing standards for consumer products. There could be the option of installing PFC at distribution substations, which would bring HV power factor towards unity. This would add an additional degree of complexity from an operational perspective, may lead to capacitors being underutilised and may prove difficulty to install spatially in existing substations.

As mentioned earlier, adding PFC at Grid Supply Points (on the DNO side), would provide no real benefits for us. The most cost effective location for PFC would likely be at primary substations; this would reduce losses upstream of the primary (33/66/132kV) and would help any potential future compliance with the ENTSO-E code requirements for the transmission/distribution NGC interface. An approximate cost benefit analysis indicates that a 5MVAr capacitor banks installed at a primary substation, would be cost beneficial if the initial installation cost was the order of £20k per MVAr installed.

Transmission companies such as National Grid make use of Mechanically Switched Capacitors (MSC) or Static VAR compensators (SVCs) to support the voltage under certain network conditions by reducing the flow of VARs on the network or even reversing the flow under certain circumstances. This is done at 400kV, 275kV and 132kV substations and several large wind farms. These devices are also being deployed as part of a few LCN projects to assess their benefits on distribution networks

A novel approach to improving the power factor of the system would be to inform customers who pay significant excess reactive power charges. If this was carried out in areas where network capacity was approaching its limit, this could mitigate reinforcement. This would only apply to half hourly metered customers, but would reduce losses with little direct expenditure from us. Using this 'soft' approach would aid the business's drive towards increased stakeholder engagement and better customer service.

Power quality

Harmonics

Non-linear connected loads such as rectifiers can cause voltage and current distortions to the power system waveform. As well as disturbing adjacent customers supply, this can cause increased losses on the network.

Although the individual devices are usually compliant with existing manufacturing product standards the sum of the individual harmonics may increase losses, which were not there 20 years ago. The management of harmonic emissions from domestic connections (less than 16A per phase) is done at a product level based on EN standards however there is no limit to the emissions from an individual connection whereas for larger connections we managed emissions from the connection in line with G5/4.

For industrial customers, detailed assessments of the connected load are usually carried out to comply with the levels stipulated in G5/4. However for residential loads, this would prove more difficult as the individual customers may be within THD limits, however the sum of the customers may not be. The solution for this could be to install filters (again akin to PFC) at distribution substations or primary substations.

The effect of harmonics on losses it not thought to be as significant as poor power factor, however this is envisaged to increase as more load is fed via switched more power supplies.

Load Imbalance

LV networks are designed such that single phase customers are balanced across the three phases of an LV main. In an ideal LV network the steady state current flowing along the neutral conductor is zero. When the loads are not balanced it leads to increased losses and voltage drop on the affected phases.

Our design policy specifies that for new developments the single phase loads should be equally distributed across the three phases. However for existing installations the level of imbalance is not measured and only becomes apparent when a fuse operates on an overloaded phase, or when there is voltage measurement on the phase.

The balancing of customer numbers on LV feeders would help to reduce load imbalance, however this assumes that all customers take equal load. A further step would be to measure the three phase currents on each LV feeder to balance load rather than customer numbers. Where the load imbalance is outside of acceptable limits action could be taken to move customers from a loaded phase to a less loaded one.

3.8.2 New technologies

Superconductors

Superconductors are materials that can have zero electrical resistance at certain conditions, namely relatively lower temperatures. The latest generation of superconductors, can exhibit superconductivity at relatively high temperatures, such as (77K or −196°C) and can be cooled more easily with readily available refrigerants such as liquid nitrogen. The advantages of superconductors on electrical networks are:-

- Reduction in resistance with a corresponding reduction in I^2R copper losses.
- A reduction in voltage drop.
- Increased loading capacities per cross sectional area of material relative to conventional conductor material.
- Reduced network voltages required to transmit similar power levels as existing cable systems.

The disadvantages are: -

- Cost
- The increased complexity of installation and additional cooling apparatus
- The cooling apparatus itself consumes energy.

In the past decade there have been several trial cable projects around the world which have used superconductors. These have been at several power ratings from 574MW (Long Island New York) to 40MW (Essen – Germany). However, the capital cost of these projects has been significant, and these projects have been subsidised by research grants from government energy departments.

We do not envisaged superconducting cable being installed on the network in the short to medium term. Any future superconductor projects on the network are likely to be at the EHV network level, where capital is spent on fewer, high capacity, high value assets.

Low Loss Transformers

Transformers procured on the Northern Powergrid network are approximately 98-99% efficient at rating. However, to transport energy from a generator to the end user, this energy on average will pass through five transformers on a network. Hence transformers account for approximately a third of the losses on the network.

The definition of low loss transformer varies between manufacturers, however if we assume that the existing stock of transformers supplied to NPG are of 'standard loss' design, reduced loss designs can be benchmarked against them. The following low loss designs assessed are:

- Low Core Loss Transformers (including Amorphous Core)
- Reduced winding resistance transformers
- Cast resin transformers
- Power electronic transformers

The graph below shows the efficiencies of various types of 1000kVA distribution transformers offered by Schneider Electric.

