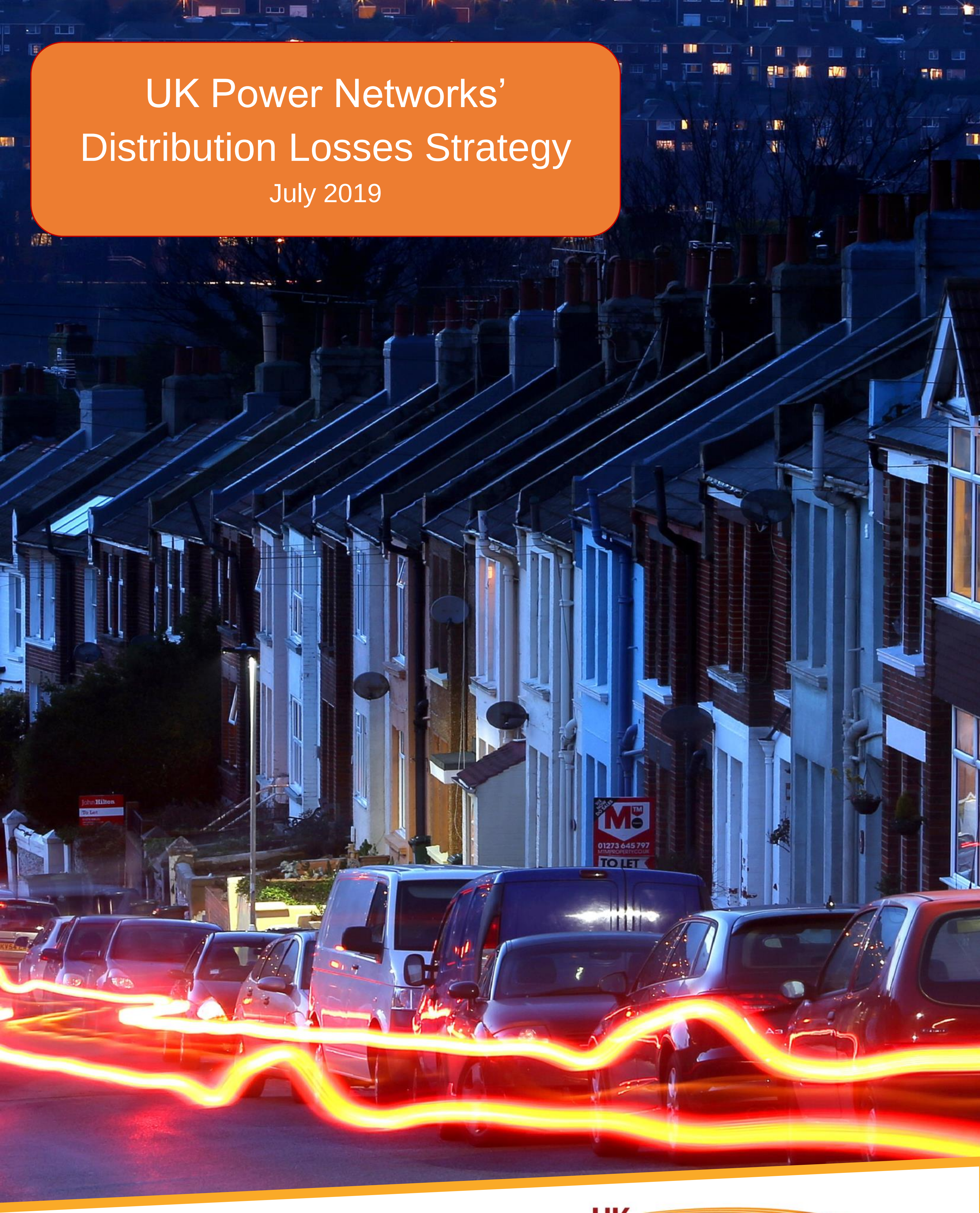
UK Power Networks' Distribution Losses Strategy

July 2019



UK Power Networks
Delivering your electricity

Contents

Executive summary

Electrical losses are an inevitable consequence of transferring electricity across the distribution network. Losses have a significant financial impact on customers as well as an associated environmental cost. As part of UK Power Networks' wider company vision to be a Respected Corporate Citizen, and in line with our statutory and licence obligations, we have prepared this strategy document describing what we are doing to manage losses on our distribution network. We discuss the technical state-of-the-art understanding of network losses and how we have contributed to that learning.

Our Vision is to achieve the greatest magnitude of loss-mitigation gains of any DNO in Great Britain. This is measured through our regulatory and environmental reporting.

Our Losses Strategy has three objectives:

- Maximise the amount of energy we save every year for our customers;
- Integrate losses management further into our existing processes and systems; and,
- Engage with stakeholders to promote loss-inclusive design, collaborate, share knowledge, and integrate this learning into our Losses Strategy.

This updated version of our Losses Strategy incorporates activities we have adopted via the Losses Discretionary Reward (LDR) mechanism. Most significantly, we have embedded processes for managing Contact Voltage Losses (CVL). This is a new category of network losses that UK Power Networks discovered through our work using the Mobile Asset Assessment Vehicle (MAAV).

Using funds from the LDR, we worked with Princeton University to analyse the impact of CVL. We determined that this new category of losses causes 590 GWh of wasted energy per year across Great Britain. Unlike traditional losses, this could in principle be wholly mitigated, as it is not necessary to the operation of the network. The economic cost of CVL is approximately £28 million per year in Great Britain alone. Identifying this opportunity for losses mitigation demonstrates that UK Power Networks are actively engaging in cutting-edge research and applying this learning in the real world, to the benefit of our customers and the wider environment. It also highlights the value of Ofgem's LDR mechanism.

We have worked with Imperial College London (ICL) to develop state-of-the-art modelling of our distribution network, and identified the most significant opportunities for mitigating losses. These are in the process of being transferred into BaU activities. The most impactful of these opportunities is our use of innovative distribution planning software to optimise the location of Normally Open Points (NOPs) on our network. We have also engaged in extensive Cost Benefit Analyses (CBA), and made changes to our design standards so that the long-term impact of network losses are better taken into account in our investment planning decisions.

In parallel with this, we have introduced amorphous streel transformers as our standard option for our 50 kVA pole-mounted distribution transformers. This decision was made on the basis of CBA undertaken as part of our LDR activities. Once again, this demonstrates both the benefit of the LDR process itself and that UK Power Networks are taking the learning from the LDR and putting it into practice. We project that deploying 50kVA single phase amorphous steel transformers will deliver a losses saving of 32 MWh per year for our customers starting in 2018. This is projected to increase as we adopt more transformer sizes, rising to a total losses saving of 500 MWh per year by the end of the RIIO-ED1 period.

In summary, in this revision of our Losses Strategy we have applied the learning and experience we have gained during the price control to date. Our overall philosophy however remains unchanged and we continue to seek cost-effective solutions to manage losses.

