Application to Innovation Roll-Out Mechanism

UK Power Networks
LV Network Visibility and Control

Executive Summary

Low Voltage (LV) networks are experiencing a quicker than expected uptake in Low Carbon Technologies (LCTs), as a result of customers responding to government policies and advancements in commercial and technological maturity. A significant uptake in Electric Vehicles (EVs) in particular is expected in the early years of the next decade, as indicated by the fact actual EVs registered in our licence areas currently exceed our RIIO-ED1 business planning forecasts by 15%.

LV networks have historically not required monitoring, and active network management was not considered cost-effective, as load growth was more predictable. However, this is changing given the uncertainty that is currently associated with the magnitude and timing of the uptake of LCTs. This is particularly relevant considering the expected clustering effect in high LCT uptake areas. There is a risk that the rapid increase in LCTs will not be seen with sufficient time to enable an optimal programme of network investment.

Given the level of uncertainty associated with LCTs and the limited level of LV network visibility today, there is a limited set of options for a DNO:

- React to network constraints after they appear, leading to a potential increase in customer interruptions, an increase in connection costs and the expected time to connect, and a reduction in the number of LCTs connected on the network;
- Commission widespread reinforcement programmes using proxy data and lower targeting efficiency in order to increase capacity for LCT; or
- Invest strategically ahead of need in network visibility in order to enable targeted and efficient network investment.

UK Power Networks has successfully trialled a range of solutions for LV network monitoring, as well as automation and control, and is now applying for an adjustment under the Innovation Roll-Out Mechanism (IRM) for the targeted deployment of an LV Network Visibility and Control System across 5,834 LV network sites (approximately 7% of our LV networks).

The proposed roll-out includes the targeted installation of Remote Terminal Units (RTUs) in priority areas of our LV networks, where key indicators point to high LCT adoption in the early years of RIIO-ED2. The RTUs will collect and transmit real-time data from the network to our network control room. The roll-out also includes the development of a Live LV Network Diagram that will be used in the control room to visualise the collected data in order to generate insight on network conditions.

The establishment of real-time network visibility in our control room will ultimately enable the use of “smart” network control solutions. Such solutions will allow UK

Power Networks' planning and control engineers to manage the network in a proactive way, thus releasing capacity and delivering network reinforcement efficiently. As a result, we will be able to facilitate LCT connections for our customers cost-effectively, while maintaining network performance and reliability.

We estimate that the roll-out of LV Network Visibility and Control across 5,834 sites in RIIO-ED1 can deliver lifetime benefits of approximately £54 million in the form of efficient LV network reinforcement, as well as an annual reduction of 20 thousand tonnes of CO_2 by cost-effectively enabling LCT connections to the LV networks for our customers.

Furthermore, we expect that this first phase roll-out will benefit our customers by improving the commercial maturity of the solution, allowing more cost-effective deployment on a site-by-site basis in the future. This will ultimately inform the efficient and effective provision of capacity in our LV networks over the RIIO-ED2 period, when we continue rolling out LV Network Visibility and Control to a wider part of our networks. We estimate that if we continue our roll-out in RIIO-ED2 at the same pace as in RIIO-ED1, our customers will realise additional lifetime net benefits of approximately £113 million. The proposed system is also fundamental to our transition to a Distribution System Operator (DSO), and a key enabler to system flexibility.

We have leveraged practical experience from our innovation trial projects to specify a system architecture that ensures that the LV Network Visibility and Control System can sustainably enable benefits in parts of the network where visibility is needed the most. The basis of our chosen architecture is building a system that is future-proof, and can enable the release of capacity cost-effectively on a site-by-site basis through RIIO-ED2, and beyond. At the same time, our chosen architecture ensures that we leverage existing network and information infrastructure, and the system's monitoring capabilities complement those that will become available through the smart meter roll-out programme.

Our business is in a position to leverage the capabilities of LV Network Visibility and Control, with an LV Control team already in place, and a number of innovation trial projects completed and embedded to business-as-usual. We have identified the systems and processes that will be impacted by the roll-out, and have specified a training programme for the users of the LV Network Visibility and Control System. Through the roll-out, we will work with all impacted business units to ensure that business processes are adapted where needed, and the transition to the new system is seamless.

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1.1 Application Title

LV Network Visibility and Control System

1.2 Estimated Total Cost

System components	Eastern Power Networks (EPN) £m	London Power Networks (LPN) £m	South Eastern Power Networks (SPN) £m	UK Power Networks – Total (UKPN) £m
LV Monitoring, Live LV Network Diagram	11.49	10.96	10.99	**33.44**
"Smart" Network Control Solutions	3.55	3.95	3.85	**11.35**
LV Network Visibility and Control System	**15.04**	**14.91**	**14.84**	**44.79**

1.3 Total Funding Request

System components	Eastern Power Networks (EPN) £m	London Power Networks (LPN) £m	South Eastern Power Networks (SPN) £m	UK Power Networks – Total (UKPN) £m
LV Monitoring, Live LV Network Diagram	11.49	10.96	10.99	**33.44**

1.4 Start date and End date of Relevant Adjustment

Start Date: 1 April 2018
End Date: 31 March 2023

	Proposed IRM Adjustment by Regulatory Year				
	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m
EPN	1.30	2.94	3.03	2.10	2.12
LPN	1.18	2.67	2.75	2.17	2.19
SPN	1.18	2.67	2.76	2.18	2.20
UKPN	**3.65**	**8.29**	**8.55**	**6.45**	**6.51**

1.5 Application Summary

UK Power Networks is applying for an adjustment under the IRM for the targeted deployment of an LV Network Visibility and Control System across 5,834 LV network sites (approximately 7% of our LV network). The roll-out will include the installation of RTUs in areas of our LV networks with high expected LCT adoption in the early years of RIIO-ED2, and the development of a Live LV Network Diagram that will visualise the collected data in our control room to generate insight on network conditions. The roll-out with enable £54 millions of lifetime net benefits for our customers.

This initial and targeted deployment of monitoring on our LV networks will subsequently enable the use of "smart" network control solutions, which will ultimately allow UK Power Networks' planning and control engineers to manage the network in real-time and in a proactive way, thus releasing capacity and deferring network reinforcement for capacity-constrained LV substations. UK Power Networks will fund the use of "smart" network control solutions using its LRE allowances, as well as connection customer contribution where appropriate.

The roll-out of LV Network Visibility and Control will enable LCT connections for our customers at a lower case-by-case cost, as well as a lower socialised cost for our entire customer base in the form of lower network reinforcement. The system will also enable us to maintain network performance and reliability in an environment of high LCT uptake.

We provide a detailed description of the issue that the LV Network Visibility and Control System will address, as well as a detailed description of the system and its components in Section 2 of our application. In the same section, we outline the expected outcome from the roll-out of the system on our network, and the ultimate impact of the roll-out on our customers.

In Section 3 of our application, we demonstrate the business case for the roll-out, including a summary of the costs and the benefits that will be delivered to customers, an explanation for the need to roll-out the solution under the IRM, and a description of how the proposed solution aligns with our wider business objectives.

In Section 4 we present our justification for the roll-out against the IRM Evaluation Criteria, including additional information on the proposed programme's Cost-Benefit Analysis (CBA), the measures we will take to assess the roll-out's success and effectiveness, and the organisational structure that will govern the entire programme.

In Section 5, we confirm that the proposed roll-out will not require any derogations or changes to regulatory arrangements, and also present a summary of our consultation with external stakeholders.

Our application is supplemented with a list of appendices in Section 6, which provide a deeper set of information and documentation to further substantiate our analysis and roll-out plan.

2 Application Description

2.1 The aims and objectives of the proposed roll-out

UK Power Networks' application to the 2017 IRM aims to fund a programme to establish LV network visibility and control across UK Power Networks' three licence areas in order to:

- manage in an efficient way the quicker than expected customer uptake of LCTs on the LV network;
- prepare for the efficient and effective provision of LV capacity in RIIO-ED2; and
- facilitate the development of DNO to DSO capabilities.

In order to achieve this aim, we will roll-out an LV Network Visibility and Control System that is consisting of a Live LV Network Diagram, as well as 5,834 RTUs on secondary substations (approximately 7% of our LV networks). This is a critical enabling system that will allow us to deploy a range of "smart" LV network control solutions that will ultimately manage constraints across the LV network more effectively at a lower cost for our customers.

We describe in the following sub-sections the reasons we believe the roll-out of the proposed solution is necessary and timely, as well as the expected impacts of the roll-out to our business and our customers.

2.1.1 The issue the roll-out will address

An accelerated uptake of LCTs on the LV networks will largely occur unmonitored, with DNOs addressing the corresponding network and customer impacts reactively.

A primary driver for change in the electricity distribution networks is the growth of LCTs. We consider LCTs as devices that reduce either grid or point-of-use carbon emissions and in doing so, impact the electricity system.

The UK Government's Fifth Carbon Plan highlights the importance of decarbonising key areas of energy consumption, such as transport, heat, and power generation in order to achieve the 2050 target of reducing greenhouse gas emissions by at least 80% relative to 1990 levels. Even though progress has been achieved over the last few years, especially in the electric power sector, the Committee on Climate Change (CCC) highlighted in its 2016 Progress Report to Parliament the need for further support beyond 2020 from the Government, in areas such as transport and heat in buildings.

In addition to Government-led policy support to LCTs, significant support has been gained in recent years by local authorities that have announced flagship programmes focusing primarily on zero and low emission vehicles. For example, the London Mayor has announced an ambitious transport electrification programme with a vision of making London the Ultra-Low Emission Vehicle capital of Europe. This will include a provision for all new taxis presented for licencing to be zero-emissions capable. Similar initiatives are also in place in smaller cities and towns across GB; in Milton Keynes for example, the local

> **Mayor of London, July 2015**
>
> *"Our famous red double-decker and inimitable black taxi are two of London's most recognisable icons. Now they are set to become symbols of the Capital's green transport revolution as our plans to introduce more hybrid, pure electric and zero emission capable models continue.*
>
> *By 2020, London will have the greenest bus and taxi fleets of any world city."*

council has established an Electric Vehicle Centre, offering a one-stop shop for EV consumer advice, as well as vehicle loans.

The accelerated uptake of LCTs on the network is currently aided not just by an increased policy focus, but also by technological and commercial developments, such as decrease in manufacturing costs and proliferation of market offerings. For EVs in particular, automotive manufacturers such as Ford, VW, Audi, and BMW have committed to increase the number of plug-in vehicle models in the market over the next few years, while battery pack costs have been reducing rapidly, and are expected to continue declining in the coming decade (the cost of lithium-ion battery packs in 2010 was $1,200 per kWh, and by 2020 their cost will be lower than $200 per kWh[1]).

UK Power Networks' internal business planning forecast[2] for the adoption of LCTs across our three licence areas indicates that, in the case of EVs, 1.9 million vehicles will be connected to our network by the end of RIIO-ED2. Comparing these figures with our forecasts in 2014 when we were defining our investment plans for RIIO-ED1, it can be seen that EVs will arrive quicker and at a higher scale than we expected (our forecast for EVs at the end of RIIO-ED2 was 550,000; see Figure 1 below). This increase in the forecasted uptake of EVs can be attributed to revised policy support, rapid reduction in the costs of materials, and improved technological performance of the last few years, and which could not have been predicted in advance.

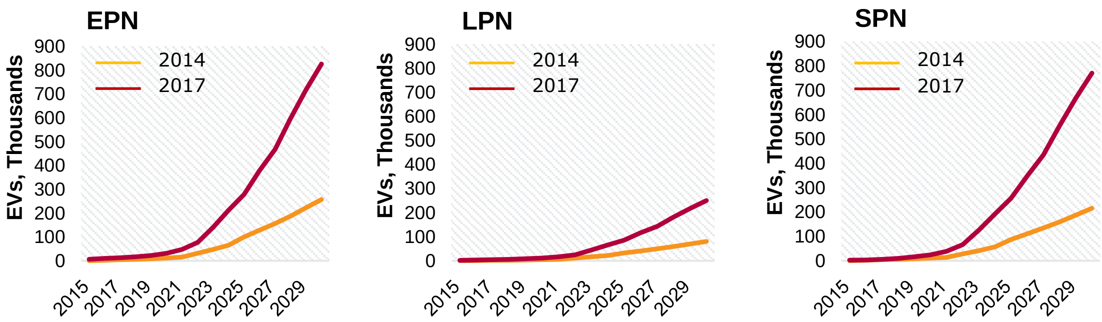


Figure 1: Comparison of connected EVs forecasts across UK Power Networks (2014 and 2017)

The issue will be particularly pronounced in the first half of RIIO-ED2, as we are now forecasting that by 2027, 330,000 more vehicles than we originally forecasted will be connected on our LV networks.

EVs are only one side of the coin; a number of other LCTs are also connecting to our networks at rates that are often dictated by rapidly changing policy decisions and new commercial offerings. For example, the Committee on Climate Change has emphasised in its reports to Parliament that decarbonising heat is essential in order to achieve the Government's ambitious carbon emission reduction targets. As a result, we would expect renewed policy focus on heat pumps impacting electricity demand from the early parts of the next decade. From a DNO perspective, the uptake in LCTs is currently an area of significant uncertainty and disruption – one that can only be efficiently and effectively prepared for with enhanced visibility and tracking.

We expect that the uptake of LCTs over the next decade will impact the LV network at a disproportionate level compared to other parts of our network. This will be driven primarily by changes in customer behaviour and domestic consumption patterns,

[1] Battery Cost Plunge Seen Changing Automakers Most in 100 Years, Bloomberg, 11 October 2016
[2] See appendix 6.3 for our approach to LCT forecasting and modelling

linked with clusters of domestic EV charging stations, domestic heat pumps, rooftop solar photovoltaic (PV) panels, as well as domestic energy storage solutions (see Table 1).

A higher level of LCTs on our network will also impact load diversity, which is the level of coincidence between our customers' load profiles over the course of the day. The impact on diversity will need to be evaluated by network planning engineers, and the assumptions under which the network is designed may need to be changed in order to ensure reliability is not impacted adversely by the changes in load profiles.

Table 1: Adoption drivers for LCTs on the LV network, and potential network impacts

Low Carbon Technology	Drivers for adoption	Potential LV network impacts
Rooftop Solar PV	» UK Government's Carbon Plan » Rising electricity prices » Large existing population of residential/SME housing structures for PV installation	» Voltage rise across LV feeders » Harmonics
EVs	» UK Government's Carbon Plan » Clean Air policy » Rapid decline in battery costs » Scale of the consumer/private vehicle fleet	» Demand profiles become unpredictable » Power quality impacts, including harmonics and voltage sags and swells
Heat Pumps	» UK Government's Carbon Plan » Large existing population of residential/SME housing	» Increase in peak demand » Power quality impacts, including harmonics and volt sags and swells
Electric Storage	» Introduction of time-of-use pricing » Rising electricity prices » Reducing battery costs	» Demand profiles become unpredictable

DNOs currently have limited visibility of the demand on LV feeders due to limited historical penetration of monitoring devices. In the past when electrical devices were limited to domestic appliances such as kettles and white goods (e.g. clothes washers, tumble dryers), the load on the LV networks grew predictably, and therefore there was limited need for LV network monitoring.

UK Power Networks currently monitors power flows across its network in real-time down to the 11kV network in its control room. The control room has limited visibility across 11% of the HV/LV network interfaces of its approximately 80,000 LV sites, however there is no real-time visibility of the LV circuits on any of the LV sites. As a result, distribution planning engineers become aware of increases in peak demand on LV feeders beyond their capacity through:

- collection of Maximum Demand Indicator (MDI) readings following site visits and inspections;
- repeated fuse operations due to high load current; and
- customer-initiated voltage investigations.

Once capacity issues are identified, the network is typically reinforced in order to provide additional capacity to accommodate the increased load.

Despite limited visibility on the LV network, GB DNOs have been able to manage LV networks effectively over time using the reactive approach outlined above, due to the predictability of customer demand and the relatively slow rate of change on the network. However, the forecasted rapid increase in LCTs in the early years of RIIO-ED2 will increase the magnitude and occurrence of network constraints on the LV network, with load patterns and constrained locations becoming less predictable and more volatile.

Given the level of uncertainty associated with LCTs and the limited level of LV network visibility today, there is a limited set of options for a DNO to:

- React to network constraints after they appear, risking a potential increase in customer interruptions, a conservative estimate in connection costs, and a reduction in the number of LCT connected on the network;
- Commission widespread reinforcement programmes using proxy data and lower targeting efficiency in order to increase capacity for LCT; or
- Invest strategically ahead of need in network visibility in order to enable targeted and efficient network investment.

2.1.2 Description of the Proven Innovation that will be rolled-out

In order to establish visibility and control over the LV network and to enable proactive and cost-effective LV network management for our customers, we are proposing to roll out an LV Network Visibility and Control System ahead of the RIIO-ED2 period.

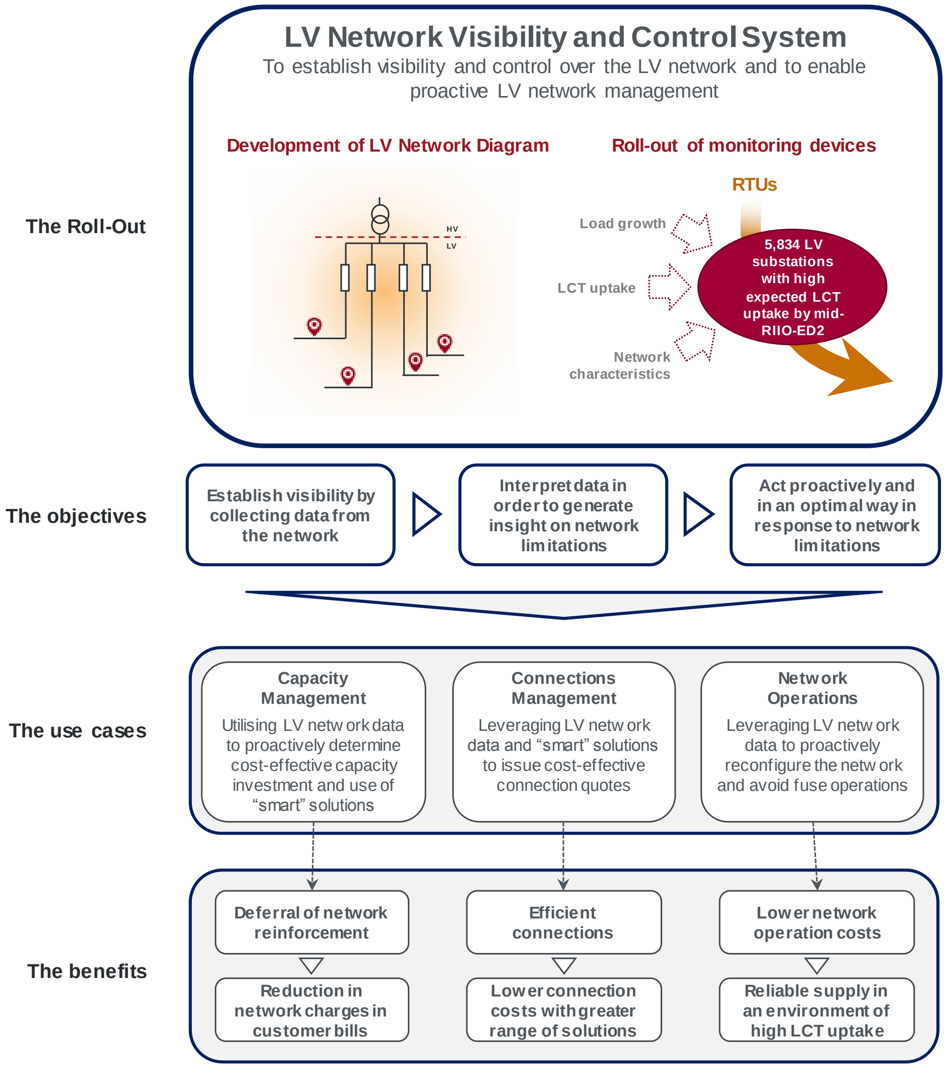


Figure 2: Overview of the LV Network Visibility and Control System

UK Power Networks considers LV network visibility as a key component in our Smart Grid development programme, as well as our roadmap to becoming a Distribution System Operator (DSO). In order to better understand the nature and magnitude of the challenges the LV networks will face, we delivered at the end of DPCR5 and in the early years of RIIO-ED1 a number of innovation projects that allowed us to demonstrate the ways in which the LV networks can be actively managed. Two of our innovation projects in particular (SULVN and FUN-LV) proved at a smaller scale the technology we are proposing to roll out with our application (see Figure 3).

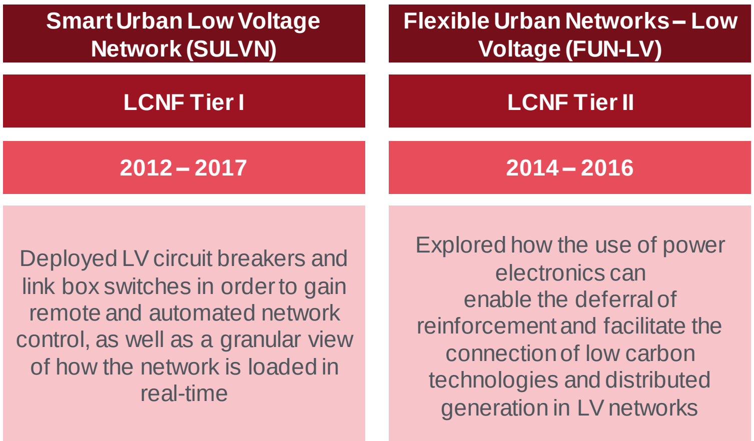


Figure 3: UK Power Networks LV Network Monitoring and Control trial projects in DPCR5 and RIIO-ED1

Through our experience in these projects[3], we have developed capabilities in the following key areas of effective network monitoring:

a) Collecting data from the network;
b) Interpreting data in order to generate insight on network constraints; and
c) Acting in an optimal way in order to manage network constraints.

The LV Network Visibility and Control System we are proposing to deploy on our networks will cover each of these three components:

– <u>Collecting data from the network:</u> We will deploy RTUs on the LV network that will collect three-phase power flow data in real-time, and will transmit the data to our Network Control Centre;

– <u>Interpreting data in order to generate insight on network constraints:</u> We will develop a Live LV Network Diagram in our Distribution Management System (DMS), and will integrate the information gathered by the RTUs into the DMS and data Historian in order to visualise the current state of the network; and

– <u>Acting in an optimal way in order to manage network constraints:</u> We will utilise LV network data to deploy "smart" network control solutions that will allow us to reconfigure the LV network. Such solutions will allow us to maximise the available network capacity at the lowest cost for our customers, ultimately facilitating cost-effective LCT connections.

Of the three components outlined above, we are applying for an adjustment under the IRM for only the costs associated with the integrated monitoring system, i.e. the roll-out of RTUs across 5,834 LV sites (approximately 7% of our LV networks) over the

[3] Refer to Appendix 6.8 for details on the lessons learned from these projects.

course of RIIO-ED1, and the development of the Live LV Network Diagram in our Network Control Centre. These two components are key enablers to the overall solution, which need to be deployed in advance and cannot deliver a sufficient level of benefit to the network by themselves (further details on the timing and magnitude of benefits are provided in Section 3).

The establishment of LV network visibility will enable us to control our networks actively. This will begin early in the roll-out, when we start collecting granular time-series data on our LV networks. We expect that the use of the data will allow us to release latent network capacity that is currently unavailable due to phase imbalance or the use of conservative planning assumptions due to the lack of time series data.

With the development of the Live LV Network Diagram, we will subsequently be able to deploy "smart" network control solutions on our networks, such as Automated LV Interconnection, Soft Open Point Interconnection, Timed LV Connections, LV Active Network Management (LV ANM), and Real Time Thermal Rating (RTTR) of Distribution Transformers. Real-time visibility is essential for the realisation of the full potential of such solutions; with real-time visibility in place, we will be in a position to specify which parts of the network can be benefited from such solutions the most, and to control the solutions from our control room in real-time.

The use of "smart" network control solutions can enable capacity release on specific parts of our networks or connections on a scheme-by-scheme basis. UK Power Networks will fund such deployments either through its Load Related Expenditure (LRE) allowance in RIIO-ED1 and RIIO-ED2, or from connecting customer contributions, where appropriate according to the Connections Charging Methodology. Ultimately, we expect that the "smart" network control solutions will allow us to deliver a more focused investment programme, thus enabling reductions in our customers' bills and reductions in connections costs through the use of innovative and "smart" connection designs.

Further details on the "smart" solutions that will be enabled by the LV Network Visibility and Control System are provided in section 2.2.3 of this document.

The roll-out of LV Network Visibility and Control is a critical enabler in our journey to becoming a DSO (see sub-section 2.2.5 for further details), enabling enhanced capabilities such as more accurate losses calculations, and phase identification. In addition, the solution we have specified will allow us to realise an enhanced level of network visibility when combined with the use of smart meters (see sub-section 2.2.6 for further details).

2.1.3 Roll-out timing and plan

We will begin the roll-out in 2018, focusing on priority parts of our networks. We are aiming to establish monitoring across 5,834 LV network sites, which are forecasted to have the highest customer uptake of LCTs by the first half of RIIO-ED2. The roll-out of LV Network Visibility and Control across further parts of our networks will be included in our RIIO-ED2 business plan.

The roll-out of the LV Network Visibility and Control System will involve the separate development of the Live LV Network Diagram and the roll-out of RTUs on LV feeders. In parallel to the hardware deployment, we will work with our distribution planning engineers and our network control engineers to ensure that business processes are adapted in a way that will allow us to take full advantage of the LV Network Visibility and Control System's functionality, and ultimately deliver the expected benefits to our customers.

The roll-out programme will be organised in three work streams, as outlined in Table 2 below.

Work stream 1 will focus on the development of the Live LV Network Diagram in our Network Control Centre. We expect that the development of the Live LV Network Diagram across our three licence areas will require four years, with an additional year required for testing and quality control. The diagram will be developed in our existing DMS.

Work stream 2 will focus on the roll out of RTUs across 5,834 secondary substations in the period between 2018 and 2023. We will continue the roll-out across our LV networks in RIIO-ED2, however the costs associated with the RIIO-ED2 roll-out are not included in the scope of the IRM funding application.

The objective of Work stream 3 is to manage the impact of the new system to our business, and to ensure that the envisioned customer benefits of the system are realised in time for RIIO-ED2. This will involve working alongside the system's user groups to ensure that any gaps in skills and capabilities are filled either through up-skilling our existing staff or hiring new planners and control engineers. In this work stream, we will also work alongside the users to ensure that business processes, policies, and standards are adapted to take advantage of the enhanced network visibility and smart grid capability the system will provide.

Table 2: The roll-out work streams

#	Name	Objective
WS1	**Develop Live LV Network Diagram**	Develop a Live LV Network Diagram in our DMS
WS2	**Roll Out LV Network Monitoring Devices**	Deploy RTUs across 5,834 secondary substations and establish real-time data feed to the DMS
WS3	**Business Process Alignment and Benefits Realisation**	Ensure that business processes and resources are in place to leverage the capabilities of the LV Network Visibility and Control System

A detailed plan for the roll-out is included in Appendix 6.1 of our application, and the programme's organisation chart is included in Appendix 6.6.

2.1.4 The expected outcome of the roll-out

Establishing an LV Network Visibility and Control System across 7% of our LV network by the end of RIIO-ED1 will allow us to optimise our investment programme in response to the uptake of LCTs. It will also generate valuable insight that will inform our RIIO-ED2 investment programme, and further roll-out of LV Network Visibility and Control. The roll-out will enable £54 million of lifetime benefits for our customers.

The roll-out of the LV Network Visibility and Control System will enable us to change the way in which we manage and design our LV network, resulting in more efficient investment decisions. Specifically, we have defined three core use cases for the business utilisation of LV Network Visibility and Control System:

a) Capacity Management;
b) Connections Management; and
c) Network Operations.

The table below outlines the expected change in the way each of these three use cases is delivered following the roll-out of the LV Network Visibility and Control System.

