UK Power Networks
Delivering your electricity

Losses Discretionary Reward (LDR)
Tranche 3 Submission

THE SUNDAY TIMES 25 BEST BIG COMPANIES TO WORK FOR 2019

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Contents

1 Executive Summary

Our approach to managing and reducing distribution losses is founded on our overall vision, values and strategy. We want to be a top-class performer. We want to be an employer of choice, a responsible and trusted corporate citizen and sustainably cost efficient. Losses represent a substantial but under-appreciated burden on customers and society. Our corporate strategy therefore demands we do our utmost to minimise losses: a goal reflected in our Distribution Losses Strategy: the most recent version was published in July 2019.

During RIIO-ED1 we have taken forward a large number of initiatives in line with our strategy. Some of these are ground-breaking worldwide. All of them are designed to extend the boundary of best practice and ultimately to make it business as usual. They have resulted in tangible learning about losses and tangible benefits for customers. They have delivered better outcomes for customers, other stakeholders and the environment or have the potential to do so. Many of our initiatives are driven by a holistic view of the impact of losses. What we do to manage distribution losses impacts generation, transmission and supply. Customers do not see the sources of losses upstream from their meters, just the units that they pay for. Our initiatives in RIIO-ED1 therefore emphasise collaboration for a holistic loss reduction.

Learning is central to our approach. We see learning and leveraging outcomes from that learning as a continuous process. Our learning activities result in new knowledge, new insight, and actionable recommendations which drive benefits directly (e.g. lower distribution losses) or indirectly (e.g. via knowledge transfer, lower wholesale prices or lower transmission losses, or by highlighting areas we need to understand better). We have engaged widely with our peers to share our learnings and to learn from others. Many of the initiatives here are founded on substantive benchmarking and research activity early in RIIO-ED1. We have successfully leveraged much of this learning. For example, the researchers from Imperial College London (who worked independently through Imperial Consultants) brought the value of Normal Open Point (NOP) optimisation to our attention during Losses Discretionary Reward Tranche 1. During Tranche 2, we leveraged this knowledge to the point where we are actively decreasing losses by shifting NOPs between HV feeders.

This submission makes the case that we should be rewarded under the LDR incentive. It describes the specific initiatives which we believe are exceptional and why and provides evidence to support this which refers to the four specific criteria that Ofgem sets out. We have formed our own judgement of which ones contribute most strongly to our case and they are:

- Trialling the use of amorphous steel in transformers to achieve substantial efficiencies;
- Detection of Contact Voltage Losses (CVLs) using a specialist Mobile Asset Assessment Vehicle (MAAV) which detects energy leaking from defective underground cables;
- Optimising the configuration of NOPs in our HV networks;
- Building a robust new Cost Benefit Analysis (CBA) approach to support conductor upsizing; and
- Identifying how we can target losses differently using a time-weighted cost benefit approach.

There are several other initiatives which make a lesser contribution but nonetheless support our case and these are also included in the submission. They all contribute to reducing losses which is the ultimate goal. Together we expect the initiatives that we describe here to contribute around **58,500 MWh** per annum in loss reduction by the end of RIIO-ED1. At the end of Tranche 2, the initiatives that have already been implemented were worth **3,671 MWh** per annum: customers are benefitting now. Our work now will also lay the foundation for RIIO-ED2 and this submission describes how.

Ofgem has been clear that there should be a high bar for a successful award under the Losses Discretionary Reward (LDR). We agree. Any reward is paid for ultimately by customers. It is therefore right that the standard for awarding it should be high and should reflect work done or in progress which has or will contribute strongly to customers' benefit.

Under any regulatory incentive mechanism there is a question of how reward will be used. Distribution losses are significant and are a loss to customers. There is much still to discover and do to reduce them and it is our clear strategy to reduce them as far as possible. Therefore, should we be successful we would propose to re-invest 100% of the reward proceeds to drive future loss reduction as we did in Tranche 1.

2 Introduction

This submission provides evidence about the learning, engagement, activities, processes and innovation throughout RIIO-ED1 and how these have already or will benefit customers.

Table 1 lists the initiatives which support our case for a reward. Each of these is exceptional in some way. For each we have indicated our view of the strength of its contribution, considering whether they:

- have led to ground-breaking new knowledge or its application of knowledge;
- accelerate the adoption of exceptional initiatives into business as usual;
- extended the reach of our work across other DNOs or holistically across the energy value chain; and
- have involved the committing of material resources not funded under RIIO-ED1 regulatory mechanisms.

All of the initiatives provide a foundation for improvements through Tranche 3 and RIIO-ED2. Throughout our submission we also refer to other actions embedded in BAU processes, which have provided a solid platform to enable our more transformative and innovative actions.

Table 1

Key actions and initiatives

PAGES	NAME	ANNUAL MWH	LDR CASE	TIMING/STATUS
11, 19, Appendix A1	Use of MAAV to detect CVLs	42,300	H	T2 BAU London
				T3 Business case: 2 more vehicles + extend; trial differential metering[1]
				ED2 BAU
20, Appendix A1	NOP Optimisation	10,000	H	T3 Optimise HV, Trial LV
				ED2 Implement LV, dynamic optimisation
12, 14, Appendix A1	Amorphous steel transformers	1,400	H	T3 BAU 50 kVA. Trial 25-200 kVA Pole Mounted
				ED2 BAU
11, 14, Appendix A1	Conductor cross-sectional size optimisation	4,800	H	T3 Business Case
				ED2 Implement, BAU
20, Appendix A1	CBA for transformer size optimisation	130	M	T2 BAU
8, 10, 14, Appendix A1	Power Potential for Loss Management	TBD	M	T3 Trial
				ED2 BAU
8	Improve Grid and Primary Transformer Efficiency	TBD	M	T3 Business Case
				ED2 Implement, BAU
8, 14	Flexibility markets for loss management	TBD	L	T3 Trial
				ED2 BAU
8, Appendix A1	Upgrade 6.6kV lines	360	L	T3 Business Case
				ED2 Implement, BAU
17	Time of Day CBA for decision-making, incentives	Enabling	H	T3 Trial
				ED2 BAU
7, 15, 17, Appendix A1	Integrated Loss calculations in Active Network Management	Enabling	M	T3 Business case, trial
				ED2 Trial, implement
15, 16, 17	Improved project and portfolio management tools	Enabling	M	T2 BAU
7, 15, 17, 20, Appendices A1 & A3	Smart meter data exploitation	Enabling	L	T3 Business Case, Trial
				ED2 Trial, Implement

1 "Differential metering" compares aggregated downstream consumption to upstream measurements to detect energy losses.

Note on headings: Appendix A1 contains project synopses. **Annual MWh** is the estimated annual loss reduction in RIIO-ED2. We do not quantify a loss benefit for enabling initiatives. **LDR case:** is our evaluation, referred to above. **Timing/status** indicates when this initiative began and its current status.

In the remainder of our submission: **Section 3** summarises the strategic context for loss management; **Section 4** summarises the benefits to customers over the course of Tranches 1 to 3; **Sections 5 to 8** examine Ofgem's four criteria in detail and substantiate our case for reward against each; the Appendices provide more detailed information. We refer throughout this submission to research, benchmarking and other reports. These are available on our Losses Webpage and links to the specific reports are provided.

3 Our strategy for managing losses

We published the latest version of our Distribution Losses Strategy in July 2019 setting out the context for our loss reduction activities, the scale of the issues and strategic approach. Our thinking is developing all the time and we continue to make tangible progress towards reducing losses. This submission therefore contains elements of new thinking, new initiatives which go beyond or add depth to our strategy and explains where we have actioned some of our strategic commitments or made plans more concrete. This Section therefore briefly summarises our strategy: why losses are important, our strategy to reduce them and what is new in this submission.

3.1 Why losses matter

Losses arising from electricity distribution through power networks represent a substantial but under-appreciated burden on customers and society. Customers pay for losses in their energy bills. We estimate that the power required to cover energy losses in our electricity networks costs approximately £300m every year. Unnecessary additional costs adversely affect customers with that burden being felt more greatly by those in fuel poverty. The need to cover energy losses drives more capacity to generate additional power and increased capacity in downstream transmission and distribution networks to convey more energy; this capacity requires substantial investment and has an environmental cost. Lower losses is particularly worthwhile during peak demand periods: energy prices are the highest at these times, and so are the energy losses in distribution networks.

Our energy system is in transition. We have already seen a radical change to the generation mix with renewable sources becoming a major source of power, at times the only source, with carbon-intensive generation declining in scale. The government's commitment towards net-zero by 2050 will drive huge changes, in particular from the de-carbonisation of transport and heat. This will have pervasive impacts on our energy networks. On top of this, 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. Consumers are changing their behaviour in response to all of this. Much is business as usual but will only increase in scale and continue to change quickly. This means that the energy landscape is becoming increasingly complicated and increasingly 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. Our aim is to make sure we are at the forefront in meeting the challenges and realising the opportunities.

3.2 Our Distribution Losses Strategy

Our Distribution Losses Strategy is built on our corporate vision, values and strategy. We want to be a top-class performer. We want to be an employer of choice, a responsible and trusted corporate citizen and sustainably cost efficient. This means that we seek to do what is right for our customers by providing them with the best possible service at the best possible price. We aim to be as efficient as possible. We seek to limit the environmental impact arising from our business activities. And we must keep innovating to secure these goals, as explained in our Innovation Strategy.

Given the importance of losses for customers and society, our corporate strategy therefore demands we do our utmost to minimise losses.

Our Distribution Losses Strategy sets out our vision and objectives for energy loss management. Our vision is to lead in the creation of energy efficient distribution networks in Great Britain. The three objectives which will drive us towards the vision are to:

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

All of the actions initiatives and plans discussed in this submission contribute to our achieving these objectives but it is worth highlighting a number of the key themes:

- Dynamic management and control of networks based on the granularity that smart meter data brings;
- Exploiting new sources of data including smart meters and new ways of analysing it;
- Holistic approach to understanding and managing losses. We endeavour to stretch the influence of our strategies and actions across the boundaries of our networks to benefit the wider interests of the UK and its people;
- Optimising our physical networks and the efficiency of individual assets embedded in these networks;
- Maximising the loss reduction opportunities from using flexible distributed generation and in moving to a distribution system operation model;
- Effective collaboration with our peers, across the energy system and internationally;
- Continuous learning and collaboration;
- Robust processes and better decision-making tools to deliver benefits in the shortest time possible; and
- Our work is driven by a genuine concern for society and the environment.

3.3 How this submission enhances our Distribution Losses Strategy

Specific initiatives which go beyond our July 2019 Distribution Losses Strategy illustrate that our work is dynamic and responsive to new learning, including:

- Using smart meters and LV monitors to complement the use of our MAAV in detecting CVLs and identifying non-technical losses;
- Enhanced CBA to improve energy efficiency when we renew or upgrade distribution transformers (Section 8.3 refers);
- Accelerating our trial of 25 kVA up to 200 kVA pole mounted amorphous steel transformers;
- Better CBA to optimise the cross-sectional sizes of HV and LV conductors;
- Use of flexibility markets to target loss reduction;
- Building the business case for upgrading 6.6 kV networks; and
- Automating of NOP optimisation.

4 Delivering for customers during RIIO-ED1

Over RIIO-ED1 we have already delivered tangible loss reductions for customers.

Table 2 shows the reductions by Tranche. Loss reductions in Tranches 1 and 2 are the annual amounts estimated to have been realised at the end of that Tranche. The Tranche 3 figures are forward estimates of the annual reduction.

Table 2 shows that the scope of our actions has increased and will continue to grow in Tranche 3 and beyond. The energy savings impact shown here are for a single year. The impact stated of most will grow significantly over time, for example as improved asset specifications start to proliferate.

Table 2

Annual value of interventions in MWh after Tranches 1-3

INITIATIVE	END OF TRANCHE 1	END OF TRANCHE 2	TRANCHE 3 (ESTIMATED)
Use of MAAV to detect CVLs		1,802	42,300
NOP Optimisation		100	10,000
Amorphous steel transformers	32	32	1,400
CBA for transformer size optimisation		130	130
Flexibility markets for loss management			TBD
Power Potential for Loss Management			TBD
Conductor cross-sectional size optimisation	727	1,607	4,800
Upgrade 6.6kV lines			360
Improve Grid and Primary Transformer Efficiency			TBD
Annual totals	**759**	**3,671**	**58,512+TBD**

5 Our approach to understanding losses

This Section provides evidence about our learning and how it has improved our understanding of losses.

5.1 Overall learning strategy and direction

Securing lower losses requires us to increase our understanding of how and where they arise, and how best to tackle them. Our learning about losses fits within UK Power Networks' overall approach to learning and insight. It involves:

- Benchmarking and high-quality best practice and academic research;
- Collaboration to understand and share best practice, to generate new ideas and solutions;
- Embedded innovation and a problem-solving culture;
- Learning by doing;
- Data exploitation (smart meters and use of statistical techniques);
- A holistic approach – looking beyond DNO boundaries; and
- Developing insight, testing, trialling and capitalising on new findings.

5.2 Summary of the key learning initiatives and their tangible outcomes

Key learning initiatives from Tranches 1 and 2 are set out below. This is not all the learning we have or will undertake, because much of our learning is organic but the table highlights some specific and important initiatives.