Introduction

Losses can never be eliminated completely and management of losses requires long-term investment and focus to make a significant impact. Losses are complex and require extensive analysis in order to implement cost-effective measures.

Our Vision is to achieve the greatest magnitude of loss-mitigation gains of any DNO in Great Britain. This is measured through our regulatory and environmental reporting.

A loss-mitigation gain is a reduction in losses as a result of an action taken by UK Power Networks. They are a saving in energy relative to what would have happened if we had not undertaken that action. These actions benefit our customers in the form of lower electricity bills.

To achieve our Vision we have identified three objectives. These three objectives are as follows:

- Maximise the amount of energy we save per year;
- Integrate losses management further into our existing processes and systems; and,
- Engage with stakeholders to promote loss-inclusive design, collaborate, share knowledge, and integrate this learning into our Losses Strategy.

The benefits of delivering this strategy are wider than the direct financial benefit of the energy saved. When losses are reduced:

- Less generation is required to sustain losses;
- The ability of our network assets to deliver useful energy is maximised; and,
- The cost of connecting to our network is reduced as less reinforcement is required.

This Losses Strategy and the actions embedded within it is reviewed periodically to ensure that it remains current and continues to incorporate new technologies and approaches.

1.1 Why we manage losses

The electricity distribution network, taken as a whole, represents one of the largest consumers of energy in the country.

We have a social responsibility to reduce the financial cost of these losses to our customers and a moral duty to reduce the impact that losses have on the wider environment. We have legal obligations imposed by legislation (such as section 9 of the Electricity Act) and licence conditions set by Ofgem, our regulator. We also need to anticipate the likely impact of the transition to a low carbon economy.

Financial: The financial impact extends beyond the additional generation required to feed losses. Reducing losses to the most economic level maximises the available capacity of plant and equipment to deliver useful energy (i.e. rather than supply losses) so keeping costs to our existing and future customers low. If losses are minimised then lower levels of capital and operational expenditure will be incurred in providing, maintaining and reinforcing generation, transmission and distribution assets. There is also a benefit in terms of avoided material extraction, manufacturing and construction costs through not having to install generation to feed losses.

Environmental: Carbon emissions attributed to losses from distribution networks across the UK represent approximately 2%[1] of the national total. Reducing losses to the most economic level reduces the amount of generation required purely to supply network losses. A disproportionate level of less efficient (and generally higher carbon footprint) generation will be called upon to compensate for variable losses at times of peak demand. Reducing this reliance on fossil-fuelled power stations therefore has a direct carbon benefit. Even though the carbon intensity of electricity is reducing the environmental impacts extend to issues such as visual amenity or preventing land being used for other purposes.

Regulatory: At the start of the RIIO-ED1 regulatory price control Ofgem recognised that a key way to improve the efficiency of network infrastructure is to reduce its losses. This aligns with the Energy Efficiency Directive (EED) which imposes a set of binding measures to help EU nations reach energy efficiency targets[2]. In addition sections of the Electricity Act and our Distribution Licence Conditions require us to develop and maintain an efficient, co-ordinated and economical system ensuring losses are as low as reasonably practicable.

Future: As we move to a low carbon economy, the electricity demand on our network is expected to grow as a result of the ongoing electrification of heat and transport[3]. Therefore, the need for efficiency grows ever more important given the non-linear relationship between load growth and losses (i.e. losses = I^2R: where I represents current and R represents the resistance of the conductor).

[1] In 2017 losses represented 7.5% (26.5 TWh of the total 353 TWh) of total annual consumption according to the Digest of UK Energy Statistics:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/736152/Ch5.pdf.

26.5 TWh equates to 9.32 $MtCO_2e$ of a UK total of 460.2 $MtCO_2e$ or 2%. See https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/695929/2017_Provisional_emissions_statistics_one_page_summary__1_.pdf and https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2017

[2] EED target originally set in 2012 requiring a 20% reduction by 2020. This was updated in 2016 to a 30% target by 2030.

[3] National Grid System Operator: Future Energy Scenarios. http://fes.nationalgrid.com/

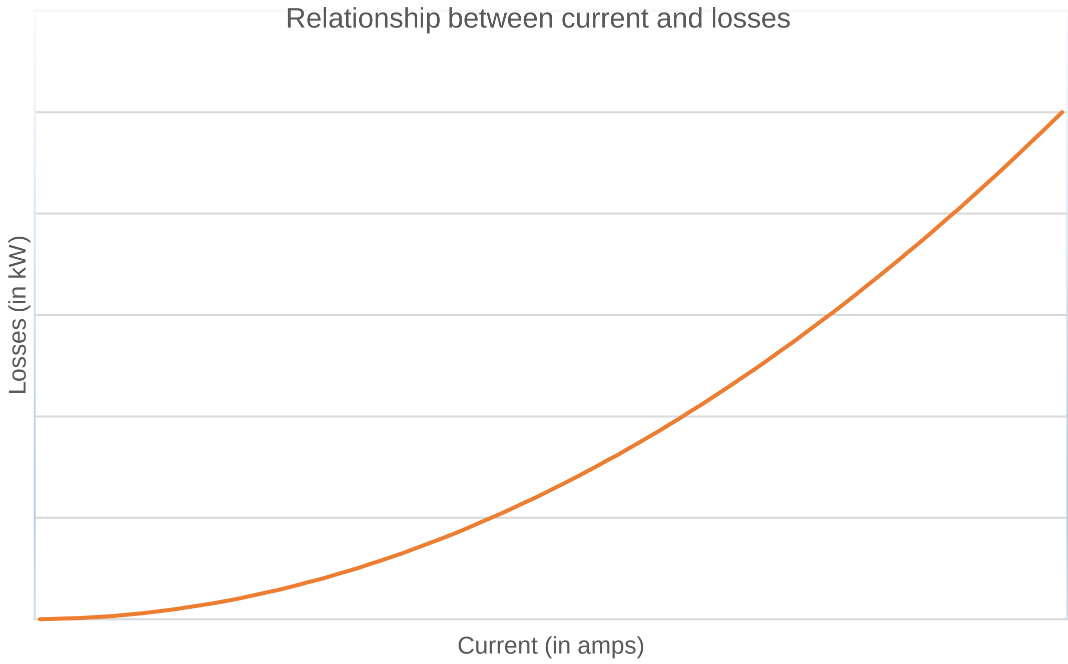


Figure 1: *The relationship between current and losses is non-linear: as current increases the losses increase by the square of the current, i.e. a quadratic relationship.*

1.2 What are losses?

Distribution network losses are the difference between the electrical energy that enters our distribution network and the energy that is delivered to our customers. Losses are the unavoidable consequence of transferring electricity across the network; but can be minimised using appropriate strategies, assets, and systems.

