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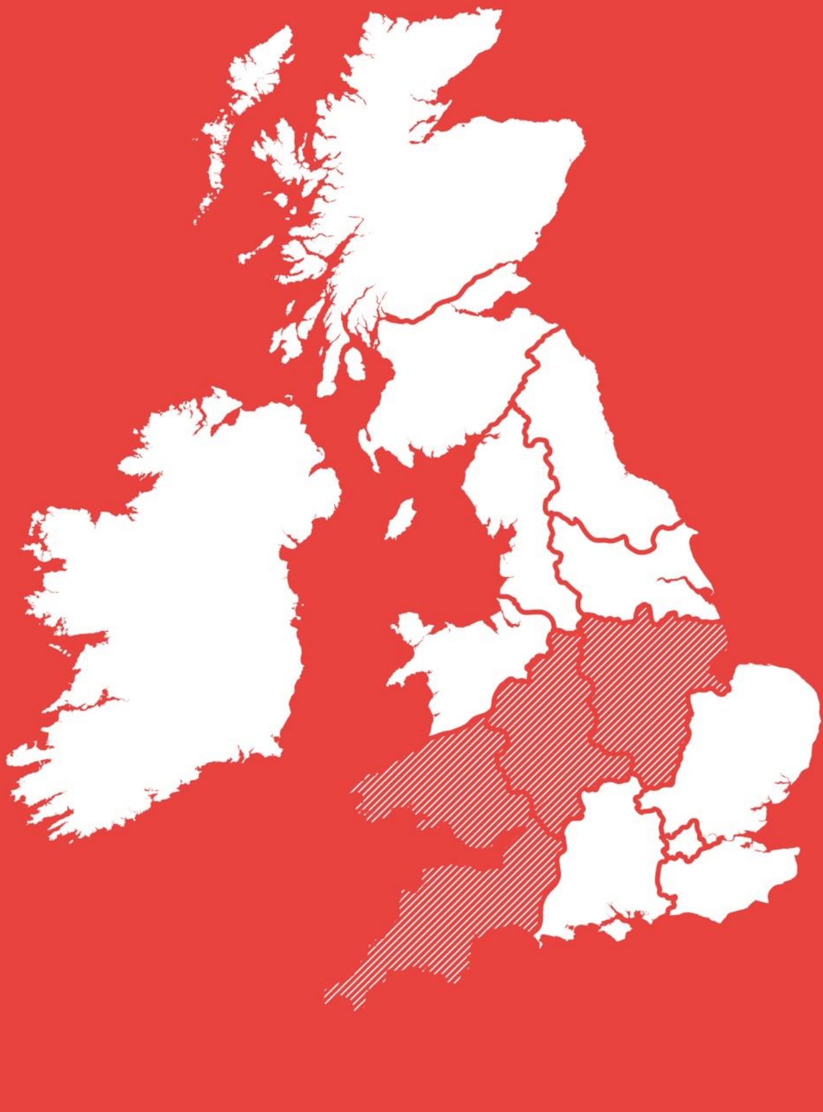
OPENLV

OPENING UP THE SMART GRID



SDRC 5

Knowledge Capture, Dissemination and Transferring the OpenLV Solution to Business as Usual

ea technology

RIIO NIC NETWORK INNOVATION COMPETITION

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Glossary

Term	Definition
ANM	Active Network Management
App	Application
APT	Advanced Persistent Threat
BAU	Business-as-Usual
CBA	Cost Benefit Analysis
CI	Customer Interruptions
CIA	Confidentiality, Integrity and Availability
CIRED	International Conference on Electricity Distribution
CML	Customer Minutes Lost
CSE	Centre for Sustainable Energy
CVSS	Customer Vulnerability Score System
DECC	Department for Energy and Climate Change
DER	Distributed Energy Resources
DNO	Distribution Network Operator
DSM	Demand Side Management
DSO	Distribution System Operator
DUoS	Distribution Use of System
EV	Electric Vehicle
GB	Great Britain
LCNI	Low Carbon Network Innovation
LV	Low Voltage
LV-CAP™	Low Voltage Common Application Platform
NaFIRS	National Fault and Interruption Reporting Scheme
NIC	Network Innovation Competition
NPV	Net Present Value
Ofgem	Office of Gas and Electricity Markets

Term	Definition
PV	Photovoltaics
R&D	Research and Development
RIIO-ED1	RIIO (Revenue = Incentives + Innovation + Outputs) – Electricity Distribution 1 (Ofgem price control framework)
RTTR	Real Time Thermal Rating
SAVE	Solent Achieving Value from Energy Efficiency
SC	[Future Energy] Scenario
SDRC	Successful Delivery Reward Criterion
SSEN	Scottish and Southern Electricity Network
TEC	Tamar Energy Community
TOTEX	Total Expenditure
Tx	Transformer
WPD	Western Power Distribution

Executive Summary

Background

The OpenLV Project trials an innovative new open access platform that was developed by EA Technology.

The OpenLV Platform

- **Enables Open Data**
- **Hardware and Software agnostic**
- **Decentralised analysis and control**

Uniquely, the OpenLV Platform provides a substation monitoring and operating system (EA Technology's LV-CAP™) that has been designed to be hardware agnostic and, in a method analogous to a smartphone, to be able to host multiple apps.

The trial system allows hosted apps to share monitored data and each other's outputs. LV-CAP™ was designed so that calculations and decisions can be made locally, speeding up reaction times and reducing the amount of data that needs to be sent to central aggregation servers. It provides a secure environment for the maintenance and management of apps, while continuing to ensure the security of the electricity network.

In addition, it provides a cost-effective method to support recommendations made by the Energy Data Taskforce in their Strategy for a Modern Digitalised Energy System.

The OpenLV Project is funded through the Network Innovation Competition (NIC). It is led by EA Technology in partnership with Western Power Distribution (WPD). Commencing in January 2017, the project is scheduled to conclude dissemination and decommissioning activities in 2020.

The OpenLV trial

The OpenLV Project is seeking to prove the technology and assess how it enables benefits to the Distribution Network Operator (DNO), community groups, businesses, and academia.

This trial opened access to 100 Million data points from 80 substations.

The trial was organised to investigate:

- the benefits of decentralised analysis and LV network automation in **Method 1**;
- how OpenLV enables community action in **Method 2** of the trial; and,
- how OpenLV creates new opportunities for business and Academia in **Method 3** of the trial.

To achieve this, 80 trial platforms were deployed across WPD's four licence areas and were operational between December 2017 and February 2020.

Further information on the overall project can be found in the Full Bid Submission, along with previously published documentation and Successful Delivery Response Criteria (SDRCs) submissions, all of which are available on both the project website and WPD's Innovation page for the OpenLV Project [1]. This information includes full details and outcomes of the three project Methods, which can specifically be found in SDRC4 publications Method [2], Method 2 [3] and Method 3 [4] respectively.

Report Purpose

In this report we present the final results and learning from the OpenLV trial, with particular emphasis on the Project legacy, including:

- Recommendations for business as usual deployments of distributed intelligence platforms;
- Cyber-security requirements for safe use of distributed intelligence on the distribution network;
- Enduring development tools for businesses and community groups to develop their own applications; and,
- A 'Guidebook for Community Groups' to aid in understanding and effectively utilising network data.

We also present the findings of Cost Benefit Analysis (CBA) of an LV-CAP™ style deployment, primarily undertaken using EA Technology's Transform™ tool.

Key Findings

The cost benefit and economic analysis, presented in full in Section 3, separately explores the benefits of Distributed Intelligence for both networks and customers based on the use cases explored in the OpenLV Project. This analysis considers the benefits achievable were the solution to be widely deployed across the GB LV network, beyond WPD's licence areas.

We have undertaken a value stacking approach to our assessment of network benefits and have shown through our analysis that distribution networks are able to gain from the LV-CAP™ platform, through:

- Reduced network expenditure needed to maintain network constraints within statutory limits; and,
- Regulatory incentive rewards for the minimisation of customer interruptions and minutes lost (CI/CMLs).

The Transform Model, which is accepted by the industry as the leading tool to evaluate the merits of different network investment approaches, has been deployed to quantify the reduced level of network expenditure that can be achieved, under various future energy uptake scenario, through the LV-CAP™ platform and associated applications (or 'apps'). These apps being:

- Network capacity uplift through real time thermal rating (RTTR) of transformers:
    - The technical and commercial characteristics of the network capacity uplift solution/app have altered significantly over the course of the project from what was assumed at the outset, in the original OpenLV bid documentation economic analysis, but this has not adversely affected the overall potential benefits the platform can provide to the network. Utilisation of RRTR capability in a distributed intelligence platform can provide a proven transformer uplift of 25% without incurring significant costs associated with data transmission and asset monitoring.

- Demand Side Management (DSM) for Electric Vehicles (EVs):
    - As well as reduced network expenditure, we have calculated that the use of the LV-CAP™ platform with RTTR uplift application can reduce managed DSM charging events for EVs by 17% at peak weekday times, as based on data from the Electric Nation project [5], the world's largest EV smart charging trial. This is only one quantifiable way in which the LV-CAP™ platform can allow DNOs, customers and community groups to work more closely together to improve the customer experience.

An independent study considering CI/CMLs was later completed to assess a further LV-CAP™ deployable application:

- Pre-fault detection and fault prevention.

The summary of the cumulative benefits resultant from our value stacking assessment (see Section 3.2) are shown in Table 1 for two energy uptake scenarios. The figures shown represent net present value (NPV) of distribution network expenditure across Great Britain (GB) in discounted totex terms from 2020 to 2050. Through the combined impact of all value stacking apps considered, an overall reduction in projected network expenditure is shown. This is the overall calculated net benefit of distributed intelligence platforms across GB.

Table 1: 2020 to 2050 NPV forecast of network expenditure with stacked uplift, DSM and fault prevention apps (inc. dedicated fault prevention installations)

Transform setting and applications evaluated	Fast low-carbon transition	Slow low-carbon transition
Standard	£15,123m	£13,528m
+ Uplift solution available	£15,713m	£13,277m
+ DSM enabled for EVs	£14,826m	£13,138m
+ Fault prevention app installed	£14,451m	£12,794m
+ Fault prevention hardware and application on wider LV network	£13,319m	£11,644m
Net benefit	**£1,804m**	**£1,864m**

Wider roll-out of Distributed Intelligence platforms has the potential to reduce network expenditure by at least £1,804 million by 2050, without leveraging all potential value streams that would be reasonably expected to be available once the platform was widely deployed.

Network benefits of LV-CAP™ between £1.80 to 1.86 billion.

As LV-CAP™ is fundamentally an open platform, designed from the outset to avoid the issue of vendor lock-in, new applications and sources of value will emerge through time from across the industry, although the precise nature of these apps cannot be known in advance.

Significant interest in developing applications and services to utilise distributed intelligence platforms was indicated by the industry supply chain, with a willingness to commit Research and Development funding, once clarity from DNOs regarding likely requirements and associated procurement processes is available.

Such development will also require certainty on the ongoing availability of data to ensure continuity of service by any application developed and deployed; ideally such a commitment will be provided by the industry as a whole rather than individual DNOs.

Examples of additional value that can be leveraged from the deployment of such devices include assisting community groups in planning local developments within the existing capacity constraints of the LV network, significantly accelerating the delivery schedule and reducing cost.

To facilitate the development of appropriate hardware platforms by multiple vendors, four key operational tiers (or use cases) for the deployment of distributed intelligence platforms have been defined, detailing the minimum recommended capabilities of the overall system to be deployed, encompassing scenarios from basic monitoring by exception through to self-contained LV Automation platforms.

In all conceivable use cases and deployments considered, cyber-security is deemed to be paramount, with stringent security requirements recommended for all deployments of a distributed intelligence platform on the GB Distribution Network.

1 Introduction

1.1 Background

Great Britain has about 1,000,000 Low Voltage (LV) feeders; these have largely been designed and operated on a fit-and-forget basis for the last 100 years, but things are set to change. LV networks are expected to see radical change as we, as customers, alter our behaviour and requirements, stemming from the vehicles we drive, to the generation and storage devices we put onto and into our homes.

The technology trialled as part of the OpenLV Project provides a new, open and flexible solution that not only provides the DNO, community groups and the wider industry with data from the LV network, but also enables these groups to develop and deploy apps within LV substations through a common hardware platform. The OpenLV Project is seeking to prove this technology and assess how the provision of LV network data and the ability to develop and deploy apps can provide benefits to the DNO, community groups and the wider industry across GB.

Figure 1 summarises the data flows and functions that the OpenLV Platform enables.