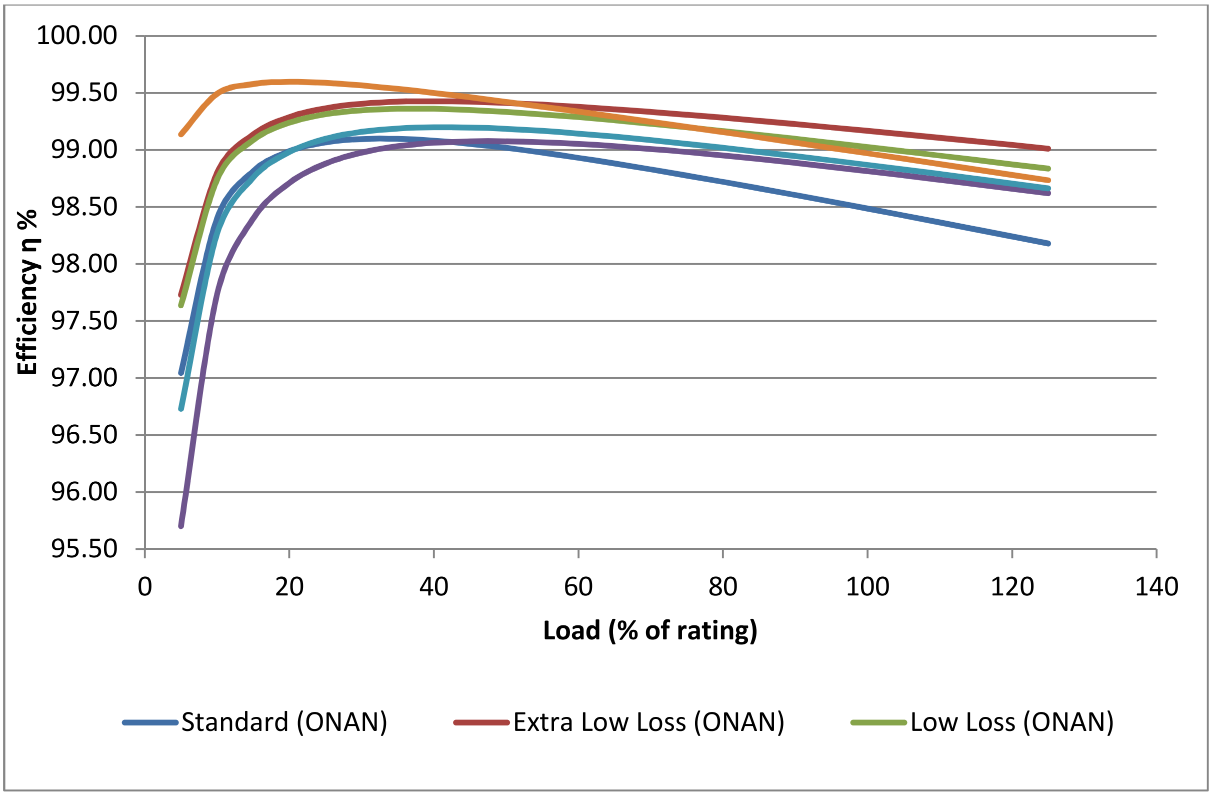

Figure 5: Efficiency graph against load for several 1000kVA Schneider transformers

Low core loss transformers employ core materials such as amorphous steels, laser etched high permeability core steel and microcrystalline steels to reduce the no load iron losses. Amorphous core transformers have the lowest iron loss of any core material in the market place. Historically these transformers have been popular in the USA as the wound core method used in the USA lends itself to one piece cores, rather than the stack produced cores of European manufacturing methods. However due to their impressive iron loss performance, amorphous core transformers are becoming more popular in Europe.

Reduced Winding Resistance

A method of reducing copper losses is to reduce the resistance of the windings. This can be either by reducing the resistivity of the winding material, increasing the cross sectional area or reducing the number of windings[11].

However there is a trade-off when reducing winding resistance, such as increasing core size to accommodate the larger windings which in turn leads to increased iron losses in the core. This then influences the X/R ratio of the unit and can lead to more onerous network fault level requirements.

Cast Resin Transformers

Instead of using oil as a dielectric medium, an epoxy resin is used to encapsulate the windings. The main advantages of cast resin transformer are they are virtually maintenance free, moisture resistant, flame retardant and self-extinguishing. This makes them ideal for integration within buildings, where the risk of fire is a primary concern.

The losses from cast resin transformers follow similar principles to oil filled transformers, namely core and winding losses. However, as cast resin transformers can be placed within buildings they can

[11] Heathcote [1998] – "J&P Transformer Book".

often be located closer to the load centre which reduces losses in LV sub mains cabling. As Midel oil filled transformer have similar fire performance properties and efficiencies to cast resin, the use of cast resin transformer is not thought to be of any cost benefit to Northern Powergrid.

Power Electronic Transformers

The use of power electronic 'transformers' has been increasingly used in consumer electronics for charging mobile devices and in powering computers. There are different technologies available for this, included the basic AC/AC buck, to high frequency modulated devices. The benefits of using solid state devices for distribution transformers are a reduction in weight, better power quality, power factor correction ability, elimination of oil and reduction in losses[12]. Commercially, there are no power electronic utility transformers on the market from manufacturers; however ABB have created a traction power electronic transformer rated at 1.8MW and 25kV. This device operates at several voltage inputs and frequencies to allow international operation of rolling stock. It is not envisaged that a power electronic distribution transformer will enter the market for some time and will be a premium product for specialist application when it does.

Impacts of low loss transformers

Several manufacturers now offer low loss transformers such as ABB, Siemens and Schneider, however there is a significant premium.

There is also concern that due to lower iron losses in the transformer core that ferroresonance can occur more readily[13].

Cast resin transformers have shorter thermal time constraints, which lowers their overload capacity.

Power electronic transformers may have a limited fault current contribution, which may lead to problem achieving disconnection times on the LV network. There is also a concern with regards to the robustness to environment, as the electronics are more sensitive to temperature and humidity than standard transformers.

