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DSO Losses Strategy 2020

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WESTERN POWER DISTRIBUTION

Serving the Midlands, South West and Wales

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Contact Details

Email
pwhite@westernpower.co.uk

Postal
DSO Development Team
Western Power Distribution
Avonbank
Feeder Road
Bristol
BS2 0TB

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1 Glossary

Abbreviation	Term
A	Ampere
ac	alternating current
Al	Aluminium
BAU	Business As Usual
CBA	cost-benefit analyses
CSE	Centre for Sustainable Energy
CT	Current Transformer
Cu	Copper
DC	Direct Current
DINIS	Distribution Network Information System
DSR	Demand Side Response
DNO	Distribution Network Operator
DSO	Distribution System Operator
ENA	Electricity Networks Association
ES	Energy storage (battery)
EU	European Union
EV	Electric Vehicle
EVA	Enhanced Voltage Assessment
EHV	33kV and up to and including 132kV (WPD standard)
FCL	Fault Current Limiter
FPL	Flexible Power Link
GWh	Giga Watt hour
HH	Half hourly
HV	11kV (WPD standard)
IIS	Interruptions Incentive Scheme
IPSA	Independent Power System Analysis
IPC	Insulation piercing connector
kVA	Kilo Volt Ampere
kW	Kilo Watt
kWh	Kilo Watt hour
LCNF	Low Carbon Network Fund
LCT's	Low Carbon Technologies

1 Glossary

Abbreviation	Term
LDB's	Link Disconnecting Boxes
LEAN	Low Energy Automated Networks
LV	240/400V Low Voltage
m	million
MPAN	Meter point administration number
MV	Medium Voltage
MVA	Mega Volt Ampere
MWh	Mega Watt hour
NIA	Network Innovation Allowance
NOP's	Normal Open Points
PSSE	Power System Simulation and Engineering
PV	Photo Voltaic (Solar)
PMT	Pole Mounted Transformer
RIIO-ED1	Revenue = Incentives + Innovation + Outputs – Electricity Distribution 1
RIIO-ED2	Revenue = Incentives + Innovation + Outputs – Electricity Distribution 2
SCADA	System control and data acquisition
SMETS 1	Smart Metering Equipment Technical Specification first version
SMETS 2	Smart Metering Equipment Technical Specification second version
SVO	System Voltage Optimisation
TASS	Transformer Auto Stop Start
TDH	Total Harmonic Distortion
UGC	Underground cable
UK	United Kingdom
UKPN	United Kingdom Power Networks
UKRPA	UK Revenue Protection Agency
UMS	Unmetered supply
UPRN	Unique property reference
WPD	Western Power Distribution
WSP	Engineering Consultants

2 Aims, Objectives and Outputs

2.1 Aims of this Document

The intention of this document is to provide an outline of the actions that are being taken by Western Power Distribution in order to reduce losses. The Introduction and Theory section provides a basic explanation of losses on distribution networks. A comprehensive list of the actions that are being taken to reduce losses can be found in the Polices and Actions section and summarised in the Table of Outputs. Much of the WPD strategy is based around the recommendations produced by SOHN Associates in their 'Management of Electricity Distribution Network Losses' report which is attached in Appendix [1].These recommendations are referenced throughout the report. This year WPD has included items from the ENA Technical Losses Working Group, including research completed by the Engineering Consultants WSP. The document, in addition has extended its focus to take into account future changing demands on the electricity network as a result of the introduction of Low Carbon Technologies (LCT's) and the UK Governments Carbon Plan 2011 and Road to Zero Strategy 2018.

2.2 Objectives

WPD's objectives regarding losses management are that by the end of the RIIO- ED1 period:-

- The losses across the WPD network will have been reduced to a level that is as low as economically and practically viable;
- All future investment decisions will take losses into account to ensure that the best balance is achieved between network investment costs today and energy supply costs for future customers;
- Providing the SMETS 2 smart-meter data is available, WPD will have the tools and methods in place to accurately locate the points on the network with particularly high losses;
- All of the WPD stakeholders will be aware of the importance of losses; and
- Using the knowledge gained from various innovation projects, computer modelling and investment appraisal WPD will through BAU have produced new and effective means to reduce losses;

2.3 Outputs

During RIIO-ED1 WPD are undertaking: -

- The pro-active replacement of 1,996 distribution transformers;
- Purchase and installation of circa 90 single phase 25kVA 11kV amorphous PMTs;
- The oversizing of 448 ground-mounted transformers and 575 pole-mounted transformers per annum;
- The design intervention for losses on new installation of 8,184 distribution transformers and 11,880 kilometres of underground cables;
- The discontinuation of cable tapering on all new 11kV and LV Mains cable circuits;
- The standardisation of new 11kV and LV mains cables to 185mm^2 and 300mm^2, with LV service cables the minimum conductor size is now 25mm^2 Cu. or 35mm^2 Al.;
- The identification of units lost to supplier side abstraction, unmetered supplies and theft in conveyance;
- A comprehensive programme of stakeholder engagement including biennial stakeholder consultation events;
- A comprehensive review of the WPD policies to ensure losses are a priority consideration for all the investment decisions;
- Voltage reduction across WPD;

3 Standard Conditions of the Electricity Dist. Licence

3.1 Part B: The Distribution Losses Strategy - Clause 49.4

WPD's Losses Strategy has been reviewed and modified to ensure that it provides economically beneficial interventions that will help keep distribution losses as low as reasonably practicable. The CBA's used in this version of the Losses Strategy are based on current WPD cost models and use the current Ofgem valuation of losses.

3.2 Part B: The Distribution Losses Strategy - Clause 49.5

A copy of this Losses Strategy document is available externally on the WPD website: -

https://www.westernpower.co.uk/About-us/Innovation-Low-Carbon/Losses.aspx

During the RIIO-ED1 period WPD plan to work through the recommendations of the 'Management of Electricity Distribution Network Losses' report (listed in Appendix 1 on page 43). Since the last version of the WPD Losses Strategy in February 2019, WPD has updated the Losses Strategy to include the recommendations considered during the past 12 months.

WPD's Losses Strategy document has undergone considerable restructuring, to make the document easier to read and navigate. A number of sections have been added, to provide more detail on certain areas. All of the WPD policies on losses and the actions WPD is taking have been compiled into a single section, titled 'Policies and Actions.'

This year will see WPD continue with their Losses Strategy, of the replacement of pre 1958 transformers, tapering of LV and 11kV circuits is no longer permitted, i.e. the use of 4mm² and 16mm² LV service cables, 95mm² Al. LV mains and 95mm² 11kV cables is no longer permitted, and this redefined sizing is incorporated in WPD Policy documents and is rolled out as business as usual.

WPD is also looking holistically at the design of new low voltage networks on housing estates and at the provision of upgraded services to retro-fit properties where LCTs are being fitted. This work is focussed on Wales in conjunction with Pobl and Sero Homes.

In addition WPD is taking the governments Road to Zero Strategy to reduce the overall carbon emissions and by using the new build and retrofit projects gain knowledge on the modelling and all the effects PV, ES, HP and electric vehicle charging will have on the LV and 11kV networks.

Vehicle charging is likely to be the first major low carbon technology demand to be seen on the low voltage network, which has to be accommodated as a result of the Governments de-carbonisation of transport and heat as per the Road to Zero plus with the introduction of updated Building Performance Regulations of April 2020 which will see the installation of a 7kW type 2 EV charger on every new building. WPD are currently working with a number of Local Councils with a view to creating charging hubs using low loss padmount transformers, in addition working with councils to meet their clean air objectives. WPD's losses strategy plans will be completed alongside the normal business as usual.

WPD has previously focussed work on transformers to the older larger ground mounted units. In 2019 we broadened our focus to start addressing losses on single phase pole mounted 11/0.4kV transformers. WPD has purchased 90 25kVA single phase amorphous PMTs. Single phase transformers are outside of the Eco design transformer legislation, the transformers that have been purchased have reduced Iron losses of 16W compared to the current CRGO transformer Iron losses of 65W.

4 Stakeholder Input, Review and Governance

4.1 Stakeholder Engagement

Stakeholder engagement is hugely important to every part of WPDs business. So, in developing the Losses Strategy, WPD carried out a specific programmes of stakeholder engagement.

In November 2014 we presented our draft third Losses Strategy to invited stakeholders with a specific interest in Losses. Our invitation list – carefully selected from our general stakeholder engagement database – included stakeholders with a technical awareness and interest in losses. We targeted people from manufacturers, other network operators, electricity suppliers, customer groups, academics, consultants and regulatory bodies.

The events

On 6th November 2014 WPD held a stakeholder event at the IET in Birmingham. WPD welcomed over 30 representatives who had the opportunity to learn more about the work that formed the losses strategy. WPD provided a draft strategy and launched a consultation period, which closed in December 2014 when the strategy was finalised.

On 12th November 2015 WPD held second stakeholder event where WPD gave an update on the losses work and all the changes that had been incorporated into the losses strategy. WPD welcomed stakeholders who had not previously attended and took the opportunity to summarise once more the whole content of the losses strategy. The feedback WPD received on the day really supported the high level objectives and actions of the losses strategy.

At the 2015 event WPD also discussed the future timing and format of stakeholder integration through the RIIO-ED1 period. The stakeholders agreed with the idea of reviewing and re-issuing the Losses Strategy each year. They suggested that specific dissemination events would be useful every second year or whenever a significant development had occurred.

On 14th November 2017 WPD held a third Losses stakeholder event where WPD gave an update on our work plan, current learnings and suggested updates to our strategy as a result. Our proposals for Superfast Electricity were discussed in detail at this event. This was our first biennial event based on stakeholder feedback.

On 9th December 2019 WPD held a third Losses stakeholder event where WPD gave an update on our work plan, current learnings and suggested updates to our strategy as a result. At this event we discussed our Losses Investigation project and were also pleased to welcome SSEN to share our event collaboratively to discuss LEAN transformer management.

The strategy

In January 2016 WPD published the 2016 version of the Losses Strategy, pulling together everything WPD had learnt in 2015. This revision included updates on all the work carried out since the last review and showed how WPD were progressing on items on the SOHN list of recommendations.

Since that time WPD has published annual updates to the Strategy. New items have been included as they have developed and the strategy has grown to take account of decarbonisation and the impact of Low Carbon Technologies.

In March 2020 WPD published the 2020 version of the Losses Strategy, the updated document includes updates on all the work carried out since the last 2019 Losses Strategy document review and shows how WPD have progressed on all the items listed in the SOHN recommendations.

4.1.1 Timeline for stakeholder engagement:

January 2014
Discussion around the Losses Strategy as part of general stakeholder engagement

November 2014
Stakeholder engagement event focused on losses

December 2014
Specific Expert Stakeholder review of proposed 2015 version of Losses Strategy

January 2015
General stakeholder review of proposed 2015 version of Losses Strategy

November 2015
Specific Expert Stakeholder review of proposed 2015 version of Losses Strategy

January 2016
General stakeholder review of proposed 2016 version of Losses Strategy

January 2017
General stakeholder review of proposed 2017 version of Losses Strategy

January 2018
General stakeholder review of proposed 2018 version of Losses Strategy

January 2019
General stakeholder review of proposed 2019 version of Losses Strategy

4.1.2 Topics Covered at Stakeholder Engagement

January 2014 - General Stakeholder engagement where losses were included as a topic
- The concept of losses
- Ways losses can be reduced
- Early versions of the WPD Losses strategy
- High level objectives and results

November 2014 - specific Losses stakeholder event
- SOHN losses report
- Losses strategy items including process of selection
- Cost benefit analysis,
- Early transformer replacement for pre-1958 units
- Discontinuation of small sizes of transformers and cables for new works
- Design changes for networks to remove tapering
- Network phase balancing
- Revenue protection

November 2015 - specific Losses stakeholder event
- SOHN Losses Report
- Losses Strategy update
- Innovation projects and losses
- Low voltage cable length modelling
- Heat recovery from large transformers

November 2017 - specific Losses stakeholder event

- SOHN Losses Report
- Losses Strategy update
- Innovation Projects and losses
- Losses Investigation Project –
- Measuring losses
- Collaborative Working
- Housing estates of the future
- Retro-fit service cables and loss reduction

November 2019 - specific Losses stakeholder event – in conjunction with SSE.