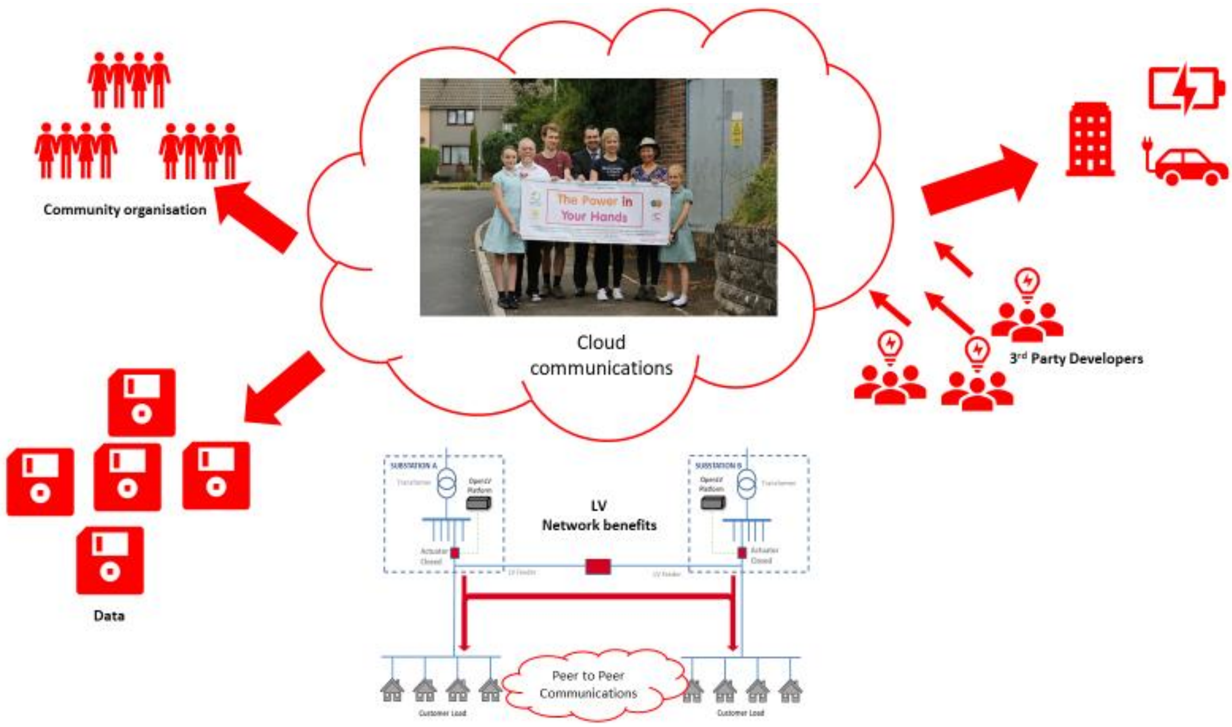


Figure 1: OpenLV Platform data interconnection

The OpenLV Platform:

- Allows local network measurement to be captured and shared into the cloud; and,
- Enables computer applications to be placed in local substations. These applications can be used to create local physical effects such as controlling network devices or local non-network devices, such as Electric Vehicles.

These applications can also be used to minimise the amount of data that needs to be sent by conducting local processing rather than continuous data streams. Once the data is in the cloud, there are features which allow the data gathered from the platform to be shared with communities, business's and the research sector.

Because of the containerised architecture of the applications that can be placed on the OpenLV Platform, this means that this platform can also help avoid vendor tie in for substation equipment, which helps maximise the value of monitoring units located within substations.

The OpenLV Project explored the impact of these capabilities upon stakeholders in the manner described in the next section.

1.2 Changing data landscape

Since the commencement of this project in 2017, there have been a large number of changes across the data landscape, both in the regulatory space and also the technical realm.

Of particular note, in 2019, the Energy Data Taskforce published their Strategy for a Modern Digitalised Energy System [6]. This document made five recommendations, detailed below:

- **Recommendation 1: Digitalisation of the Energy System** – Government and Ofgem should use existing legislative and regulatory measures to direct the sector to adopt the principle of Digitalisation of the Energy System in the consumers' interest.
- **Recommendation 2: Maximising the Value of Data** – Government and Ofgem should direct the sector to adopt the principle that Energy System Data should be Presumed Open, supported by requirements that data is 'Discoverable, Searchable, Understandable', with common 'Structures, Interfaces and Standards' and is 'Secure and Resilient'.
- **Recommendation 3: Visibility of Data** – A Data Catalogue should be established to provide visibility through standardised metadata of Energy System Datasets across Government, the regulator and industry. Government and Ofgem should mandate industry participation though regulatory and policy frameworks.
- **Recommendation 4: Coordination of Asset Registration** – An Asset Registration Strategy should be established to coordinate registration of energy assets, simplifying the experience for consumers through a user-friendly interface in order to increase registration compliance, improve the reliability of data and improve the efficiency of data collection.

- **Recommendation 5: Visibility of Infrastructure and Assets** – A unified Digital System Map of the Energy System should be established to increase visibility of the Energy System infrastructure and assets, enable optimisation of investment and inform the creation of new markets.

The OpenLV Project, is already promoting these aims in so far as it enables an open platform for inputting data into the energy system digital domain as well as making it open.

Furthermore, the trialled system was intended from the outset to enable sharing of data both within, and without the energy industry.

This project shares learning to show how these aims can be promoted even further and supports the findings from the strategy.

1.3 What did we do?

The OpenLV Project explored how the platform could change the experience of users through three distinct use cases, each demonstrating different elements of the platform's potential.

In order to do this LV-CAP™ equipment was installed in substations across WPD's license areas. Prior to each installation it was necessary to ensure that the substation was suitable (e.g. had sufficient mobile phone reception, provided a large enough space for the equipment to be installed and was not pole mounted).

It was also necessary to ensure that the substations chosen to test the network benefits of the technology provided a good cross-section of network load types. Figure 2 below shows the extent of the surveying process undertaken by the project.

Figure 2: Process to achieve project substation installations

Direct Network Benefits

This stream of the project sought to explore how the OpenLV Platform could increase the efficiency and effectiveness of LV networks through obtaining better capacity utilisation of existing assets or through improved information about how hard the network is operating. A summary of the processes undertaken is shown below in Figure 3.

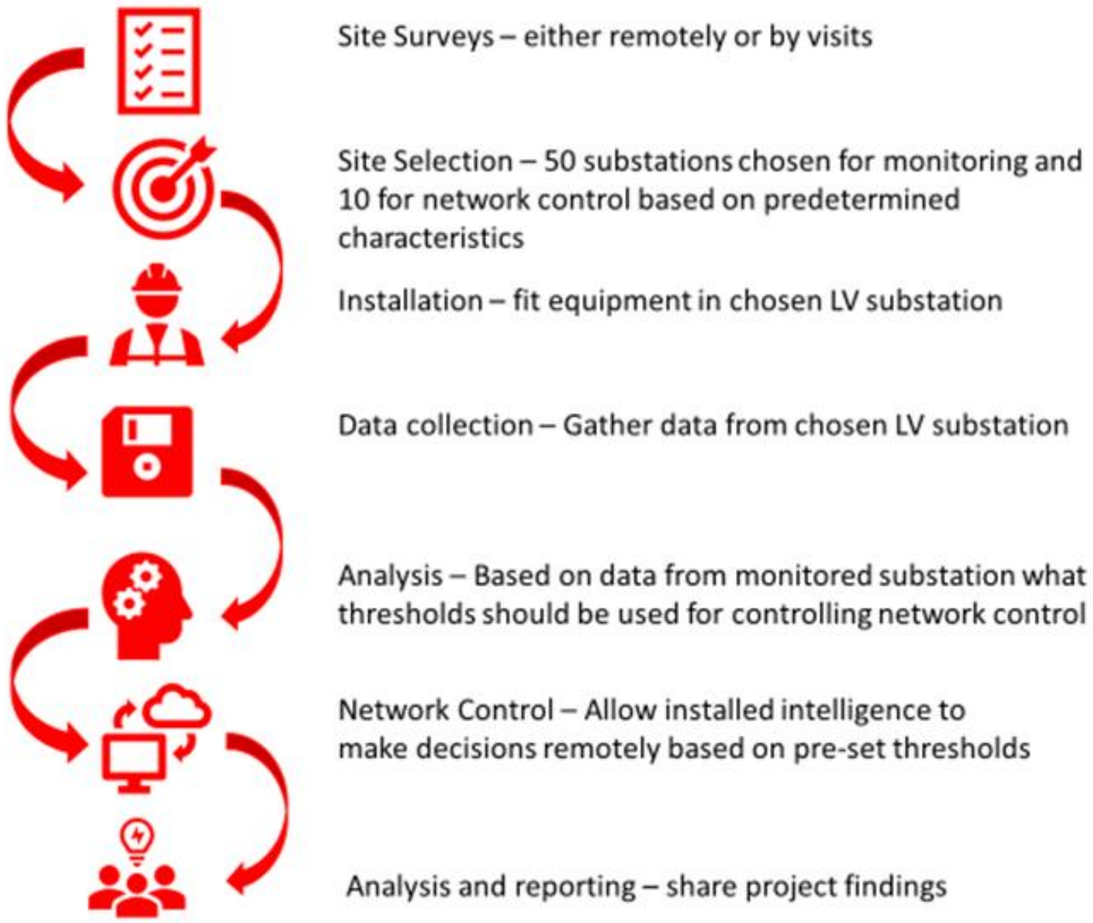


Figure 3: OpenLV investigated how the project approach could benefit LV networks

Engaging with Community Organisations

The second project use case sought to quantify the appetite among community organisations for access to LV network data and discover how they would use the information. Once it was confirmed there was an interest among community groups to access LV data, organisations were recruited, and a trial was undertaken. This process is summarised in Figure 4 below.

Figure 4: The OpenLV Project explored how community organisations could benefit from LV substation data

Engaging with businesses and academia

The third project use case sought to investigate the willingness of businesses and academia to develop apps for deployment to the platform, or to utilise the data that the platform made available. Figure 5 illustrates the process undertaken.

Figure 5: The Project team engaged with business and academia to see how they would benefit from LV substation data

1.4 Where did we do it?

The map below shows the geographical locations of the substations where OpenLV installed LV-CAP™ equipment, categorised visually according to what type of organisation was making use of the data (for example, the red pins denote that the installation was primarily to investigate the benefit of the technology to the network).

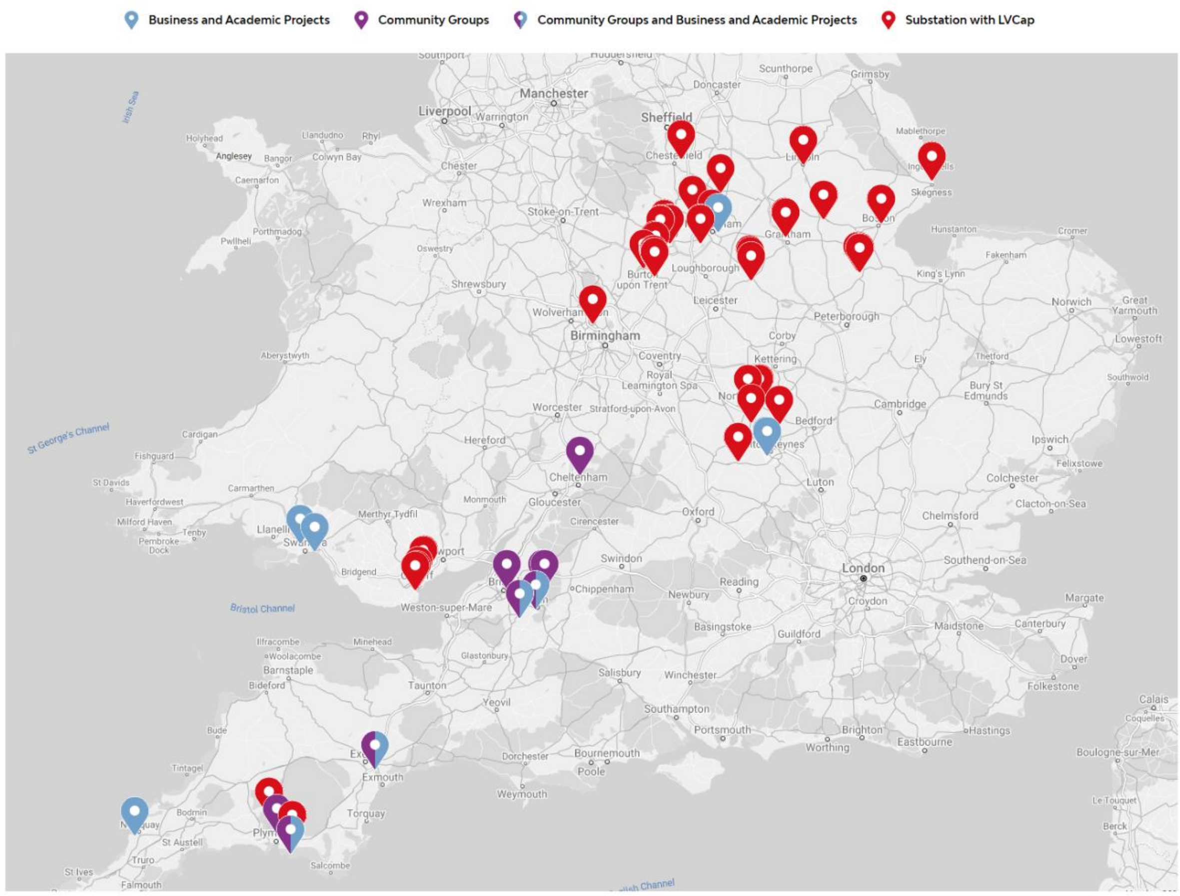


Figure 6: Geographical spread of OpenLV installations

The OpenLV technology was installed in 80 low voltage distribution substations located in WPD's licence areas – the Midlands, the South West and South Wales. The software could ultimately be deployed across the electricity network.

1.5 How much of it did we do

The infographics in Figure 7 and Figure 8 below illustrate the extent of interest that the project team were able to measure from community organisations and businesses and academia.