Low loss and cast resin transformers are often much larger than a similarly rated standard oil filled transformers. Cast resin transformers also require extra ingress protection when place outdoors. The table below shows the extent to which the size increases for 1000kVA ground mounted transformers for different technology types. The Ecodesign Directive has recognised this issue and as such has given pole mounted transformer designs longer to comply with this standard, as there are concerns that the larger pole mounted transformers may be too heavy to be accommodated on a pole.

1000kVA 11/.433kV Transformer (Schneider Electric estimates)						
Type	**Mass (kg)**	**Increase in Mass from Standard %**	**Length (mm)**	**Width (mm)**	**Height (mm)**	**Increase in Volume %**
Standard	3135	-	1680	1170	1710	-
Ecodesign Tier 1 (laser etched high permeability core	4450	42%	1825	1175	1830	16%

[12] E.R. Ronan [2002] - "A Power Electronic-Based Distribution Transformer" IEEE Transactions on Power Delivery

[13] R. A. Walling [2003] - "Ferroresonance in Low-Loss Distribution Transformers" PESGM 2003 - IEEE

steel)						
Ecodesign Tier 2 (laser etched high permeability core steel)	6080	94%	1935	1215	2075	45%
Amorphous	6000	91%	2300	1450	1700	68%

Table 5 : Schneider Electric estimates

Carbon Neutral Substations

Carbon neutral substations have been investigated by EA Technology for Northern Powergrid, which looked at several case studies of the energy lost at major substations. The report makes recommendations to investigate several options for reducing losses, some of which are described below.

Heat recovery from transformers at major substations to heat substation buildings

As has been discussed previously, transformers are between 98-99% efficient. However the 1-2% heat losses are still significant in terms of actual heat output. A typical 15/30 CER transformer loaded to 15MVA, has copper losses of 80kW and iron losses of 8.5kW[14].

Major substations (primary, supply and grid supply), have control rooms and switch rooms which are temperature controlled to avoid condensation within equipment. The heating is usually supplied via resistive heaters mounted on the walls.

A typical primary substation constructed in the 1970's has an annual heating requirement of about 3.2MWh and a peak requirement of about 5.7kW. The electricity supplied to the heaters is supplied by the auxiliary supply and classed as a system loss.

In theory the heat output from one of the primary transformer's iron losses alone, would be enough to heat the substation building and the lowest outdoor ambient temperatures often coincides with high demand on the transformers, where the copper losses are the highest.

Modern distribution substation design takes advantage of this method, where the switchgear and transformer are in close proximity, in one room or enclosure. The heat output from the transformer is sufficient for the switchgear and separate resistive heaters are not required.

The methods for extracting the heat from the transformers would require a separate study but could be in the form of a heat exchanger on the transformer and radiators/fan coil unit within the substation building.

The use of low level waste heat from substations and other areas of high electrical losses such as Data Centres have been used before for district and amenity heating. For example in Switzerland, the low level waste heat (27-40^{o}C) from an IBM data centre has been used to heat a local swimming pool[15]. The details of how revenue could be generated from this waste heat would have to be assessed, or whether it would be 'gift' to the local community and marketed as such.

Although there would be limited scope for us to heat public amenities from substations this proves the concept that low level waste heat can be effectively 'recycled'.

Solar heating at major substations to heat substation

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[14] Brush Transformer Test Certificate

[15] http://www-03.ibm.com/press/us/en/pressrelease/23797.wss

An alternative to the previous example - the use of solar heating technology could also be explored as an alternative to using the waste heat from substations.

Use of local renewable generation to support substation auxiliaries

It is noticeable that other public and private organisations have become more aware and active in recognising applications for these technologies and implementing projects. Examples are: petrol stations, supermarkets, office blocks, road signs and parking meters.

The use of PV and of wind power could be used to offset the energy used by substation auxiliaries. According to DECC, in July 2012, the cost of small scale PV per kW is £2,493, has a return on investment of 6.3%, has a 20-25 year lifetime and requires minimum maintenance.

There are also synergy benefits with substation battery charging and black start capability or other prolonged loss of EHV substation supply.

Design of the energy efficient substation to be carbon neutral

The government has set out within its energy policy plans for all new homes to be carbon neutral by 2020. An initial entry point for us may be to start plans to introduce a mirror of the carbon neutral homes initiative in terms of developing plans and designs for the carbon neutral substation. A method of reducing energy consumption would be to increase the U value of the building fabric for new substation buildings to reduce the heating demand. This could be embedded into the design specification for new substation buildings and retrofitted to existing ones.

By increasing the insulation U value to the substation buildings it is estimated that energy consumption could be reduced by up to 2.5GWh over a licence area or a saving of £325k per year[16].

3.8.3 Changes to network operations

Voltage reduction at night

Historically voltage reduction has had been used to reduce demand, as much of the load has been 'voltage dependent' (tungsten lamps and resistive heating). As the resistance of these devices is fixed, applying a lower voltage reduces the current drawn, less power is transferred and hence overall load is reduced. However, increasingly more load is 'voltage independent', as it is fed via a switched mode power supply, which effectively changes its impedance based on voltage (such as HF fluorescent, LED, PCs VFD fed motors)[17]. Therefore lowering voltage may not lead to the demand savings as desired and could actually increase I^2R losses.

The risk of mal-operation or network voltage conditions being inadvertently placed outside of statutory limits would also have to be factored in.

Switching out under-utilised plant

At times of low load at twin transformer major substations, the combined iron and copper losses of the two transformers can be higher than the equivalent iron losses and copper losses of one transformer. At these times losses could be saved by switching out one of the transformers and re-energising it when the load increased. The implementation of NMS APRS v5 will enable the switching out of under-utilised plant to be achieved more easily.

[16] EA Technology - Andrew Bower et al (2013). S5195_2 - "Energy Efficient Substation".