Table 3

Learning in Tranches 1 and 2

LEARNING INITIATIVE	LEARNING PARTNERS	KEY LEARNING	LEADING TO...	MORE INFORMATION
TRANCHE 1				
International Best Practice Report: Network Losses	Own research	Optimal EHV network configuration Increasing HV voltages Improving distribution transformer efficiency Altering demand profiles to decrease losses	Network topology research Optimised transformer sizing Amorphous steel transformers Using flexibility markets to influence losses	Report
Loss Reduction Strategies	Researchers from Imperial College London	The value of HV feeder reconfiguration	Using DPlan to drive calculations and reconfigure feeders Using smart meter data to inform network reconfiguration though our Active Network Management System (ANM)	Report
CVLs	Princeton University	Theoretical underpinning and quantification of CVLs	Deployment of MAAV to detect losses and validate theory	Section 8.1 Report
KASM	Bigwood Systems Inc.	The value of automated load flow calculations to optimise network configuration	Proposals to use our ANM to optimise network configuration in real time	Report
International Best Practice Smart Meters	Own research: International Best Practice	Using differential metering to detect losses Using smart meter data to optimise transformer and conductor sizes	Proposal to use smart meters and LV monitors to detect CVL and enhance MAAV coverage	Report

LEARNING INITIATIVE	LEARNING PARTNERS	KEY LEARNING	LEADING TO…	MORE INFORMATION
TRANCHE 2				
CVL	On the ground trialling Osmose Utility Services	Validation of CVL loss theory. Detailed understanding of loss characteristics New business processes	Potential for differential metering to better target CVL detection Extension of BAU operations and improved business cases	Section 8 Appendices A1, A2, A3
Power Potential Losses Project	Researchers from Imperial College London	Using distributed generation to manage system voltages can affect losses	We can utilise the project's market platform to decrease losses when voltage management services is not required	Section 5.5 Section 7.2.4 Appendix A1 Report
Network Topology	Researchers from Imperial College London	Potential of specific network re-configurations to reduce losses	We will consider the potential for targeting investment in our networks based on better understanding of the loss benefits	Section 5.6.1 Appendix A1 Report
Studied losses in HV and LV underground feeders	Own research and development	Use of statistical techniques to overcome data scarcity	Proposal to create new investment cases for overhead conductors in Tranche 3	Section 7.2.2 Appendix A1

5.3 Improving our understanding of losses

We continue to improve our understanding across all network levels and loss types. Table 4 shows how our understanding has developed and provides evidence that we continue to seek the maximum value from our learning, showing:

- Learning from Tranche 1
- Learning outcomes from our work in Tranche 2
- Interventions we have made in Tranche 2 as a result or expect to make in Tranche 3.

It does not convey the depth and richness of the research effort we have undertaken: but it shows evidence of continued progress in (i) developing our understanding and (ii) actually exploiting that understanding for tangible benefit.

Table 4

Knowledge increase over Tranches 1 to 3

NETWORK LEVEL	TRANCHE 1 LEARNING	TRANCHE 2 LEARNING	INTERVENTIONS
Losses in LV networks	36-47% of losses Key opportunities from benchmarking Losses impact of: – Phase imbalance – Poor power factor Conductor size (significant) and tapering (adverse) Low Carbon Technology (LCT) uptake Harmonic distortion (negligible)	Robust relationship of Load Loss Factor and customer numbers Statistical approach towards LV feeder size optimisation and cost benefit assessment Progressed work on how aggregated smart meter data could address LV loss issues	T2: More accurate CBA to optimise underground conductor design standards T3 planned: – More accurate CBA methodology to upsize overhead conductor design standard sizes[2] – Explore NOP Optimisation for LV

2 We discuss the work that we have done to better understand the benefits obtainable from increasing conductors' cross-sectional sizes in Appendix A1.

NETWORK LEVEL	TRANCHE 1 LEARNING	TRANCHE 2 LEARNING	INTERVENTIONS
Losses in HV networks	17-27% of losses Key opportunities from benchmarking Losses impact of: – Phase imbalance – Voltage optimisation Academic work: NOP Optimisation highlighted by Imperial's researchers	Statistical approach towards HV feeder size optimisation and cost benefit assessment New CBA to optimise underground main line sizes NOP Optimisation (manual calculations using DPlan) Quantified the energy savings obtainable from upgrading 6.6kV networks to 11kV (Imperial's researchers)	T2: More accurate CBA to optimise underground conductor design standards T3 planned: – Test economic viability of upgrading 6.6kV networks – Use ANM to reconfigure HV networks automatically
Losses upstream from HV networks	17-24% (Imperial's researchers)	Network Topology Study (Imperial's researchers) highlighted: – The value of replacing old power transformers with Eco 2021 units – Quantified the loss reduction obtainable from upgrading 33kV lines to 132kV – Using Future Energy Scenarios to determine optimum power transformer sizes to minimise losses Using the Power Potential Market Platform to reduce energy losses	T3: – Test CBA to improve Grid and Primary transformer efficiency – Test CBA to expedite power transformer replacement – Develop new CBAs to optimise EHV conductor sizes – Test the use of flexibility markets to influence system-wide losses – Establish firm nexus between pricing and variable losses to alleviate losses and consequently, pressure on generation during peak demand periods
No-load losses in distribution transformers	7-10% (Imperial's researchers)	Amorphous steel PMTs	Trial amorphous steel transformers Adopt Eco 2021 specifications
Load losses in distribution transformers	9-13% (Imperial's researchers)	Optimised transformer sizing	Optimised transformer sizing continued
CVLs	590,000 MWh per annum in Britain (Princeton University)	Continued using our MAAV and confirmed the accuracy of previous academic research.	T3 planned: Develop the use of smart meters and LV monitors combined to detect CVL and illegal consumption

It is worth noting that in some cases learning or opportunities that were identified have not been taken forward, which may have been for a variety of reasons. For example, we found that power factor correction is infrequently economically viable. See Appendix A4.

5.4 Learning from Smart Meters

Data from smart meters will provide a rich source of granular data which should enable us to manage our networks in a more targeted way. It will enable us to replace estimates of consumption data with aggregated actual data and underpin our plans for a dynamic approach to managing our networks and loss reduction.

Our International Best Practice Report for Smart Meters during Tranche 1 built our understanding of global best practices. This looked at experience in **Poland, Italy, Portugal, Canada and the USA**. It highlighted the use of smart meter data to:

- optimise distribution transformer sizing;
- facilitate NOP optimisation in our HV and LV networks; and
- drive load flow analyses, which will enable us to highlight lossy hotspots in our networks.

During Tranche 2 we built on this by identifying opportunities to locate CVLs and illegal consumption by comparing aggregated smart meter data to upstream measurements from our LV monitors. Section 8.1 elaborates.

During tranche 3 we will continue to prepare to use smart meter data to drive load flow analysis in our ANM. This approach will enable us to understand the distribution of losses in our networks across space and time. One loss reduction initiative that will benefit is NOP optimisation. See Section 8.2 and Appendix A3 for more details.

5.5 Holistic approach to losses

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.

During Tranche 1, Imperial's researchers identified that reducing losses in our networks by 1% could simultaneously reduce the (smaller) level of losses on National Grid's network by 5.5%. We propose to use this insight on the wider impact of losses to help account for loss improvements beyond our own networks in deciding on interventions: to factor them into our cost benefit analyses.

During Tranche 2 we progressed an innovative approach to managing losses across distribution and transmission systems, the Power Potential (Losses) project, which is looking at the potential role of distributed generation in providing voltage control services to the system operator.

> We understand how the Power Potential platform might be used to manage distribution losses in a world where distributed generation provides voltage support.

We are looking to use the opportunity to understand how losses might be impacted in both distribution and transmission networks. We worked with Imperial's researchers to assess the impact of the use of distributed generation. It highlighted, for example, that optimising our transformers' tap settings would impact losses in both networks and that the Power Potential market platform could be used to secure a distribution loss reduction of up to 1.3% in EHV networks. Full details of the Project can be found at Section 7.2.4 and in Appendix A1.

Further evidence of holistic thinking comes from our use of a time-weighted CBA approach that will help to justify investment or interventions to reduce losses at peak times and also alleviate peak demand from generation and potentially reduce and defer investment. It will provide a strong foundation for the use of flexibility markets to influence losses during peak demand periods. See Section 7.5 for further details.

5.6 Ideas which could deliver customer benefit in RIIO-ED2

We elaborate throughout this report where and how our initiatives will help preparations for RIIO-ED2 (from our perspective and also from an industry perspective). We highlight here three examples, not discussed elsewhere, where our learning has identified opportunities which are more radical or difficult to achieve but could deliver substantial benefits.

5.6.1 Network Topology

International benchmarking in Tranche 1 led to our Network Topology project in collaboration with researchers from Imperial College London during Tranche 2 to identify specific opportunities and the losses benefit. One example was amorphous steel transformers, discussed in Section 7.2.1 and Appendix A1. It also highlighted opportunities from network investments:

- Upgrading 2,015 km of our 6.6 kV circuits to 11 kV could potentially save 16,000-23,000 MWh/year; and
- Upgrading 10,750 km of 33 kV circuits to 132 kV could potentially save between 220,000-400,000 MWh/year.

We will explore these business cases in preparing for potential investment in RIIO-ED2.

5.6.2 Grid and Primary Transformer efficiency

Beyond our work on amorphous steel to increase transformer efficiency (see Sections 6.3.4 and 7.2.1), we have also been working on an idea to reduce the size of grid and primary transformers through the use of cooling technology intermittently to cope with the additional heat which a smaller tranformer would produce during contingency situations. This could potentially be cost beneficial when cooling is required infrequently, e.g. when there is more than one transformer at a site for redundancy. The benefit would be the lower constant losses produced by a smaller unit. This idea is at a conceptual stage and will be developed further as to its technical feasibility and business case in Tranche 3.

5.6.3 Enabling flexibility to emulate ripple control

International benchmarking drew our attention to the use of ripple control in **New Zealand** to reduce losses. Ripple control enables remote switching of customer loads to deal with system conditions in a way which does not impact the customer experience. This can allow deferral of system upgrades and help to lower energy losses due to lowered load profiles. Implementing such a measure would require appropriate commercial arrangements with customers and the installation of additional equipment at customer premises. We will explore this alongside use of flexibility markets and a time-weighted cost benefit approach (see Section 7.5) to influence load profiles.

6 Effective Engagement & Sharing Best Practices

In this Section we provide evidence about our approach to engagement with partners and stakeholders.

6.1 Summary of our engagement activity

We have engaged with and continue to engage with national and international stakeholders to:

- obtain fresh ideas that we can rapidly translate into benefits for customers;
- understand how losses occur at various levels in our networks;
- increase what we are able to do to help the environment; and
- stretch the positive impact of our knowledge and activities beyond the boundaries of our networks.

We summarise below our engagement with key stakeholders.

Table 5

Summary of engagement activity

STAKEHOLDER	AREA	TRANCHE	KEY OUTCOMES	FUTURE
International Utilities Working Group CKI Group	International benchmarking	T1	New loss reduction strategies identified	Further work to validate/ implement ideas
Universities, Research Bodies, Consultants	Loss reduction strategies Loss quantification CVL	T1, T2	New potential loss reduction strategies and techniques validated and quantified The existence of and scale of CVLs understood Potential for CVL control identified	Further exploitation of ideas raised by these reports. Operationalisation of CVL reduction
National Grid	KASM Network Losses Project Power Potential	T1, T2	Analyse optimal network configuration Analyse potential for loss management using Power Potential market platform	Trial market platform for loss management once implemented
Transformer Manufacturers	Amorphous steel transformers	T1, T2	Specify and build 50 kVA PMTs for trials Specify and build 25-200 kVA PMTs for upcoming trials	All investment in 25-200 kVA PMTs will be amorphous steel by end of RIIO-ED1 Further work on increasing grid and primary transformer efficiency
Individual DNOs	NPg: Amorphous steel transformers	T2	Shared work on PMTs (UK Power Networks) and GMTs (NPg)	Trial and procure amorphous steel GMTs in T3
ENA Technical Losses Task Group	Improved CBAs	T2	Sharing of key knowledge e.g. CBA methodology	UK Power Networks promoting standardised CBAs and technical peer review

The quality and productivity of our stakeholder relationships over RIIO-ED1 is a step-change compared to past experience. Some of the relationships have been exceptionally productive in creating new knowledge and new applications of knowledge in loss management. None of the initiatives discussed in this Section have been considered or rewarded via the Stakeholder Engagement Incentive that forms part of the Broad Measure of Customer Service.

6.2 Our partners

6.2.1 Benchmarking and research partners

Over the course of RIIO-ED1 we have collaborated with our peers internationally and nationally to understand actual and "best" practice in other networks. We have also formed productive partnerships with top universities and consultancies to discover, research and validate new and emerging ideas, technologies and strategies for reducing losses on our and others' networks.

Many of the ideas we have taken forward during RIIO-ED1 originated from two international best practice studies, one into energy loss management and a second into smart metering. Relationships with other members of the **International Utilities Working Group**[3] (IUWG) and other businesses in the CKI group shaped the success of these exercises and continue to provide valuable insight. We think that our international work has broken new ground. Our access to CKI companies is unique: it enables us to access the experience of electricity distribution businesses outside of Great Britain together with other businesses across the energy value chain.