Figure 7: Extent of community organisation interest in the OpenLV solution

Figure 7 above shows that the project team recorded substantial interest from community organisations to use the data from OpenLV technology in their communities. The use cases, and summaries of how the groups who were selected to take part in the project used the data, together with findings from the trials is discussed in detail in SDRC 4, Method 2 report [3].

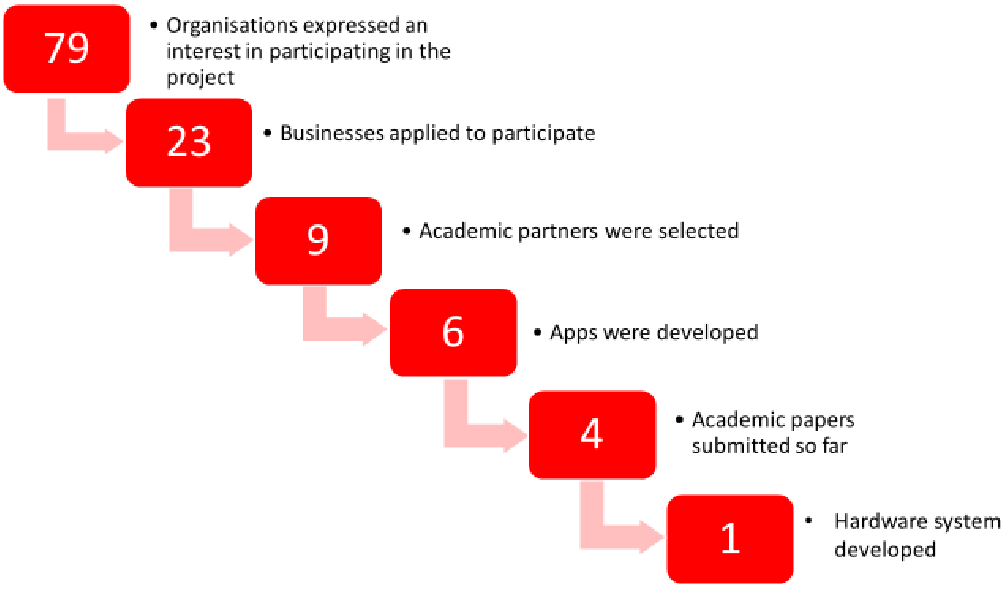


Figure 8: Extent of business and University interest in OpenLV

Figure 8 above summarises the quantifiable interest and outputs that the project team encountered from working with third parties during the trial.

1.6 Document Purpose

This report has been structured to meet the SDRC evidence criterion outlined in the OpenLV Project Direction [7]. The requirements for key project deliverables are defined as part of Network Innovation Competition Governance, with the associated evidence for each SDRC detailed in the Project Bid Documentation.

In this SDRC report we present the results and learning surrounding the following objectives:

- Summary of key project learning;
- Knowledge and learning dissemination reports and presentations;
- Network data being made available from each of the methods;
- Six-monthly progress reports submitted to Ofgem throughout the project;
- OpenLV Project presentations delivered at six industry conferences during the course of the project from March 2017 to June 2020;
- OpenLV Project presentations delivered at each of the Low Carbon Network Innovation (LCNI) conferences during the course of the project;
- Cost benefit analysis for each method;
- A summary of the training needs analysis required to enable roll out as part of Business as Usual (BAU);
- Recommendations for changes to system security ahead of wide scale deployment;
- A summary of changes that need to be made to the overall OpenLV solution to enable roll out as part of BAU;
- Delivery of the Loadsense App;
- Economic analysis / extrapolation for the Community Application Method 2; and,
- Enduring tools for community groups throughout GB to use beyond the end of the project.

1.7 Report Structure

The structure of this report is as follows:

- **Section ⍰: Key Learnings to date –** provides a summarised version of the key learnings from previous reports published by the project;
- **Section ⍰: Cost Benefit and Economic Analysis –** provides a cost benefit analysis of the potential value of the LV-CAP™ solution if it were to be adopted across GB;
- **Section 4: Training Needs Analysis -** outlines training requirements necessary to enable the OpenLV technology to be used in a business as usual context;
- **Section 5: Enduring Tools -** provides a summary of outputs from the project that are available as enduring tools to DNO, communities, businesses or Universities in the future;
- **Section 0: Business as Usual Specification –** provides a specification that could be used if a similar technology were to be adopted as business as usual;
- **Section 7: Cyber Security –** evaluation of the cyber security requirements necessary for a similar technology to progress to business as usual; and,
- **Section 8: Dissemination –** lists dissemination events attended, and marketing, recruitment and dissemination material produced by the project team.

2 Key Learnings to date

The table below summarises the main Project learning points to date, as covered in SDRCs previously published. It is split into three sections:

- **Technical Learning** covering learning about the network benefits of the technology, site selection and installation and cyber security;
- Learning from working with **Community Organisations** encompassing recruitment of community organisations, their technical capabilities and the level of support they require; and,
- Learning from working with **Business and Academia** including recruitment and support for third party app writers.

More in-depth learning can be found in each of the SDRC reports already published by the project [1].

Table 2: Summary of the overall Project learning

No.	Learning Point
1	**Technical Learning**
1.1	The OpenLV trial demonstrated that decentralised analysis and control (distributed intelligence) was capable of providing a robust and effective method of LV Network automation. This output was evidenced by the OpenLV trial platform automatically reconfiguring the LV network at times of simulated network stress, without any requirement for manual intervention.
1.2.	OpenLV demonstrated that there could be a significant capacity benefit from applying real time rating analysis to LV transformers rather than assigning a rating based on fixed or less periodic updates to rating assumptions. This benefit was estimated at 6,350MVA of capacity uplift across 39,500 of WPD’s 140,000 LV substations. Whilst it is possible, in theory, to implement this analysis using centralised computation, establishing sufficiently robust communications between central locations and large quantities of LV substations is an expensive undertaking, and would remain vulnerable to potentially harmful communications faults.
	Specification
1..3	It is important to ensure that hardware is designed to enable installation in multiple locations as the space available for hardware and the mounting requirements for the OpenLV Platform and associated LV monitoring hardware will vary on a site by site basis. Therefore, the OpenLV Platform was designed to be mounted using several approaches (magnetic, floor and wall mount).

No.	Learning Point
1.4	The sensors specified and the time intervals at which they are sampled will affect what applications are possible to run on the system and the effectiveness of their output. It may be desirable to over-specify sensors to provide for future application requirements, as well as providing additional 'stress-testing' of the trial system.
	Mobilisation
1..5	A dedicated test rig was built to enable testing of OpenLV Platforms in a controlled environment. The test rig includes relevant sensors (temperature, voltage and current) to provide data inputs to the test system. This test rig was built as early as possible within the programme to enable components to be soak tested for as long as possible prior to installation. Having a controlled test rig in a laboratory environment allows defined inputs (currents, voltages and temperatures in this case) to be applied and the outputs verified. Where necessary, scaling and unit issues can be resolved under laboratory conditions. This would be very difficult to achieve in a field situation on a live network.
	Installations
1.6	Extensive site surveys prior to site selection has greatly benefitted the installation process, with minimal problems encountered on-site. The investment of undertaking these detailed surveys prior to installation resulted in a plug-and-play approach once installation was scheduled.
1.7	The installation team took many photos at each substation after they had completed each installation. These were very valuable later to remotely identify and understand incongruities.
	Communications
1.8	Prior to installation it is essential to establish that there is adequate 3G/4G signal strength at a site to ensure reliable communications. If in doubt, then either avoid using the substation in the trials or, if unavoidable, deploy outdoor antennae to improve signal strength.
1.9	Monitoring of sites to ensure regular communications is occurring, with alarms to flag any issues, is invaluable. These alarms have allowed hardware issues, particularly with routers, to be detected and rectified promptly.
	Cyber Security
1.10	All conceivable use cases for a distributed intelligence platform have a maximum impact potential classified as 'Major'.

No.	Learning Point
1.11	Due to the inherent risks associated with integrating Distributed Intelligence platforms with the GB Distribution Network infrastructure, stringent control of access to system controls and digital signing of the measured and generated data is recommended for all deployments. Strong monitoring, system logging and automated detection and response controls is also required.
2	**Learning from working with Community Organisations**
2.1	Community organisations tend to have sparse resources available and may not be technically capable of developing software applications for their communities. The OpenLV Project realised this barrier early in the process, appointing the Centre for Sustainable Energy to support these community projects and the development of the app technology to assist in visualising the OpenLV data through the trial period.
2.2	Network topography meant that some community organisations required monitoring in more than one substation to be able to cover all the properties that they wanted data from (for example, it was necessary to monitor four substations to get all the data from Marshfield village). Some communities were unable to receive all the data they wanted – for example the project was unable to monitor all the substations that participating community groups would have liked because the Project only had a limited amount of equipment that it could allocate. Neighbourhood boundaries did not align well with substation and feeder layout.
2.3	Timescales can get pushed when dealing with community organisations. They generally are relying on volunteers so other priorities can take precedence.
2.4	Post-trial interviews with community groups provided evidence for how each group specifically used data from the app to create value. The general perspective was that the ability to discuss their energy use at the network level was transformative.
2.5	Those community groups that had a strong emphasis towards encouraging low carbon technology commented that “the data is not the driver”, rather a conversation opener or enabler.
	Recruitment
2.6	Having the Centre for Sustainable Energy and Regen, who are trusted and well known by community organisations, as part of the project team and acting as intermediaries for the OpenLV Project added to the projects credibility and made the initial ‘testing the market’ and recruitment stages more successful.

No.	Learning Point
2.7	The timing and timeframes of the recruitment period affected the total number of applications received.
	Support
2.8	Some community groups required more support to understand network configuration and terminology than was expected. Expertise and understanding of the data points and how to use them was also overestimated by the project and community groups themselves.
2.9	Some community organisations have required more support than was expected to configure the web app developed by Centre for Sustainable Energy, and to understand the data that they are receiving via it.
2.10	Training on the web app (webinars and 1:1 sessions) was valued, although some community organisations still found the web app difficult to use because of their existent knowledge and skill base.
3	**Learning from working with Business and Academia**
3.1	Asking commercial organisations to develop apps with their own funding for a research and innovation project was challenging as there was no certainty around the commercial viability of LV-CAP™ at the start of the project. Most organisations have a set development programme that is flexible, but companies are resistant to alter their R&D commitment unless they can justify it with a valid business case. A number of participants did commit their own R&D budgets to participant on this trial in the hope that they would demonstrate the interest in this platform as a means for suppliers to provide new services to the networks sector.
3.2	A number of the participant organisations put significant effort into developing apps that supported the transition to electric vehicles. These participants demonstrated how the platform could support a diversity of technological approaches to a problem.
3.3	By virtue of the trial participants being willing to develop apps that reside on 3rd party hardware it was perceived that this part of the trial demonstrated that the OpenLV Platform enables industry to overcome vendor tie-in that has been encountered on monitoring hardware traditionally present in substations.

No.	Learning Point
3.4	Academic participants suggested that access to shared data from across a wide sample of substations overcame perceived data barriers to independent network research.
3.5	The project team organised regular workshops; the first during the application process and subsequently at regular intervals during the project. The first workshop provided a vital opportunity to allow organisation to understand the project and technology. Subsequent workshops allowed the organisations taking part in the project to regularly meet with the project team (including personnel from WPD), share their experiences and find out what worked for other participant organisations. The workshops were all well attended and feedback from them was positive.
3.6	From a project management perspective, it was noted that a number of the participants were receiving research grants from elsewhere, and as a result the project obligations linked to those funding streams generally overruled the OpenLV ambitions because it was an unfunded trial. This created challenges to achieving the method 3 goals within the project timescales, as the OpenLV trials were time limited whereas for participating companies, without an immediate 'route to market', the project was a lower priority than other areas for investment.
	Mobilisation
3.7	The approach taken to signing up participants included the Memorandum of Understanding, Data Share agreement and trial design form. While the Data Share Agreement is a legal agreement with WPD, the other documents were not legally binding, but rather set out in easy to understand terms to explain the basis of the working arrangements between the project team and the participant organisations, reflecting that they were volunteering their time and efforts. Some organisations stated that they would like to gather more information before making a commitment to develop an app and commit resources to this purpose. The Guidance for Applicants documentation was therefore created to provide potential participants with further information on the project.
3.8	A number of organisations expressed concerns about giving up their ideas for potential apps. As a result, a Non-Disclosure Agreement has been utilised where applicable.

No.	Learning Point
3.9	Following receipt of 23 applications, the project team took the approach to work with as many organisations as possible to maximise learning, rather than just allocate a single OpenLV Platform to each applicant. This also enabled effective demonstration that multiple applications, from different 3rd parties can operate on the same OpenLV Platform.
	Technical Support
3.10	Although LV-CAP™ allows the use of a wide range of programming languages, it still imposes restrictions on the memory usage, processor usage and storage space available to applications. These restrictions must be clearly communicated to developers at an early stage. The main limit on the storage size of applications is the reliability and cost of deploying them to all required sites over mobile data networks.
3.11	The LV-CAP™ environment enables developers to write apps in any programming language. This has enabled the overall platform to be built up quickly and easily utilising apps developed by multiple vendors using various programming languages (C++, Java and Go) and approaches to developing those apps. Many applications were created to operate as standalone software containers, whereas others required communication from other, paired containers to operate. There were also multiple applications developed using IBM's Node-Red development tool.