[17] Carbon Trust [2011] – "Voltage Management" Technology Guide (CTG045)

The disadvantages of this would be security of supply, as if there was a fault on the single transformer, the de-energised transformer would have to be re-energised and loaded up. This would not be instantaneous, and may prematurely age the transformer as the rate of change of temperature would be more rapid than usual. Other problems may be circuit breaker wear, as they would be operated more regularly than under normal conditions.

3.8.4 Smart Meters

The roll-out of smart meters will provide us with an opportunity to access network data at lower voltage levels of our network than ever before. In the 2015-23 period we will use the new smart meter data to understand how best to measure losses on networks where LCTs are becoming more commonplace. As a result, we will be able to make more targeted investments to reduce electrical losses. And in the future, the more accurate measurement of losses would enable our regulator to re-establish a financial incentive on us to reduce losses further. (For more information, see annex 1.4 of our published business plan).

We will continue to develop our own processes, and help to develop the processes for the industry as a whole, to ensure that we are well positioned to collect data from smart meters as soon as they are installed.

In 2015-23 we intend to use smart meter demand data to more effectively plan and develop our network to meet the future challenges from the connection of LCTs, targeting the use of DSR and investment in reinforcement.

Our analysis of the likely benefits from smart meters is closely aligned to the ENA view, which differs considerably from the earlier DECC work.

We believe that the total network-related benefit that could be generated using the current smart meter functionality is around £129m present value, and is broken down as follows.

- £21m in avoided costs or cost reductions in operations and investment (the bulk from more active network management)
- £5m benefit for customers (but not to our business in avoided costs or increased revenues) as power cut durations are reduced
- £54m in avoided system losses from the use of demand-side response (which in the absence of a losses incentive scheme will benefit customers but not reduce our costs)
- £49m in avoided future costs from greater use of demand-side response

The smart meter data will be used to measure and reduce losses.

We are committed to using demand-side response in 2015-23, and our modelling, drawing on the ENA's commissioned work on network benefits of smart meters, leads to our conclusion of a reduction in system losses (compared with the position with no DSR) of £54m and a reduction in future costs of £49m.

The roll-out of smart meters creates an opportunity for us to access half-hourly performance data on our network. This data will be invaluable in helping us to understand the complex interactions (at lower voltages particularly) between network losses and increasing densities of low-carbon technologies. As mentioned in section 2.7.1 of our published RIIO-ED1 business plan, increasing our understanding in the 2015-23 period is essential in order to support the potential future reintroduction of a financial incentive for us to reduce network losses.

Our planned smart-grid investment includes low-voltage monitoring at substations as standard for the 2015-23 period (see annex 1.9 smart-grid development plan). When combined with the smart meter data, this new monitoring data will help us accurately target losses measurement at specific and critical points on our network. The understanding we gain in the 2015-23 period will help us manage the additional complexity introduced by low-carbon technologies and help develop a range of tools to manage losses effectively in future periods.

Customer benefits flow once the smart meter data becomes available.

In order to realise these potential benefits, data flows from the DCC, and in some cases suppliers, will be needed. Where contracts are required with suppliers, we will face costs of accessing data in addition to the DCC charge. The variable costs of the DCC are not yet finalised, and the costs of accessing data from suppliers are as yet unknown. We have assessed our own costs associated with delivering these benefits in total as an average of £1.6m a year. Once we receive more information on the size of these external costs and can carry out an accurate cost/benefit analysis, we will decide which activities we will go ahead with: we will make changes to the way we operate whenever the benefits outweigh the costs. In the meantime, we have included neither benefits nor the associated costs in our plan financial figures.

For this reason benefits are subject to:

- A swift and successful roll out of smart meters
- Availability of consumption data are a sufficiently granular level at a reasonable cost - this may depend on suppliers being minded to facilitate this.
- Methods of passing cost signals or device management signals to customers at a reasonable cost - this will depend on suppliers being minded to facilitate this.

3.8.5 Cost benefit analysis of practicable investment options

As part of our business plan submissions for the RIIO-ED1 review we tested the economic practicability of the options for losses investment that were technically practicable. This was done using Ofgem's prescribed cost benefit analysis (CBA) template which puts a social value on the reduction of losses.

The results of such cost/benefit analyses will vary as the input parameters change; the scope of investment to which they apply will also change. The analyses were done with regard to the typical load parameters on Northern Powergrid's licensed networks now and may not be applicable to other networks or to loading patterns which may come to exist in the future. This is worth noting as higher loads associated with electrification of heat and transport may drive higher losses and high levels of loss management investment.

Given that some of the recommended actions in this document are to investigate promising areas of loss management, we would expect that this will develop some new technically practicable investment areas over time thereby expanding the scope of investment to be considered. It should also be noted that our investment choices will also be influenced by external forces such as European directives.

We have reviewed the CBAs and are content that they remain valid at this time. We would expect that they will change during 2016 as certain plant and equipment contracts are renegotiated and investment costs change as a result.

It should be noted that the CBA's were undertaken on a sample of work in line with our asset replacement proposals. The outputs in the tables are still in line with this as the purpose of the tables is to convey the most appropriate action. The volumes and benefits however are based on the full investment work we expect to undertake including asset replacement, reinforcement and customer driven work. There is clearly a degree of uncertainty in this forecast, particularly in the customer driven work, but it represents the best view available.