International research on smart metering led us to discover the use of differential metering to detect non-technical losses.
International benchmarking highlighted the potential of transformer efficiency, HV network voltage increase and load profile alteration to reduce losses.

Research and benchmarking is now business as usual for us. We continue to seek new approaches, innovations and ideas, and understand emerging best practice. Using a structured approach, we will ensure that we commit resources effectively and ensure we efficiently target our work throughout Tranche 3 and beyond.

We have worked closely with researchers from **Imperial College London** on several initiatives, including a major study of potential distribution loss strategies (see Table 4). We also held a Losses Conference in 2017 attended by a wide range of industry experts including network operators, manufacturers, consultants, academia and Government bodies both to disseminate our learning and generate new insight. More recently we have been working with Imperial's researchers to understand how the use of distributed energy resources for voltage management in the National Grid might impact losses on distribution and transmission networks and how we might use the Power Potential market platform to reduce losses.

We partnered with the **University of Strathclyde** on an empirical evaluation of a losses reduction strategy based on LV network voltage optimisation.

See Appendix A1 for detailed project descriptions for CVL and Power Potential

A detailed theory of CVLs was developed in conjunction with **Princeton University's Andlinger Centre for Energy and the Environment.** This included detailed analysis of the typical levels of fault current associated with CVL defects, as well as projections of the magnitude of CVL in Great Britain.

Our academic partners have played a key role in enabling us to expand our knowledge and capabilities beyond business as usual activities and have provided a wealth of ideas. We quickly prioritised and acted on the most promising ones and expect to be able to further exploit them over Tranche 3 and into RIIO-ED2. We will continue to collaborate with academic partners where that is the best way of extending our knowledge.

Our partnerships have delivered distinctive outputs over RIIO-ED1, being both very extensive and unusually productive, including the discovery of genuinely new understanding with substantial potential for reducing losses.

6.2.2 National Grid

As a network owner and a system operator at the transmission level, actions of companies within the National Grid group may have a direct impact on distribution losses in our networks. The reverse is also true. National Grid is therefore an essential partner in taking a holistic approach to loss management. Over RIIO-ED1 we have increased the level of co-ordination of our activities including both day-to-day operations and in development of new loss management strategies.

In Tranche 1 the Kent Active System Management project established an Inter Control Centre Protocol (ICCP) link between the control rooms of UK Power Networks and National Grid. The link enabled our respective control rooms to share data on our respective networks to aid network control operations.

The ICCP link was paid for with innovation funds but we committed additional resources to enhance the losses modelling component. The ICCP link informs the approach that we are planning to pursue for Power Potential in the future. See Section 7.2.4 for more on how Power Potential could reduce losses. We are also exploring whether we can co-ordinate our loss reduction actions with those of National Grid more generally. See Appendix A1 for details of the KASM and Power Potential projects.

In undertaking this work we have enabled the first important steps in reaching a truly holistic integrated approach to loss management across transmission and distribution. We believe that this is both innovative and beyond what would be expected.

3 UWG members include EDF, Enedis, China Light and Power, State Grid Corporation of China, ComEd (Chicago), Con Edison (New York), Ausgrid (Sydney), Tokyo Electric Power Co and Kaisai Electric Power Corporation

6.2.3 Our supply chain

Our supply chain is an important source of innovation. One key collaboration during RIIO-ED1 has been with the transformer manufacturer **Toshiba** in the design, manufacture and trialling of transformers made of amorphous steel. Using amorphous steel can reduce constant (fixed) losses by up to 80% compared to traditional cold rolled steel. See Section 7.2.1 and Appendix A1 for details of this work.

During Tranche 1, **Toshiba** played a significant role in our amorphous steel transformer trials helping to overcome quality issues that have previously prevented its use. We worked hard to develop and nurture a relationship where they are highly responsive and contribute strongly to achieving our objectives. We will continue to work with Toshiba on the next phase of trialling in Tranche 3 and our good relationship gives us confidence that trials will be successful.

The progress we have made with Toshiba in initiating and implementing this technology is distinctive and exceptional. The high quality of engagement has led to the development of an advanced reliable product which will deliver substantial customer benefit.

6.3 Engagement with other DNOs

6.3.1 Electricity Networks Association (ENA) Technical Losses Task Group

The ENA's **Technical Losses Task Group** (TLTG) is a key forum and a strong industry voice for sharing knowledge and best practice. We are a highly active member of TLTG and use it to explore, validate and disseminate our ideas, proposals and to understand how what others are doing may drive benefits by reducing losses. Examples of insight we have shared with the TLTG include:

- a new CBA methodology suitable for considering investments in HV underground cables;
- original thinking about the idea of a time-weighted CBA to enable better decision-making. See Section 7.5 for more details; and
- our research into Contact Voltage Losses, discussed later in this Section.

Currently, the TLTG is working towards an Engineering Recommendation for Losses Management. This document will provide tailored guidance to the use of CBAs and specific recommendations for the handling of various asset types to enhance network efficiency building on our work. We will work to ensure that common methodologies are understood, promoted, and accepted as widely as possible. For example, we have led on guidance on economic conductor cross-sectional size selection.

We are pushing the TLTG to go further. Our vision is that there should be cross-company scrutiny of the technical aspects of investment proposals. Having engineers from our peers at this forum scrutinising technical aspects of our investment decisions provides transparency of thinking and therefore technical assurance at the basis of decisions. We already use TLTG to challenge the technical methodologies that we use to support our CBAs, and we continue to encourage others to do likewise.

Chapter 7 contains more details about our time-weighted CBA approach and how regulation could best provide incentive for loss reduction in ED2.

6.3.2 Promoting awareness of Contact Voltage Losses

CVLs are hugely significant, understood to be of the same magnitude as non-technical losses. Our research into CVL is ground-breaking: we are not aware of any academic or industry publication that described the CVL mechanism prior to our work. **Using our MAAV to detect CVLs is also a first in the world.** See Section 8.1 for details.

We have pro-actively shared our discoveries and learning about CVL with other DNOs.

Scottish and Southern Electricity (SSEN) was the first DNO to show an interest in using the MAAV to detect and reduce losses. We therefore loaned the vehicle to them for a two-day demonstration in 2019. The MAAV identified 26 energised structures in a small postcode area with two of these defects having high potential to reduce losses. Since then, **ENWL** has also benefitted from a similar two-day free loan to facilitate a trial. We have also offered the same trial to the **three other DNO groups**. We are committed to collaborating and sharing this revolutionary discovery. We believe that this initiative contributes strongly to our case for a reward under LDR.

Mr.Stuart Hanebuth of Osmose Utility Services presenting to the ENA TLTG on CVL management

Demonstrating our MAAV to SSEN

6.3.3 Learning from others

We actively seek to learn from the good work that our peers are doing, either through industry groups or from targeted collaboration. For example, we have learned from **SSEN**'s Low Energy Automated Networks project (LEAN). This sought to prove the feasibility of switching parallel power transformers in primary and grid substations out of service to reduce losses when low levels of utilisation warrant the action. In a series of discussions and project documentation reviews we looked in detail at the project to gain key insights and how we might use them, including site selection, the impact of load growth and the CBA. We envision replicating the conceptual approach but using our ANM system rather than installing equipment on site.

6.3.4 Collaboration with individual DNOs

We collaborate with individual DNOs on some initiatives, where it is likely to lead to better outcomes or more rapid progress than involving all DNOs. Section 6.2.3 described our collaboration with Toshiba on amorphous steel. We also collaborated with **Northern Powergrid** (NPg) on this project during Tranche 2: **UK Power Networks** worked on pole mounted transformers (PMTs), and NPg focused on ground mounted transformers (GMTs). Both parties shared details of the technical challenges that were encountered and how we have worked to surmount those challenges. We understand that following this collaboration, NPg are working towards including amorphous steel PMTs in their strategy for RIIO-ED2.

During Tranche 3, we expect to be able to use learning from NPg to accelerate our own trials of amorphous steel GMTs, leading to faster take-up of this technology to benefit customers. We will also continue to share information about this project with other interested DNOs.

6.4 How we engage wider communities of interest

Our dedicated losses website is targeted at all our stakeholders to promote understanding of managing energy losses. We continue to use this webpage to publish new material that we produce: we recognise the importance of sharing all material so that others can benefit from and leverage from our work. We also encourage other stakeholders and partners to publish material on this platform to ensure that new information is readily available to interested parties.

We also share our learning and acquire new learning at events which engage a wider audience. For example, in 2018 we shared aspects of our losses strategy at the **Low Carbon Networks and Innovation Conference**. We have also shared our work on CVLs internationally, including to the **Council of European Energy Regulators** (CEER) in July 2019.

7 Processes to manage losses and RIIO-ED2 proposals

In this Section we provide evidence about our processes for managing losses and how they are providing a firm foundation for RIIO-ED2.

Table 6:
Key business processes

PROCESS	KEY OBJECTIVES	NOW	THE FUTURE	DETAILS
Learning and best practice	Horizon scanning Understanding best practice Acquiring new knowledge by research	Substantial activity during T1 and T2. Involve Innovation Team Cross-industry sharing Transactional approach	Structured learning processes and management Develop and leverage longer-term learning partnerships Learning from trialling Targeted academic research	Section 5 – Learning Section 7.4 – Process
Network analysis and optimisation	Become a DSO loss manager Optimise network configuration, management and operation to minimise losses Embed holistic approach to loss management	Understanding impact of distributed connections and holistic network management Early stage trials of innovative approaches in some network areas, including flexibility Static optimisations of networks to reduce HV losses Preparing to use smart meter data Vision and plans for new integrated loss and network management systems	Extension of static optimisation to voltage tiers Exploitation of smart meter data and other new data sources Embedding holistic approaches Further exploitation of loss management opportunities from flexibility Dynamic optimisation using Active Network Management and integrated control	Section 7.3 Appendix A1 for specific initiatives Appendix A3 for details of network management systems
Project and portfolio management	Successful implementation	Portfolio, project and risk management tools in place since T2	Stabilisation and improvement	Section 7.4
Decision-making	Robust business decisions	Standard CBA, based on current data sets Some CBA tool enhancements	Time-weighted CBA Exploit smart data Technical peer review Industry standardisation Regulatory incentives	Sections 7.5 and 7.6

7.1 Learning and best practice

Section 5 explains learning activities and how our understanding has improved over Tranches 1 and 2. To better understand losses, we engage with our peers and industry experts, research best practices both nationally and internationally, and benchmark our own performance, involving academia to deepen our insight. We identify opportunities through horizon-scanning and gap analysis to find innovative products and processes. We are moving to a structured approach to this during Tranche 3.

We have a dedicated losses section which ensures good knowledge and awareness and works across the organisation to understand how opportunities to reduce losses can be best realised throughout the organisation. It plans and implements changes as needed. For example, we continually liaise with our infrastructure planning engineers to assess the losses impact of major developments on our 132 kV and 33 kV networks.

7.2 Implementing what we have learned

This Section explains what we have done to implement our learning from Tranches 1 and 2. Here we highlight the loss reduction initiatives which have moved towards business as usual implementation, are undergoing trials or where there are firm plans to implement in RIIO-ED1:

- Use of our MAAV to reduce CVLs. See Section 8.1;
- NOP optimisation. See Section 8.2;
- Rapid CBA to optimise transformer sizes. See Section 8.3;
- Improved portfolio, project and risk management. See Section 7.4; and
- Integration of loss optimisation within Active Network Management. See Section 7.3

The remainder are set out in Section 7.7 with project synopses at Appendix A1:

- Amorphous steel transformers;
- Conductor cross-sectional size optimisation;
- Using flexibility markets; and
- Power Potential.

7.2.1 Amorphous Steel Transformers

UK distribution networks previously used cold rolled grain-oriented steel in transformers. Using transformers made with amorphous steel can substantially reduce fixed losses by as much as 80%. Benchmarking in Tranche 1 identified the need to improve transformer efficiency and we identified the potential for this technology.

During Tranche 1 we initially focussed on 50 kVA single-phase PMTs and began to trial these on our network during Tranches 1 and 2, having ordered 54 such units initially. Trialling required a change in business processes for logistics and storage, costing and commercial compliance. Following successful trials, we have adopted 50 kVA PMTs as a business as usual intervention. During Tranche 3 we plan to trial PMTs of different sizes (25 kVA up to 200 kVA). We will also adhere to more stringent technical specifications (Eco 2021) in this trial: this standard prescribes (constant and variable) losses below those stipulated by Eco2015. We also expect to be able to begin to trial the larger GMTs. See Section 6.3.4 for details of our collaboration with NPg.

7.2.2 Conductor cross-sectional size optimisation

Variable losses are lower in conductors with larger cross-sectional areas. However, larger conductors are more expensive so this must be balanced when selecting the appropriate conductor cross-sectional size.

Imperial's researchers explored options on HV networks to change policy on minimum conductor cross-sectional size from a base case to 95mm^2, to 185mm^2 and 300mm^2. It looked at the losses impact on our networks and estimated loss savings. We used this insight to update our approach to CBA and use the statistical relationships we identified and then used it to support changes to network design standards for HV and LV underground conductors. This has led to our identifying and accurately calculating actual loss reduction benefits from investments in new cables: 1,607 MWh was reported for 2018/19. During Tranche 3 we will extend this approach to HV and LV overhead conductors.