3 Cost-Benefit and Economic Analysis

The OpenLV Project sought to demonstrate areas of benefit in three distinct use case areas, those being:

- Network Capacity Uplift:
  Demonstrating direct benefits are achievable for the network operator;
- Community Engagement:
  Demonstrating that community groups can utilise data from the platform to benefit themselves;
- OpenLV Extensibility:
  Demonstrating that the platform is capable of providing commercial potential to 3rd party businesses, and that businesses are willing to invest in such an endeavour.

These benefits have been determined to be replicable and scalable across GB and have been quantified through a range of means, depending on the particular use case being considered. It is important to note that in business focussed use cases (network capacity uplift and OpenLV extensibility), the benefits are calculated in terms of those received by the DNO, whereas when considering Community Groups, benefits have been considered which flow directly to the customer.

Initially, in Section 3.1 we will look at the replicability and scalability of the OpenLV Project across the GB LV network.

Next, in Section 3.2 we will look at network and commercial use cases, and analyse the benefits these approaches can bring DNOs across GB, exploring how the LV-CAP™ platform facilitates reduced network expenditure and required Distribution Use of System (DUoS) charges through the value stacking of numerous apps. This reduction in DUoS represents an indirect benefit to customers through reduced bills.

Subsequently, in Section 3.3 we will look at how, through community engagement, DNOs, customers and community groups can work more closely together to improve the customer experience.

3.1 Replicability and scalability of OpenLV

The OpenLV trial has sought to develop evidence with regard to whether the LV-CAP™ platform itself, and the use cases it has demonstrated, can be replicated and scaled beyond WPD's licence areas to the whole GB LV network.

3.1.1 Replicability

The first question, as to whether OpenLV benefits can be replicated across the wider distribution network, rests with hardware. The LV-CAP™ platform is intended to avoid vendor lock-in and is designed to be capable of deployment on any LV monitoring device that has been designed to be LV-CAP™ compliant. Therefore, when procuring LV monitoring devices and hardware, if DNOs were to specify that the devices should be compliant with

LV-CAP™ standards then this would overcome the first impediment to replicating the platform benefits.

The Network Benefits use case trials tested a number of network focused apps (see SDRC 4, Method 1 [2] for full details). These apps provided certain capabilities to the network. For example: a physical control capability, as illustrated by the network meshing trial; a local calculation capability, as illustrated by the transformer thermal modelling trial and RTTR app; and abilities for DNOs to obtain visibility of assets. The benefits associated with these apps would translate across DNOs. As an example, because DNOs all use a common rating standard for distribution transformers, the transformer rating app would provide national benefit.

The Community Groups use case trials demonstrated how the operations of community energy groups can be augmented through the use of network data (see SDRC, Method 2 [3]). The OpenLV trial has published a community energy app and a guide for how to gather these benefits. The guide and the app can be replicated across the country, providing there are interested community groups and an ability to share the network data in a format that is suitable for the Centre for Sustainable Energy app.

The Commercial trials (see SDRC 4, Method 3 [4]) investigated the attitudes of third parties who may seek to use the raw data from the LV-CAP™ platform for research, business processes or develop apps that sit upon substation platforms. While third party applications may be local in scope, it is expected they shall be replicable and national in scale. That is, as a local network platform, while third party developed LV-CAP™ apps will be designed to provide benefits to local communities and customers, such apps can likely be replicated and distributed across all LV-CAP™ platforms.

3.1.2 Scalability

The OpenLV LV-CAP™ architecture has been designed to be technically scalable. The OpenLV Project has also demonstrated how community engagement can be scaled through publication of a community energy data usage guide.

But, before the Methods tested across the OpenLV trial can be scaled, the commercial learning points from SDRC 4 Method 2 [3] and Method 3 [4] must be addressed to enable the entire value chain to be mobilised. These learning points include:

- DNOs start to procure LV measurement devices using specifications for LV substation monitors that have the open platform features and hardware capabilities that were demonstrated by the OpenLV trial. This would enable 3rd party apps to be loaded onto substation monitors. Deployment of apps to substation platforms enables local computation to facilitate local network benefit and reduce data transmission requirements. Failure to do this would perpetuate vendor tie-in of substation apps to manufacturer devices.

- As shown in the 3rd Party trials, there is a significant amount of interest from the industry supply chain in offering network analytical services that provide value to the DNO, but this is currently hampered by a lack of clarity. This is evidenced by a number of close down interviews which indicated suppliers would commit their R&D budget into developing apps if there was clarity with regard to how DNOs would go about signalling their requirements and procurement processes for these apps.
- Some app developers were interested in developing apps that would have a functionality to service the energy industry beyond the network sector. These developers, however, were unsure how and when DNOs would begin to share data across the LV network or even at higher parts of the network. To scale their effort the developers would need to understand and possibly ask to influence the DNOs' plans for roll out of network visibility.

3.2 CBA of Network Benefits and Commercial Trials

3.2.1 Introduction

The learning and outcomes from the Network Uplift and 3rd Party developer trials in the OpenLV Project can be examined to evaluate the benefits to networks derived from the LV-CAP™ platform and associated applications.

The LV Network Uplift trials concentrated on demonstrating equipment and applications to release transformer and feeder capacity on the LV network, hence the business case focuses on the amount of capacity that can be released and the relative costs of this action when compared to alternative techniques for resolving LV network constraints.

As such, the financial benefit can be calculated as the difference between network costs with an LV-CAP™ capacity release solution available, and without an LV-CAP™ solution available (i.e. utilising traditional reinforcement techniques and established smart solutions only).

This analysis uses the Transform Model, which is accepted by the industry as the leading tool to evaluate the merits of different network investment approaches and quantifies the likely cost saving over time that different approaches may yield. The Transform Model was used by all GB DNOs as part of their RIIO-ED1 business plan development and has received continuous support from Ofgem to date in order to ensure the tool remains accurate and up to date. The analysis is therefore based on the tool accepted by both network operators and the regulator as offering the best method to investigate scenario driven investment needs.

Meanwhile, the 3rd Party application trials show how having an open, low cost platform enables businesses and interested academic institutions to be able to offer services to the network operator and customers, or to use the available data to assist in furthering academic research and other use cases outside of the network sector. Here the economic analysis focuses on the deployment of additional apps to obtain benefits to the network.

The benefits that can be derived through these two approaches are inextricably linked as the network capacity realised by the LV Network Uplift trial is achieved via another app. Each LV-CAP™ app will be investigated in turn and value stacked on top of previous benefits to showcase the full potential of the LV-CAP™ platform.

In full, we have chosen three potential LV-CAP™ applications that possess scope for national deployment. These applications have been tested and demonstrated with the OpenLV trial and/or explored elsewhere. These applications are:

- Network capacity uplift (as demonstrated in Method 1);
- Demand Side Management for EVs; and,
- Pre-fault detection and fault prevention.

3.2.2 Network capacity uplift app

How the Transform Model was utilised to derive the financial benefits that can be achieved from the network capacity uplift application is complex. Additional information on the Transform Model's background and methodology is available in SDRC 4, Appendix 7 [2]. For our purposes, it is generally sufficient to understand that the Transform Model determines the optimal year-on-year investments (in NPV terms) and network interventions (both conventional and innovative) needed to maintain the network, given the solutions available to it to deploy and the future scenario for forecast load growth and Distributed Energy Resource (DER) deployment selected.

GB Transform 5.3, the latest approved model version in use by DNOs, is pre-loaded with eight future scenarios (SC1 to SC8) and over 100 potential solutions that may be deployed, from traditional network reinforcement to smart solutions (e.g. energy storage).

Future scenarios one to four (as numbered in Transform) are derived from the Department of Energy and Climate Change's (DECC's) past modelling work carried out for the Fourth Carbon Budget, utilising forecasts in the Government's Carbon Plan [8]. Later, Transform was updated to include scenarios five to eight which correspond to National Grid's more recent Future Energy Scenarios [9].An overview of the more up to date National Grid scenarios is shown in Figure 9.

Consumer Evolution (SC8)	
Electricity Demand	Moderate-high demand: high for electric vehicles (EVs) and moderate efficiency gains
Transport	Most cars are EVs by 2040; some gas used in commercial vehicles
Heat	Gas boilers dominate; moderate levels of thermal efficiency
Electricity supply	Small scale renewables and gas; small modular reactors from 2030s
Gas supply	Highest shale gas, developing strongly from 2020s

Community Renewables (SC5)	
Electricity Demand	Highest demand: high for EVs, high for heating and good efficiency gains
Transport	Most cars are EVs by 2033; greatest use of gas in commercial vehicles but superseded from mid 2040s by hydrogen
Heat	Heat pumps dominate; high levels of thermal efficiency
Electricity supply	Highest solar and onshore wind
Gas supply	Highest green gas development from 2030s

Steady Progression (SC7)	
Electricity Demand	Moderate-high demand: high for EVs and moderate efficiency gains
Transport	Most cars are EVs by 2040; some gas used in commercial vehicles
Heat	Gas boilers dominate; moderate levels of thermal efficiency
Electricity supply	Offshore wind, nuclear and gas; carbon capture utilisation and storage (CCUS) gas generation from late 2030s
Gas supply	UK Continental Shelf still producing in 2050; some shale gas

Two Degrees (SC6)	
Electricity Demand	Lowest demand: high for EVs, low for heating and good efficiency gains
Transport	Most cars are EVs by 2033; high level of gas used for commercial vehicles but superseded from mid 2040s by hydrogen
Heat	Hydrogen from steam methane reforming from 2030s, and some district heat; high levels of thermal efficiency
Electricity supply	Offshore wind, nuclear, large scale storage and interconnectors; CCUS gas generation from 2030
Gas supply	Some green gas, incl. biomethane and BioSNG; highest import dependency

Level of Decentralisation →

Speed of Decarbonisation →

Figure 9: Overview of National Grid Future Energy Scenarios

The technical and commercial characteristics of the network capacity uplift solution/application have altered significantly over the course of the project from what was assumed at the outset in the original OpenLV bid documentation economic analysis [10]. Likewise, the scenarios against which expected benefits have been calculated have also changed to reflect the more up to date National Grid scenarios, which were developed based on data seven years more current than the original four DECC scenarios. Therefore, as this has led to deviations between the projected benefits submitted for the project bid and the latest projections completed at the close of the project, we have revisited the original results before presenting our updated analysis and further explanation for the differences between them (see the following sections for further detail).

Forecast benefit pre-project

In the original bid, assumptions were made as to the technical and commercial characteristics of the network capacity uplift solution/application (see Figure 10). As shown in the comments of this figure, these assumptions were justified based on information available at the time.

		EHV	HV	LV	Comments
Solution Overview	Representative Solution:	**Uplift**			
	Variant Solution:	Uplift for LV transformers and cables			
	Description:	The use of measurement and ambient forecasting data to predict the rating (and hence current carrying capacity) of distribution transformers, combined with the ability to mesh downstream low voltage underground circuits at time of high load in a real-time manner.			
		EHV	**HV**	**LV**	**Comments**
Headroom Release (%)	Thermal Cable:			25%	Based on the work carried out under DS2030 (part of Smart Grid Forum Workstream 7), it was found that meshing at LV could provide a range of benefits depending on the specific geography and loading of the assets. This could be as much as 50%, so a conservative 25% has been applied.
	Thermal Transformer:			25%	Based on research being conducted at University of Manchester, it appears that transformers can be operated above nameplate rating under certain conditions without risk of premature ageing. The work is ongoing but early suggestions show an increase in rating of around 40% could be possible. A conservative assumption of 25% is taken here.
	Voltage Head:			0%	No expected benefit
	Voltage Leg:			0%	No expected benefit
	Power Quality:			0%	No expected benefit
	Fault Level:			-33%	Meshing increases fault level and, in line with standard practice within the Transform Model, this is taken to be a 33% reduction in the available fault level headroom.
Cost (£)	Capital:		£5,000		Estimate based on the cost to install the controlling and monitoring equipment to allow the active management of the LV network, in line with information from suppliers of such equipment.
	Operational Expenditure:		£50		Small ongoing opex to ensure communicatiosn channels are available for local control
	Cost Curve Type:		4		Assume a reduction in costs as solution volumes increase
	Life Expectancy of Solution:		10		A fairly conservative assumption of 10 years has been taken. Such devices have not been installed for long periods, so while asset life may well extend to 15 years, or beyond, this is an unknown and hence 10 years is applied here.
Merit Order	Totex (£):		£5,430		Calculated from capex plus NPV of opex
	Disuption Factor (1-5):		2		Low disruption as the devices can be connected to the network with minimal impact
	Disruption Cost (£):		£2,500		Figure based on Disruption Factor (taken from Table 13.7 in the WS3 Report)
	Flexibility (1-5):		4		Devices could easily be moved from one circuit to another within their life expectancy
	Lead Time:		6		(months)
	Cross Network Benefits Factor:		0		No benefit expected
Year solution becomes available:			2020		Following OpenLV project

Figure 10: Transform Model solution template for uplift solution at bid stage

Also, in the bid cost-benefit analysis (CBA), Transform scenarios three and four were those primarily considered. These are based on DECC's 'focus on high electrification' (high DER uptake) and 'purchase of international credits' (low DER uptake) scenarios respectively. Note: at this time scenarios five to eight were not yet available in Transform.