Table 3: Activities today and after the roll-out across the selected use cases

	How it is done today (<u>reactive</u>)	How it will be done with LV monitoring (<u>proactive</u>)
Capacity Management *Ensuring that the network is designed to the appropriate reliability and resilience standards, while releasing capacity cost-effectively for our customers*	» Distribution planning engineers do not have visibility on the loading of LV feeders or the phase balancing » Network reinforcement is trigged by: ○ Limited or prone to error maximum demand indications and short duration sampling; ○ Fuse operations or voltage violations are driven by high load.	» Distribution planning engineers will have access to historical loading data for each LV feeder » Reinforcement will be triggered when a feeder consistently shows high loading » Reinforcement can be deferred or achieved using "smart" solutions and network reconfiguration » Customer-to-phase connectivity will enable the detection and mitigation of phase imbalance issues to increase network capacity
Connections Management *Enabling new load and distributed generation connections on the network in order to access and utilise network capacity*	» Connections and planning engineers conduct time-intensive, ad-hoc studies on the network when connection requests are submitted » If the study demonstrates that a feeder may be highly loaded, a reinforcement scheme is commissioned	» Distribution planning engineers will be able to model connection requests using fully-archived LV network data » Detailed load profile data can be used to offer "smart" solutions, and thus avoid the need for a reinforcement scheme
Network Operations *Managing the network performance in real-time*	» Network Control Centre has no visibility on the loading of LV feeders, they operate from fuse ratings » Overloading is identified when customers report outages, and on-site investigations confirm that LV fuses have operated » Network operations crews are dispatched and fuses are replaced after each instance of overload operation	» Network Control Centre will be able to monitor LV network feeder loading live » Background data analytics will identify developing "problem circuits" and flag to Network Operations » Overloading can be avoided with the use of network reconfiguration and proactive intervention

The business changes in each of the use cases described above are expected to deliver benefits directly to our customers primarily in RIIO-ED2 in the form of reduced network design and operation costs, better informed connections, and network reliability in a high LCT uptake environment. We detail the benefits we expect to see from the LV Network Visibility and Control System in Section 3 and sub-section 4(b) of our application.

The way in which the changes across the three use cases described above will materialise across our business and our internal processes has been highlighted in the business impact assessment we have conducted as part of this application. Further details on the results of our assessment are included in Appendix 6.7 of our application.

2.2 Technical description of the proposed solution

2.2.1 The LV Network Visibility and Control System

We have specified a system architecture that leverages existing systems and infrastructure to deliver real-time network visibility and control.

The proposed solution consists of a Live LV Network Diagram in our DMS, which will collect real-time data from our LV network feeders and will provide insight into the way the network is performing. The system's components will be installed in our Network Control Centre and secondary substations, and will leverage existing IT infrastructure that will need to be scaled to handle the expanded data volumes the system will generate.

We present in Figure 4 below a graphical representation of the components of the LV Network Visibility and Control System using the Smart Grid Architecture Model (SGAM) format. SGAM is framework that is used to examine how different standards apply for different layers of smart grid architecture. SGAM was chosen by Work Stream 9 of the Smart Grid Forum to build a common lexicon to enable effective communication between stakeholders.

Representations of the system architecture across SGAM layers for Communication, Information, Function, and Business are presented in Appendix 6.9.

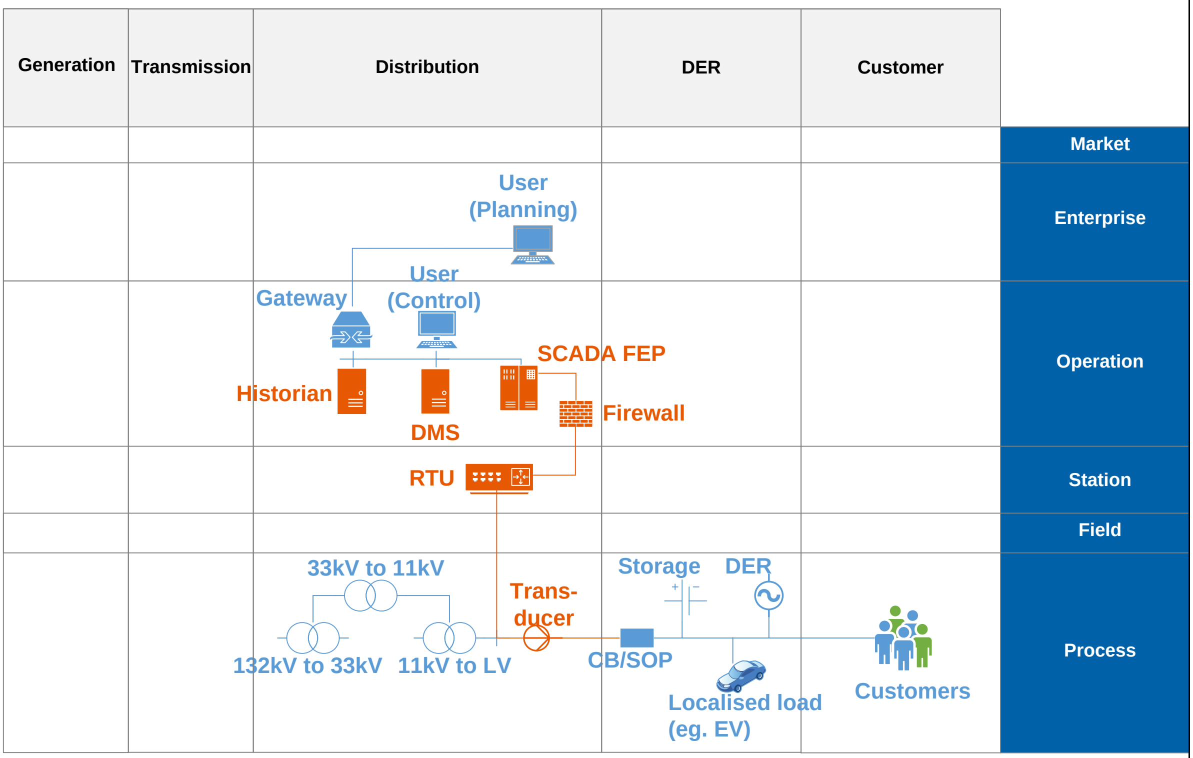


Figure 4: LV Network Visibility and Control System diagram

The main components of the system are outlined in Table 4 below.

Table 4: LV Network Visibility and Control System components

Component	Description
Transducers	Current and voltage transformers (CT, VT) are used to measure power in real-time on distribution feeders. Transducers will be deployed on our network across 5,834 sites, alongside RTUs.
RTU	Remote Terminal Units transmit telemetry data to the control room via SCADA. We will deploy 5,834 RTUs on our network as part of the proposed roll-out.
SCADA FEP	SCADA Front End Processor interfaces the control centre system with the network components. We have included in our budget provision for telecommunication links between RTU and SCADA FEP.
DMS	Distribution Management System; a software suite designed to monitor and control the distribution system. We will develop the Live LV Network Diagram in our existing DMS.
Historian	Database that maintains records of real-time data. We have included in our budget provision for additional Historian tags.

2.2.2 System architecture

We have designed our system in a way that it can enable the effective and robust use of "smart" network control devices on our networks, and can sustainably deliver benefits to our customers.

UK Power Networks currently manages the LV network using a combination of PowerOn Fusion desktop client and Geoview application. Geoview provides a geographic representation of the LV network and allows simple "dressing" of the running arrangements, however it does not allow dynamic representation of the operational state of the network, or link to HV control.

The implementation of the LV Network Visibility and Control System will involve the replacement of Geoview with a fully-connected and live LV diagram within PowerOn Advantage, which is a critical enabler for achieving network monitoring and automation at LV in a similar way to that currently provided at HV. It will, in effect, provide a "platform" for a robust system of customer-level visibility.

The use of our existing DMS in the LV Network Visibility and Control System was preferred, as it is currently the DMS that is used for the management of the HV networks. Its use will allow us to enable LV network management without the need to integrate a new system. In addition, the use of PowerOn for LV network monitoring and control was trialled successfully by UK Power Networks in FUN-LV and SULVN, as well as by SSE in New Thames Valley Vision. In these trials, PowerOn proved to be an effective system for the remote control of LV devices, the retrieval of data, the display of data for operational users, and the transfer of data to the Historian. We have also established cybersecurity protocols that will extend to the use of the LV Network Visibility and Control System.

The use of our existing DMS as the repository for the Live LV Network Diagram and all associated network data will ensure that data is managed in a way that is sustainable and compatible with our entire IS ecosystem. The data management architecture for the LV network data will be the same to the data management architecture already in use for the HV and EHV networks.

The deployment of the LV Network Visibility and Control System is not intended to only increase our monitoring capabilities; a critical component of the system is the capability to manage "smart" network control devices. The requirement of the system to be robust in order to be able to manage control signals to network plant and devices is a priority in our system architecture, and we have purposefully designed a system that is tailored to this, rather than a system that will only enable one-way monitoring.

Specifically, we will deploy RTUs on our network that include the capability to provide advanced control and interfacing with plant, with both traditional hard-wired I/O and also through a communication bus. Control will also be enabled by the live diagram in our DMS, as the "smart" network control solutions we will deploy on our network require oversight and supervision, which cannot be achieved in the absence of the diagram.

Our selected architecture has significant benefits over alternative methods of establishing LV network monitoring:

- A widespread deployment of "offline" monitoring, at a lower unit cost per site, would not allow us to establish control on our network, and would still require the development at some point in the future of the necessary infrastructure that can enable real-time visibility;
- The use of smart metering alone for LV network monitoring does not provide visibility on the network-side, and does not allow us to establish active control on the network (refer to sub-section 2.2.6 for synergies with smart meters);
- We selected a SCADA-linked and control-capable architecture that enables control of "smart" solutions on our network, thus establishing a mature system for efficient provision of LV network capacity in RIIO-ED2 and beyond (we highlight in sub-section 4(c) the expected benefits of a continued roll-out in RIIO-ED2).

We recognise that the architecture we have chosen has higher deployment costs per site compared to solutions that have been trialled by other GB DNOs and which focus on cost-effective network monitoring, however we believe that in the absence of network control capabilities, the business case for widespread LV network monitoring is less favourable.

Further to the benefits that can be delivered by the LV Network Visibility and Control System the roll-out is complete, there will be benefits that can be realised once smart meters become available on our network, and we have the ability to combine their data with those from network monitoring. We provide further analysis of the types of benefits we can achieve with the combination of LV network monitoring and smart meters in sub-section 2.2.6 of our application.

2.2.3 The "smart" network control solutions

The LV Network Visibility and Control System will enable the deployment of five "smart" network control solutions in the short-term, with more solutions expected to be specified in the future.

The development of the LV Network Visibility and Control System will enable us to deploy in a targeted way a number of "smart" network control solutions, which will in turn allow us to release latent network capacity, while avoiding the need for costly network reinforcement in order to connect LCTs.

We have successfully trialled a number of these solutions both in innovation projects, but also in our business-as-usual activities. In parallel to the deployment of the LV Network Visibility and Control System, we will update our network planning and control processes in order to embed the use of such control solutions across Capacity Management, Connections Management, and Network Operations.

By the end of RIIO-ED1, we will roll out five "smart" network control solutions. These solutions have already been successfully trialled on our network and have dedicated business process owners within our business.

- We have trialled the use of Automated LV Interconnection in FUN-LV, as well as in SULVN. Automated LV Interconnection replaces a solid link in the link box with remotely controllable switches, meshing substations together and providing capacity sharing.

  The design of such solution schemes is critically dependant on the availability of network monitoring data such as those provided by the proposed RTU equipment, and operationally, such remote switching devices must be overseen by LV Network Control in case of outage or exception.

  The use of Automated LV Interconnection is already fully specified in our internal Engineering Design Standard EDS 13-0810 "LV Auto-Reclosing Circuit Breaker".

- In FUN-LV, we also trialled the use of Soft Open Point Interconnection. The solution consists of two or three back-to-back power inverters, with a common DC busbar. The inverters are controlled by an autonomous control system that takes measurements from various neighbouring LV circuits and calculates the level of power flow required across the DC busbar, providing (controllable) capacity sharing through meshing.

  The design of such solution schemes is critically dependant on the availability of network monitoring data such as those provided by the proposed RTU equipment, and operationally, the power electronic devices work autonomously by monitoring on-line RTU data across the network. In addition, these schemes must be overseen by LV Network Control in case of outage or exception.

  The use of Soft Open Point Interconnection is specified in our internal Engineering Design Standards EDS 09-0040 "Dual Terminal Power Electronics Device", and EDS 09-0039 "Multi-Terminal Power Electronics Device".

- Timed Connections have been offered by UK Power Networks to connectees on the HV network, and have been developed based on lessons from our Low Carbon London and business as usual-led connections trials. Using detailed analysis of historical data, such as those obtained through monitoring devices, a connection can be offered to customers based on "time of the day" or "day of the week/weekend/season". Customers are permitted to export or import at set times and not at others, or may have a fixed limit imposed on their output at certain times.

  In lieu of a DNO-controlled disconnect switch, LV Network Control oversight of these schemes is required in order to ensure scheme performance and network integrity.

  The use of Timed Connections is specified in our internal Engineering Design Standards EDS 08-5021 "Timed Connections".

- LV Active Network Management (LV ANM) was successfully trialled in Low Carbon London, as well as by Electricity North West in My Electric Avenue. With LV ANM, load from EV infrastructure can be managed at peak times by sending a curtailment or maximum load notification to the charge point, or group of charge points in real-time.

  This solution requires historic and on-line data for scheme design and management, respectively. Real-time oversight by LV Network Control is also required in order to dispatch ANM control signals, ensure scheme performance, and ensure network integrity.

- Real Time Thermal Rating (RTTR) of Distribution Transformers is the continuous calculation of a transformer's thermal capacity using temperature measurements from the substation environment. UK Power Networks has successfully trialled RTTR in power transformers in the NIA-funded Power Transformer Real Time Thermal Rating project. The solution has also been trialled successfully for distribution transformers by Electricity North West ("Distribution Transformer Real Time Thermal Rating"), and Northern PowerGrid ("Customer-led Network Revolution").

  Detailed historic load and thermal data for each asset are required where real-time ratings are applied in order to develop new thermal ratings models. The assets must also be monitored by LV Network Control in order to reliably operate the transformer capacity increased beyond nameplate rating.

  The use of RTTR is specified in our internal Engineering Design Standard EDS 04-0033 "Transformer Up-Rating".

Table 5 List of enabled "smart" network control solutions

"Smart" solution	Benefits	Where it has been trialled before
Automated LV Interconnection	» Capacity increase/deferral of network reinforcement	» FUN-LV (Method 1) and SULVN
Soft Open Point Interconnection	» Capacity increase/deferral of network reinforcement » Voltage management » Current phase balancing	» FUN-LV (Method 2 and 3)
Timed LV connections	» Capacity increase/deferral of network reinforcement » More efficient connections	» Offered at HV currently by other DNOs » Lessons from Low Carbon London
LV Active Network Management (LV ANM)	» Capacity increase/deferral of network reinforcement » More efficient connections	» Low Carbon London » My Electric Avenue (ENW)
Real Time Thermal Rating (RTTR) of Distribution Transformers	» Capacity increase/deferral of network reinforcement	» Power Transformer Real Time Thermal Rating » Distribution Transformer Real Time Thermal Rating (ENW) » Customer-led Network Revolution (NPg)

We expect that over time, the list of “smart” network control solutions will increase as more solutions become mature, both technically and commercially. We are currently planning on specifying four additional “smart” solutions for development in the mid-term (see Appendix 6.9.4).

We expect that further development and re-prioritisation of our list of “smart” network control solutions will be informed by the needs and requirements of our LV network customers, as more and more proposed solutions involve active participation from customers in the context of a bilateral or multilateral commercial arrangement (e.g., LV DSR).

The process of leveraging the capabilities of the LV Network Visibility and Control System in order to enable the use of “smart” network control solutions will be managed during the roll-out by Work stream 3: Business Process Alignment and Benefits Realisation. We will work side-by-side with the primary business owners of the solutions to ensure that the solutions are implemented in accordance with the expectations of the business users (planning and control engineers).

In parallel, we will regularly review and update our list of “smart” network control solutions for long-term development, in accordance with our overall Smart Grid Strategy and DSO Roadmap.

2.2.4 The impact on our business

We have worked with the users of the proposed solution to understand how LV Network Visibility and Control can be embedded to our existing business processes in order to successfully realise benefits for our customers.

In addition to the deployment of the required assets on our network and control room, a key output of the roll-out will be the alignment of our internal business processes to the capabilities of the new system. Such changes will have their own impact to our business, both in terms of costs, but also in terms of staff availability and capability.

In order to assess the impact of the roll-out across the business units currently responsible for the three use cases outlined above, we have conducted a business impact assessment. In our assessment, we identified the business processes and the tools that will be impacted by the introduction of the proposed solution. Throughout the roll-out, we will monitor the way the business incorporates the capabilities of the LV Network Visibility and Control System across the identified processes; this will be part of the scope of Work stream 3.

In our assessment, we also identified the staff that will use the system across Distribution Planning, Network Control, and Network Operations, and we have specified appropriate training time in the roll-out budget.

Based on this assessment, we believe that the business is well positioned to take advantage of the capabilities the LV Network Visibility and Control System can offer, and ultimately realise the benefits the system can deliver to our customers.

We highlight in Table 6 below the main impacts from the roll-out across the three use cases, with further details on the outcome of our business impact assessment included in Appendix 6.7 of our application.

Table 6: Summary of impacts to our business across the three use cases

Use Case	Summary of impacts
Capacity Management	» Facilitates greater penetration of Automated Interconnection, SOP Interconnection, LV ANM, Timed Connections, and RTTR. » Directional, three-phase feeder loading data will enable planning engineers to make reinforcement investments more effectively, especially for LV meshed networks. » Data quality will be improved by not having to rely on MDI readings, which can be misleading or prone to error (MDIs can record a peak demand during abnormal operating conditions, which may not represent a capacity issue). » Fault repairs will be prioritised more effectively using time-series data.
Connections Management	» Use of LV data from Historian, which can be automatically transferred into new planning tools, will enable smart connection solutions to be used more frequently. » Connection costs will be more accurate through less estimation of available capacity, i.e. feeder demand profiles and phase imbalance levels will be known rather than estimated. » Ability to offer a wider range of connection options (e.g., Timed Connections) in cases where network reinforcement is required
Network Operations	» Ability to check present demand and demand history to confirm whether issues are due to changes to normal running conditions or are likely to be due to a fault. » Improved access to feeder load data will enable improved load distribution when back-feeding from the LV network is necessary due to HV interruptions. » Ability to coordinate fault response more efficiently by sending correct teams to faults in the first instance.

2.2.5 Enabling our transition to DSO

LV Network Visibility and Control is a key enabler to our vision of becoming a DSO and supporting a smarter, more flexible energy system, and we will continue its roll-out in RIIO-ED2.

UK Power Networks recognises the importance of establishing an LV Network Visibility and Control System as an enabler to a future where DNOs will become DSOs, and will be expected to not only enable LCTs on the network, but also actively manage their contribution to the entire system. Figure 5 below highlights key DSO activities in our DSO Roadmap that will be facilitated by LV Network Visibility and Control.

In order to take further steps towards our vision of becoming a DSO, the deployment of LV monitoring across our licence areas will be an important part of our RIIO-ED2 investment programme, and we believe that with our experience in delivering an initial roll-out in RIIO-ED1, we will be able to better inform our RIIO-ED2 cost estimates for LV monitoring across a larger part of the network.

The experience and the lessons from this initial, targeted roll-out of the LV Network Visibility and Control System will also allow us to have a better understanding of the optimal way in which we can deploy the system on our network at scale, the locations at which it can deliver the most value, and the impact it can ultimately achieve in the management of the uptake of LCTs on our networks.

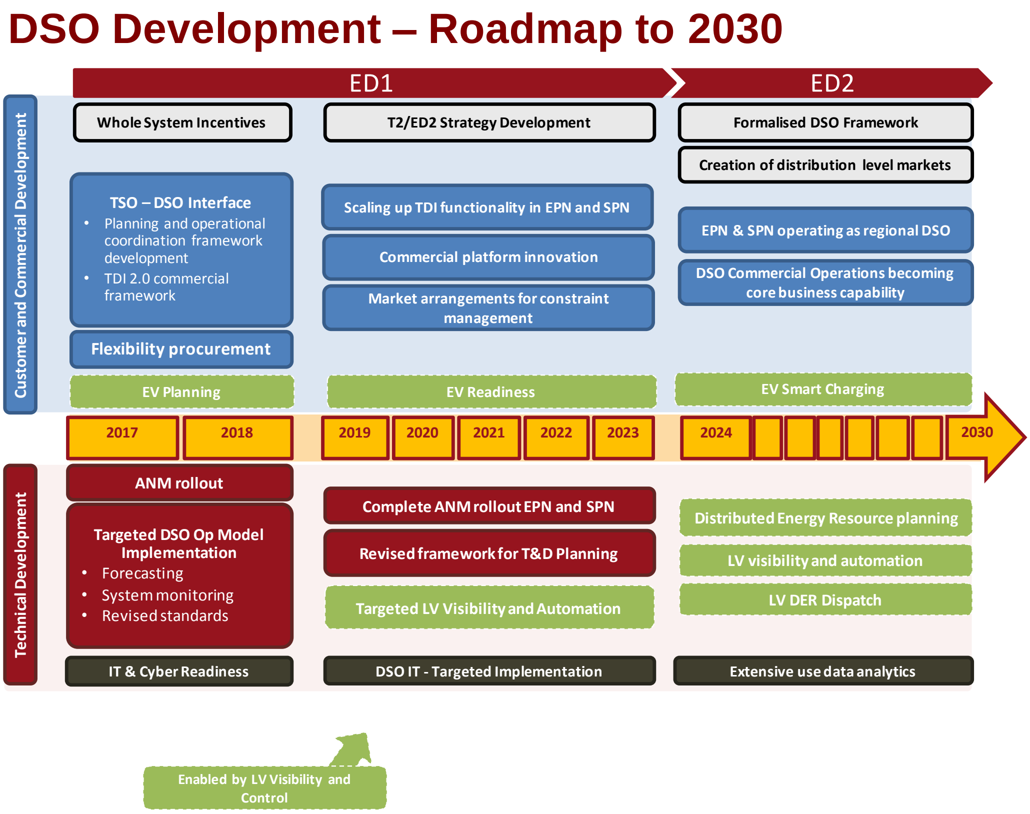


Figure 5: UK Power Networks DSO Roadmap

In addition, LV Visibility and Automation is a core capability that we have included in our DSO Roadmap for development by RIIO-ED2, as outlined on our response to the November 2016 Ofgem/BEIS *Call for Evidence on a Smart, Flexible Energy System*. Without an enabling LV Network Visibility and Control System in place, we will not be in a position to develop LV DER Dispatch capabilities, rendering the creation of distribution-level markets inefficient and suboptimal. This was highlighted in our response to question 44 of the Call for Evidence:

> *"To deliver decarbonisation at lowest cost, a paradigm shift is required in system operation. This will require investment in new IT and communications systems, along with the data and analytical processing to drive advance distribution management…"*

We detail in section 4b.2 below the impact of the proposed system on wider energy operations when considering our role as a DSO.

2.2.6 Unlocking enhanced capabilities in conjunction with smart meters

The combination of the LV Network Visibility and Control System and smart meters will allow us to deliver a wider range of solutions for the benefit of our customers, as well as target part of the network for further deployment of LV network monitoring in an efficient way.

In addition to enabling DSO capabilities, the proposed system has the potential to unlock enhanced network visibility when its capabilities are combined with those of smart meters:

- The combination of smart meters and LV network monitoring will allow us to develop phase-level connectivity in our network, which can enable phase balancing across our feeders.
- Smart meters will enable us to make more informed decisions about where we can deploy LV network monitoring next. With the presence of smart meters, we will be able to track shifts in customer consumption profiles and identify parts of the network that may be at risk; these parts of the network could be considered for LV network monitoring deployment.
- The delivery of Timed Connections, one of the "smart" network control solutions that can be enabled by the LV Network Visibility and Control System, will likely require the use of smart meters in the long-term in order to monitor effectively customer compliance to the Timed Connection arrangements.
- With smart meters in place, we will be able to manage voltage on our network more effectively, and also allow us to measure more accurately and reduce losses.

The use of smart meters may also enable behind-the-meter network management such as DSR with domestic loads, something that is currently not easily achieved in the absence of advanced metering infrastructure.

The LV Network Visibility and Control System we are proposing to roll out will provide complementary capabilities to smart meters; however, there is functionality that can only be achieved through the proposed system, and which cannot become available even when smart meters become ubiquitous on LV networks. Without network assets, such as RTUs on our network feeders, we will not be able to deploy "smart" network control solutions such as controlled switches for interconnection and soft open points.

Furthermore, with the establishment of real-time network monitoring, we will be able to manage our network using operational measurements rather than planning assumptions, enabling us to move away from "worst case scenario" network management. This will not be possible in the absence of network monitoring, even after a widespread roll-out of smart meters on our networks, as smart meters will not provide monitoring of network assets.

3 Application Business Case

3.1 Overview of the benefits of LV Network Visibility and Control

The LV Network Visibility and Control System will enable a proactive approach to LV network management.

The current approach to LV network management, as illustrated on the left side of Figure 6 below, involves limited capability in real-time control, as the Network Control Centre has no real-time data feed on the LV networks. As a result, the management of the LV network is done reactively, in response to fuse operations or customer notifications of voltage instability, and involves the dispatch of field crews and expensive site visits. Similarly, LV network reinforcement is triggered from either repeated fuse operations or the use of MDI data, which can be obtained following a site visit to a secondary substation.

On the right side of the diagram we illustrate how LV network management will be achieved when the LV Network Visibility and Control System will be in place. With a real-time data feed between the network and the Network Control Centre via SCADA, proactive network control can be achieved, thus avoiding the need for costly site visits. In addition, data can be used proactively by the Distribution Planning and Connections teams in order to reinforce the network efficiently, and to specify connection offers to customers more effectively.

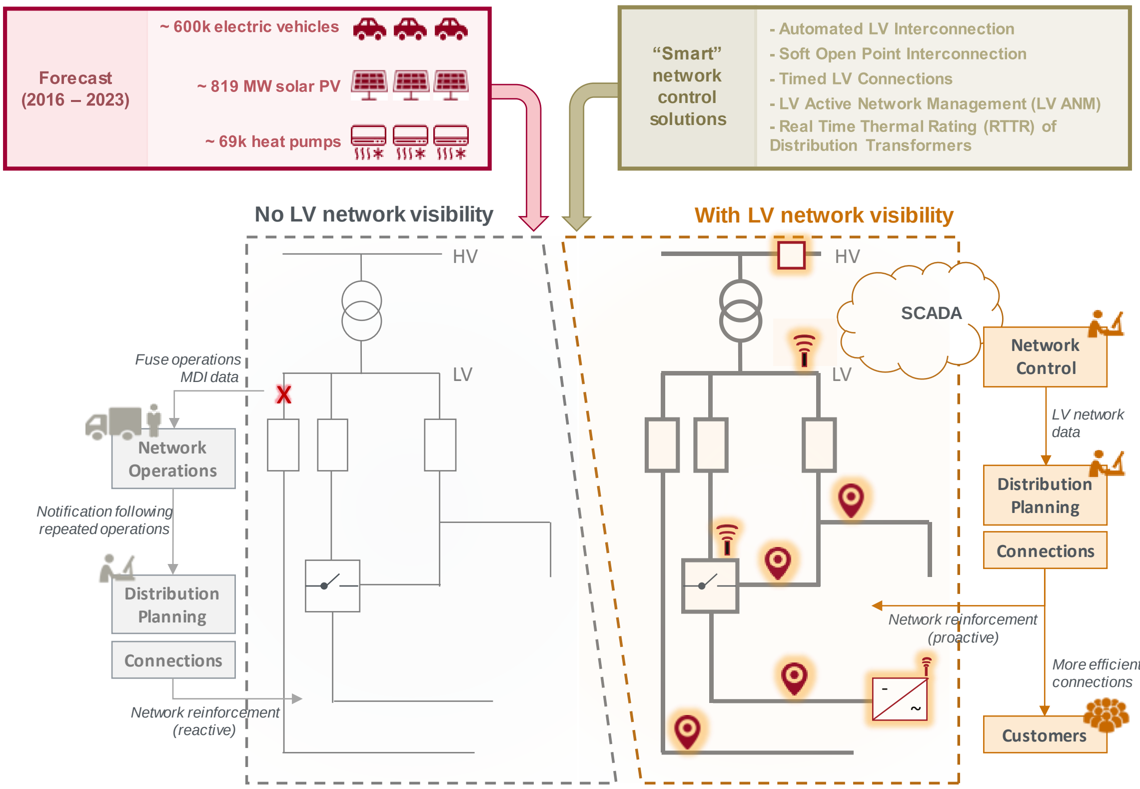


Figure 6: Overview of LV Network Visibility and Control System benefits

3.2 Long-term value for money

3.2.1 The benefits of the roll-out for our customers

The proposed solution will deliver customer benefits through improved Capacity Management, Connections Management, and Network Operations in RIIO-ED2, with some reinforcement deferral benefits beginning to accrue in RIIO-ED1.