7.2.3 Using flexibility markets

Flexible demand and generation connected to distribution networks are increasingly prevalent and we already use flexibility services offered: they enable us to defer capital-intensive network reinforcement that would otherwise be required to sustain increased demand. We access these services using the **Piclo Flex** marketing platform: a core element of the toolkit that enables us to fulfil our role as Distribution System Operator. To date we have not used these services for loss reduction services but we will explore this during Tranche 3. Influencing load profiles during peak demand periods will enable us to reduce energy losses across all network levels (including National Grid's transmission networks) and could also help reduce required peak network and generation capacity.

> We have a clear strategy to support our transition to Distribution System Operator. Visit our Future Smart website or download our Flexibility Roadmap document

7.2.4 Power Potential

UK Power Networks partnered with **National Grid** to trial the Power Potential project. It includes a market platform for services using reactive power from distributed generators to regulate system voltages.

We funded our Power Potential Losses Research project to explore energy loss benefits from optimising power flows by adjusting transformers and generators' active and reactive power outputs. These can be adjusted so that energy losses in distribution networks are minimised. It also looked at the economics of using these services.

The Power Potential trial is expected to go live in 2020. It is to be trialled on a small part of our SPN Network. We are working toward the co-ordination of loss reduction activities with National Grid during Tranche 3. We aim to test whether using this new market mechanism is a practical way of achieving the loss reductions expected.

7.2.5 Reporting loss reduction benefits

Customers will only benefit from our loss reduction initiatives to the extent that we implement our ideas on the ground and they start to deliver lower distribution losses. We report the loss reductions from our initiatives in our E4 RIGs reports.

Table 2 in Section 4 summarises the losses that we have reported against each of our initiatives in the E4 RIGs by Tranche and indicates the losses we may report in future. We have declared loss improvements due to conductor and transformer size optimisation in our 2018/19 E4. We are set to declare a loss improvement due to NOP optimisation in our next RIGs report. Note that energy loss improvements attributed to the use of our MAAV are stated in our E6 submission for Innovative Solutions during this current regulatory period. We anticipate that we will be able to attribute greater loss improvements to the use of a wider variety of amorphous steel PMTs in future RIGs Reports.

7.2.6 Initiatives not taken forward

As with any innovation activity, some initiatives did not turn out as expected or deliver expected benefits. Appendix A4 explains why we have not taken forward some of the specific commitments that we made in Tranches 1 and 2.

7.3 Using Smart Meter Data

We are already using DPlan software to optimise our networks in static mode based on existing load monitoring. See Section 8.2 for its use in NOP optimisation. We are now working towards enhancing our NOP calculations in DPlan through the use of the smart meter data that recently became available to us[4].

Smart meter data allow for much richer, more detailed information about customer loads on our networks. Exploiting it will require systems, tools and skills to collect and analyse so we can take actions to benefit customers. We have developed a vision for a system and operational architecture to allow dynamic management and control of our networks using smart meter data. See Appendix A3 for details.

We are implementing a new Active Network Management System (ANM); it is an intelligent software platform which will be the most advanced network control system anywhere[5]. This ANM features a Losses Module which can calculate losses in feeders and transformers. We are working towards using this tool to highlight very lossy transformers & line sections.

Our work on ANM builds on learning from the Kent Active System Management (KASM) project (described at Appendix A1) which implemented a contingency analysis tool and load flow modelling in HV networks in our SPN area, and allowed data sharing with National Grid via an Inter Control Centre Protocol (ICCP) data link.

We are investing in **LV monitors** (mounted in secondary transformers) to help us prepare for a large-scale uptake of EVs, heat pumps, and increased distributed generation. These monitors, in combination with smart meters, will enable load flow analyses on individual phases of LV circuits and identify lossy hotspots, allowing us to reconfigure feeders at the HV and LV levels to decrease energy losses. It should also unlock spare network capacity.

Aggregated smart meter consumption data will allow us to better understand **transformer utilisation and efficiency**. Smart meter data will enhance the rapid CBA process used to optimise distribution transformer sizing (Appendix A1).

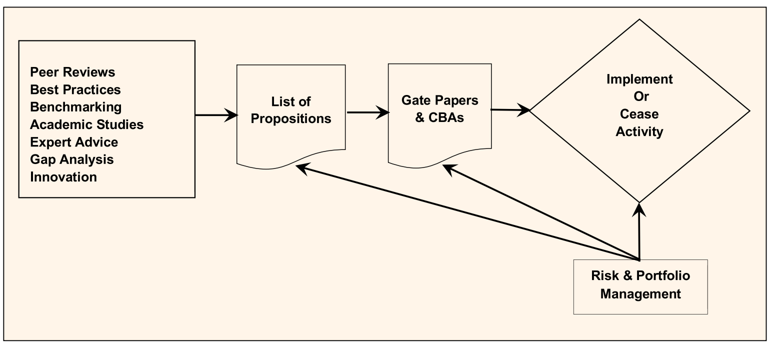
Smart meters and LV monitors in combination will allow us to detect illegal consumption and CVLs using **differential metering**[6]. (See Section 8 and Appendix A1 for details.)

Current loss-related business processes use measurements from instruments in our HV networks. Aggregated smart meter consumption data will enable **more accurate loss calculations**. This will allow us to better manage network-wide losses, could support future incentive mechanisms and allow for more robust scrutiny by stakeholders.

Smart meter data will inform our **Strategic Forecasting Project** looking at planning scenarios in RIIO-ED2 and beyond.

7.4 Portfolio, project and risk management

Since our Tranche 2 submission we have sought to reflect best practice in the processes we use to identify, prioritise, develop, test and implement loss reduction initiatives. We surveyed published documents, professional bodies and staff members qualified in programme or project management[7]. **Ofgem**'s LDR guidance has also been valuable.



4 Ofgem approved of our Data Privacy Plan in the first quarter of 2020.
5 ANM is currently in testing. See: https://www.ukpowernetworks.co.uk/internet/en/news-and-press/press-releases/Plans-unveiled-for-worlds-most-advanced-electricity-network-control-system.html.
6 Differential metering" compares aggregated downstream consumption to upstream measurements to detect energy losses.
7 E.g. the Project Management Institute's Project Management Body of Knowledge. Team members have Masters level and Prince II qualifications.

We have developed tools for portfolio, project and risk management tailored to loss reduction:

- Continual learning and best practice, described at Section 6.3 above;
- Prioritisation of initiatives using a screening matrix;
- A stage gated development process reliant on robust CBAs; and
- Risk and portfolio management to maximise the energy loss reductions that we achieve.

7.4.1 Project screening

We screen projects to focus our engineering and project management resources on initiatives that are likely to deliver most value. We rank initiatives using a screening matrix, utilising these criteria:

Criteria / Weight	Annual MWh savings	Maturity of knowledge & technology	Payback period	DSO readiness / strategic value/ compliance	Organisational readiness	Data availability	Structural limitations / other risks	Man-hours invested per MWh saved	Weighted total
Weight	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	[Rank]
MAAV	14900	3	2	3	3	3	3	1	97.7
Normal open point optimisation	10000	3	3	3	3	3	3	1	86
HV UG conductor upsizing	1500	3	3	3	3	3	3	2	62.5
LV UG conductor upsizing	1500	3	3	3	3	2	3	2	59.5
KASM	200	3	3	2	3	3	3	1	53.6
Amorphous steel transformers	500	3	3	3	3	1	3	2	53.5
Distribution transformer size optimisation	150	3	2	3	2	2	3	2	49.45
HV OH conductor upsizing	1500	2	1	3	2	3	1	2	44.5
Improve power transformer specifications	1000	1	1	3	2	3	2	2	43
LV OH conductor upsizing	1500	2	1	3	2	1	1	2	38.5
Power Potential	1000	1	1	3	1	3	1	1	35
Reactive compensation	250	3	1	1	1	3	1	0	30.75
Phase imbalance improvement	500	2	1	3	1	1	1	1	30.5
LV Voltage Optimisation	500	2	1	3	1	1	1	1	30.5
Unmetered consumption	500	1	1	1	1	1	1	2	23.5

- Annual MWh savings, based on best information available;
- Maturity of knowledge and technology: with the highest score where we have sufficient information to produce gate papers and CBAs;
- Economic benefit: time to financial break-even point. Initiatives with a payback period less than ten years score highest;
- RIIO-ED2 readiness/compliance: activities that help prepare for RIIO-ED2, our future role as DSO or relate to ESQCR compliance score most highly;
- Organisational readiness: this factors in specific implementation issues (e.g. available space to store inventory);
- Data availability: availability of frequently sampled data which helps our research work;
- Structural limitations/other risks: readiness of physical structures such as poles and platforms; and
- Labour intensity (per MWh saved): to optimise use of use of internal resources in expediting project delivery.

The weightings are based on the expert judgement of losses engineers. We update our project screening each year to accommodate new initiatives and to reflect increased knowledge of existing initiatives.

7.4.2 Project Stage Gates

During Tranche 2, we have adopted a gated project lifecycle with three gate approvals. This ensures well-managed implementation so that initiatives are implemented with clear objectives, a good business case, manageable risks and a high chance of delivering the desired loss reduction outcomes.

Table 7

Project Stage Gates

Gate	Approval	
GATE A	**Concept approval**	
	Generally based on desktop study. It confirms the clarity of our understanding and the scale of the opportunity. It gauges the likelihood of producing a practicable solution which is cost beneficial. The Gate A paper describes:	
	The issue to be addressed	
	Our level of knowledge	
	Estimated annual costs and benefits	
	Risks, assumptions and timescales	
GATE B	**Business case approval**	**Stakeholders** Procurement, Design Engineering, Asset Information Systems, Operational Finance, Logistics, Control Room, Operations, Property and Consents, Asset Sourcing and Standards, Equipment Specialists, Capital Programme, Communications
	Passing Gate B requires:	
	Scope of work defined in detail	
	Detailed explanation of our supporting research methods, results, evidence and conclusions	
	In depth engagement with all relevant internal stakeholders	
	Robust detailed positive CBA – using Ofgem's CBA worksheets	
	Risk analysis and mitigations	
GATE C	**Implementation approval**	
	Passing Gate C requires:	
	A detailed project plan and detailed implementation plans (e.g. covering training, logistics, risks, monitoring)	

7.4.3 Risk and portfolio management

We mitigate commercial risk, for example from unforeseen input price movements using a risk margin factored into CBA. We reduce the risk of regretted investment by seeking to avoid investments with very long paybacks. We understand the potential for this to prevent investment which may deliver long-term value: we therefore periodically review our risk margin policy and will consider how to relax this constraint going forward to maximise the overall level of benefit that we deliver for our customers.

Typically, similar investments in different locations on the network will deliver different loss reductions because of local load profiles and network utilisation. We therefore adopt a portfolio approach which allows an element of trade-off between more and less cost beneficial projects. The E4 Losses Snapshots provides an overall view of risk at the portfolio level. We will continue to refine our risk management practices going forward.

7.5 Towards better decision-making

In common with other DNOs to date we have based our CBA on **Ofgem**'s standard templates which value losses using an average value, currently £48/MWh. We are looking to improve this approach because:

i the increasing prevalence of distributed generation, renewable generation and new forms of load like EVs may make load profiles more peaky or unpredictable; and

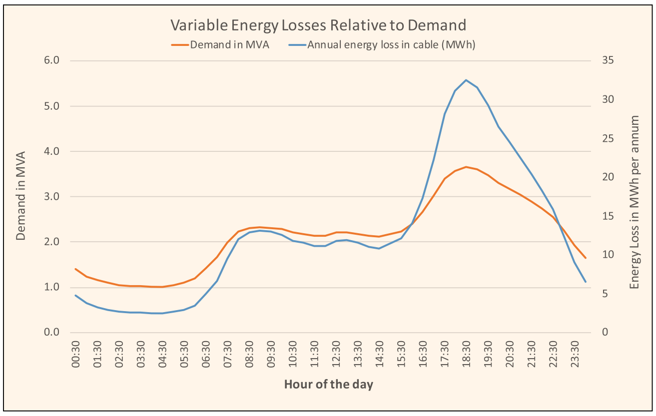
ii smart metering may make it feasible to design loss reduction interventions targeted to peaky load profiles.

Variable losses change with load and so there can be a significant variation in losses across a day as demand changes. The wholesale price of energy also varies over the day: when demand is high the price will be high. The current average cost attributed to losses takes account of this variation as it averages across all time intervals.

However, losses increase disproportionately with increasing current across the network ($P_{loss} = I^2 \times R$). This means that at peak times, losses increase to a relatively greater degree than power does, as illustrated below, and hence to a relatively greater degree than the price.

Graph 1

How varying demand influences variable energy losses



The existing approach to CBA does not account for this: the value attributed to losses at peak times of day is less than it should be. This means that some initiatives which might have reduced peak losses substantially but have had less of an impact on average losses may not have been deemed sufficiently cost beneficial.

Smart meter data, in conjunction with loss calculations in our ANM, will provide accurate information about losses at specific times and places: we will be increasingly confident about what losses are caused when and where and for what reason. This opens up the prospect of more precise management of losses and more targeted design of loss reduction interventions which have predictable time of day impacts. Our decision tools should reflect this.

In addition, the profile of load across our network is becoming far less predictable, both in terms of its impact on specific components of our network and its impact on total system losses at specific times of day. If this results in more uneven load profiles, then there is more benefit from targeted loss interventions and missing loss reduction opportunities is less acceptable.