Table 3 shows the NPV of distribution network investments across GB in discounted totex terms from 2016 to 2050, as calculated using Transform in the OpenLV bid submission, with and without the uplift solution (detailed in Figure 10) available. The table shows that the original uplift solution entered into Transform was able to demonstrate a potential network benefit in excess of £2bn out to 2050. This value was highly dependent on the future demand DER uptake scenario selected.

Table 3: 2016 to 2050 NPV (at 2016 values) pre-project forecast of network expenditure without and with uplift solution

Transform setting	SC3 (High uptake)	SC4 (Low uptake)
Standard (no uplift solution)	£14,638m	£1,445m
+ Uplift solution available	£12,590m	£1,325m
Net benefit	**£2,048m**	**£120m**

However, in regard to thermal cable uplift through the meshing of LV networks, the results from the OpenLV trial do not support an uplift factor of 25%, as used in the original solution. As presented in SDRC 4 Method 1 [2], we found that across the transformer pairs looked at for meshing, the greatest capacity uplift was limited to 0.12%. It should be understood that the OpenLV Project was aiming to prove how autonomous and decentralised network control could be carried out through the LV-CAP™ platform (and was successful in this regard), rather than the use of meshing to achieve any form of capacity uplift. Network meshing was simply one of many applications looked at over the course of the project and it is emphasised that the networks utilised were selected on the basis of 'being safe to implement experimental automated meshing technology' rather than being optimised to benefit from network meshing.

While other meshing approaches not explored in this trial (e.g. meshing at the link box level, or meshing on more diversely loaded transformer pairs) may support a greater network uplift factor and be deployable on the LV-CAP™ platform given development, for the purposes of this analysis we have taken a conservative view based on the meshing arrangement physically deployed and tested. Therefore, the level of feeder capacity uplift used in our post-project CBA will be set to zero.

On the other hand, the work by the University of Manchester cited in the original solution (see Figure 10) has evolved into an application for calculating the Hot Spot Temperature of a transformer in order to provide an accurate Real Time Thermal Rating (RTTR) greater than the nameplate rating of a transformer. The app developed was deployed for testing and real-life calibration onto LV-CAP™ platforms as part of the trial. The app was successful in developing an instantaneous RTTR for LV transformers between 149% and 224% of nameplate rating (see SDRC 4 Method 1 [2] for further details).

Considering the extent to which transformers can be loaded beyond the nameplate rating, WPD's Company Directives and Policies reference multiple industry standards and define the following principles:

- Policy Document SD4/8 [11]: when discussing the implementation of Active Network Management (ANM) schemes then "the maximum load on any item of plant or equipment, excluding overhead lines, shall not exceed 125% of its rating" when the effect of the implemented ANM scheme is disregarded;
- Standard Technique TP4B/2 [12]: states that when selecting fuses for 11kV and 6.6 kV transformers, "Transformer overloads up to 150% of nameplate rating shall be possible".

This means that in the absence of an ANM scheme, WPD may run its transformers to 125% of nameplate rating (based on a cyclic load basis). However, even with active network management monitoring the hot spots of these units, 11kV and 6.6kV transformers will not be able to be loaded above 150% due to protection limitations.

Therefore, although the RTTR may allow instantaneous loading as high as 224% of nameplate rating, this shall be limited to no higher than 150% in reality. As such, when inputting the uplift solution into Transform, a transformer uplift of 25% capacity is appropriate (i.e. the 150% rating with hot spot LV-CAP™ enabled ANM less the 125% rating without ANM), as was used in the original bid submitted solution. Please note that those transformers which received a calculated RTTR of 149% have been rounded up to 150% for speed of Transform Model computation.

In summary, the project data has shown that transformer uplift of 25% through an LV-CAP™ hosted RTTR application is justifiable, while no significant uplift in feeder capacity has been detected through the tested mesh application. The removal of feeder capacity uplift from the original solution drives a number of changes in the projected financial benefits as further explored in the following section.

Forecast benefit at project close

The previous section has shown that the original solution used in Transform for the bid CBA require significant adjustments in the light of the data gathered throughout the OpenLV Project.

Although the updated uplift solution is the most significant cause of change in the cost-benefit analysis results, other factors are also in play which drive differences between the original benefit projections and the latest forecasts.

To wit, the Transform Model is constantly evolving and has undergone a major revision since used to prepare the OpenLV bid, including: an overhaul of available solutions; improvements to the handling of voltage limits; and the addition of a further four future load and DER uptake forecasts (scenario five to eight). It is therefore appropriate to utilise the most up to date version of the Transform Model available for the latest economic analysis. Table 4 provides a comparison of Transform 2016 vs GB Transform 5.3, the latest model version in use by DNOs. All Transform results, unless otherwise stated, provide NPV of GB distribution network expenditure in discounted totex amounts.

Table 4: 2016 to 2050 NPV (at 2016 values) forecast of network expenditure using standard Transform settings

Transform (Standard)	SC3 (High uptake)	SC4 (Low uptake)	SC5 (Fast transition)	SC8 (Slow transition)
Transform 2016	£14,638m	£1,445m	-	-
GB Transform 5.3	£13,901m	£1,677m	£13,564m	£12,073m

Note: all further results presented are derived from GB Transform 5.3 and based on NPV figures normalised to 2020 rather than 2016 as was appropriate for the bid.

While original analysis centred around scenarios three and four, we will instead look more closely at scenarios five and eight in the updated CBA. These newer scenarios have been developed seven years more recently than the original scenarios considered for the bid stage CBA, and better reflect the latest thinking on the future energy landscape. Unlike in 2011, when DECC first published the information that led to the development of scenarios one to four, the pertinent question in regard to the future energy landscape is no longer 'if' there will be a high uptake of DER and a low carbon transition, but rather 'when'. Scenarios five and eight both represent high decarbonisation pathways with a fast and slow transition respectively.

A comparison of the four base Transform scenarios discussed, with no OpenLV applications yet considered, is shown in Figure 11. It can be seen that the high decarbonisation scenarios three, five and eight are broadly similar in terms of network costs but each possesses unique uptake rates for DER, with SC5 and SC8 being significantly more up to date. As stated, we will concentrate now on SC5 and SC8, National Grid's fast and slow decarbonisation pathways respectively.

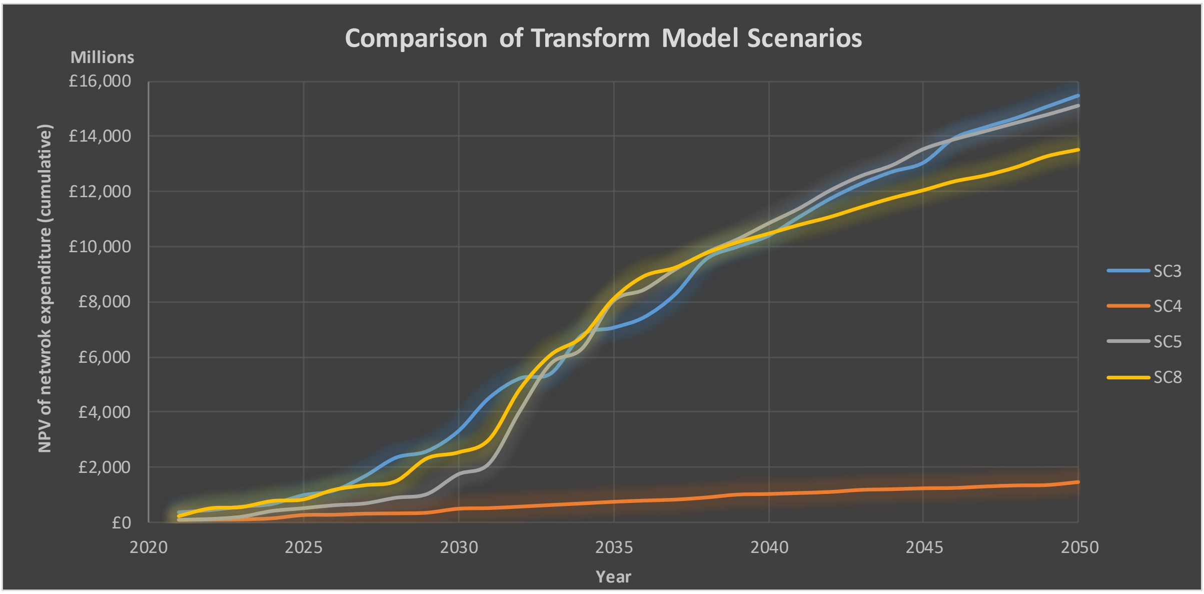


Figure 11: Comparison of base Transform Model Scenarios (no OpenLV applications considered)

By way of the described changes to the Transform Model, uplift solution characteristics, and future energy scenarios examined, Table 5 shows updated figures for the benefit that can be derived through the uplift solution.

Table 5: 2020 to 2050 NPV[1] post-project forecast of network expenditure without and with uplift solution

Transform setting	SC5 (Fast transition)	SC8 (Slow transition)
Standard	£15,123m	£13,528m
+ Updated uplift solution available	£15,713m	£13,277m
Net benefit	**-£590m**	**£251m**

From Table 5 it is immediately apparent that for scenario five the inclusion of the uplift solution into the Transform Model seems to have increased network expenditure to the value of £590m. Following investigation, it has been determined that this result is a side effect of the way in which Transform selects an optimum network development pathway, as opposed to being due to an inherent lack of value in the LV-CAP™ platform and RTTR app under this scenario.

The Transform Model has been configured to seek optimum network investments and interventions for sequential and overlapping five-year windows, as opposed to over the entire lifetime (i.e. 2020 to 2050+) of the simulation.

For example, for 2025 Transform will look at the current condition of the simulated network, identify problem areas and identify solutions to resolve these constraints. To identify the optimum solutions to deploy in 2025, Transform will examine the forecast network state over the 2025 to 2029 period. In doing so, it will ensure that the chosen solutions are those which minimises network costs over the entire five-year window, not just minimise costs in 2025. So, it may be the case that it is more optimal to invest in a more expensive solution (that releases additional headroom) than is immediately required in 2025, in order to prevent the need for a second solution deployment in 2027. Following selection of appropriate solutions for 2025, the Transform Model will update its network simulation and move on to consider constraints that arise in 2026, and so on.

The Transform Model has been artificially limited to consider these five-year windows as standard. This restriction offsets the effect of 'perfect prediction' on forecast network expenditure. In the Transform environment the eight future energy scenarios for customer load and DER uptake (SC1 to SC8) are perfectly defined which allows for perfect choices in network investment to be selected. The reality, however, is that there is high uncertainty as to how the load on any single network element will evolve over time, particularly out to

[1] Note that the standard Transform setting values presented in this table are higher than those shown in Table 4 due to expenditure now being discounted to 2020 values, rather than 2016 as was used in the bid forecast. This increase is somewhat offset by no longer considering base network expenditure from 2016 to 2020 as this has past and can no longer be impacted by the project outcomes.

distant timeframes such as 2050. In truth, it is not possible or realistic for network operators to make perfect investment decisions given this inherent uncertainty. By reducing Transform's perfect view to five years ahead, the model works to accurately reflect the genuine levels of network expenditure across GB that might realistically be expected.

In relation to the uplift solution, the increase in NPV shown in scenario five is caused by the Transform Model selecting the uplift solution to bring maximum short-term benefits (over the five year window) when, considering the lifetime of the network, it would have been more optimum to select a more expensive solution (e.g. to install an additional transformer) that brings benefits over a longer timescale.

That the Transform Model shows a net gain for the slow transition pathway (SC8), and net loss for the fast transition pathway (SC5) supports the assertion that the increase in NPV is due to optimum investments over short windows being detrimental to the long-term system cost. On the slow transition pathway, a low impact solution, such as the uplift solution, can be sufficient to relieve network constraints for a considerable time as network conditions are somewhat stable. However, on the fast transition pathway, the contributions of low impact solutions can be overtaken by the fast-evolving needs of the network relatively quickly, requiring additional investments and interventions to prevent network constraints emerging. This is made clearer when examining the number of interventions that the Transform Model allocated during each scenario (see Table 6).

Table 6: 2020 to 2050 forecast of interventions without and with uplift solution

Transform setting	SC5 (Fast transition)	SC8 (Slow transition)
Standard	1,122k	893k
+ Updated uplift solution available	1,528k	1,152k
Net increase (LV interventions)	406k	259k

By including the uplift solution, the number of interventions allocated by Transform to resolve network constraints increases significantly, particularly in the fast transition scenario. This is due to the uplift solution being relatively low cost and low impact in comparison to larger solutions which Transform can leverage. The use of smaller solutions increases the number of interventions needed. In the case of the slow transition, these low impact solutions bring value over the full life of the deployment. However, in the case of the fast transition, low impact solutions are often inefficient investments long-term, being unable to keep up with changing network conditions. This leads to the need for Transform to allocate an even greater number of new interventions in comparison to SC8 to maintain the network.

While there are instances in SC5 where the uplift solution brings net financial benefit, generally it represents a sub-optimum long-term investment in fast evolving network areas. As is, the LV-CAP™ platform and RTTR application would only be suitable for areas of the network with low expected volatility.

It must be reiterated however that the RTTR application and uplift solution is only one segment of the total value stack that the LV-CAP™ platform can bring about, as will be further explored below.

