UK Power Networks
Delivering your electricity

UK Power Networks

Distribution Losses Strategy

UK POWER NETWORKS UPDATE 2023

1 Welcome

Our approach to managing and reducing distribution losses is founded on our overall vision, values and strategy as a top-class performer. We want to be an employer of choice, a responsible and trusted corporate citizen, sustainably cost efficient whilst enabling the Net Zero transition for all.

Energy losses represent a substantial but under-appreciated burden on customers and society. Energy losses are inherent to the transfer of electricity across the transmission and distribution networks and are estimated to be **7.2% of the total** electricity consumed in Great Britain. Electricity networks totalled **20.7TWh** of energy losses in 2022, a value expected to increase to **42.3TWh** as the country moves towards Net Zero by 2050 [1]. The increase offsets a larger reduction from fossil-fuelled generators as the country transitions away from gas and coal, resulting in an overall carbon emissions reduction.

Losses have a significant financial impact, estimated to be **£12.1bn** across Great Britain and funded by our customers, as well as an environmental cost of **3.8MtCO_2** per year [2].

Barry Hatton
Director of Asset Management

As part of UK Power Networks company vision 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.

Throughout the previous price control period of RIIO-ED1, between April 2015 and March 2023, we have identified new ways in which we can reduce losses on our network with UK Power Networks, being the first DNO to establish dedicated engineering capability to drive losses improvement projects and achieving an average **2.3%** reduction in energy lost year on year [3].

We anticipate that electricity energy consumption will increase by up to **240%** to **759TWh** per annum as customers turn to electricity to power their cars and heat their homes as well as generating their own electricity and proactively engaging with the distribution network via new services. These changes in our customers' behaviour will affect electrical energy losses as utilisation of the existing network increases, further emphasising the importance of losses management measures.

Our strategy for RIIO-ED2, a crucial period in the transition of our network to net zero carbon, is to embed losses mitigation measures in our work programme and continue to explore new technologies and approaches. Where the measures we identify throughout the period demonstrate a long-term benefit to customers, we will adopt them to achieve further reduction in losses. We expect a reduction of 8.5% in the five year period by investing £540m over the period [4].

In this Distribution Losses Strategy, we show that our thinking is continuously developing, underpinned by our strong approach to innovation and accelerated by our Digitisation Strategy and the first Distribution System Operator, as we continue to make tangible progress towards managing losses to economically justified levels and to factor appropriate loss mitigation measures into all categories of network investment.

1. Section 4.1 Why we manage losses.
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3 Executive summary and vision

As the Distribution Network Operator (DNO) for London, the East of England and the South East of England, UK Power Networks is the UK's biggest electricity distributor delivering power to over 8.3 million homes and businesses covering more than 29,250 square kilometres and serving 19 million people from Cromer in the East to Brighton on the South Coast.

Decarbonisation is one of the greatest challenges facing our generation. We are in the midst of a rapid shift in technology, society and energy. Our business, together with the wider energy system and society at large, will need to undergo significant changes over the next decade if Net Zero is to be achieved by 2050.

UK Power Networks Distribution Losses Strategy is built upon the corporate vision, values and wider societal need. We want to be a top-class performer, an employer of choice, responsible and trusted corporate citizen, sustainably cost efficient and enabling Net Zero transition for all. This means that we seek to do what is right for our customers by providing the best possible service at the best possible price, aiming to be as efficient as possible and limiting the environmental impact arising from our business activities.

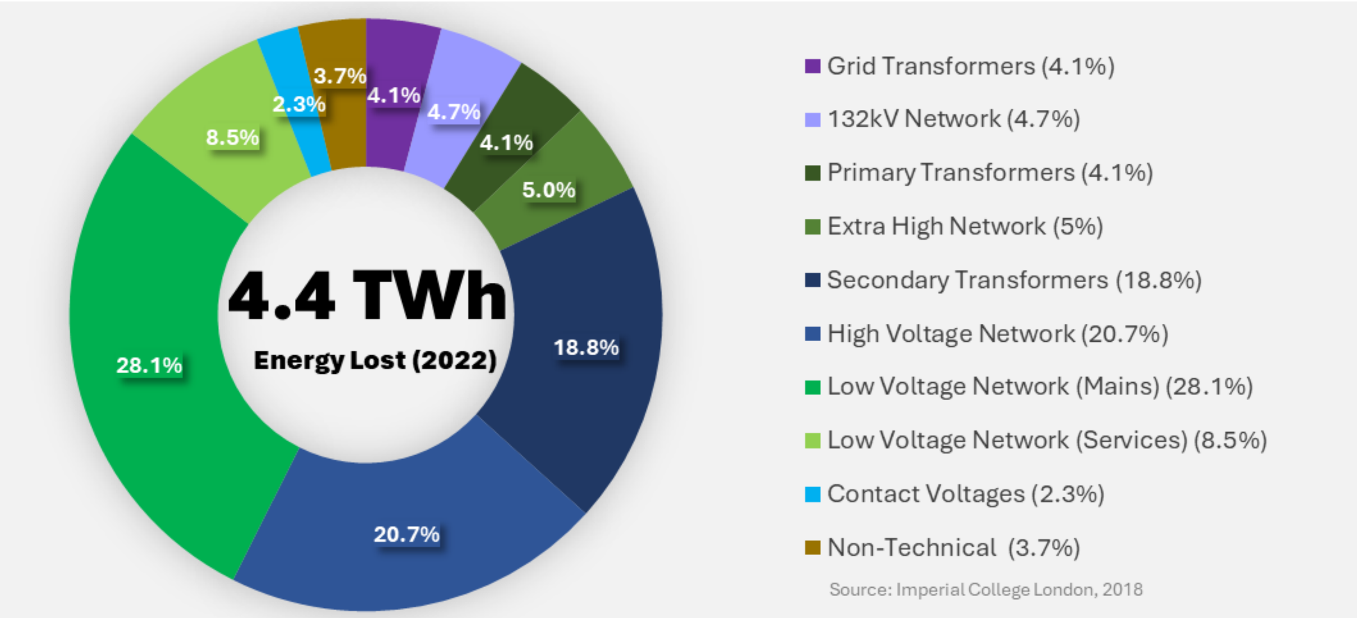
This Distribution Losses Strategy sets out our ambition to lead the creation of energy efficient distribution network in Great Britain, underpinned by three objectives:

- Maximise the amount of energy saved per year.
- Integrate losses management into business processes and systems.
- Continue working with stakeholders and innovators to integrate learning into our Distribution Losses Strategy.

(Imperial College London, 2018)

The electrical energy lost in the network represents a cost to customers and contributes to Great Britain's carbon emissions. UK Power Networks declared 4.4TWh of energy losses across all the network components in 2022, representing 21.2% of the total in Great Britain.

Figure 1. UK Power Networks reported energy losses and breakdown by component



Executive summary and vision

In the transition to Net Zero, we will see an increase in energy losses across the transmission and distribution networks as the demand for electricity increases following the connection of heat pumps and electric vehicles. From the current value of 20.7TWh (NGESO, 2023), each of the four different future scenarios leads to an increase in energy losses up to 42.3TWh. Continuing the pathway to minimize energy losses on our network, where reasonably practicable and cost effective, results in savings for our customers and further reduces UK Power Networks carbon footprint.

Our strategy for RIIO-ED2, 2023 to 2028, is to embed losses mitigation measures in our wider investment programme whilst continuing to explore new technologies and approaches. Various measures that demonstrate a long-term benefit to customers and achieve further reductions in losses are highlighted in this strategy, including the following:

- Changes to design policy that drive efficiencies and optimise asset replacement, reinforcement and customer connection.
- Optimising our physical networks and the efficiency of individual assets embedded in these networks.
- Leveraging the power of analytics and exploring new sources of data including smart meters.
- Identifying network planning and operational solutions that further reduce network energy losses.
- Adopting dynamic management of the network based on consumption data and network insight.
- Carrying out a whole system approach to understanding and managing losses, stretching the influence of our strategies and actions across the boundaries of the network for wider benefits.
- Quantifying energy losses reduction as an outcome from individual investment programmes and how it compares against the overall reduction.
- Create robust processes and better decision-making tools to deliver timely benefits.

In this document we outline our strategy to manage losses on our distribution network to the lowest economically reasonable level, taking account of the costs and benefits of a variety of potential measures. Producing a Distribution Losses Strategy is part of our license requirement and we are required to report losses to our industry regulator, Ofgem, to make sure we are applying best practice, continuously reviewing current and future interventions to further manage losses on our network.

Combining all mitigation measures explored in this strategy document, we see electricity energy losses in UK Power Networks decreasing from the current value of 4.4TWh to 4.0TWh over the course of RIIO-ED2.

4 Introduction

Distribution network losses are the difference between the electrical energy that enters our electricity 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 or reduced using appropriate strategies and solutions.

The electrical energy lost in the network represents a financial cost to our customers and contributes to Great Britain's carbon emissions due to the carbon intensity of electricity generation [Explainer 1]. Although the carbon intensity of electricity generation is decreasing year on year, it still remains a major contributing factor to the UK CO_2 emissions.

Continuing the pathway to minimize energy losses on our network, where reasonably practicable and cost effective, results in savings for our customers and further reduces UK Power Networks carbon footprint. At a time where energy costs are high, attention on operating an efficient network is key.

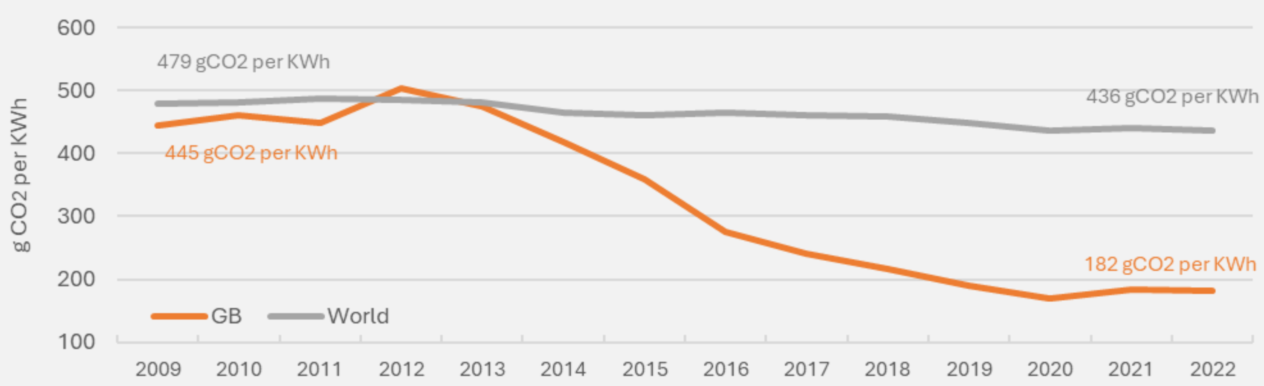
Reducing losses effectively can free up network capacity, an essential consideration as further reinforcement would be required to meet the expected increase in consumption with the electrification of heat and transport required to meet Net Zero by 2050.

Growth in distributed generation (DG) and other low carbon technologies (LCT) such as electric vehicles (EV) charging points (EVC) and heat pumps (HP) will lead to increased peak power flow and total energy demand, resulting in greater network losses. In addition, the operation of a smarter and flexible network means that a greater utilisation of existing assets will be necessary, giving rise to additional network losses.

Delivering the best whole-system approach for our customers through operating an efficient, coordinated and economical distribution network is necessary to manage distribution losses as we progress to a smart and flexible electricity network.

Explainer 1 Carbon Intensity

A measure of how clean the generated electricity is, it refers to how many grams of carbon dioxide (CO_2) are released to produce a kilowatt hour (kWh) of electricity. Electricity generated from fossil fuels is more carbon intensive, whilst renewable energy sources, such as wind, hydro or solar, produce next to no CO2 emissions, so their carbon intensity value is much lower.



Sources: https://www.nationalgrid.com/stories/energy-explained/what-is-carbon-intensity
https://ourworldindata.org/grapher/carbon-intensity-electricity

Introduction

UK Power Network Distribution Losses Strategy and the actions embedded within it is reviewed periodically to ensure that it remains current and continues to incorporate new technologies or approaches.

In this section we describe the origins of distribution network losses, how the industry classifies losses, an understanding of the physics involved and difficulties in accurately measuring losses.

Distribution network losses are typically classified as:

- Technical network losses
  - Fixed Losses
  - Variable Losses, including:
    - Contact voltages
    - Power quality (Harmonics & Phase unbalance)
    - Electrical power conversion efficiency (Power Factor)
    - Electricity network ancillary equipment
- Non-technical losses
  - Illegal abstraction (Supplier & Conveyance)
  - Monitoring (Unmetered supplies & Supplier Data Issues)

The 2023 Distribution Losses Strategy update emphasizes two new sub-categories of technical losses, Power Quality and Electrical Power conversion which have been previously identified as future areas of focus. The rollout of the Power Quality strategy and additional network information gained by monitoring and analytics provide further insight and enables the quantification of these losses.