We have developed a time-of-day weighted CBA approach which uses tailored profiles for a more realistic valuation of losses in our CBAs. Such time-weighted profiles will be beneficial and practical: we will be able to develop robust profiles for both application-specific [8] energy losses and wholesale energy prices in the market. This could lead to more opportunities being identified for cost beneficial ways of reducing losses and be good for customers. Resulting flatter load profiles could also lead to lower required peak capacity requirements in transmission, distribution and generation: a holistic impact.

UK Power Networks is a leading voice on this issue and we have been pushing the industry to consider this via our involvement with the **ENA's TLTG**. We look forward to collaborating with other DNOs. Better understanding will strengthen and support our preparations for RIIO-ED2.

8 Energy loss profiles are equipment specific. For example, we see only variable losses in conductors, while we observe variable and constant losses in transformers.

7.6 Losses incentives in RIIO-ED2

Our proposed CBA approach is central to proposals for a new regulatory incentive for RIIO-ED2. We have been working with the ENA's TLTG on a report examining approaches which would adequately incentivise efficient management of both technical and non-technical losses. We believe that standardising on the more sophisticated time-weighted CBA approach to investment decisions that we have been advancing, potentially coupled to a reputational incentive mechanism, is the most appropriate way of encouraging all DNOs to manage losses.

Losses vary significantly and are heavily influenced by factors largely outside DNO control: consumer-led adoption of renewables such as photovoltaics, a substantial uptake of heat pumps and electric vehicles and the availability of flexibility services. Such factors will make estimating future losses more difficult, and make setting up-front loss reduction targets very problematic. Local and international experience[9] suggests that setting measurable ex-ante incentives for losses is not effective in practice. Loss reduction targets could also discourage the uptake of low carbon or smart grid technologies which could increase losses but have a larger wider benefit, for example using flexibility to defer investment in network capacity may mean less technically efficient equipment remains in service for longer.

A more sophisticated CBA approach could also allow for the more rapid progression of cost beneficial proposals identified between price controls, allowing for quicker exploitation of rapidly advancing smart grid technology and take up of smart meters. A reputational incentive would hold the DNOs to account. We look forward to working with our peers and other stakeholders to inform RIIO-ED2. It will be a focus of our, and the TLTG's work in 2020.

7.7 Preparing for RIIO-ED2

The initiatives described earlier in this submission prepare us for substantial changes and opportunities during RIIO-ED2, in particular the roll-out of smart meters and smart grid technology, the take-up of distributed and flexible load and generation and low carbon technologies. Net zero, including the de-carbonisation of transport and heat will have a pervasive impact on networks. We look to make substantial improvements to our network assets, our operations and business processes to manage these changes.

At a strategic level this will involve:

- Capturing, understanding and exploiting the rich detailed data from smart meters to inform the temporal and spatial distribution of losses across our networks;
- Operationalising dynamic loss management via real-time network management systems (ANM) using smart meter and other new data;
- Embedding a holistic approach to loss management;
- A structured and productive programme of engagement with partners;
- Having the right incentive framework in place; and
- Further embedding an innovation business culture and processes.

We highlight here some specific Tranche 3 initiatives which will be essential for RIIO-ED2. We will:

- continue to use 50 kVA amorphous steel PMTs and trial PMTs of all sizes up to 200 kVA, as well as GMTs;
- continue to optimise NOPs in our HV networks and test viability in our LV networks. We will work towards dynamic optimisation using our ANM;
- test the use of existing and newly-developed flexibility markets, including Power Potential, to manage losses by influencing load profiles to mitigate load peaks;
- continue to assess transformer renewal programmes and optimise transformer sizes to benefit losses;
- continue to use our MAAV to eliminate CVL defects and look to better target CVL detection and extend it to other network areas;
- work towards a new losses incentive mechanism and approach for technical peer reviews of investment cases; and
- use our improved CBA approaches to support conductor and transformer size optimisation.

We will build business cases and test investments for ED2, potentially including

- improving losses in our grid and primary power transformers even further;
- upgrading 6.6 kV networks to 11 kV; and
- replacing old, higher loss power transformers ahead of schedule to reduce losses.

9 WSP Technical Losses Mechanism Study, p.32. Their report can be accessed in the following location: https://www.energynetworks.org/assets/files/CEP023%20Technical%20Losses%20Mechanism%20Study%20Final%20Report.pdf

We will continue to horizon scan for new knowledge of processes, techniques and equipment. We will also continue and enhance our effective collaboration with external parties and ensure we continue to integrate our work on losses with the ANM implementation.

Innovative approaches and new learning during Tranches 1 and 2 have already delivered considerable benefits to customers. Leading up to and during RIIO-ED2 we will embed what we have discovered and tested during Tranches 1 and 2, and build holistic and productive collaborations across the energy value chain and new industry-wide approaches. The initiatives described in this document all support this and will be central to our RIIO-ED2 proposals.

8 Innovative approaches to losses management and actions taken to incorporate these approaches into business as usual activities

In this Section we provide evidence about selected initiatives which we believe are truly innovative. While most of the initiatives in this submission contain innovative elements, the ones described here are particularly so: they tangibly shift best practice boundaries and there is substantial progress towards implementing them into business as usual:

- Using a MAAV to detect CVLs;
- 11 kV NOP optimisation; and
- Rapid CBA for transformer size optimisation.

Our innovation in relation to smart meters is focussed on how the data can be used once available. The innovations described here use smart meter data, but see Section 7.3 for a full discussion.

We confirm that none of the innovations highlighted in this Section of our submission have been funded through the RIIO-ED1 price control and the innovation stimulus mechanisms.

8.1 Using a Mobile Asset Assessment Vehicle (MAAV) to detect Contact Voltage Losses

The discovery of the significance of CVLs and finding a completely new way of detecting and reducing them is a major change in the landscape of loss reduction. UK Power Networks has been at the forefront of this initiative, which moved forward substantially over Tranches 1 and 2. The detailed arrangements to deploy this technology in a new way into business as usual is already delivering for customers.

During Tranche 1 we collaborated with Princeton University to help us understand the theoretical background in detail. This work developed a theory that explains and quantifies the energy loss we observed in the real world. This losses research component was entirely funded by UK Power Networks.

During tranche 2, we have used our MAAV in BaU operations in our central London area to detect energy losses and enhance public safety. We have implemented a comprehensive set of processes to manage and mitigate the impact of CVL defects, including a risk-based process for categorising CVL discoveries based on detected voltage, total harmonic distortion (THD) and other characteristics. See Appendix A2. Our work has helped confirm that the existence of faults is in accordance with theory.

> Princeton University's analysis suggests typical cable phase-to-earth CVL defects can consume 6.1 kW per incident. Extrapolating to the wider LPN network, the total losses figure rises to 17,200 MWh annually. Extrapolation across Great Britain yields an estimate of 590,000 MWh in wasted energy per year due to CVL.
>
> Find more information about this initiative in Appendix A1. Also see Sections 5 (learning) and 6 (engagement). Princeton's report is available on our Losses Website.

We have attributed an annual loss reduction of **1,802 MWh** for 2018/19 in our London Power Network (LPN): see our 2018/19 Environmental & Innovation (E6) Report. During Tranche 3, we plan to enhance its potential, effectiveness and impact by:

- working towards using LV monitors and smart meters combined to detect the presence of CVLs. We will be able to use this information to guide MAAV operations towards suspected CVL defects. Better targeting of MAAV surveys will allow us to cover a wider footprint effectively and result in a better hit rate for CVL detection; and
- better targeting will also improve the business case for deploying more MAAVs. We are considering business cases for two additional vehicles in Tranche 3.

The purchase of our MAAV and its use to enhance customer safety was funded via the Network Innovation Allowance. However, all our investment into research of CVLs and the use of MAAVs for loss reduction has been funded outside of the RIIO-ED1 price controls and innovation stimulus mechanisms.

8.2 11 kV Normal Open Point Optimisation

Normal Open Point (NOP) optimisation seeks to optimise the position of normally open switches on lines connecting radial networks. This can reduce variable losses by lessening uneven load. During Tranche 1 we explored this innovative strategy with Imperial's researchers, who attributed a value of £5.4 to £8.9 million in potential loss reductions over ten years. Taking advantage of this opportunity requires finding a holistic optimal network configuration and then adjusting the switches to it.

We have implemented DPlan, our distribution planning software to analyse our networks and provide optimised switching recommendations. This contrasts with a traditional approach of loss analysis on a line by line basis. The optimisation also identifies spare capacity to accommodate load growth in parts of our network.

During Tranche 2 we began to use DPlan to determine optimal NOP positions in our networks. Our early work involved using knowledge from other systems and projects to ensure our confidence about the results of DPlan simulations. We encountered some complications that required an innovative approach to overcome. For example, our work on reducing feeder losses (Appendix A1) helped us to understand in detail how losses occur in each subsection of a feeder: this knowledge enabled us to confirm the accuracy of network simulations that underpin Normal Open Point Optimisation.

We have focussed our work first on our 11 kV networks as this is where the opportunity is the greatest and where it is simplest to implement because we can switch remotely from our control room. We have identified switching that should deliver a cumulative reduced loss of **50,000 MWh** over RIIO-ED2. This is a substantial benefit for customers. We have now initiated some of the required switching operations and this is now essentially business as usual and will continue during Tranche 3.

Beyond these activities there are opportunities to go further, which we will be considering during Tranche 3:
- Extending the approach to NOPs in LV networks;
- Using smart meter data for a more robust optimisation; and
- Extending the concept to work dynamically such that switching operations are triggered automatically in response to real-time optimisation. This would be achieved via integrating loss optimisation functionality into our Active Network Management system.

Our work on NOP optimisation was not funded under RIIO-ED1 or any of the innovation stimulus mechanisms.

We believe that our identification of the opportunity, and the use of a system wide optimisation approach and advanced network analysis tools to realise it is innovative. We have needed to develop new analysis and processes to enable us to progress it to actual implementation. The further steps we are considering will push best practice further and will require substantial technical and organisational changes.

8.3 Rapid CBA processing to optimise distribution transformer sizes

We justify all loss reduction initiatives using CBAs. In Tranche 2, we identified an opportunity to use a statistical relationship identified by another DNO to improve the CBA that supports our investment in new secondary transformers. Every year we replace a substantial number of secondary transformers on our networks. These replacements present an opportunity to optimise transformer sizing to increase efficiency and reduce losses. To do so requires analysis of transformer utilisation, the shape of the load profile and transformer loss characteristics.

We enhanced **Ofgem**'s MS Excel-based CBA worksheets to enable us to rapidly perform the new loss calculations we have derived and present the results for different transformer sizes to enable faster, more robust and efficient decisions.

We have implemented this as business as usual and used it in over 50 successful decisions to upgrade so far, with estimated annual loss reductions of around 170 MWh. Some of the transformers have now been installed. This shows how we seek to innovate in all aspects of the loss reduction process, rather than focussing on technical improvements only. We are planning to demonstrate our approach to other DNOs via the ENA's TLTG.

Appendices

A1 Synopses of projects undertaken

Using a Mobile Asset Assessment Vehicle to detect CVLs

What we did

The ground-breaking work on CVLs by UK Power Networks constitutes the most significant change in industry understanding of network losses in the last several decades. A Contact Voltage (CV) is an electrical potential which exists between two separate surfaces. They can be caused by defects on our network, as well as by defects on third party assets such as lighting columns or customer installations. Our discovery was that there are significant energy losses associated with these contact voltages. It is estimated that the total of CVL energy losses is comparable to that of non-technical losses within Great Britain, estimated to be as much as 1% of total losses. In the case of UK Power Networks such losses may have a value of around £3m per annum.

During Tranche 1, UK Power Networks started using a MAAV to detect CVs in Central London. CVL defects emit electromagnetic waves that can be detected by the MAAV's sensors as the vehicle drives along the road. When a CVL defect is detected, its sensors will alert the operators. They then perform further analysis of the site, identify the energised objects (e.g. lighting column), and mark the site for pro-active repair by UK Power Networks' network operational teams. See Appendix A2 for a visual summary of how CVLs occur and how we detect them with MAAV.

Our use of the MAAV led to our recognising the potential significance of energy losses associated with CVs. We moved quickly to explore and validate our thinking through our work with **Princeton University** to develop the CVL theory and to quantify the potential scale of such losses.

Since then we have continued to scan our networks with the MAAV in the current central London area of operation. We have created and implemented business processes and tools to manage its use for loss detection and reduction as business as usual. These allow us to identify and quantify losses associated with CVLs revealed by the MAAV. We have therefore improved our understanding of what CVLs exist in practice, and where and why they occur. This helps to validate the theoretical research we have done. It also allows us to prioritise actions to remove the defects causing CVLs.

We are now developing our approach to CVL by considering how to exploit data from smart meters to help target our MAAV activity using an approach called "differential metering". This will involve:

- LV monitors, installed in secondary substations, which measure energy flowing into LV feeders;
- Smart meters which measure energy flowing out of LV feeders into customers' installations;
- Load flow calculators (in our Active Network Management System) to calculate variable losses occurring between secondary transformers and customer installations; and
- Examining loss characteristics where higher than expected losses are present to diagnose whether CVL is likely to be a potential cause – using our prior research and data that we will acquire in live operation.

This will allow us to more accurately prioritise the MAAV surveys driving benefits from our investment in this, as well as in smart meters and LV monitors.