Our losses strategy combines the following two distinct areas:

- Technical network losses
- Non-technical losses

1.2.1 Technical losses

Technical losses are inherent to the distribution of electricity and cannot be completely eliminated. As energy passes through our network a small proportion of this is lost as heat. Technical losses can be categorised into fixed losses and variable losses. Fixed losses exist whenever the network is energised or “switched on”. Variable losses arise when energy is transferred over the system, and are a non-linear function of the system utilisation. The level of the technical losses within a system will depend on a number of factors, but for a typical distribution network around 30% of its technical losses will be due to fixed losses and around 70% will be due to variable losses.

Technical loss type	
Variable or Copper (Cu) losses:	These losses are due to the electrical resistance of conductors and hence have a non-linear (quadratic) relationship with the current passing through the conductor.
Fixed or Iron (Fe) losses (also known as 'no load' losses):	These are incurred as a result of the magnetising forces involved in transforming electricity. The losses are fixed in the sense that, unlike variable losses, the losses are not a function of the load current passing through the conductor (i.e. transformer windings); they are present and virtually constant so long as the transformer is energised, even when supplying no load.
Contact voltage losses (CVL):	Contact voltage losses are a new category of losses, discovered by UK Power Networks through our LDR work. Contact voltage losses occur due to defects in low voltage cables. These defects can be caused through aging, chemical corrosion or third-party damage. They cause energisation of the metallic cable sheaths with consequent losses through heating. Contact voltage loss magnitudes are considerable, but typically masked by existing load as they are not significant enough on their own to operate protective devices.

Technical losses also include the energy involved in running network ancillary equipment such as transformer cooling fans and pumps and other auxiliary energy supplies directly associated with electricity distribution (battery charging, substation heating, lighting, Air Blast Circuit Breaker air compressors, tunnel cooling systems, etc.).

1.2.2 Non-technical losses

Non-technical losses arise where electricity is delivered and consumed but that usage is not properly measured and accounted for. Electricity theft is a key component of non-technical losses and adds to the costs borne by legitimate customers; it may additionally create dangerous situations risking fire or electrocution. Also contributing are data issues with unmetered supply equipment inventories and certain records held by electricity suppliers.

To explain these broad categories in more detail:

Non-technical losses types	
Theft from suppliers	This arises where the occupier seeks to avoid charges by tampering with their meter, installing hidden bypasses or simply wiring their consumer unit directly to the cut-out assembly.
Theft in conveyance	These are situations where a premise has no supplier associated, illegal services are installed or existing services are split and self-energised with rogue meters or direct-to-main connections.
Under-declaration of unmetered supplies	Certain items such as streetlights, advertising hoardings and telecommunications infrastructure are not individually metered since they represent modest and predictable loads[4]. Energy bills are based upon the declared inventory of equipment connected to our network and electricity may be "lost" where the customer has not kept up to date a list of what is installed.
Supplier Data Issues	Accurate accounting of energy depends on suppliers ensuring that they have the correct registration and energisation status for every customer.

[4] http://www.legislation.gov.uk/uksi/2001/3263/contents/made

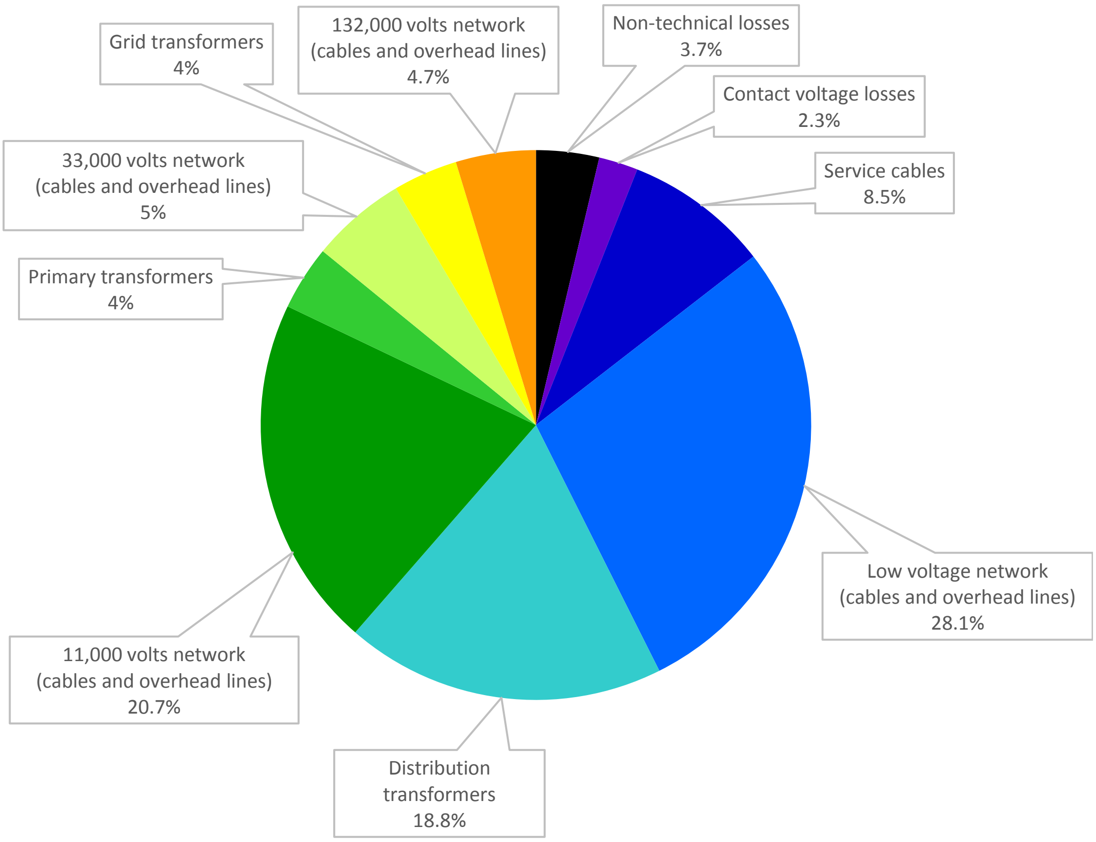
1.3 Scale of losses in the UK

According to the latest national figures available, losses in 2017[5] were as follows:

Total transmission and distribution losses across whole of the UK:		**26.5 TWh**
	Transmission (technical) losses:	6.5 TWh
	Distribution (technical) losses:	19.1 TWh
	Non-technical losses:	0.9 TWh

1.4 Where losses occur on our networks

Losses on our distribution networks are estimated[6] to occur on the following component parts of our networks:



[5] Digest of UK Energy Statistics (DUKES): electricity
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/736152/Ch5.pdf

[6] https://www.ukpowernetworks.co.uk/losses/static/pdfs/strategies-for-reducing-losses-in-distribution-networks.d1b2a6f.pdf

1.5 Regulatory and Legal Framework

UK Power Networks operates within a regulatory and legal framework. The key components of this framework are the regulator Ofgem, the Electricity Act 1989, environmental legislation, and the Losses Discretionary Reward.