Pole Mounted Distribution Transformers:

Options considered		Decision	Northern Powergrid Combined NPV			
			16 years £m	24 years £m	32 years £m	45 years £m
Baseline	Cheapest acceptably rated asset	Rejected	-	-	-	-
1	Capitalised Cost Transformer (current policy)	Adopted	0.04	0.07	0.09	0.11
2	EcoDesign 2015 Minimum Transformer	Rejected	-0.10	-0.13	-0.15	-0.16
3	EcoDesign 2020 Minimum Transformer	Rejected	-0.20	-0.21	-0.21	-0.22

We considered the minimum functionally acceptable transformer against the two stages of Ecodesign transformer and our current capitalised cost transformer specification (where the cost of losses over the transformer's life is added to the capital cost of the transformer when the contract evaluation is done).

The current specification provides the greatest benefit in Ofgem's CBA model and it also meets the present EcoDesign requirements.

Our plan is to install 3,517 units over the2015-23 period, a benefit of 4.9GWh over 2015-23.

Ground Mounted Distribution Transformers:

Options considered		Decision	Northern Powergrid Combined NPV			
			16 years £m	24 years £m	32 years £m	45 years £m
Baseline	Cheapest acceptably rated asset	Rejected	-	-	-	-
1	Capitalised Cost Transformer (current policy)	Adopted	6.40	10.16	12.83	15.57
2	EcoDesign 2015 Minimum Transformer	Rejected	5.70	9.67	12.50	15.40
3	EcoDesign 2020 Minimum Transformer	Rejected	4.77	9.12	12.24	15.43

We considered the minimum functionally acceptable transformer against the two stages of Ecodesign transformer and our current capitalised cost transformer specification (where the cost of losses over the transformer's life is added to the capital cost of the transformer at the tender evaluation stage).

The current specification provides the greatest benefit in Ofgem's CBA model and it also meets the present EcoDesign requirements.

Our plan is to install 3,317 units over the2015-23 period, a benefit of 142.9GWh over 2015-23.

Power factor correction:

Options considered		Decision	Northern Powergrid Combined NPV			
			16 years £m	24 years £m	32 years £m	45 years £m
Baseline	No mainstream investment at present (current policy)	Adopted	-	-	-	-
1	PFC installed at three PSS	Rejected	-0.08	-0.06	-0.04	-0.02

We considered the potential for installing power factor correction at specific substations to reduce losses.

At present Ofgem's model shows that this is marginally of less benefit than taking no action. However we expect that power factor correction may become cheaper to install in future as equipment process fall and we are intending to trial some such equipment around the mid part of this regulatory period. The trial is in the scoping stage.

300mm² waveform LV cable in preference to 185mm² waveform on cable overlays:

Options considered		Decision	Northern Powergrid Combined NPV			
			16 years £m	24 years £m	32 years £m	45 years £m
Baseline	Overlay 185mm^2 with 185mm^2	Rejected	-	-	-	-
1	Overlaying LV cable with 300mm^2 Wf (current policy)	Adopted	0.35	0.84	1.20	1.56

When we install new LV mains cables the Ofgem CBA shows a clear benefit in utilising 300mm^2 even though 185mm^2 would carry the load current. We are pursuing this option in our investment plans and will install 2,569 km over the2015-23 period, a benefit of 40.9GWh over 2015-23.

300mm² Triplex HV cable in preference to 185mm² for second leg and beyond out of primary (already 300mm² on first leg):

Options considered		Decision	Northern Powergrid Combined NPV			
			16 years £m	24 years £m	32 years £m	45 years £m
Baseline	185mm^2 on second leg and beyond	Adopted	-	-	-	-
1	300mm^2 for all 11kV network feeders	Rejected	-0.31	-0.11	0.05	0.24

When we install new 11kV cables the Ofgem CBA shows a clear benefit in utilising 300mm^2 even though 185mm^2 would carry the load current. We are pursuing this option in our investment plans and will install 2,669 km over the2015-23 period, a benefit of 6.7GWh over 2015-23.

We have yet to do the same analysis for 20kV cables, but we will be doing this during 2016.

33/11kV Transformer:

Options considered		Decision	Northern Powergrid Combined NPV			
			16 years £m	24 years £m	32 years £m	45 years £m
Baseline	Cheapest acceptably rated asset	Rejected	-	-	-	-
1	Capitalised Losses Transformer (current policy – identical unit to baseline in this instance)	Adopted	0.00	0.00	0.00	0.00

We considered the minimum functionally acceptable transformer our current capitalised cost transformer specification (where the cost of losses over the transformer's life is added to the capital cost of the transformer when the contract evaluation is done).

The current specification provides the greatest benefit in Ofgem's CBA model and it meets the present EcoDesign requirements. We are pursuing this option in our investment plans and will install 51 units over the2015-23 period. We are not claiming any benefit in this area as it is in line with our practice for many decades.

66/11kV Transformer

Options considered		Decision	Northern Powergrid Combined NPV			
			16 years £m	24 years £m	32 years £m	45 years £m
Baseline	Cheapest acceptably rated asset	Rejected	-	-	-	-
1	Capitalised Losses Transformer (current policy)	Adopted	-0.03	-0.01	0.00	0.02

We considered the minimum functionally acceptable transformer our current capitalised cost transformer specification (where the cost of losses over the transformer's life is added to the capital cost of the transformer when the contract evaluation is done).

The current specification provides the greatest benefit in Ofgem's CBA model and it meets the present EcoDesign requirements. We are pursuing this option in our investment plans and will install 23 units over the2015-23 period. We are not claiming any benefit in this area as it is in line with our practice for many decades.