3.2.3 DSM for EVs app

Work on the industry leading Electric Nation project [5] has shown how group management of electric vehicle charging can be utilised to ensure that EV demand remains within the capacity of the local network. As the LV-CAP™ platform possesses the capability to monitor substation headroom in near real-time, within the Transform Model we have enhanced the LV-CAP™ solution (previously the uplift solution) to allow the managed charging of groups of EVs within the future scenarios. This allows EV demand within the network simulation to be flattened at peak times, as was done in the real-life Electric Nation trial, and also reduces the need for EV driven constraint investment. Table 7 provides the results of this, showing the impact of stacking value from first the uplift solution and then the new DSM app on top of the standard Transform Model. The combined impacts of the uplift and DSM solutions provide a net benefit by decreasing projected network expenditure.

Table 7: 2020 to 2050 NP forecast of network expenditure with stacked uplift and DSM apps

Transform setting	SC5 (Fast transition)	SC8 (Slow transition)
Standard	£15,123m	£13,528m
+ Updated uplift solution available	£15,713m	£13,277m
+ DSM enabled for EVs	£14,826m	£13,138m
Net benefit	**£297m**	**£390m**

For both scenarios considered, we can see that a solution allowing managed EV charging can drive significant decreases in network expenditure. This is to be expected given the expected high uptake rate of EVs in the future and their high demand rating (typically 7kW for home charging). Further insight into how smart charging has driven a decrease in forecast network expenditure can be found in Table 8.

Table 8: 2020 to 2050 forecast of interventions with stacked uplift and DSM apps

Transform setting	All LV interventions		LV-CAP™ interventions	
	SC5 (Fast transition)	SC8 (Slow transition)	SC5 (Fast transition)	SC8 (Slow transition)
Standard + updated uplift solution available	1,528k	1,152k	465k	441k
+ DSM enabled for EVs	1,312k	1,076k	493k	444k
Net increase of LV interventions	-216k	-76k	28k	3k

The table shows that the added DSM functionality has decreased the overall number of interventions required compared to the LV-CAP™ with uplift solution only. This is to be expected as the previously allocated LV-CAP™ deployments now possess additional capability to meet network needs, reducing the need for other interventions. It should also be noted that the number of LV-CAP™ interventions has increased overall. This is due to the increased ability and value of this solution overtaking others in Transform's solution allocation order.

It must be stated that interventions in Transform are counted at a feeder rather than a substation level. As such, for example, the 444,000 LV-CAP™ feeder interventions shown in Table 8, in fact represents 141,000 substation installations of LV-CAP™ over the 2020 to 2050 lifetime of the forecast. In this example, there is an average of approximately 3.1 feeders making use of each LV-CAP™ solution over the lifetime of the simulation, in order to prevent otherwise necessary network investments, per substation.

The ratio of LV-CAP™ installations to feeders being supported varies by scenario and across the simulation lifetime but is relatively stable at approximately 3.1. This shows the synergy that exist where LV-CAP™ platforms are installed on substations where multiple feeders are facing network constraints. This of course drives down installation costs while maintaining benefits. Figure 12 shows LV-CAP™ substation installations per year over this period.

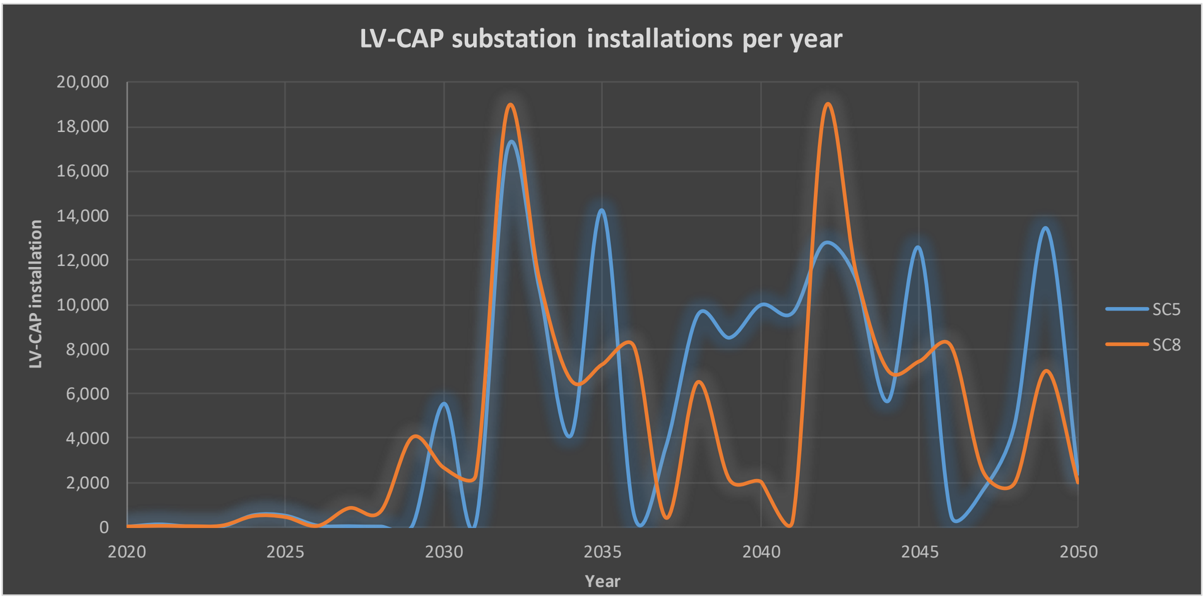


Figure 12: Forecast LV-CAP™ installations per year

Be aware that within this analysis we have not accounted for any additional network costs in order to allow for this DSM enabled solution. From the network side, the LV-CAP™ platform with appropriate app is sufficient to provide an external signal to smart chargers while the cost of a smart charger is born by the customer directly rather than by the network and wider customer base through DUoS charges. As smart charging standards develop and evolve it is expected that smart chargers will become the norm and, as technologies mature, not incur significant additional costs to customers over the cost of a 'dumb' charger.

It is possible that DSM of additional loads such as domestic appliances can bring further reductions in network expenditure, however this has not been explored in this analysis. While the Electric Nation project has demonstrated that customers show a high degree of flexibility as to the times in which they are willing to charge their EVs, and are not unduly inconvenienced by managed charging curtailment events, similar evidence does not exist exploring customer acceptance of DSM for other load types, particularly those without a storage component.

In other words, it has been shown that even when no incentive payment is offered, customer flexibility around charging times is sufficient to enable DSM of EVs. However, for existing domestic load that does not possess energy storage to offset customer impact, there is unlikely to be such a degree of acceptance of curtailments. As such, any network expenditure saving from DSM of existing domestic loads may, by necessity, be used as payment for the customers providing the flexibility service, rather than providing a network wide saving reducing DUoS charges across the customer base. The concept of flexibility payments for customer is further explored in Section 3.3.3.

Ultimately, with the inclusion of the value stack from DSM of EVs in the Transform solution, the LV-CAP™ platform shows a net decrease to network expenditure of a minimum of £297m over 2020 to 2050 (see Table 7), with additional value streams yet to be leveraged.

3.2.4 Fault detection and prevention

Under RIIO-ED1 price control incentives, DNOs are encouraged to maintain customer supply, as measured through the number of customer interruptions and customer minutes lost (CI/CMLs) across the network. Where DNOs outperform their CI/CML target for a year, as set by Ofgem, they are rewarded for reducing the number and impact of outages on customers, and where they fail to meet their target, they are penalised. The effective nominal values for each CI/CML to a DNO are £15.44 and £0.38 respectively, up to a cap of 3% of their allowed revenue. This is visualised in Figure 13.

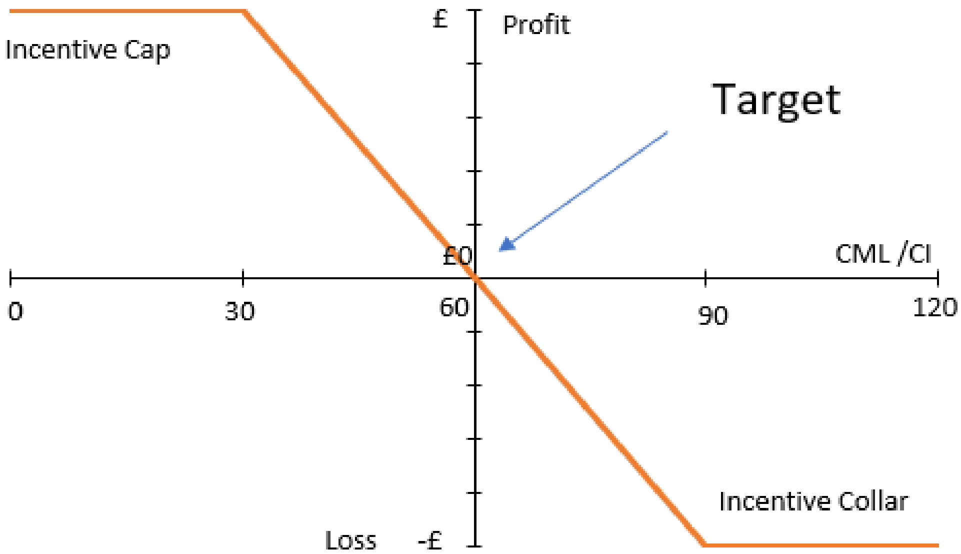


Figure 13: DNO CI/CML incentive scheme mechanism

While a reduction in CI/CMLs can deliver a direct financial benefit to network operators, CI/CML financial values are also a proxy for the cost to customers and society of outages. Therefore, reducing CI/CMLs brings benefits to both networks through reduced penalties and/or rewards, and customers through improved continuity of supply.

To this end, work is underway across the industry to investigate the role pre-fault detection and fault prevention techniques can play in reducing the instances of customer interruption and so allow DNOs to meet and exceed their CI/CML targets, as well as improve the customer experience. These techniques have typically required dedicated and bespoke hardware installations for this specific purpose. With the emergence of open access, multi-purpose substation platforms such as LV-CAP™, fault prevention techniques are being developed into deployable applications that can be hosted on suitable devices with sufficient on-board intelligence and network monitoring capabilities.

Subsequently, to further understand the value that can be achieved through the LV-CAP™ platform, we have simulated the use of a fault prevention app in our economic analysis. While the Transform Model is a powerful tool it is focused around maintaining network conditions during normal operation and, as such, does not have the facility to forecast CI/CML costs. However, to undertake this study in line with our value stacking approach, we have taken our previous Transform results as a starting point.

To elaborate, the Transform Model has provided year-on-year projections of LV-CAP™ installations out to 2050. Given these assets on the network, we have established the additional cost of the fault prevention application on each substation and the reductions in CI/CML each installation can bring. Note: reducing CI/CML costs does not remove the need for fault repair (i.e. even with pre-fault detection allowing fault locations to be identified ahead of time, physical repair of the developing fault, with associated cost, will still be necessary), but it assumed that advanced fault warning is sufficient to arrange alternative customer supplies during planned repair outages.

Additional cost is driven solely through software licences priced at a realistic commercial level. Benefit stems from two key factors:

- The typical CI/CML cost associated with a permanent LV feeder fault (i.e. physical repair was necessary as opposed to auto-reclose or fault replacement); and,
- The number of permanent LV feeder faults that can be prevented through pre-fault detection, per feeder per year.

The DNO Common Network Asset Indices Methodology [13], as developed under RIIO-ED1 and adopted across all GB DNOs, sets out the process for assessing, forecasting and reporting asset risk. To effectively price asset risk it was necessary to develop reference costs of failure for a variety of network assets. In line with this, the typical CI/CML cost of an LV feeder fault was determined to be £3,699, as sourced from the asset risk methodology (see Table 9).

Table 9: CI/CML cost for LV feeder fault as per asset risk methodology

Ref. # of customers	Customers restored in <3 min	Customers restored after manual switching	Manual switching time	Repair time	CI/CML cost
80	25%	89%	1hr	7hrs	£3,699

An additional consideration for the cost associated with permanent LV feeder faults is the prevalence of preceding non-permanent (or non-damage) faults which are also preventable. To illustrate, for every permanent LV feeder fault there can exist a number of preceding intermittent faults with the same underlying cause. These non-damage faults are typically resolved through fuse replacement, and from National Fault and Interruption Reporting Scheme (NaFIRS) data we can see that non-damage faults have an average restoration time of 64 minutes. This allows us to calculate CI/CMLs costs for non-permanent faults which can also be prevented through the LV-CAP™ platform with suitable software. The updated CI/CML cost that can be prevented resolves to £4,534 using conservative estimates of the number of preceding faults per permanent fault.

For a more robust analysis it is also possible to consider that the manual switching time of one hour used in the asset risk methodology is, according to NaFIRS data, only the average time for manual switching restoration on an LV cable fault. In regard to the final CBA figures presented, this average is a suitable value. Nonetheless, it is useful to see the impact restoration time has on the economic analysis of fault prevention, as the greater the amount of time customers are off supply, the greater the benefit from fault prevention techniques. As such, we will also show results for a manual switching time of 2.15hrs, the 75th percentile. This resolves to a total fault cost of £6,107.

Moving on to consider the fault rate, work to determine the effectiveness of fault prevention applications in regard to number of faults prevented is still underway and constantly evolving, however initial results from EA Technology's internal analysis have been utilised to complete this portion of the CBA.

Table 10 shows the effect of the additional fault prevention application value stack on the overall reduction in network expenditure (i.e. through the combined impact of all three value stacking apps considered, an overall reduction in projected network expenditure is shown). In addition, for information, Table 11 presents similar results but using the 75th percentile of switching time to illustrate the effect fault duration has on the value of fault prevention applications.