1.5.1 Ofgem

Ofgem is the Office of Gas and Electricity Markets. They are a non-ministerial government department and their principal objective is to protect the interests of existing and future customers of electricity and gas. They are independent of government, the energy industry and other stakeholders.

1.5.2 Electricity Act 1989 & Distribution Licence

We hold three distribution licences enabling us to distribute electricity in compliance with the Electricity Act.

Within the distribution licences, the terms relating to losses are:

- Section 9 of the Electricity Act 1989 that requires us to “develop and maintain an efficient, co-ordinated and economical supply of electricity distribution”; and
- Condition 49 of our Licence Conditions that requires us to “to ensure that Distribution Losses from our Distribution System are as low as reasonably practicable, and to maintain and act in accordance with our Distribution Losses Strategy”.

1.5.3 RIGs & Environment Reports

Under our licence conditions we are required to report annually to Ofgem on the progress of our losses activities through the Regulatory Instructions and Guidance (RIGs) report.

The reporting guidelines require that only activities where all or some of the costs that are incurred relate to managing losses are reported. We refer to these activities as “reportable”.

Other activities undertaken often reduce losses but no additional costs were incurred that relate to losses. We refer to these activities as “non-reportable”.

Although in the RIGs report we only state losses savings attributable to “reportable” activities we also calculate losses savings for “non-reportable” categories wherever possible. Both categories are stated in our Annual Environment Report[7] which is available on our website[8].

[7] https://www.ukpowernetworks.co.uk/internet/en/about-us/documents/Annual_Environment_Report_2017-18v1.0.pdf

[8] https://www.ukpowernetworks.co.uk/internet/en/about-us/regulatory-information/

1.5.4 Losses Discretionary Reward

For the RIIO-ED1[9] price control Ofgem introduced the Losses Discretionary Reward (LDR) to encourage and incentivise DNOs to undertake additional actions to better understand and manage losses on their networks. The LDR process requires DNOs to make three submissions to Ofgem. We are due to make our third and final submission, Tranche 3, in 2020.

The LDR process has enabled us to undertake a number of significant projects:

- Development of the theory of contact voltage for losses reduction resulting in a report by Princeton University[10]. This resulted in the development of the mobile asset assessment vehicle, building our systems and processes and adopting this loss activity as BaU;
- A major research project involving holistic network modelling with Imperial College London[11] resulting in the publication of a report on strategies for reducing losses on distribution networks;
- Kent Active System Management[12] was an Innovation funded project developing a contingency analysis tool to facilitate connection and manage curtailment of distributed generation on part of our 132kV network. Through the LDR we developed the contingency analysis tool to consider losses enabling circuits to run in a loss optimal configuration and consider losses when analysing contingency options;
- Detailed analysis of the potential benefits of reducing losses on LV networks through voltage optimisation[13] [14];
- Development and adoption as BaU of 50kVA single-phase pole mounted amorphous steel transformers;
- Report on International benchmarking[15];
- Report on the use of smart meter data[16]; and
- Report on cross-border collaborative works with SSEN[17].

[9] https://www.ofgem.gov.uk/network-regulation-riio-model/current-network-price-controls-riio-1/riio-ed1-network-price-control

[10] https://www.ukpowernetworks.co.uk/losses/static/pdfs/analysis-of-contact-voltage-losses.f7e1d56.pdfhttps:/www.ukpowernetworks.co.uk/losses/static/pdfs/analysis-of-contact-voltage-losses.f7e1d56.pdf

[11] https://www.ukpowernetworks.co.uk/losses/static/pdfs/strategies-for-reducing-losses-in-distribution-networks.d1b2a6f.pdf

[12] https://www.ukpowernetworks.co.uk/losses/static/pdfs/kasm-distribution-network-losses-and-strategies-for-reducing-losses.4781973.pdf

[13] https://www.ukpowernetworks.co.uk/losses/static/pdfs/lv-feeder-losses-reduction-using-the-powerperfector-iq-test-report.23267b4.pdf

[14] https://www.ukpowernetworks.co.uk/losses/static/pdfs/lv-voltage-optimisation-for-losses-mitigation.90b33f6.pdf

[15] https://www.ukpowernetworks.co.uk/losses/static/pdfs/managing-losses-international-best-practice.78dda2a.pdf

[16] https://www.ukpowernetworks.co.uk/losses/static/pdfs/smart-meters-and-losses-best-practice-review.bbbb974.pdf

[17] https://www.ukpowernetworks.co.uk/losses/static/pdfs/uk-power-networks-collaboration-project-with-scottish-and-southern-energy.6048377.pdf

These projects have increased our understanding and we have the following LDR projects in progress during 2019:

- Expanding the range of kVA ratings of amorphous steel transformers;
- Review of the potential benefits and cost-effectiveness of power factor correction on 11kV feeders;
- Development and analysis of systems for optimisation of normally open points on 11kV and LV networks;
- Continuation of our research with Imperial College London to review potential benefits of different network topologies and voltages; and
- Working with Imperial College London to review a possible expansion of the Power Potential Innovation project[18] [19] reviewing losses on the emerging reactive power market on the distribution/transmission interface.

The academic and LDR outputs are being subjected to scrutiny using network impedance data, measured load data and robust cost-benefit analysis. Some of these outputs are in the process of being implemented as BaU activities. Some outputs require further data or implementation of systems beyond the direct control of losses. It is anticipated that many of these actions will result in benefits in the remainder of RIIO-ED1.

[18] https://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/power-potential/Project-Documents/TDI+2.0+Joint+Infographic_NewColors.pdf

[19] https://www.nationalgrideso.com/innovation/projects/power-potential

Our approach to managing losses

1.6 Summary of our strategy

Our Losses Strategy was first published in 2014 and sought to provide a comprehensive overview of the technical and non-technical losses on an electricity network, and suggested approaches that could be taken to minimise these losses. Over the course of RIIO-ED1 and supported by the LDR process our strategy has evolved and it is timely to capture recent advances in understanding and implementation.

Our strategy has three stages:

Understand losses	Plan and design	Build and operate
This primarily involves research, studies, monitoring and other actions that seek to increase our understanding of losses on our network, where they are most prevalent, what causes them and how they can be best determined, quantified, managed and finally optimised. This is an iterative process and our understanding will continue through the remainder of RIIO-ED1 and beyond.	This is a more involved and hands-on stage, where we robustly test outputs from our understanding, ensure planned activities are cost-effective and change policies and standards where required. We highlight the next areas of focus, identify timescales over which benefits may be delivered and further quantify the extent of benefits that may be provided.	In this stage we deploy the changes on the network to reduce losses, for RIIO-ED1, RIIO-ED2 and beyond. This is often the most resource intensive and costly phase. This phase is partly proactive but mainly opportunistic to share costs with other initiatives for the benefit of our customers. As part of this phase we periodically complete a full economic assessment of any changes implemented to validate assumptions made and track benefits achieved.