4.1 Why we manage losses

The electricity distribution network, taken as a whole, represents one of the largest consumers of energy in the country. Losses arising from electricity distribution represent a substantial but under-appreciated burden on customers and society.

Customers pay for losses in their energy bills and we estimate that the power required to cover energy losses across the distribution and transmission networks in Great Britain to be approximately £12.1bn[1] every year at current prices. This additional cost adversely affects customers, a burden felt more greatly by those in fuel poverty.

The benefits of loss mitigations reflect the wider needs of the society and our approach to managing and reducing distribution losses is founded on our overall vision, values and strategy.

Figure 2. UK Power Networks vision

1. In 2022 the GB Distribution system losses were 14,799GWh and GB transmission losses 5,965GWh (NGESO FES 2023). Ofgem RIIO-ED2 value for energy losses at £58.22/MWh.

Introduction

An employer of choice

The strength of an organisation is its people. To really have a positive impact, net zero ambitions need to be embedded from the ground up as well as from the top down. Creating a culture in which everybody is accountable for taking action that supports decarbonisation and aims to reverse climate change.

Working towards Net Zero goals helps an employee feel part of a bigger project of helping to create a healthier world.

Sustainably cost efficient

The financial impact extends beyond the additional generation required to offset the energy lost in the distribution of electricity. Reducing losses to the most economic level maximises the available capacity of plant and equipment to deliver useful energy, keeping costs to our existing and future customers low.

When losses are minimised, lower levels of capital and operational expenditure will be incurred in providing, maintaining and reinforcing generation, transmission and distribution assets, with the added benefit across the supply chain from avoided material extraction, manufacturing and construction costs.

A respected and trusted corporate citizen

We hold three distribution licences enabling us to distribute electricity in compliance with the Electricity Act *(HM Government, 2022)* and in accordance to the Standard License Conditions *(OFGEM, 2023)*. Within the distribution licences, the terms relating to losses are:

- Section 9(a) of the Electricity Act 1989 that requires us to "develop and maintain an efficient, coordinated and economical system of electricity distribution"
- Condition 49.1 of our Licence Conditions requires us to "Distribution Losses from its Distribution System are as low as reasonably practicable, and to maintain and act in accordance with its Distribution Losses Strategy".

At the start of the RIIO-ED1 regulatory price control Ofgem recognised that improving the efficiency of network infrastructure requires a reduction in losses. Together with the Energy Efficiency Directive (EED), setting binding measures to help EU nations reach energy efficiency targets *(European Commission, 2023)*, the Electricity Act and Distribution Licence Conditions.

Carbon emissions attributed to energy losses from electricity networks across Great Britain represent approximately 1.6% of the national total at 3.8MtCO_2. Distribution network energy losses also account for 94.5% of UK Power Networks Business Carbon Footprint (BCF), referenced in the Environment Report 2022/23 *(UKPN, 2023)*.

In RIIO-ED2, network operators are expected to embed losses mitigation strategies as part of business as usual and demonstrate improvements made through the period.

Enabling the Net Zero transition for all

Our energy system is in a transition and we have already seen a radical change to the generation mix with the increase in renewable energy resources and the decline in carbon-intensive electricity generation. The government's commitment towards Net Zero by 2050 is driving further changes, in particular from the decarbonisation of ground transportation and domestic heat.

Reducing losses to the most economic level reduces the amount of generation required, including disproportionately less efficient, and generally higher carbon footprint, generation that is called upon to compensate the system at times of peak demand, reducing the country's reliance on fossil-fuelled power stations.

Introduction

2. Energy lost in the transmission and distribution networks was 20,764GWh in 2022 (NGESO FES 2023) with an average carbon intensity of 182gCO_2 per kWh of electricity produced in the same year. This equates to an estimate of 3,779,048 tonnes of CO_2, rounded to 3.8MtCO_2 emitted in 2022, from an estimated total UK carbon emissions of 331.5Mt CO_2.

Consumers are also changing their behaviour in response to these challenges, with the energy landscape becoming increasingly complex and interconnected: it is not possible or sensible to simply look at operations in one part of the system without considering their impacts elsewhere in the energy system or beyond, for example on the environment or other sectors.

Increasing complexity opens up new challenges and new opportunities for efficient loss management. Technological advances in engineering, digital and information technology will continue to change how small scale generation connects to distribution networks. These new connections allow small-scale participation in markets for energy and related services, such as the provision of flexibility services. The embedding of digital approaches across all aspects of society, sometimes referred to the Fourth Industrial Revolution, also provides huge opportunities.

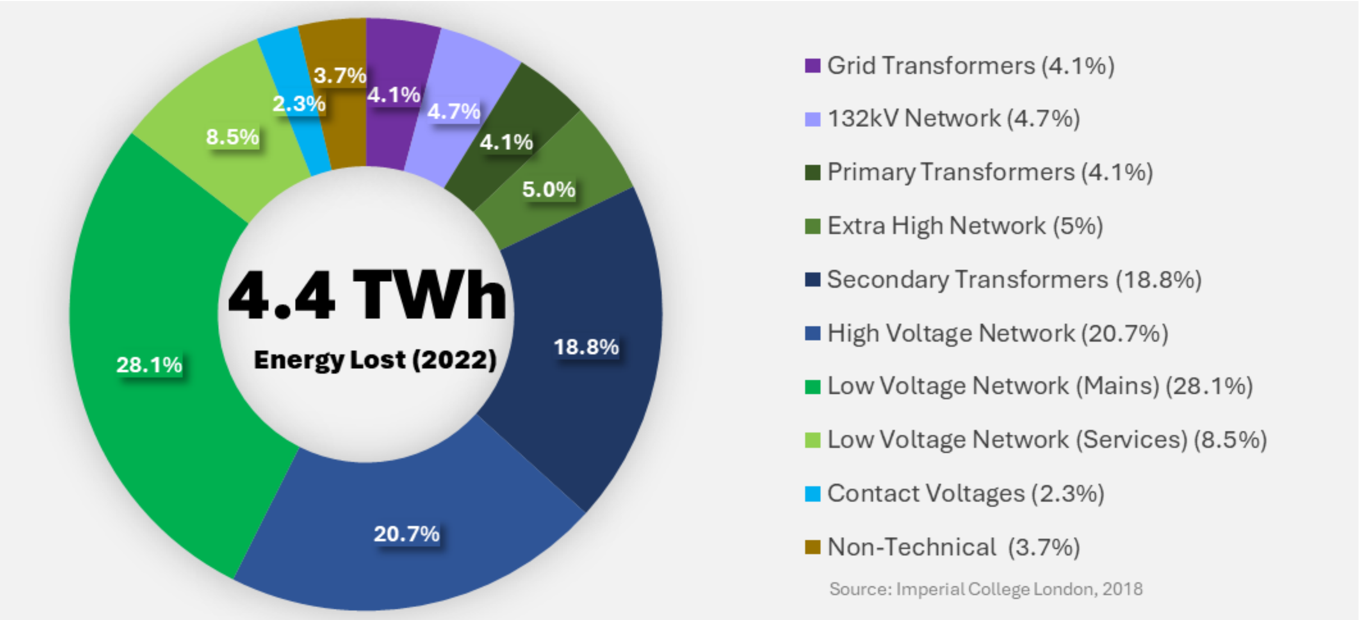
According to the latest information available from National Grid Electricity System Operator, Future Energy Scenarios, the total transmission and distribution losses across Great Britain in 2022 was 20.7TWh *(NGESO, 2023)*.

Figure 3. Total transmission and distribution electricity losses in GB

Data item	2022
GBFES Annual Demand[1]	**286.5 TWh**
GBFES System Losses: Distribution & Transmission	**20.7 TWh**
GBFES System Losses: Distribution	14.799 GWh
GBFES System Losses: Transmission	5.965 GWh
GBFES System Losses: Distribution & Transmission	**7.2%**
with UK Power Networks representing	21.2%

UK Power Networks declared a value of 4.4TWh of energy losses in 2022 *Figure 4*, representing 21.2% of the total distribution and transmission losses and on a path of reduction by 0.4% per annum as reported in the RIIO-ED1 period of 2015 to 2022.

Figure 4. UK Power Networks reported energy losses and breakdown by component



1. Source FES 2023 Data Workbook V003 – Key Stats: Customer demand plus on-grid electrolysis meeting GB hydrogen demand only, plus losses, equivalent to GBFES System Demand Total in ED1 of data workbook.

4.2 Understanding technical losses

Technical losses are a measure of the amount of electrical energy used in the transportation of power across the distribution network, they are inherent to the distribution of electricity.

Technical losses consist of two elements: **Fixed losses** exist whenever the network is energised. **Variable losses** arise when energy is transferred over the system, a non-linear function of the system utilisation.

Technical losses arise for physical reasons and depend on the energy flowing through the network, the nature of distribution overhead conductors and cables and transformers. The total amount of technical loss is made up of a fixed component, a function of the network itself, and a variable component which is dependent on the level of load on the network. Variable losses may also be impacted by the power factor, network imbalance and the effects of harmonics.

The level of the technical losses within a system depends on various factors, for a typical distribution network 30% are due to fixed losses and 70% to variable losses. The most common forms of technical losses are:

Fixed losses

A function of the network itself, fixed losses depend mainly on the number of components and equipment connected to the network and energised. Expressed by heat dissipated from network components that are energised, they are referred to as ‘fixed’ or ‘no-load’ losses as they are independent of how much electrical energy the network delivers and can occur even when no energy is being delivered.

Most fixed losses are due to the physical properties of materials within power transformers. They result from inefficiencies and imperfections of electrical insulation of the various components and the energy required to create and maintain the magnetic field that enables operation of the transformer. This leads to the flow of very small currents within the transformer as well as similar effect seen in overhead conductors, underground cables, and other network equipment. Called ‘dielectric’ or ‘leakage’ losses, they vary with the voltage level, the diameter of the conductor, and with weather conditions such as rain and fog.

In a typical distribution network 30% of its technical losses will be due to fixed losses.

Variable losses

Created by the heating effect of electricity passing through electricity cables, conductors and transformer windings, variable losses have a non-linear relationship with the current passing through.

All conductors, whether they are coils in transformers, aluminium or copper wires in overhead lines or underground cables and even in switchgear, fuses, or metering equipment, have an internal electrical resistance which causes them to heat up when carrying electric current. Energy is lost as power flows through the equipment in proportion to the square of the electrical current. Additionally, variable losses are dependent on the length and the cross section of the network line as they vary in proportion to the conductor resistance. The resistance of a conductor decreases as its cross sectional area increases. Therefore, the effect of losses is reduced with larger cable sizes. A similar principle also applies to the variable losses in transformers, where the cross sectional area of windings, and the materials used in them, influence the variable losses.

Additional factors such as the effect of network unbalance, power factor and power quality can also have an impact on variable losses, as they influence the value of the currents flowing through the conductors.

In a typical distribution network around 70% of its technical losses will be due to variable losses.

Contact voltage losses

Contact voltage losses occur due to defects in low voltage cables, caused through aging, chemical corrosion or third-party damage. These defects result in the 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.

Power Quality – Harmonics

The overall management of power quality and its limits is the subject of specific Engineering Recommendations [(G5/5, P28 & P29)] and Distribution Code [(DCODE, 2023)]. From a losses perspective, two aspects are most relevant:

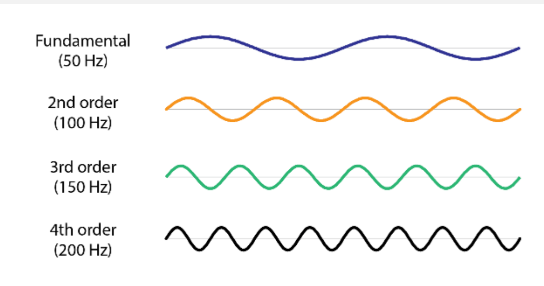
- Harmonic background levels: Total Harmonic Distortion (THD)
- Phase unbalanced or negative phase sequence (NPS) voltage

Harmonic effects are distortions to an Alternate Current (AC) profile and can occur in transformer windings because the magnetising current is not perfectly sinusoidal.

Harmonics can develop from distorting loads usually associated with industrial processes, for example arc furnaces, or more widely from domestic customers equipment such home appliances, air conditioning units, fluorescent and LED lights, computers and other non-linear loads are connected to the network. A common measure used amongst network operators is the Total Harmonic Distortion (THD), the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency of 50Hz [Explainer 2].

Explainer 2 Total Harmonic Distortion (THD)

Harmonics are integral multiples of the fundamental frequency. For example, if the fundamental frequency is 50 Hz, the second order frequency is 100 Hz, third order 150 Hz, and the fourth order 200 Hz.



$$THD_V = \sqrt{\sum_{h=2}^{h=100} (V_h)^2}$$

THD_V	is the total harmonic voltage distortion
h	represents the harmonic order (multiple of 50Hz)
V_h	represents the individual harmonic voltage (%)

Sources: https://www.hioki.com/in-en/learning/electricity/thd.html
https://dcode.org.uk/assets/uploads/ENA_EREC_G5_Issue_5__2020_.pdf

As well as potentially causing interference with communication and electronic protection systems, the presence of harmonics in will directly contribute in a direct proportion to the variable energy losses (a 10% THD increase will cause losses to increase by 10%) and effectively de-rate plant and equipment. Also, the presence of harmonics in transformer windings will increase hysteresis and stray losses, especially eddy currents losses as they are proportional to the square of the frequency.