- SOHN Losses Report
- Losses Strategy update
- Losses Investigation Project
- Collaborative Working
- Housing estates of the future
- Retro-fit service cables and loss reduction
- Amorphous padmount transformer
- Primary transformer heat pump to heat substation
- SSE presentation on TASS / Lean project

4.2 Industry-wide Engagement

WPD along with all the other DNOs and ESB hold regular meetings of the ENA Technical Losses Task Group, much of the work WPD have carried out at an industry level can be seen in the WPD Innovation Strategy. The Innovation Strategy included plenty of projects and initiatives, many of which show a reduction in losses as part of their targets to increase utilisation of the network. Higher levels of utilisation will always increase losses, but a smoother demand profile can contribute to the overall reduction of network losses.

WPD use demand side response to reduce the peaks of load and associated losses on our network. As a result of our FALCON project, we found that customers are often not able to help us with DSR due to contracts in place with National Grid. We are working with National Grid to change their standard terms and conditions to allow customers to operate in both markets. Centrica is lauding a ‘world first’ as its Local Energy Market (LEM) enables National Grid ESO and Western Power Distribution (WPD) to simultaneously procure flexibility from the same platform. WPD have set up the DSR Forum, where DNOs, Ofgem and National Grid are represented, to discuss this in more detail.
International Best Practice

WPD have engaged with the parent company PPL as to what methods they use to minimise losses but because of the fundamental way the British and American systems operate there is no common ground. PPL state that the level of losses on their LV and MV system is at 3% and as a consequence they have no active losses measurements.

While WPDs research into the optimum length of low voltage feeders did not produce any evidence to change our proposals, the research WPD conducted with SOHN Associates has been presented as a paper in the Cired conference held in Helsinki in June 2016.

One of the regular topics in the ENA Technical Losses group is a section on best practice where all information that is gleaned from parent companies or data obtained from other sources is discussed and made available.

4.3 Sharing Best Practice

It's important to WPD to engage with other network operators to develop best practice – a desire that can be traced back to WPDs IFI project on Losses that was completed with UKPN. This took place before the specific work on the WPD Losses Strategies and really helped WPD to shape its own strategy. WPD have shared the project's findings with many other network operators and are pleased that elements of it and references to it appear in other DNO strategies. Scottish and Southern Energy Power Distribution (SSEPD) not only shares WPDs intervention on pre-1960 transformers, but has cited WPDs IFI project as the research source.

With WPDs Losses Investigation project there have been regular updates on this project in the WPDs Losses Stakeholder events, at the LCNI in Telford and at WPDs Balancing Act events where all our innovation projects are disseminated. All the documents are available for download on the WPD Innovation website.

WPD are also always keen to learn from others and use their research to develop WPDs plans. The third WPD Losses Strategy included topics highlighted in other DNO strategies and this collaborative approach continues. One of the items for further research in WPDs current strategy is the de-energisation of plant when not required. WPD have been investigating SSEPD's Low Energy Automated Networks LCNF project with a view to explore the viability in adopting the process, at this moment in time finding a suitable substation location with the fibre optic communications is proving troublesome.

WPD were pleased to see that other DNO losses strategies now include some of the elements of the WPD SOHN plan. All DNOs face similar issues so this kind of peer review and inclusion is a fantastic development.

As part of the sharing of best practice WPD have recently purchased circa 90 25kVA amorphous cored single phase pole mounted transformers on the back of work carried out by UKPN and Scottish Power on amorphous transformers. The single phase amorphous PMTs are currently being installed on the WPD 11kV network as part of BAU.

4.4 Losses in relation to wider Stakeholder Engagement

WPDs specific stakeholder engagement for losses is detailed in 4.1 above, but the story doesn't end there. Losses have also formed part of the more general stakeholder engagement work. In January 2015, WPD proposed the topic of Losses with the stakeholders at six general sessions to find out if there was an appetite. WPD soon realised that losses were of real interest to the stakeholders although many were content to leave the more technical debate to a specific stakeholder event. Smaller subsets of stakeholders were keen to engage in more depth and attended our various November events in 2015, 2017 and 2019.

4.5 Stakeholder Feedback

The majority of the feedback received at the last consultation was positive and stakeholders were pleased that WPD were heading in the right direction, so they were happy for WPD to continue working as they are. As a result of the discussions, suggestions were made for specific actions that should be taken. New subject areas such as the impact of EVs, HPs and future LCT effects that will have on the network have been added to the losses strategy.

4.6 Losses Strategy Review

The WPD losses strategy is reviewed on an annual basis and stakeholder consultation events will occur biennially. This frequency of review is supported by the stakeholders. WPD has a range of LCNF and NIA projects that are ongoing which are continuing to provide important new insights. Each year WPD will develop and act on the strategies targeted in SOHN document, obtain new information from the innovation projects, construct new strategies (which may be based on the results of the innovation projects) and then record the progress in the next strategy document.

The intention is both to review what has been done in the previous year and plan what is intended to do in the coming year and update the strategy accordingly.

4.7 Losses Strategy Governance

The WPD losses strategy is developed within the Distribution System Operator and Future Networks Team and is approved by the CEO. Within this governance, the DSO and Future Networks Manager is responsible for the development of topics to address from the SOHN "Management of electricity distribution network losses" report. Each year the recommendations from this report are developed into areas for investigation. During the RIIO-ED1 period WPD will address each of the recommendations and plan to develop at least one technical and one non-technical recommendation per year. Appendix 1 shows plans for each recommendation and a justification for the WPD assessment of each plan.

4.8 Innovation funding

WPD can confirm that innovative losses activities have been carried out outside of other RIIO-ED1 financial initiatives, this ranges from the asset upgrade provisions developed after the agreement of the ED1 plan through to the projects which are being supported by WPD rather than being funded through innovation funding mechanisms.

5 Innovations and Projects

Innovation projects are the main way in which new methods can be developed to reduce losses, which is why they are a cornerstone of the losses strategy. Many of the projects have a focus on network monitoring and automated control, aiming to flatten load profiles. WPD is also looking at developments such as energy storage and heat recovery.

5.1 SOHN Associates Losses Report

The SOHN losses report [1] was commissioned by WPD and UKPN to provide an assessment of all the ways in which losses could be reduced. The report was written in partnership by SOHN Associates and Imperial College London, to provide an academic viewpoint on the range of the problem. The scope of the investigation was very broad, as the intention was to come up with as many potential solutions to reducing losses as possible. Using a network modelling tool designed by Imperial College and intelligent forecasting for future demand, potential approaches to reducing losses were identified. The report looked at possibilities such as heat recovery; active network management and asset replacement. These possible approaches led to 26 recommendations for DNO's to consider. These recommendations have formed the basis of the WPD losses strategies and all will be considered during the course of RIIO-ED1.

5.2 LV Templates

The LV Templates project set up a highly monitored network in South Wales, to see if it was possible to characterise substations into a number of 'templates' which could be used to describe the temporal load and voltage behaviour of substations nationwide. The areas chosen for monitoring had dense populations of LCT's. This was to enable scaling up to represent the UK as a whole. The project found that around 82% of UK substations fitted one of ten district templates identified in this project.

The project also provided data on the voltages seen on the LV network. It concluded that there is scope to reduce the network voltage and remain within the statutory voltage parameters. Reducing the voltage will reduce the overall demand and makes a contribution to loss reduction. The voltage on the LV network can be reduced in many ways but WPD has chosen to change the settings at the primary substation level. At this point on the network, the voltage change can be made automatically without interrupting customers. WPD has completed a programme of voltage reduction in the South Wales area, and results have shown that a 0.88% reduction in primary voltage resulted in an average demand drop of 1.16%. As a result of this, losses increased in percentage terms but this is because the current has to be slightly higher to deliver the same power, which increases the variable loss, but the power required is lower, therefore overall losses are reduced. Based on these results, WPD has now commenced a programme of voltage reduction across all the WPD licence areas, the current status is, 1403 completed substations and 714 outstanding substations, with a target completion date of 2020.

5.3 Losses Investigation

Data relating to the power consumed by all individual connections on an LV cable or network was not included in the LV Templates monitoring, which was set up to measure the overall profile of a distribution substation.

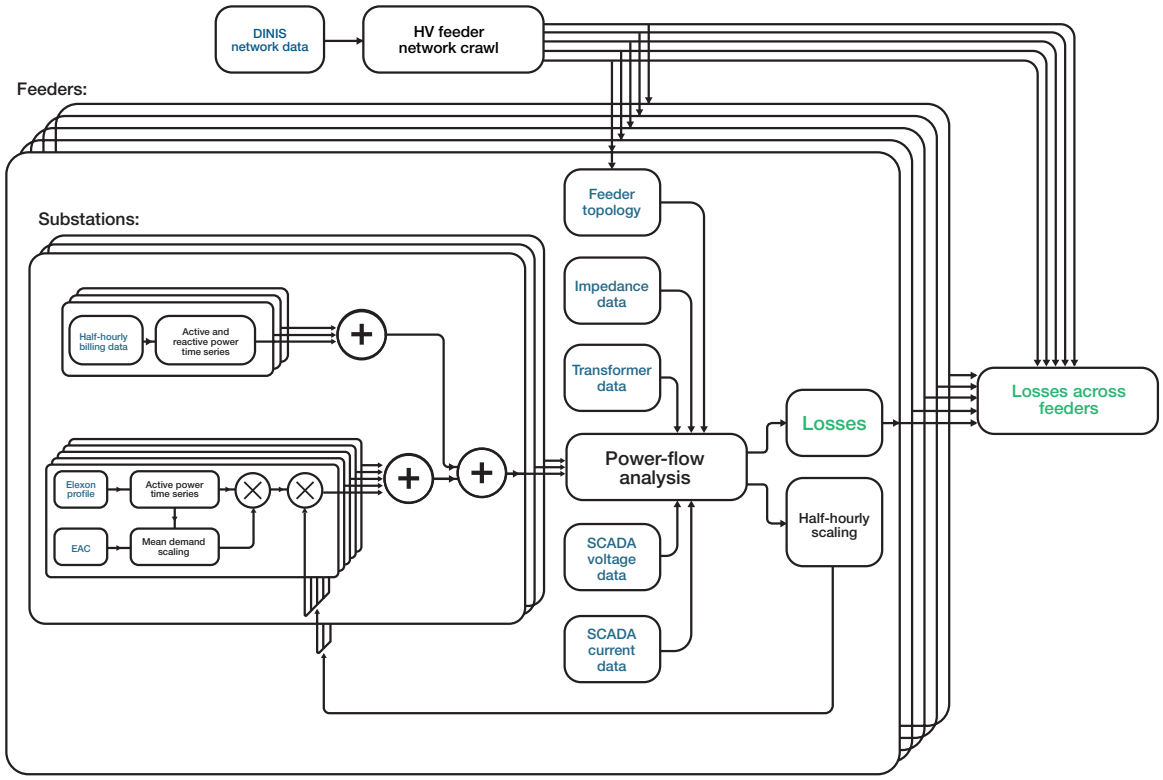
Through a field-work programme, for HV feeders, one minute resolution logging equipment is being installed at the Primary Substation on the source breakers of the sample feeders, and at each load connection point along the feeder. This provides comprehensive information about actual power flows for a complete HV feeder, allowing actual losses to be assessed for a specific feeder.

For LV feeders, one minute resolution logging equipment has been installed at Distribution Substations, monitoring the entry/exit of power onto LV feeders; and one minute data is being logged at all connection points along the sample LV feeders. As with HV feeders, this instrumentation provides comprehensive information about power flows for a complete LV feeder, and allows actual LV losses to be assessed for a specific feeder. The LV field work was carried out on the Isle of Man in collaboration with Manx Utility Authority, as WPD are not allowed access to individual customer data in their own regions.

The Losses Investigation report has been completed and final reporting has been carried out, but as the initial work only looked at the East Midlands area this has now been extended to the whole WPD area.