Use 100mm^2 Al 11kV conductor on spurs in preference to 50mm^2

Options considered		Decision	Northern Powergrid Combined NPV			
			16 years £m	24 years £m	32 years £m	45 years £m
Baseline	50mm^2 Al 11kV OHL (current policy)	Adopted	-	-	-	-
1	Using 100mm^2 11kV OHL for spurs	Rejected	-0.32	-0.36	-0.37	-0.39

We considered using $100mm^2$ conductor on 11kV spurs in preference to $50mm^2$. However due to the typical loading on such circuits the losses savings do not presently justify the increased investment costs.

This is a particular area which may change in future though. Electrification of transport and heat may lead to significantly higher loads on circuits of this type, particularly in semi-rural areas such as commuter villages. Such changes in load may make $100mm^2$ conductors viable and we will review the CBA as electric transport and heat penetration rises.

4 Non-Technical Losses and Electricity Theft

We consider non-technical losses and electricity theft to be an important issue; it is often linked to organised crime and the production and distribution of illegal drugs. We have been a key player in increasing the focus on electricity theft within our industry and will continue our active engagement on this issue.

Such losses are hard to quantify by their very nature, but we are taking action in the following key areas where they occur.

Unregistered connections (untraded MPANs)

We take a range of actions to meet our obligations under standard licence condition (SLC) 49 to minimise losses through relevant theft, including for unregistered customers and theft of electricity from our distribution assets (theft in conveyance).

Unregistered customers, otherwise referred to as ‘untraded’ MPANs, are situations where customers use electricity without being registered by a supplier and therefore do not receive electricity bills.

We proactively seek to resolve unregistered customers with suppliers and their agents i.e. to get them registered so that the units used are traded and properly accounted for in industry arrangements (so that they no longer contribute to losses).

We arrange visits customers premises in support our activities, including to identify whether properties are occupied or empty and to obtain customer details where premises are occupied. Customer details are invaluable in resolving such cases to support effective communication with the customer and their chosen supplier.

Theft in conveyance

Theft in conveyance cases are where electricity is taken from our assets, for example, from service connections to properties (cases where a supplier and its metering is not involved).

To allow us greater focus and control in this area we are bringing this activity in house during 2016, ending our previous us of contract resource.

Field visits to unregistered customers and high risk premises

In addition to field visits for unregistered customers we also undertake visits to other premises where there is a higher risk of improper electricity usage.

Our visits to de-energised and therefore supposedly unoccupied premises are based on an MPAN selection process that targets premise that have been de-energised by suppliers and reflected as such in trading systems. It is possible that such premises are in fact energised and occupied.

We also use the visits as an opportunity to identify any asset issues including any tampering or illegal abstraction.

Unmetered Supplies (UMS) Connections - ensuring accurate inventories

We undertake regular reviews with Local Authorities and developers to ensure all UMS equipment is formally documented to meet BSC requirements.

We have produced a downloadable website document that details the UMS requirements whilst also offering advice on energy saving initiatives in this area.

We routinely undertake UMS process audits with local authorities with the aim of ensuring their business processes and IT equipment are robust and that enough rigour is being applied to ensure that accurate energy use is captured in their submissions.

Theft and meter tampering (managed by energy suppliers)

We have worked with industry colleagues to develop the National Electricity Revenue Protection Code of Practice.

We attend the United Kingdom Revenue Protection Agency (UKRPA) meetings and liaise with its members to ensure that we are aware of current issues around detecting and dealing with meter tampering; illegal abstraction; and the prevention of theft. UKRPA also run an energy fraud reporting service whereby anyone can report a suspected theft.

We run a quarterly Meter Operator (MOP) Safety Forum to bring all MOPs who operate across our Licence areas together to discuss revenue protection and safety issues. The aim is to establish 'best working practices' and reduce the number cases that adversely affect Northern Powergrid, customers and the other industry participants.

We continue to provide support and assistance to the nationwide Crimestoppers commercial cannabis cultivation campaign through awareness briefings for front-line staff and support to Police following intelligence leads.

We are working with local Police to help identify potential cannabis farms in our regions and we have representatives on the Home Office's Cannabis Cultivation and Power Companies Working Group.

5 Recommendations

This loss reduction strategy has highlighted a multi-layered approach to reducing losses. Several of the existing loss reduction techniques are straight forward to implement and are incorporated into everyday asset replacement and reinforcement schemes. We have identified additional elements of our design policy that will be reviewed in light of new information and our intention is to complete these investigations in line with the dates shown in Appendix 2.

Other proposed techniques are on a project specific level, where detailed measurements of the problem (such as power factor) and site surveys will have to be carried out before implementation. Due to the need to investigate potential operational problems it is proposed that these solutions are trialled on our network or alternatively we understand the learning from trials in other DNOs if appropriate.

Clearly the EU Ecodesign Directive will have the greatest impact and we will continue work to understand the wider implications of this legislation. We will continue to work with manufacturers to ensure better cost certainty and technical differences to existing stock are understood prior to mass adoption. At present we are assuming that cost efficiencies driven by the legal requirements will make compliant distribution units more economic than distribution units of a higher specification. For power transformers we are assuming we will continue to purchase to existing specifications which appear at present to be in-excess of the Ecodesign requirements on the basis that we not make a retrograde step in performance.

We will, through the existing innovation knowledge sharing process, continue to disseminate the findings of any work we do associated with network losses and identify best practice learning from other DNOs.

A summary of the different strategies and actions is shown in the following table. A more detailed view can be found in Appendix 2.