The take-up of low carbon technologies has the potential to increase harmonic levels significantly. Looking to the future, the main causes of harmonics in distribution networks are expected to be:

- Solar Photovoltaic micro-generation inverters
- Electric vehicle chargers
- Heat pump soft-start systems
- Variable speed motor drives
- Switch mode power supplies (associated with personal computers and modern TVs)
- DC railway traction supplies

The emergence of vehicle to grid (V2G) *Explainer 3* systems which allow electric vehicles to export real or reactive power to the grid creates a potential further challenge in the future.

Maintaining control of harmonics is a necessary exercise, carried out by an effective application of engineering standards when assessing new non-linear loads connecting to the distribution network as it provides the best opportunity for containing harmonic background levels within G5/5 limits.

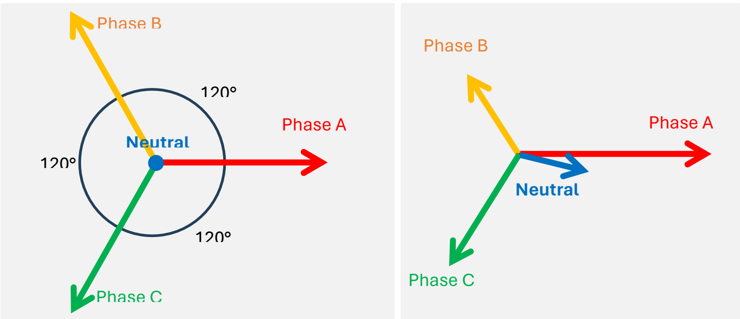
Explainer 3 V2G
Vehicle to Grid, or V2G enables plug-in electric vehicles to not only receive power from the grid but also to send power back when needed. Whilst the electrical energy conversion process of V2G also yields a loss of energy, these systems are usually associated with local generation in a domestic or commercial environment which promotes self-consumption of electricity and its use as a flexible resource thus also supporting the network at the times of need.

Power Quality – Unbalance

The United Kingdom electricity network operate on three phases with electricity transported along three conductors. The electricity network is designed to be balanced, meaning that the current flowing on each of the three phases has the same magnitude, with an offset of 120 degrees between phases *Figure 5*.

The dynamic nature of electricity generation and consumption means that network power flows are not evenly distributed across all three phases, with higher currents in at least one phase and excess current flowing through the neutral conductor if present. Due to the quadratic dependence of losses with current, this load unbalance increases energy losses.

Figure 5. Diagram of a balanced and unbalanced three phase system



a. Balanced three phase system b. Unbalanced three phase system

Unbalance is found on most parts of the Low Voltage network due to the prevalence of single phase customers with variable consumption and generation profiles (in particular due to domestic solar photovoltaic and energy storage) and incorrect connection to the upstream three phase network. On the High Voltage network, unbalance is due to the uneven distribution of single-phase transformers or two wire spurs and different loads on each phase for three-phase customers.

Balancing load profiles over time is complex and costly but can be significantly reduced by improved visibility of power flows on the LV network, altering network configuration carefully balance load and generation on each phase and the installation of automatic balancing systems *(see 5.3)*

It is common practice amongst DNOs to incorporate power quality losses in the wider variable losses category.

Electrical Power conversion efficiency (Power Factor)

Power in electricity networks is defined by real power (P), as the capacity of the system to do work measured in watts (W), reactive power (Q), as the power that flows back to the source from inductors and capacitors and apparent power (S), as the scalar product of voltage and current measured in Volt ampere (VA).

Power factor is the ratio of the real power (P) to the apparent power (S). Where it is less than unity, the current has to increase to deliver the required amount of real power, which results in a loss. This has historically been an issue for commercial and industrial customer installations, where most motor loads or power electronic loads were seen but developments in domestic power electronics and heat pumps mean that is occurring more on the LV network.

It is common practice amongst DNOs to incorporate power factor losses in the wider variable losses category.

Electricity network ancillary equipment

Technical losses also include the energy involved in running network ancillary equipment such as transformer cooling fans and pumps, as well as other auxiliary energy supplies directly associated with electricity networks such as battery chargers, heating, lighting, air compressors, tunnel ventilation systems and others.

We are increasingly deploying metering equipment at our substations to accurately determine electricity consumption, investigate the benefits of micro generation and other actions to further reduce energy lost.

4.3 Understanding non-technical losses

Non-technical losses represent energy that is consumed but not properly measured or accounted for. They are caused by factors that are external to the network and reflect energy lost that is not directly related to the distribution of electricity and independent of the physical characteristics of the network and its components.

This type of loss involves the abstraction of electricity via theft and data issues with unmetered supply equipment inventories or records held by electricity suppliers, adding to the costs as seen by legitimate customers, and possibly creating dangerous situations. Non-technical losses cannot be reduced by upgrading equipment or altering network, instead investigations, audits and collaborations with other industry stakeholders is required.

The most common forms of non-technical losses are:

Suppliers losses

This arises where the occupier seeks to avoid charges by making an illegal connection, tampering with the electricity meter, installing bypasses or simply wiring the consumer unit directly to the cut-out assembly. These situations, whilst rare in occurrence, are treated very seriously and result in immediate disconnection of and prosecution under the law.

Conveyance losses

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. These losses can also occur where new connections are unauthorised, where the process is incomplete and where reconnection takes pace after the formal disconnection process was concluded.

Unmetered supplies

Not all supplies connected to the electricity distribution network are metered. Certain items such as streetlights, advertising and telecommunications infrastructure are not individually metered as they represent modest and predictable loads which would be neither practical nor cost-effective to measure using conventional means. Circumstances where unmetered supplies are permitted are identified in *The Electricity (Unmetered Supply) Regulations 2001* (HM Government, 2001). The Unmetered Supplies Operator (UMSO) is responsible for the maintenance of the Unmetered Supply Inventories and Unmetered Supplies (UMS) Certificates and ensuring the set up and appropriate trading of new UMS Meter point Administration Numbers (MPAN).

Energy billing is estimated based upon the declared inventory, rating of the equipment and the approximate time of use. Such estimates can be inaccurate where the customer has not kept up to date list of what is installed. In order to reduce these energy losses, UK Power Networks works alongside customers with unmetered supplies to improve the accuracy of this information and produce more accurate bills.

UK Power Networks currently tracks circa 13 million UMS, over 6,000 MPANS and 4,000 customers. This related to an estimated total annual electricity consumption of 546 GWh across our three Licensed areas [Table 1].

Table 1. Annual Consumption August 2022-July 2023

	EPN	LPN	SPN
Un Metered Supplies	238,233 MWh	164,795 MWh	143,278 MWh

Unmetered connections and DNO’s own consumption can be contracted from an energy supplier and paid for by regular tariffs as any other normal consumption and therefore can be excluded from the losses calculations.

Supplier data issues

Accurate accounting of energy depends on suppliers ensuring that they have the correct registration and energisation status for every customer.

4.4 Why we measure losses: Different perspectives

Equivalent electricity generation	Equivalent CO_2 emissions
Network energy losses represented **7.2%** of the total electrical energy consumption in 2022. **20.7TWh of energy losses** in 2022 from a total of **286.5TWh annual demand** in the year. The planned 3.2GW nuclear power station at Sizewell C is expected to generate 25.7TWh per year. **Equivalent energy to 80% of Sizewell C output per year**	The average carbon intensity of electricity generated in 2022 was **182gCO_2 /kWh**. Carbon emissions related to electrical energy losses equated to **3,779,048 tCO_2.** Average new car emissions of 119gCO_2 (Statista, 2023) per kilometer for an average of 12,000km per year equating in 1.42tCO_2 per year per car. **CO_2 emissions of 2.66 million new passenger cars**

Introduction


(Proposed Sizewell C Nuclear power station, Suffolk)


(Of the 33.27 million cars in the UK)

4.5 Measuring distribution network losses

Electricity losses are reported through the GB Settlements arrangements. This process is used by electricity suppliers to determine the amount they have to pay for purchases from generators and is defined in the Balancing and Settlement Code (BSC). Electricity distributors obtain information about the electricity entering and leaving the system by reference to the industry-standard data flows to bill suppliers for distribution network charges.

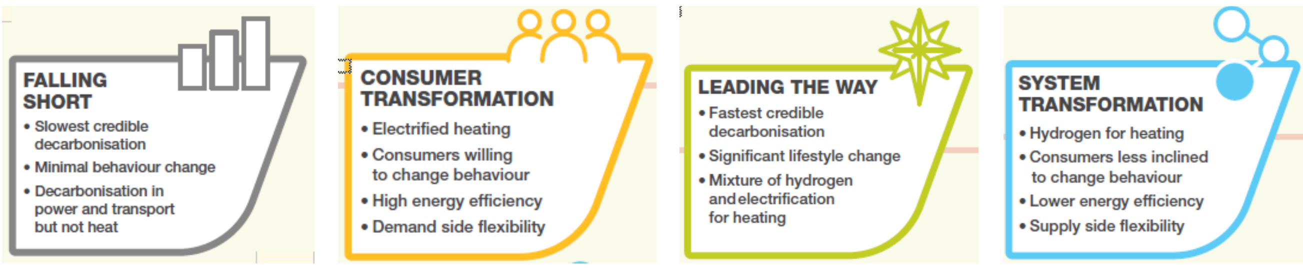
The reported losses represent the difference between the units entering and the units leaving the network.

From a UK Power Networks perspective, maintaining an updated and accurate record of unmetered supplies is therefore important to minimise any inaccuracies in losses reporting. Our approach to energy loss management takes a holistic perspective and therefore we seek to increase our understanding about how interactions between our networks and other parts of the energy system affect losses throughout it.

4.6 Forecast electricity losses

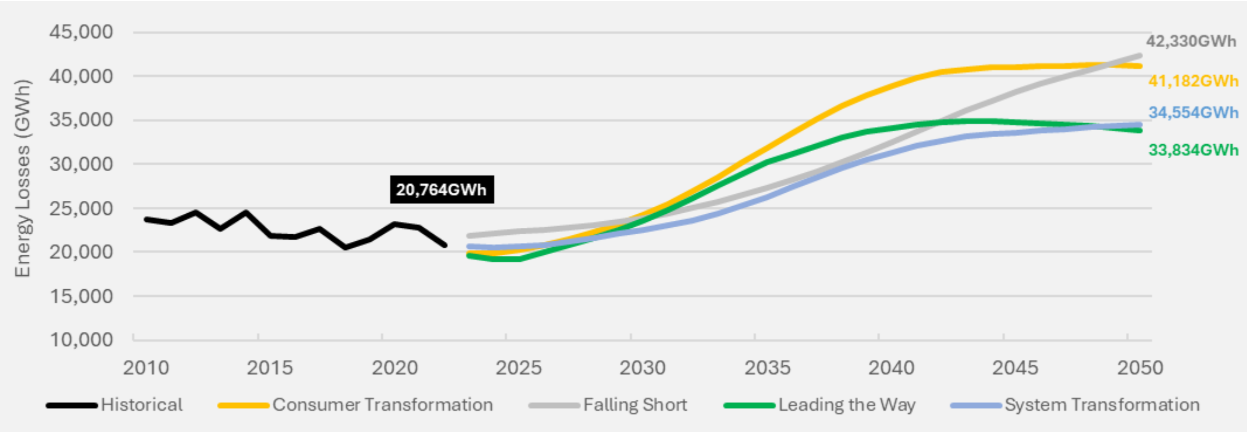
National Grid Electricity System Operator's Future Energy Scenarios (FES)*(NGESO, 2023)* sets out credible scenarios to achieve Net Zero by 2050 and meet UK Government's commitment to a decarbonised electricity system by 2035. Based on extensive stakeholder engagement, research and modelling, each scenario considers how much energy might be needed, where it could come from and how network operators continue to maintain system reliability.

Figure 6. Four future energy pathways between now and 2050 (NGESO, 2023)



In the transition to Net Zero, we will see an increase in energy losses across the transmission and distribution networks as the demand for electricity increases following the connection of heat pumps and electric vehicles. From the current value of 20.7TWh of energy lost, each of the four different scenarios leads to a higher level of energy lost, ranging from 34.1TWh (Leading the Way) to 42.3TWh (Falling Short)[Figure 7].