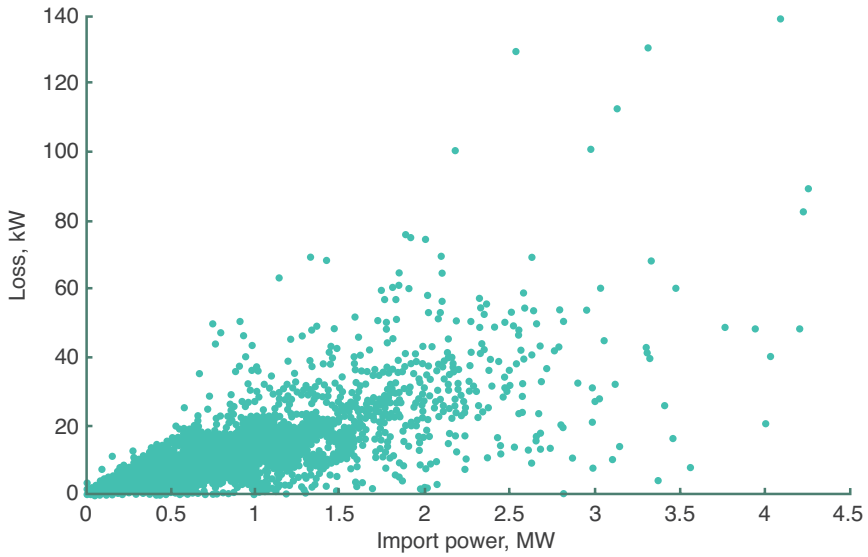
With development of the HV feeder loss estimation process now complete, feeder-specific annual mean loss estimates have been generated for 2130 feeders in the East Midlands region of WPD, the three remaining WPD areas are currently being developed. Details of findings and learning for the HV loss estimation work are available, with key items including:

Method - for each HV feeder, the loss estimation method combines network topology data with demand data in order to run a power-flow analysis from which the individual feeder losses are calculated. These individual feeder results are then collated so that loss characteristics of the overall HV feeder set can be examined and identified. An outline of the method is shown in the diagram overleaf: -

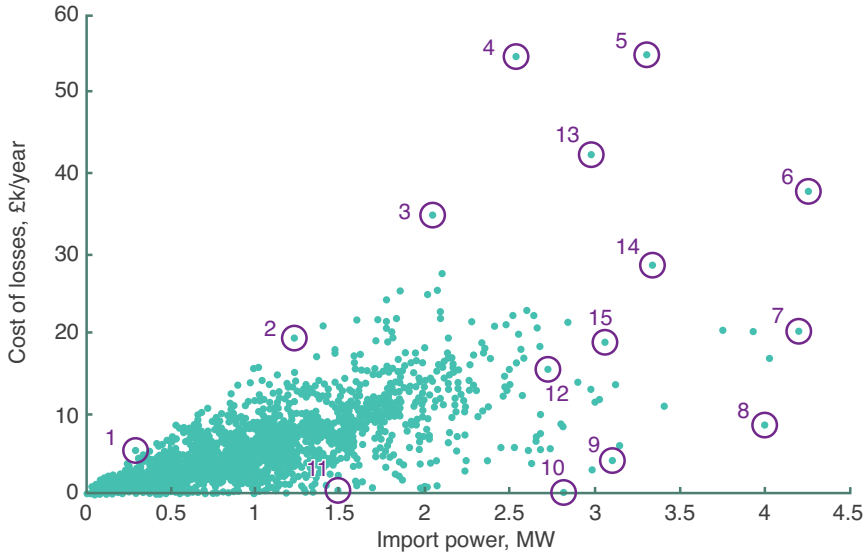


The results of the loss estimation method for the monitored HV feeders established at the start of the project have been found to be in good agreement to the loss assessments of these feeders using the measured data.

Results - one of the fundamental outputs from the HV feeder loss estimation result set is a scatter plot of mean total loss power versus feeder mean power, see below. Many other forms of analysis are provided, and these are detailed in the recent progress report.



Validation - In addition to overall method validation, a number of outlying results have been reviewed. The review of each feeder included: feeder topology, together with broad characterising metrics and drivers of the level of loss. The review also considered potential opportunities to reduce the losses, as a test of the capability of the analysis to support mitigation investigation work. The feeders included in the validation work are highlighted on the plot shown below, with the vertical axis now representing the annual cost of individual feeder losses.



In all 15 cases reviewed, the estimated level of loss could be linked to characteristics of the network (e.g. length, cross-sectional areas number of connected transformers), and the load (e.g. how the load is distributed across connected substations, and the location of dominate loads on the HV feeder).

Signposting – the HV feeder loss estimation process has demonstrated how HV feeders with high losses can be identified. These high loss feeders can then be reviewed to assess the cost-benefits of loss mitigation. The results also identify a set of higher loss individual feeder branches, and possible higher loss distribution transformers.

Learning – Detailed points of specific learning are described in the final report.

5.4 New and retro fit homes in Wales

WPD is looking to new and innovative areas to reduce losses, to this end WPD are working with Pobl and Sero Homes where currently in Tonyrefail, South Wales circa 250 new build homes are being built, each house is fitted with PV, ES, HP, EV charging, smart white goods each device is connected to a PLC these homes will be supplied via three phase service cables and dark fibre to each house, WPD will be fully monitoring the 11kV LV Mains feeders and each home to replicate the Isle of Man Losses Investigation which was looking at single phase LV services. What WPD are envisaging is a reduction of losses in the LV services cables, LV Mains cables and in the 11/0.4kV unit substation supplying the housing estate. It is envisaged that use of three phase service cables will reduce out of balance loads in the LV mains cables and on the 11/0.4kV transformer.

In a second project WPD are again working with Pobl and Sero Homes in Bleanu y maes, Swansea where currently circa 700 retro fit homes are being modified, each house is fitted with PV, and ES each device is connected to a PLC these homes will be supplied via three phase service cables, and some on street EV charging WPD will be fully monitoring the 11kV LV Mains feeders and each home to replicate the Isle of Man Losses Investigation which was looking at single phase LV services. What WPD are envisaging is a reduction of losses in the LV services cables, LV Mains cables and in the 11/0.4kV unit substation supplying the housing estate. It is envisaged that use of three phase service cables will reduce out of balance loads in the LV mains cables and on the 11/0.4kV transformer.

5.5 EQUILIBRIUM

The focus of the Network Equilibrium project is to balance voltages and power flows across the distribution system, using three methods to integrate distributed generation within electricity networks more efficiently. The project considers three methods to improve voltage and power flows: Enhanced Voltage Assessment (EVA); System Voltage Optimisation (SVO) and a Flexible Power Link (FPL).

In some places, parts of the higher voltage networks are run in parallel with the lower voltage networks. This means there is more than one open point between the two levels of the network. The advantage of this configuration is that it allows loads to be better balanced, in most cases.

With the FlexDGrid and Equilibrium projects WPD has developed methods to monitor and automatically reconfigure networks. There are areas of the network where it is not possible to operate with parallel feeding arrangements (meshing) due to technical limitations. These can be due to loads, generation or fault levels.

The EVA method enables the two technology solutions, SVO and FPL, to be suitably modelled and understood. The EVA also demonstrated the value of expanding the current voltage statutory limits for 11kV and 33kV networks to +/-6% and +/-8% respectively. This would facilitate an increase in utilisation of the existing system removing or deferring the need for additional asset investment. These models will also enable the network to be optimised in terms of full system losses, aligned with the learning from LV Network Templates and reducing the voltage as strategic points on the network.

The SVO method assesses the operational state of the network in real-time, considering connectivity and connected load and generation, to determine the optimal voltage and then communicate these calculated values to the on-site voltage control relays to implement the voltage change. The SVO system will then calculate the optimised voltage level, lowest value for generation inclusion and highest value for load facilitation, enabling on-site changes to voltage to occur. The system went live in March 2018 and has demonstrated significant network value through actively being able to control the voltage on the system.

The FPL device is an AC-DC DC-AC converter provided by ABB, which has been built, tested and was installed on the live Exebridge substation 33kV system in June 2018. This has enabled WPD to connect the Barnstaple and Taunton BSPs networks in parallel, providing the flexibility to move real and reactive power around the network to optimise the operation of the system and enable increased utilisation of the existing assets.

The FPL aims to enable active power transfer between two network groups whilst independently controlling reactive power between each of the two grid groups to provide additional voltage support. The device works by connecting the two, previously distinct, networks together with two back-to-back AC-DC converters, removing any phase displacement or fault level constraining issues that currently exist. The device itself produces relatively high levels of loss so it will only be used for short periods when the losses benefits outweigh the costs. This has been trialled and the benefits of the FPL have been demonstrated to ensure that there are no network violations on the system whilst enabling more generation to connect to the system.

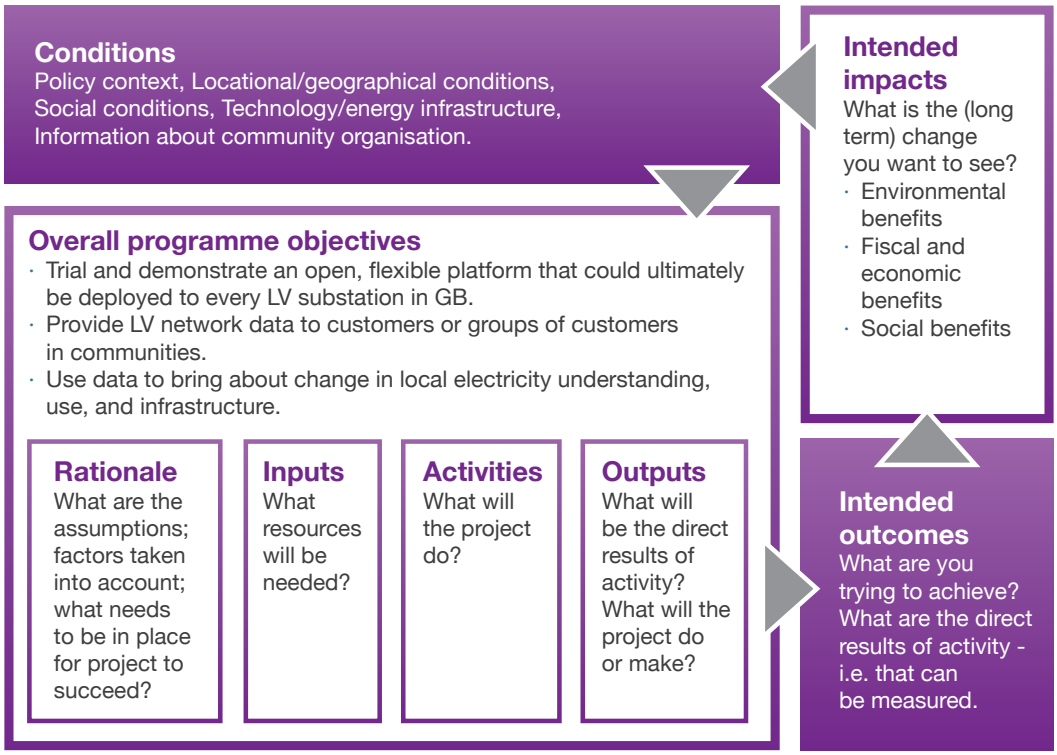
5.6 OpenLV

The OpenLV Project was about trialling and demonstrating an open, flexible platform that could ultimately be deployed to every LV substation in Great Britain. Through three key Methods, the Project demonstrated the platform's ability to provide benefits to the network, customers, commercial entities and research organisations. Once deployed, the OpenLV platform can be used to provide data to customers or groups of customers in communities.

The Method 2 trials involve the active engagement of communities to provide organisations and individuals with direct access to LV network data through a secure third party hosted service. This is unique to the OpenLV project so there is learning to be gained from looking at how this will be achieved with the Community Engagement trials, and the ways in which community organisations propose to use LV network data in their communities.