Note that the values shown are likely somewhat under representative as they include only those LV-CAP™ platforms previously slated for installation under the Transform Model analysis (i.e. the number of LV-CAP™ interventions, presented in Table 8 remain static). As such, there will be instances where Transform has selected alternative solutions to solve constraints which, when also including the value of fault prevention LV-CAP™ can provide, are no longer optimum. A future version of Transform, capable of considering CI/CML costs directly when evaluating the merit of which solutions to apply, would feasibly select to install additional instances of the LV-CAP™ platform and thus drive decreased network expenditure.

Table 10: 2020 to 2050 NPV forecast of network expenditure[2] with stacked uplift, DSM and fault prevention apps – standard switching time

Transform setting and applications evaluated	SC5 (Fast transition)	SC8 (Slow transition)
Standard	£15,123m	£13,528m
+ Updated uplift solution available	£15,713m	£13,277m
+ DSM enabled for EVs	£14,826m	£13,138m
+ Fault prevention app (mean switching time)	£14,451m	£12,794m
Net benefit	**£672m**	**£734m**

Table 11: 2020 to 2050 NPV forecast of network expenditure with stacked uplift, DSM and fault prevention apps – high switching time

Transform setting and applications evaluated	SC5 (Fast transition)	SC8 (Slow transition)
Standard	£15,123m	£13,528m
+ Updated uplift solution available	£15,713m	£13,277m
+ DSM enabled for EVs	£14,826m	£13,138m
+ Fault prevention app (75th percentile switching time)	£14,249m	£12,608m
Net benefit	**£874m**	**£920m**

[2] The fault prevention application provides benefits through CI/CML regulatory rewards rather than through a direct reduction to network expenditure as has been previously evaluated. However, to maintain a unified presentation of results, the impact of CI/CML rewards has been shown as equivalent to, or applied to, a reduced network expenditure.

As well as the value from stacking fault prevention on top of previously installed LV-CAP™ units (as shown in Table 10), additional work has been undertaken to evaluate the benefit that might be brought about by the installation of LV-CAP™ platforms and fault prevention software as standalone systems, without the additional value stacks previously explored. Fault prevention is a high value proposition and can potentially bring the network net financial benefits, even without the reduction in network expenditure evaluated by Transform.

For this analysis, we have considered all LV substations that are not, for a particular year, allocated an LV-CAP™ solution by the Transform Model. We have determined the maximum number of platforms that can be installed at any one time without overlap and, given the 10-year lifetime of the solution, smoothed installation rates over the 2020 to 2050 period. This gives an average of 24,900 additional LV-CAP™ installation per year across the two scenarios considered – significantly greater than the Transform Model allocated interventions displayed in Figure 12. Possessing this data, we have evaluated the lifetime costs (including the cost of the platform and the fault prevention app) and benefits (from reduced CI/CMLs) for these new installations. Installations which show a negative benefit have been excluded as these would simply not be installed in reality. Table 12 presents the results.

Table 12: 2020 to 2050 NPV forecast of network expenditure with stacked uplift, DSM and fault prevention apps (inc. dedicated fault prevention installations)

Transform setting and applications evaluated	SC5 (Fast transition)	SC8 (Slow transition)
Standard	£15,123m	£13,528m
+ Updated uplift solution available	£15,713m	£13,277m
+ DSM enabled for EVs	£14,826m	£13,138m
+ Fault prevention app	£14,451m	£12,794m
+ Fault prevention hardware and app on wider LV network	£13,319m	£11,664m
Net benefit	**£1,804m**	**£1,864m**

Our results show that fault preventions are a high value proposition and can bring significant savings to network operators.

3.2.5 Summary of network benefits

As LV-CAP™ is fundamentally an open platform, new applications and sources of value will emerge through time from across the industry, although the precise nature of these apps cannot be known in advance. Presently, we have explored a limited number of well-defined value stacks that the LV-CAP™ platform can leverage to drive reduced network expenditure between £1,804m and £1,864m, depending on future uptake rates. Figure 14 has been generated to show how this value grows over time.

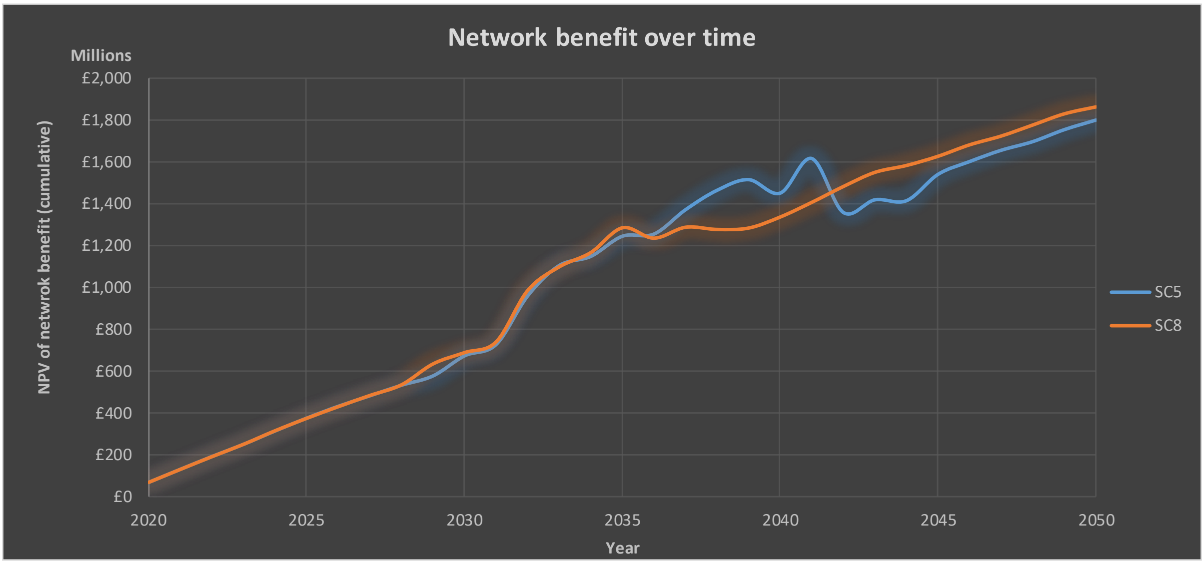


Figure 14: Network benefit over time (cumulative)

As previously discussed, the slow transition scenario (SC8) provides more opportunity for low impact solutions to resolve network constraints and generate savings for the networks. This is opposed to the fast transition scenario (SC5) where more aggressive solutions such as traditional reinforcement are more necessary, with corresponding reduced uptake in the LV-CAP™ solution. Ironically, the LV-CAP™ platform may help drive future growth towards the lower savings fast transition route as it provides a means to engage individuals and communities in their energy use and can help encourage and enable the uptake of DER technologies, as explored further in Section 0

3.3 Community engagement benefits

In addition to the indirect effects on the amount of DUoS required to be paid by customers in order for network operators to successfully manage constraints and outages on the distribution network, as has been shown in the cost assessment presented in Section 3.2, the LV-CAP™ platform also has the potential to directly improve the customer experience. Regen was contracted as part of the OpenLV Project to assess the value and benefits that derive from community engagement trials within the project [14] and has developed three community use cases to explore the primary value streams the project has brought directly to communities and customers. These community use cases are:

- Transparency value;
- Engagement value; and,
- Flexibility value.

These value streams cannot be directly evaluated for quantified cost-benefit savings to community groups based upon the data gathered within the project trial. This is primarily due to insufficient time available during the project for community projects to fully mature (details of the community groups and their project objectives are located in the Regen Value & Benefits Report, previously published as part of SDRC 4 [14]). Therefore, while the OpenLV trial has assisted in the inception and development of community project initiatives and ideas, none have been fully completed to date, limiting the data available for evaluation. As such, this section will primarily present the qualitative benefits that have been reported by trial participants.

3.3.1 Transparency value

Communities having access to OpenLV data means they can identify opportunities, assess and evaluate plans for distribution connected projects and investments.

Description of value

Two communities involved in the OpenLV Project trial (Owen Square and Marshfield) anticipated using the gathered substation data as a planning tool for new demand or generation in their communities. Both organisations have on-going work plans that extend beyond the trial period. However, they have both made progress through the trial in using the data to inform future plans.

The trials have therefore successfully demonstrated that **the OpenLV data provided an important insight into the functioning of the local electricity network**. They reported that an appreciation of the data meant they were better able to understand the local network and where there might be potential to invest, for example in new homes, EV chargers or renewable energy.

Owen Square felt that by **making this information transparent** for their substation (and others) it would help them in identifying where network capacity might support their plans to increase the electrification of heat, reducing planning time. This value case implies a potential cost saving for both community energy organisations (who would avoid work in areas that were not suitable), and for WPD who would avoid having to responding to requests about unsuitable areas.

Although primarily interested in engaging their residents, housing association Rooftop felt that **the information from substations would be increasingly useful to make decisions about where to put new homes and which technologies they would install in new housing developments**. Rooftop is, where possible, looking to electrify heat in new homes and include EV charging points. They noted they would also welcome a tool to help them identify where there was more substation capacity available to build additional housing on their existing estates or to build higher density housing[3].

Figure 15 summarises the transparency value from substation data.

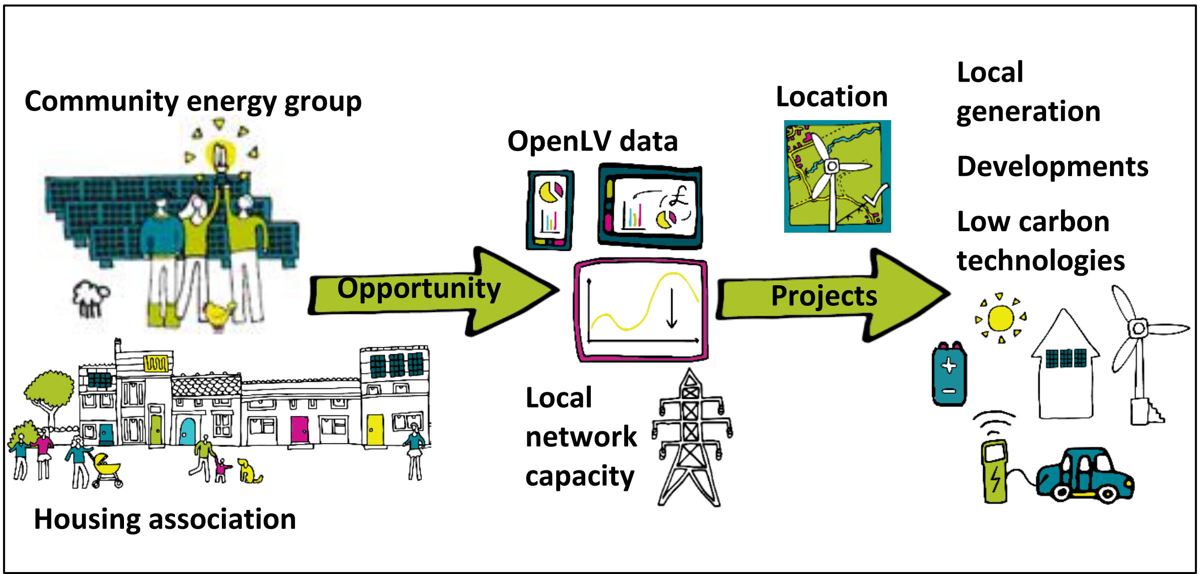


Figure 15: Transparency value from substation data

[3] NB: This tool is currently available for primary substations but not secondary substations.

Evidence of value

The seven trial participants were asked to rate a series of statements between 1 (strongly disagree) and 5 (completely agree) and give reasons for their responses. The results to the questions about the transparency value case are shown in the Table 13.

Table 13: Average scores on transparency value

Transparency value case	Average score (1-5)
Using the data from the OpenLV unit (accessed via the OpenLV app) makes it easier to understand how the local electricity infrastructure is set up and how much electricity is used.	4.3
The data (from one or more substations) can help communities plan where to locate future demand or generation.	2.9
Community energy organisations will require support from DNOs to fully understand what the OpenLV data is revealing.	3.4

The interviews showed that most communities agreed that OpenLV provided important background information about local electricity networks. However, the responses were more split when asked specifically about how OpenLV could help them plan future for demand or generation.

In their responses this score reflected that the OpenLV data was only one, albeit important, element of the information they needed to make a siting or technology investment decision.

The results also showed that communities felt they needed a level of support from DNOs or project partners to understand what the data was telling them. It was noted that in many communities the level of support needed will vary depending on the skills and experience of the volunteers. The participants agreed that most communities would require basic support to understand the information they were being given and how to process it.

3.3.2 Engagement value

OpenLV data helps build community knowledge on energy use and energy infrastructure.

Description of value

The trials successfully demonstrated the potential for substation data to provide locally relevant and engaging information for communities on electricity use and the network. The data was found to be particularly valuable to community energy groups, because it shows people how they are connected as a community and how people share the local electricity network assets. Marshfield noted that what attracted most interest from its community was the substation feeder map, as people were naturally interested in where they fitted into the network [15].

The data provided by the OpenLV Project differs from most of the other available data about electricity and energy use which provides information about either national trends or individual households. **This community level information therefore has significant potential to be used to interest and engage people who are naturally interested in their local community, but not specifically interested in energy**.