The LV Network Visibility and Control System has the potential to deliver benefits to our customers across all three use cases: Capacity Management, Connections Management, and Network Operations, as outlined in Table 7.

Table 7: Summary of expected benefits from the roll-out

Use Case	Benefit	Description	What our customers will see
Capacity Management	**Deferral of network reinforcement**	Deferral of network reinforcement by optimising capacity using "smart" network control solutions	Lower network costs in their electricity bills
Connections Management	**Efficient connections**	Ability to conduct connection studies more efficiently using LV network diagram and historical LV network data	Lower connection costs via increased connection options (technical and commercial)
Network Operations	**Avoided site visits following fuse operations and voltage violations**	Reduction in costs by avoiding the dispatch of a field crew following a fuse operation or a voltage violation	Lower network costs in electricity bills, and maintenance of network reliability in an environment of high LCT uptake

The realisation of the benefits through the roll-out will be phased; we expect to realise some benefits in the first four years of the roll-out, when the Live LV Network Diagram will still be in the process of being developed, just by collecting detailed network data using the deployed monitoring equipment. This will be done by improving the load balance across our LV feeders, and by specifying network reinforcement using time-series data rather than MDI measurements (MDI data does not capture the duration of load peaks on the LV network, and can therefore lead to conservative planning assumptions).

Once the Live LV Network Diagram is developed and operational, we will start realising the full suite of benefits, given that we will be able to deploy "smart" network control devices in an informed and targeted way. We summarise in Table 8 the timing of the benefits realising through the roll-out, and subsequently through RIIO-ED2.

The Cost-Benefit Analysis (CBA) we have prepared as part of our application (see sections 4b.1 and 6.4 for detailed description) demonstrates that the roll-out of the system has the potential to deliver lifetime benefits of £54 million in the form of deferred network reinforcement, as well as enable LCTs that can deliver an annual reduction of 20 thousand tonnes of CO_2 emissions by the end of RIIO-ED2.

Table 8: Phasing of the benefits through the roll-out

Phase	Timing	System components delivered	Benefits realised
I	**2018-2022**	» Gradual roll-out of RTUs » Network Diagram under development » Business process and resource alignment	Some reinforcement deferral achieved by utilising granular, time-series data
II	**2022-2023**	» Continued roll-out of RTUs » Network Diagram live; data quality review » Business processes adapted to new system » "Smart" network control solutions being deployed	Gradual ramp up of benefits realisation as we deploy "smart" control solutions
III	**RIIO-ED2**	» Continued roll-out of RTUs » Network Diagram live with confidence in data quality » A number of "smart" network control solutions integrated to system	Full suite of benefits across the three use cases

3.2.2 Wider network benefits

The development of an LV connectivity model will enable additional network benefits, such as improved fault detection and reduced network losses.

Further to the benefits outlined above, a significant upgrade in the way we manage our networks will be achieved through the development of an LV connectivity model. With a connectivity model in place, we will be able to encode the links between substation feeders and user premises, thus allowing us to determine which phase customer loads are connected. Being able to associate customer loads with phases on our LV feeders will enable us to identify faults on the network more quickly and efficiently, as well as assess the impact on our customer more accurately. We also expect that with phase identification, we will be able to balance load between the phases of a feeder, thus releasing latent network capacity at a low cost.

Case study: the benefits of a connectivity model in network analytics

Historically there has been a business case to perform network sweeps to analyse the entire network in order to identify reinforcement needs.

In 2011 every section of the network including telecontrol points, normal open points, and primary breakers needed to be investigated in order to assess the investment requirements. Even though the result of this analysis was a successful retrofit programme, it took required work from six planners over three months to conduct the analysis.

A similar analysis was conducted on the HV network, following control diagram and data enhancements. The analysis was completed by one analyst in two weeks, as it only required the development of a script.

We expect that the following benefits will also be enabled by the LV Network Visibility and Control System; however, we recognise that there is less certainty with regards to the timing and magnitude of these benefits:

- Reduction in losses, as well as improvement in our ability to calculate and report losses more accurately (see below for further details);
- Increase in asset life and condition-based Asset Management, with maintenance targeted to assets with increased loading;

- Ability to create LV capacity heat maps that our customer can access to inform their connection requests; and
- Measuring and proactively improving power quality.

Network visibility as a key enabler of our losses strategy

Network losses within a distribution network currently have to be estimated due to the difficulty relating the energy flowing into the network, at the interface with the transmission network, and ultimately to the end consumer. In the case of UK Power Networks, there are in excess of 8 million exit points on our network. Losses within the GB DNO networks are currently estimated to be between 6% and 8%, and this varies significantly with network types, load profiles, and types of customers connected. Importantly, of the losses associated with the electricity distribution network the largest share of these, 45%, occur within the LV network. In the context of a 350 TWh annual GB electricity consumption, almost half of the distribution network losses equates to 9.5 TWh per annum of energy lost within the LV network – the network where visibility is lowest.

Ofgem recently published a paper for the Secretary of State (Energy Efficiency Directive: An assessment of the energy efficiency potential of Great Britain's gas and electricity infrastructure) which estimated that in 2012/13, network losses on the GB DNO networks were 19.6 TWh. Valued at £48.32/MWh, the total cost of losses is approximately £1 billion per annum.

UK Power Networks understands the theory behind losses and through the work proposed in our Losses Discretionary Reward tranche 1 submission, we are gaining a better understanding of where these losses occur on our network. However, whilst these activities will provide a better understanding of where our focus should be applied, it will still be based on assumptions and calculations. To effectively identify the networks with the highest losses, and understand how those losses relate to electricity supply characteristics such as phase imbalance, power factor and power quality, it is necessary to have measured data. A holistic view, i.e. one which provides visibility of energy flowing in to, and out of our networks, will ensure that we are able to target networks that provide the largest benefits.

Most losses occur on the LV network, and this is currently the area of our network across which we have the least visibility. It is anticipated that smart meters will provide an excellent indication of power flowing out of a circuit and we anticipate being able to utilise this data to great effect. Where 100% penetration of smart meters is achieved, it should be possible to use modelling software and suitable algorithms to gain an enhanced understanding of losses. Where smart meter penetration is less than 100%, or where a higher degree of certainty is required before making losses-related investment decisions, it is necessary to relate the energy flowing in to the circuit as well as out of it.

Distribution substation LV monitoring will enable this degree of visibility and will ensure that activities related to losses reduction are targeting the worst-performing parts of our networks. It will also ensure that we apply the most relevant interventions, by highlighting which aspects of the electricity supply characteristics are causing most losses.

3.3 Roll-out strategy

We will roll out the LV Network Visibility and Control System across LV feeders on our network that are forecasted to have the highest customer LCT uptake by the middle point of RIIO-ED2.

In order to understand the magnitude of the challenge and the level of expected benefits from the roll-out of the system, we conducted an analysis of the required investment across our approximately 80,000 secondary substations. Our analysis leveraged the LRE model (for details on the LRE model, see Appendix 6.3) and our internal business planning forecasts to generate a loading profile for each of our secondary substations through to the mid-point of RIIO-ED2. Further details on our approach for this analysis can be found in Appendix 6.4.

Using the results of our analysis, we have identified 5,834 sites where we believe that enhanced network visibility can deliver the most value to our customers in the short-term. These sites are the ones with the most forecasted LCT capacity by the mid-point of RIIO-ED2, which is when the full system would be available if we started its implementation at the beginning of RIIO-ED2.

We note that a number of the sites targeted for deployment of the proposed solution in RIIO-ED1 are already equipped with monitoring technology on the HV side of the substation. We have recognised and discounted in the roll-out budget the cost efficiencies related to incremental retrofits to these sites compared to a site with no monitoring in place.

Based on our internal planning forecasts, our roll-out strategy will deliver monitoring at LV network sites that will see approximately 13% of all LCT installations by the end of RIIO-ED1 (see Table 9). These sites will also be associated with approximately 900 thousand of our customers.

Table 9: Target sites for the roll-out of the LV Network Visibility and Control System in RIIO-ED1

	EPN	LPN	SPN	UKPN
Planned sites (total)	**1,831**	**2,020**	**1,983**	**5,834**
Sites with no RTUs	1,318	1,454	1,428	**4,200**
Sites with existing RTUs	513	566	555	**1,634**
Expected number of customers associated with planned sites	203,241	416,120	279,603	**898,964**
Number of LCT installations associated with planned sites	57,301	36,352	103,544	**197,197**
% of LCT installations targeted for monitoring	8%	19%	19%	**13%**

Given the inherent uncertainty in the uptake of LCTs on the network, we expect that the LCT uptake and load growth on our secondary substations will change dynamically through the end of RIIO-ED1. Even though we commit to delivering the LV Network Visibility and Control System across 5,834 secondary substations (for details on our proposed roll-out outputs, refer to sub-section 4b.3), we also want to ensure that we are intervening at the correct sites.

In order to do so, we have included in our roll-out plan under Work steam 3 an annual review of our roll-out strategy, during which we will employ the same approach as the one described above (and in more detail in Appendix 6.4) in order to target those sites that have the highest LCT uptake based on the most recent LCT uptake forecast. Practically, this means that the list of sites we will target with our roll-out will change dynamically year-over-year, but we believe this is an appropriate arrangement given the level of uncertainty and volatility associated with LCT growth on the LV networks.

In the long-term, we expect that our annual roll-out targeting approach will be further enhanced by the use of smart metering data, which can give early indications for parts of our networks that may be congested. With the presence of smart meters, we will be able to track shifts in customer consumption profiles and identify parts of the network that may be at risk; these parts of the network could be considered for LV network monitoring deployment.

We note also that in the instance where LCT growth is lower than anticipated in a site where monitoring has already been deployed, we will maintain the capability to re-deploy the monitoring equipment to a different site in order to ensure that monitoring is deployed in parts of the network that is most cost-effective for our customers. This will be part of our annual roll-out strategy review, and we have included a provision in our roll-out budget for the relocation of RTUs.

3.4 Roll-out costs

We have developed a robust and efficient roll-out budget based on our experience from trialling the LV Network Visibility and Control on our network in the early years of RIIO-ED1.

The components of the LV Network Visibility and Control System have been trialled in previous projects delivered by UK Power Networks (FUN-LV, SULVN), and therefore we have a good understanding of the costs that make up the proposed solution. Despite this, the roll-out of the LV Network Visibility and Control System to a scale such as the one described in our application has inherent challenges, and therefore careful cost planning is required.

We have built up the budget for the roll-out from the bottom up, using established unit costs from our business-as-usual work where possible, and benchmarking our costs against the actual costs in our prior innovation trials involving the components of the proposed solution.

Table 10 provides a summary of the roll-out costs per licence area. A detailed budget is included in Appendix 6.2.

Table 10: Summary of roll-out costs per license area

Cost category	EPN [£m]	LPN [£m]	SPN [£m]	UKPN [£m]
Project Management and Governance	**0.44**	**0.28**	**0.28**	**0.99**
Labour	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	**xx.xx**
WS1: Develop Live LV Network Diagram	**3.01**	**1.99**	**1.98**	**6.98**
Labour	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	**xx.xx**
WS2: Roll Out LV Network Monitoring Devices	**7.80**	**8.53**	**8.58**	**24.91**
Labour	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	**xx.xx**
WS3: Business Process Alignment	**0.24**	**0.16**	**0.15**	**0.56**
Labour	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	**xx.xx**
Total	**11.49**	**10.96**	**10.99**	**33.44**

One of the benefits of an early, targeted roll-out of the LV Network Visibility and Control System on our LV networks is that it will allow us to assess the implementation costs ahead of the development of our RIIO-ED2 investment plans. Even though the solutions we will be deploying on our network have been trialled before, we expect that we will gather additional knowledge and inform further efficiencies from the roll-out at a much larger scale.

As described in our roll-out plan (see section 2.1.3), we will roll-out 5,834 RTUs over the course of RIIO-ED1, and we will develop the Live LV Network Diagram between 2018-2022. Based on the detailed project plan and cost phasing, the costs and Relevant Adjustment for each regulatory year are as shown in Table 11 below.

Table 11: Expected roll-out costs for each regulatory year

Year	EPN [£m]	LPN [£m]	SPN [£m]	UKPN [£m]
2018/19	1.30	1.18	1.18	3.65
2019/20	2.94	2.67	2.67	8.29
2020/21	3.03	2.75	2.76	8.55
2021/22	2.10	2.17	2.18	6.45
2022/23	2.12	2.19	2.20	6.51
Total	**11.49**	**10.96**	**10.99**	**33.44**

We have included a mapping of the costs that are outlined in Table 10 and Table 11 to the RIIO-ED1 RIGs tables in Appendix 6.2 of our application. We note that there are no costs associated with the roll-out of LV Network Visibility and Control in our respective RIIO-ED1 business plan tables.

3.5 The case for IRM funding

The roll-out of an LV Network Visibility and Control System has been in our Smart Grid Roadmap, and we have already delivered a range of key projects within our innovation portfolio in order to specify and prove ready the appropriate solutions. The more rapid increase in the uptake of LCTs across our networks compared to our initial forecasts at the beginning of RIIO-ED1 means that waiting until RIIO-ED2 to roll out the solution would result to missed opportunity for customer benefits.

In our RIIO-ED1 plan, we described that “the connection of Low Carbon Technologies to distribution networks is expected to have a dramatic effect on the need to reinforce LV networks when compared to historic trends”, and that this “presents an opportunity for smart technologies to solve the network issues that arise from LCTs to avoid the large expenditure that would be necessary if using traditional reinforcement techniques, which may also prove disruptive to the public”.

Having recognised the need to prepare ahead of the dramatic increase in LCTs in the long-term, we also recognised the need to appropriately specify in the short-term “smart” solutions that will enable us to address the issue efficiently and at the lowest cost for our customers. In order to do so, we commissioned a number of projects considering the ways in which LV networks can be managed in an environment of increased LCT penetration (see Figure 7).

We believe that with the successful conclusion of the last two projects in particular (SULVN and FUN-LV), we have developed capabilities and practical experience in the ways in which we can monitor and control the LV networks effectively.

Demonstrated the business benefits of the smart collection, utilisation and visualisation of network data, and developed a business-as-usual visualisation and reporting tool to support effective information reporting based on these monitoring data	**Distribution Network Visibility (DNV) (2010-2013)**
Developed thorough experience in working practices and methods regarding LV monitoring, as well as drove improvements in the monitoring equipment available in the market	**Low voltage current sensor technology evaluation (2011-2013)**
Investigated ways in which we can assess solar PV connections, and evaluated their impact on our LV networks. In this project, we developed experience in the way LCT connected on the LV network change domestic energy consumption patterns, and the subsequent impact on LV networks	**Validation of PV Connection Assessment Tool (2012-2014)**
Demonstrated at a large scheme level the use of new solid-state switching technology for use on LV distribution networks, as well as the enhanced operational management of the LV network provided by visibility of the real-time network running arrangement and load monitoring information	**Smart Urban Low Voltage Network (SULVN) (2012-2017)**
Explored how the use of power electronics can enable UKPN to defer conventional reinforcement of the network, whilst still being able to facilitate the connection of LCT and distributed generation	**Flexible Urban Networks – Low Voltage (FUN-LV) (2014-2016)**

Figure 7: Our prior experience in trialling LV Network Monitoring and Control

The development of LV Network Visibility and Control was not included in our RIIO-ED1 business plan because at the time, our forecasts for LCT uptake were more uncertain than they are now, and also indicated a much lower impact from LCTs on our networks at the start of RIIO-ED2.

It was our view at the time when our RIIO-ED1 plan was specified that it would be more sensible to take a "long-term" view on an issue that was going to materialise primarily in RIIO-ED2, and we therefore decided in favour of a staged approach in which we first trialled the system at a smaller scale in RIIO-ED1, before we deploy at a larger scale in RIIO-ED2.

Our decision at the time also considered the potential downside of investing early in unproven solutions, and the impact that investment may have on customers, should the LCT uptake be lower than expected. We also recognised that should LCT uptake exceed our expectations, as has happened, mechanisms such as the IRM exist within the RIIO framework for this reason.

Whilst we still consider our approach was appropriate at the time given the information available, our long-term view is not immune to externalities, such as a more rapid increase in LCTs driven by targeted Government policy and improved technological maturity (see, sub-section 2.1.1). We therefore believe that given the fact we are currently forecasting a significant increase in LCT adoption across our networks in the first half of RIIO-ED2 compared to our forecast at the end of DPCR5, we must ensure that we are prepared earlier than previously forecasted.

4 Evaluation Criteria

a) Will deliver additional carbon, environmental or any other wider benefits

The roll-out of the LV Network Visibility and Control System can enable LCT customer connections by reducing network constraints, and achieve annual carbon emissions reduction of approximately 20 thousand tonnes of CO_2.

We outlined in Sections 2 and 3 of our application the ways in which the roll-out of the LV Network Visibility and Control System will enable efficient capacity management on the LV networks. We expect that the management of capacity on LV feeders that would have otherwise been considered constrained, as well as the deferral of costly reinforcement, have the potential to facilitate LCT connections that would have otherwise been considered uneconomical.

Specifically, based on our roll-out strategy, we expect to deploy monitoring on 5,834 secondary substations across our three licence areas, which are expected to have approximately 13% of the LCT installations that will be connected on our LV networks by the mid-point of RIIO-ED2.

We estimate that the LCTs that will be associated with the sites where LV Network Visibility and Control will be established have the potential to deliver a reduction in CO_2 emissions of approximately 20 thousand tonnes per annum. Such savings in carbon emissions can deliver cost savings at a societal level of more than £280,000 per annum (see Table 12).

Table 12: Summary of avoided CO_2 emissions and associated cost savings

Type of Benefit	EPN	LPN	SPN	UKPN
Avoided CO_2 emissions [ktonnes per annum]	9.36	5.14	5.71	**20.22**
Avoided cost from CO_2 emissions [per annum]	£131,298	£72,177	£80,166	**£283,642**

We provide further details on our approach and assumptions in Appendix 6.4 of our application.

b) Will provide long-term value for money for energy consumers

b.1. Costs and benefits

The roll-out of the LV Network Visibility and Control System can deliver lifetime net benefits of approximately £54 million in the form of deferred network reinforcement.

We outlined in Section 3 of our application the expected benefits of the proposed solution for our customers, which are underpinned by our capability to deploy "smart" network control solutions on our LV networks. We expect that our ability to actively control the LV network will allow us to deliver significant benefits to our customers in the long-term in the form of reduced LV network reinforcement, efficient connections, and reduced network operation costs.

In order to quantify the level of expected benefits that the proposed solution can enable, we have prepared a CBA for the duration of RIIO-ED1 and RIIO-ED2. Our analysis only considers the benefits from the deferral of network reinforcement, given the uncertainty associated with estimating the number of connection requests or fuse operations on our LV networks.

When considering the impact of the proposed solution on network reinforcement deferral, our CBA demonstrates that the roll-out of the LV Network Visibility and Control System has the potential to deliver net benefit of £54 million on a lifetime basis (see Figure 8 below). We note that lifetime is assumed to be 45 years, in accordance with the RIIO-ED1 CBA templates.

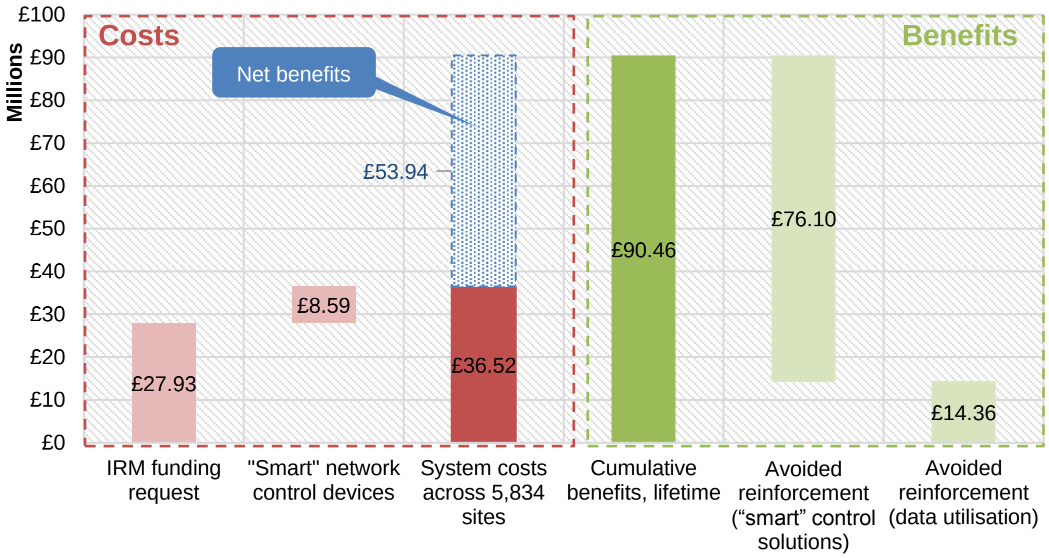


Figure 8: Summary of CBA results, expressed in lifetime NPV values

In our CBA, we have considered the costs of the initial and targeted roll-out of monitoring across 5,834 secondary substations and the development of the Live LV Network Diagram by the end of RIIO-ED1; these costs are outlined in detail in Section 3 of our application, and form the basis of our IRM funding request.

We have also considered the costs of the use of "smart" network control solutions across the 5,834 sites we will roll out the LV Network Visibility and Control System in RIIO-ED1; these costs will be covered by our RIIO-ED1 and RIIO-ED2 LRE allowance, as well as connection contributions when appropriate, and will start accruing towards the end of RIIO-ED1 and through the first years of RIIO-ED2.

We present in Table 13 the deployment volumes for the "smart" network control solutions, based on the assumptions we have used in our CBA analysis. This deployment profile is based on the expected level of network constraints and the forecasted level of LCT uptake as of today; the deployment profile will be evaluated through RIIO-ED1 and RIIO-ED2 to ensure efficient use of the "smart" solutions on our LV networks.

Table 13: Number of "smart" network control solutions deployed as part of our CBA

"Smart" solution	Number of sites deployed by the end of RIIO-ED2
Automated LV Interconnection	346
Soft Open Point Interconnection	115
Timed LV connections	4,584
LV Active Network Management	1,146
RTTR for Distribution Transformers	247

In addition to the benefits delivered by the "smart" network control solutions, we expect that we will be able to defer network reinforcement by utilising the network data that will become available during the roll-out. In the presence of granular time-series data on substation demand, we expect that we will be able to release latent network capacity by balancing load across phases, and by conducting network planning studies based on operation data.

We summarise in Table 14 below the level of benefits achieved in our CBA by category.

Table 14: Benefits and costs in our CBA, by category (in lifetime NPV values)

Benefits	EPN [£m]	LPN [£m]	SPN [£m]	UKPN [£m]
Reinforcement deferral ("smart" control solutions)	18.88	35.64	21.58	**76.10**
Avoided reinforcement (data utilisation)	2.32	7.58	4.46	**14.36**
Total benefits (lifetime NPV)	**21.20**	**43.22**	**26.04**	**90.46**

Costs	EPN [£m]	LPN [£m]	SPN [£m]	UKPN [£m]
LV Network Visibility and Control System	9.61	9.14	9.18	**27.93**
"Smart" network control solutions	2.64	3.01	2.94	**8.59**
Total costs (lifetime NPV)	**12.25**	**12.15**	**12.12**	**36.52**

As outlined in sub-section 2.1.3 of our application, we expect that the majority of the benefits from the roll-out of LV Network Visibility and Control will occur after RIIO-ED1, with only a small proportion of benefits beginning to accrue while we are still in the process of completing the roll-out in RIIO-ED1.

Table 15: Level of benefits achieved in our CBA, by price control period (in lifetime NPV values)

Licence area	Benefits in RIIO-ED1 [£m]	Benefits after RIIO-ED1 [£m]	Total [£m]
EPN	0.81	20.39	**21.20**
LPN	2.37	40.85	**43.22**
SPN	2.37	23.67	**26.04**

A detailed description of our approach for the CBA in included in Appendix 6.4 of our application.

b.2. Impact on wider energy operations

The roll-out of LV Network Visibility and Control will enable the provision of whole-system benefits, such as network flexibility and improved network charging.

In our response to the Ofgem/BEIS *Call for Evidence on a Smart, Flexible Energy System* we outlined our vision for becoming a DSO. At the heart of our vision is increased visibility on either side of the network we are managing, as highlighted in our response to question 43:

> *"The key priority for us will be to have visibility of the actions which others will be taking on our network and ensuring other parties have visibility of the actions we take"*

The development of an LV Network Visibility and Control System is a critical enabler to achieving active management of our networks, thus enabling "smart" capabilities. With the system in place, we expect that we will be able to deliver a number of the solutions that are specified in our DSO vision:

- Forecasting load and generation growth across the distribution network;
- Providing transparent information to stakeholders, including heat maps of spare capacity and DUoS charges; and
- Developing advanced real-time system-wide control that can deliver whole system benefits.

In addition to the above, an LV Network Visibility and Control System can support the role of the DSO as a flexibility provider across the whole system. As the number of LCTs increases, a DSO can use its knowledge of the network to manage flexible resources and deliver benefits such as:

- Optimised DER revenue from services;
- Efficient procurement of services for other parties across the value chain; and
- Maintenance of high quality system security.

The National Infrastructure Commission reported in March 2016 that a smart system can provide gross benefits of up to £8 billion per annum by 2030[4], and this includes the optimisation of Distributed Energy Resources (DER). We believe that in the absence of an LV Network Visibility and Control System, our ability to provide network flexibility with benefits across the whole system will be compromised.

Further to enabling DSO functionality, an LV Network Visibility and Control System will be an important enabler to any future "smart" network charging arrangements. Ofgem and BEIS highlighted in their *Call for Evidence for a Smart, Flexible Energy System* the importance of aligning price signals with efficient network operation. By monitoring the LV network in real-time, DSOs will be able to associate increases in peak demand to specific customers. Depending on future charging arrangements, a DSO may be able to utilise targeted commercial offerings in order to manage demand from such customers and subsequently defer reinforcement, the costs of which would have been socialised across DUoS customers.

Lastly, we highlight the importance of LV network visibility to the development of community energy projects. WPD is currently trialling an open platform for data exchange between communities using LV network data in order to develop innovative energy solutions. Similarly, we believe that with the development of the LV Network Visibility and Control System on our network, we will be in a position to provide additional information and data to our customers that will enable the development of community-owned micro-generation, energy saving initiatives, and "smart" technologies.

b.3. Assessment of the success of the roll-out

We are proposing that the effectiveness of the roll-out is assessed based on the number of customers that are associated with sites with "live" visibility at the end of RIIO-ED1.

UK Power Networks has a successful track record of managing a complex portfolio of capital-intensive, multi-year projects against a pre-determined set of KPIs and outputs in DPCR5 and RIIO-ED1. We will employ the same approach in the roll-out of the LV Network Visibility and Control System.

Specifically, we will track the deployment volumes against our roll-out strategy at a secondary substation-level every month. In addition, we will track our roll-out expenditure across all three of our work streams every month. Our official reporting

[4] Smart power: A National Infrastructure Commission Report, March 2016

will be done via Table E8 of the RIIO-ED1 RIGs tables on an annual basis. We will also track the benefits that will be achieved by devices that are enabled by the LV Network Monitoring and Control System (such as the "smart" network control solutions outlined in sub-section 2.2.3) in Table E6 of the RIIO-ED1 RIGs tables.

Further to the above, we will track on a quarterly basis the LCT count in the sites where LV network visibility is established, as well as the count of feeders and customers in each of the sites. Such metrics will allow us to assess the coverage of LV network visibility in our network, and against the actual LCT growth. We will use these metrics to inform our annual targeting strategy review for the roll-out.

A completed list of KPIs that we will track throughout the roll-out is provided in Table 16.