The logic model provides a means of planning community-based project activity to achieve a set of outcomes for use of the OpenLV data, as well as a structure against which to evaluate the trials. Figure below shows the basic template which was used. Much of the content of the logic models was common to all the projects, particularly in terms of project activities and intended outcomes.

As customers better understand their electricity usage as a community, and their local network performs in a more efficient way balancing demand and generation, the overall volume of losses seen on the network will drop as peaks are reduced.



5.7 Industrial & Commercial Storage Project

Four sites were selected to integrate different configurations in the application of storage. The fundamental operation of the energy storage system will be to store energy at times of low load seen on the network and dissipate energy at times of high load in order to actively manage the load on both the LV and HV networks. More specific applications include peak shaving; load shifting, transmission and distribution support, and islanding or emergency back-up. Through this project WPD will be able to develop an alternative connection agreement for behind the meter storage designed for Industrial & Commercial Customers.

At Spilsby WPD has installed a 50kW/210kWh with 30.75 kW of local PV generation to test peak shaving and PV self-consumption. We will show how storage charges from PV and at peak demand, storage can be used to eliminate peaks and reduce losses. Batteries designed to capture surplus electricity generated by a solar PV system can allow consumers to store solar electricity for use later in the day.

Site Name	Status	Application
Spilsby	Commissioned - Online	PV self -consumption
Boston	Commissioned - Online	Active Control by WPD - Nortec
Cardiff	Commissioned - Online	Part 1: Providing Grid Services Autonomously (Primary Frequency Support)
		Part 2: 3rd Party Controller Integration (In collaboration with KiwiPower)
Taunton	Commissioned - Online	Emergency Load Backup

At Boston WPD has installed a 50kW/210kWh with 21 kW of local PV generation. Third party controller integration allows the Powerpack user to change the battery behaviour during the operations. The controller will run multiple services on the customer's behalf. This could be for example a combination of frequency support services and wholesale trading activities.

At Cardiff WPD has installed a 50kW/210kWh with 8 kW of local PV generation. This project has two parts at this site. Part 1 will show the Energy Storage Capability to support the grid via Frequency Support Mode. Part 2 of the project adds 3rd Party Controller (KiwiPower) integration to test the communication interfaces, data monitoring and send remote direct commands to the batteries.

At Taunton WPD has installed a 50kW/210kWh with 50 kW of local PV generation this will demonstrate Backup & Islanding modes. Despite expectations, some storage systems will not provide power during a power-cut. Some battery storage systems however do have an 'off-grid' functionality, providing a limited amount of power to your premises, or to essential equipment (such as your fridge-freezer, lighting etc.). But a battery may run out of power before the power cut ends – or have already run out of power if it's been discharging all evening and the power outage starts late at night or early in the morning. If a system is required to operate in 'island' mode, i.e. continuing to provide power to critical loads during times when the distribution network is not available, it is important to understand the load handling and load shedding capabilities of the energy storage system.

As well as being capable of operating in 'island' mode, the battery/hybrid inverter must be rated to supply the power required by the load (including any inrush current). Typically, critical loads will be separated from other loads and connected to the energy storage system via a dedicated distribution board. An automated make and break contactor disconnects mains supply and connects the energy storage system to these loads, so that they receive a continuous electricity supply while ensuring power from the electrical storage system is not fed back to the distribution network. Additional consideration should be given to the operation of protective devices and the provision of continuous earthing when operating in island mode. RCDs for the critical loads will need to be capable of operating under both supply conditions and not trip as a result of the transition.

6 Improving Understanding

In order for WPD to reduce losses effectively, there is a need to have a far better understanding of them. WPD needs to quantify the losses that are present on the network; identify where they occur; understand why they occur and have methods for predicting what effect certain actions taken to reduce losses will have on the losses.

6.1 Quantifying and Monitoring

Raw levels of losses in kWh are of significance for any DNO, but a direct comparison with other DNO losses levels is more difficult: indeed, DNO losses depend not only on the network structure, but also on network energy flows. Losses rates make a comparison between loss and energy flow levels. Consequently, they provide reference values that may be comparable between networks, even if they are detailed by voltage level for relevant benchmarks.

Raw losses values and losses rates have to be calculated over long periods (at least 3 years) to ensure stability and robustness, as total losses for a given year may not be significant due to variability and uncertainty (due to data collection hazards or climatic conditions). In order to see the effect of reducing losses WPD needs to be able to determine the baseline level of current losses. The Losses Investigation project aims to establish such a baseline for several highly monitored LV and HV feeders picked to be representative of the main UK network topologies. This will allow WPD to better understand the locations of the losses on the network as well as the main causes. The project will also establish the level of information required to accurately assess the losses across the rest of the network and enable a more targeted approach to reducing losses. There is more detail on this project in Section 4.3.

To measure overall losses on the network, the power entering the network from the transmission network and the power which leaves the network are compared. The measurement at the customer end can be very inaccurate in the case of domestic customers as some meter readings can be estimated values. Statutory limits for domestic energy metering is -3.5% to +2.5% accuracy. This rough calculation does not discriminate between technical and non-technical losses, nor does it give any indication of where the losses occur. There are other monitored points along the network, typically substations, which can help identify where the losses occur.

WPD's standard LV distribution cabinets have always been manufactured with a simple current transformer (CT) fitted, which measures the peak load. When transformers are replaced, they are now installed with more accurate current transformers, which are wired to a terminal block where more advanced monitoring equipment can be attached. On the EHV network half-hourly loading data is recorded at all the substations. However, currently there are areas of the network, especially at LV where there is no monitoring at all.

6.2 Smart-meters

The roll out of SMETS 2 smart meters has the ability to change the nature of network monitoring. It still needs to be considered that the statutory limits for domestic energy metering is [±]1.5% accuracy. DNO's should have the access to data points representing the consumption across their respective networks and LV feeders. This smart meter data will be readily available in providing data for the relevant circuits and updated on far shorter timescales, thereby providing vastly improved data on network loadings. Smart meters are also being installed at other points on the WPD network, so there will be a more complete picture of load flow across the network. Provided the SMETS 2 smart meter roll out is completed by the deadline of 2020, it is important to ensure that the necessary data analysis tools are in place to make maximum use of the data generated.

The deployment of smart meters should enable DNO's to implement a number of key strategies to manage losses. Firstly, customers could be incentivised to use less energy at peak times by using time-of-use tariffs, which would flatten the network load profile to reduce losses. Secondly, it would enable areas of high loss to be identified, so that targeted action can be taken to reduce them. Finally, it would allow for real-time network management, meaning generation from both distributed and non-distributed sources and power flow across the network could be controlled to match present demand.

6.3 Computational Modelling

In order to forecast, what will happen on the WPD network in the future and to determine what is happening on the unmonitored parts of the network, the most powerful tool is computational modelling. Modelling effectively creates a virtual, fully monitored network which can then examine and test new ideas. Using the modelling tools WPD should be able to map where losses occur on the network, allowing for a targeted approach to loss reduction. Modelling can also be used to predict the effect of future changes to the network, so that the effect on losses of all possible future actions can be considered before the changes are actually carried out.

WPD's LV system modelling tool includes losses calculations for each scenario used, but as one of the first measures WPD undertook was to increase the underground cable size and removed cable tapering this means upgrades are uniform across the company. The WPD 11kV system modelling tool also includes losses calculations, but as one of the first measures WPD undertook was to increase the underground cable size and removed cable tapering at 11kV this means upgrades are uniform across the company. At EHV WPD currently uses two system modelling tools, PSS/E and IPSA. PSS/E can create losses calculations, it is envisaged that PSS/E will become the standard system within WPD by Q4 of 2019. This date has been delayed due to a compatibility issue between the latest release of PSS/E and the WPD corporate IT hardware/operating system, which will be refreshed during 2019. Whilst all EHV designs are bespoke, WPD has completed work to provide templated solutions for generation connections, these templates incorporated the losses impacts.

Modelling should become even more useful once used in conjunction with smart meter data. By feeding the data into the model, this will be able to produce models of the network in real-time. Data at specific metering points can then be predicted and compared to the real data, to establish the success of the model. The software will need to be redesigned to incorporate this feature. Once this level of insight into the network is established, it will be possible to create more targeted losses strategies, leading to far more effective loss reduction activities.

6.4 Harmonics

Harmonics are generated whenever non-linear loads are connected to the network. The currents generated by harmonics cause problems on the network and contribute to increased levels of losses, because of the harmonics $I^2R+\sqrt{H}$ add to the total losses in the distribution transformers. Eddy currents in transformers will increase with the square of the harmonic frequency, so can become significant. Within the UK a derating factor, K factor, can be applied to transformers to take account of the harmonic currents. K factor is a weighting of the harmonic load currents according to their effects on transformer heating.

WPD network monitoring does not routinely measure harmonics. Assumptions based on calculations of known harmonics can be inaccurate due to the effects of diversity, which apply to harmonics in a similar way to network loadings. The only accurate method of assessing harmonic spectra is to measure the harmonics using monitors on the network. WPD is continuing to record data from the LV Templates monitored network, which gives WPD an indication of harmonic effects by measuring Total Harmonic Distortion (TDH) across an individual distribution substation area.

The standard retro-fit LV harmonics monitoring solution is capable of recording Total Harmonic Distortion (THD) data where appropriate. Reducing harmonic effects is difficult; the principal approach is to ensure that customers use devices that produce minimal harmonic effects. The harmonics can also be reduced by fitting harmonic filtering devices, but the economic benefit of reducing harmonics is not great enough to justify the cost of the filters.

6.5 Asset Replacement

Asset replacement is the ongoing and most direct way in which WPD can reduce technical losses. From a losses point of view old transformers and underground cables encompass the majority of assets which provide the best value to a DNO and customer to reduce the losses seen on a network. With this in mind it then becomes part of the business as usual that WPD will be changing pre 1958 transformers for newer models which will reduce overall losses as new transformers have lower losses than old ones. In addition the variable losses in cables can be reduced by using cables with larger cross sectional areas, which also increases their capacity. Where overhead line conductors are replaced WPD aims, where possible, to replace smaller diameter conductors with larger diameter conductors.

7 Policies and Actions

7.1 Assessment

This section contains all the various areas that WPD are currently focusing on with a view to reduce losses going forward. These actions can be split into three areas: - actions completed before 2018, actions completed during 2018 and plans for 2019 and beyond. These actions will allow WPD to reorganise the network to make it run more efficiently with the revenue protection, identifying actions that can be taken to prevent or reduce energy loss to theft or unmetered supplies. However, there are also some discussions, particularly in the network design section, of policies where WPD will be able to implement in the near future, with reference to the innovation projects which are investigating them. Where appropriate, WPD has referenced the SOHN recommendations to which the actions correspond to.

7.2 Actions Completed Before 2018

- The discontinuation of cable tapering on all feeder and service cables;
- A comprehensive programme of stakeholder engagement including biennial stakeholder consultation events;
- Reducing cable lengths;
- Rationalisation of transformer sizes and application;
- Start of voltage reduction across WPD;
- The on-going reduction the variable losses in underground cables by removing the smaller cross-sectional area cables from normal use;
- The development of a new losses page on the WPD website;
- Creation of a Losses Engineer post within the Policy Section;

7.2.1 Cable Tapering

Since 2012 WPD as part of the business as usual have installed link disconnecting boxes (LDB's) between LV substations on non-tapered LV mains cables, thereby providing the possibility of mesh connections and back feed potential under fault conditions.

In addition since the start of 2015 WPD has amended the design policy and now all designs of the LV mains underground cable network are designed without cable size tapering. Networks shall be planned using either 185mm^2 or 300mm2 Wavecon cables. The size chosen for a particular scheme will be used throughout that scheme and tapering is no longer considered. (Recommendation 13)

7.2.2 Cable Sizes

To reduce the variable losses in underground cables either a lower resistance conductor must be used e.g. using a copper conductor or the cross-sectional area of the conductor needs to be increased. Once an underground cable is laid and the cable trench is reinstated, it becomes expensive to make alterations to the underground cable. The opportunity to reduce losses exists when an underground cable is installed or replaced. The resistance of a 185mm^2 Al LV cable is around half that of its 95mm^2 equivalent. The additional cost of the cable is less than £10 per metre, a marginal cost when compared to the excavation costs, which can be between £50 and £100 per metre. Whilst this cost is marginal, it is only appropriate to oversize cables in some cases. (Recommendation 8)

In the case of underground cables on the LV network, it is cost-effective to uprate them, but only in conjunction with other works.