An additional benefit is that if MAAV surveys fail to detect CVL defects in areas highlighted by the differential metering arrangement described above, we will have a level of certainty that non-technical losses are occurring. This knowledge will help us to conduct targeted theft detection investigations.

Why does this exceed expectations or go above and beyond?

The MAAV was initially trialled as an NIA-funded project focussed on safety. Therefore the vehicle itself and its use for safety purposes does not contribute to our case per se.

However, our conversion of this opportunity into a business as usual process which is already delivering savings for customers and has the potential to deliver substantially more loss reduction in Tranche 3 does exceed expectations. None of the work needed to exploit the opportunity was funded under the RIIO-ED1 price control.

What have we learnt?

We have discovered the potential for significant CVLs to be reduced. We have developed underpinning theories and a robust quantification of the scale of such losses. Princeton University's analysis suggests typical cable phase-to-earth CVL defects can consume 6.1 kW per incident. Multiplying this 6.1 kW power loss by the defect rate and extrapolating to the wider LPN network, the total losses figure rises to **17,200 MWh** annually. Extrapolation across Great Britain yields an estimate of **590,000 MWh** in wasted energy per year due to CVL.

We have learned how to develop and implement businesses processes and tools for detecting and analysing CVLs. We have used our practical experience of operating the MAAV to learn more about CVLs and where and why they occur. We have noticed the the use of differential metering in our literature reviews and propose to use it to increase the effectiveness of this activity.

How have we shared our learning?

Our approach is new and innovative and has been of great interest to other DNOs. We have shared our learning with them both in theory and in practice. We have held sessions at the **ENA TLTG** to explain what we have done and how we are exploiting our ideas. We have published our research.

We have loaned our MAAV to two DNOs in each case for a two day trial. This allowed them to see the process in action and to discover losses in their own areas.

As this is a ground-breaking new approach to understanding losses and reducing them there is interest beyond DNOs in the UK.

How will this benefit customers?

Customers will benefit from our being able to secure a significant reduction in losses. The scale of the reduction that we can achieve will depend on how we deploy the initiative over the remainder of RIIO-ED1 and into RIIO-ED2. In Tranche 3 we will continue to deploy our existing MAAV and expect the annual amount of losses saved from using this one vehicle to be around **15,000 MWh** by the final year of RIIO-ED1. To maximise the potential we are considering how and where to deploy the vehicle, particularly by extending its area of operation so it covers more areas and by using differential metering to better target its activity.

We are also developing the business cases for investment in a further two MAAVs and if these are brought into operation, this should lead to an additional annual saving of around **30,000 MWh**. This energy saving amounts to circa £1.73 million per annum in 2019/20 monetary value.

What has already been achieved?

We have already identified a continuous stream of new CVL defects and declared the energy loss improvement achieved through mitigating these defects in last year's Innovative Solutions (E6) regulatory reporting pack submission. The total cumulative loss reduction declared in 2018/19 was **2,700 MWh**.

Amorphous Steel Transformers

What we did

During Tranche 1, our international benchmarking identified the potential for reducing losses by increasing transformer efficiency. We highlighted this in our Tranche 2 LDR submission. In Tranche 2, we worked with Imperial's researchers to explore the potential of this as part of a wide-ranging study on loss reduction strategies.

To date, UK distribution networks have typically used cold rolled grain-oriented steel in transformers. All transformers incur constant losses: the fixed losses that occur when a transformer is energised whether or not current is flowing. Using transformers made with amorphous steel can help to minimise constant losses by reducing hysteresis and eddy current losses (classified as constant losses). Typically, metals have a crystalline structure in which the atoms are orderly arranged. This orderly arrangement is broken when the metal is heated to the point where it melts. In the molten state, there is no clear structure in the steel, which leads to metal in this state being described as "amorphous". To preserve this amorphous state, steel used for amorphous transformer cores is produced by rapidly solidifying the molten alloy metal.

Eddy currents are induced in a transformer's iron core under the influence of the magnetic field that transfers energy between windings. Losses linked to these eddy currents can be reduced by minimising the thickness of steel laminations used in the transformer's iron core, while the higher resistivity of amorphous steel further helps to reduce eddy current losses. The absence of a crystalline structure in amorphous steel leads to easier magnetisation of the material, which lowers hysteresis losses.

Using amorphous steel can decrease constant losses by up to 80%.

Amorphous steel can be used in transformers of various sizes. We decided to prioritise our trialling on smaller pole-mounted secondary transformers (up to 200 kVA). Larger ground-mounted transformers (to 1000 kVA) may also benefit and in order to progress work on these efficiently we have exchanged information from trials with Northern Powergrid. They have been conducting trials of the larger ground-mounted units.

During Tranche 2, we obtained prices and specifications for 50 kVA single phase units from **Toshiba**, a prominent manufacturer. The business case to test loss reduction benefits against incremental costs was strongly cost beneficial and we therefore ordered 54 units which were trialled on our network starting in 2018/19.

We have pioneered the use of amorphous steel pole mounted transformers to deliver cost-efficient energy improvements for our customers

Photo 1:
New Amorphous Steel PMT

Trialling required us to change various business processes and arrangements including: logistics and storage, technical compliance and costing.

Following the success of the first trial we have initiated a further trial during Tranche 3 which will cover a range of sizes: 25 kVA up to 200 kVA. This will also involve adhering to more stringent Eco 2021 specifications.

We have found positive net benefit for all PMTs ranging from 25 kVA up to 200 kVA. As a result, we have obtained management approval and placed an order for 56 new amorphous steel transformers of all sizes mentioned above.

Why does this exceed expectations or go above and beyond?

Our activity in this area exceeds expectations. We have identified a potentially significant source of loss reduction and then acted to move the idea through to the point that it is become business as usual for us. We did not envisage this activity before RIIO-ED1 commenced and it has not been funded via the price control or via innovation funding mechanisms.

We have maximised the potential customer benefit by collaborating with another DNO by means of sharing information-with Northern Powergrid to extend the scope of application of the technology.

What have we learnt?

We have quantified the potential for substantial loss reduction from this technology and have worked through the practical and cost implications of implementing the technology for our secondary (pole mounted) transformers by conducting trials on the ground. These have included working through physical installation issues, logistics and business processes. We have been able to prove the economic case for using this technology now that improved steel quality has enabled us to push for its use.

How have we shared learning with others?

We have shared our learning with **Northern Powergrid**. For example, we have shared with Northern Powergrid our approach to address structural challenges associated with amorphous steel PMTs. In turn they have shared information about weight and size problems related to amorphous steel GMTs.

How will this benefit customers?

We install about 500 new PMTs on our networks annually. We will deploy amorphous steel transformers for these replacements once our trial planned for Tranche 3 is complete. To the extent that we install more of these PMTs, the overall loss reduction benefit will continue to accrue. Conservatively assuming that the new amorphous steel PMTs will remain in service for 50 years, we estimate that the overall associated loss reduction benefit will accrue to 650,000 MWh over the next five decades as the new technology continues to proliferate.

We plan to be able to start installing amorphous steel GMTs once trialling has been completed.

What has already been achieved?

Customers are already benefitting from the new transformers operating on our network. We have installed 29 units on our network to date and have declared a loss reduction for this activity in our E4 Losses Snapshot for 2018/19.

Normal Open Point Optimisation

What we did

Normal Open Points (NOPs) are locations in our network where two radial circuits meet at an open switch. For historical reasons, load may not be optimally distributed across our network; some circuits may have more connected customers, or the customers may draw heavier loads on average. For example, if two circuits have identical customer numbers, but one circuit feeds a street with gas heating, and the other feeds a street without, we would expect to see higher load on the non-gas heated circuit due to electric heating. Because variable losses are nonlinear against load magnitude, unevenly distributed loads cause excessive losses in some feeders.

In their ground-breaking study on strategies to reduce losses in distribution networks, Imperial's researchers identified 11 kV network reconfiguration as having a potential capitalised value of between **£5.4 and £8.9 million** in loss reductions over ten years. On this basis, we have started a programme of work to reconfigure our 11 kV network to be as efficient as possible, while being careful to consider other potential impacts such as on fault restoration.

We have capitalised on our learning to deliver lower energy losses and at the same time release spare capacity

To develop the underlying understanding, Imperial's researchers modelled a situation where all NOPs in our LPN HV Network were closed. Next, they progressively opened switches in branches where current flows were minimal. They continued the process until the resulting network consisted of radial feeders only. This theoretical approach reduced HV losses by 17%. The benefit of this approach is that the network is considered holistically in the sense that lesser utilised parts are used to alleviate loading on parts that are more intensively utilised. In this manner, network reconfiguration releases spare capacity and reduces losses at the same time. We explain in later sections how we shaped our internal processes and tools to derive benefit from Imperial's researchers' recommendations.

Why does this exceed expectations or go above and beyond?

Our work was not funded under RIIO-ED1 or any of the innovation stimulus mechanisms. We believe our use of network optimisation to give a whole-network optimisation of its open switch configuration is innovative. We have taken a new idea from our academic research and found a way to implement it in a manner that considers the impact across the whole system and ensures that customers are not adversely impacted.

What have we learnt?

There is a substantial opportunity to reduce variable losses by more than 15% in HV networks. We have understood the optimal configuration of open switches on our HV networks needed to achieve this. We have also created a new way of validating that our network optimisation software is producing sensible results by comparing them to detailed loss analysis at a feeder level from another of our initiatives.

How have we shared learning with others?

We have published the Imperial's researchers' study which details the work done to identify, validate and quantify the value of this initiative on our Losses Website.

How will this benefit customers?

Customers will benefit from lower losses once we have switched our 11 kV network to its optimal configuration. Further potentially substantial benefits could arise once we extend the approach. We are considering:

- Optimising NOPs on our LV networks;
- Using smart meter data to increase accuracy of our optimisation; and
- Embedding loss optimisation in our Active Network Management systems to enable real-time monitoring and automated switching.

What has already been achieved?

We started the necessary physical switching operations during 2019 and so customers are already starting to benefit.

Loss management using Power Potential's Market Platform

What we did

The rapid uptake of Distributed Generation (DG) in southern parts of the UK leads to elevated system voltages at times of low demand, constraining the connection of more distributed generators. Opposite to these constraints, reactive support from distributed generators can be used to support low system voltages that occur during times of high demand.

National Grid and UK Power Networks have partnered to trial Power Potential, which includes a market platform to address voltage regulation problems by utilising active and reactive power from DG to suppress or elevate system voltages, and thus avoid the need for network upgrades. The trial is expected to commence in 2020.

Losses are not the primary focus of Power Potential but reactive power flows will impact losses. UK Power Networks saw the potential need to mitigate the impact and realise the opportunity to reduce losses via optimised power flows. We therefore commissioned Imperial's researchers to investigate the opportunity. The first phase of our Power Potential Losses Research project quantified the baseline losses, i.e. the losses when distributed generators in the project footprint do not alter their behaviour to influence voltages or energy losses. The next phases of the project described energy loss benefits obtainable from optimising power flows in such a way that energy losses in distribution networks are minimised. The project also addressed the economics of using these services, examining the potential prices at which it might be economic to use them to reduce losses under various costing assumptions.

Why does this exceed expectations or go above and beyond?

Power Potential is funded by the NIC. However, the additional work on losses was conceived and funded by ourselves. We have identified a genuinely innovative means by which we could create value for customers across the whole system and support the wider objectives of the Power Potential project.

What have we learnt?

The study concluded that:

- Using distributed generators to manage voltages in the National Grid network could increase distribution network losses in 132 kV and 33 kV networks by up to 2.1% without any intervention to manage energy losses;
- We could improve distribution system energy losses by up to 1.3% if we use Power Potential's market platform to manage energy losses while voltage management to address system constraints is not required. The market will determine the prices at which it is economic to purchase reactive energy;
- Optimising reactive power supplies from distributed generators and power transformers (by optimising tap settings) can benefit network losses in distribution and upstream transmission networks;
- The study observed no increase in the peak hourly value of losses meaning network losses attributed to Power Potential should not increase system generation capacity requirements; and
- Co-ordinating loss reduction activities with National Grid will maximise benefit of voltage and reactive power management to both networks.

Power Potential represents a valuable opportunity to embed holistic network loss management across transmission and distribution networks to maximise benefit for customers

How have we shared learning with others?

A dedicated microsite hosted by National Grid explains the project and its overall benefits. In February 2020 we published our report. Now we have published this report we expect to engage other DNOs to share our learning.

How will this benefit customers?

Customers will benefit from an additional tool by which distribution losses can be reduced. The scale of benefit depends on the success of the forthcoming trial and the extent to which the initiative can be replicated across our and others' networks.

What has already been achieved?

The Power Potential trial is expected to go live in 2020. It is to be trialled on part of our SPN network.

Rapid CBA processing to optimise distribution transformer sizes

What we did

Every year we install a substantial number of new distribution transformers in our networks. Each replacement is an opportunity to right-size the transformer to improve network energy efficiency by reducing losses. We identified an opportunity to make our decision-making better by designing a more sophisticated approach to evaluating the costs and benefits of transformer investment. We make many such decisions and the calculations are complicated and so there is also a benefit to making these calculations as easy as possible to execute and to reduce the risk of mistakes.