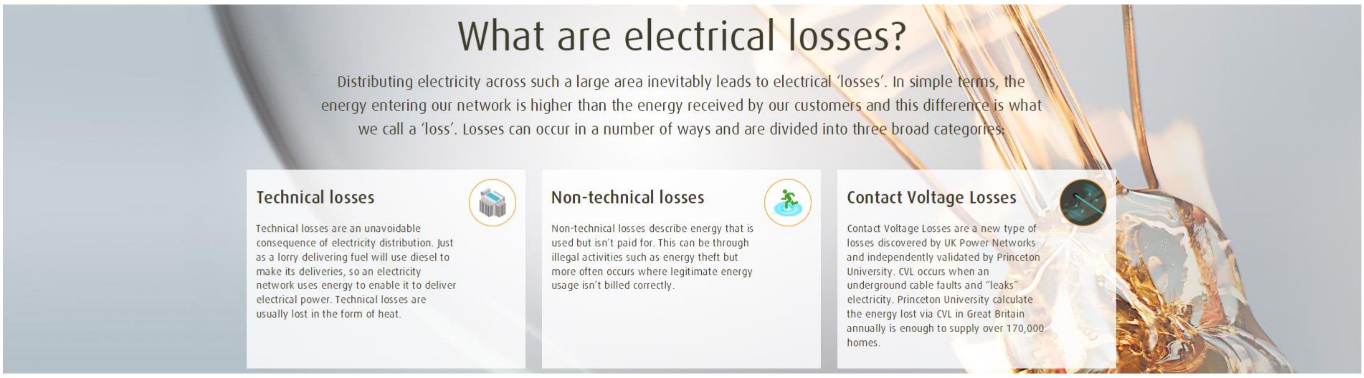
Figure 7. Electricity energy losses – Historical and forecasts based on FES



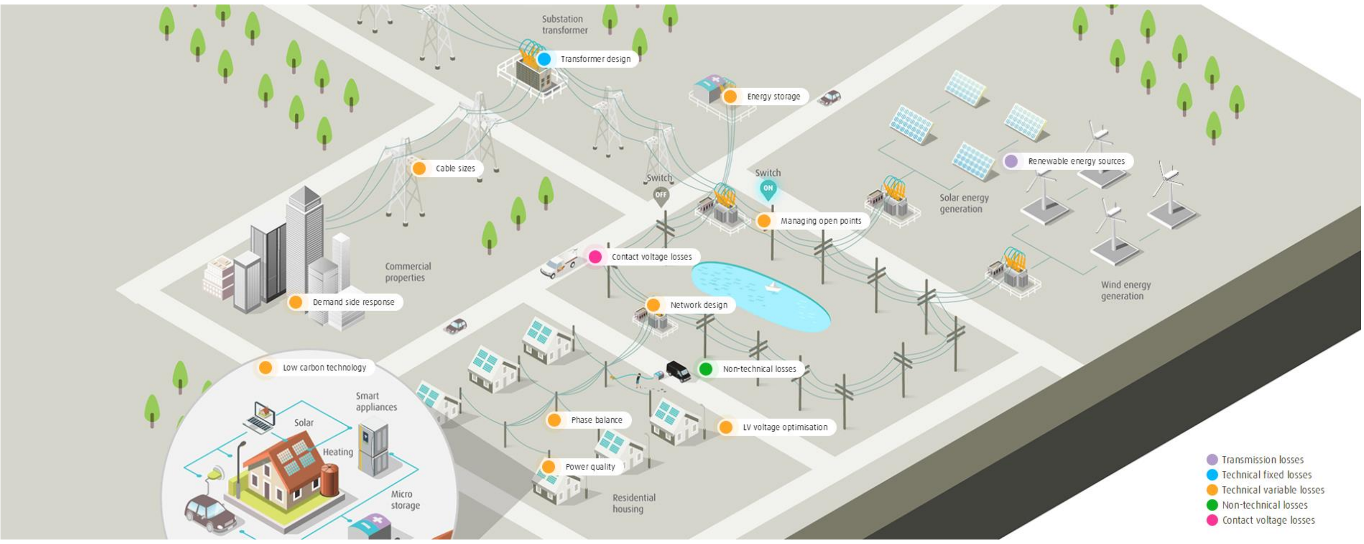
The importance of losses mitigation approaches presented in this strategy document will be even more important in the future, to further reduce energy lost to a economical minimum.

4.7 Knowledge sharing with the public

UK Power Networks created an interactive losses website 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 continue to work with academia, equipment manufacturers, suppliers, customers and the wider industry at every opportunity.



Introduction



UKPN Losses website: https://losses.ukpowernetworks.co.uk/

5 LOSSES MITIGATION MEASURES

Our strategy for RIIO-ED2, the price control period between April 2023 and March 2028, is to embed losses mitigation measures in our wider investment programme whilst continuing to explore new technologies and approaches.

Various measures that demonstrate a long-term benefit to customers and achieve further reduction in losses are highlighted in this strategy. In this section we will be exploring these measures, the knowledge gained from various innovation projects and the potential energy losses reduction following successful implementation.

5.1 Managing technical losses

We have identified four initiative groups to the management of technical losses in the distribution network. Starting from well-established **Design Policy**, determining the most appropriate asset specifications and application of the most appropriate size for the intended application to achieve a reduction in energy losses over the lifetime of the asset.

Network Operation, utilising enhanced operability tools to improve standard network operation arrangements and optimise the network in real-time, very closely linked with **Network Planning** designing the network with a losses reduction mindset together with other drivers including the potential acceleration of replacement of high loss assets, further maximising network capacity and enable the connection of DER.

The initiative groups are all underpinned by **Data & Analytics**, utilising more available data, integrated systems and analytics that become available to better model and understand losses on our network and improve the planning and operation of the network to optimise losses.

Design Policy

Transformers

Power transformers represent 27% of the total electrical energy lost in the distribution network.

With the introduction of Ecodesign directive 2009/125/EC *(European Commission, 2009)*, the replacement of transformers with more efficient units has become normal practice. The EU Directive mandated the adoption of low loss transformers for distribution networks in two phases from 2015 (Tier 1) to 2021 (Tier 2), with UK Power Networks leading the way by implementing the 2021 (Tier 2) specification ahead of legislative requirements.

Given the diverse range of networks and utilisation levels the ratio between fixed and variable losses varies considerably and needs to be factored into any assessments. The variable losses in a transformer are much lower when the unit is partially loaded and increase quadratically as a unit becomes fully loaded. It is therefore possible to reduce the overall losses by oversizing transformers when they are installed.

Due to the high cost of transformer replacement it is not cost effective to consider losses reduction as the sole justification for the investment. We therefore seek opportunities with other investment drivers such as customer connections, condition based replacement or network reinforcement to support the change in specification and size of the transformers, further reducing losses in the most cost-effective way.

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.

Extra High and 132kV network: Grid & Primary transformers

We have over 2,319 Grid and Primary transformers (UK Power Networks, 2023) on our networks with different technical characteristics, voltage ranges, sizes, condition and age.

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.

As assets are replaced in RIIO-ED2, our policy is to increase the capacity of the units to cater for future load growth, such as increasing Low Carbon Technologies, where the capacity of the existing units is forecasted to be exceeded before 2050.

Figure 8. 132/33kV Grid Transformer (Tilbury, Essex)

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.

High Voltage network: Distribution transformers

We have 119,287 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 1,000 distribution transformers based on condition, age, load, fault or to accommodate new connections.

Analysis from Imperial College London (Imperial College London, 2018) showed significant electrical losses from distribution transformers, with an estimated 18.8% of losses on our networks from these assets due to their high utilisation, a function of how the electricity network is designed and operates.

Losses mitigation measures

As older assets exhibit higher losses it is important to address transformer specifications and plan for their replacement by adopting informed decisions. This importance is elevated as transformer life expectancy is 45-70 years and made more relevant with the anticipated uptake of electric vehicles and other low carbon technologies that are expected that meet the Net Zero by 2050 ambition but also lead to an increase in network utilisation.

When replacing existing transformers there will be a significant reduction in losses due to development of transformer specifications and efficiency. Previously developed analysis to support the selection of transformer size has been proven effective and has been embedded in our Engineering Standards so that all transformer selection and installation include loss inclusive design by default.

Figure 9. Pole mounted transformer

Design Policy

Amorphous steel core transformers

Amorphous steel core transformers (AMT) have an even lower level of fixed losses than standard transformers.

There are however a few complicating factors to bear in mind considering the use of amorphous steel transformers. The amorphous material is more expensive than the silicon steel used in Cold Rolled Grain Oriented (CRGO) Steel transformers, and the magnetic saturation point of amorphous steel is lower than the saturation point of silicon steel, which leads to more steel being required to manufacture amorphous steel transformers. Due to these factors, amorphous steel transformers are larger, more expensive and heavier.

Table 2 shows the extent to which the use of amorphous steel could reduce no load losses.

Table 2. Comparison of CRGO and AMT transformer energy losses

Transformer Ratings	CRGO Steel Transformer		Amorphous Transformer		Reduction
	Fixed Losses	Variable Losses	Fixed Losses	Variable Losses	Fixed Losses only
25kVA 1Ph 11/0.25kV	70	900	15	900	79%
50kVA 1Ph 11/0.25kV	90	1100	22	1100	76%
50kVA 1Ph 11/0.25-0-0.25kV	90	1100	22	1100	76%
100kVA 1Ph 11/0.25-0-0.25kV	145	1750	38	1750	74%
100kVA 3Ph 11/0.43kV	145	1750	53	1750	63%
200kVA 3Ph 11/0.43kV	300	2750	90	2750	70%

We will always ensure that we are providing value-for-money for our customers so will continue to monitor the relative cost of AMT and CRGO transformers as well as the demand for energy efficient transformers.

Design Policy

Rationalised overhead conductors and underground cables

Overhead conductors and underground cables represent 52.3% of the total electrical energy lost in the distribution network.

Continuing with our strategy of analysing the incremental cost difference and energy losses between the minimum standard cables size, which meets thermal ratings requirement, and larger cables with lower resistance, we have rationalised our range of cable sizes particularly at low voltage (LV) and 11kV for both commercial benefits due to economies of scale when purchasing from suppliers as well as variable losses reduction benefits from installing larger cable sizes.

In any cable installation project, the costs of the civil works for excavation, installation and reinstatement typically outweighs the cost of the actual cable. This is a pragmatic approach as with the current value of electrical losses, it is unlikely that this will be the primary driver on any cable replacement programme at any voltage level.

Low Voltage network

We estimate that 36.6% of electrical energy losses on our networks occur on our low voltage networks, highlighting the importance and value of installing lower loss LV cables. The challenges with LV networks are the sheer scale and the limited availability of consumption data for the 91,405km of LV underground mains cables and 341,000 spans of LV overhead line, as well as the 7,334,000km of underground LV service cables and 423,000 spans of overhead services.

With the rollout of smart meters, LV visibility programme at secondary transformers and data analysis tools, we've been able to determine the utilisation on the LV networks in a more accurate way, further improving the understanding of energy losses at this voltage level, improving our forecasting ability and meet OFGEM Regulatory Reporting requirements in RIIO-ED2. From our analyses we found that increasing standard cable sizes is the most cost-effective practice.

We have adopted and changed our Engineering Standards EDS 08-2000 *(UKPN, 2023)* and EDS 08-2100 *(UKPN, 2023)* specifying 300mm^2 Aluminium cable as the standard size for LV mains cables for all but a very limited number of exceptions and 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.

Comprehensive system-wide study demonstrated that we save 6.35 MWh/annum for every kilometre of underground main line that we upsize from 185 to 300 mm^2 aluminium, further revealing that the Net Present Value (NPV) for this change was strongly positive.

High Voltage Network

We estimate that 20.7% of energy losses occurs across the 46,000km of underground cable circuits and 277,400 spans of overhead conductor on the High Voltage network.

Benefiting from visibility of load data when compared to LV, we can also see a wide range of utilisation across the high voltage network and a similar step improvement and cost-efficiency of the increased standard cable size.

We have adopted and changed our Engineering Standard EDS 08-3000 *(UKPN, 2023)* specifying 185mm^2 aluminium cable as our minimum standard size for 11kV mains cables for all but a very limited number of exceptions. With additional data and analysis we have further increased this minimum size to 300mm^2 Aluminium for certain approved cases.

Similarly to LV, comprehensive system-wide studies demonstrated that we save 5.94 MWh/annum for every kilometre of HV underground main line that we upsize from 185 to 300 mm^2 aluminium, also with a positive NPV.

Extra High and 132kV Network

We estimate that around 9.7% of energy losses on our network occurs on the Extra High and 132kV EHV circuits. We have 4,661km of underground cable circuits and 47,200 spans of overhead conductor on the Extra High Voltage network, as well as 1,310km and 7,380 spans on the 132kV network.

The replacement of these assets requires bespoke costs and benefit analysis, carried out alongside the primary investment driver.

The cable core size and material will depend upon installation conditions and rating requirements, taking account future network development plans. The energy lost in a cable circuit is proportional to the currents flowing in the metallic sheaths of the cables, therefore, by reducing or eliminating the metallic sheath currents through different methods of bonding, it is possible to increase the cable rating.

Where reasonable and feasible, UK Power Networks shall maximise the use of the highest distribution voltage possible within an area and minimise the use of lower voltages to customer connections and low load density areas. In addition, for distances under 5km, the largest feasible cross section of conductor is used.