For LV service cables there is no justification in the targeted uprating of cables, but it can be demonstrated that a benefit exists in discontinuing the smallest service cable size of 16mm2. The cost of this will be around £0.33m per year at current prices. (Recommendation 4)

On the LV mains UGC network, WPD will install the next size up for all our cable designs in the RIIO-ED1 period. This will cost us around £2.89m per year at current costs. This means WPD will discontinue the installation of 95mm^2 LV mains cables.

At 11kV it can be demonstrated that a benefit exists, in new build work, to discontinuing the smallest cable size of 95mm2, costing around £1.42m per year at 2014 prices.

In 2013 WPD renewed the MV framework contract, with the 33kV cable supply WPD took the opportunity to harmonise our cable sizes with other voltages. WPD discontinued the 240mm2 size and standardised on the following 185/300/400/630 and 800mm2 cable sizes.

7.2.3 Transformers

Since 2015 all newly manufactured small, medium and large power transformers are required to meet EU Ecodesign Regulation 548/2014, which ensures that transformers meet certain standards of efficiency. Ecodesign has now become business-as-usual for WPD and the requirement to replace transformers with more efficient ones is well established. At 11kV the distribution transformers used on the WPD network comply with the 2015 Ecodesign directive. Since 2011 all the WPD transformers purchased at voltages above 11kV, the transformer specifications already exceed the requirements of the Ecodesign 2015 directive. (Recommendation 9)

The variable losses in a transformer are much lower when the unit is partially loaded and increase quadratically as a unit becomes fully loaded. It is therefore possible to reduce the overall losses by oversizing transformers when they are installed. By using customer meter data to estimate the loading on all of the 500kVA, 800kVA and 1MVA 11kV transformers in the South West, WPD has completed a CBA which identified which transformers on the network are worthwhile oversizing. WPD found that it would be justified to oversize 325 transformers, which would save 854MWh per annum in losses. (Recommendation 8)

Using data from the Centre for Sustainable Energy (CSE) WPD forecasts that the majority of up-take of LCTs will be on approximately 7% of our network; in these cases investment in oversized transformers is clearly justified. WPD as part of the business as usual aim to oversize on average 109 transformers per annum at a cost of around £0.11m per annum.

The smallest size of ground-mounted transformer is a 315kVA unit. There is benefit in oversizing these transformers universally on installation. WPD plans to install a minimum ground-mounted transformer size of 500kVA in RIIO-ED1. WPD would aim to oversize on average 448 transformers per annum at a costing approximately £0.38m per annum.

Older designs of ground-mounted transformers have much higher losses than new designs. Whilst it is not efficient to replace all transformers early simply to reduce losses, it is envisaged to replace very old units and large capacity units in advance of their normal asset replacement plan. WPD aims to replace 1,996 pre-1958 ground-mounted distribution transformers (the entire fleet of these units) in the RIIO-ED1 period at a cost of roughly £2m per annum. (Recommendation 10)

Pole-mounted transformers are relatively small in size, but there is a benefit in oversizing the smallest transformers universally on installation. WPD plans to install a minimum pole-mounted transformer size of 25kVA (single-phase) and 50kVA (three-phase) in RIIO-ED1. WPD aims to oversize, on average, 575 transformers per annum, which will cost around £0.30m per annum.

7.2.4 Reducing Cable Lengths

After the SOHN Report was produced, WPD employed SOHN to undertake a redesign trial of recommendation 11 using the WPD new standard of large cross sectional area (csa) cables the trial showed no benefit in additional transformers, in addition to SOHN work WPD have changed the Policy Documents which set out the design methodologies to be used by changing the design impedances to be used which automatically reduces circuit length. With the Governments Carbon Plan 2011, the governments Road to Zero Strategy 2018 which layout the de-carbonisation of heating and transport and the introduction of 7kW EV chargers to all new buildings as part of the Building Performance Regulation change in April 2020. WPD are now designing networks to cater for the increased loads and for decreasing the losses as BAU.

7.2.5 Voltage Reduction

The LV Templates project provided data on the voltages seen on the LV network and concluded that there is scope to reduce the network voltage and remain within the statutory voltage parameters. Reducing the voltage will reduce the overall demand and will contribute to loss reduction.

The voltage on the LV network can be reduced in many ways but WPD has chosen to change the settings at the primary substation level. At this point on the network, the voltage change can be made automatically and while the network remains connected.

WPD has completed a programme of voltage reduction in the South Wales area, and results have shown that a 0.88% reduction in primary voltage resulted in an average demand drop of 1.16%. As a result of this, losses increased in percentage terms but this is because the current has to be slightly higher to deliver the same power, which increases the variable loss, but the power required is lower, therefore overall losses are reduced. Based on these results, WPD has now commenced a programme of voltage reduction across all the WPD licence areas, the current status is, 1403 completed substations and 714 outstanding substations, with a target completion date of 2020.

In some places, parts of the higher voltage networks are run in parallel with the lower voltage networks. This means there is more than one open point between the two levels of the network. The advantage of this configuration is that it allows loads to be better balanced, in most cases.

The FlexDGrid project previously and now in the Equilibrium project WPD is developing methods to monitor and automatically reconfigure networks. There are areas of the network where it is not possible to operate with parallel feeding arrangements (meshing) due to technical limitations. These can be due to loads, generation or fault levels.

The FlexDGrid project, which investigates the management of fault levels, showed that the installation of a Fault Current Limiter (FCL) has significant losses benefits through enabling the parallel operation of two or more transformers. Using an average network approach and the standard Birmingham 132/11kV transformer, the FlexDGrid work showed that the windings of unmeshed transformers can have an uneven load distribution, typically a 70% to 30% split. Through the installation of an FCL and subsequent network meshing, it allows these uneven windings to be balanced so that each takes 50% of the load. WPD estimates that this could provide savings of around 94 MWh per annum per substation.

7.3 Actions Completed During 2019

- The continued pro-active replacement of 1,996 distribution transformers;
- The design intervention for losses on new installation of 8,184 distribution transformers and 11,880 kilometres of underground cables;
- The purchase of 88 amorphous cored 25kVA single phase PMTs;
- Start the installation of the amorphous single phase 11kV PMTs;
- WPD have been building IT systems to receive and analyse the smart meter data, and although WPD have had their privacy plan approved in 2018 thus allowing WPD to use the data, there have been teething problems dealing with DCC and getting the system able to receive all data.;
- The update of the existing modelling tool for LV mains of the WPD network, to output direct losses data and be compatible with smart-meter data;
- A comprehensive programme of stakeholder engagement including biennial stakeholder consultation events;
- The on-going development of the losses page on the WPD website;
- Continued membership of the ENA Technical Losses group;
- Completion of the Innovate UK feasibility study of An Energy Revolution for the market town of Caldicot where a reduction of losses were proposed by using three phase service cables.
- Ongoing voltage reduction across WPD;

7.3.1 Asset Replacement

WPD's work to uprate assets continues through RIIO-ED1. The detail of the plans are shown in section 9.4

7.3.2 Network Design and Policy review

WPD's LV system modelling tool includes losses calculations for each scenario used, but as one of the first measures WPD undertook was to increase the underground cable size and removed cable tapering this means upgrades are uniform across the company. At LV and 11kV, planners are able to comply with the majority of losses designs by using the uprated selection of cables and transformers made available since 2016. At EHV WPD currently uses two system modelling tools, PSS/E and IPSA. PSS/E can create a losses calculation, it is envisaged that PSS/E will become the standard system within WPD by Q4 of 2019. This date has been delayed due to a compatibility issue between the latest release of PSS/E and the corporate IT hardware/operating system, which is currently being refreshed. Whilst all EHV designs are bespoke, WPD has completed work to provide templated solutions for generation connections, these templates incorporated the losses impacts.

7.3.3 Stakeholder Engagement

The WPD stakeholder engagement plans continue and full details are detailed in Section 5. In 2017 WPD hosted the latest Stakeholder Engagement session. At that event WPD shifted the focus of the losses work and introduced plans to target electric vehicle and other Low Carbon Technologies demand as the next significant area of increased losses on WPD network. During early December 2019 the latest bespoke WPD Losses stakeholder event took place at the IET in Birmingham, SSEN joined WPD to give feedback on their Losses project TASS/LEAN.

7.3.4 Losses pages on WPD website

WPD has developed and published a set of pages related to losses on the WPD website. They explain losses in more detail and lead into actions that are being taken to reduce losses as a result.

The WPD Losses page, along with all the DNO's losses pages can now be accessed via requisite links from the ENA Technical Losses page.

7.3.5 Revenue Protection - Supplier Side Abstraction

WPD investigative work for suppliers uncovers around 8,000 cases per year of illegal abstraction. Around 1,000 of these cases are related to cannabis production and, as a result, WPD works closely with local police. WPD identify around 2.8GWh per year of lost units which are passed through to suppliers for entry into the settlements process.

WPD has engaged with industry partners via the UK Revenue Protection Agency (UKRPA) and have created a reporting system to make it simple for meter operators to report incidents of interference to us.

WPD has strong relationships with local police and other emergency services, providing assistance on awareness courses run at Police and Fire training centres across the regions covered by WPD. The training helps the emergency services detect illegal abstraction and also ensures their safety near installations that have been tampered with.

WPD also investigate points of connection which are energised but not registered. Where a connection has become energised without a supplier, it is often very complicated to unravel the registration process and appoint a supplier. Customers in this situation have often tried to rectify the situation without success, and WPD are able to help them resolve the issue.

WPD have completed the initial review of sub-station load from information received following site inspections. This revealed estimated annual losses of approximately 5 GWh (9% increase). This has been corrected with effect from 1st July 2018.

7.3.6 Revenue Protection - Unmetered Supplies

WPD has established good working relationships with unmetered customers, in particular street lighting authorities, whose unmetered connections form approximately 90% of the total unmetered load. This involves regular group and individual meetings, which include discussions about inventory accuracy. Working closely with customers, together with the checks and balances we have in place, have provided us with a reasonable degree of confidence that unmetered system losses are minimised.

The unmetered connection agreements for larger customers, requires them to provide accurate monthly detailed inventories of all their unmetered connections. Checks are made when new inventories are loaded by WPD, to ensure there are valid reasons for records which have been removed. WPD introduced a revised new connections process in 2016. This enables more accurate detail of the unmetered equipment to be captured, resulting in the correct calculation of annual consumptions for smaller Non Half Hourly traded MPANs. For HH traded customer MPANs, the information enables checks to be made against the larger inventories provided. The process also prevents connection dates being agreed without a valid UMS registered MPAN being recorded, therefore, minimising the risk of load being connected and not accounted for. The current estimated loss from unregistered MPANs is 20,000 kWh, which is mainly made up of MPANs created prior to the revised process being implemented.

In Addition WPD will carry out physical street lighting site audits using independent contractors when our own internal inventory checks show further investigation is required. WPD has not found any such cases in recent months.

7.3.7 Revenue Protection - Theft in Conveyance

In many cases, theft in conveyance occurs when a non-standard connection is made directly to the WPD network; or where a service to a new property is installed and connected to the network without WPD's knowledge but using 'industry standard' equipment. It is often difficult to identify these connections, especially where the property is rented and the landlord states that energy bills are included in the rental payments.

WPD works with housing groups and local authorities in this area, and find that the police awareness training often helps identify cases.

WPD has registered a scheme, under Schedule 6 of the Utilities Act 2000, which allows action to take place to recover the monetary value of units abstracted while in conveyance. WPD publishes the unit price in the statement of charges; and in addition have taken cases to court where appropriate.

In an effort to reduce theft of electricity from the network WPD is currently checking records of both MPAN and UPRN databases. By assuming all properties with a UPRN have an electricity supply and filtering out all those that correspond to MPANs, WPD is left with a list of properties without an MPAN and some of these might be unregistered connections.