1.7 Stakeholder engagement

We recognise that effective engagement is a two-way dialogue that benefits both parties. As such we continuously seek input from our stakeholders to inform our decisions and evaluate our performance, while encouraging the sharing of knowledge to help shape industry-wide understanding of 'best practice' for managing electricity losses with the aim of helping the UK meet its carbon objectives.

Key elements of our stakeholder engagement consist of:

- **Building best practice:** we held a losses conference in July 2017 to share our understanding of losses and learn from others. We also actively participate in bi-monthly meetings at the ENA[20] technical losses task group comprising other DNOs, TOs and TSO. This task group seeks to encourage discussion, sharing of knowledge and to help build consensus around best practice for the benefit of customers; and

- **Knowledge sharing:** we have created an interactive losses website[21] that aims to explain distribution losses to a wider audience. On this website we also publish the reports we have produced or commissioned so we can share our learning with others. We plan to further promote our reports through suitable online platforms and events during 2019/20 and beyond. We continue to work with academia, equipment manufacturers, suppliers, customers and the wider industry at every opportunity.

1.8 Cost-effective assessment: the Cost Benefit Analysis

When considering a potential losses activity we have to make sure that it is cost effective. To do this in a consistent manner we use the Cost Benefit Analysis (CBA) method developed by Ofgem for RIIO-ED1. The CBA puts monetary values to the costs and benefits and these are then considered over the life of the asset or activity. The CBA shows if and when an activity becomes cost-effective.

This CBA process allows a consistent and comparable analysis of potential activities.

1.9 Processes & systems

Once an activity has been analysed and deemed cost-effective through CBAs we seek to effect change and capture the volume of the activity, the costs and benefits.

This process requires internal stakeholder engagement with the output principally being changes to our Engineering Standards[22].

Changing our Engineering Standards is an effective means of ensuring that high volume activities have loss inclusive design built into their design considerations by default.

For some low volume but high cost activities, such as major projects replacing power transformers, we undertake site-specific losses calculations and assessment of the options. For these major projects we have well-established BaU processes to review project options, designs, costs and progress. We have extended this governance process so that it captures the value of losses to ensure that losses are included as one of the many considerations in our major projects.

---

[20] http://www.energynetworks.org/electricity/engineering/technical-losses.html

[21] https://www.ukpowernetworks.co.uk/losses/index.html

[22] G81 standards: https://g81.ukpowernetworks.co.uk/

2 Our solutions to managing losses

2.1 Contact Voltage Losses

Contact Voltage Losses are a new category of network losses that we discovered through our LDR-funded work with Princeton University. CVL was discovered as a positive side-effect of the Mobile Asset Assessment Vehicle (MAAV) Innovation project that focussed on safety. Based on our work surveying Central London, Princeton University's Andlinger Centre[23] calculated that CVL account for 590 GWh of losses in Great Britain every year. This is the most significant change in our industry's understanding of network losses to have occurred in recent times. Importantly, because these defects are not necessary for the functioning of the network so there is no reason they cannot be wholly mitigated through intensive scanning and repair programmes.

The Mobile Asset Assessment Vehicle (MAAV) is a vehicle equipped with advanced electromagnetic wave sensors. It drives through urban environments and detects defective underground cables. While these cables have not 'faulted' in the traditional sense of triggering a fuse or other protective device, they are defective in the sense that a conductor is exposed to the general mass of the earth in a way that is contrary to the intended operation of the network. In some cases, these defective cables have metallic sheathes. When the sheath comes into contact with the live phase conductor, the entire length of sheath is energised at system voltage. As well as being a safety hazard, this results in energy leakage in the form of dissipated heat.

Working with Princeton University and the manufacturer of the MAAV, we have developed a BaU process to conduct surveys to detect faults and instigate cable repairs. Since the MAAV became a BaU activity for UK Power Networks, we have mitigated over 800 MWh of network losses. This was mainly driven by de-energising faulty lighting columns. It also makes the conservative assumption that the energised lighting columns would only have remained in their defective state for a single year, in the absence of our intervention. We have evidence to suggest these defects can in fact sustain for a much longer span of time.

We are pleased to introduce this as a BaU activity to our Losses Strategy and will seek to gain further understanding from the findings. We feel the discovery of CVL demonstrates a perfect case study for how innovative analysis from the LDR and other Ofgem Innovation funding streams can drive genuine and significant benefits for our customers and the wider public.

2.2 Technical losses

In this section we have listed the solutions that we have adopted as BaU. These activities are subject to annual review to ensure they remain cost-effective and that we apply learning from the LDR and our other activities to these established categories.

2.2.1 Transformers

The three main categories of transformers on our networks are grid, primary, and distribution transformers and there are common elements when considering losses that apply to all three.

[23] https://www.ukpowernetworks.co.uk/losses/static/pdfs/analysis-of-contact-voltage-losses.f7e1d56.pdfhttps:/www.ukpowernetworks.co.uk/losses/static/pdfs/analysis-of-contact-voltage-losses.f7e1d56.pdf

Transformer losses comprise of fixed and variable losses. Given the diverse range of networks and utilisation levels the ratio between fixed and variable losses varies considerably and needs to be factored in to any assessments. Newer transformers typically have lower losses than older transformers. It is interesting to note that there have been significant advances in transformer efficiency over the course of many decades. These developments continue with the Ecodesign[24] 2015[25] specifications and anticipated 2021 specifications. These advances lead to a significant reduction in losses as assets are replaced.

EU Directive 2009/125/EC[26] mandates the adoption of Ecodesign transformers for distribution networks in two phases from 2015 to 2021. We adopted Ecodesign 2015 requirements ahead of legislative requirements and are preparing for the 2021 specifications. It should be noted that where existing transformers are replaced with Ecodesign 2015 transformers of the same size there are typically considerable losses savings but as Ecodesign is a legislative requirement this activity is deemed as non-reportable.

Given the high cost of any transformer replacement it is unlikely to be cost-effective with losses as the primary driver. We therefore have to seek opportunities where there are other primary drivers such as connections, replacement or reinforcement and consider whether losses can cost-effectively warrant a change in the specification or size of the transformer.

2.2.1.1. Grid & primary transformers

We have over 2,300 grid and primary transformers on our networks with significant ranges in voltage, size, condition and age. In a typical year we would expect to replace or install around 30-40 grid and primary transformers.

The low volume but high value allows us to make site-specific losses calculations and undertake CBAs where these assets are being installed or replaced. There are considerable losses savings especially when replacing older transformers but there is unlikely to be a direct cost attributable to losses. For this reason the vast majority of this activity is non-reportable.

2.2.1.2. Distribution transformers

We have over 118,000 distribution transformers on our networks ranging from small single phase pole mounted transformers supplying electricity to a single dwelling to 1MVA three phase ground mounted transformers supplying electricity to hundreds of homes and businesses. In a typical year we would expect to replace or install over 800 distribution transformers on the basis of condition, age, load, fault or to accommodate new connections.