	Ease of deployment	**Actions**
Existing loss reduction techniques		
Increasing cable sizing	Straight forward	Implement the policy of installing a minimum cable size of 300mm^2 at 11kV where practical (e.g. if bending radii and termination arrangements allow). Carry out cost benefit analysis for 20kV feeders. Continue to install a minimum of 300mm^2 mains LV cables that are of a larger capacity than the minimum size option having taken into account capitalised electrical losses in the assessment of lifetime cost within our designs.
Transformer loss specification	Straight forward	We will continue with our current policy to purchase transformers that have lower electrical losses than the minimum cost units available based on having taken into account capitalised electrical losses in the assessment of lifetime cost rather than

		simply purchase price. Market test the likely costs and availability of lower loss units that may become viable using Ofgem's prescribed cost benefit analysis and fixed data.
Increasing transformer sizing	Straight forward	We will continue with our current distribution transformer oversizing policy. We will review this in light of the Ecodesign Directive and carry out cost benefit analysis of economic sizing of low loss transformers and update our design policy as necessary.
Network configuration	Straight forward	Review design policy on the optimal loading of circuits by assessing the impact on losses, customer numbers and taking into account operational constraints. Implement changes to the policy where necessary and mobilise a project to effect operational network configuration changes to the existing network where justified.
Power factor correction	Moderate	Commission trial installation of power factor correction equipment at distribution S/S and primary S/S. Capture learning from other innovation projects to combine with our own experience with a view to establishing a firm design policy.
Power quality	Moderate	Commission trial installation of harmonic filters at distribution substations and primary substations as part of innovation projects with a view to gaining experience and establishing a firm design policy.
Load imbalance	Moderate	Commission trial installation of equipment to improve phase imbalance as part of innovation projects with a view to gaining experience and establishing a firm design policy. Mobilise project to understand how smart metering data can be used effectively to understand phase loadings. Establish an enduring process that identifies the worse imbalances and take corrective action.
Loss measurement	Difficult	Evaluate methods for assessing network losses using domestic smart metering data and contribute to developing an output based losses incentive for RIIO-ED2.

Theft Reduction	Straight forward	Continue to offer a full revenue protection service for those electricity suppliers that wish to take it up
New techniques		
Superconductors	Difficult	Monitor the development of low temperature superconductors and research projects in the next regulatory period. Pursue the most promising developments via innovation projects to understand their potential exploitation.
Low Loss transformers	Moderate	Implement findings from the EcoDesign Directive. Assess whether it is economic to purchase units with a specification in excess of the Ecodesign Directive requirements. Assess the implications on our network fault levels and ferroresonance of using low loss transformers that have a different X/R ratio than our current units. Establish guidelines for their application and incorporate these into our design policies.
Design of the energy efficient substation to be carbon neutral	Moderate	We led an innovation project in 2011/12 to gain an understanding of the electrical and thermal energy demands of EHV substations in relation to their local climate. Learning from this project will be used to develop Ecodesign solutions that reduce the net energy requirement of both existing and new substations. An immediate example of this is to review the substation building fabric specifications such that the use of higher thermal insulation levels may be incorporated into the design policy where economically beneficial.
Changes to network operations		
Voltage reduction at night	Moderate	No action as unlikely to reduce losses but watching brief on ENW project.
Switching out under-utilised plant	Moderate	Investigate the effects of frequent switching of plant and how network performance will be affected once our new Network Management System is implemented and incorporate findings into our operational policies.

Table 6 : Strategies and Actions

6 Update process

This losses strategy will be updated as necessary driven by changes to the inputs to our strategy. However events that would be expected to trigger changes going forwards would include the following scenarios

- The strategy will be reviewed following the annual revision of our investment plans. Any change to the investment plan may require a revision to Appendices 2-Actions to implement the losses strategy and 3-Report on previous year's actions and also our overall view of losses movements.
- The strategy will be revised following major changes to the contracts through which investment with losses impacts are delivered. Input price changes will affect the degree to which we should be pursuing losses management investment.
- The strategy will be reviewed should the penetration of electric transportation and heat change significantly.

As a result of these scenarios, a review of the losses strategy would be expected annually as a minimum, and possibly more frequently at times.

The review would take the form of an internal expert review and engagement with stakeholders to confirm direction and actions remain appropriate.

Revision of the strategy would be undertaken following this review incorporating changes as appropriate, but in the event of no changes being required then as a minimum a statement that the previous strategy remains valid should be expected.

Appendix 1 - Change Log

Version	Changed section	Detail
Version 1.0		
July 2013		Business plan submission
Version 1.1		
July 2015	Guidance for the reader	Updated to reflect the change from WJBP document to standalone losses strategy
July 2015	Summary	Completely re-written to reflect inclusion of theft and greater emphasis on smart metering and the status as a standalone document
July 2015	Scope	Completely re-written to reflect inclusion of theft and greater emphasis on smart metering and the status as a standalone document
July 2015	Electrical losses	Minor update to improve clarity
July 2015	Calculation of electrical losses	Minor update to reflect changes to the smart meter roll out
July 2015	Ecodesign and energy labelling policies	Updated to reflect the progress in the Ecodesign directive
July 2015	Network operations	Minor change to improve clarity
July 2015	Impact of future time of use tariffs	Minor update to reflect changes to the smart meter roll out
July 2015	Transformers	Updated to reflect the progress in the Ecodesign directive
July 2015	Smart meters	New section added in line with feedback from Ofgem · Highlights the opportunities · Lays out the techniques that will be pursued · Level of perceived benefit and alignment with previous perceptions of benefit · Reference to the ED1 Business Plan - Annexes 1.4 and 1.9 in particular · A discussion of the benefits, dis-benefits and prerequisites of smart metering
July 2015	Electricity theft	New section added covering other kinds of losses (not just those that arise because of electrical impedance) · Discussion of the issues around theft and the problems caused by it