Table 16: Delivery KPIs for the roll-out

#	Type	KPI name	KPI description	Owner
1	Programme internal	Diagram completeness	Monthly tracking of progress against development, testing, go-live milestones	Work stream 1
2	Programme internal	RTU roll-out volumes	Monthly tracking of commissioned RTUs at a secondary-substation level	Work stream 2
3	Programme internal	Roll-out costs	Monthly tracking of costs across the programme's work streams	Programme Management Office (PMO)
4	Programme internal	LCT coverage	Quarterly tracking of LCTs connected on sites with LV network monitoring	Programme Management Office (PMO)
5	Programme internal	Feeder coverage	Quarterly tracking of LV network feeders with LV network monitoring	Programme Management Office (PMO)
6	Programme internal	Customer coverage	Quarterly tracking of customer count in sites with LV network monitoring	Programme Management Office (PMO)
7	Regulatory reporting	RIGs Table E8	Annual reporting of IRM costs against allowance	Programme Manager

UK Power Networks recognised the value of sharing with the entire DNO community the knowledge and experience that is gained in the implementation of flagship projects. Therefore, we are committed to reporting annually our progress in the roll-out of the LV Network Visibility and Control System in our Innovation Summary, as well as our Environmental Report, which are open to the public.

Our roll-out strategy for RIIO-ED1, as explained in detail in Appendix 6.4, is to target the sites that are expected to require investment by the mid-point of RIIO-ED2, and which will experience high LCT uptake in the same period. These sites are associated with a number of LV network customers, and we are proposing that the output measure the effectiveness of the roll-out is assessed against is the achievement of "live" network visibility across a baseline number of customers in each of our three licence areas.

We believe that this metric (number of customers associated with sites with "live" visibility) is appropriate to assess the effectiveness of the roll-out, as it is encompassing both of the components of the system we are requesting funding under the IRM for (RTUs and Live LV Diagram).

To this end, we will track throughout the duration of the roll-out the number customers that have "live" visibility (i.e., are associated with sites that are connected in real-time to the Live LV Network Diagram) against the baselined number of customers associated with the sites we will be targeting (see Table 17 below).

We note that we do not expect sites to have "live" visibility prior to the last year of the roll-out, given that the Live LV Network Diagram will only become operational at that stage of the roll-out. Prior to this point, we will still be able to measure and report progress using the set of KPIs reported in Table 16 above.

Table 17: Roll-out outputs matrix

	2018/19	2019/20	2020/21	2021/22	2022/23
EPN					
Sites with LV monitoring (cumulative)	183	595	1,007	1,419	1,831
LV feeders with monitoring (cumulative)	378	1,228	2,078	2,928	3,778
Customers associated with sites with LV monitoring (cumulative)	20,313	66,045	111,777	157,509	203,241
Sites with "live" visibility	-	-	-	-	1,831
LV feeders with "live" visibility	-	-	-	-	3,778
Customers associated with "live" visibility	**-**	**-**	**-**	**-**	**203,241**
LPN					
Sites with LV monitoring (cumulative)	202	656	1,110	1,565	2,020
LV feeders with monitoring (cumulative)	569	1,848	3,126	4,407	5,689
Customers associated with sites with LV monitoring (cumulative)	41,612	135,136	228,660	322,390	416,120
Sites with "live" visibility	-	-	-	-	2,020
LV feeders with "live" visibility	-	-	-	-	5,689
Customers associated with "live" visibility	**-**	**-**	**-**	**-**	**416,120**
SPN					
Sites with LV monitoring (cumulative)	198	644	1,090	1,536	1,983
LV feeders with monitoring (cumulative)	418	1,357	2,296	3,236	4,177
Customers associated with sites with LV monitoring (cumulative)	27,918	90,804	153,690	216,576	279,603
Sites with "live" visibility	-	-	-	-	1,983
LV feeders with "live" visibility	-	-	-	-	4,177
Customers associated with "live" visibility	**-**	**-**	**-**	**-**	**279,603**

c) Will not enable the licensee to receive additional commercial benefits which are greater or equal to the cost of implementing the Proven Innovation

Based on our CBA, the roll-out of the proposed solution will enable us to realise net benefits of approximately £54 million for our customers across our three licence areas, on a lifetime basis. We do not expect to realise net benefit in RIIO-ED1.

Based on our CBA, the majority of the benefits will start to accrue towards the end of RIIO-ED1, when the LV Live Network Diagram will be developed, and the capability to control “smart” network control devices is established. Some benefits are realised prior to the completion of the diagram, as we have included in our CBA the potential “offline” use of network data by our planning engineers to defer the need for network reinforcement, primarily by using load balancing across our LV feeders, and by using operational planning assumptions deriving from time-series data instead of MDI.

As it can be seen in Figure 9, the Net Present Value (NPV) of the LV Network Visibility and Control System will become positive in RIIO-ED2. In RIIO-ED1, the roll-out will not generate sufficient benefit to cover the costs of the deployment of monitoring. Benefits will continue to accrue as we continue deploying “smart” network control solutions over the course of RIIO-ED2 across the 5,834 secondary substations the solution will be rolled-out across in RIIO-ED1.

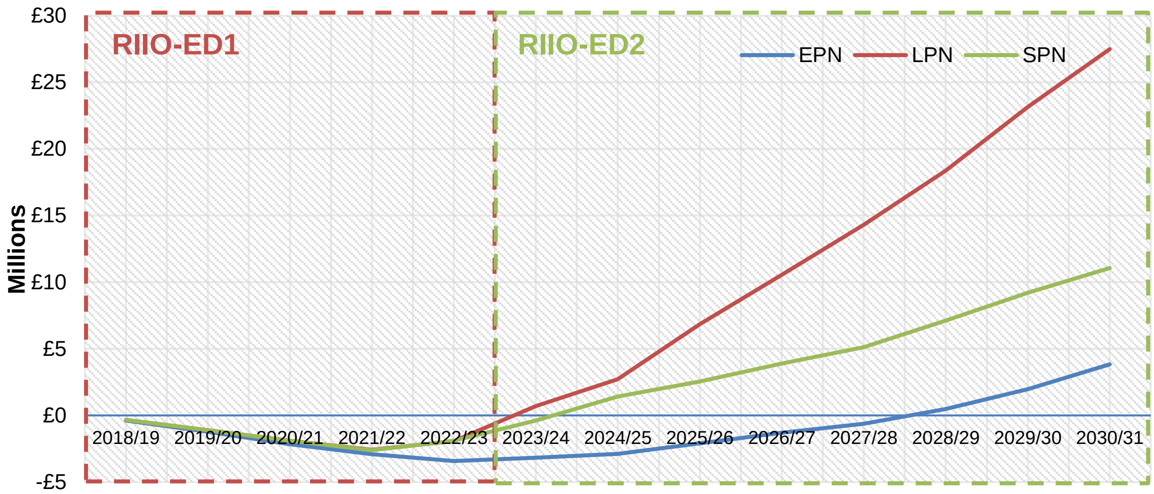


Figure 9: NPV of the net benefits of the LV Network Visibility and Control System based on the proposed RIIO-ED1 roll-out across 5,834 sites

It should be noted that there is potential for additional benefit in RIIO-ED2 by the continued deployment of monitoring across a larger part of our network. We expect that the deployment of LV network monitoring will over time become even more cost-effective on a site-by-site basis, given that critical infrastructure such as the Live LV Network Diagram and the enabling infrastructure for the “smart” network control solutions will already be in place after the end of RIIO-ED1. We also expect that the monitoring equipment costs will decrease due to technological maturity and competition between suppliers.

We illustrate in Figure 10 the NPV of the LV Network Visibility and Control System, when considering a continued roll-out in RIIO-ED2 at a similar pace as our RIIO-ED1 roll-out (9,600 sites in total; 400 sites per licence area, per annum). The lifetime net benefit of this additional roll-out of LV Network Visibility and Control would exceed £113 million.

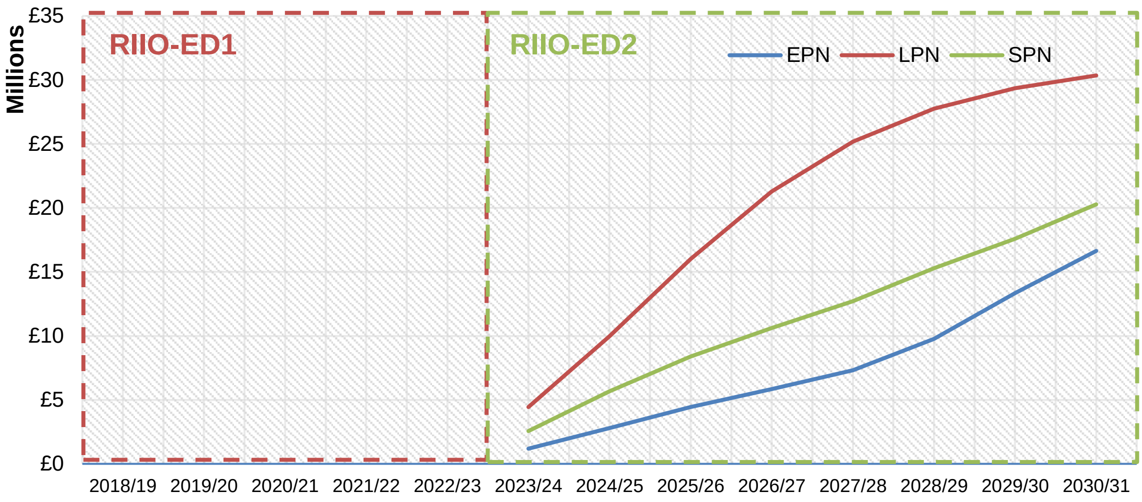


Figure 10: NPV of the net benefits of the LV Network Visibility and Control System based on additional RIIO-ED2 roll-out across 9,600 sites

We have determined the number of sites for the RIIO-ED2 roll-out using the same methodology we have used to determine the roll-out strategy for RIIO-ED1, however we have extrapolated our network constraint analysis to the end of RIIO-ED2. We have also assumed a per-site deployment cost that is lower than the costs in RIIO-ED1, given the expected level of commercial maturity of the solution, as well as the fact the Live LV Network Diagram will already be in place in RIIO-ED2.

UK Power Networks will continue to develop and refine such a RIIO-ED2 programme, and we expect to include a provision for the continued roll-out of LV Network Visibility and Control in our RIIO-ED2 business plan submission.

The roll-out of the LV Network Visibility and Control System will not materially impact UK Power Networks' performance against its RIIO-ED1 output commitments, or the RIIO-ED1 incentives package. We do not expect to receive commercial benefit in RIIO-ED1 as a direct result of the roll-out.

We outline in Table 18 the expected impact against RIIO-ED1 outputs and secondary deliverables.

Table 18: Expected impact on RIIO-ED1 outputs and secondary deliverables

Output / secondary deliverable	Expected impact
Totex Incentive Mechanism (TIM)	» Our funding request under the IRM is for an enabling system that will allow us to deploy in a targeted way "smart" network control solutions; these will be funded using our LRE allowance or the appropriate connections charging methodology allocations. » Establishing LV network visibility may reveal network constraints that were not considered previously, and thus lead to an increase in LRE. Given the uncertainty in this area, we did not consider such impacts to our baseline TIM performance in the context of our IRM application.

Broad Measure of Customer Satisfaction (BMoCS)	» The proposed solution does not seek to change our call centre processes. Any reductions in fuse operations will not impact the BMoCS, as customers are only surveyed after they experience an interruption. » We expect that our ability to provide improved live updates to our customers for network interruptions will be enabled primarily by the presence of smart meters, and not this solution. » Whilst the proposed system will enable more accurate and efficient connection designs, site visits will still be required when reviewing connection applications (for example, in order to assess physical design requirements). Therefore, we do not expect significant change in our connection time to quote.
Interruptions Incentive Scheme (IIS)	» The roll-out of LV Network Visibility and Control will enable us to maintain network reliability at the same levels as those achieved today in a future where LCT connections will increase significantly; we expect this to start materialising in the early years of RIIO-ED2. » We have assessed that the impact of the proposed roll-out on our RIIO-RD1 reliability performance will be immaterial.
Health Indices (HI)	» The deployment of LV monitoring may improve the completeness of input data to the Common Network Asset Indices Methodology in relation to temperature readings; however, this is only one of several input data points for distribution transformer assets, and this will only apply to a limited number of sites across our LV networks where temperature sensors are deployed. » Therefore, we do not expect any impact on our ability to achieve our risk point target for the period.
Load Indices (LI)	» Load Indices are only recorded at primary substation level, and not at any level of network managed by the proposed solution. » By enabling more LCT capacity on our LV networks, we do not expect to see improvement in the Load Indices of primary substations.

d) Will not be used to fund any of the ordinary business arrangements of the licensee

Our budget includes costs that are directly associated with the deployment of the LV Network Visibility and Control System, and we will track expenditure on this basis throughout the duration of the roll-out.

The costs that we have included in our budget for the roll-out are directly associated with the deployment of the LV Network Visibility and Control System ("the proven innovation"). Specifically, we have included in our budget three types of expenditure:

1) Direct costs associated with the development of the Live LV Network Diagram, and the roll-out of the RTUs in secondary substations. In this category, we include materials, labour, and contractor costs.

2) Indirect costs associated with the management of the roll-out programme. In this category, we have only included labour that relates to direct oversight of the programme and the three work streams.

3) Indirect costs associated with training staff that is required as a result of the deployment of the new system. In this category, we have only included labour costs for the training.

The costs of integrating the specified "smart" network control solutions (see section 2.2.3) with the LV Network Visibility and Control System are not part of our request for a Relevant Adjustment under the IRM.

Our business plan for RIIO-ED1 did not include provisions for the roll-out of monitoring in our LV networks, or for the development of a Live LV Network Diagram, and we therefore would not be able to fund the deployment of the system using our RIIO-ED1 allowance.

We will track costs monthly, as outlined in criterion b) above, to ensure efficient expenditure and adherence to the programme budget, and will report annually our costs using Table E8 of the RIIO-ED1 RIGs.

We are confident that we will be able to track and attribute costs to the roll-out programme accurately, as our delivery teams have the capability to their record their work using handheld devices at a granular level of detail and resolution. Any additional costs that may be incurred during the course of the roll-out and are not directly attributable to the LV Network Visibility and Control System (e.g., opportunistic substation works during site visits) will be covered by the business using our RIIO-ED1 totex allowance.

e) Involves Proven Innovation and warrants limited funding support

Live LV network monitoring does not currently exist across GB DNOs; however, UK Power Networks has successfully trialled its use in two innovation projects that concluded in the last two years.

Despite the fact LV network monitoring does not currently exist across GB DNOs, there have been a number of trials demonstrating the technical maturity of the proposed solution. UK Power Networks in particular has demonstrated successfully the use of an LV Network Visibility and Control System in its final form in the first years of RIIO-ED1 in two innovation projects: SULVN and FUN-LV. We can therefore confirm that the proposed solution is mature, proven, and is classified as Technology Readiness Level (TRL) 9.

In SULVN, we developed a three-phase LV connectivity model in our DMS, which is also the DMS used by five out of the six GB DNO groups, for a small part of our network (40 secondary substations). We also deployed LV circuit breakers and link box switches in order to gain remote and automated control on the network, as well as a granular view of how the network is loaded in real-time, thus enabling better informed decisions.

In FUN-LV, we deployed LV network monitoring across 36 trial schemes on our network, and also trialled the use of power electronic devices in order to reconfigure the network and defer the need for costly network reinforcement using interconnection and meshing between substations. In FUN-LV, we were also able to extend the three-phase connectivity model we developed in SULVN across 90 secondary substations in London and Brighton, and successfully proved remote network reconfiguration and control switching modes.

Prior to RIIO-ED1, UK Power Networks commissioned a Tier 1 Low Carbon Networks Fund project on Distribution Network Visibility (DNV). The project successfully demonstrated that the collection and visualisation of network data from RTUs can enable planning engineers to identify the impact of LCTs on load measurements ("load masking") and plan more effectively for future connections, thus validating the benefit of more widespread LV network visibility.

It is worth noting that other GB DNOs such as Western Power Distribution ("LV Connect & Manage"), Scottish Power ("Flexible Networks for a Low Carbon Future"), and Scottish and Southern Electricity Networks ("New Thames Valley Vision") have trialled similar approaches to LV network monitoring in recent years.

Given the fact GB DNOs do not currently have widespread LV network monitoring capabilities, we believe that the solutions cannot be considered as Ordinary Business Arrangement. However, as we have successfully trialled at a small scale on our network the use of the same LV Network Visibility and Control System, the solution should be considered as Proven Innovation.

f) Is ready to be rolled-out with any funding provided being used in the price control period

We have already specified a complete programme governance structure, a project plan, and a risk register; we are prepared to initiate the roll-out once funding is awarded.

As part of preparing our application to the IRM, we have invested in a significant amount of preparatory work to enable the programme to start in a timely manner. The outcomes of this work are:

- We have identified internally the governance structure for the delivery of the roll-out, and the accountable parties;
- We have engaged with Ofgem, local authorities, and customers, and have gathered support for the roll-out;
- We have conducted a business impact assessment and have developed a plan to bridge the gaps identified in the assessment;
- We have developed a robust project plan in collaboration with our internal Distribution Delivery and Information Systems teams;
- We have worked closely with our DMS provider to specify the requirements, the budget, and the plan for the development of the Live LV Network Diagram;
- We have confirmed that our RTU standard enables the functionality required to realise the benefits of the proposed solutions; and
- We have engaged with internal stakeholders across the business (Network Operations, Network Control, Network Planning, Distribution Capital Delivery) and gained support across multiple UK Power Networks business units.

A detailed roll-out plan for the roll-out is included in Appendix 6.1. In our roll-out plan we identify the main tasks under each phase of the project, their expected duration, and the dependencies between the tasks.

The roll-out plan has been drawn up using the experience from our Distribution Delivery team project managers, and lessons learned from earlier large capital projects such as the BT21CN migration were used to inform the roll-out plan. The plan has been validated by our Senior Management team, and we have used their inputs on the project scope and delivery phases. The roll-out plan provides a clear line-of-sight between aim, objectives, methods, deliverables and outputs.

We have also included in Appendix 6.6 the roll-out programme's organisation chart, which highlights key roles in the programme such as:

- Programme Manager**:** Responsible for coordinating the delivery of the work across the three work streams, and the adherence to the overall project plan and budget.

- Technical Design Authority**:** Responsible for specifying a solution that is in alignment with the requirements of the business and the users, and is in compliance with internal standards and specifications.

- Project Management Office**:** Provides support to the Programme Manager as required in the programme's day-to-day activities.

The roll-out will be delivered primarily by internal resources, with targeted support from external suppliers where needed.

Specifically, the development of the Live LV Network Diagram will be managed by our Information Systems team, with support from our Live Systems and Control Centre staff. The diagram will be sourced by our DMS and GIS supplier.

The roll-out of the RTUs on our network will be delivered by our Distribution Capital Delivery teams. Our teams will operate separately across our three networks and will be managed by three separate delivery managers, who will be reporting directly to the overall Programme Manager. We believe that utilising teams with local knowledge of the challenges of each licence area will be a success factor in the effective and efficient roll-out of the RTUs. Staff that will be responsible for the deployment of the RTUs will be dedicated to this task, and will work full-time for the duration of the roll-out, given the volumes of RTUs that will be deployed.

Lastly, the activities under Work stream 3 will be managed internally by the work stream lead and one additional supporting resource, with contribution from the system's users (Distribution Planning, Network Control Centre, Connections functions).

Throughout the roll-out of the LV Network Visibility and Control System, we will implement five control measures to ensure that the programme is delivered to its overall aims, as defined in this application.

Specifically, we will implement:

1. Review Process: All formal outputs from the roll-out will be put under formal review process (configuration management). Each output will go through the formal specialist or management product review. An output is not deemed completed until it has passed this review process. It is the responsibility of the work stream managers and the programme manager to ensure all outputs are placed under review.

2. Approval Process: This process will be implemented to ensure all deliverables are appropriately approved before they are agreed as complete and released. The governance boards will check to ensure each deliverable is completed to the quality, cost and time levels as agreed in the initiation documents and detailed plans and designs for each work stream.

3. Sign off Process: This is the process to formally sign off all formal documents.

4. Risk and Issue Management: This process allows for the communication and escalation of key risks and issues within the programme and defines where decisions will be made and how these will be communicated back to the work stream where the risk or issue has arisen.

5. Change Management: The purpose of this process is to control and agree any changes to the agreed baseline of the project, whether the change relates to time, cost or quality. A key interaction in this process is between the design authority board and the project board to check and approve proposed quality changes. Approvals for changes will have to be within the board's delegated authority; otherwise the change will need to be escalated further up the governance structure.

In addition to these control measures, we will adopt internal programme monitoring and reporting procedures as follows:

- Monthly reporting to the Programme Steering Group and to the UK Power Networks' Executive Management Team by the Programme Sponsor to provide regular review points and allow full financial and project control;

- The roll-out management team comprising the Programme Manager, Work stream Managers and Programme Management Officer, will meet fortnightly to monitor the project progress against its plans, project risks and project issues; and

- Work streams will be managed in accordance with milestone plans supported by detailed plans and a clearly defined list of deliverables for each work stream.

Finally, we will embed risk management within programme roles and responsibilities in the following ways:

- The Programme Steering Group will assess change requests, review the impact on the business case, and identify and review risks and issues associated with major change requests;

- The Programme Manager and the Senior Responsible Officer will be responsible for the operational management of the roll-out, focused on reviewing progress against plan, and resolving risks and issues. They will also approve change requests within a defined tolerance and prepare change requests for submission to the Steering Group for changes;

- Regular risk reviews undertaken by the Programme Manager with results reported to the Programme Sponsor and Steering Group;

- A Design Authority who will review and approve all key project deliverables to ensure they are fit for purpose. Change requests may be initiated by the Design Authority directly or by the work streams. Change requests initiated by the work streams will be reviewed by the Design Authority prior to submission; and

- Quarterly supplier reviews will track and discuss progress and risks to project delivery.

We have produced a risk register and risk management process for the roll-out that demonstrates how these roles interact. The risk register details the identified risks and mitigation strategies in Appendix 6.5. The organisation chart for the roll-out programme is provided in Appendix 6.6

We believe that the largest risk for this programme is the adaptation of our business operations in order to take advantage of the capabilities of the new system. With this in mind, we have already worked with the primary user groups of the new system in order to ensure that the system we are specifying is in alignment with their expectations, and that the impact of the system to their business processes is understood (see section 6.7 for details on the business impact assessment).

Furthermore, we have included a separate work stream in the programme (Work stream 3) that will work alongside our users to ensure the readiness of our business to incorporate the new information that the system will make available to planners and control room engineers.

5 Regulatory Issues

5.1 Confirmation of no derogations

UK Power Networks can confirm that the proposed roll-out will not require a derogation or changes to regulatory arrangements.

5.2 Consultations with stakeholders and our customers

In addition to our internal coordination when developing our application to the IRM, we have actively consulted and sought input in shaping the proposed roll-out from a range of our customers and external stakeholders. This has included representatives of local authorities, local enterprises, and members of the academia.

The feedback we have received from stakeholders and customers has been clear and consistent in support of both the need to invest in visibility, and to be ready to roll-out "smart" solutions at-scale within the LV networks.

As part of our consultation with stakeholders, we coordinated with Imperial College London in developing our approach to our cost-benefit analysis modelling, and we also sought their views on how the proposed roll-out fits within the wider context of smart grids, and the transition to DSO.

Furthermore, we sought out the view of local government and enterprise organisations across all three of our licence areas, sharing details of our proposed rollout and from which we gained useful input into our targeting strategy. A number of these stakeholders have provided letters of support which can be found in Appendix 6.10, including:

– the Greater London Authority, representing our customers across EPN (755,595) and SPN (428,526), as well as 2,346,076 within LPN;
– the Cambridge Council;
– the Greater Cambridge Greater Peterborough Enterprise Partnership; and
– Imperial College London.

We also note the extensive consultation conducted in developing UK Power Networks' response to the Ofgem/BEIS *Call for Evidence on a Smart, Flexible Energy System*, of which LV visibility and control is a critical part. In this way, the proposed roll-out has also considered external feedback from: renewable generators, storage developers, aggregators, suppliers and new IT platform providers.

6 Appendices

In this Section, we provide additional, in-depth information that supplement our application.

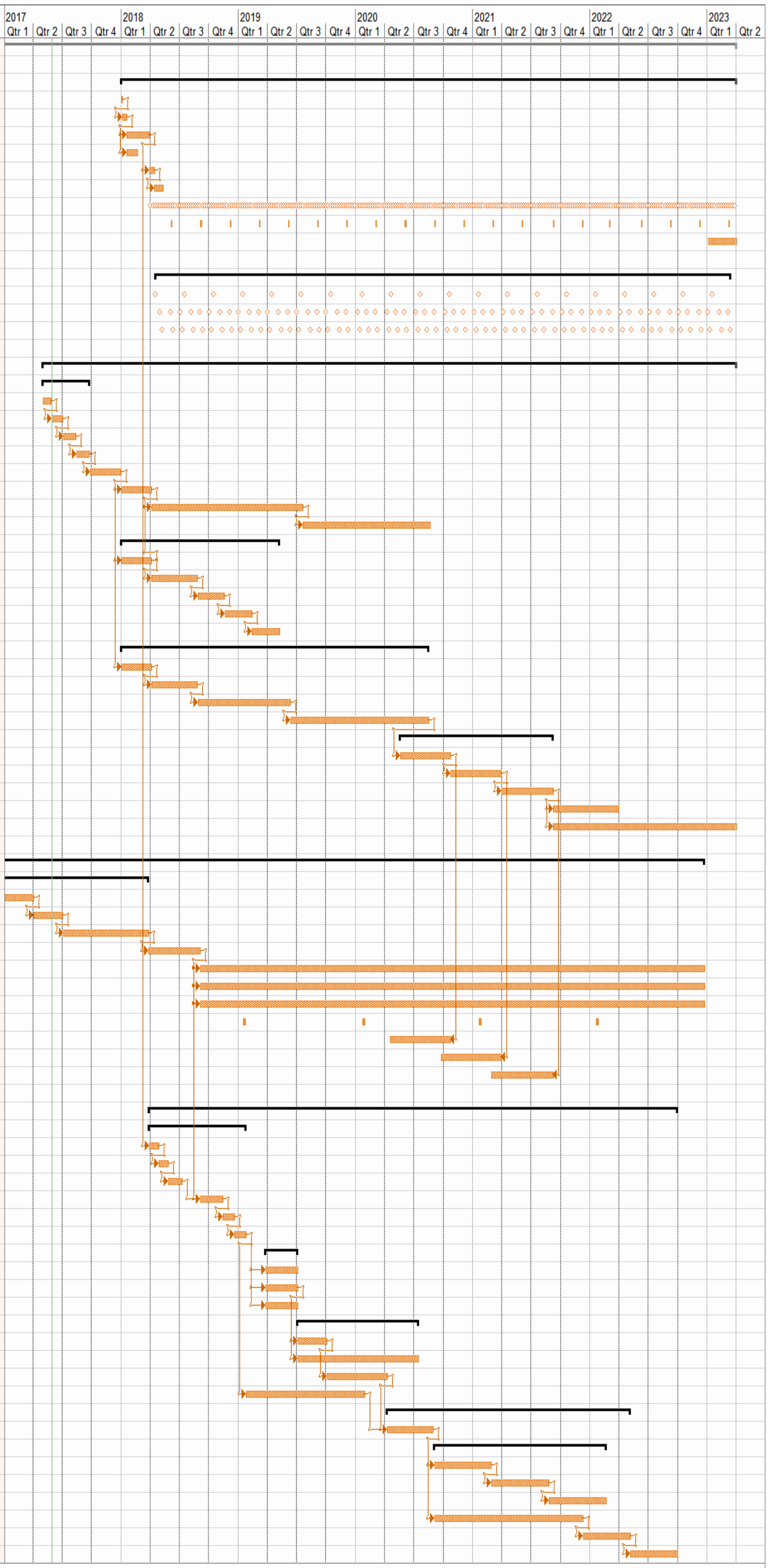
List of Appendices

6.1 Detailed Roll-out plan

We present below the plan for the roll-out on a quarterly basis. Our plan is based on our prior experience delivering the solutions that are within the scope of the roll-out. Upon confirmation of the funding award, each of the programme's work streams will prepare detailed plans that will be reviewed with the Programme Manager on a quarterly basis.

As shown in the Gantt chart below, we have already started work for Work streams 1 and 2 as an investment towards the success of the roll-out. We are confident that the team will be mobilised and ready to continue the work from day 1 in April 2018.