Our recent analysis with Imperial College London[27] showed the significance of losses on distribution transformers with an estimated 20% of losses on our networks occurring on these assets.

As the older assets are likely to exhibit higher losses than the average it follows that making an informed decision about transformer specification and replacement is important. This importance is elevated as transformer life expectancy is 45-70 years and made more relevant with the anticipated uptake of electric vehicles[28] and other low carbon technologies that are expected to increase network utilisation.

---

[24] http://ec.europa.eu/growth/industry/sustainability/ecodesign_en

[25] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R0548

[26] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0125

[27] https://www.ukpowernetworks.co.uk/losses/static/pdfs/strategies-for-reducing-losses-in-distribution-networks.d1b2a6f.pdf

[28] https://www.ukpowernetworks.co.uk/internet/en/have-your-say/documents/EV%20Presentation_2018.03.13_V0.1

When replacing existing transformers there will be a significant reduction in losses due to the on-going development of transformer specifications and efficiency. However given the RIGs guidance from Ofgem although replacing these transformers on a like for like basis will reduce losses this is a non-reportable activity as there are no incremental costs.

For all transformer installations and replacements we specify Ecodesign 2015[29] transformers as a minimum. We intend to specify Ecodesign 2021 compliant transformers ahead of legislative requirements.

We have developed a detailed analysis which makes site-specific recommendations to our asset replacement programme. This analysis selects a transformer size for each site where losses are minimised to the most-cost effective level.

Now that we have proven the effectiveness of this analysis we aim to develop this further and change our Engineering Standards so that all transformer selection and installation includes loss inclusive design by default.

2.2.1.3. Amorphous steel transformers

Amorphous steel-cored transformers have an even lower level of fixed losses than standard transformers. However amorphous steel is difficult to manufacture in large plate sizes (not least because it is brittle) and is generally available only for smaller distribution transformers. In addition the cost is considerably higher than for laser etched/cold rolled conventional steel-cored transformers.

Our analysis with Imperial College London highlighted that the fixed losses are disproportionately high on small lightly loaded transformers such as rural pole mounted transformers.

Through our LDR activities we developed a specification for a 50kVA single phase amorphous steel transformer where the increased cost is outweighed by the long-term losses benefits.

Accordingly we now purchase and install these transformers as BaU.

We are currently looking to expand the range of pole-mounted transformers where cost effective and will look to continue this development with ground-mounted transformers if feasible.

2.2.2 Cables

In the past we have rationalised our range of cable sizes particularly at low voltage (LV) and 11kV. This has both commercial benefits due to economies of scale when purchasing from suppliers as well as loss reduction benefits. Limiting the range of available options will naturally lead to larger overall cable sizes hence lower resistance and losses.

On cable installation projects the costs of the civil works for installation and reinstatement typically outweigh the cost of the actual cable. In many cases installing a larger cable has no impact on the costs of the civil works. So our strategy with cables is to analyse the incremental cost difference and losses between the minimum standard cables size (which meets thermal ratings etc.) and larger cables with lower resistance.

This is a pragmatic approach and given the current value of losses it is unlikely that losses will be the primary driver on any cable replacement programme at any voltage level.

[29] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R0548

2.2.2.1. Low voltage cables

We estimate that between 36-47% of losses[30] on our networks occur on our low voltage networks. This estimate highlights the importance and value of installing lower loss LV cables.

The challenges with LV networks are the sheer scale and the availability of data. We have over 94,000 km of LV underground mains cables, 5.9 million underground LV service cables and limited visibility of load at the LV feeder level at present.

There is also a very wide range of utilisation on our LV networks but we have analysed and found that increasing standard cable sizes is cost-effective.

We have adopted and changed our Engineering Standards[31] [32]specifying 300mm^2 aluminium cable as our standard size for LV mains cables for all but a very limited number of exceptions.

We also specify a minimum size of 35mm^2 aluminium for all LV service cables.

When changing the Engineering Standards we also prohibited the tapering of cable sizes, a practice which has been shown to increase losses. We also sought to promote balancing of load across phases.

2.2.2.2. 11kV cables

We estimate that between 17-27% of losses[33] on our networks occur on 11kV networks.

The challenges with 11kV networks are very similar to those on our LV networks. We have over 45,000 km of 11kV underground mains cables but benefit from some additional load data compared to LV.

Again there is also a very wide range of utilisation on our 11kV networks but we have analysed and found that increasing standard cable sizes is cost-effective.

We have adopted and changed our Engineering Standards[34] specifying 185mm^2 aluminium cable as our minimum standard size for 11kV mains cables for all but a very limited number of exceptions.

With the benefit of additional data and analysis we are investigating the potential to increase this minimum size further to 300mm^2 aluminium.

[30] https://www.ukpowernetworks.co.uk/losses/static/pdfs/strategies-for-reducing-losses-in-distribution-networks.d1b2a6f.pdf

[31] https://g81.ukpowernetworks.co.uk/library/design-and-planning/lv/eds-08-2000-lv-network-design

[32] https://g81.ukpowernetworks.co.uk/library/design-and-planning/lv/eds-08-2100-lv-customer-supplies

[33] https://www.ukpowernetworks.co.uk/losses/static/pdfs/strategies-for-reducing-losses-in-distribution-networks.d1b2a6f.pdf

[34] https://g81.ukpowernetworks.co.uk/library/design-and-planning/hv/eds-08-3000-hv-network-design

2.3 Non-technical losses

We are determined to mitigate non-technical losses so far as is practicable. In particular we actively tackle the theft of electricity from our network and aid suppliers in meeting their theft obligations. Our actions help ensure that we operate efficiently and avoid honest customers 'picking up the tab'. Reducing theft also helps lessen the incidence of dangerous situations and serves to promote the efficient use of energy.

2.3.1 Theft from suppliers

Our Service Delivery Centre provides a 24-hour/365-day emergency contact point which can receive telephone calls from members of the public, supplier agents and the emergency services. They ensure that leads are correctly re-routed to the appointed revenue protection agent or, where applicable, via the national Stay Energy Safe service. In certain emergency situations we may also dispatch a UK Power Networks field resource to site to ensure public safety.

Our staff and subcontractors identify suspected instances of theft during their daily activities. These are similarly routed back to our Service Delivery Centre for passing on to the relevant supplier.

UK Power Networks collaborates with Stay Energy Safe (also known as the Energy Theft Tip-Off Service[35] or ETTOS) operated by Crimestoppers. Where leads lack a clearly defined address and they are struggling to identify the correct premise and supplier, they refer the information to us as the distributor. With our specialist resources we can normally identify the relevant details and avoid a 'dead-end'.

Our key commitments:

- Collate information concerning suspected theft whether from members of the public, supplier agents, the emergency services, our staff or contractors and ensure it is routed to the relevant supplier or their revenue protection agent;
- Aid the effective operation of the ETTOS by providing expert assistance in matching leads to premises permitting the identification of the relevant supplier;
- Share insight and best practice with suppliers at industry forums; and
- All activity will be in accordance with industry Codes of Practice.