7.3.8 ENA Losses Group

WPD along with all the other DNO's and ESB hold regular meetings of the ENA Technical Losses Task Group, during 2017 the group had tasked the consultants WSP to conduct a project on the Impact of Low Carbon Transition on Technical Losses on the typical networks that all DNO's have, the project was completed in early 2018.

During 2019 the ENA Technical Losses group issued a contract to WSP for producing a recommendation for a Regulatory Incentive Mechanism, this contract should be completed by Q3 2019, during October 2019 WSP presented the Regulatory Incentive Mechanism paper at the LCNI in Glasgow.

7.3.9 Distributed Generation and DSO

Traditional power stations are large and centralised; therefore it is justifiable to connect them directly to the National Grid transmission system. In contrast to this, renewable energy sources and storage tend to be smaller and more distributed around the country; meaning they are usually connected to local distribution networks. This disrupts the traditional flow of power from generators to transmission networks, to distribution networks, to the customer. If the energy from distributed generation is used locally (and within a suitably short period of time) then this reduces losses.

As WPD moves towards a DSO way of working there will be a need to manage energy flows across the network to increase utilisation and balance demand and generation. This has the potential to increase losses if power flows increase or demand and generation cannot be balanced. Alternatively it could reduce losses if the network was perfectly balanced. This balance must be achieved against an economic and efficient measure so the cost of losses should be considered. Work completed for the ENA Technical Losses Working Group by the Engineering Consultants WSP has shown that losses could increase as a result of DSO flexibility, smart solutions allow greater utilisation of network assets and losses increase as a consequence.

7.4 Plans for 2020 and beyond

WPD plans for 2020 are to build on the work done so far and move the company's focus to new areas of potential increased losses. WPD will focus more towards low carbon technologies and, in particular, the effects of electric vehicle charging.

- Continuation of the asset replacement scheme started at the beginning of ED1;
- Ongoing voltage reduction across WPD;
- Electric Vehicle Charging;
- LV phase imbalance correction;
- Network Optimisation at 11kV;
- HV phase imbalance and power factor;
- Desktop studies of the LV network and customer connections using data supplied by installers of domestic solar, electric vehicle charging and heat pumps;
- Conversion of legacy networks;
- Use of local transformer heat;.
- WPD are currently involved with Pobl and Sero Homes in producing the Housing Estate for the Future in Parc Erin Tonyrefail.
- WPD are currently involved in the redesign of the existing 1950s network to come up with an enhanced network for partners Pobl and Sero Homes in the retro fitting the Blaen-y-maes Housing Estate where each house is expected to be fitted with a three phase LV service cable, solar panels and battery storage all devices will be programme logic controlled.
- Pad Mounted low loss transformers to support car park EV charging installaitons.
- As WPD have large amounts of long single phase overhead lines feeding small single phase transformers and single phase transformer. Whilst these units are outside the Eco design transformer legislation, WPD will explore what losses could be reduced by using alternative transformer designs.

7.4.1 EV's and Streetlights

WPD is looking at part of the Blaen-y-maes Housing Estate project which will be supplying a dedicated three phase 4 core 300mm^2 Wavecon LV mains cable to street furniture / lights to overcome the issue of charging electric cars where the house holder does not have a dedicated driveway to enable EV charging i.e. terrace housing or housing association housing. In conjunction with an LV accessory supplier a new small insulation piercing connector / joint for LV mains / service cables has been designed. The use of an SNE cable would overcome earthing issues associated with CNE cable circuits.

7.4.2 Automatic LV Mains Phase Imbalance Correction

WPD are in discussions with a manufacturer to understand if it is possible to produce a dynamic means of controlling the phase imbalance on an LV mains cable. If successful a dynamic method will reduce three phase imbalance on existing LV mains cables and unit transformers compared to static means.

7.4.3 11kV Network Optimisation

The potential to reduce losses from moving NOPs has been considered as a small part of WPD's FALCON project (Tier Two LCNF funded), and has also been briefly considered under WPD's Losses Investigation Project (NIA funded). Evidence from both these investigations suggests that there is potential in reviewing the current NOP positions on HV networks.

Estimated annual cost savings from NOP-change loss reductions, for three feeders being considered by the losses Investigation project, are £405, £2,892 and £599. This suggests:

- Modest per feeder savings are possible, though care would have to be exercised in the amount of investment/ expenditure that would be economically viable to achieve the benefits (e.g. feeder identification/assessment/ modelling and implementing any mitigating network automation/fault passage indication required);
- Over large numbers of feeders the cumulative savings might be material; but
- Significant variation in benefit may occur. Three is not a sample number that can reasonably be projected from.

It should be noted that:

- This is not a saving to WPD, but a saving to end consumers through WPD further optimising its network operation;
- Altering NOPs will change the available capacity on the feeders involved, and will change the numbers of customer connected to a feeder; however,
- Customer numbers may be mitigated through post-fault automated switching schemes based on fault passage indicators.

Both investigations suggest that the improvement arises through a change from the existing NOP to a preferred revised static NOP, i.e. there is little further benefit arising from having a dynamic NOP position that changes over peak/off-peak, weekday/weekend or summer/winter periods.

To identify preferred NOP positions and assess potential benefit, some form of modelling is necessary. This requires network data and a (per distribution substation) load model to allow power flow analysis to be iteratively performed. The FALCON project and the Losses Investigation project have tried different approaches to identifying the preferred open points and further consideration of the most cost-effective method is required.

The Losses Investigation project provided a means to model losses on a large number of HV feeders, which is a significant portion of the work required to then go on and identify the potential for changes to NOP positions that could reduce losses. WPD will consider how to use the process knowledge gained through the Losses Investigation project to further investigate NOP optimisation once the Losses Investigation project has reported.

7.4.4 Three Phase LV Service Cables

Delays in the project sign off by the Welsh government and wayleave issues saw a delayed start on this project, physical site work started in October 2019 on the new build project with Pobl, Sero Homes and WPD in producing a 238 home new build estate at Parc Erin in Tonyrefail - Housing Estate for the Future, where each house will be fitted with a three phase LV service cables, solar panels, battery storage, heat pump, electric vehicle charging, smart washing machine and dishwasher all device will be programme logic controlled. The housing estate will be fully monitored on the 11kV and LV side with a view to ascertaining the losses and load balancing on a three phase connected housing estate when compared to the single phase connected houses in Losses Investigation Project on the Isle of Man, the object being to produce an audit trail showing losses are reduced by using three phase service cables on new build properties. WPD have been involved in the design exercise of a second losses project with Pobl and Sero Homes in retro fitting circa 700 homes in the Blaen-y-maes Housing Estate, where each house is fitted with a three phase LV service cable, solar panels, battery storage and possible heat pump all devices will be programme logic controlled. In 2019 WPD had the view that this project would have had a decision on three phase service cables by early Q1 of 2020, but due to delays in Welsh government sign off of the project, the removal of EU funding because of Brexit and subsequent replacement funding from the UK government. This project has now been sign off by all parties and is due to start physical work in Q2/Q3 of 2020. Discussions are on-going with the Welsh government on whether heat pumps should be fitted or not. As there are no driveways in Blaen-y-maes WPD will be looking to provide the cabling for on street charging to be installed by the council / third parties.

The housing estate will be fully monitored on the 11kV and LV side with a view to ascertaining the losses and load balancing on a three phase connected housing estate compared to the single phase connected houses in Losses Investigation Project on the Isle of Man, the object being to produce an audit trail showing losses are reduced by using three phase service cables on upgraded retrofitted properties.

7.4.5 Legacy network conversions

WPD have examined the issues of converting the legacy 6.6kV network in Bath into an 11kV network and it is scheduled that the primary 33/6.6kV substation at Twerton will be changed to 33/11/6.6kV during 2020 which will be last major obstacle in converting Bath to an 11kV network, once complete the next objective will be to roll out the conversion on the other 6.6kV legacy networks throughout WPD to reduce losses on the existing 6.6kV networks.

7.4.6 Transformer Heat Recovery

The commercial application of heat recovery has previously been investigated and discounted by WPD. There is a benefit in the local use of heat for WPD's site demands at larger substations. It could be possible to use the local heat to provide warmth in adjacent buildings containing switchgear and other equipment. A heat pump will be used to extract local heat and use it. WPD are now working with a primary transformer manufacturer to produce a working model with the heat pump mounted within the oil circuit complete with monitoring at the oil/water interface to prevent the ingress of water into the oil, once a transformer has been produced it will then be installed and be monitored to prove if the project is successful if this process is passed the project will be costed and costed and checked for viability before making it BAU.

7.4.7 Small size pole mounted transformers

Consequently WPD have purchased circa 90 single phase amorphous transformers, these transformers have Iron losses of 16W compared to the standard CRGO transformer Iron losses of 65W. Using these figures one year's cost of Iron losses for an amorphous cored 25kVA single phase transformer compared to an identical CRGO cored 25kVA single phase transformer using the following formulae show below: -

No-load losses = no-load loss in watts * relevant hours.

1 Years amorphous 25kVA transformer iron losses = 140W.

1 Years CRGO 25kVA transformer iron losses = 569W.

This gives an iron loss saving of 429W per year per transformer by using the single phase 25kVA 11kV amorphous cored transformer. Using the Ofgem price of £48.42£/MWh, this equates to a cost saving of just the iron losses per transformer per year of £20.78

7.4.8 Substation Footprint

WPD have raised the issue of the current substation foot print where the existing ground mounted transformer is a 1MVA and with the need to meet the governments Road to Zero Strategy of de-carbonising heat and transport could see a circa 40% increase in load on the LV network. This possible increase will create issues in existing suburbs or housing estates and where new substations need installing to meet the growing load requirements and taking into account current legislation. Various proposals have been made to the ENA Losses group and to the ENA LCT group to creating a unified DNO response.

7.4.9 Car Park Charging & Padmount transformers

WPD are currently working with Wilson Power Transformers of Leeds to design and manufacture a 1MVA amorphous cored transformer specifically for multiple electric vehicle car charging in car parks etc. There are a number of County Councils showing interest in this concept where they are looking to install electric vehicle off street car charging hubs. We expect the hubs to provide an 11kV connected charging solution to cater for up to six 150kW rapid chargers and this would be used in areas where there is no off street parking in housing estates or in depots where fleet charging is required.

8 Future Considerations

There are a number of potential ways to reduce losses which rely on technology that are not yet suitably developed. As such none of these methods are likely to be implemented during RIIO-ED1, but it is important that WPD monitors them for RIIO-ED2 and beyond. Some of the methods are considered by some of the innovation projects, while others are beyond even their scope.

8.1 Superconductors

The variable losses in a network are directly related to the resistance of the current-carrying conductors. A superconductor theoretically has no resistance, which would practically eliminate variable losses in cables. Superconductors must be cooled to very low temperatures or they will still provide a resistance. Research into finding superconductors that can operate at higher temperatures is still ongoing, but as of yet none have been found which can operate above -70°C, it is unlikely they will become practical in the near future.

WPD is aware of developments in Essen, Germany where an oxide ceramic superconductor has been used to replace a 1km section of a network interconnector between two major substations. The cooling load for the superconductor must be taken into account when considering the overall loss reduction of the system. Whilst superconductors may well provide a large loss reduction in the future, it is likely that the cooling systems required will only be practical to install on very high voltage networks, perhaps only the transmission networks. But as the majority of losses actually occur on the 11kV and LV network, therefore it is unlikely superconductors will provide a beneficial solution to electrical losses in distribution.

8.2 Heat Recovery

Transformers generate heat during normal operation. Normally, this heat is lost to the atmosphere. The tendency of heat harvesting trials that have taken place has been to focus on the larger transformers with forced cooling systems.

The heat harvested from the transformers could then be sold as a commercial product to nearby customers or can simply be used to heat local substation buildings.

WPD has obtained details of a trial in Germany from an equipment manufacturer and have concluded that the end user of the heat needed to be very close, within a 10- 20m radius of our heat source. The German trial also suggested that interaction with single large heat users was more beneficial than a solution with many small domestic users.