Finding the optimum transformer size involves analysing the whole-life energy efficiency of transformers of various sizes, requiring us to consider for each one: its peak load, its load loss factor (LLF[10]), its loss specifications (constant and variable) as well its costs.

We substantially improved the speed of this analysis, prompted by a graph presented by another DNO, (**Northern Powergrid**), which attributes a LLF to conductive electrical apparatus based on the number of customers downstream from it. We took this forward by developing and validating a mathematical expression for the graph which they presented.

Figure 1

Transformer Size Optimisation CBA Tool

Imaginary prices displayed due to commercial sensitivities.

USER INDEX
Cells that require user selection
Cells that require numeric inputs from user

Inputs:	Current values
Current Financial year	2019/20
Present Cost for Base Option	£ 11,055.50
Present Cost for Optimised Option	£ 11,159.20
Transformer peak load in kVA	680.0
LLF estimated	0.2243

Calculation results:	Values
WACC Used	3.93%
Discounting factor	118.97%
12/13 Cost of Base Case	**£ 9,292.36**
12/13 Cost for Optimised Option	£ 9,379.51
Please select Base Option	DISTX_800_3_UKPN
Please select Optimised Option	DISTX_1000_3_UKPN
Annual MWh loss for Base Option	17.62
Annual MWh loss for Optimised Option	16.29
Annual MWh saving	**1.334**
Differential "Real" cost for upgrade	£ 87.16

Counter	Transformer specifications	Calculated MWh Losses per annum	Efficiency rank
1	DISTX_100_3_UKPN	160.28	6.0
2	DISTX_200_3_UKPN	65.09	5.0
3	DISTX_315_3_UKPN	38.9	4.0
4	DISTX_500_3_UKPN	24.5	3.0
5	DISTX_800_3_UKPN	17.6	2.0
6	DISTX_1000_3_UKPN	16.3	1.0
7			
8			
9			
10			

Term (years from first out flow)	N PV (£m)
8	£0.000446
24	£0.001202
32	£0.001424
45	£0.001669
45 Yr NPV in £'s	£1,669.01

10 The load loss factor, when multiplied by the power loss at time of peak load and the number of load periods under consideration, yields the total quantity of energy lost (e.g. MWh)

This allowed us to develop a tool to calculate these values quickly. It performs the required losses calculations in a customised front end to **Ofgem**'s standard MS Excel-based CBA worksheets. This front end calculates annual losses for all available transformer sizes, and uses formatting to highlight the option that would produce the lowest annual losses.

Baseline and incremental costs relevant to the optimised transformer that the user selects are routed automatically from the customised front end into the discounted cash flow analysis. This arrangement enables us to analyse and optimise the efficiency of many installations in a relatively short amount of time.

Why does this exceed expectations or go above and beyond?

This is an innovative development of a business process. It is an example of our ongoing intent to improve on best practice in loss reduction not only in technical applications but across the whole range of business processes.

What have we learnt?

We have derived a statistically robust mathematical relationship between customer numbers and load loss factors. We have developed an efficient and effective business process to leverage this new knowledge.

How have we shared learning with others?

This was originally based on an idea from another DNO's published report (**Northern Powergrid**'s LDR Tranche 2 submission[11]). It is an example of us looking for, and exploiting best practice from a range of sources.

We have shared details of the regressed graph with other DNOs via the **ENA TLTG** in April 2019.

We produced positive results by leveraging the research of our peers

How will customers benefit?

Over the last twelve months, we used this approach to optimise transformer sizes in 53 investment decisions. We calculate that these investments lead to a total annual loss reduction of **168 MWh**, which is to customers' benefit. Without this approach we would have replaced like with like.

We will continue to use this approach which means that benefits to customers will compound. In addition, the increasing availability of smart meter data should allow greater precision in transformer load calculations.

What has been achieved already?

Use of the new CBA tool is now business as usual. Some of the 53 units have now been physically installed and the benefits of these were included in the loss improvements that we declared in our 2018/19 RIGs report.

Imperial College London's Researchers: Network Topology

What we did

During Tranche 1 we completed a substantial international benchmarking and best practice study which looked into all aspects of loss management. We drew on the breadth of experience of members of the **International Utilities Working Group** and of other companies within the **CKI Group**: it owns six other distribution network operators as well as many other businesses across the energy value chain. We also selected **Germany** and **New Zealand** for a detailed deep-dive. These were assessed as being reasonably comparable to the UK across a range of factors.

Our work identified a number of promising ideas which have contributed to or prompted many of the initiatives in this submission. To deepen our understanding, we subsequently formed a partnership with Imperial's researchers resulting in a detailed report on the value of changing network topology to reduce losses.

This provided valuable insight into ideas to reduce network losses by adjusting network topology, in other words by looking at the rating and configuration of network components and the way that they combine to form the distribution network. As would be expected there are variations in approaches between countries. Our aim was to understand what loss reduction benefits might be gained should we make adjustments to network topology in this instance.

Why does this exceed expectations or go above and beyond?

Our benchmarking and research efforts were not funded under RIIO-ED1 or any of the innovation stimulus mechanisms. The breadth and depth of our research effort is substantial and it also considers some quite radical ideas that may well have been dismissed in the past, such as a re-design of parts of our network.

11 See page A2 of Northern Powergrid's LDR tranche 2 submission document for further details.

What have we learnt?
Two ideas have emerged from this work as leading contenders to be taken forward.

First, there is a substantial benefit to be had from removing 132/33kV transformation stages in our networks and instead increase the amount of 132/11 kV transformation.

Second, there are a small number of areas in our LPN and SPN areas where our high voltage network operates at 6.6 kV. There is an opportunity to upgrade these to 11 kV and thus realise the loss savings associated with the use of higher-rated equipment. We have looked in detail at the opportunity: there are 41 individual network sections across the two networks, with total length of 2,015km which if upgraded to 11 kV could lead to savings of around 14,600 MWh. We do not think upgrading to voltages greater than 11 kV would be sensible in practice because most of the surrounding networks are at this voltage.

How have we shared learning with others?
We have published both our international benchmarking report and Imperial's researchers' report for Network Topology.

How will customers benefit?
Should we go ahead and make the investments to implement these network changes then customers should benefit from the substantial loss reductions. The precise amount realised will depend on the detailed business case.

What have we done already?
Our work so far has been to identify the opportunity and to quantify it at a high level. Clearly as the investments are significant this will require the development of robust business cases as part of our work towards RIIO-ED2.

Kent Active System Management Network Losses project

What we did
Kent Active System Management (KASM) is an innovation project implementing a contingency analysis tool for UK Power Networks' SPN network. It implements load flow modelling on UK Power Networks' 132 kV and 33 kV networks, and integrates with National Grid's network status via an Inter Control Centre Protocol (ICCP) data link.

The KASM project was not initially focussed on loss reduction and management. However, we realised the potential for using the contingency analysis tool implemented by KASM to reduce losses. We therefore extended our collaboration with **Bigwood Systems Inc**. (which had built and implemented the system) to deliver the KASM Network Losses project beyond the innovation funded original KASM project.

This losses project developed a new KASM Losses Module, which allows for granular analysis of network losses in the KASM area, specifically calculating line and transformer losses for different network configurations. It also sought to model the relationship of losses to renewable load conditions and locations and to understand impact of network topology on losses.

Why does this exceed expectations or go above and beyond?
The original KASM project was funded via the ED1 Low Carbon Networks Fund and so this aspect of the initiative was as expected and is not seen as "above and beyond". However, using this tool to study losses in depth does go beyond what was expected. This aspect of the work was funded by UK Power Networks.

What have we learnt?
The project has revealed the potential for a better optimisation of network topology to reduce the level of losses. While the quantum of loss reduction from the activity was not determined as material enough to make the relevant switching changes in the area, the project gave valuable insight into how we can use new techniques and systems to better manage losses on a real-time or near-term basis. This will be invaluable going forward into our ANM system implementation.

How have we shared learning with others?
We have published a report for this project on our Losses Website.

What are the benefits for customers?
Customers will benefit from this project ultimately from reduced cost of power to cover system losses as our ANM system is implemented.

What have we done already?
The KASM initiative is now complete.

Optimising conductor cross-sectional size standards

What we did

During Tranche 2 we worked on developing and implementing new RIGs reportable categories and promoting this work to our peers. We initiated this work with a detailed study to better understand loss improvements attributable to increasing the cross-sectional area of HV underground cables.

Due to data scarcity, we deployed **statistical methods** to understand our networks better. We randomly selected feeders from our three licence areas, divided them into short sections and estimated changed losses for each section should cross-section be increased from 185mm^2 to 300mm^2. We used regression analysis and calculus to quantify potential system-wide benefits and then built that into our CBA tools which allows us to trade off various factors in determining optimal cross-sectional size.

We used statistical methods to overcome data scarcity and shared our new approach with our peers

After completing this study, we applied the same methodology to review the benefits that we attribute to 185mm^2 to 300mm^2 LV cable upgrades. The loss improvements for HV and LV conductor upgrades that we have declared in our 2018/19 RIGs reports were based on this new approach.

Why does this exceed expectations or go above and beyond?

The innovative development of new reportable categories is a new initiative and not funded via RIIO-ED1 price controls.

What have we learned?

Our work on the underground HV cable study concludes that we will save on average **6 MWh** per annum for each kilometre of main line HV aluminium underground conductor that we upgrade from 185mm^2 to 300mm^2. Our CBA suggests this would lead to substantial net benefits across all our networks.

How have we shared learning with others?

We shared the technical aspects of our new method with other members of the **ENA's TLTG** to ensure that they can benefit as well. We will use the experience gained during this study to develop further RIGs reportable categories for overhead networks during Tranche 3.

How will customers benefit?

Customers will benefit from this initiative because more precise quantification of loss reduction enhances our ability to target our solutions. To take our case study on underground conductor cross-sectional size, it allows us to better prove the business case for investing in larger conductors leading to lower losses and costs overall. Defining more granular reporting categories enables comparison between distribution network operators which should enable more granular bench-marking and hence a stimulus to all DNOs to achieve the highest standard which will of course benefit all customers.

What have we done already?

In Tranche 2 we have already started to use our enhanced approach to make more robust investment decisions on underground cables, leading to loss savings when the investments are made. We will extend the approach to overhead conductors in Tranche 3.

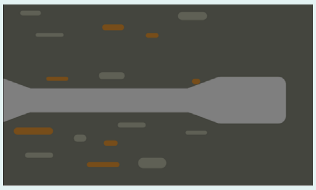
A2 Detecting Contact Voltage Losses with MAAV

This Appendix explains in more detail what causes CVLs and how we detect and address them.

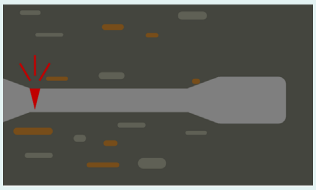
The diagram below explains how a CVL defect arises, its impact and how we detect it with our MAAV.

Figure 2

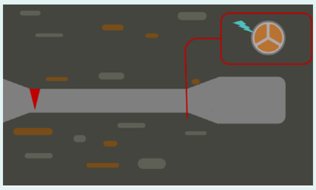
Description of the evolution of a CVL defect, from initiation to resolution by MAAV scan.



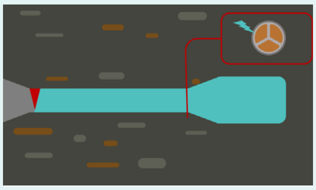
2.1
CVL defects begin with a section of lead-sheathed cable. In this case the section runs between a joint and a 'pot-end'. Pot ends are sections of abandoned cable with cores separated within a container and filled with pitch.



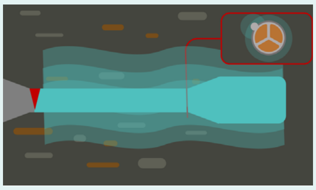
2.2
CVL defects start with damage to the lead sheath. The damage can be caused by third party action, defective or poorly-installed joints, or natural ageing of the cable. The purpose of this lead sheath is to provide a low impedance pathway for fault current.



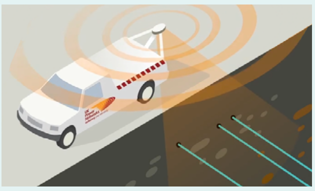
2.3
Following the damage to the sheath, a phase-to-earth fault occurs downstream of the damaged sheath. Because the sheath is damaged, the fault impedance is too high, and the fault current is too low to cause fuse operation.



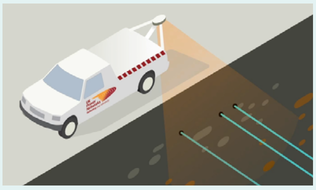
2.4
Over time heating from the fault causes the faulted phase to come into contact with the lead sheath itself. The sheath then becomes energised at the system voltage level of 230 Volts.



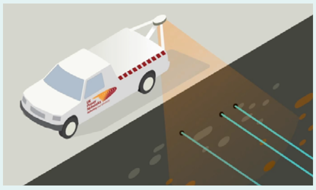
2.5
The energised outer sheath causes the insulation (typically paper) to be burned away. This heat energy can cause the faulted phase to melt the lead sheath, effectively welding the phase to the sheath. A section of cable several metres in length is now energised at system voltage.



2.6
Mobile Asset Assessment Vehicle (MAAV) scans pick up Contact Voltages (CVs) on the surface near the defective cable. The MAAV is equipped with sensors that pick up the electromagnetic emissions associated with energised structures on the surface.