Benefits calculated on rationalised cable sizing only suggest **savings of 16.25GWh per year**, further increased by the elimination of tapering for network mains. The expected split between DNOs, as a percentage of the total improvement in losses, is 14% in EPN, 11% in LPN and 14% in SPN.

Network Planning

Small section overhead conductors

UKPN put forward a RIIO-ED2 reinforcement investment case for HV OHL Small Section Conductors (SCC) in Eastern Power Networks (EPN) and South Eastern Power Networks (SPN) licensed areas. The £21.2m investment programme reinforces 3.34% of small section conductor on the UKPN network, equating to 783km of 11kV overhead conductor, addressing many network issues and with the added benefit of reducing network losses by replacing small section conductors with lower impedance, lower losses, standard conductors.

Explainer 4 Small section conductors (SSC)
UK Power Networks define small section conductors as those below the standard design conductor sizes currently in operation, in particular 50mm2 ACSR for HV spurs and 100 mm2 ACSR for main lines.

The replacement of small section conductors results in the reduction of heat losses along the section of overhead line, for the same current flow, that was subject to investment. This reduction is proportional to the reduction in resistance. The table below highlights the reduction of resistance for small section conductors when compared to standard sizes, 50mm^2 and 100mm^2 with a reduction between 71% and 150% expected:

Table 3. Resistance of conductors and reduction when compared to standard size

Conductor	Resistance (Ω)	Reactance (Ω)	Reduction compared to:	
			50mm ACSR	100mm ACSR
.025 COPPER OH	1.092	0.388	**94%**	293%
.025 CADMIUM COPPER OH	1.106	0.391	**97%**	298%
.025(25mm) ACSR OH	1.102	0.395	**96%**	296%
.025(25mm) AL ALLOY OH	1.088	0.373	**94%**	291%
.04 CADMIUM COPPER OH	0.693	0.378	23%	**149%**
.04(40mm) ACSR OH	0.694	0.38	23%	**150%**
.04(40mm) AL ALLOY OH	0.688	0.358	22%	**147%**
.05 CADMIUM COPPER OH	0.567	0.37	1%	**104%**
.05 COPPER OH	0.55	0.368	-	**98%**
50mm ACSR	0.562	0.391	-	**102%**
.05(50mm) AL ALLOY OH	0.544	0.351		**96%**
.058 COPPER OH	0.47	0.386	-	**69%**
.06 CADMIUM COPPER OH	0.471	0.38		**69%**
.06(60mm^2) ACSR OH	0.476	0.389	-	**71%**
100mm ACSR OH	0.278	0.381	-	-

Figure 10. High voltage small cross sectional conductor teed off from main line.

Network Planning

Optimising network configuration

HV and LV distribution networks are typically operated with a radial topology. However, in order to minimise customer minutes lost under fault conditions, the networks are designed in such a way that the load can be supplied from another adjacent feeder via a Normally Open Point (NOP) switch.

Moving open points to better balance customer numbers between two or more feeders usually results in improved balancing of load and hence lowers losses.

As the networks evolves the original network configuration can become inefficient. In certain cases it may be beneficial to modify the existing circuit or substation configuration to enhance operational flexibility, leading to a estimate reduction of 17% in energy losses *(Imperial College London, 2018)*.

Network Operation

Switching out underutilised plant

Following the principles of the security of supply standards P2/8 *(ENA, 2023)*, UKPN Grid and Primary substations usually operate with two or three transformers in parallel, to cater for unplanned outages without impacting our customers. At times of low demand, it is theoretically possible to switch off one of the transformers.

As the total energy lost is a combination of both fixed and variable losses, switching off the transformer reduces fixed losses but results in a redistribution of the variable losses to the remaining units. At times when a transformer is loaded at less than 45% of its given rating and the combined fixed losses are greater than the combined variable losses, this process will result in a reduction of the total energy losses.

Assessments carried out by UKPN and Imperial College highlight potential saving of up to 10% if a transformer is switched off for a long duration and 6% if switched off for a month.

Altering the network operation does have significant technical and security of supply implications that need to be addressed. The system would also not be suitable for high load sites and is dependent on the particular plant at that location.

Network Planning

Distributed Energy Resources (DER)

Historically power stations were large and normally centralised, connecting directly to the National Grid transmission system at 275kV or 400kV, but in recent years we've seen a significant increase in renewable energy and storage of smaller scale and distributed across the network: Commonly called Distributed Energy Resources (DER).

This disruption to the historical power flow from generators, via transmission and distribution networks to the customer is beneficial as the energy produced locally is used locally.

The presence of greater levels of generation on our distribution networks, generally connected at 11kV or 33kV, gives rise to a number of additional challenges to the operation of the distribution network. Provided the voltage and fault-level management issues can be economically overcome, DER will provide opportunities for improved network management, including management of losses.

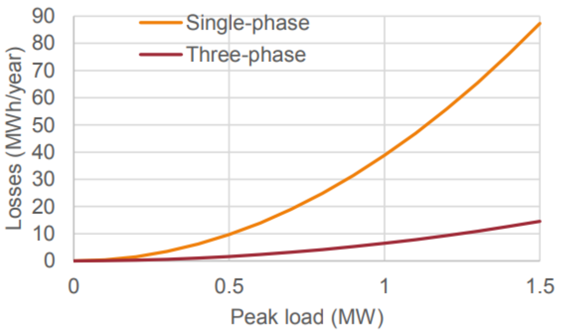
This includes optimise power flows by achieving a better overall balance between generation and demand and hence help to flatten network demand profiles. Even where a suboptimal level of balance might cause a localised increase in losses, the overall impact will still be to reduce losses overall due to reductions in upstream power flows required to serve downstream demand. Moreover, if more of the losses are being supplied by renewable energy sources, then the overall carbon footprint of losses will be reduced.

As penetration of distributed generation increases, achieving maximum export may mean that the generation has to export to wider parts of the network, dependant on location of the generation and consumer demand (i.e. distributed generation connected at a rural location and supplying an urban demand).

Network Planning

Upgrade from single to three phase

Figure 11. Ratio of losses for Single and Three phase system



Upgrading single-phase to a three phase can reduce losses significantly. Studies previous carried out identified the relation between the losses for the single-phase and three-phase spur are presented in Figure 11.

Upgrading from single-phase to a three-phase system achieves a very substantial losses reduction of 83%, attributed to the fact that after the upgrade more conductors are used to transfer the same energy at a lower current.

Network Planning

Network utilisation

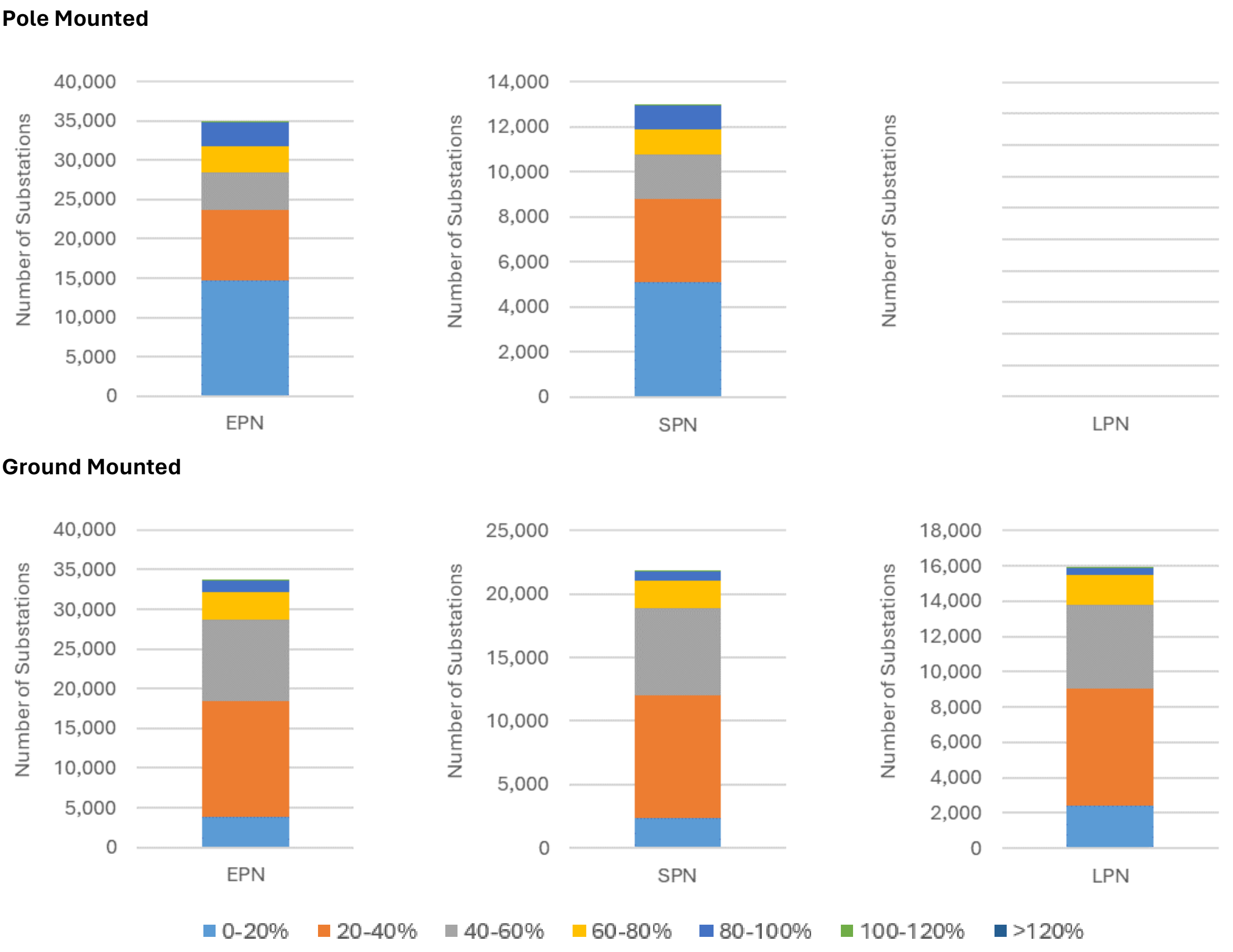
All potential decarbonisation scenarios place the distribution network in the centre stage with the electrification of transport and heat, as well as increasing volumes of renewable generation, and novel technologies such as battery storage. This is likely to result in a significant increase in utilisation of the network, particularly at LV and HV, as customers connect new sources of distributed energy resources.

The outcome is that as utilisation increases, losses will also increase.

Ofgem introduced a new reporting requirement in RIIO-ED2 for DNOs to report utilisation of secondary substations, both pole mounted and ground mounted, and thus track progress of the expected demand increase of electrical vehicles and heat pumps. Table 4 represents UK Power Networks submission for the regulatory year of 2022/23, across the three DNOs.

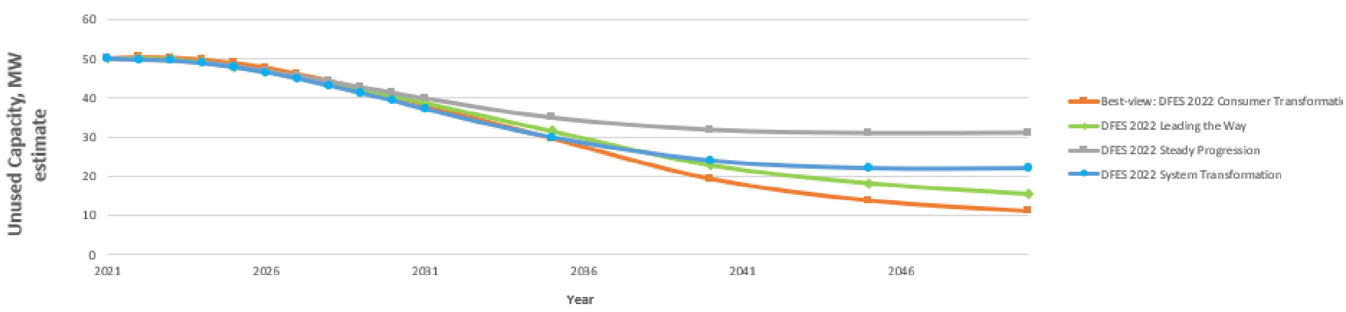
Losses mitigation measures

Table 4. Utilisation bands for secondary substations



The increase in utilisation is also reflected in UKPN Strategic Forecasting System, looking forward to 2050 and following 4 scenarios in similar way to NGESO FES.

Figure 12. Unused demand capacity at substations *(UKPN, 2023)*



Network Planning

Upgrading network voltage

As losses are proportional to the square of the current, and current is directly proportional to the voltage, increasing network voltages can reduce losses for the same energy transfer. For example, phasing out legacy 2kV, 2.2kV or 6.6kV networks to 11kV, although generally driven by capacity requirements, can reduce losses by up to 66%.

Network Planning

Power Quality – Harmonics

UKPN has rolled out fixed Power Quality monitoring at Grid and Primary substations and comprehensive information about the total harmonic content is now available for 418 substations, with additional information provided by temporary monitors installed ahead of customer connections.