Working with the Centre for Sustainable Energy, WPD overlaid the major substation locations on datasets from both Ordnance Survey and the National Heat Map. Where a potential user of heat was identified in close proximity to one of the substations aerial photography was used, large scale map data and individual Heat Map Points to assess the suitability for trialling.

The results showed that out of the 1,600 major substations only 159 had nearby large customers. There were 30 which were classed as ‘possible’, 59 classed as ‘no’ and another 70 which would require more detailed investigation. National Grid work has also shown that, for their sites, heat can generally only be used at their own substation based office installations.

Although WPD have shown that a district heating system is not feasible at this time. WPD have completed a feasibility study with a heat pump manufacturer to scope out a proof of concept in using a ground source heat pump which is incorporated into the oil circuit of a primary grid transformer to provide the heat to heat up the substation buildings rather than use storage heaters.

8.3 Active network configuration for losses

One way to reduce the fixed losses on the network is to switch assets off. An asset on “hot standby” (energised but not actually supplying electricity) will continue to produce fixed losses. Disconnecting duplicate or reserve assets will reduce losses but will also affect supply security and therefore has to be carefully considered before being adopted.

WPD has analysed the impact of switching off duplicate transformers at a 33kV/11kV site, and have modelled the effect on customers by using network fault data and telecoms (SCADA) availability data. Using data from 2013, it has been concluded that the cost due to the Interruptions Incentive Scheme (IIS) of transferring customers to a “cold” transformer far outweighs the saving in losses. The implications of leaving a transformer off-line and the inconvenience to the customer of the short interruption during successful transfers should also be considered in any assessment.

WPD is continuing to monitor Low Energy Automated Networks (LEAN), the LCNF Tier 2 project being undertaken by Scottish and Southern Electricity Networks (SSEN). This project studied the effects of turning off lightly loaded primary transformers using a technique called TASS (Transformer Auto Stop Start). The project findings thus far suggest that the technique would produce beneficial results at sites which are suitable.

WPD are currently conducting their own analysis of the LEAN project using the tools provided by SSEN to assess the potential benefits of TASS on the WPD network. It has been established that in WPD out of a sample of 25 primary substations, only 1 which appear suitable and are in the process of costing the installation of equipment and undertaking a CBA to show its net worth. WPD is also concerned about the potential penalties of Customer Minutes Lost and Customer Interruptions would have significant financial swings if the technique was to fail and cause an interruption. This would easily outweigh the potential benefits.

Developments in network management systems beyond RIIO-ED1 and the increasing levels of monitoring and control will provide a platform for the reconfiguration of networks to reduce losses without the current concerns over supply security.

9 Summary & Conclusions

9.1 Summary

The traditional heart of the WPD loss-reduction programme lies in asset replacement. WPD intends to: -

- meet or exceed the Ecodesign 2015 directive with all new transformers purchased;
- oversize the 11kV ground-mounted transformers which are highly loaded enough that replacement is economically justified;
- replace the entire complement of pre-1958 ground-mounted distribution transformers;
- install a minimum size of 25kVA for single-phase pole-mounted transformers and 50kVA for three-phase units;
- discontinue 4 & 16mm2 Cu. LV service cables;
- discontinue 95mm2 LV Wavecon mains cables and 95mm2 Al. triplex 11kV cables; and
- standardise on 185/300/400/630 and 800mm2 Cu. Single core cables for the 33kV network.

WPD aims to continue working alongside suppliers to investigate transactional theft; to perform regular random audit checks in order to monitor unmetered supplies and to investigate theft in conveyance by comparing the metering records to Ordnance Survey records and investigating properties without meters.

9.2 Plans for 2020

In 2020 WPD are extending the reach of the loss reduction programme to prepare for the effect of electric vehicles, heat pumps and other LCT demands. WPD intends to resolve the following issues:-

- Electric Vehicle Charging;
- Heat pump installations;
- Conversion of legacy networks;
- Substation Footprint;
- Car Park Charging hubs;
- Three phase service cable Parc Erin new build project;
- Three phase service cable Blaenu y maes retro-fit project;
- Three phase LV mains cable load balancing;
- Ongoing installation of single phase amorphous transformers;
- Ongoing voltage reduction across WPD;

WPD has multiple innovation projects which are likely to lead to great advancements in network design. A lot of these advances will rely on the smart-meter roll out, which the company is preparing for. By using the data from the smart meters alongside the real-time network control tools this will ensure the network is working in the most efficient manner at all times. It is envisaged that when the end of the RIIO-ED1 period is reached, it will be these network design and active network control measures that will be the focus of the loss-reduction activities.

9.3 Assessment of our Losses Performance

WPD is now at a point where most of the straight-forward actions that can be taken to reduce losses have been initiated. WPD has put the replacement of almost all assets, for which it would be economically beneficial to do so, into the policy documents, although CBAs will need to be repeated as costs and savings will change over time. WPD's shift of approach to electric vehicles and heat pumps will bring a new range of initiatives in the coming years.

9.4 Table of Outputs

Proposal	Interventions per Annum	Savings per Annum (kWh)	Interventions through RIIO – ED1	Savings through RIIO – ED1 (MWh)
Transformers				
Replace pre-1958 transformers	250	2,694,543	1,996	21,556
Install a minimum size of pole-mounted transformer	575	68,072	4,600	545
Discontinue 315kVA ground-mounted transformers	448	1,140	3,584	9
Install low loss amorphous single phase PMT	88	38	88	114
Cables				
Discontinue small size service cables	343 km	412,629	2,744	3,301
Upsizing LV cables	694 km	3,049,799	5,552	24,398
Discontinue small size 11kV cables	448 km	951,421	3,584	7,611
Imbalance				
Correct Imbalance at LV substations	Per substation	1,014	Per substation	

10 Appendix 1: Progress on SOHN Recommendations

In 2014 WPD and UKPN collaborated and commissioned the SOHN Report on losses, this report has formed the backbone to the WPD Losses Strategy as it provided an impressive 26 recommendations (see below) for further work and action. These recommendations now form the basis of the work WPD have carried / carrying out throughout the RIIO-ED1 period.

The 26 recommendations

The key recommendations listed below have allowed us to shape our Losses Strategy and turn the recommendations into BAU. They ensure that our work stays focused and relevant to the management of the electricity network. In addition since 2014 some of the WPD Innovation projects are focusing on specific elements of the report to help the electricity industry gain a better understanding of Losses.

Recommendation 1: The network modelling and analysis tools used in the study are based on calibrated representative network models data. Given the increasing importance of losses, it would be appropriate that DNOs establish the capability of modelling and evaluating loss performance of their present and future networks, under different future development scenarios.

Action - This has now been adopted and become BAU for LV and 11kV. At LV with the WinDebut platform includes losses calculations for each scenario used.

Benefit for customers - WPD's LV and 11kV system modelling tools includes losses calculations for each scenario used. However, as one of the first measures WPD undertook in this area was to increase the underground cable size and remove cable tapering, this means upgrades are uniform across the company. WPD's Network Planners are therefore able to comply with the majority of losses designs by using the uprated selection of cables and transformers made available in 2016.At EHV WPD currently uses two system modelling tools, PSS/E and IPSA. PSS/E can create a losses calculation, it is envisaged that PSS/E will become the standard system within WPD by Q4 of 2019. Whilst all EHV designs are bespoke, WPD has completed work to provide template solutions for generation connections, these templates incorporated the losses impacts.

Recommendation 2: DNOs to consider carrying out more systematic data gathering associated with power factor to assess the materiality of the issue and to enhance the understanding of the costs and benefits of power factor correction at consumers' premises. The business case for power factor correction may then be developed.

Action - Since 2010 WPD has been including an excessive reactive power charge for HV and LV half hourly metered, via the Use of System Charge, with a power factor of 0.95 lagging.

Benefit for customers - This is to ensure that the reactive power is kept to the minimum. When sizing a circuit the total load has to be catered for, this means both the active load and reactive load need to be catered for, cumulatively, even though the customer would only effectively use the active load. By keeping the power factor at or about 1 means the customer is paying and using all the power. If for example they had a very bad power factor they could end up paying for one unit of power but in real terms only do half a unit effective work so they pay for the power that was wasted because of a poor power factor.

Recommendation 3: Further work is required to assess the extent of the imbalance problem and to test various solutions, which will not only reduce losses but deliver many other benefits of a well-balanced network. It may be appropriate to develop policies and working practices for avoiding excessive imbalance in future.

Action – WPD has completed the LV Templates project where imbalance was addressed. In addition WPD has just completed the Losses Investigation project in IOM where feeder and services (typically single phase) on the LV and 11kV systems are fully monitored, with data now being assessed by Loughborough University and subsequently published to share the learnings with others.

Benefit for customers - Using substations that are part of LV Templates project, WPD has identified that the phase imbalance in the LV network can lead to neutral currents at around 35% of the phase current. More recent work from the Losses Investigation Project suggests that ratios of neutral current to phase current are higher still. Majority of feeders have neutral current/mean phase current ratio above 0.35. Neutral current ratios tend to be higher for feeders with lower mean current. Going forward WPD is involved in a new build of circa 230 houses where the services will be three phase and all service and feeders on the LV and 11kV will be monitored in a similar manner to the IOM Losses Investigation project so a direct comparison can be made between the respective losses from single phase versus a three phase estate. The new build houses will also include EV chargers and Heat Pumps so that the out of balance can checked with the enhancement that is expected.

Recommendation 4: The inaccuracy of loss calculation using half-hourly data at the edges of the LV network should be recognised when conducting network studies.

Action – WPD's LV system modelling tool includes losses calculations for each scenario used, but as one of the first measures WPD undertook was to increase the underground cable size and removed cable tapering this means upgrades are uniform across the company.

Recommendation 5: As the benefits of peak demand reduction may be material, an assessment of the opportunities enabled by alternative SmartGrid techniques to achieve this should be carried out.

Action – WPD use demand side response to reduce the peaks of load and associated losses on our network. As a result of our FALCON project, WPD found that customers are often not able to help with DSR due to contracts in place with National Grid. WPD is working with National Grid to change their standard terms and conditions to allow customers to operate in both markets.

Benefit for customers – Centrica's newLocal Energy Market (LEM) enables National Grid ESO and Western Power Distribution (WPD) to simultaneously procure flexibility from the same platform. WPD have set up the DSR Forum, where DNOs, Ofgem and National Grid are represented, to discuss this in more detail.

Recommendation 6: As the benefits of active voltage control in LV distribution network may be significant, comprehensive assessment of the opportunities to further reduce network losses should be carried out.

Action – WPD is reviewing the roll out of ENWs project Smart Street project which is using 11/0.4kV transformers complete with OLTC to address the issue of clusters of Low Carbon Technology where there are voltage fluctuations happening on an almost daily basis.

Benefit for customers - In addition the WPD Innovation team are undertaking a project with Efacec which will be looking to address the issues around dealing with wide variations of voltage on the LV network.

Recommendation 7: When considering active network management solutions and technologies to facilitate low-carbon connections, the impact on losses should be given full consideration Future Consideration

Action – WPD, via the ENA Technical Losses group, commissioned WSP to undertake the Impact of Low Carbon Transition – Technical Losses Report.

Benefit for customers - In summary the report states losses are expected to be impacted by the predicted increase in electrical demands as Great Britain (GB) adopts Low Carbon Technologies (LCTs) for heat and transport such as heat pumps (HPs), electric vehicles (EVs) and photo voltaic solar generation (PVs). Increases in demand are associated with increased losses, however, absolute losses could be reduced if larger conductors or additional circuits are added and network utilisation is reduced. Distributed generation connected in close proximity to demand reduces losses when the generation offsets power flowing through the wider network to supply the demands, however, distributed generation can increase losses when the generation is sufficiently in excess of the demand.

Recommendation 8: There is a clear case for fundamentally reviewing cable and overhead line ratings to ensure that future loss costing has been included in the economic rating calculation. This could be based on Ofgem's loss investment guidelines or on loss-inclusive network design standards

Recommendation 9: In future, losses may drive early asset replacement when economically efficient. If early replacement programmes are economically justified and capable of being funded, appropriate resources would need to be made available to facilitate delivery of such programmes.