2.7
Because the cables are buried, once detected, MAAV operatives undertake more analysis of the defect site. They will measure voltages between energised structures and an earth reference point, and record data about the energised structures such as location, structure type and measured voltage.



2.8
A risk-based approach is used to prioritise responses to detected defects. UK Power Networks operational teams mitigate defective cables. This involves excavation and replacement of the defective cable.

Once our MAAV identifies a CVL defect, we prioritise our response using a structured prioritisation matrix that we have developed. It considers:

- the voltage measured at surface level;
- the harmonic content of the neutral (or fault) current; and
- the type of energised structure.

Figure 3

Prioritisation matrix to support operational responses

Energised Object	0.1 Volt to 0.99 Volts		1 Volt to 4.49 Volts		4.5 to 9.9 Volts		10 Volts to 24.9 Volts		Greater than 25 Volts	
	Less than or equal to 5% THD	Greater than 5% THD	Less than or equal to 5% THD	Greater than 5% THD	Less than or equal to 5% THD	Greater than 5% THD	Less than or equal to 5% THD	Greater than 5% THD	Less than or equal to 5% THD	Greater than 5% THD
Lighting Column	719	719	713	713	712	713	712	712	711	711
Traffic Lighting	719	719	713	713	712	713	712	712	711	711
Illuminated Street Furniture (Bus Shelter, bench, etc)	729	729	723	723	722	723	722	722	721	721
Footway or Carriageway	724	729	722	723	722	723	721	722	721	721
Non-Illuminated Street Furniture (Bus Shelter, bench, etc)	724	729	722	723	722	723	721	722	721	721
Metal Utility Covers	729	729	723	723	722	723	721	722	721	721
Fences / Other	729	729	722	723	722	723	721	722	721	721

The three-digit prioritisation codes are used by our Control Centre to determine the appropriate response and allow for programme monitoring, reporting, and analysis.

The first digit of the priority code schema (i.e. 7) indicates that this is a MAAV finding, the second digit indicates whether the finding is a council-owned asset or a UKPN cable fault, and the third digit indicates the appropriate response time. This ranges from one hour to a week. Findings measuring less than 1 Volt are retained for analytical and monitoring purposes.

When the Control Centre receives prioritised incident reports from the MAAV survey team, they will create a 'Customer Safety Check' incident within the UK Power Networks dispatch system. Details of the event are recorded in the comments of the incident. From this point the event will follow normal dispatch processes based on the priority. At the conclusion of the resulting investigation and mitigation the event will be updated with the repair details.

UK Power Networks' losses team periodically export reports from our dispatch system to determine the quantum of mitigated losses achieved through CV repair activities.

A3 System architecture to reduce losses through the use of smart meter data

We are working[12] to integrate smart meter data into the existing systems that UK Power Networks uses to manage LV and HV networks. One important application is DPlan, which we are using as our primary tool for LV and HV network modelling functions.

Figure 4 illustrates the high-level conceptual system architecture underlying our operational systems. This will support DPlan and the use of smart meter data for network modelling and operations.

DPlan is itself is built on a client-server architecture, with the network model itself held on the server. Client applications sit on the user's machine, and populate the network model with load data. Load data is taken from the Network Measurement Historian, which will acquire data from smart meters and a range of other current and future sources, including EV charging points.

Figure 4

High level conceptual system architecture

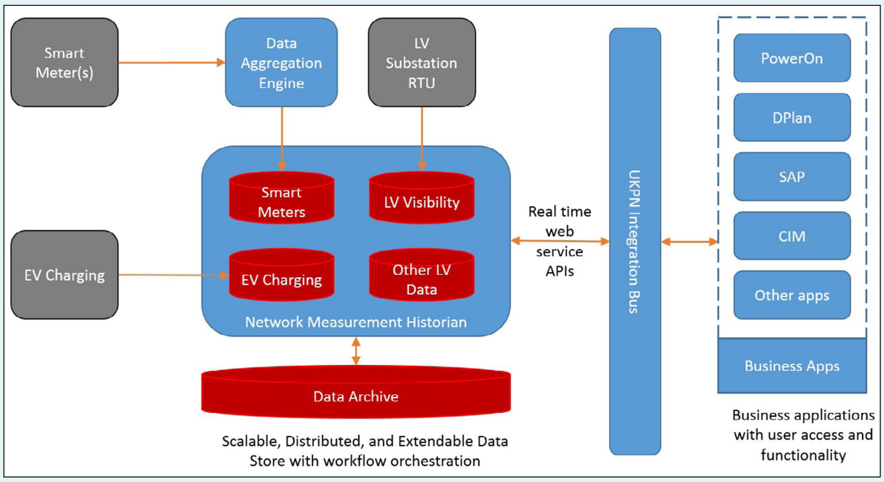
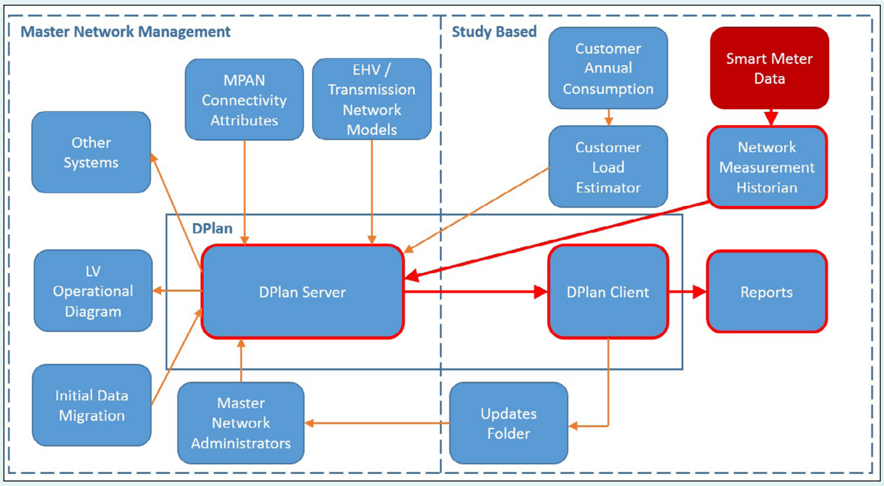


Figure 5 illustrates how our various systems will integrate with DPlan. The Customer Load Estimator currently uses customers' annual consumption to estimate temporal loading for network simulation purposes. As more smart meter data becomes available, this functionality will be used less as smart meter data is used instead to enable increasingly accurate network simulation.

We use DPlan's network optimisation capability to manage losses. DPlan analyses existing network configurations on the HV network and proposes alternative configurations based on load flow modelling. Using smart meter data will enhance the accuracy of our load flow modelling calculations. The accuracy of load modelling will therefore improve over time as the roll-out of smart meters continues.

Figure 5:

Business systems and processes to support DPlan



Our approach to NOP optimisation (see Appendix A1) uses current readings from various points on the HV network. DPlan uses these to automatically allocate representative loads on a pro-rata basis to distribution substations that do not currently possess SCADA measurements. This pro-rata approach is potentially a source of inaccuracy in our estimates of loss reduction benefits from this initiative. Smart meter data will increasingly enable us to improve the accuracy of our optimisation going forward.

12 Use of smart meter data is the subject to approval by Ofgem of UK Power Network's Data Privacy Plan for use of smart metering data. Ofgem approved our Data Privacy Plan in the first quarter of 2020.

A4 Commitments made in earlier submissions

We set out below where initiatives discussed in previous LDR submissions have been superseded or taken forward in a different way to planned. This is to be expected when exploring innovative new ideas: it is good practice to change course when better knowledge reveals more efficient or beneficial ways to achieve a goal or when a proposition proves not to be feasible or deliver insufficient value.

Power Factor Correction (PFC)

In our LDR Tranche 2 submission we undertook to measure power factor on a selection of feeders and to trial Power Factor Correction (PFC) where the CBA is positive.

During Tranche 2 we captured accurate power flow data on a selection of the HV feeders recommended by Imperial's researchers. While data logging continued, we built tailored models for these feeders in DigSilent Power Factory. We used this simulation environment because it features an Optimised Capacitor Placement Module. This module iteratively places available capacitor sizes on each available network node seeking to minimise losses. Once complete, the user is presented with a recommended location, a recommended capacitor size and an estimated energy loss improvement.

Next, we used **Ofgem**'s CBA worksheets to assess the economic viability of power factor correction in our networks. We used known labour and equipment costs to determine that a new HV capacitor bank must decrease losses by more than 19 MWh per annum to produce a positive Net Present Value.

We completed this study in 2019. Due to this project, we now understand that it is possible to decrease losses economically on some feeders by improving their power factors. The justification is, as expected, heavily reliant on the active and reactive power flow patterns on feeders being adequate to justify the incremental investment. The intervention will, as a result, be viable on a very small number of feeders only.

During the project execution, we further encountered a considerable list of complicating factors that would burden power factor correction projects. As a result, we have assigned a low priority to this activity in our Project Portfolio. Examples of these complicating factors are:

- Power factor is not a constant. It fluctuates over time. This fluctuation complicates the selection of an appropriately sized capacitor, and it potentially introduces a need to switch capacitors in and out of service. Switching adds cost and complexity; and
- Capacitors do not have the same life expectancy as overhead lines. As a result, CBAs need to account for capacitor renewal before lines reach their end of asset life. Capacitor installations require some periodic maintenance as well, which must also be reflected in CBAs.

Unmetered Consumption in Grid and Primary substations

We previously undertook to measure and analyse energy consumption in a range of our Grid and Primary substations to improve the understanding of our unmetered energy consumption. The aim was to assess our understanding of the split between operational losses and own consumption and, as a result, improve energy efficiency in our own Primary and Grid substations.

To fulfil our commitment, we captured data at seven of our substations for six months. To avoid uncertainty, we carefully distinguished between own consumption and operational losses during the data capturing process. The investigation concluded that we would require more data to solidify findings and we are working through the business case for installing the necessary additional metering.

Incorporate Losses into Connection Offers

During Tranche 1 we investigated a pair of major connections which were geographically situated close to the border between our networks and those of **SSEN**. In each case, the customers had asked for connection quotations from both DNOs. Given the magnitude of the loss inclusive cost difference that we have observed between two connection offers at the time, we indicated that we were planning to investigate further during Tranche 2. We proposed to work with ICL to determine an effective solution to the issue.

Changes to the connection charges to incorporate connection losses would depart from current practice of quoting for the least cost of installation only. It would depart from accepted current practice. We believe that taking this further, even if only to make customers aware of the loss cost may require regulatory approval and we have not prioritised this at this time.

KASM

We previously undertook to extend the functionality of the KASM software tool in two directions: to incorporate the 11 kV network in the KASM area and to use this model to estimate power factor in the resulting network without the need to add costly monitoring devices. This proposed work stream has been superseded by our ANM, in which we envision to incorporate the management and reporting of network losses.

Power Perfector/LV Voltage Optimisation

We previously indicated that we were planning to collaborate with manufacturers to develop products which exceed 'off the shelf' specifications to enhance LV voltage management. This included the development of the **iESCO PowerPerfector** for use in a network environment. However, due to the proliferation of smart meters and the data available from these new meters, we have decided to investigate possibilities to use smart meter data to improve LV voltage management instead. We have been liaising with our Innovation Team and another DNO to progress the study.

Data Analytics

In our LDR Tranche 2 submission, we committed to developing a Losses Data Analytics project. We originally envisioned this as being similar to our KASM Losses Module, except that it would be applied to LV networks rather than EHV networks, as was the case with KASM. However, as we progressed, we realised that it would be efficient to use DPlan instead.

Another aspect of interest in the KASM tool was the use of state estimation technologies to determine network parameters in areas of the network where there is currently low penetration of accurate monitoring. The use of state estimation technologies will be incorporated into our ANM solution. We anticipate that this functionality will allow us to determine network parameters like power factor, even in cases where there is insufficient monitoring to simply measure the parameters.

Further Stakeholder Engagement and Sharing of Best Practice

We indicated in our Tranche 2 submission that we were planning to conduct webinars and disseminate learning at future events. We also indicated in our Tranche 1 submission that we would share the outcome of our best-practice review, benchmarking methodology and impact of innovative solutions with members of the TLTG.

During Tranche 2, we changed direction slightly because we had more important information to share with the TLTG. We chose this direction on the basis that our CBA methodologies and practices can be adopted by fellow engineers who are empowered to benefit from our knowledge and suggestions.

In addition to sharing in this forum, we have presented our strategy and related developments on the UK Power Networks stand at the 2018 Low Carbon Networks and Innovation Conference. This session provided an opportunity for discussion with an audience beyond the ENA TLTG.

Losses in the DSO Environment

Our Tranche 1 submission indicated that we were going to embed losses as a decision parameter in the new DSO operating model, including the consideration of losses as part of any decision regarding system planning, operation or control. We are continuing work towards this aim by maintaining close working relationships with colleagues, especially members of our Innovation and Smart Grid Development teams. To demonstrate progress in this regard, earlier sections of this submission discussed how we are working to manage losses in Power Potential and through the use of our flexible connections market platform.

Glossary

EHV	Extra High Voltage
GW	Gigawatt
GWh	Gigawatt-hour
HV	High Voltage
kVA	Kilovolt-Ampere
LV	Low Voltage
MWh	Megawatt-hours

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