2.3.2 Theft in conveyance

This category of theft is much less prevalent but where it does occur it is the responsibility of the distributor to resolve. UK Power Networks has a comprehensive process to identify, investigate and resolve before ensuring that those persons who have benefitted from 'free' supplies pay back the full market value of the electricity taken.

Our key commitments:

- Pursue cases of theft in conveyance with thorough field investigations conducted in accordance with the Revenue Protection Code of Practice[36];
- Follow up with property owners and occupiers to ensure that the necessary steps are taken to enable these premises to be brought back within normal industry arrangements;
- Maintain systems to monitor the resolution of theft through new MPAN registrations;

[35] https://www.stayenergysafe.co.uk/report-energy-crime/

[36] https://www.dcusa.co.uk/Documents/Schedule%2023%20-%20Revenue%20Protection%20Code%20Of%20Practice%20v1%200.pdf#search=revenue%20protection%20code%20of%20practice

- Robust use of distributor's statutory powers ensuring persons are charged for the electricity they have stolen and the associated costs incurred;
- Develop new and innovative approaches to maximise the identification of theft cases; and
- Detailed analysis to best understand causal and geographic trends.

2.3.3 Under-declaration of unmetered supplies

UK Power Networks has legally binding contractual arrangements with all unmetered supplies customers requiring the maintenance of a fully accurate inventory.

Our key commitments:

- Conduct desktop analysis to ensure that customers' submitted data meets expected standards and fully covers the electricity they consume; and
- Physical on-street audits will be undertaken if there is sufficient business justification.

2.3.4 Supplier data issues

This is principally an issue for electricity suppliers but we work with suppliers to support and assist where we can to ensure accurate data is recorded across all industry systems.

2.4 List of potential activities under current review

The below activities are currently under assessment and review either as part of the LDR process or through our licence condition obligations. If these activities are deemed cost-effective they will proceed through our project governance process with the aim that they are ultimately adopted as a BaU activity.

2.4.1 Optimisation of network configuration

The configuration of a network directly influences the losses that are incurred. Networks are primarily configured to meet operational and supply requirements. These requirements in many cases will ensure that losses through configuration are minimised by coincidence. Through our LDR projects with Imperial College London[37], and the Kent Active System Management project[38] we recognised the potential for ensuring that our networks are optimised for losses taking into account other network requirements.

This is a particularly appealing losses activity as the capital costs are often negligible, however the analysis can be time-consuming.

As an activity through the LDR we are seeking to identify an existing software platform or adaptation that we can use to evaluate and reduce losses due to network configuration across all voltage levels but particularly at 11kV and LV.

We anticipate that this activity will lead to a reduction in losses during 2019/20.

2.4.2 11kV feeder power factor correction

The Imperial College London research undertook extensive modelling and identified power factor correction as a potential loss reduction activity. The report listed 300 11kV feeders as potentially having poor power factor on our networks.

---

[37] https://www.ukpowernetworks.co.uk/losses/static/pdfs/strategies-for-reducing-losses-in-distribution-networks.d1b2a6f.pdf

[38] https://www.ukpowernetworks.co.uk/losses/static/pdfs/kasm-distribution-network-losses-and-strategies-for-reducing-losses.4781973.pdf

As an LDR activity we are seeking to verify the modelling using data measured from sites and more detailed modelling. Once we have undertaken sufficient detailed modelling and comparison against measured data we will undertake a CBA to determine if measures to correct power factor are cost-effective.

We anticipate being able to publish a report on the findings in early 2020.

2.4.3 Network topology

Through the LDR we have commissioned Imperial College London to undertake detailed analysis to help inform our long-term strategy.

This study aims to understand the impact that Ecodesign transformers, the uptake of low carbon technologies and the potential that rationalisation of voltage levels could have on losses and on our losses strategy.

We anticipate being able to publish a report on the findings in early 2020.

2.4.4 Smart meters

Smart meters present a potentially exciting opportunity to understand losses on our low voltage networks at a much more granular level than ever before. There are however, significant challenges not least of which is ensuring data privacy. We undertook a benchmarking exercise in 2017/18[39] that highlights some of these challenges and through the LDR we are looking to the market to see if there are any potential solutions to these issues that we have not considered already. We also recently submitted a Data Privacy Plan to Ofgem and we await their review and approval.

This is a rapidly developing area and we are collaborating with suppliers, industry and our DNO peers to find solutions to be able to access and utilise this data effectively.

2.5 List of potential activities for future review

The below activities are currently under review either as part of the LDR process or through our licence condition obligations. We engage with primary drivers and keep a watching brief on developments within the wider industry and it is likely that these potential activities will be subjected to further assessment towards the end of RIIO-ED1.

2.5.1 Overhead lines – conductor sizes

In general the length of overhead lines at all voltage levels is gradually reducing and they are being replaced by underground cables. However we recognise that losses are significant on these networks particularly at LV and 11kV.

There are associated challenges with assessment of losses benefits in that there is often little data on overhead lines or pole mounted transformers at LV and 11kV on which we can base our analysis. By comparison installing larger underground cables is relatively simple in that that the larger cable is laid in the same trench that was intended for a smaller cable. Whereas with overhead lines increasing conductor sizes often increases the strength requirements of the supporting structures (poles, ground stays etc.) to accommodate the increased mass and wind loading whilst maintaining clearances.

We undertook an initial analysis at the start of the price control period and were unable to identify any clear cost-effective measures to reduce losses.

[39] https://www.ukpowernetworks.co.uk/losses/static/pdfs/smart-meters-and-losses-best-practice-review.bbbb974.pdf

However with the benefit of our recent activities and understanding we will undertake a further detailed analysis. Any cost-effective improvements that can be adopted as BaU will be implemented through changes to Engineering Standards.

2.5.2 EHV cables

Replacing or installing cables on our EHV networks comes at a significant cost. We are working with our Planning and Connections teams to optimise cable selection for losses on a case by case basis. The volumes of cable installation projects on our EHV networks is low compared to lower voltage levels but we anticipate that the learning from these projects will result in standardisation of new minimum cables sizes on our highest voltage networks.

2.5.3 Flexibility & Active Network Management

The field of flexibility and wider active network management (ANM) is rapidly evolving and UK Power Networks has developed a FutureSmart strategy[40] setting out a flexibility roadmap[41] for development. Most of the drivers behind flexibility and ANM seek to increase utilisation of our existing networks. This has the potential to increase losses on our networks but will add renewable generation so a holistic view of the benefits needs to be taken. We are closely engaged with developments and seek to ensure that losses are included in any cost and design considerations. However this field also has the potential to provide losses benefits and we watch developments with interest.

2.5.4 Switching out grid and primary transformers

Most grid and primary transformer sites have multiple transformers and due to the inherent fixed losses it has long been understood that there is a potential to reduce losses by switching out transformers during very low load conditions. There are however competing factors, such as reliability of supply, together with the costs of any control or switchgear required. Our work with Imperial College London[42] considered benefits to be negligible on all but a few sites.