		· Description of the actions we are taking along with Crimestoppers and energy suppliers
July 2015	Strategy summary table	Entry on theft added
July 2015	Change Log	New section detailing the versions and (at a summary level) the changes made
Version 1.2		
Jan 2016	Guidance for the reader	Reference to the appendices on changes, plans and progress added
Jan 2016	Summary	Strategy reviewed to add additional methods of utilising smart meter data and network configuration to manage losses Level of losses movements reviewed in light of the full range of investment with will affect losses (reinforcement and customer driven in addition to asset replacement). Table of forecast losses movements added
Jan 2016	Cost benefit analysis of practicable investment options	Anew section added indicating the results of the CBAs undertaken, the implications and the actions and benefits that flow from them.
Jan 2016	Non-Technical Losses and Electricity Theft	A new section replacing the Electricity Theft section from the July 2015 revision. The scope is similar to, but slightly wider than, the previous version and the content has been fully revised in line with the thinking that has been emerging since the start of the 2015-23 period.
Jan 2016	Update process	A new section describing the events that would trigger update of this strategy and the likely frequency thereof has been added
Jan 2016	Appendix 1 - Change log	The change log has been updated
Jan 2016	Appendix 2 - Actions to implement the losses strategy	A new section detailing the action plan that flows from the losses strategy, including asset related investment, policy changes, procedural changes and R&D.
Jan 2016	Appendix 3 - Report on previous year's actions	Blank at this time, this section will in future revisions contain information on our progress with the action plan

Appendix 2 - Actions to implement the losses strategy

The actions to implement the losses strategy fall into two categories: ongoing programmes and one-off improvements.

Ongoing programmes

Action		Units	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23
Increasing cable sizing	Implement the policy of installing a minimum cable size of 300mm^2 at 11kV where practical (e.g. if bending radii and termination arrangements allow).	Metres 11kV cable	324	343	336	339	336	329	331	331
	Continue to install a minimum of 300mm^2 mains LV cables that are of a larger capacity than the minimum size option having taken into account capitalised electrical losses in the assessment of lifetime cost within our designs.	Metres LV cable	332	318	319	320	320	320	320	320
Transformer loss specification	We will continue with our current policy to purchase transformers that have lower electrical losses than the minimum cost units available based on having taken into account capitalised electrical losses in the assessment of lifetime cost rather than simply purchase price.	66kV Ground Mounted Transformers	4	-	1	7	2	1	6	2
		33kV Ground Mounted Transformers	6	2	12	7	9	7	3	5
Increasing transformer sizing	We will continue with our current distribution transformer oversizing policy.	HV Pole Mounted Transformers	499	165	470	473	474	477	478	481
		HV Ground Mounted Transformers	403	412	417	417	417	417	417	417

One-off improvement actions

Action		Ease of deployment	Completion
Increasing cable sizing	Carry out cost benefit analysis for 20kV feeders.	Straight forward	2016

Network configuration	Review design policy on the optimal loading of circuits by assessing the impact on losses, customer numbers and taking into account operational constraints. Implement changes to the policy where necessary and mobilise a project to effect operational network configuration changes to the existing network where justified.	Straight forward	2017
Transformer loss specification	Market test the likely costs and availability of lower loss units that may become viable using Ofgem's prescribed cost benefit analysis and fixed data.	Straight forward	2017
Increasing transformer sizing	We will review this in light of the Ecodesign Directive and carry out cost benefit analysis of economic sizing of low loss transformers and update our design policy as necessary.	Straight forward	2017
Low Loss transformers	Implement findings from the EcoDesign Directive. Assess whether it is economic to purchase units with a specification in excess of the Ecodesign Directive requirements. Assess the implications on our network fault levels and ferroresonance of using low loss transformers that have a different X/R ratio than our current units. Establish guidelines for their application and incorporate these into our design policies.	Moderate	2017
Design of the energy efficient substation to be carbon neutral	We led an innovation project in 2011/12 to gain an understanding of the electrical and thermal energy demands of EHV substations in relation to their local climate. Learning from this project will be used to develop Ecodesign solutions that reduce the net energy requirement of both existing and new substations. An immediate example of this is to review the substation building fabric specifications such that the use of higher thermal insulation levels may be	Moderate	2019

	incorporated into the design policy where economically beneficial.		
Power factor correction	Commission trial installation of power factor correction equipment at distribution S/S and primary S/S. Capture learning from other innovation projects to combine with our own experience with a view to establishing a firm design policy.	Moderate	2020
Power quality	Commission trial installation of harmonic filters at distribution substations and primary substations as part of innovation projects with a view to gaining experience and establishing a firm design policy.	Moderate	2020
Load imbalance	Commission trial installation of equipment to improve phase imbalance as part of innovation projects with a view to gaining experience and establishing a firm design policy. Mobilise project to understand how smart metering data can be used effectively to understand phase loadings. Establish an enduring process that identifies the worse imbalances and take corrective action.	Moderate	2020
Loss measurement	Evaluate methods for assessing network losses using domestic smart metering data and contribute to developing an output based losses incentive for RIIO-ED2.	Difficult – forms part of our enhancing understanding of losses proposals	2021
Superconductors	Monitor the development of low temperature superconductors and research projects in the next regulatory period. Pursue the most promising developments via innovation projects to understand their potential exploitation.	Difficult	2023-31

Voltage reduction at night	No action as unlikely to reduce losses but watching brief on ENWL project.	Moderate	To be programmed if ENWL project is successful
Switching out under-utilised plant	Investigate the effects of frequent switching of plant and how network performance will be affected once our new Network Management System is implemented and incorporate findings into our operational policies.	Moderate	To be programmed once the results of SSEPD project are available

Appendix 3 - Report on previous year's actions

To be completed in future years' updates.