Reducing harmonic effects is difficult and the principal approach is to ensure that customers use devices that produce minimal harmonic effects or install harmonic filtering devices.

Further actions are being sought as part of the Distribution Losses Strategy, including:

- Voltage issues investigation, identifying and addressing root causes. Smart meter functionality incorporating half hourly time-series RMS voltage recordings and configurable high / low voltage alerts will greatly assist this objective.
- Effective power quality management has a beneficial consequence for losses, in particular ensuring as far as practical that NPS voltages do not exceed P29 limits at the point of common coupling where large single phase loads are supplied.
- Steps taken to ensure that, as far as practicable, connections of new non-linear loads or applications involving AC/DC/AC conversion, including photovoltaic generation, electric vehicle chargers and heat pump soft start systems, do not give rise to background harmonic levels higher than those specified under G5/5 planning guidelines. Further tools have been developed and are being rolled out in 2024 to assist in the assessment of a high volume of LCT connections.
- Steps will be taken to avoid risk of harmonic resonance, in particular due to rural 11kV undergrounding projects and long 11kV underground cable extensions to serve DER installations.

Distribution Losses Strategy provided a high-level estimate of potential savings through the RIIO-ED2 period of in excess of 12.75GW/h across the three licence areas, representing a reduction of 1.25%. This improvement is likely to be offset by the influx of non-linear devices and the uptake of LCTs which increase the network harmonic levels.

Network Planning

Power Quality – Unbalance

Phase unbalance gives rise to higher than necessary currents in one or more phase conductors of a cable or overhead line and hence higher than necessary losses overall. On LV networks, where balance is traditionally poor due to the lower level of demand diversity, the effect is further exacerbated due to the residual current in the neutral which gives rise to further variable losses.

Previous Distribution Losses Strategies recognised the impracticality and excessive cost involved in tackling unbalance in the existing Low Voltage network as the single investment driver and suggested that its application is carried out in sequence with the connection of services, both underground and overhead, which should be applied to all new developments irrespective of whether they are installed by an ICP, IDNO or UK Power Networks. Another opportunity presents itself with UKPN condition-based LV link box renewal programme in the form of improved load sharing between electrically adjacent LV feeders and substations.

In relation to the High Voltage network, the investment programme to replace small section conductors offers an opportunity to address unbalances, even with single phase transformers as they can be reconnected to a different phase following a network study. Additional opportunities are taken during 11kV overhead resilience works to economically upgrade single phase (2-wire) spurs to 3 phase and achieve equal phase distribution of connected single-phase transformers and any 2-wire sub-spurs and could be implemented immediately.

Previous Distribution Losses Strategies suggested savings due to improved phase balance and load sharing in excess of 12.75GWh per annum and split between DNOs, as a percentage of the total improvement in losses, of 10% in EPN, 9% in LPN and 12% in SPN.

Network Operation

Contact voltage losses

Contact voltage losses (CVL) are a new category of network losses discovered through the LDR funded work with Princeton University, United States *(Princeton University & UK Power Networks, 2018)*. CVL was discovered as a positive side-effect of the Mobile Asset Assessment Vehicle (MAAV) Innovation project that focussed on safety and is estimated to represent 2.3% of the total electrical energy lost in the distribution network.

The MAAV is equipped with advanced electromagnetic wave sensors which detects defective underground cables as it drives through urban environments. While these cables have not fully developed a fault, in the sense of triggering a fuse or other protective device, they are defective as the live conductor is exposed to the general mass of the earth in a way that is contrary to the intended operation, resulting in energy leakage in the form of dissipated heat. In some cases, the metallic sheath comes into contact with the live phase conductor and becomes energised at system voltage, creating a safety hazard that needs to be quickly resolved.

During the RIIO-ED1 price control period, the use of the MAAV has realised a cumulative energy loss reduction of 9.3GWh. This method is currently being used by Consolidated Edison company in New York and has been recognised by the council of European regulators (CEER) in their 2nd report on power losses *(CEER, 2020)* and other adopted by UK DNOs such Scottish Power Energy Networks.

Network Operation

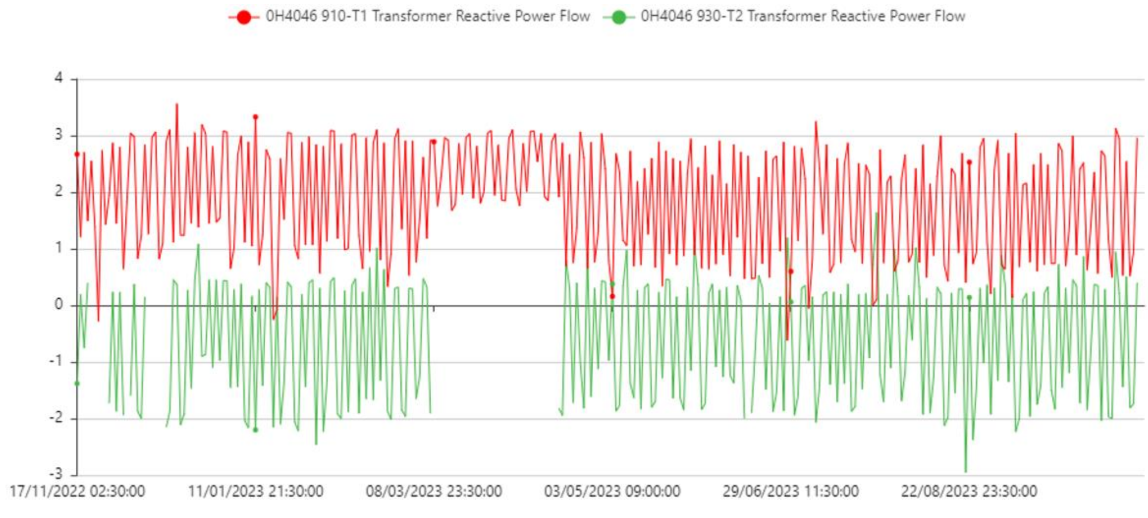
Transformer circulating currents

If two or more transformers are connected in parallel, any difference in the voltage produced by the transformers generates circulating currents flowing in both the primary and secondary windings, in particular if they are operating with an abnormal automatic voltage control system (AVC).

The current is proportional to the voltage difference between the transformers divided by the sum of the impedances around the circulating path. For a two transformer substation, the circulating currents in each transformer are equal in magnitude, opposite in direction and independent of the load current.

The example of St Ives Primary substation, equipped with two 33/11kV 18/24/30MVA transformers operating with an unbalanced automatic voltage control system (AVC), resulting in the tap position of one unit to be 3 steps apart from the other one. This created 1.25MVAr of reactive power flow between the transformers.

Figure 13. St Ives Primary substation – Reactive power flow plot for each transformer



St Ives Primary delivered 88.5GWh of energy in the period between 1st October 2022 and 1st October 2023, with an additional 10GWh of equivalent energy lost due to the circulating current or 10% of the total.

Network Operation

Voltage management policy

Maintaining voltage at the lowest permissible level within the statutory limits will ensure that variable losses associated with resistive loads are minimised, within the network operational and technical constraints.

For LV networks, distribution transformer tap positions are set to provide the most optimal voltage profile that can be achieved and maximise the available statutory bandwidth of 216V - 253V. In particular, operating at the lower end of the bandwidth generally gives rise to lower losses. It also provides maximum headroom to embedded DER which further reduces losses where generation capacity is consumed locally.

Automatic Voltage Control systems (AVC) are managed in accordance with documented policies, regularly reviewing optimum 33kV and 11kV busbar voltage set points and selection of distribution transformer tap settings. Operating transformers at lower voltages also reduce associated fixed iron losses. Consideration given to voltage optimising opportunities surrounding new AVC technologies, such as GenAVC and SuperTAPP n+, particularly for networks with significant DER power flows.

The use of modern voltage regulators on 11kV overhead line and LV networks is becoming necessary as a result of the impact of DER and micro-generation on 11kV and LV feeder voltage regulation, as well as automated reconfiguration systems, such as General Electric's Automatic Power Restoration Systems (APRS) adopted by UKPN.

Increased visibility of network parameters is required before the approach can be fully implemented. This visibility will come from existing transducers, power quality monitors, power factor information from 11kV RTUs and customer data from smart meter information. This information further improves our existing modelling tools and enables a more accurate planning of the network.

Design Policy

Electricity network ancillary equipment

In considering the possibility for reducing energy demand at operational buildings, careful consideration is given to the need to continue to protect the environment of the building and the operational equipment it houses. This is particularly relevant to indoor switchgear which is sensitive to humidity. The use of dehumidifiers or heat pumps are being considered as they provide a lower-energy option than traditional direct electrical heating.

Other options include the possible re-use of heat emitted by operational equipment, e.g. transformer coolers at grid or primary substations, especially where, for other reasons, a heat exchanger is used to water-cool the transformer oil. There may be opportunities for exporting low grade heat off site and an example of such system was commissioned at Bankside substation in London, where waste heat from the system transformer cooling system is used to provide low grade heat to the adjacent Tate Modern Gallery. Whilst this does not reduce energy losses, it does mean that the energy is reused with consequential carbon offsetting benefits.

5.2 Managing non-technical losses

Even though non-technical losses represent 3.7% of the total estimated losses on our distribution network, UK Power Networks are committed to mitigate them so far as practicable. Our actions help ensure that we operate efficiently, avoid increased cost for our customer, help lessen the incidence of dangerous situations and serve to promote efficient use of energy.

We manage non-technical losses related to **electricity abstraction**, the statutory offense of dishonestly using, wasting or diverting electricity, further enabled by increase in **electricity monitoring** We tackled the theft of electricity from the network and aid suppliers in meeting their obligations in the areas listed below.

Losses mitigation measures

Electricity Abstraction

Suppliers losses

UK Power Networks Service Delivery Centre provides a 24-hour/365-day emergency contact point for 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 operated by Crimestoppers (CrimeStoppers, 2023). 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 identify the relevant details and assist in the resolution of the issue.

Our key commitments are:

- Respond to network tampering notifications by collating information concerning suspected supplier losses from members of the public, supplier agents, emergency services, staff or contractors and ensure it is routed to the relevant supplier or the revenue protection agent.
- Aid the effective operation of 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.
- Act in accordance with industry Codes of Practice.

Electricity Abstraction

Conveyance losses

This category is much less prevalent but where it does occur it is the responsibility of the distributor to resolve. UK Power Networks has comprehensive processes to identify, investigate and resolve such situations, ensuring that payment of the electricity taken is made at the full market value.

Our key commitments are:

- Pursue cases of conveyance losses with thorough field investigations conducted in accordance with the Revenue Protection Code of Practice (DCUSA, 2013).
- 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.
- Proactively monitor the number and status of metering points registered as disconnected and de-energised by suppliers.
- Cooperate fully with ELEXON (ELEXON, 2023) audits to check settlement data and resolve any inaccuracies identified, seeking to refine internal processes to prevent their reoccurrence.
- Maintain systems to monitor the resolution of theft through new MPAN (Metering Point Administration Number) registrations.
- 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 conveyance loss cases.
- Detailed analysis to best understand causal and geographic trends.

In 2022/23 we have seen 480 cases of theft in conveyance resolved across our three licence areas, with a further 649 cases still under investigation as UK Power Networks continues to work with property owners to facilitate appropriate connection arrangements or awaiting meter point registration by the customer's chosen supplier. Whilst domestic sites represented the largest component, significant commercial and industrial sites also featured.

The overwhelming majority of cases are resolved through the customer registering their metering point with a supplier in accordance with normal industry processes. Nevertheless, in a small number of cases UK Power Networks may need to consider disconnection of the unauthorised supply. In the absence of serious safety concerns we seek to avoid enforced disconnections but our policy provides for this as a last resort to avoid the indefinite continuation of electricity theft.

Table 5 summarises key figures in respect of non-technical losses activities and projected energy savings as a result of resolved instances of theft in conveyance. UK Power Networks declared a reduction of 14,979MWh in the period between April 2022 and March 2023, above the eight year average of 8,009MWh from 2015 to 2023.

Table 5. Summary of losses costs and benefits from resolved theft in conveyance cases in RIIO-ED1

Non-Technical energy losses	2022/23 reduction	ED1 Yearly reduction	Volumes in 2022/23	
Countering Theft in Conveyance	14,979MWh	8,009MWh	Resolved cases	480
			In Progress	649

Electricity Monitoring

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 are:

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

Electricity Monitoring

Substation metering

Within a typical substation, a variety of electrical equipment such as heaters, lights, battery chargers, Transformer Pumps & Fans are supplied via incoming Low Voltage Alternating Current (LVAC) supplies. Across the UK Power Networks Grid and Primary substation portfolio, the vast majority of these sites are unmetered, with LPN being the exception where 75% of sites are metered. Our unmetered service (UMS) portfolio is the largest in the UK and accounts for 60% of UKPN's total electricity bill.