ID	Task Name	Duration	Start
0	**LV Network Monitoring System Roll-Out**	**318.8 wks**	**Mon 02/01/17**
1			
2	**1 Programme Management**	**266.8 wks**	**Tue 02/01/18**
3	1.1 Programme kick-off	0.1 wks	Tue 02/01/18
4	1.2 Programme governance and controls in place	2 wks	Tue 02/01/18
5	1.3 Programme team mobilisation and resourcing	10 wks	Tue 16/01/18
6	1.4 Create communication plan	5 wks	Tue 16/01/18
7	1.5 Review roll-out strategy	2 wks	Tue 27/03/18
8	1.6 Refine long-term plan and detailed short-term plan	4 wks	Thu 12/04/18
9	**1.7 Programme management meetings (weekly)**	**253.4 wks**	**Tue 03/04/18**
271	**1.8 Cost, KPI and outputs tracking (quarterly)**	**242.3 wks**	**Tue 05/06/18**
292	1.9 Programme review and transition for RIIO-ED2 delivery	13 wks	Mon 02/01/23
293			
294	**2 Programme Governance**	**249.4 wks**	**Tue 17/04/18**
295	**2.1 Steering Group meetings (quarterly)**	**241.4 wks**	**Tue 17/04/18**
316	**2.2 SRO review meetings (monthly)**	**246.4 wks**	**Tue 01/05/18**
376	**2.3 Programme Sponsor review meetings (monthly)**	**246.6 wks**	**Tue 08/05/18**
436			
437	**3 WS1: Develop Live LV Network Diagram**	**301.7 wks**	**Mon 01/05/17**
438	**3.1 Proof of concept**	**21 wks**	**Mon 01/05/17**
439	3.1.1 Define requirements	4 wks	Mon 01/05/17
440	3.1.2 Specify proof of concept design	5 wks	Mon 29/05/17
441	3.1.3 Implemented specified solution	6 wks	Mon 03/07/17
442	3.1.4 Test and refine	6 wks	Mon 14/08/17
443	3.2 Procurement and contract negotiations	14 wks	Mon 25/09/17
444	3.3 Commissioning and RTU integration pre-work	13 wks	Tue 02/01/18
445	3.4 PowerOn software upgrades	65.4 wks	Thu 05/04/18
446	3.5 Netmap software upgrades	55 wks	Fri 19/07/19
447	**3.6 Network modelling**	**68.4 wks**	**Tue 02/01/18**
448	3.6.1 Define network modelling requirements	13 wks	Tue 02/01/18
449	3.6.2 Collect network information from existing sources	20 wks	Thu 05/04/18
450	3.6.3 SPN network modelling	11.8 wks	Tue 28/08/18
451	3.6.4 EPN network modelling	11.8 wks	Mon 19/11/18
452	3.6.5 LPN network modelling	11.8 wks	Tue 12/02/19
453	**3.7 Data prep**	**133 wks**	**Tue 02/01/18**
454	3.7.1 Specify data and define sources	13 wks	Tue 02/01/18
455	3.7.2 Collect data	20 wks	Thu 05/04/18
456	3.7.3 Map data to network diagram	40 wks	Tue 28/08/18
457	3.7.4 Cleanse data	60 wks	Wed 12/06/19
458	**3.8 Data import**	**66 wks**	**Tue 19/05/20**
459	3.8.1 SPN data import	22 wks	Tue 19/05/20
460	3.8.2 EPN data import	22 wks	Thu 22/10/20
461	3.8.3 LPN data import	22 wks	Mon 29/03/21
462	3.9 Test and commission Network Control Centre system	29 wks	Mon 06/09/21
463	3.10 Post-go live data cleanse and quality control	80.2 wks	Mon 06/09/21
464			
465	**4 WS2: Roll Out LV Network Monitoring Devices**	**305 wks**	**Mon 02/01/17**
466	**4.1 Specify and procure RTUs and telecoms solutions**	**64 wks**	**Mon 02/01/17**
467	4.1.1 Supplier engagement to optimise design	13 wks	Mon 02/01/17
468	4.1.2 Review options and hardware demos	13 wks	Mon 03/04/17
469	4.1.3 Assess baseline and improved options, prepare and let equipment order	38 wks	Mon 03/07/17
470	4.2 Mobilise and train delivery teams	22 wks	Tue 27/03/18
471	4.3 SPN RTU roll-out (2,482 sites; approximately 2-3 RTUs per day)	219 wks	Tue 04/09/18
472	4.4 EPN RTU roll-out (2,482 sites; approximately 2-3 RTUs per day)	219 wks	Tue 04/09/18
473	4.5 LPN RTU roll-out (2,482 sites; approximately 2-3 RTUs per day)	219 wks	Tue 04/09/18
474	**4.6 Review of site selection for RTU roll-out**	**153.8 wks**	**Tue 15/01/19**
479	4.7 SPN Test and commission RTU link to PowerOn	26.4 wks	Thu 16/04/20
480	4.8 EPN Test and commission RTU link to PowerOn	26.4 wks	Tue 22/09/20
481	4.9 LPN Test and commission RTU link to PowerOn	26.4 wks	Thu 25/02/21
482			
483	**5 WS3: Business Process Alignment and Benefits Realisation**	**228.9 wks**	**Tue 27/03/18**
484	**5.1 Set up offline business processes**	**41.9 wks**	**Tue 27/03/18**
485	5.1.1 Define ouputs and process requirements	4 wks	Tue 27/03/18
486	5.1.2 Design process	4 wks	Thu 26/04/18
487	5.1.3 Review with users	6 wks	Fri 25/05/18
488	5.1.4 Collect data from first year RTU roll-out	10 wks	Tue 04/09/18
489	5.1.5 Populate templates and review with users	5 wks	Tue 13/11/18
490	5.1.6 Test and refine with users	5 wks	Tue 18/12/18
491	**5.2 Specify business requirements**	**13.2 wks**	**Wed 27/03/19**
492	5.2.1 Specify internal policy and process change requirements	13.2 wks	Wed 27/03/19
493	5.2.2 Specify hiring requirements and develop hiring programme	13.2 wks	Wed 27/03/19
494	5.2.3 Specify training requirements and develop training programme	13.2 wks	Wed 27/03/19
495	**5.3 People requirements**	**52.4 wks**	**Wed 03/07/19**
496	5.3.1 Develop training supporting content	13 wks	Wed 03/07/19
497	5.3.2 Hire and train new staff	52.4 wks	Wed 03/07/19
498	5.3.3 Deliver training to existing staff	26 wks	Thu 03/10/19
499	5.4 Work with business owners to embed "smart" solutions	51 wks	Thu 24/01/19
500	**5.5 Internal policy and process change requirements**	**105 wks**	**Tue 07/04/20**
501	5.5.1 Revise operational manuals, internal policies, and relevant documentation	20 wks	Tue 07/04/20
502	**5.5.2 Run offline trials of new operational approach**	**75 wks**	**Tue 01/09/20**
503	5.5.2.1 Capacity Management	25 wks	Tue 01/09/20
504	5.5.2.2 Connections Management	25 wks	Thu 25/02/21
505	5.5.2.3 Network Operations	25 wks	Wed 25/08/21
506	5.5.2.4 Measure outputs and performance	65 wks	Tue 01/09/20
507	5.5.3 Apply process improvements based on measured outputs and performance	20 wks	Thu 09/12/21
508	5.6 Business-as-usual system go-live	21 wks	Wed 04/05/22



6.2 Detailed roll-out budget

6.2.1 Detailed budget breakdown

- In Work stream 1, we have included the costs of our staff that will be responsible for the development, commissioning and testing of the Live LV Network Diagram. We have also included the costs of contractors that will support the development of the diagram.

  We have already specified and are currently in the process of delivering at our own cost an initial phase for the development of the LV diagram, which will allow us to better specify the scope of work for the development of the full diagram. Following the completion of this initial phase, we will procure support from our contractors based on the outcomes of the initial phase we are currently delivering.

  We have selected the contractors that will support our work in this work stream based on our existing system configuration and based on our existing DMS, as we believe that we can achieve efficiencies in the development of the diagram and the commissioning of the system by maintaining the solution in the same IT environment we are currently using.

  In order to ensure value for money in the delivery of the diagram, we have introduced procurement levers in the initial phase of development we are currently in the process of delivering, which are linked to the provision of a competitive price for the delivery of the full diagram. The pricing for the development of the full diagram will be reviewed and negotiated as part of a full due diligence by both our Procurement and IS Commercial teams.

- In Work stream 2, we have included the costs of our staff that will be managing the delivery of the RTU roll-out, as well as the costs associated with procurement, installation and commissioning of the RTUs on our network. The RTUs will be procured from our list of approved suppliers, which has been specified in advance based on products that are in compliance with our RTU standard.

  Our budget for the RTU procurement has embedded volume discounts that we are confident we can secure, *[redacted]*. We have significant experience in procuring and installing RTUs in our HV network, which we will leverage to ensure that the installation of RTUs on the LV network is on time and at an efficient cost.

  The budget for Work steam 2 also includes provisions for data storage (Historian tags), as well as the telecommunication costs for the data transmission between RTUs and the SCADA front end in our control room.

- In Work stream 3, we have included the labour costs of the work stream lead that will work with the business owners in order to ensure operational readiness and the realisation of the benefits of the solution. We have also included the labour costs associated with the training of staff in Distribution Planning, Network Control, and Connection functions in the way the new system will used.

- We have also budgeted labour costs relating to the time of the resources that will be managing the programme, such as the Programme Manager, the PMO, and the Steering Group.

We provide below a detailed breakdown on the costs under each of the programme's work streams. The costs in the tables below are expressed in 2012/13 values.

6.2.1.1 Project Management and Governance

EPN	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m	Total £m
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
LPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total £m**
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
SPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total £m**
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

6.2.1.2 WS1: Develop Live LV Network Diagram

EPN	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m	Total £m
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

LPN	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m	Total £m
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
SPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total £m**
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

6.2.1.3 WS2: Roll Out LV Network Monitoring Devices

EPN	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m	Total £m
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
LPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total £m**
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
SPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total £m**
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

6.2.1.4 WS3: Business Process Alignment and Benefits Realisation

EPN	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m	Total £m
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
LPN	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**Total**

	£m	£m	£m	£m	£m	£m
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
SPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total £m**
Labour	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Materials	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Contractors	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

6.2.2 Detailed RIIO-ED1 RIGs tables mapping

We detail in the tables below the incremental costs and volumes from the roll-out against the relevant RIIO-ED1 RIGs tables.

6.2.2.1 CV11 – Op IT and Telecoms

Asset costs and volumes / Costs

EPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Substation RTU, marshalling kiosks, receivers	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Communications for switching & monitoring	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Control centre hardware & software	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
LPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Substation RTU, marshalling kiosks, receivers	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Communications for switching & monitoring	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Control centre hardware & software	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
SPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Substation RTU, marshalling kiosks, receivers	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Communications for switching & monitoring	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
Control centre hardware & software	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

Asset costs and volumes / Additions

EPN	2018/19 #	2019/20 #	2020/21 #	2021/22 #	2022/23 #	Total
Substation RTU, marshalling kiosks, receivers	132	297	297	297	297	**1,318**
LPN	**2018/19 #**	**2019/20 #**	**2020/21 #**	**2021/22 #**	**2022/23 #**	**Total**
Substation RTU, marshalling kiosks, receivers	145	327	327	327	327	**1,454**
SPN	**2018/19 #**	**2019/20 #**	**2020/21 #**	**2021/22 #**	**2022/23 #**	**Total**
Substation RTU, marshalling kiosks, receivers	143	321	321	321	321	**1,428**

6.2.2.2 C9 – Core CAI

Costs

EPN	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m	Total
Project Management	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
LPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Project Management	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
SPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Project Management	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

6.2.2.3 CV35 – Op Training (CAI)

Learner costs / Costs

EPN	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m	Total
Operational Up-skilling (Engineer)	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
LPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Operational Up-skilling (Engineer)	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
SPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Operational Up-skilling (Engineer)	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

Learner costs / Volumes

EPN	2018/19 #	2019/20 #	2020/21 #	2021/22 #	2022/23 #	Total
Operational Up-skilling (Engineer)	0	0	0	99	99	**198**
LPN	**2018/19 #**	**2019/20 #**	**2020/21 #**	**2021/22 #**	**2022/23 #**	**Total**
Operational Up-skilling (Engineer)	0	0	0	70	70	**140**
SPN	**2018/19 #**	**2019/20 #**	**2020/21 #**	**2021/22 #**	**2022/23 #**	**Total**
Operational Up-skilling (Engineer)	0	0	0	59	59	**118**

Cost of Training Provision / Costs

EPN	2018/19 £m	2019/20 £m	2020/21 £m	2021/22 £m	2022/23 £m	Total
Trainer and course material costs	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
LPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Trainer and course material costs	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**
SPN	**2018/19 £m**	**2019/20 £m**	**2020/21 £m**	**2021/22 £m**	**2022/23 £m**	**Total**
Trainer and course material costs	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**xx.xx**

6.3 Our approach to modelling

6.3.1 Background

With the growing likelihood of LCTs arriving onto the distribution network, we realised ahead of our RIIO-ED1 business plan submission the need to model a variety of scenarios in order to account for the highly uncertain nature of these technologies. In order to do so, we invested in the development of a method of quickly identifying and quantifying the impact, at all voltage levels, of different LCT uptake scenarios.

Working with Imperial College London (ICL), we developed a novel solution in the form of a holistic network modelling tool. The Load-Related Expenditure (LRE) model uses an optimal power flow (OPF) engine that recognises the various sets of nodal information, which has been extracted from UK Power Networks' different power flow models, as well as historic system maximum demand data as measured and collected on each HV circuit.

Using load and LCT growth forecasts from our Load Growth Scenario Model (see 6.3.3 below), the LRE model is able to identify overloaded assets on the network, and subsequently to generate a reinforcement cost profile for each specific load growth scenario (Figure 11).

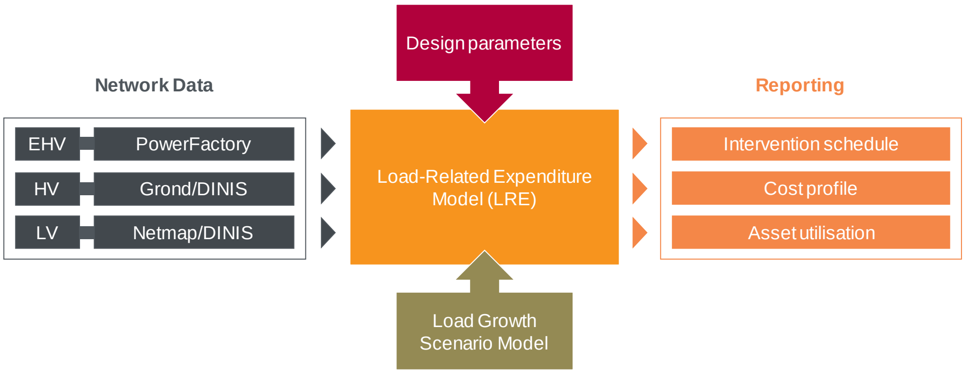


Figure 11: Overview of the LRE model inputs and outputs

6.3.2 LRE Model inputs

The model uses three input categories:

- Physical network data, which are nodal datasets extracted from UK Power Networks' various modelling tools and data systems;
- Design parameters, which are specified point data and network interventions; and
- Load growth forecasts, developed using the Load Growth Scenario Model (see below).

6.3.3 The Load Growth Scenario Model

In order to model variable economic scenarios and the likelihood of future technologies being implemented onto the distribution network, we commissioned the development of a Load Growth Scenario Model in collaboration with Element Energy. This model uses socioeconomic data, historical trends, and government projections in order to forecast the uptake of energy efficiency measures and LCTs. These forecasts are updated regularly and serve as an input to the LRE Model, enabling us to not only forecast multiple scenarios of future load growth, but also the reinforcement expenditure impact of each of these scenarios (see example in Figure 12).

The first version of the model was developed in 2011, with a significant update in 2012 that allowed us to integrate granular consumer data, which in turned allowed us to apply scenarios at the level of individual distribution substation. In 2015, a further update of the model was undertaken to incorporate LCT data from the Low Carbon London trials, and to update the LCT uptake forecasts to reflect the most up-to-date policy and technology data.

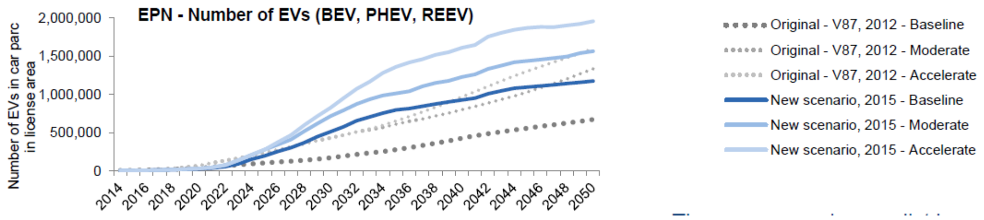


Figure 12: Example output from the Load Growth Scenario Model

6.3.4 LRE model outputs

Once the input data are specified, the model's OPF engine drives the process of identifying the need for interventions, using thermal, voltage or fault level constraints. Thermal and fault level constraints are modelled against equipment ratings that are pre-populated in the model, whereas voltage constraints are modelled against statutory limits defined in ESQCRs (Electricity Safety, Quality, and Continuity Regulations).

Once interventions are identified, a cost profile is generated using UK Power Network's cost data, as shown in Figure 13 below.

Grid	Substation type	Year of Replacment	Voltage	Sum of Rating	Sum of Recommended Replacement	Sum of Replacement Cost
BOURN PRIMARY	GMT	2017	HV	500	800	14587.7096
BOURN PRIMARY	GMT	2024	HV	200	315	10877.8996
Bourn Primary 11kV	Primary	2027	33	19.6	24	759918.8558
HALSTEAD PRIMARY	PMT	2032	HV	15	50	9358.1396
Hendon Way Primary 11kV	Primary	2032	33	48	60	836005.8342
HENSTEAD PRIMARY	GMT	2014	HV	100	200	14347.2696
HENSTEAD PRIMARY	PMT	2024	HV	5	50	9358.1396
HORNCHURCH LOCAL PRIMARY	GMT	2030	HV	315	500	13457.88
LUTON NORTH GRID	GMT	2021	HV	315	500	13457.88
LUTON NORTH GRID	GMT	2032	HV	315	500	13457.88
MELTON PRIMARY	PMT	2028	HV	5	50	9358.1396
MELTON PRIMARY	PMT	2031	HV	5	50	9358.1396
MERRYHILL PRIMARY	GMT	2027	HV	600	1000	28934.9792
MERRYHILL PRIMARY	GMT	2029	HV	350	800	14587.7096
Newtown Primary 11kV	Primary	2025	33	30	36	731797.8342
PLAYFIELD PRIMARY	GMT	2032	HV	315	500	13457.88
ROYSTON PRIMARY	PMT	2028	HV	10	50	9358.1396
SOUTH HARLOW PRIMARY	GMT	2024	HV	200	315	10877.8996
SOUTH HARLOW PRIMARY	GMT	2028	HV	300	500	13457.88

Figure 13: Example output table from LRE Model

6.3.5 Ability to model "smart" solutions

Using a set of pre-determined rules, the LRE model is able to suggest where certain smart interventions may be deployed in order to address the need for an intervention. In order to generate the cost-benefit analysis for the IRM roll-out, we have generated investment plans using the following smart interventions:

- Timed Connections; and
- LV ANM.

6.4 Cost-Benefit Analysis

6.4.1 Defining the roll-out strategy

A critical success factor to the roll-out of the LV Network Visibility and Control System in RIIO-ED1 is targeting sites in our network that will benefit the most from the system's capabilities.

In order to determine which sites in our network we should target with our roll-out, we conducted a detailed study across our approximately 80,000 secondary substations, looking at the existing capacity and expected loading by the end of RIIO-ED1 using our internal business planning forecasts and assumptions.

This study was prepared using the LRE model, which uses power flow analysis to determine thermal and voltage violations on the network based on a forecasted profile of load and LCT growth (see Appendix 6.3 for further details on the LRE model). In addition to the outputs from the LRE model, we used operational data such as MDI readings, substation customer count, and our internal business planning forecasts for LCT growth and load growth across our three licence areas.

The data described above were used to filter sites using a series of composite criteria, which combined the following requirements:

a) Evidence of constraints, either by high utilisation (from MDI) or indication from LRE model;
b) High LCT growth by the mid-point of RIIO-ED2, based on our internal business planning forecasts;
c) High customer count; and
d) Presence of LCTs today.

These criteria allowed us to shortlist approximately 30,000 out of our initial list of 80,000 secondary substations. These sites are the ones where it would be considered technically favourable to deploy the LV Network Visibility and Control System in RIIO-ED1.

As a second step in our targeting approach, we modelled the economic impact of the use of "smart" network control solutions across the shortlisted sites. Specifically, we modelled the expected benefits of the deployment of Automated Interconnection, Soft Open Point Interconnection, Timed Connections, LV ANM, and RTTR in the 30,000 shortlisted sites, and subsequently ranked the sites based on their net benefit potential on a lifecycle basis (assumed to be 45 years, in accordance to the RIIO-ED1 CBA template).

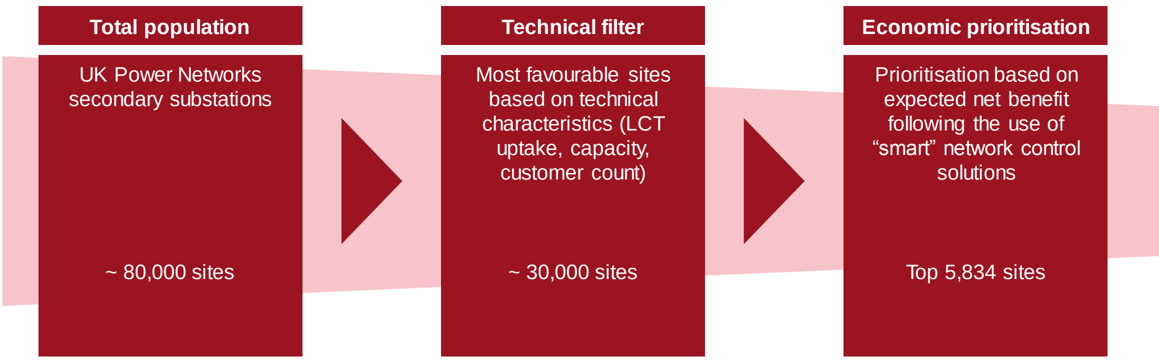


Figure 14: Overview of our approach for targeting sites for RIIO-ED1 roll-out

The results of this targeting strategy are summarised in Table 19 below. As it can be seen, by targeting 5,834 secondary substations, we will enable network visibility and control across 13% of the LCT installations that will be connected on our LV network by the mid-point of RIIO-ED2.

Table 19: Roll-out strategy summary

	EPN	LPN	SPN	UKPN
Planned sites (total)	**1,831**	**2,020**	**1,983**	**5,834**
Sites with no RTUs	1,318	1,454	1,428	**4,200**
Sites with existing RTUs	513	566	555	**1,634**
Expected number of customers associated with planned sites	203,241	416,120	279,603	**898,964**
Number of LCT installations associated with planned sites	57,301	36,352	103,544	**197,197**
% of LCT installations targeted for monitoring	8%	19%	19%	**13%**

We are committed to delivering a roll-out programme only in sites where it is truly beneficial to our customers. To this end, we will continue to assess the benefits that can be achieved in the sites we are targeting in our roll-out on an annual basis, and we will focus our roll-out only on those sites that can deliver a net benefit.

Furthermore, we maintain the capability to revisit and relocate monitoring equipment between network sites in instances where in certain sites, we recognise that we are not delivering value to our customers. To this end, we have included a provision in the roll-out budget for the relocation of monitoring equipment (we have assumed that this will be required for 10% of the targeted sites).

6.4.2 LV network reinforcement benefits from "smart" solutions

LV network reinforcement benefits relate to the savings that can be achieved by the deferral of LV network reinforcement when using network control solutions that are enabled by the LV Network Visibility and Control System.

In order to quantify the benefit of the system compared to the "do nothing" scenario, we modelled the impact of "smart" network control solutions to our networks using the LRE model. The "smart" solutions were modelled across the substations that have been included in our roll-out programme (5,834 secondary substations), and based on the parameters shown in Table 20 below.

Table 20: Modelling assumptions for "smart" network control solutions

"Smart" solution	Unit Cost	Benefit	Source
Automated LV Interconnection	£13,745	Deferral of network reinforcement by 10 years (only applicable to 6% of sites due to technical limitations)	FUN-LV Cost Benefit Analysis (SDRC 9.6), December 2016
Soft Open Point Interconnection	£56,042	Deferral of network reinforcement by 15 years (only applicable to 2% of sites due to technical limitations)	FUN-LV Cost Benefit Analysis (SDRC 9.6), December 2016

Timed LV connections	£8	5% peak load reduction across deployed substations	20% apportionment of costs to establish VPN links with suppliers and third-party providers, informed by Low Carbon London trials
LV Active Network Management	£32	5% peak load reduction across deployed substations	80% apportionment of costs to establish VPN links with suppliers and third-party providers, informed by Low Carbon London trials
Real Time Thermal Rating (RTTR) of Distribution Transformers	£189	Deferral of network reinforcement by 5 years (only applicable to 10% of sites due to technical limitations)	Based on the costs of two temperature sensors

We summarise in Table 21 below the number of "smart" network control solutions that, based on our model, have been deployed across the 5,834 sites we are targeting for LV network monitoring by the end of RIIO-ED2.

Table 21: Summary of "smart" network control solutions in our CBA model, by end of RIIO-ED2

"Smart" solution	EPN	LPN	SPN	UKPN (total)
Automated LV Interconnection	109	121	116	**346**
Soft Open Point Interconnection	36	40	39	**115**
Timed LV connections	1,417	1,591	1,576	**4,584**
LV Active Network Management	354	398	394	**1,146**
RTTR for Distribution Transformers	60	103	84	**247**
Costs (in lifetime NPV terms) [£m]	**£2.64**	**£3.01**	**£2.94**	**£8.59**

The ultimate outcome of our approach was to quantify the difference in the reinforcement costs between the "do nothing" counterfactual scenario, and the use of "smart" network control solutions that are enabled by an LV Network Visibility and Control System.

Table 22: Summary of lifetime benefits "smart" solutions

Description	EPN [£m]	LPN [£m]	SPN [£m]
Lifetime benefit from deferred reinforcement costs [£m]	£18.88	£35.64	£21.58

6.4.3 LV network reinforcement benefits from data utilisation

Further to the benefits that can be achieved from the use of "smart" network control solutions, we have considered the ability to avoid LV network reinforcement with the use of the granular time-series data that the proposed solution will collect. The use of more detailed data in network planning can release latent network capacity either through load balancing across phases, or by using operational assumption in network planning studies, instead of MDI data.

The level of benefits we expect to realise by using detailed network data is summarised in Table 23 below.

Table 23: Summary of lifetime benefits from accurate data utilisation

Description	EPN [£m]	LPN [£m]	SPN [£m]
Lifetime benefit from avoided reinforcement costs [£m]	£2.32	£7.58	£4.46

6.4.4 Summary of reinforcement deferral benefits

The combination of the benefits streams outlined above, with the costs of the roll-out and the costs of the "smart" network control solutions allows us to evaluate the cost-effectiveness of the proposed solution, and to assess the "break-even" point. In order to do so, we used the CBA template for RIIO-ED1, which is attached to our application.

The results of the CBA are presented in Table 24 below.

Table 24: Summary of the results of the CBA

Benefits	EPN [£m]	LPN [£m]	SPN [£m]	UKPN [£m]
Reinforcement deferral ("smart" control solutions)	18.88	35.64	21.58	**76.1**
Avoided reinforcement (data utilisation)	2.32	7.58	4.46	**14.36**
Total benefits (lifetime NPV)	**21.20**	**43.22**	**26.04**	**90.46**

Costs	EPN [£m]	LPN [£m]	SPN [£m]	UKPN [£m]
LV Network Visibility and Control System	9.61	9.14	9.18	**27.93**
"Smart" network control solutions	2.64	3.01	2.94	**8.59**
Total costs (lifetime NPV)*	**12.25**	**12.15**	**12.12**	**36.52**

Net benefits (lifetime NPV)	**8.95**	**31.07**	**13.92**	**53.94**
"Break-even" point	**2028/29**	**2023/24**	**2024/25**	

* The costs associated with our IRM application will occur in RIIO-ED1; only costs of the "smart" network control solution, which are not included in our funding request, will occur in RIIO-ED2.

As can be seen above, the LV Network Visibility and Control System has the potential to deliver net benefits of approximately £54 million across our three licence areas in lifetime NPV. Given the magnitude and timing of the benefit realisation, we expect that the system will "break-even" by mid-RIIO-ED2, and will continue to deliver net benefits on a site-by-site basis through the rest of RIIO-ED2, and beyond.