Our DNO peers at SSEN are undertaking a project in this area using Transformer Auto Stop Start technology through their Innovation funded project LEAN[43]. We are actively engaged with SSEN on this project and are keen to understand the potential losses benefits and if we can apply the same or similar solution to our network.

2.5.5 Voltage management

There are potentially significant losses benefits from active voltage management as we demonstrated at LV[44] [45]. This is a potential activity that we are keen to develop but are we are currently limited by the data and the data analysis we have available. We keep a close watching brief on developments within UK Power Networks, most notably our LV visibility project, and also across our DNO peers.

2.6 Activities requiring new technology or significant cost change

The below activities have been reviewed and although they present a potential opportunity to reduce losses they are not deemed to be cost-effective at this time. We keep a watching brief on costs, the value of losses, new technology or systems that may change this.

---

[40] http://futuresmart.ukpowernetworks.co.uk/

[41] http://futuresmart.ukpowernetworks.co.uk/wp-content/themes/ukpnfuturesmart/assets/pdf/futuresmart-flexibility-roadmap.pdf

[42] https://www.ukpowernetworks.co.uk/losses/static/pdfs/strategies-for-reducing-losses-in-distribution-networks.d1b2a6f.pdf

[43] https://www.ssen.co.uk/LEAN/

[44] https://www.ukpowernetworks.co.uk/losses/static/pdfs/lv-voltage-optimisation-for-losses-mitigation.90b33f6.pdf

[45] https://www.ukpowernetworks.co.uk/losses/static/pdfs/lv-feeder-losses-reduction-using-the-powerperfector-iq-test-report.23267b4.pdf

2.6.1 Legacy networks

Small parts of our network contain isolated legacy networks running at 2, 3.3 or 6.6kV. These legacy networks are aging and there is an asset renewal driver arising from the increasing obsolescence of these systems.

Replacement with conventional 11kV networks using standard cable sizes will significantly reduce variable losses. Using Ecodesign distribution transformers will also reduce fixed and variable losses.

The losses savings associated with replacement of these legacy networks will be sizeable but the losses on their own are not significant enough to effect any change to these asset replacement programmes. However, as these asset replacement projects go through design, specification and delivery stages the changes we make through our Losses Strategy and Engineering Standards will ensure that the future 11kV networks that are installed will have loss inclusive design included by default.

2.6.2 Power quality and harmonics

It has long been recognised that power quality and in particular harmonic distortion causes a level of losses on distribution networks. Through our LDR activities Imperial College London[46] sought to study the impact of power quality and harmonics with respect to losses. On balance they concluded that the impact is likely to be low and reducing.

Given this finding, at this stage we intend to keep a watching brief on developments only.

2.6.3 Phase balancing

Phase imbalance particularly on our LV networks presents an opportunity to reduce losses. However we currently have limited visibility of our networks at LV feeder level and phase connectivity.

We are working closely with other teams in the business that are leading improvements in data capture and visibility with a view to making full use of this data for losses purposes in due course.

2.6.4 Power factor management

The impact of poor power factor is potentially significant and we are undertaking a project to consider power factor correction on 11kV feeders. Poor power factor is often a localised issue but potentially has implications on whole system management. We are interested in the potential of power factor correction on our LV networks and the potential that distributed generation could have on importing/exporting VARs on our higher voltage networks.

We do however recognise that the value of losses is currently insufficient to warrant intervention and look for opportunities where there are other primary drivers.

[46] https://www.ukpowernetworks.co.uk/losses/static/pdfs/strategies-for-reducing-losses-in-distribution-networks.d1b2a6f.pdf

3 Appendix

3.1 Glossary of terms

Term	Definition
2009/125/EC	EU Directive – Ecodesign of Energy Related Products Directive
ANM	Active Network Management
BaU	Business as Usual
CBA	Cost Benefit Analysis
CVL	Contact Voltage Losses are a result of defects in low voltage cables which can lead to energisation of the cable sheath and losses through heating.
DG	Distributed Generation
DNO	Distribution Network Operator
DSO	Distribution System Operator
EED	Energy Efficiency Directive
EHV	Extra High Voltage
ETTOS	Energy Theft Tip-Off Service
EV	Electric Vehicle
HV	High Voltage
I^2R	Losses = I^2R, where I represents current and R represents the resistance of the conductor
kV	Kilo-Volt
kVA	Kilo-Volt Amps
LCTs	Low Carbon Technologies
LDR	Losses Discretionary Reward
LV	Low Voltage
MAAV	Mobile Asset Assessment Vehicle
MWh	Mega-Watt hour
NIA	Network Innovation Allowance

Non-reportable category	Refers to RIGs reporting requirements under Section 3.3 of Annex J – Environment and Innovation. These are categories of losses activities where none of costs incurred relate to managing distribution losses but where losses benefits were coincidental.
NOPs	Normal Open Points
NPV	Net Present Value
Reportable category	Refers to RIGs reporting requirements under Section 3.3 of Annex J – Environment and Innovation. These are categories of losses activities where some or all of the costs incurred relate to managing distribution losses.
RIGs	RIGs (Regulatory Instructions and Guidance) is an annual report that we submit to Ofgem containing performance data, costs and financial information. One of the RIGs reports is the E4 losses snapshot and commentary, within Annex J, where losses activities are reported.
RIIO-ED1	RIIO-ED1 is the first electricity distribution price control to reflect the new RIIO (Revenue = Incentives + Innovation + Outputs) model for network regulation. RIIO is designed to drive real benefits for customers. It provides the companies with strong incentives to step up and meet the challenges of delivering a low carbon, sustainable energy sector at value for money for existing and future customers.
TO	Transmission Operator
TRAS	Theft Risk Assessment Service
TSO	Transmission System Operator
WACC	Weighted Average Cost of Capital

3.2 Change log

July 2019:

Our Licence Condition obligations under section 49.5(b) requires us to maintain an up to date record of any modifications we have made to our Distribution Losses Strategy, to explain the reasons for and the effects of each such modification, and how the modification better facilitates ensuring losses are as low as reasonably practicable and based on up to date cost benefit analysis.

We have undertaken a wholesale revision of our Distribution Losses Strategy. Our previous Distribution Losses Strategy detailed many possible activities to reduce or manage losses. During RIIO-ED1 to date we have assessed these activities and prioritised those that are viable and cost effective. This revised Distribution Losses Strategy targets and highlights those viable and beneficial activities. It also sets out the potential activities that we are investigating or plan to investigate further during RIIO-ED1 and beyond. We believe that these changes make it very clear to the reader what we are doing to reduce or manage losses and that these activities are based on up to date cost benefit analyses.

UK Power Networks (Operations) Limited

Registered office: Newington House, 237 Southwark Bridge Road, SE1 6NP
Registered number: 3870728 registered in England and Wales