The corresponding UMS charge is calculated using a methodology of estimation based upon an assumption of the equipment installed and three corresponding archetypes (Small, Medium and Large), assigned based on the number of Circuit Breakers at a given site. One of the three archetypes and corresponding modelled electricity consumption is assigned to each substation site, which is used to calculate the total Estimated Annual Consumption (EAC).

In 2001, The Electricity (Unmetered Supply) Regulations were revised, along with Section S of the Balancing & Settlement Code (BSC), to specify that unmetered supplies were, 'only permissible where load is of a predictable nature and is less than 500W', or where it is 'technically impractical' to install a meter. Additionally, in 2020, the BSC Panel determined that Suppliers and Unmetered System Operators (UMSOs) must identify all unmetered supplies over 100kW and put in place an action plan to migrate those supplies to half-hourly (HH) settlement.

In response to these BSC revisions, a review of the UMS EAC, which had remained unchanged since 2011, was undertaken and Engineering Design Standard EDS 08-112 updated to require that all Grid and Primary substations will have metered LVAC supplies and that existing sites be converted at the earliest opportunity.

A programme of smart meter retrofit installations started in 2020 targeting the first 270 sites across EPN, LPN and SPN. Analysis of a 35 substation sample which benefited from the installation of smart meters revealed a net reduction of 126,686kWh per year and savings to consumers of £59,542. Continuing with this programme, we will be installing smart meters in the remaining 1,400 Grid and Primary substations.

Figure 14. Inside a UK Power Networks substation (Fulbourn Grid, Cambridgeshire)

Electricity Monitoring

Supplier data issues

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

Electricity Monitoring

Future areas of focus

Detecting fraud proactively allows to mitigate safety risks and financial impacts and can be performed by using network data and Artificial Intelligence capabilities.

Considering that UK Power Networks is best placed to access the necessary network data, we will analyse the cost and benefit and feasibility to proactively detect fraud on our network. We continue to monitor smart meter roll-out across our network and utilise this data together with low voltage monitoring data and data analytics to identify excessive consumption and network losses.

5.3 Managing losses through innovation

Innovation is a driving force behind our performance, ensuring that we are the safest, most reliable and cost-efficient electricity network in the UK, leading the way in tackling Net Zero and the Energy System Transition challenges, whilst protecting vulnerable customers.

To help turn this vision into a reality, our innovation strategy has focused on six fundamental themes.

Consumer vulnerability	Net zero and energy system transition	Whole energy system
Flexibility and commercial evolution (DSO)	Proactive optimised assets and practices	Data and digitalisation

Source: https://innovation.ukpowernetworks.co.uk/

Fostering a culture of innovation that serves our customers and stakeholders well, delivered by passionate people, we continue to seek new solutions that deliver further reduction in energy losses as highlighted by the following measures.

Losses mitigation measures

UK Power Networks
Delivering your electricity

Network Operation

Phase switch system (PSS)

National Grid's Future Energy Scenarios show that irrespective of the scenario, energy demand is going to increase by 25% between now and 2038. It is expected that most of the new demand will be connected to low voltage distribution networks. This in turn is likely to cause a larger phase unbalance than currently observed as domestic load is normally connected to one phase, leading to early reinforcement of the LV network.

The project demonstrated that this solution reduces unbalance between phases, leading to a reduction of the current flowing and consequential reduction in total energy losses.

Further information can be found in: Phase Switch System - UKPN Innovation (ukpowernetworks.co.uk)

Network Operation

Active response

Active Response is trialling a revolutionary way of managing spare electricity network capacity that could save customers £271 million by 2030 and cut more than 448,000 tonnes of carbon emissions by 2030.

By 2030 it is anticipated there will be up to 4.5m electric vehicles in use across London, the East and South East of England, where UK Power Networks delivers electricity. The charging of these vehicles could significantly increase the peak demand and drive higher utilisation of the existing electricity network. In order to accommodate this increased demand, UK Power Networks would traditionally reinforce the existing network assets to provide more capacity which takes time, costs money, and causes disruptions to customers.

Active Response is trialling responsive, automated electricity network that re-configures itself in real-time, moving spare capacity to where the demand is. This in turn reduces the need for network extension and the installation of new electrical assets that would otherwise increase energy losses.

Further information can be found in: Active Response - UKPN Innovation (ukpowernetworks.co.uk)

Network Planning

Loadshare

First-of-its kind in Great Britain project trialling an innovative power electronics technology to release additional capacity on the network. It has already saved our customers more than £8 million and has directly enabled enough renewable power to run an additional 45,000 homes.

LoadShare solved a critical pinch point on a 132kV power line on the Essex and Suffolk border, by allowing more electricity generated from renewable sources to feed into the system, without spending time and money building new electrical cabling and substations.

By increasing electricity generation within the distribution network, we have been able to reduce energy losses that would have otherwise been imported from the transmission network. Whilst the increased utilisation of the 132kV power line offsets the losses improvement, the overall balance is positive and the solution is therefore recommended for further deployment.

Further information can be found in: LoadShare - UKPN Innovation (ukpowernetworks.co.uk)

Network Operation

Smart Transformer (Project Stratus/Amp X)

Figure 15. Smart transformer trial in UKPN

Project Stratus will see smart electricity transformers installed in streets across East Sussex which, if successful, will provide live data on electricity usage and demand, on a scale never-before achieved, increasing network resilience and lay the groundwork for a low carbon future.

Using state-of-the-art power electronic technologies, the smart transformers can flexibly adapt to make sure power is directed when and where power it is needed, balancing load on the network, and protecting against multiple kinds of potential faults.

We expect a reduction of energy lost from built in capabilities of smart transformers, such as dynamic voltage management, avoidance of curtailment of distributed energy resources and provision of ancillary services such as synthetic inertia to the electrical network.

Further information can be found in: UK Power Networks spearheads world-first smart transformer trial | UK Power Networks

Network Planning

Low Voltage optimization: EcoVAR

Electricity distribution networks can be affected by various power quality issues, specifically voltage fluctuations and phase unbalance. This is expected to grow with the higher integration of electrical vehicles and distributed energy resources including micro generation (as per ENA Engineering Recommendation G98), domestic energy storage systems and vehicle to grid.

Figure 16. Installation of 3 phase, 3 unit EcoVAR 1

UK Power Networks and ECOJOULE Energy are carrying out a pilot programme for the installation of five EcoVAR 1 systems at key High Voltage overhead network locations. Each EcoVAR system comprises three 10kVA pole mounted power electronics STATCOM [Explainer 5] units, using reactive power compensation to actively control network voltage, resulting in a more refined automatic voltage management, reducing phase unbalance by 50% and providing fast dynamic response to wider network changes, significantly reducing customer issues.

We are also considering to pilot the second generation of the system - EcoVAR 2, a single three-phase 40kVA pole mounted STATCOM unit which also allows for transfer of active power between phases.

We expect a reduction of energy losses on the high and low voltage networks by up to 10%, by means of voltage support and reduction of phase unbalance following the installation and through the operational lifespan of the system.

Explainer 5 STATCOM
A STATIC synchronous COMpensator or STATCOM is a fast acting device capable of providing or absorbing reactive current and regulating the voltage at the point of connection to a electrical network.
Static Synchronous Compensator (STATCOM) - ENTSO-E (entsoe.eu)

5.4 Managing losses through data and analytics

We believe that the key to the Distribution Losses Strategy is a full and comprehensive electrical model of our existing distribution network with much of the information we require sitting within our existing network records system, and our existing network models.

We possess many legacy network records based on scanned of paper technical information and drawings, held in Geographical Information System (GIS) and others. Information is being digitised as part of network vectorisation programme with new installed network assets recorded in vectorised format as standard.

In conjunction with this process of vectorisation, we are moving our entire 11kV and LV network model into a single network modelling system, levering the benefits gained by digitisation. Together with detailed network measurements from smart meters and additional LV network visibility, will enable us to calculate losses for all individual components in near-real time and target mitigation efforts where they are most effective.

Data and Analytics

Computational network modelling

Computational network modelling is key to understand what will happen on our network in the future and determine what is happening on the unmonitored parts of the network. Modelling is a comprehensive virtual electrical equivalent of the distribution network, used to determine the most efficient customer point of connection, within required parameters and how it changes future network performance.

By utilising modelling tools, UKPN is able to map where losses occur on the network, enabling a targeted approach to loss reduction and predict the effect of future changes so that the effect on losses of all possible future actions can be considered before changes are carried out.

Network modelling is even more useful when used in conjunction with smart meters, by providing actual data and respective network topology, real-time network models can be produced. Data at specific metering points can then be predicted and compared to the real data to validate the model, resulting in a very accurate representation of the real network.

Once this level of insight is established, it will be possible to accurately calculate energy losses across the entirety of the network, create more targeted losses strategies, leading to far more effective loss reduction measures.

Data and Analytics

Learning from smart meters

Data from smart meters provides a rich source of granular data on the LV network that enables us to manage our networks in a more targeted way. Increasingly available and disaggregated data provided to DNOs replaces previously used estimates, based on typical consumption data, with actual data and underpins our plans for a dynamic approach to managing our networks and loss reduction.

Our International Best Practice Report for Smart Meters *(UKPN, 2018)* built our understanding of global best practices. This looked at international experiences highlighted the use of smart meter data to:

- Optimise distribution transformer sizing.
- Facilitate Normal Open Point (NOP) optimisation in our HV and LV networks.

- Drive load flow analyses to highlight energy loss hotspots in our networks.

Further to the adoption of smart meter, we have seen an increase in customer participation driven by price signals such as time of use tariffs, to reduce their energy costs. The change in the consumption profile resulting from a large numbers of customers responding to such price signals changes the pattern of load on the distribution network driving higher utilisation of parts of the LV network, thereby affecting the energy losses and the way in which distribution and transmission operators manage network assets.

Figure 17. Home smart Meters

Data and Analytics

LV monitoring rollout

Improving the monitoring of the Low Voltage network is key to a smarter electricity network which responds to swiftly changing electricity demand and generation. Improvements to our digital architecture mean we can now collect and store more data to gain a better live picture of how our network is performing.

We are investing to install strategically targeted low voltage monitoring equipment in thousands of substations that will are affected by the rapid uptake of low carbon technologies, like electric vehicles and heat pumps. The data produced through the programme will give us early sight of potential challenges on the network, improve the visibility of network losses, maximising network efficiency to keep costs low whilst ensuring our network is Net Zero ready.

Data and Analytics

Envision LV network insight

Envision is developing a software based machine learning tool that will generate greater Low Voltage (LV) network insights faster and cheaper compared to traditional methods of physical monitoring. The project is a key step to widening the flexibility market and building a smart grid that enables cleaner, greener energy resources to connect quicker and at lower cost.

Better forecasting allows us to plan ahead and invest strategically to facilitate the Net Zero carbon emissions revolution, by identifying low voltage network locations that operate with a high utilisation factor and better target losses reduction investments.

Further information can be found in: Envision - UKPN Innovation (ukpowernetworks.co.uk)

6 Progress of losses mitigation measures

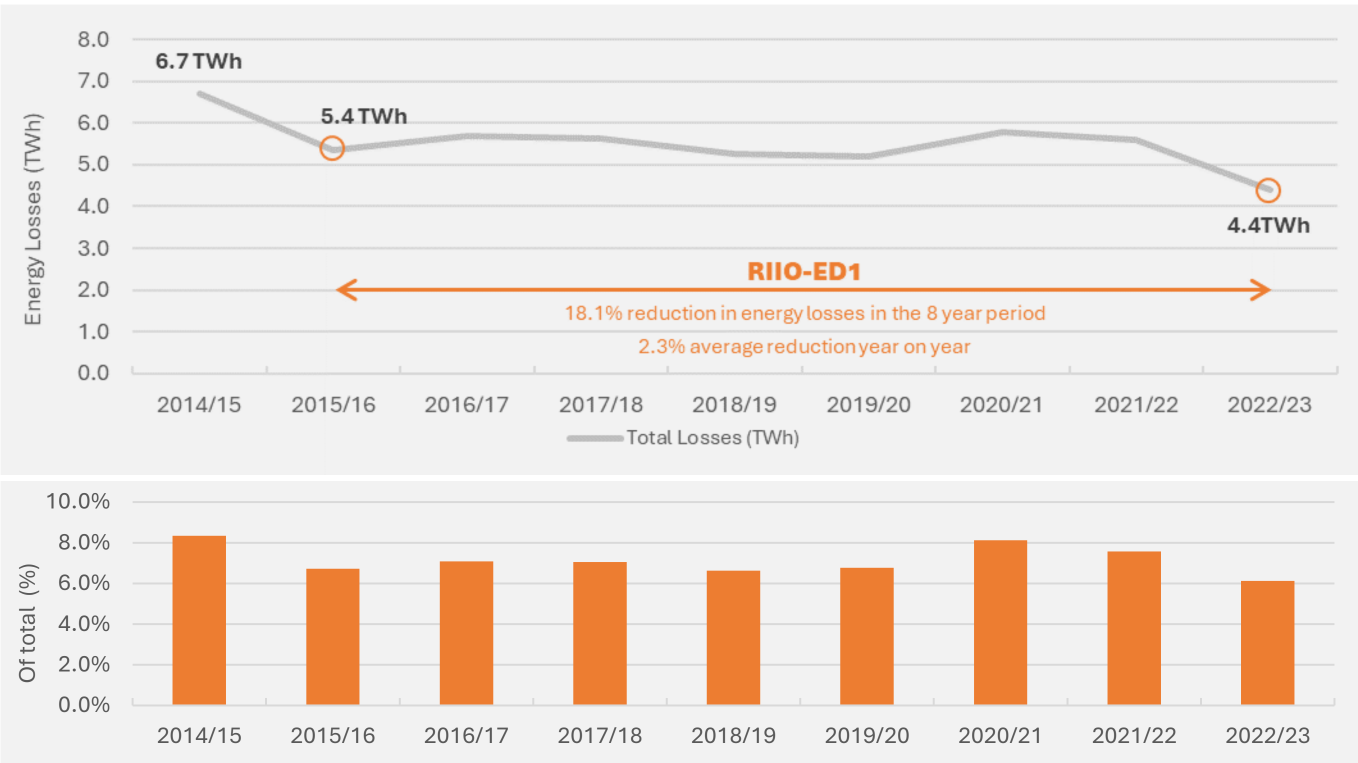
The electrical energy lost in the network represents a cost to customers and contributes to Great Britain's carbon emissions. UK Power Networks declared 4.4TWh of energy losses across all the network components in 2022, representing 21.2% of the total in Great Britain and in a reduction path of 0.4% per annum.