6.4.5 CO_2 benefits

The roll-out of LV Network Visibility and Control has the potential to enable more efficient LCT connections on the LV networks, which in turn have the potential to deliver carbon savings when compared to conventional power utilisation and generation technologies, such as internal combustion vehicles for EVs, gas boilers for heat pumps, and the national grid electricity mix for solar PV.

In order to calculate the level of CO_2 emissions that can be avoided by the LCTs that will be enabled by the LV Network Visibility and Control System, we examined the level of capacity that we expect to release in the 5,834 sites we are targeting with our roll-out. In our analysis, we have only considered the capacity that will be released by Timed Connections and LV ANM, as these "smart" solutions will be primarily offered to LCT-connecting customers, and hence we can assume that released capacity will be taken up by new LCTs.

We subsequently converted the released capacity to avoided CO_2 emissions, as can be seen in Table 25 below.

Table 25: Summary of avoided CO_2 emissions analysis

Type of Benefit	EPN	LPN	SPN	UKPN
Cumulative capacity released* [MW]	32.18	36.02	40.00	**108.20**
LCTs enabled				
EVs	543	1,235	1,372	**3,150**
Heat Pumps	342	612	679	**1,633**
Solar PV	5,385	2,550	2,832	**10,768**
Avoided CO_2 emissions [ktonnes per annum]	9.36	5.14	5.71	**20.22**
Avoided costs from CO_2 emissions [per annum]	£131,298	£72,177	£80,166	**£283,642**

* Sum if import and export capacity, diversified

As outlined in Table 25, the roll-out of LV Network Visibility and Control across 5,834 secondary substations can enable savings of approximately 20 thousand tonnes of CO_2 emissions per annum, with associated cost savings of approximately £284 thousand per annum (based on average traded cost for CO_2 in RIIO-ED1, from RIIO-ED1 CBA template).

We document below additional assumptions that were used in our analysis.

Table 26: Assumptions used in CO2 analysis

Metric	EVs	Heat Pumps	Solar PV
Average unit size [kW]	17.7 (charging station)	7.8	3.7
Assumed energy utilisation, per annum* [kWh]	1.12 – 2.06	5.72 – 7.21	4.92 – 5.18
CO_2 emissions savings, per kWh of energy utilisation [tonnes]	0.27	0.11	0.33

* Figures vary between our three licence areas

6.5 Roll-out risk register

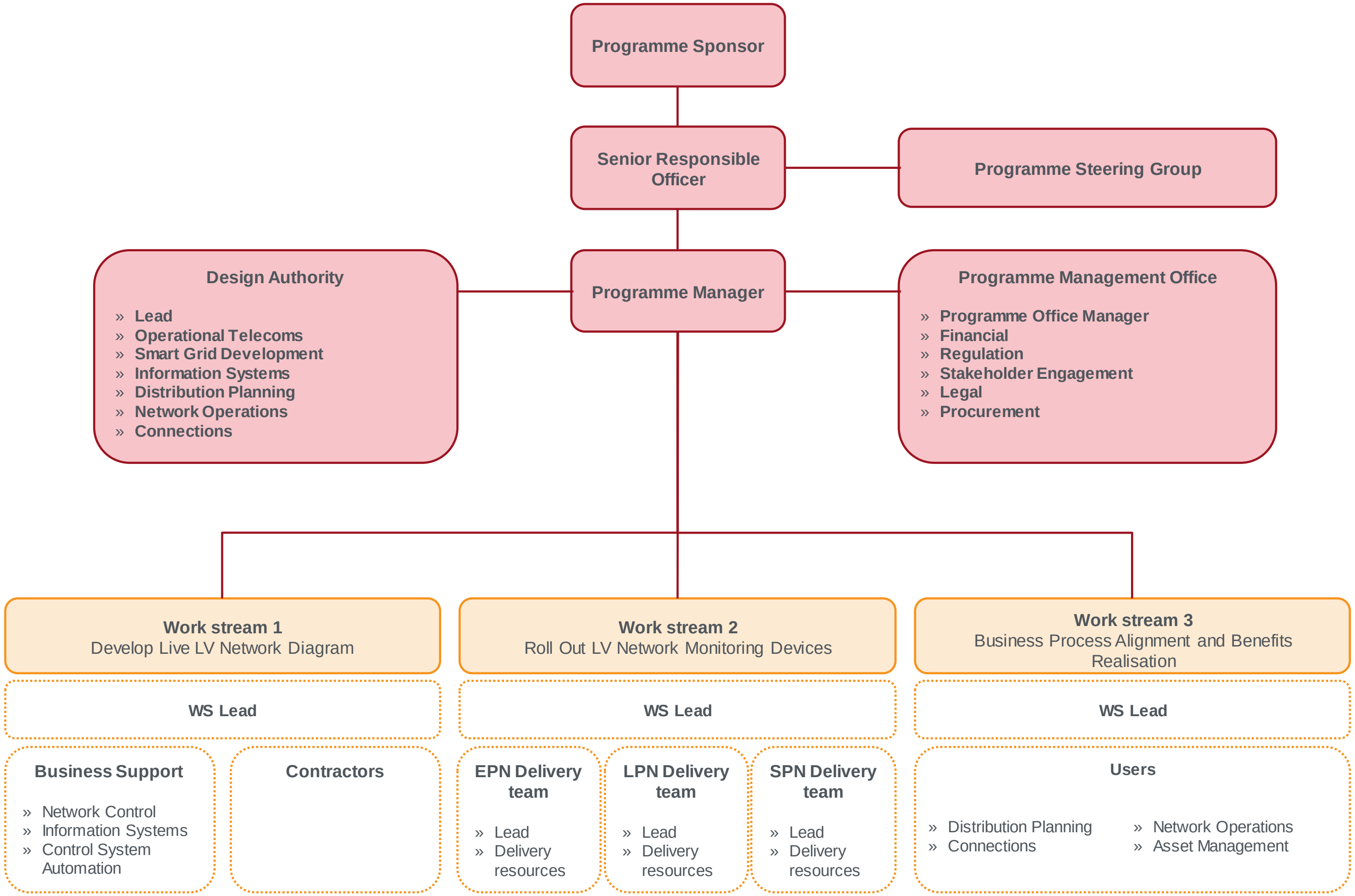
Ref	Status	Category	Description	Owner	Probability	Severity	Mitigation
R001	**Open**	**Benefits realisation**	**Control Engineers do not make the required use of the new functionality, risking benefits realisation and network performance**	Users	Low	Medium	We have engaged with relevant business units in the project specification stage to ensure that the requirements of the control room engineers are met.
R002	**Open**	**Benefits realisation**	**Control Engineers and Planners do not make the required use of the new data and solutions to improve network utilisation and LCT connections**	Users	Low	Medium	We have engaged with relevant business units in the project specification stage to ensure that the requirements of the control room and planning engineers are met.
R003	**Open**	**LCT uptake**	**LCT uptake rate is lower than anticipated**	External	Low	Low	Our forecasts over the past couple of years have consistently underestimated the uptake of EVs and solar PV. The UK's commitment to carbon emission reduction targets support significant growth of LCT technologies.
R004	**Open**	**Operations**	**A number of RTUs fail after being commissioned, resulting in limited confidence in the devices between users**	UK Power Networks	Low	Medium	A full set of quality tests to be completed before installation, with the design and operation meeting the UKPN requirements, ensuring full confidence in the equipment installed. Monitor defects and issue reports supplied by RTU manufacturers for existing installs.
R005	**Open**	**Procurement**	**Delays in the procurement and sourcing of the RTUs**	UK Power Networks	Low	Low	We have already liaised with a list of approved suppliers and have confidence in our procurement timelines. Throughout tendering and contractual negotiations, we will ensure RTU suppliers are able to meet the project delivery timelines. We will include penalty clauses within their contract.

R006	**Open**	**Procurement**	**RTU suppliers goes out of business after the devices have been paid for and delivered, resulting in lack of continuity**	Suppliers	Low	Medium	Carry out full financial diligence checks in line with approved standards of practice and the UKPN procurement procedures.
R007	**Open**	**Project delivery**	**RTUs are not installed and commissioned in time causing delays**	UK Power Networks, Supplier	Medium	Medium	Regular progress meetings / reports to track progress against the plan
R008	**Open**	**Project delivery**	**The LV diagram is not delivered in time causing delays**	Diagram supplier	Low	Low	Regular progress meetings / reports to track progress against the plan.
R009	**Open**	**Project delivery**	**Exceeding the estimated budget for the programme**	UK Power Networks	Low	Medium	We have conducted detailed project planning and cost reporting, based on our prior experience in delivering the specified solution in pilot projects. We will review expenditure monthly as part of the programme's governance.
R010	**Open**	**Project delivery**	**Exceeding the estimated timeline for the programme**	UK Power Networks	Low	Low	We have conducted detailed project planning, and have included resources with significant experience in project management and IT project implementation. We will track progress against the plan monthly as part of the programme's governance.
R011	**Open**	**Resource planning**	**Underestimating the required resources for the programme**	UK Power Networks	Low	Medium	We have specified our resource plan for the roll-out based on the delivery of similar programmes in the past. The programme Steering Committee will resolve staffing issues if they arise.
R012	**Open**	**Resource planning**	**Delivery teams are too under-resourced or re-prioritised to deploy all of the funded monitoring**	UK Power Networks	Medium	Medium	We have engaged the relevant business units within UK Power Networks to confirm their support of the project, and will confirm resourcing commitments during programme mobilisation.

R013	**Open**	**Solution specification**	**The visualisation of the outputs in the control room is not in line with operator expectations**	UK Power Networks	Low	Low	We have engaged with operators early in the process to help inform the design. The diagram will be in the same DMS we are currently using in our control room.
R014	**Open**	**Solution specification**	**The LV diagram does not perform to specification**	UK Power Networks	Low	Medium	We have had the specification reviewed by UKPN specialists during planning and preparation.
R015	**Open**	**Solution specification**	**Network diagram and asset data are of insufficient quality to 'go-live' with active LV control**	UK Power Networks, Suppliers	Low	High	We have included resources in our team that will be responsible for data cleansing. We have also allowed additional time in our plan for data quality reviews. We have funded an initial preliminary design phase that will allow us to assess data migration requirements.
R016	**Open**	**Solution specification**	**Network diagram and asset data are of insufficient quality to achieve the required benefits once live**	UK Power Networks	Low	High	In the context of the scope of WS3, we will work with the implemented solution's users early in the programme to ensure that benefits can be realised. The functionality within the DMS will support continued refinement of data quality.
R017	**Open**	**Solution specification**	**The specified RTUs are not suitable for general population of UK Power Networks sites due to operational or site-specific constraints**	UK Power Networks	Low	Medium	We have already developed an RTU spec for business-as-usual deployment which has taken into account site-specific constraints.
R018	**Open**	**Solution specification**	**The RTUs do not perform to specification, so not all benefits are realised**	UK Power Networks, Suppliers	Low	Medium	We have already developed an RTU spec for business-as-usual deployment which has taken into account the requirements for the use cases and benefits.

6.6 Roll-out organisation chart

The roll-out will be governed as a dedicated programme, with a separate organisation structure as can be seen below.



The programme will be led by a dedicated Programme Manager, who will be responsible for the timely delivery of the programme's deliverables and outputs. The Programme Manager will report directly to the Senior Responsible Officer and the Programme Sponsor, while the programme will report monthly to a Steering Group.

The work will be delivered by the three programme Work streams as below:

– Work stream 1 will be responsible for the development of the Live LV Diagram. The Work stream will have of a dedicated Work stream manager, who will be supported by internal resources and contractors.

– Work stream 2 will be responsible for the roll-out of the RTUs on the LV network. The roll-out will be done regionally across our three licence areas by dedicated teams from our Distribution Capital Delivery team. Each delivery team will have one team lead and two delivery engineers with direct experience in installing RTUs on the network.

– Work stream 3 will be responsible for the realisation of the project benefits across the business, as well as ensuring the readiness of the business to operate the solution once it is complete. The work stream will be led by a dedicated Work stream lead, who will draw support from the LV Network Visibility and Control System's business users on a part-time basis.

The overall programme team will be supplemented by the Programme Management Office, which will provide specialised support to areas such as Procurement, Legal, and Finance. In addition, the Programme's Technical Design Authority will be made up from resources from across our business that will be responsible for ensuring the developed system will comply with our internal design requirements and specifications.

6.7 Business impact assessment

6.7.1 Introduction

To fully understand the impact of the roll-out of the LV Network Visibility and Control System on the business, we conducted an assessment of the way the system will change business processes. For each business process, we identified the individual elements that is susceptible to being impacted, and we went over the practical implications with the respective business owners of these processes. Specifically, in order to complete our assessment, we interviewed the following team managers:

- Distribution Planning: EPN, LPN and SPN
- Connections: EPN, LPN and SPN
- Network Control: Combined team for all three licence areas

The detailed outcomes of these interviews and the impact on the business processes for each use case is summarised in sub-section 6.7.2 below. We also summarise below the impact of the roll-out of "smart" network solutions on the LV networks.

6.7.2 The outcomes of our assessment

Based on our Impact Assessment, we are confident that the business is well positioned to take advantage of the capabilities of the LV Network Visibility and Control System. We will work with the business users of the proposed solution throughout the roll-out, and in the context of Work stream 3 to ensure that the business processes are adapted in the way we highlight in the following pages.

In our assessment, we also confirmed that the benefits of the roll-out can be realised across the business without the need for additional staff. It was established that staff will be able to undertake more advanced studies and data analysis by working more efficiently, with time spent performing additional analysis being offset by a reduced number of site visits to read meters and install data loggers.

We noted in our assessment the need to ensure staff are properly trained on the capabilities and functionality of the new system. Therefore, we have specified in the roll-out programme provisions for the training of the staff that will use the LV Network Visibility and Control System on a day-to-day basis (see Table 27).

Table 27: Training provisions included in the roll-out programme

	Type	Time required	Resources	Total requirement
Distribution Planning	Basic training and familiarisation with new data tools	Two days per team member	20 team members in EPN, 20 in LPN, and 9 in SPN	98 person-days of training
Connections	Basic training and familiarisation with new data tools	Two days per team member	159 team members across the three license areas	318 person-days of training
Control Room	System training for LV desk	One day per team member	40 team members across the three license areas	40 person-days of training

We provide in the following pages illustrations of the business processes that will be impacted by the introduction of the LV Network Visibility and Control System, as well as the impact of the “smart” network control solutions that will be enabled by the system.

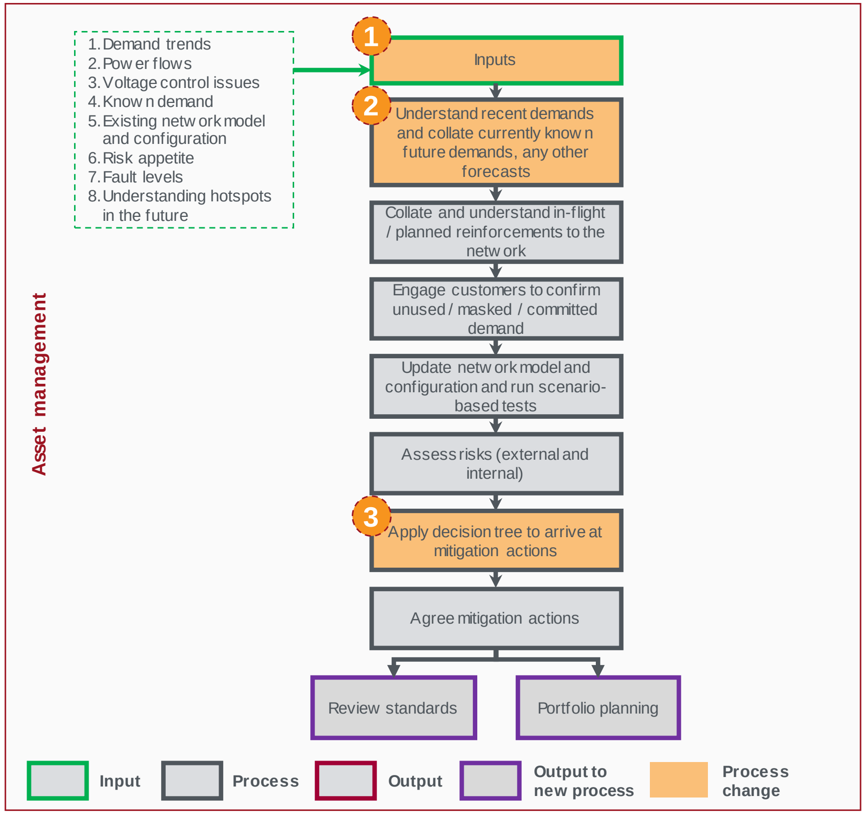
Use Case #1a: Capacity Management
(SD0.SDD.71.PDD.Manage Network Capacity)

Use Case Description

'Manage Network Capacity Requests and Design Referrals' process manages the current consumption and reviews usage against customer contracted demand. This iterative approach ensures that network performance operates within the defined tolerances. All customer capacity requests received from Connections are analysed and quoted accordingly.

Use Case Outputs

» Network investment
» Connection cost and design



#	Type / BTP ref	Description	Qualification
1	» Network Planning	» Monitoring data will lead to improved **knowledge** of : • Demand trends • Power flows • Voltage regulation • Phase balancing • Existing network configuration » Monitoring data will lead to improved **understanding** of : • Hotspots in the future • How to prioritise fault repair order	No net impact on the total amount of work done, but engineers will spend more time analysing data and less time on site visits. MDI data is collected on average every 4 years, or every year in London. MDI data can record maximum demand during abnormal operating conditions (e.g. during outages or fault restoration), which can lead to confusion over whether reinforcement is needed. Errors can also result from manual MDI reading. The feeder loading data from the proposed project will enable better targeting of reinforcement for meshed networks More accurate data will reduce estimation and risk when making investment decisions. No impact on fault levels
2	Network Planning A2.6.3.1	» Load flow models will be extended to include historic demand on LV feeders for forecasting purposes	

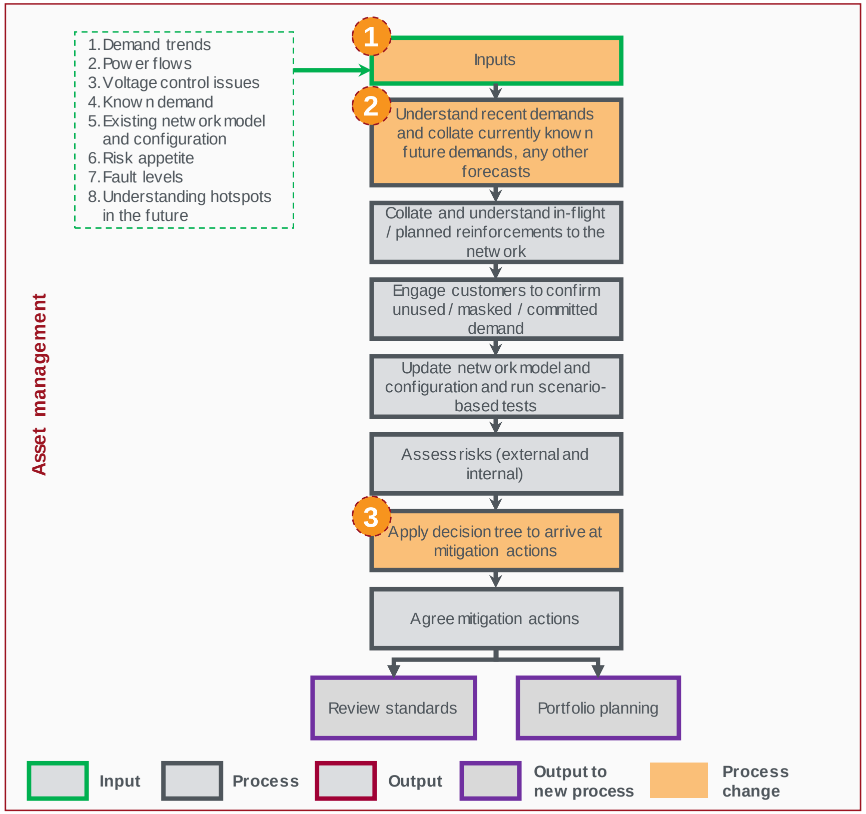
Use Case #1a: Capacity Management
(SD0.SDD.71.PDD.Manage Network Capacity)

Use Case Description

'Manage Network Capacity Requests and Design Referrals' process manages the current consumption and reviews usage against customer contracted demand. This iterative approach ensures that network performance operates within the defined tolerances. All customer capacity requests received from Connections are analysed and quoted accordingly.

Use Case Outputs

» Network investment
» Connection cost and design

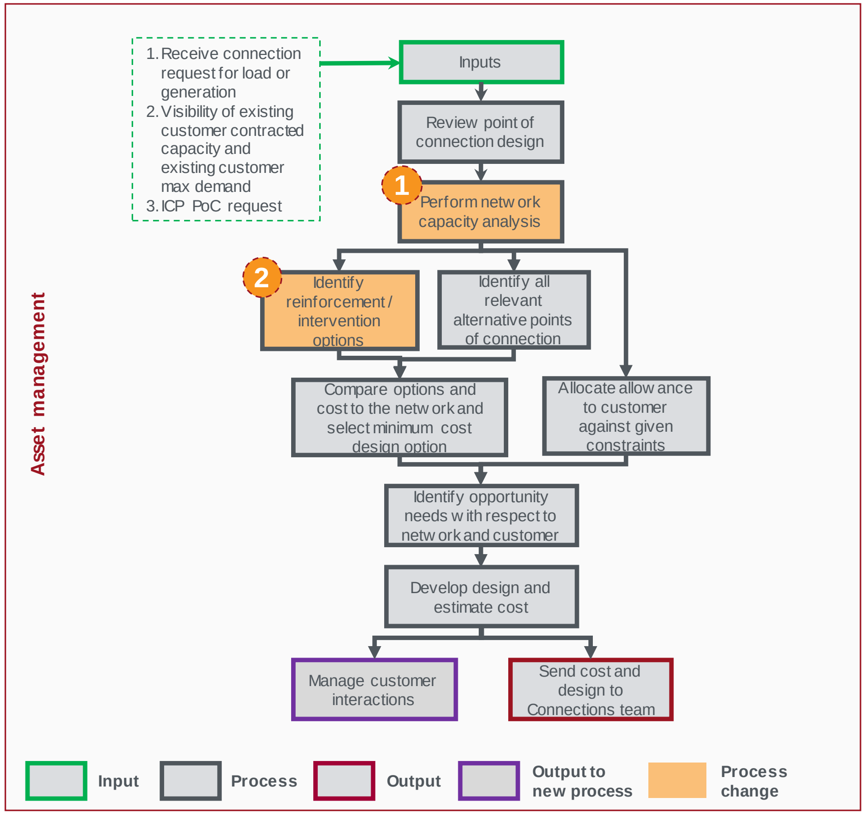


#	Type / BTP ref	Description	Qualification
3	Network Planning A2.6.3.6	» New connection / reinforcement solutions will be facilitated by LV monitoring and control: • Timed – subject to the connection agreement • FunLV1 – not subject to the connection agreement • FunLV2/3 – not subject to the connection agreement • ANM – may be subject to the connection agreement	D-PLAN LV network modelling software will enable efficient planning for ANM and timed connections. Load flow and fault level studies in D-PLAN will enable efficient planning for FUN-LV

Use Case #1b: Capacity Management
(SD0.SDD.71.PDD.Manage Network Capacity)

Use Case Description
'Manage Network Capacity Requests and Design Referrals' process manages the current consumption and reviews usage against customer contracted demand. This iterative approach ensures that network performance operates within the defined tolerances. All customer capacity requests received from Connections are analysed and quoted accordingly.

Use Case Outputs
» Network investment
» Connection cost and design



#	Type / BTP ref	Description	Quantification
1	Network Planning A2.6.1.2	» RTU data will be used to improve granularity and efficiency of capacity analysis studies for the LV networks. » Analysis of historic LV phase imbalance will be undertaken when assessing available LV network capacity.	Presently MDI readings are used, which are not per feeder. Feeder load is measured using data loggers if required for connections, which involves site visits. IRM proposal will reduce site visits and negate requirement for data loggers, thus accelerating connection times by one week. MDI meters are hard to read and have inconsistent scales, thus mistakes are made when reading them. IRM will improve data measurement quality. Half-hourly IRM data will improve accuracy of giving estimates for connections, reduce network overloading risk, and enable faster quotes, hence improving customer service.
2	Network Planning A2.6.1.5	» New relevant solutions: • Timed • FunLV1 • FunLV2/3 • ANM	D-Plan software / planning tool will be rolled-out in 2018 in SPN, but these solutions will not be used until ED2 in SPN.

Use Case #2: Connections Management

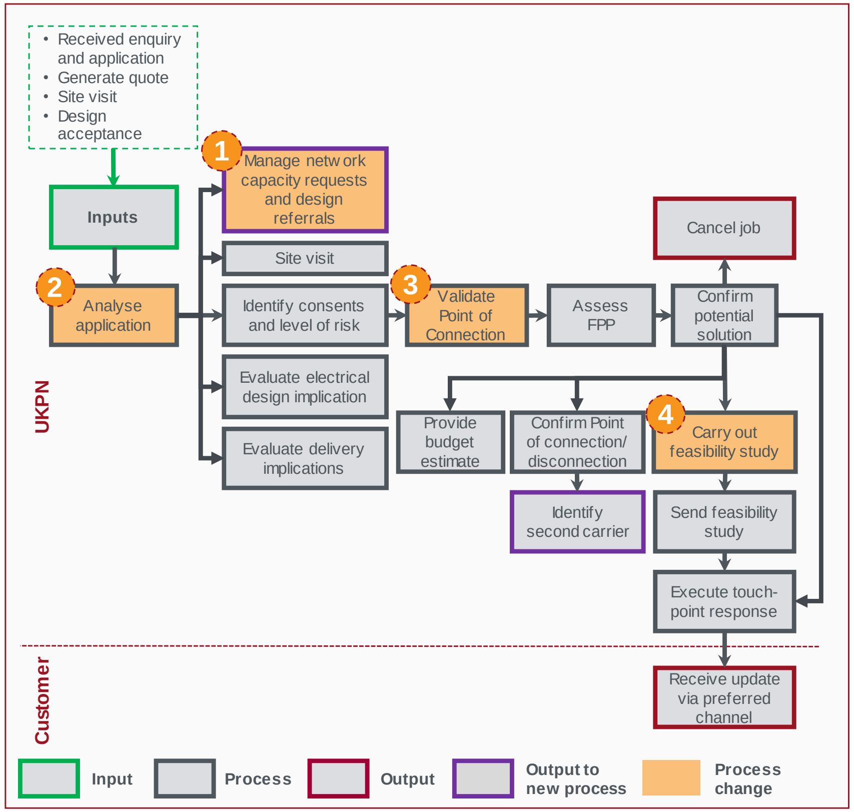
(SD0.SDD.71.PDD.Connections)

Use Case Description

The scope of this process is to identify what the customer requirement is e.g. budget estimate, formal quote, or disconnections request and pass it to relevant teams for action. This process utilises case-based reasoning to identify the type of connection request and category of customer as per customer.