Action – the following actions have now been rolled out as business-as-usual:

- Discontinued small size cables for large conductor size cables on new works
- Discontinued small size transformers for new works
- Adoption of a 'next size up' design policy
- Targeted early retirement of older than 1958 ground mounted transformer designs.

Benefit for customers – Asset replacement is the ongoing and most direct way in which WPD can reduce technical losses. From a losses point of view old transformers and underground cables encompass the majority of assets which provide the best value to a DNO and customer to reduce the losses seen on a network. With this in mind it then becomes part of the business as usual that WPD will be changing pre 1958 ground mounted transformers for newer models which will reduce overall losses as new transformers have lower losses than old ones. In addition the variable losses in cables can be reduced by using cables with larger cross sectional areas, which also increases their capacity. Where overhead line conductors are replaced WPD aims, where possible, to replace smaller diameter conductors with larger diameter conductors as BAU.

Recommendation 10: The transformer loss calculations indicate that the benefits of investing in low-loss transformers may be significant and this should be considered further to establish or otherwise the low-loss transformer business case in line with UK energy and carbon policy.

Action – WPD has always purchased low loss transformers since pre-privatisation and all primary and ground mount transformers meet or exceeded the Euro Eco design. In 2018 WPD purchased circa 100 amorphous pole mounted single phase transformers to install and monitor as single phase does not form part Euro transformer Eco design this are now being rolled out onto the network. In addition WPD is pushing the ENA Losses group to produce an industry standard for amorphous cored transformers.

Benefit for customers –All customers pay for the losses therefore by reducing the no load losses of the transformers reduces the wasted energy that would be necessary to drive those losses, it also then by default frees up extra generation.

Recommendation 11: Network designers may consider the option of installing additional distribution transformers to minimise LV network reinforcement cost and reduce losses.

Action – After the SOHN Report was produced WPD employed SHON to undertake a redesign trial of recommendation 11 using the WPD new standard of large cross sectional area (csa) cables the trial showed no benefit in additional transformers. With the Governments Carbon Plan 2011, the governments Road to Zero Strategy 2018 which layout the de-carbonisation of heating and transport and the introduction of 7kW EV chargers to all new buildings as part of the Building Performance Regulation change in April 2020.

Benefit for customers – WPD is now designing networks to cater for the increased loads and for decreasing the losses as BAU.

Recommendation 12: In the light of future developments, particularly in relation to the integration of low carbon demand and generation technologies, it may be appropriate to reconsider long-term distribution network design. This may take a strategic view of future voltage levels and include consideration of losses in the decision-making.

Action - WPD is involved in a new build of circa 230 houses in Parc Erin Tonyrefail where the services will be three phase.

Benefit for customers – All service and feeders on the LV and 11kV will be monitored in a similar manner to the IOM Losses Investigation project so a direct comparison can be made the losses on a single phase and three phase estate can be compared and analysed for out of balance on the LV main and unit transformer. The new build houses will also include PV, ES, EV chargers and Heat Pumps so that the out of balance can checked with the enchantment that is expected.

Recommendation 13: In order to reduce losses and provide future flexibility within LV networks, LV tapering policy may be re-examined. Adopted

Action - Since 2012 WPD as part of the business as usual have installed link disconnecting boxes (LDB's) between LV substations on non-tapered LV mains cables, thereby providing the possibility of mesh connections and back feed potential under fault conditions. In addition since the start of 2015 WPD has amended the design policy and now all designs of the LV mains underground cable network are designed without cable size tapering. Networks shall be planned using either 185mm^2 or 300mm^2 Wavecon cables. The size chosen for a particular scheme will be used throughout that scheme and tapering is no longer considered.

Benefit for customers – All customers pay for the losses therefore by reducing the losses of the LV Mains circuits reduces the wasted energy that would be necessary to drive those losses, it also then by default frees up extra generation.

Recommendation 14: A review of DNOs' network modelling and analysis tools and capabilities may be required to support design engineers in applying new policies and processes relating to loss-inclusive network design.

Action - In order to forecast, what will happen on the WPD network in the future and to determine what is happening on the unmonitored parts of the network, the most powerful tool is computational modelling. WPD's LV system modelling tool includes losses calculations for each scenario used, but as one of the first measures WPD undertook was to increase the underground cable size and removed cable tapering this means upgrades are uniform across the company. The WPD 11kV system modelling tool also includes losses calculations, but as one of the first measures WPD undertook was to increase the underground cable size and removed cable tapering at 11kV this means upgrades are uniform across the company. At LV and 11kV, planners are able to comply with the majority of losses designs by using the uprated selection of cables and transformers made available in 2016. At EHV WPD currently uses two system modelling tools, PSS/E and IPSA. PSS/E can create losses calculations, it is envisaged that PSS/E will become the standard system within WPD by Q4 of 2019. This date has been delayed due to a compatibility issue between the latest release of PSS/E and the WPD corporate IT hardware/operating system, which will be refreshed during 2019. Whilst all EHV designs are bespoke, WPD has completed work to provide templated solutions for generation connections, these templates incorporated the losses impacts.

Benefit for customers – Modelling effectively creates a virtual, fully monitored network which can then examine and test new ideas. Using the modelling tools WPD should be able to map where losses occur on the network, allowing for a targeted approach to loss reduction. Modelling can also be used to predict the effect of future changes to the network, so that the effect on losses of all possible future actions can be considered before the changes are actually carried out. Modelling should become even more useful once used in conjunction with smart meter data. By feeding the data into the model, this will be able to produce models of the network in real-time. Data at specific metering points can then be predicted and compared to the real data, to establish the success of the model. The software will need to be redesigned to incorporate this feature. Once this level of insight into the network is established, it will be possible to create more targeted losses strategies, leading to far more effective loss reduction activities.

Recommendation 15: There is an opportunity for considerable further learning in Europe and also from National Grid. It would be beneficial to share experiences of waste heat recovery installations among DNOs.

Action – WPD have carried out a provisional analysis with a heat pump manufacturer of using a heat pump in the oil line between the primary transformer and the cooling fins bank to heat the substation buildings

Benefit for customers – This proved viable and WPD is now working with a primary transformer manufacturer to come up with a bespoke design, this is ongoing and will be rolled out as soon as complete, where the installation can be monitored with a view to make it BAU.

Recommendation 16: An Innovation Project, based upon learning from this initial Study, may be initiated in order to gather further insight into the technical and practical solutions which can be tested at more sites. The Project could be scoped to also tackle the regulatory and commercial market structural issues which will also need to be overcome to bring heat recovery and use into mainstream application.

Action - WPD is now working with a primary transformer manufacturer to come up with a bespoke design. This is ongoing and will be rolled out as soon as complete, where the installation can be monitored with a view to make it BAU.

Recommendation 17: DNOs may maintain an awareness of the potential for heat recovery when planning the installation of EHV transformers and seek to install more systems where the recovered heat may be of commercial use.

Action – WPD has discounted commercial use based on a report by Centre for Sustainable Energy (CSE). In addition, WPD has checked all its grid transformer sites with a view to creating a mini district heating system but because of the distance involved between building and transformers it becomes un-viable.

Recommendation 18: Further work on heat storage may be integrated with future trials work on recovery of heat from the distribution network, as it may improve the economics of more basic heat recovery systems.

Action – WPD has discounted commercial use based on a report by CSE. In addition WPD have checked all their grid transformer sites with a view to creating a mini district heating system but because of the distance involved between building and transformers it becomes un-viable.

Recommendation 19: DNOs should develop loss-inclusive network design strategies, based on their specific data, in order to ensure that the overall economic network operation and design criteria are met. This should include network modelling capability for answering “what-if” questions in order to predict the impact of proposed network polices, projects and network demand forecasts on the overall reported network losses.

Action – WPD has created the Network Strategy team with responsibility for producing and assessing the impact of a range of Distribution Future Energy Scenarios (DFES), aligned with those developed by National Grid

Benefit for customers – DFES have been produced for all four WPD licence areas to predict the impact of proposed network polices, projects and network demand forecasts on the overall reported network losses.

Recommendation 20: DNOs, with support from DECC and Ofgem, may determine the common basis in relation to loss mitigation and loss-inclusive network design and investment.

Recommendation 21: There is a need to establish the basis for assumptions on future electricity costs and carbon prices that would be used in loss-inclusive network investment that is consistent with the overall UK low carbon policy.

Action – WPD carry out the Ofgem Cost Based Analysis (CBA) with any Losses project to prove the case for the particular project. WPD use the Ofgem supplied value of £48.42/MWh in the CBA calculations. In addition, when converting carbon WPD use the DEFRA carbon conversion factors for both UK electricity (kWh) and Transmission & Distribution (kWh) the 2019 values for example are 0.2556 kgCO2e for Electricity and 0.02170 KgCO2e for Transmission & Distribution.

Benefit for customers – By adopting this method of assessment this ensures that the customer gets a consistent and auditable approach in CBAs.

Recommendation 22: Early in the RIIO-ED1 period, DNOs may develop more accurate means of measuring and reporting of distribution network losses.

Action – WPD has recently concluded the Losses Investigation project in conjunction with the Isle of Man, Manx Utility Authority and Loughborough University. One of the key issues identified is that measuring losses is difficult because the level of losses that are being looked for are small circa 7% and the losses on the Smart meter for example are -3.5% to +2.5%. This is also shown by the ENA Losses Measurement Report.

Benefit for customers – The ENA Technical Losses group employed WSP to recommend a new Losses mechanism which can be used by Ofgem during ED2, the proposal is to use a CBA method as adopted by other utilities around the world this would. By adopting this method of assessment this ensures that the customer gets a consistent and auditable approach in CBAs.

Recommendation 23: The DECC/Ofgem comparison of reported losses shows a discrepancy which may cause a distorted view of GB DNO losses, within industry, government and internationally.

Action – Currently DNOs and IDNOs are treated differently: DNOs are required to reduce losses but IDNOs are not. Where the IDNO network connects to the host DNO network at the Point of Common Coupling no metering is allowed therefore all the losses incurred on the IDNO network are all lumped together on that particular host DNO network, this then will show a discrepancy on that particular host DNO feeder. It is part of the ENA Losses group to ensure that this becomes a level playing field.

Benefit for customers – This would ensure that all new networks were designed to similar criteria and the ability to connect new LCT equipment can be meet.

Recommendation 24: DNOs may grasp opportunities to influence loss reporting in other countries and as it is presented in international studies. This is in order to ensure that GB DNOs' loss management performance is presented accurately.

Action – As part of the ENA Technical Losses group all DNOs report back into the group on what their respect owners carry out on losses and what each DNO has learnt from other sources. All these items are then discussed and considered by the group and whether to take them forward or not.

Benefit for customers – If losses can be reduced by adopting methods that have been trailed oversea then this will ultimately see a reduction of losses on the network which reduces the wasted energy that would be necessary to drive those losses, it also then by default frees up extra generation.

Recommendation 25: Industry, government and regulators should consider developing appropriate regulatory and commercial frameworks that would facilitate development of loss-generated heat schemes where economically justified.

Action - WPD have not seen a commercial heat solution yet.

Recommendation 26: DNOs' loss strategies may be "stress tested" to demonstrate that they can deliver an objective of achieving an economic level of losses based upon avoided loss valuation, engineering costs and future network demands.

Action - The ENA LCT Group issued a contract to WSP Consulting to produce the LCT Planner Tool Design and Methodology.

Benefit for customers – This carried out essential stress testing of the methodology in practice to ensure the results achieved were correct.

Western Power Distribution (East Midlands) plc, No2366923
Western Power Distribution (West Midlands) plc, No3600574
Western Power Distribution (South West) plc, No2366894
Western Power Distribution (South Wales) plc, No2366985

Registered in England and Wales
Registered Office: Avonbank, Feeder Road, Bristol BS2 0TB

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wpdnetworkstrategy@westernpower.co.uk

www.westernpower.co.uk

@wpduk