Our strategy for RIIO-ED2, a crucial period in the transition of our network to net zero carbon, is to embed these in our wider work programme while we continue to explore new technologies and approaches. Where the measures we identify throughout the period demonstrate a long-term benefit to customers, we will adopt them to achieve further reduction in losses.

6.1 Historical performance

UK Power Networks has achieved a significant and sustainable reduction in Energy losses in the period between April 2014 and March 2023, from a peak of 6.7TWh to 4.4TWh at the end of RIIO-ED1 *Figure 18*. In percentage terms, this takes from a peak of 8.3% to 6.1% of the total energy distributed, a continuous reduction with the exception of 2021 and 2022, years of recovery from COVID-19.

Figure 18. UK Power Networks Energy Losses to the end of RIIO-ED1 – March 2023 (Value and percentage)



High penetration of Low Carbon Technologies as part of the transition to Net Zero and the influence of political incentives and market trends will likely alter the energy losses reduction forecast. Nevertheless UK Power Networks will continue to focus on the downward path of minimizing energy losses on our network, where reasonably practicable and cost effective, further reducing our carbon footprint and passing on the savings to our customers.

6.2 Alignment with sustainability strategy

UK Power Networks sustainability strategy (UKPN, 2023) fulfils an annual requirement under standard condition 47 (Environment Reporting) of the Electricity Distribution Licence and is been prepared on a yearly basis for the three licensed distribution companies, and used to update stakeholders on the performance across the key environmental measures we work to and our efforts to deliver environmental benefits for our customers and the wider communities in the regions we serve.

Figure 19 shows a summary of total energy losses, both technical and non-technical, on our networks and business carbon emissions from data that has been developed from RIG table E3 – BCF worksheets.

Figure 19. Summary of losses per year and licence area

DNO	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
Total losses (tCO_2e)									
EPN	1,178,316	1,034,381	1,016,939	838,822	603,788	448,578	607,329	531,037	359,902
LPN	913,887	880,009	779,598	644,058	503,865	495,864	407,761	341,426	290,718
SPN	663,791	559,249	541,021	489,723	379,314	380,844	328,261	313,823	196,685
Total losses (GWh)									
EPN	2,860	2,238	2,468	2,386	2,133	1,755	2,605	2,501	1,861
LPN	2,218	1,904	1,892	1,832	1,780	1,940	1,749	1,608	1,503
SPN	1,611	1,210	1,313	1,393	1,340	1,490	1,408	1,478	1,017

Distribution energy losses account for 94.5% of our total Business Carbon Footprint (BCF), with the remaining elements including operational transport, temporary generation, building and substation energy usage, business travel and fugitive (SF_6) emissions.

6.3 Expected RIIO-ED2 energy losses reduction

Combining all losses mitigation measures explored in the Distribution Losses Strategy document, we see a continuing decreasing pathway for the next four years of RIIO-ED2, from the current value of 4.4TWh to 4.0TWh across a range of initiatives with an investment value of £540m over the period.

Table 6. Cumulative losses improvement for RIIO-ED2

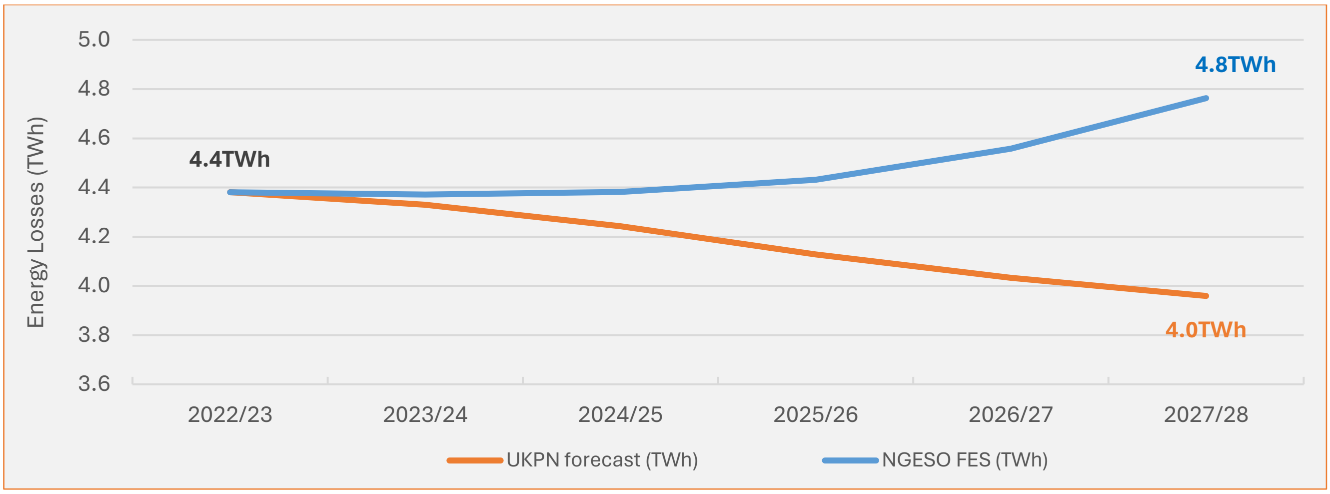
		Cumulative Improvement (MWh)				
Loss Mitigation Measure	**Voltage**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Transformers	132kV	1,000	10,270	16,967	23,905	30,003
Transformers	33kV	766	2,648	6,792	10,212	11,320
Transformers	11kV	19,141	41,300	70,447	90,183	113,599
Overhead and Underground	132kV	57	80	201	245	268
Overhead and Underground	33kV	42	122	192	227	277
Overhead and Underground	11kV	21	69	113	157	211
Overhead and Underground	LV	0	2,805	10,719	19,062	27,078
Small Section Conductors	11kV	32	104	169	235	316
Power Quality	All	255	510	765	1,020	1,275
Voltage Management	All	12,400	12,400	12,400	12,400	12,400

Progress of losses mitigation measures

Substation Metering	LV	217	434	651	868	1,085
Circulating currents	33kV	0	10,000	20,000	30,000	40,000
Other Non-Technical Losses	N/A	8,009	16,018	24,027	32,037	40,046
Base increase (NGESO FES)	All	9,562	-10,456	-49,886	-125,942	-205,450
Forecast energy losses reduction (MWh)		**51,502**	**86,304**	**113,557**	**94,609**	**72,428**

Figure 20. **UK Power Networks and FES Energy Losses forecast in RIIO-ED2**

Loss Mitigation Measure	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28
UKPN Total Losses (TWh)	4.4	4.3	4.2	4.1	4.0	4.0
NGESO FES (TWh)	4.4	4.4	4.4	4.4	4.6	4.8



7 Appendices

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Appendices

7.2 Glossary of terms

2009/125/EC	EU Directive Ecodesign of Energy Related Products
AC	Alternate Current
AMT	Amorphous Steel Transformer
APRS	Automatic Power Restoration System
AVC	Automatic Voltage Control
BCF	Business Carbon Footprint
bn	Billion
BSC	Balancing Settlement Code
CBA	Cost Benefit Analysis
CRGO	Cold Rolled Grain Oriented
CVL	Contact Voltage Losses
DC	Direct Current
DER	Distributed Energy Resources
DERMS	Distributed Energy Resources Management System
DG	Distributed Generation
DNO	Distribution Network Operator
DSO	Distribution System Operator
EAC	Estimated Annual Consumption
EED	Energy Efficiency Directive
EHV	Extra High Voltage (including 33kV and above)
ENA	Energy Networks Association
EPN	Eastern Power Network
EU	European Union
EV	Electric Vehicle
EVC	Electric Vehicle Charger
FES	Future Energy Scenarios
GB	Great Britain
HH	Half Hour
HP	Heat Pump
HV	High Voltage
HVDC	High Voltage Direct Current

ICP	Independent Connections Provider
IDNO	Independent Distribution Network Operator
kV	Kilo-Volt
kVA	Kilo-Volt Amps
LC49	Licence Condition 49
LCT	Low Carbon Technologies
LDR	Losses Discretionary Reward
LPN	London Power Network
LV	Low Voltage
LVAC	Low Voltage Alternate Current Supply
MAAV	Mobile Asset Assessment Vehicle
MPAN	Meter Point Administration Number
Mt	Megaton
NGESO	National Grid Electricity System Operator
NOP	Normal Open Point
NPS	Negative Phase Sequence
NPV	Net Present Value
RIG	Regulatory Instructions and Guidance
RIIO	Revenue = Incentives + Innovation + Outputs
RIIO-ED1	RIIO Electricity Distribution - Price Control Period between April 2015 and March 2023
RIIO-ED2	RIIO Electricity Distribution - Price Control Period between April 2023 and March 2028
RMU	Ring Main Unit
SPN	Southern Power Network
SSC	Small Section Conductor
THD	Total Harmonic Distortion
TWh	Terawatt hour
UK	United Kingdom
UKPN	UK Power Networks
UMSO	Unmetered Supplies Operator
V2G	Vehicle to Grid

Appendices

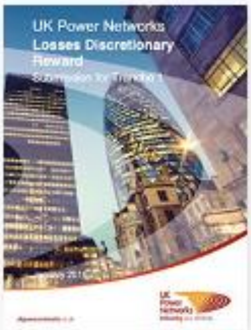
7.3 The learning so far

UK Power Networks Distribution Losses Strategy

November 2021

UK Power Networks Distribution Losses Strategy

July 2019

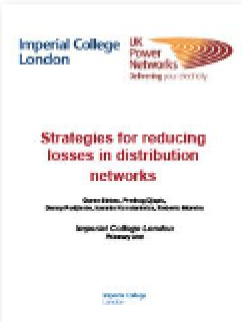


UK Power Networks Losses Discretionary Rewards Tranche 1

January 2016

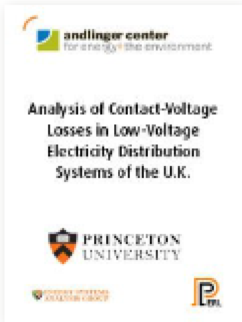
UK Power Networks Losses Discretionary Rewards Tranche 1

February 2018



Strategies for reducing losses in distribution networks

February 2018

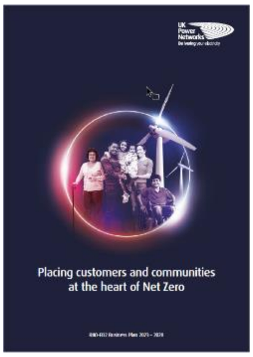


Analysis of Contact-Voltage Losses

January 2018

UK Power Networks Business plan

2015-2023



UK Power Networks Business plan

2023 – 2028

This document serves as an update to UK Power Networks Losses Strategy in accordance with section 49.5(b) of the Standard conditions of the Electricity Distribution Licence.

We have undertaken a complete revision of the 2021 Distribution Losses Strategy, detailing activities to reduce and manage electricity network energy losses. During RIIO-ED1 we have assessed these activities and prioritised those that are viable and cost effective, continuing their adoption in the RIIO-ED2 price control period that started on the 1st of April of this year.

We believe that these changes make it very clear to the reader what we are doing to reduce or manage losses and that identified activities are based on up to date cost benefit analyses.

UK Power Networks Holdings Limited

Registered in England and Wales No. 7290590
Registered office: Newington House,
237 Southwark Bridge Road, London SE1 6NP

www.ukpowernetworks.co.uk

UK Power Networks Holdings Limited is the holding company
of the companies in the UK Power Networks group of companies