Use Case Outputs

» Connection quote



#	Type / BTP ref	Description	Impact
1	Network Planning A2.6.1	» Liaison between Connections and Asset Management to assess available capacity	Common use of tools (DNV and D-Plan) will streamline processes.
2	Network Planning C2.1.1	» Analysis will be accelerated by historic LV feeder demand data	Feeder level load flow data will save on average one week of data-logger time plus site visits.
3	Network Planning C2.1.9	» Analysis will be accelerated by historic LV feeder demand data	Network reinforcement at LV will be de-risked through better knowledge of network loading, phase balancing and voltage regulation, leading to less estimation and better decisions.
4	Network Planning C2.1.17	» Feasibility Study will be accelerated by historic LV feeder demand data » ANM and timed connections will be used at LV as an additional option » Historic LV phase unbalance will be checked, as phase balancing may release capacity » Design practices will need to be amended to include by historic LV feeder demand data	

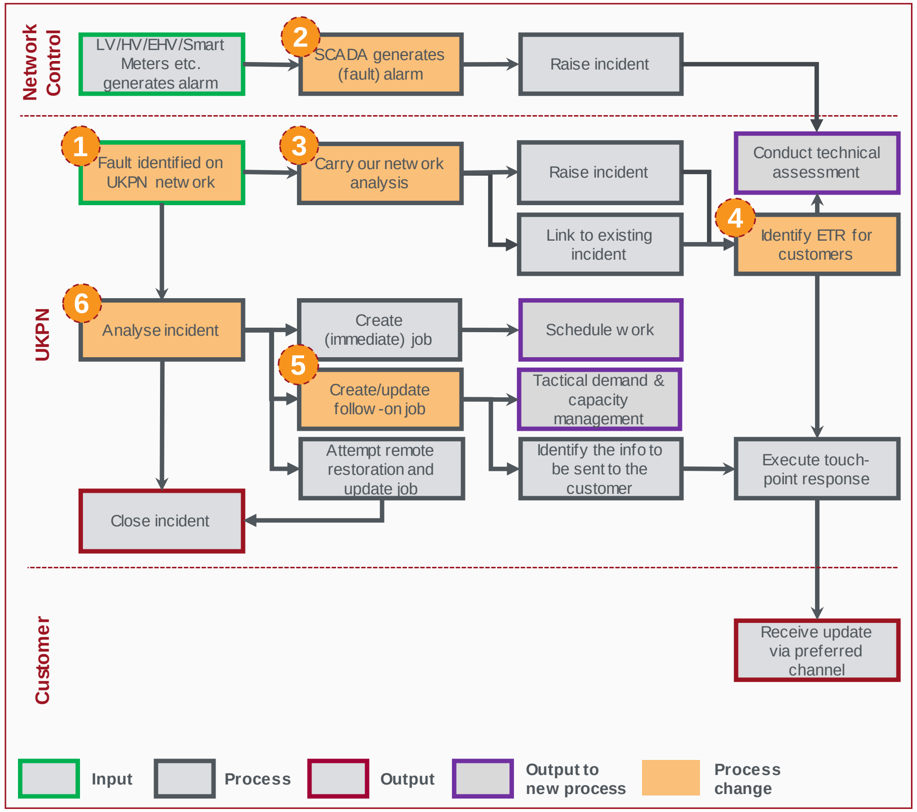
Use Case #3: Network Operations
(SD0.SDD.71.PDD.Faults)

Use Case Description

The faults process identifies all urgent reactive work, removes any risk posed to the public, restores supplies quickly and returns the network to normal running conditions. This includes fault notifications via customer contact (using their channel of choice), via SCADA alarms or via other routes.

Use Case Outputs

» Network restoration in response to a fault



#	Type / BTP ref	Description	Quantification
1	Control room	» LV diagram will be used to identify which LV feeders / phases are off supply to decrease fault restoration time	Currently rely on customers informing of loss of supply. We will be able to react quicker if SCADA alarms are received
2	Control room F1.1.8	» Will use feeder data from LV diagram as well as smart meter data to estimate fault location	Will reduce fault location time on site as all information of who is affected will be readily available and drastically reduce the section of network that has faulted
3	Control room F1.1.1	» Will use LV diagram data to identify which LV feeders / phases are off supply to decrease fault restoration time	As per point 2
4	Network Operations F1.1.5	» Estimated time of restoration accuracy will be increased by LV diagram data	Not material as still reliant on info from the staff for what needs to be done
5	Network Operations F1.2.8	» Fault start time will be recorded more accurately with LV diagram data	Will give a definitive start and end time in the same manner as HV networks
6	Control room F1.2.1	» Will use LV diagram data to identify incident type more efficiently	Will enable the correct skill set to be sent to site in the first instance

LV Network Monitoring System: Impact of "smart" network control solutions

	Timed LV connections	LV ANM	Automated LV Interconnection; SOP Interconnection	RTTR of Distribution Transformers
Technology Hardware	» Logic programmed into RTUs » LV diagram coordination	» Logic programmed into RTUs » LV diagram coordination	» LV diagram shows network connectivity » Data sent to PowerON via RTUs	» LV diagram shows temperatures and RTTR » Data sent to PowerON via RTUs
Technology Software	» D-Plan » PowerON Advance; PI	» D-Plan (potential future addition) » PowerON Advance; PI	» D-Plan (for planning) » PowerON Advance; PI	» PowerON Advance; PI
Asset management - standards	» EDS 08-5021 » Created 2017; awaiting approval » Affects Connections, Dist. Planning, Inf. Planning and AM	» Asset management based on extensive experience of planning, implementing and managing advanced network management schemes at higher voltages.	» EDS 13-0810 for LV Automated Interconnection » EDS 09-0039 and EDS 09-0040 for SOP Interconnection » Approved 2017 and 2014	» EDS 04-0033 » Approved 2016 » Mainly technical focus
Network operations - planning	» Develop and strategically manage LV network to facilitate connections and load growth			
Connections	» Manage network connections above 70KVA and below 1MVA. Also demand referrals of up to 200KVA.			
Network operations - small services	» Manage network connections below 70 KVA			
Network operations - control	» Monitor compliance with timed thresholds	» Monitor compliance with ANM logic	» Monitor correct operation of FUN-LV 1	» Monitor correct operation of RTTR
Network operations - field	» Install and maintain RTUs			

6.8 Lessons learned from relevant innovation projects

Project name	Flexible Urban Network Low Voltage (FUN-LV)
Network	LPN
Start Date	01/2014
End Date	12/2016
Funding Mechanism	LCN Fund Tier 2

Issue Description

Efforts to decarbonise energy generation, heat and transport place increasing demands on distribution networks. This creates particular problems for the LV networks closest to customers, where DNOs have the obligation of supplying electricity within tightly defined voltage limits and at a sufficient quality (harmonics, sags, swells and flicker). Analysis carried out by Imperial College to support UKPN's RIIO-ED1 business plan predicted an increasing trend of voltage issues and demand rises that could overload transformers and underground cables, requiring £132.6m of network reinforcement during the RIIO-ED1 period if reinforced by conventional means.

Objectives

In this project, power electronics were used for the first time, in combination with remote configuration and informational tools. This allowed to access latent/spare capacity that already exists and achieve shorter reinforcement timescales than in conventional methods. The increased visibility also aids the effectiveness of network planning. The project was expected to demonstrate headline savings of £2.36m across 36 trial schemes, whilst importantly providing greater flexibility, faster connections and reducing the risk of long interruptions due to HV faults.

Detailed objectives of the project included:

- **Optimisation of capacity on the LV network** closest to customers to accommodate the forecasted growth in electric vehicle charging, heat pumps and micro-generation on existing connections by making the network more flexible and resilient through capacity sharing between substations;
- **Improvement of connection offers** (time & cost) in urban areas by knowing where best to connect, and by managing voltage, power flows and fault current through the use of power electronics;
- **Advancement of the future network architecture** debate for the sector by evaluation and learning dissemination in terms of financial learning, benefits and architecture of the power electronics applications on different network architectures and by providing network configuration control in combination with remote switching.

Outputs

Throughout the project the following milestones were achieved:

- Monitored candidate LV networks and identified network issues;
- Assessed how these networks would have been reinforced conventionally in order to resolve issues;
- Identified where power electronics solutions can be used as an alternative to resolve issues;
- Deployed and evaluated power electronics devices installed on the LV distribution network in London and Brighton.

Furthermore, the project evaluated the relative benefits that the various functions of power electronics can provide, including:

- Acting as 'soft open points' (SOPs) between distribution substations for capacity sharing;
- Controlling voltage on LV networks;
- Controlling fault levels.

Key lessons and contribution of the project to our LV network monitoring capabilities

The project has shown that network meshing has a significant potential to assist UKPN to deliver LV reinforcement committed to in the RIIO-ED1 business plan. It also reduces the financial risk for customers and DNOs caused by the uncertainty in volume, timing and location of the low carbon transition. Furthermore, meshing has proven to provide a network upgrade option with fewer logistical and disruption issues for customers.

The project also carried many wider lessons for UKPN and LV network monitoring, such as:

- **Planning and Site Selection** – Importance of accurate load data, network architecture and appropriate connection agreements in order to realise desired transfer profiles and maximum benefits from meshing;
- **Installation & Commissioning** – Lengthy engagement with local authorities and trial holes were essential to siting of street furniture. However, all FUN-LV devices proved much quicker to install than traditional reinforcement options;
- **Design Considerations** – Specification has been updated to revise requirements on size, noise, ventilation and protection; and
- **Analysis and Tools** – Extensive monitoring, sophisticated modelling and visualisation tools are all necessary to optimise device performance and manage wide power electronics deployments.

Electricity Distribution Innovation Roll-Out Mechanism Submission Pro Forma

Project name	Smart Urban Low Voltage Network (SULVN)
Network	LPN
Start Date	07/2012
End Date	03/2015
Funding Mechanism	Innovation Funding Incentive / LCN Fund Tier 1

Issue Description

UK Power Networks and TE Connectivity have been working in collaboration, as part of an Innovation Funding Incentive (IFI) funded project, to develop a new solid-state switching technology for use on LV distribution networks. The devices developed in the IFI project retrofit to existing LV plants, and the system provides previously unavailable remote switching and re-configuration of the LV network. In addition, the system has the ability to provide visibility of power flows on the LV network down to link-box level, as near real time communications and built in sensors allow extensive load monitoring data to be collected.

The SULVN project focused on the industrialisation of hardware developed during the IFI project and its potential for helping DNOs address the challenges faced with the transition to a low carbon economy.

Objectives

SULVN was a large-scale demonstration of single phase circuit breakers (CB) and link box switches (LBS), integration with PowerOn (Distribution management system) and an evaluation of the expected benefits, funded as a NIA project. The project consisted of 40 substations and associated link boxes.

Case studies were developed to:

- Investigate how a greater understanding, visibility and control of the network can lead to LV active network management, and facilitate the connection of LCTs;
- Quantify the expected improvement to quality of supply when using remote control and automation to create a self-healing LV network; and
- Use the unprecedented visibility of the LV network available (single phase load monitoring at link box level) to validate current LV modelling and increase our understanding of the LV network.

Outputs

The project delivered the following outcomes:

- Industrialisation of hardware (based on learning from the prototype deployment undertaken in the LV remote control & automation IFI project);
- Integration of LV hardware with a SCADA based control system utilising LV connectivity models; and
- Roll out of the technology and evaluation of the expected benefits which are expected to include reduced losses, increased capacity headroom, early visibility of emerging loading or power quality issues. A potential improvement in quality of supply of up to 75% has been identified in the trial area.

Key lessons and contribution of the project to our LV network monitoring capabilities

The key lessons from the project included:

- An improved understanding of the LV network, and greater insight into the potential challenges DNOs are likely to face with the transition to a low carbon economy;
- How active network management of the LV network can optimise the use of existing LV plant, and potentially facilitate the connection of additional and low-carbon loads;
- The business benefits of creating an automated, self-healing LV network; and
- How extensive load monitoring data can be utilised to enhance modelling of the LV network.

Project name	Distribution Network Visibility (DNV)
Network	EPN
Start Date	09/2010
End Date	09/2013
Funding Mechanism	LCNF Tier 1

Issue Description

Improving remote telemetry is key to a 'smarter' electricity network which responds to swiftly changing electricity demand and generation. Improvements to our IT architecture mean we can now collect and store more data to gain a better live picture of how our network is performing. The DNV project aimed to enhance those capabilities.

Objectives

The main objective of the DNV project was to demonstrate the business benefits of the smart collection, utilisation and visualisation of existing data.

Detailed project aims included:

- Maximising the capabilities of remote telemetry (Remote Terminal Units) at UKPN's substations;
- Trialling various optical sensors that could potentially be used to provide detailed monitoring of sites with no RTUs;
- Using software to improve the understanding of network performance as well as establish optimum levels of distribution network monitoring and frequency of sampling;
- Evaluating alternative solutions for sites in the South East and East of England;
- Deciding what data should be collected and how often;
- Providing further sources of data for the Low Carbon London project; and
- Sharing findings with relevant groups.

Outputs
By maximising the capabilities of remote telemetry (e.g. RTUs) at the substations and developing software to improve the understanding of network performance, UKPN engineers were provided with greater visibility of the distribution network to enable proactive network management and earlier identification of critical issues. Furthermore: – An in-depth cost/benefit assessment of a variety of network data has helped to evaluate what data should be collected and how often; – The distribution network visibility (DNV) application has now been introduced into UKPN business units as part of business as usual deployment strategy. The benefits delivered through the use of the application will be tracked to support continued improvements to customer services; and – Training sessions have ensured that those within the business units that will be using the DNV application are comfortable with the tool. The training sessions were tailored to the needs of each unit and focused on functions of the application that are most relevant to the teams within the units.
Key lessons and contribution of the project to our LV network monitoring capabilities
The key lessons from the project included: – **Embedding into Business as Usual** - the training sessions have been well received and have resulted in many employees now using the application as part of their everyday working routine. IT department have developed a clear process for managing existing and new DNV users. This has enabled to capture any need for future improvements to the application, recording any identified problems with the application, etc.; – **Benefits delivered to the business** - real benefits have been delivered to the business through the use of the DNV application. The benefits include the facilitation of new customer load and generation connections, the identification and proactive resolution of high temperature issues at secondary substations and deferring network reinforcement; and – **Benefits delivered to customers** - the DNV application is enhancing customer service at UKPN by improving visibility of network conditions, allowing to proactively manage electricity network issues before they result in power cuts. It also means the ability to identify and assess spare capacity on the network to support the connection of additional load or generation. The DNV tool also supports a reduction in carbon emissions by enabling the connection of new LCTs such as electric vehicles and heat pumps.

Electricity Distribution Innovation Roll-Out Mechanism Submission Pro Forma

Project name	Low voltage current sensor technology evaluation
Network	LPN
Start Date	12/2011
End Date	06/2013
Funding Mechanism	LCN Fund Tier 1

Issue Description

A large variety of current sensor technologies are available on the market, which require testing in both controlled laboratory and operational field environments before deployment onto the distribution network. UKPN collaborated with Western Power Distribution (WPD) to assess a range of installation scenarios. The project also aimed to generate knowledge around the wider roll out of these monitoring technologies in the low carbon future.

The project involved working with manufacturers of LV monitoring solutions whose equipment had met the project requirements. The monitoring equipment needed to be capable of measuring the current flow in individual LV ways of an LV distribution board or cabinet. In that regard, a joint tender was completed from which seven different monitoring solution manufacturers were selected to participate in the project.

Objectives

The project aimed to carry out a range of laboratory tests at National Physical Laboratory (NPL) to assess a range of accuracy scenarios. A test bench was built at NPL using an LV cabinet ensuring that the test facilities would mimic as closely as possible the real-life situation encountered in field installations. A side by side comparison was then completed using the results.

Another key focus of the project was the safe installation of monitoring equipment. Installation training for each manufacturer's equipment was carried out at UKPN's Sundridge Training Centre. Following the development of installation methodologies, equipment was installed at 14 outdoor substations in Market Harborough by WPD and 14 indoor sites in central London by UKPN.

Outputs

The project has led to the development of installation policies to enable LV monitoring equipment to be installed safely and without the need for an outage on the substation. Several methods of making voltage connections were trialled and a hierarchy of preferred methods was developed. These included:

- Use of existing voltage take off points;
- Insulated and fused busbar clamp; and
- Modified fuse carriers.

The transmission of data via GPRS was also demonstrated but no data integration with the DNO SCADA system was attempted as it was out of scope for the project.

Basic current and voltage measurements were provided by the equipment from all manufacturers along with the apparent, real and reactive power and power factor. A number of manufacturer's equipment offered more advanced monitoring functionality which included the measurement of neutral current, power frequency, harmonics, substation air temperature, disturbance recorder functionality and network event alarms.

Key lessons and contribution of the project to our LV network monitoring capabilities

The project led to a comprehensive evaluation of seven commercially viable LV monitoring solutions and the development of installation policies to allow wider scale deployment on the LV network. The lessons from the installations will also benefit any further LCNF projects involving LV monitoring:

- The key learning was around the safe installation of monitoring equipment in a diverse range of substations, and how the mitigation of constraints that each of these might present to the installer;
- How the accuracy of various monitoring solutions is impacted under different environmental conditions and installation scenarios;
- The project demonstrated that the current generation of monitoring solutions are mature enough to allow sufficient data to be collected by DNOs to assess the performance of LV networks. Monitoring solutions can provide network load measurement with accuracies to within 2.5% for Rogowski coils, and 1% or better for solid state sensors, such as split core CTs; and
- As a result of the field and laboratory trials, feedback was provided to manufacturers, leading to improvements in their products.

Project name	Validation of PV Connection Assessment Tool
Network	EPN / SPN
Start Date	01/2012
End Date	11/2014
Funding Mechanism	LCN Fund Tier 1

Issue Description

Domestic solar panels and other small-scale renewable generation are usually being connected to the LV electricity networks without needing the consent of the DNO. Low penetration does not cause any significant impact on the network, but network issues arise when penetration levels are high.

Increasing clusters of solar panels connected to the electricity network will result in more two-way power flows on our cables and substations. Conventional reinforcement is often expensive so the challenge is to find smarter ways to support increasing use of small-scale distributed generation, without risking overloading the electricity network.

Objectives

The objectives of the project included:

- **Trial design** - Collect real-life data needed to inform the trial methods, by deploying monitoring equipment to 20 distribution substations and 10 customers' PV installations;
- **Validate the PV connection assessment tool** – Ensure that UKPN's spreadsheet-based connection assessment tools were fit for purpose, by comparing them to PowerFactory models and real-life measurements;
- **Validate assumptions in UKPN's PV connection assessment policies** – Validate existing and recommend new design assumptions by analysing real-life data, and document them in formal design procedure;
- **Understand the impacts of PV generation on LV distribution networks** – Conduct a desktop review of available solutions to inform the DNO community of which are the best solutions to trial or adopt in likely constraint scenarios; and
- **Understand how information available to PV installers could be used by DNOs** – Obtain data that PV installers had collected from their PV generators, and determine if it could reduce DNOs' need to deploy LV network monitoring schemes.

Outputs

The project delivered the following outcomes:

- **A validated and pragmatic connection assessment approach**, comprising a formal design procedure and an improved tool, that UK Power Networks will adopt into business as usual and share with other GB DNOs during 2015. The formal design procedure includes recommended design assumptions, based on real life data;
- **A rich dataset, available for GB DNOs and academic institutions to use**, comprising of measurements from 20 distribution substations and 10 customers' PV installations (total 25,775 days of valid data); and
- **A review of voltage control solutions** that could be trialled or adopted in GB, including recommendations of which solutions best suit likely constraint scenarios.

Key lessons and contribution of the project to our LV network monitoring capabilities

Following the project, UKPN gained a better understanding of the challenges of DNOs recruiting trial participants directly, such as data protection, incentive payments, low response rates, complex stakeholder relationships, and rarity of suitable customer premises.

When deploying LV network monitoring schemes in future innovation projects, DNOs need to consider issues such as availability of field staff, reliability of mobile communications, equipment failure, and data archiving.

G83 notifications are not accurate, and DNOs need access to better information about the existing PV generation connected to their networks.

In addition to trial projects delivered by UK Power Networks, GB DNOs (SSE, SPEN, WPD) completed 13 projects in the last six years that focused on LV network monitoring and control. The main themes explored through these projects included:

- Assessment of the impact of the uptake of LCTs (solar PV and EV) on the distribution networks and ways to mitigate the emerging issues;
- Demonstration of the benefits of LV network monitoring for network planning;

- Validation of various options to monitor the LV network and assessment of ways to decrease the costs of the equipment;
- Development of best practises regarding sensor installations;
- Exploring ways to establish communication between sensors and the control room;
- Improvement of the analytical readiness of the control centres for the big data from monitoring sensors; and
- Design and implementation of LV connectivity diagrams.

These efforts prove that LV network monitoring is one of the key focus areas across all DNOs, demonstrating the increased emphasis in this part of the network. We provide below a short description of a selection of relevant projects.

#	Project	Network operator	Funding mechanism	Start date	End date	Objectives and benefits
1	**Demonstrating the Benefits of Monitoring Low Voltage Network with Embedded PV Panels and EV Charging Point**	Scottish and Southern Electricity Networks	LCN Fund Tier 1	September 2010	October 2011	» Demonstrate a no (or low) Customer Minutes Lost (CML) retro-fit 11kV LV substation monitoring solution; » Analyse the data on LV feeders to understand the performance of the LV network; » Assess the impact of PV system and Electric Vehicle (EV) charging behaviour on the network; » Identify the additional capacity of connecting PV panels and EV charging points on the LV feeder; » Assessment of multiple monitoring products; » Develop modes of operation for the transmission of data to suit a control room requirement.
2	**New Thames Valley Vision (NTVV)**	Scottish and Southern Electricity Networks	LCN Fund Tier 2	January 2012	March 2017	» As part of SSE's NTVV project, 300 substations monitors were installed on the LV network » The monitors were made up of RTUs, a current sensor, a voltage sensor, and associated communication infrastructure » Energy import and export was recorded on a half-hourly basis in Pi Historian via PowerOn Fusion » The project generated knowledge and lessons around the use of data for LV network planning and operations, as well as the potential use of Active Network Management schemes
3	**Flexible Networks for a Low Carbon Future**	Scottish Power Energy Networks	Network Innovation Allowance	January 2014	December 2016	» Enhanced monitoring and analysis to precisely determine existing performance and the

						deployment of novel technology for improved network operation; » Includes flexible control and dynamic rating; » To ensure representative and replicable outputs, the project involves three carefully selected trial areas across SP Distribution and SP Manweb, covering various network topology and customer demographics: St Andrews in Scotland, Wrexham in Wales and Whitchurch in England.
4	**Low Cost LV Substation Monitoring**	Scottish and Southern Electricity Networks	Network Innovation Allowance	March 2016	March 2018	» Reduction of the cost of LV monitoring to make it economically viable to fit LV monitoring devices in large volumes to the secondary substations; » This project aims to procure the basic communications unit for a target price in the region of £30 to £40; » It is intended that the project will deliver complete systems which can be procured for a figure in the region of £500 with the potential to lower costs if economies of scale can be achieved by purchasing the current measuring devices in sufficiently large quantities; » The data parameters delivered will be similar to those obtained in the New Thames Valley Vision project; » A lower level of accuracy is expected but still sufficiently accurate to determine the benefits which low cost monitoring of a large section of LV network can bring in terms of customer service, network planning and operational decisions.
5	**LV Connectivity Modelling**	Scottish and Southern Electricity Networks	Network Innovation Allowance	October 2015	July 2016	» The output of the project is to produce LV connectivity diagrams, using software, for the trial area which is within an acceptable level of accuracy when compared with the manually derived diagram.
6	**Network Constraint Early Warning Systems (NCEWS)**	Scottish Power Energy Networks	Network Innovation Allowance	February 2017	May 2019	» Improve Data Analytical preparedness of current LV connectivity models which are embedded with GIS linear Asset Management systems for future high levels of SM data penetration;

						» Increase visibility and understanding of Customer and LCT relationship to 'aggregated' LV circuit Component level using SM data and other related customer connectivity intelligence; » Integrate initial volumes of smart meter 'Profile Limit' data to research minimising Network Monitoring requirement to provide early and ongoing warning of Network Constraint; » Provide Big Data/Data Science Research Knowledge Transfer capability to SPEN; » Transfer expert LV Network Constraint Management into SMART systems utilising Data Analytics and Big Data; » Provide next step requirements for BAU use of Early Network Constraint monitoring systems in the management of increasingly Dynamic Smart Grids: Within full SM and increasing LCT penetration scenarios; » Proof of Concept (POC) SM Data Visualisation systems to demonstrate Business value from Constraint early warning systems in Network Planning Management (Connections and Reinforcement Management).
7	**Real Time Fault Level Monitoring (RTFLM) - Stage 1**	Scottish Power Energy Networks	Network Innovation Allowance	January 2017	March 2018	» Prototype Development - To design and develop a prototype RTFLM solution suitable for trial deployment on the network; » Prototype Testing - To prove that the prototype is suitable for network trials without any detrimental impact on the network; » Extended Site Trials - To generate consistent and reliable measurements over an extended period of time without any detrimental impact on the network; » Design Review and Recommendations - The identification expected benefits based on the limited site trials and the business case for BaU adoption, as well as the further developments required;

						» Dissemination - To ensure that external and internal stakeholders are fully aware of this projects findings and any expected benefits expected through BaU adoption.
8	**Supply Point Monitoring**	Scottish and Southern Electricity Networks	Innovation Funding Incentive	September 2014	December 2019	» The Supply Point Monitoring Device will fill the void in LV monitoring until a smart meter is installed and communications between the proposed Data Communications Company (DCC) and DNOs can be established; » The device will initially be used to support research and development projects where granular energy consumption information is required and smart meters are not available; » As the device is DNO owned network operators will have a means to enable the collection of consumer energy consumption and other technical data without the need to interfere with supplier smart meter roll out plans; » Additionally, the device has been designed to integrate with existing DNO systems thereby removing the need wait until more complex DCC interfaces and DNO systems are available; » Where smart meters cannot be installed by suppliers the Supply Point Monitoring device will provide DNOs with an enduring means of collecting energy consumption and technical data from such locations.
9	**Smart Grid Equipment – LV Link Box Monitoring**	Western Power Distribution	Innovation Funding Incentive	April 2011	March 2013	» The remote monitoring of link boxes in LV distribution networks will provide real time data to facilitate the active management of LV smart grids. It will also provide historic demand data which can be used for planning purposes and identify if remedial measures are required to mitigate unbalance, power factor or harmonic issues; » The monitoring of IDNO interfaces will confirm the presence of unmetered supplies and provide demand figures for planning purposes;

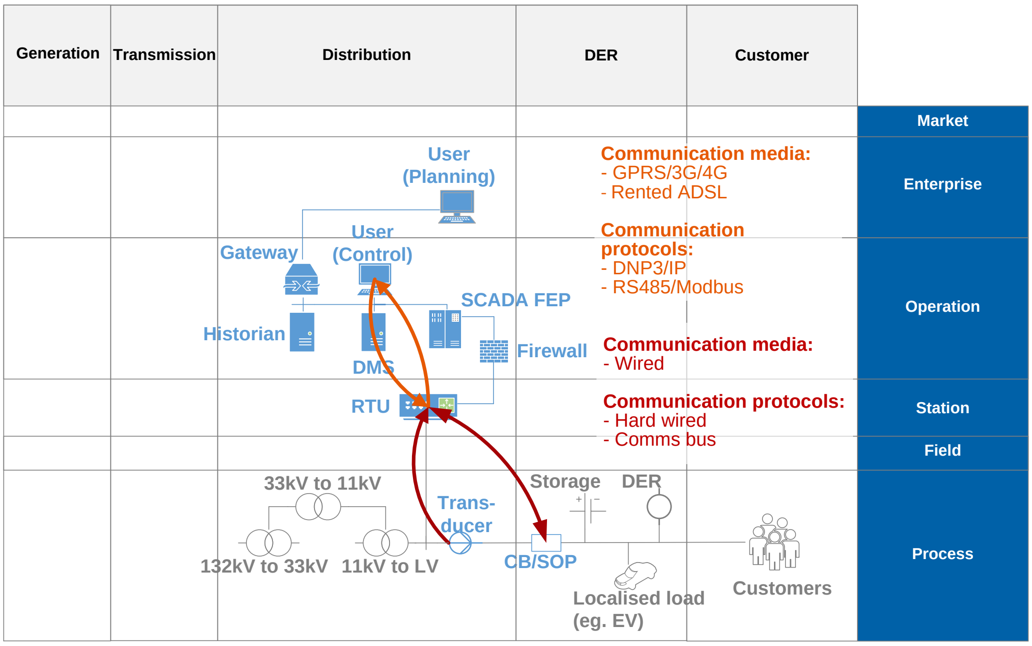
						» The remote monitoring of fused link box interconnections can confirm the integrity of the connection and give early indication of potential network problems.
10	**Photovoltaic Impact on Suburban Networks**	Western Power Distribution	LCN Fund Tier 1	November 2012	November 2013	» How to measure and capture voltage, current, harmonic, real and reactive power data on a range of distribution assets in suburban areas; » How to install equipment safely with minimal or no interruption of supply; » How often the network characteristics need to be monitored; » How to interrogate the large amounts of data generated to highlight significant network issues created by the installation of PV panels; » What the effect is of installing large numbers of PV panels on the LV network.
11	**CarConnect**	Western Power Distribution	Network Innovation Allowance	April 2016	October 2019	» The objective of this project is to equip GB Distribution Network Operators with the tools and solutions to enable them to manage PIV market growth by: » Assessing their (non-meshed) LV networks to predict which parts of their LV network will be susceptible to PIV penetration; » Determining whether PIV/V2G demand control services can be used to avoid or defer reinforcement; » Monitoring LV networks to detect PIV charger installation growth; » Procurement and deployment PIV/V2G demand control solutions as soon PIV induced LV network stresses arise.
12	**LV Connect & Manage**	Western Power Distribution	Network Innovation Allowance	March 2016	April 2019	» The objectives of this project are to trial and demonstrate the following: » Broadband over powerline, providing the communications solution between distribution substations and customers (enabling the bi-directional power flow control of LCTs); » ANM solutions with intelligence distributed into the LV network to monitor and control LCTs in

						real-time and optimize import / export patterns within operational limits; » ANM solutions, as a short or long term alternative to network reinforcement, in areas where network constraints are becoming a problem due to the localized uptake of LCTs; » New business processes, based on proven, off-the-shelf technology, which can be quickly and cost effectively deployed to connect and manage LV customers' LCTs.
13	**Understanding Networks with High Penetrations of Distributed Generation and other Low Carbon Technologies**	Western Power Distribution	Innovation Funding Incentive	April 2010	March 2013	» Identification of changes required to conventional network design to maximise the penetration of micro generation and other LCTs; » Understanding the effect of increasing generation output from a cluster of micro generation on the distribution network, in particular thermal rating, voltage rise and fault level; » Understand the effect of increasing demand from clusters of LCTs and other likely domestic climate change adaptation technologies on the distribution network. In particular voltage drop, flicker and power factor; » Ability to ensure that any modified design also reduces network losses.

6.9 Technical description of the system

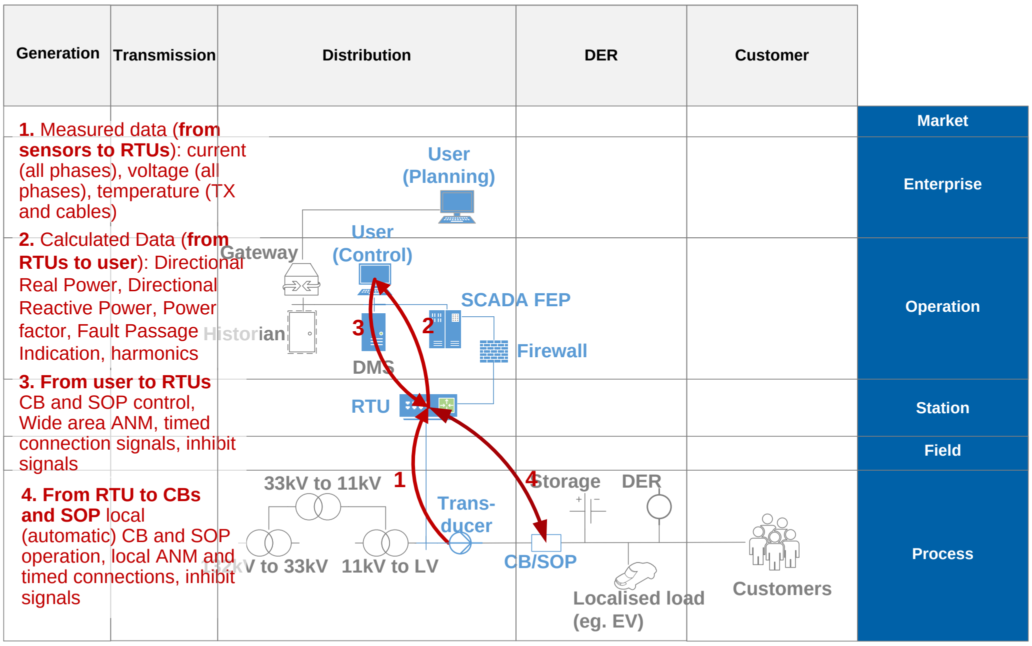
6.9.1 Additional Smart Grid Architecture Model (SGAM) layers of the proposed solution

Communications



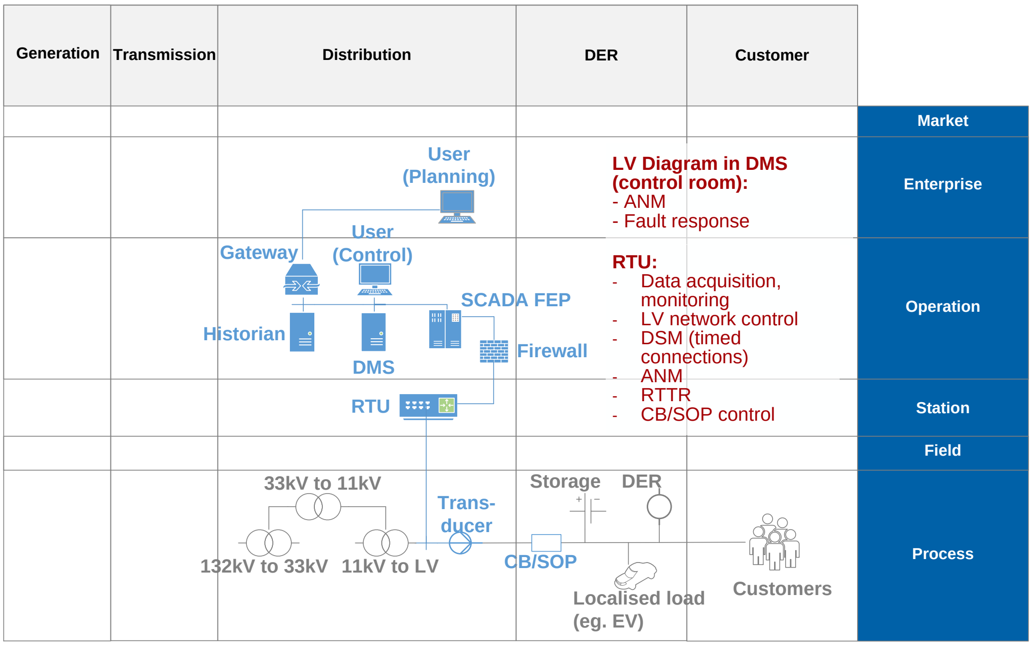
The VTs, CTs and temperature sensors will collect data from the feeders, which will be transmitted to the control room via standard SCADA connections, including wired and wireless options, depending on options available at each secondary substation.

Information



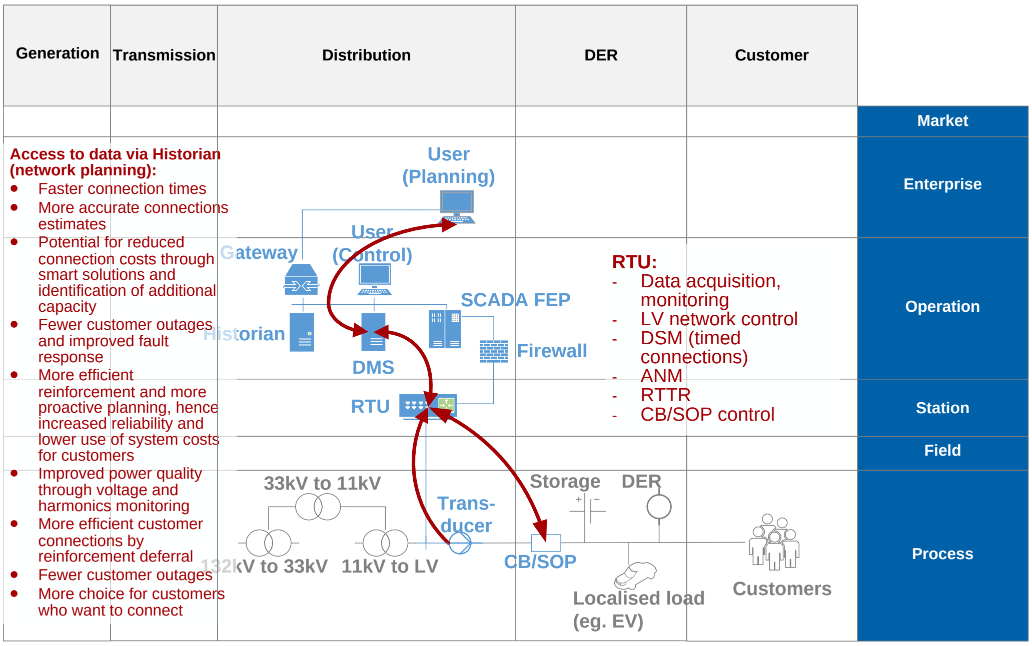
Current, voltage and temperature will be measured at each feeder and transmitted via SCADA to the control room. The control room will be able to issue control signals to "smart" network control devices such as switches and soft open points via the RTUs.

Function (Capacity Management and Connections Management)



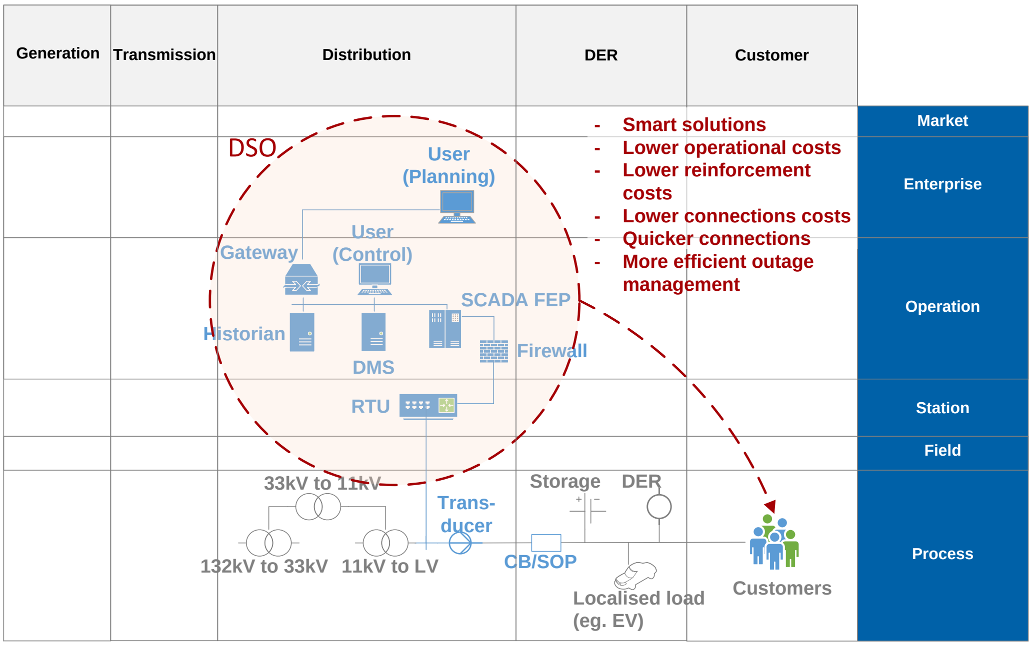
For offline analysis in the context of network planning, queries will be ran by planning engineers using data stored in the data historian. Planning engineers will also have access to offline versions of the DMS to review the LV connectivity model.

Function (Network Operations)



For real-time control room operation, control engineers will review data in the control room using the DMS. At the same time, control signals can be issued to "smart" network control devices using the RTUs.

Business



The LV Network Management System will enable DSO capabilities and offerings such as Active LV Network Management, and Timed Connections. Ultimately, the customers will realise benefits from more efficient connections, and more efficient network planning and operation.

6.9.2 Live LV Network Diagram specifications

The global functional specification of the LV diagram will be as follows:

- The LV diagram shall show a representation of the EPN, LPN, and SPN networks in the control room;
- The LV diagram shall be integrated into the PowerOn Advantage DMS;
- The LV diagram shall enable LV load flow and outage scenario analysis in the control room;
- The LV diagram shall enable job management for LV outage restorations and compatibility with the Outage Management System (OMS);
- Network data shall be displayed or hidden as specified by the control engineer; and
- Control room engineers shall have control over how they are notified of alarms relating to the LV network.

The extent of the LV diagram representation will be as follows:

- Three-phase LV feeder representation from the secondary transformer to the end of the feeder or to the normal open point;
- Secondary transformers shall be shown, including connectivity with the 11kV network;
- The location of customer connection points shall be shown, but real-time demand data for residential customers shall not be shown until control room access to smart meter data becomes available; and
- The point of connection of electric vehicle charging points shall be shown on the LV diagram.

The LV diagram will display the following network information at 10-minute intervals, unless real-time information is requested by control engineers:

- Individual phase voltage;
- Individual phase current;
- Directional real power;
- Directional reactive power;
- Power factor;
- Fault passage indication;
- Load thresholds;
- Current and voltage harmonics; and
- Secondary transformer and ambient temperature.

The LV diagram will enable the following control options:

- SCADA-enabled circuit breakers;
- SCADA-enabled soft open points; and
- Curtailment of LV-connected generation or demand by agreement with customer.

The LV diagram will enable the following automation:

- LV automatic network management schemes based on loading thresholds and wide-area LV network monitoring data; and
- Algorithmic restoration of outages using APRS.

The LV diagram data storage requirements:

- Data transmitted from the LV network will be available in the PowerOn Advantage DMS and will be stored on a UK Power Networks Historian server. Data will be retained for offline analysis for a time duration that is in accordance with UK Power Networks data retention policy.

6.9.3 RTU specifications

In addition to the standard requirements and approvals required for UK Power Networks substation, LV Wall Mounted Distribution Boards, Cabinets and Pillars installation, the functional specification of the RTUs are defined in internal Engineering Design Standard EDS 05-9003 "UK Power Networks RTU Specification", as well as in EDS 08-5040 "Guidelines for The Provision of System Monitoring".

We outline below the list of specifications:

1. The RTUs will connect to the following transducer inputs:

   - CTs;
   - VTs; and
   - Temperature Sensors.

2. Operational RTUs will provide local control, remote control and monitoring for LV switchgear and LV distribution boards.

3. The RTUs will connect to the following outputs and two-way communications interfaces:

- Alarms;
- Inhibit signals;
- Constraint signals; and
- Network control for smart CB and SOP devices (e.g. FUN-LV).

4. The RTUs will be capable of measuring from their transducer inputs:

   - Individual phase voltage;
   - Individual phase current;
   - Directional real power;
   - Directional reactive power;
   - Power factor;
   - Fault passage indication;
   - Secondary transformer and ambient temperature; and
   - Load thresholds to enable Timed Connections and LV ANM.

Document Number: EDS 05-9003
Version: 2.0
Date: 23/06/2014

ENGINEERING DESIGN STANDARD

EDS 05-9003

UK POWER NETWORKS RTU SPECIFICATION

Network(s): EPN, LPN, SPN

Summary: This specification covers all RTU types for use in UK Power Networks from 132kV to LV

Owner: James Ford **Date:** 23/06/2014

Approved By: Steve Mockford **Approved Date:** 29/10/2014

This document forms part of the Company's Integrated Business System and its requirements are mandatory throughout UK Power Networks. Departure from these requirements may only be taken with the written approval of the Director of Asset Management. If you have any queries about this document please contact the author or owner of the current issue.

Circulation

UK Power Networks	External
☐ All UK Power Networks	☐ G81 Website
☒ Asset Management	☐ Contractors
☒ Capital Programme	☐ ICPs/IDNOs
☒ Connections	☐ Meter Operators
☐ HSS&TT	
☒ Network Operations	
☐ UK Power Networks Services	

Document Number: EDS 08-5040
Version: 1.0
Date: 31/10/2016

ENGINEERING DESIGN STANDARD

EDS 08-5040

GUIDELINES FOR THE PROVISION OF SYSTEM MONITORING

Network(s): EPN, LPN, SPN

Summary: This document provides guidance on the requirements for System Monitoring across UK Power Networks licence areas.

Owner: Matthew White / Lynne McDonald **Date:** 31/10/2016

Approved By: Barry Hatton **Approved Date:** 01/12/2016

This document forms part of the Company's Integrated Business System and its requirements are mandatory throughout UK Power Networks. Departure from these requirements may only be taken with the written approval of the Director of Asset Management. If you have any queries about this document please contact the author or owner of the current issue.

Applicable To

UK Power Networks	External
☐ All UK Power Networks	☐ G81 Website
☒ Asset Management	☐ Contractors
☒ Capital Programme	☐ ICPs/IDNOs
☒ Connections	☐ Meter Operators
☐ HSS&TT	
☒ Network Operations	
☐ UK Power Networks Services	
☐ Other	

Figure 15: Our internal engineering standards for RTUs and network monitoring (EDS 05-9003 and EDS 08-5040)

5. The RTUs will also be capable of measuring the following from their transducer inputs, although this capability may not be used at first:

   - Voltage Harmonics up to 23rd harmonic; and
   - Current Harmonics up to 23rd harmonic.

6. The RTUs will have the following power requirements:

   - Connection to normal LV board; and
   - UPS battery back-up power to enable monitoring and control following power outage.

7. The RTUs will enable transmit data to the PowerOn Advantage DMS and the Historian database server via standard UK Power Networks SCADA connections including wired or wireless options depending on options available at each RTU location:

   – GPRS/3G/4G; and
   – Rented ADSL for LPN sites that are underground and cannot get a GPRS/3G/4G signal. Provided by Exponential-e.

8. The RTUs will be equipped with the following substation communications protocols:

   – DNP3/IP; and
   – RS 485/Modbus.

6.9.4 Roadmap for future "smart" network control solutions

We expect that over time, the list of "smart" network control solutions will increase as more solutions become mature, both technically and commercially. We are currently planning of specifying four additional "smart" solutions for development in the mid-term (see Figure 16).

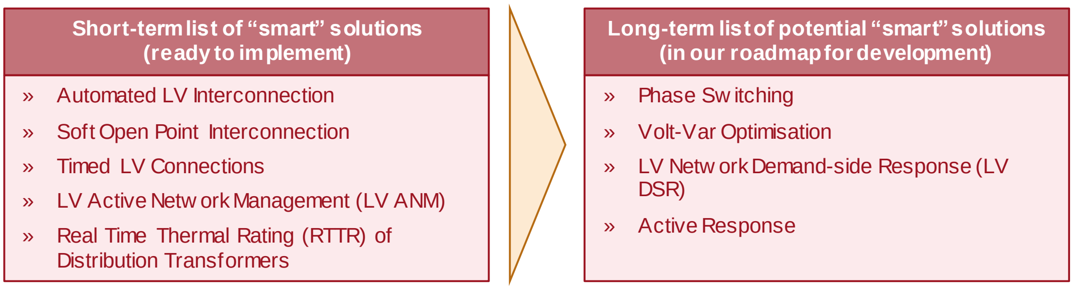


Figure 16: "Smart" network control solutions roadmap

<u>Phase Switching</u> is the management of customer load across LV feeder phases using power electronic devices, or physical service phase swapping, where appropriate;

<u>Volt-Var Optimisation</u> is the process of optimally managing voltage levels and reactive power to achieve efficient network operation and reduction of system losses;

<u>LV Network Demand-Side Response</u> (LV DSR) is dispatchable demand turn-down at LV connections using a remote management and control system, which leverages dynamic time-of-use pricing; and

<u>Active Response</u> is the use of automated power electronic devices at low and high voltage levels, combined with an advanced automation and optimisation system, which enables increased network meshing where it is not currently possible; UK Power Networks has submitted a bid to the 2017 Network Innovation Competition to trial Active Response; the bid has successfully passed the Initial Screening Proposal stage (ISP).

6.10 Support letters from stakeholders and customer groups

6.10.1 Greater London Authority (GLA)

MAYOR OF LONDON

David Boyer
Innovation Lead
UK Power Networks
Newington House
237 Southwark Bridge Road
London
SE1 6NP

26 May 2016

Dear David,

I am writing to express my support for the UK Power Networks Smart Visibility and Control – Innovation Rollout Mechanism Submission 2017.

The Mayor believes poor air quality is not only a public health issue but a matter of social justice. We currently estimate over 9,000 Londoners are dying prematurely from long-term exposure to air pollution every year and our latest research shows that 25% of schools in the capital are in areas exceeding safe legal pollution levels.

We also want to establish London as a Zero Carbon City by 2050 and a leader in low-carbon innovation and industry. We have an ambitious plan to create an integrated low carbon energy system as part of this, which will reduce and manage energy demand in buildings, use heat networks and large-scale heat pumps for grid balancing and storage, increase the use of local and renewable energy sources and accelerate the uptake of ultra low emission vehicles.

It is imperative that London's low voltage network is capable of delivering this ambition. Demand on the network will increase as we move towards 2050 and this means making the most of opportunities such as those being put forward by UKPN as part of your Innovation Rollout Mechanism Submission 2017. We also need to urgently address the significant financial and practical burden placed on Transport for London and its delivery partners as they rollout vital electric vehicle charge points in the capital, which largely stems from a very limited level of low voltage network visibility.

In all, I believe the investment in the project you are proposing will help to develop an integrated energy system that can deliver secure, affordable and ultimately zero carbon energy to our residents, businesses and transport system.

Yours sincerely,

S A Rodrigues

Shirley Rodrigues
Deputy Mayor for Environment and Energy

City Hall, London, SE1 2AA • mayor@london.gov.uk • london.gov.uk • 020 7983 4000

6.10.2 Cambridge Council

My ref: UKPN_IRM_001

Date: 27th May 2017

Contact: Sheryl French
Direct dial: 01223 728552
E Mail: Sheryl.French@cambridgeshire.gov.uk
Emma.Davies@cambridge.gov.uk

Cambridgeshire County Council

Economy, Transport and the Environment

Energy Investment Unit

Box SH 1315
Shire Hall
Castle Hill
Cambridge
CB3 0AP

Tel: 01223 728552

James Watson and David Boyer
UK Power Networks
Innovations Team

Dear James and David,

Thank you for the very informative presentation and discussion on the 2017 Innovation Rollout Mechanism.

TO WHOM IT MAY CONCERN

On behalf of Cambridgeshire County Council's Energy Investment Unit and Cambridge City Council, we are delighted to offer our support for UK Power Networks' submission to the Innovation Rollout Mechanism 2017.

As local authorities we have seen first-hand the significant growth in demand for electric vehicle charging points, both from our residents and from fleet operators. This is a development which we strongly support, and we are highly committed both to reducing harmful emissions and embracing the economic benefits of a low carbon economy. But we know that the increase in the number of electric vehicles is not without its challenges and we have concerns that the distribution networks will come under further stress.

We are working closely with UK Power Networks to identify the right locations for electricity storage and distributed generation, but it is clear that at some stage in the future investment will be required in the electricity network if we are to be able to use these fast-emerging low carbon technologies to their full potential.

Cambridgeshire is in the middle of a rapid growth phase, with 6,500 of new homes and commercial space planned in new settlements in the Waterbeach Barracks, a 10,000 home garden city at Wisbech and thousands of new home at Northstowe alongside those planned or under development around the Cambridge fringes. This is a tremendously exciting time for Cambridge and the County and we want to ensure our new developments are fit and ready for a low carbon future.

For both local authorities, one of our key challenges is to be able to understand how the availability of network capacity aligns with development for our region. We recognise that the solution proposed by UK Power Networks supports our ambition to be informed and better able to meet the demands of our residents and businesses. We look forward to working with UK Power Networks so that we better enable the move to a low carbon economy.

Having considered the merits of this project, we believe the project is essential if we are to continue to meet the demands of our population for low carbon technologies, be it electric vehicle charging points, renewable energy or the growing market for domestic electricity storage. We very much hope you will give this proposal your support and look forward to working with UK Power Networks if it is given your consent to proceed.

Yours Sincerely,

Sheryl French — Project Director, Energy Investment Unit, Cambridgeshire County Council

and

Emma Davies — Senior Sustainability Officer (Design and Construction) Cambridge City Council

CAMBRIDGE CITY COUNCIL

6.10.3 Greater Cambridge Greater Peterborough Enterprise Partnership

GREATER CAMBRIDGE
GREATER PETERBOROUGH
ENTERPRISE PARTNERSHIP
DEFINING THE FUTURE

David Boyer
UK Power Networks
Newington House
237 Southwark Bridge Road
Camberwell
London SE1 6NP

To whom it may concern

I write on behalf of the Greater Cambridgeshire Greater Peterborough Local Enterprise Partnership to offer my wholehearted support to UK Power Networks' submission to the 2017 Innovation Rollout Mechanism. GCGP LEP in partnership with New Anglia LEP and Hertfordshire LEP have created the Low Energy East project and network. Collectively we are researching and assessing the potential for local energy generation, distribution, use, storage and supply across our combined 34 local authority, 5 county area so the UK Power Networks' proposed work dovetails perfectly. This work is funded by the Department for Business, Energy and Industrial Strategy.

Having met the UK Power Networks team for this project in person and studied their proposals, I am confident that this investment will reap dividends in supporting our purpose to drive forward sustainable economic growth in the region.

One of the critical challenges that we face is building the evidence base to demonstrate how demands on the electricity network are changing with the rise of low carbon technology. We believe that UK Power Networks proposal marks a hugely important step forward in furthering our understanding by collecting data on this issue and better pinpointing long-term investment for economic growth.

Our area is currently home to 1.3 million people, 700,000 jobs, 60,000 enterprises and generates £30 billion per annum. I would urge you to note the support of business and enterprise and hope this important project can progress.

Signed by

R Bourgeois

Paul Bourgeois – Head of Sustainability and Local Energy East project lead

Date: 26th May 2017

GCGP.CO.UK @YourLEP Your Local Enterprise Partnership

T: 01480 277180 E: info@gcgp.co.uk Company Registration No. 07553554
Unit 3, The Incubator, Alconbury Weald Enterprise Campus, Alconbury Airfield, Huntingdon, Cambridgeshire PE28 4WX

6.10.4 Imperial College London

Imperial College London

Imperial College London
Department of Electrical and Electronic Engineering

Room 1103
South Kensington campus
London SW7 2AZ, UK
Tel: +44 (0)20 7594 6169 Fax: +44 (0)20 7594 6282

g.strbac@imperial.ac.uk
www.imperial.ac.uk/controlandpower

Prof Goran Strbac
Chair in Electrical Energy Systems

28 May 2017

To Whom It May Concern

Application to Innovation Roll-Out Mechanism
UK Power Networks - LV Network Visibility and Control

I am very pleased to have the opportunity to write and express my strong support of the UK Power Networks' submission to the 2017 Innovation Rollout Mechanism.

Imperial College London has completed extensive research and modelling in the area of the developing smart electricity networks, the role of networks in enabling the low carbon transition and the importance of the emerging the Distribution System Operator. This research has provided evidence across the industry and government regarding the major challenges and opportunities for cost effective energy decarbonisation, including the Department of Business, Energy, and Industrial Strategy[1], the National Infrastructure Commission[2], and the Committee on Climate Change[3].

Electrification of segments of heat and transport sectors will place new electricity demands on the low voltage networks. For this reason I strongly believe that the low voltage system is indeed set to be the next, major focus area for the whole energy system, much as HV and EHV networks have needed to respond to the rapid uptake of distributed renewable generation in recent years.

Given very limited level of LV network visibility today and the high level of uncertainty associated with uptake of low carbon technologies, in case that DNOs take a reactive approach in responding to network constraints, this would lead to a slower uptake of low carbon technologies, in-efficient reinforcement costs, and reduced network performance. In the face of this challenge, I concur with UK Power Network's assessment of the strategic options for responding, and that both visibility and smart low voltage networks are essential to an informed and effective response. Clearly, this initial and targeted deployment of monitoring in the LV networks will facilitate proactive network control and planning, including application of advanced

[1] "Analysis of electricity system flexibility for Great Britain" (report for BEIS, 2016),
[2] "Delivering future-proof energy infrastructure" (Report forNational Infrastructure Commission, 2016)
[3] "Value of Flexibility in a Decarbonised Grid and System Externalities of Low-Carbon Generation Technologies" (report for Committee on Climate Change, 2015)

Imperial College of Science, Technology and Medicine technologies thus releasing capacity that is currently unavailable due to the lack of time series data, leading to deferral of network reinforcement for capacity-constrained LV substations.

In addition to supporting efficient low voltage capacity, I also concur with the range of wider benefits noted by UK Power Networks in their submission as enabled through the solution. Clearly, understanding the opportunities for management of distribution network losses will require data on power flows in the low voltage networks, as distribution losses occur to a great majority in that network. The system proposed by UK Power Networks will also be essential for any DSO model involving low voltage customers participating in flexibility programmes.

Having reviewed the full scope and strategy of UK Power Networks proposed rollout, and discussed the cost benefit analysis modelling in detail with UK Power Networks, I can confirm the full support of Imperial College for this investment as an important, least-regret solution for achieving a cost-efficient transition to low carbon energy system.

Kind regards,

Goran Strbac

Prof Goran Strbac

Imperial College of Science, Technology and Medicine