For community energy organisations, using this information as part of their engagement toolkits provided them with a source of valuable information including local profiles of usage (when a peak might occur) and facts about the community (who is connected to which substation) that they felt made conversations with households easier, more productive and potentially less time consuming.

Tamar Energy Community (TEC) noted in their final interview that the information was **a useful conversation starter** for households (though further conversations could still be difficult) but that being able to show local peaks helped people understand the idea of time-of-use-tariff and, by implication, the need for smart charging or other appliances.

An unexpected benefit to TEC was that the project and data also helped build a more sophisticated understanding of local electricity networks within the community organisation itself. It has been consistently proven that having a community group as a messenger of information gets a significantly higher response. It is therefore inherently valuable for these community energy organisations to have a more detailed knowledge of the challenges of the energy transition and implications for local infrastructure.

Furthermore, the idea that people can take energy actions in order to help their local community has been found to be more effective in encouraging people to change behaviour than other motivators. For example, the Scottish and Southern Electricity Network's (SSEN) Solent Achieving Value from Energy Efficiency (SAVE) project tested energy efficiency, demand reduction and shifting with Time-of-use-tariffs to defer network upgrades. They found that community engagement with the message of being part of a caring, connected community, rather than saving money or the planet, led to a reduction in peak demand on the local substation [16].

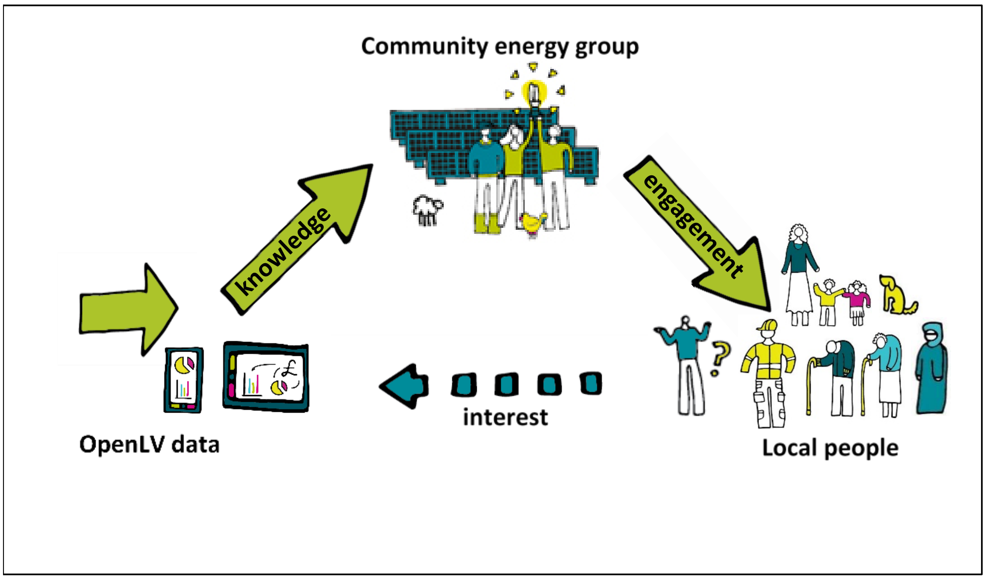


Figure 16: Community energy organisations using OpenLV as an engagement tool

Figure 16 summarises the community energy organisations using OpenLV as an engagement tool.

Evidence of value

In the final interview, the seven trial projects were asked to rate a series of statements between 1 (strongly disagree) and 5 (completely agree) and give reasons for their responses. These results to the questions about the engagement value case are shown in Table 14.

Table 14: Average scores engagement value

Engagement value case	Average score (1-5)
Local substation data is an important source of information for community energy organisations.	4.1
Local substation data helps people understand broader climate and energy issues – low carbon transitions.	3.8
Local substation data helps people understand the needs of the local electricity infrastructure and network.	4.1
Local substation data helps people accept the need for smart appliances (including smart meters and smart EV charging).	3.1
Encourages people to switch to the time-of-use tariff.	3.9

The responses showed that communities all agreed that the OpenLV information was valuable for them and noted that it was particularly useful for engagement because the information was locally relevant and tangible.

They felt that this helped people understand the needs of the local network and in some instances, helped conversations about responding to climate change.

Rooftop noted that the data itself doesn't communicate directly and so any OpenLV data for residents or communities will need to be supplemented with a robust engagement strategy as it was the use and context of the data in messaging, meetings or house calls – that changed understanding or encouraged actions such as switching or changing use profiles.

3.3.3 Flexibility value

OpenLV data and functionality supports community level aggregation and coordination of community level demand-side management.

Description of value

OpenLV could enable communities to realise value (e.g. payments from DNO) from taking collective community level action to change their profile of electricity usage at a substation or a combination of substations. For example, some communities, particularly those with larger flexible loads such as EVs, batteries or electric heating, will be able to change their load profile to a greater or lesser extent either through coordinated household action or automated smart technologies. This could open several potential sources of value for communities where investment may be avoided or delayed in a local substation, or network, for which the DNO may be willing to make a payment. Although, this third value case for communities is an area which remains, at present, in a nascent form of commercial viability.

The OpenLV information and functionality opens up significant potential for the substation to act as a community aggregator and to remotely prompt actions by users under a particular substation. This would be with the objective to change or manipulate their aggregated usage in response to local network conditions. Bath and West Community Energy used OpenLV data as part of their Solar Streets project and aimed to measure the impact of domestic PV and battery installations on the local substation. They also wanted to use it to build a business case for further installations and understand what flexibility services the community might be able to provide.

As part of their trial they hoped to run two demand reduction and shifting campaign months. Unfortunately, due to delays installing the PV and battery technology these campaigns were not run before the end of the official OpenLV trial period in October 2019.

It must be noted however that is not necessarily new value but would instead be a redistribution to communities of existing value created by savings generated through contracting flexibility instead of more costly network investment. This can be understood in the context of DSM for EVs as was explored in Section 3.2.3.

We showed that by adding a DSM for EVs application to the LV-CAP™ platform we could reduce network expenditure across GB through avoided investment in more costly solutions. We did not, in this analysis, account for any flexibility payment to customers for allowing this control. This was justified through evidence from the Electric Nation project showing high customer acceptance of EV management, even where no incentive payment is offered. In effect, we assumed that the reduced network expenditure saving would be distributed across customers through a reduction in DUoS payments.

Customer acceptance of EV charge curtailment was likely largely driven by the energy storage characteristics of this technology offsetting any strong impact on the customer experience. For most loads, no storage is available and so any flexibility service offered via these loads would be much more likely to have a direct and immediate impact on the customer. As such, it is probable that customers will expect payments for such flexibility services provided. The payment for these services would effectively come from the savings generated from reduced network expenditure. That is, the savings pot remains static, with benefits distributed to flexibility providers, or the wider customer base through reduced DUoS charges, according to commercial arrangements entered.

Cost saving aggregation model

A further benefit of community aggregation would be cost saving against typical aggregation models. Aggregators are already exploring the potential for domestic demand response which involves each household having an individual contract and smart monitoring. However, monitoring substations instead of individual households could involve significantly less administration costs and lower barriers to participation. Those households wanting to participate on a basic level could just shift in response to signals, they would not need to switch suppliers, share data or require any administrative effort or investment.

This community DSM model would instead require both contracts and payments to be made at a community or substation level. By implication, this means payments would in part or in whole benefit a community fund or community organisation rather than the participating households.

The SAVE project suggests that this community element could in some cases provide a much higher motivation for households than individual payments. Where individual household payments may be relatively small, collectively across a substation they could provide a useful source of additional revenue for community organisations, schools etc.

Figure 17 summarises the flexibility value for local communities.

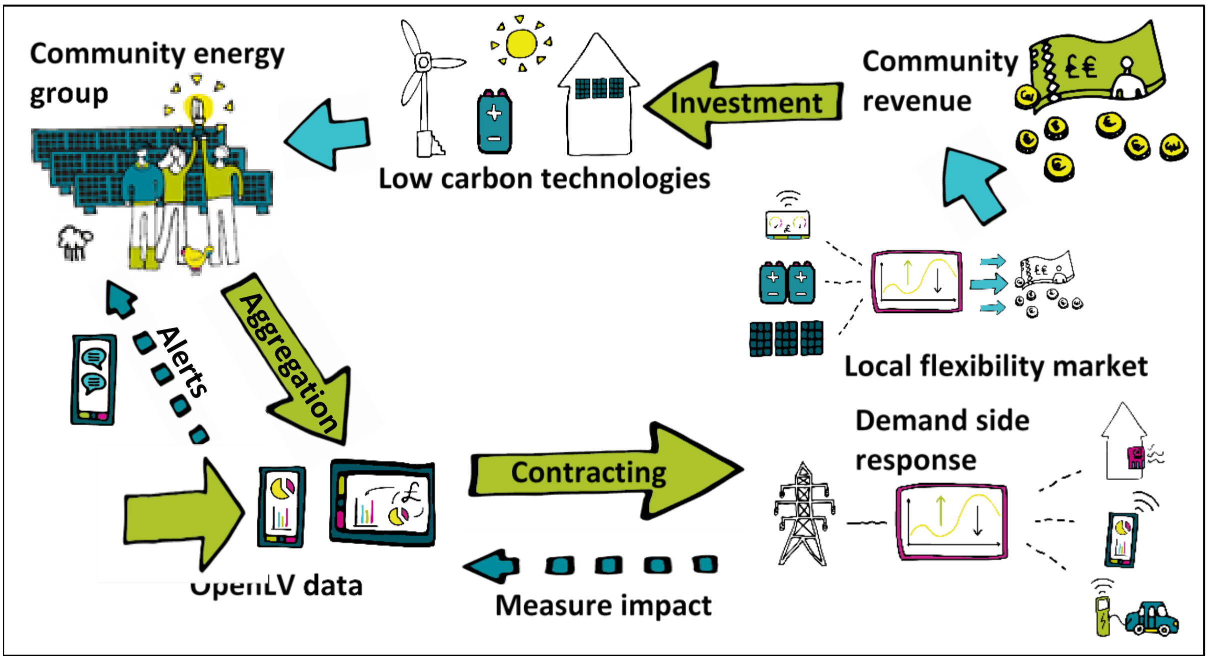


Figure 17: Flexibility value for local communities

Evidence of value

In the final interview the seven trial projects were asked to rate a series of statements between 1 (strongly disagree) and 5 (completely agree) and give reasons for their responses. These scores relating to the transparency value case are shown in Table 15.

Table 15: Average scores from flexibility value

Flexibility value case	Average score (1-5)
Accessing revenues by providing local network services to DNO.	4.4
Switch timing of electricity demand to maximise use of local renewable generation (this would reduce carbon and/ or avoid curtailment).	4
Work with a new renewable generation project to share access to the network (creating cheaper connection charges).	3.8
Create a local electricity market contracts with local generation – local tariffs etc.	3.5

All the community energy organisations noted that they would be interested in developing demand side response or flexibility business models in the future.

Flexibility services provided to DNOs were the most popular and recognised as the closest to market.

Housing association Rooftop, however, felt that these business cases only related to more affluent areas with existing community energy organisations. However, they also noted that they were keen to sell their solar power to residents, but they understood the regulations did not allow this at present.

Need for flexibility

As the LV-CAP™ platforms improves awareness of the local network, it also allows more precise understanding of the level of flexibility, or DSM, that is necessary to maintain network conditions within statutory limits. While it has been shown that the use of flexibility can, in many instances, reduce overall network expenditure by offsetting more expensive interventions, the use of any flexibility product should be reduced to the lowest level required. This both minimises any flexibility payments to be paid and reduces the negative impact on the customer experience from curtailment events.

One area where we can quantify how accurate substation monitoring can minimise customer instruction is DSM for EVs. As discussed in Section 3.2.3, the LV-CAP™ platform is anticipated to facilitate the smart charging of electric vehicles. In addition to the positive benefits towards network expenditure and reduced DUoS charges that have already been discussed, the LV-CAP™ platform would also improve the experience of persons who seek to charge electric vehicles.

This is because the LV-CAP™ platform would allow smart charging systems to obtain an insight into the actual available capacity in the local network, thus maximising the availability and/or charge rate for customers. This is opposed to regulating smart charging through typical substation demand curves as has been done in previous smart charge trials (e.g. Electric Nation), potentially curtailing charging at time when headroom was still, in fact, available.

The potential benefit of this insight has been explored by extrapolating work undertaken in WPD's Electric Nation project [5]. This project trialled smart charging solutions with 673 EV drivers to demonstrate the technical feasibility of this type of demand management. It also completed research to show the customer acceptability of smart charging/demand management.

In Electric Nation, profiles of available capacity for EV charging were developed (i.e. spare network capacity based on existing loading levels and feeder capacity). These profiles were developed using data from a single representative network in the East Midlands. Demand management providers then managed the capacity made available to active chargers so that the available capacity profile was not breached. Data from Electric Nation has been used to demonstrate the extent to which the additional capacity released by OpenLV could reduce the amount of management required for this network.

Figure 18 below shows the proportion of weekdays where management would be necessary based on the 'winter' profile applied in Electric Nation (blue curve), and a winter curve with an additional 25% capacity uplift, as provided by LV-CAP™ RTTR uplift solution (see Section 3.2.2).

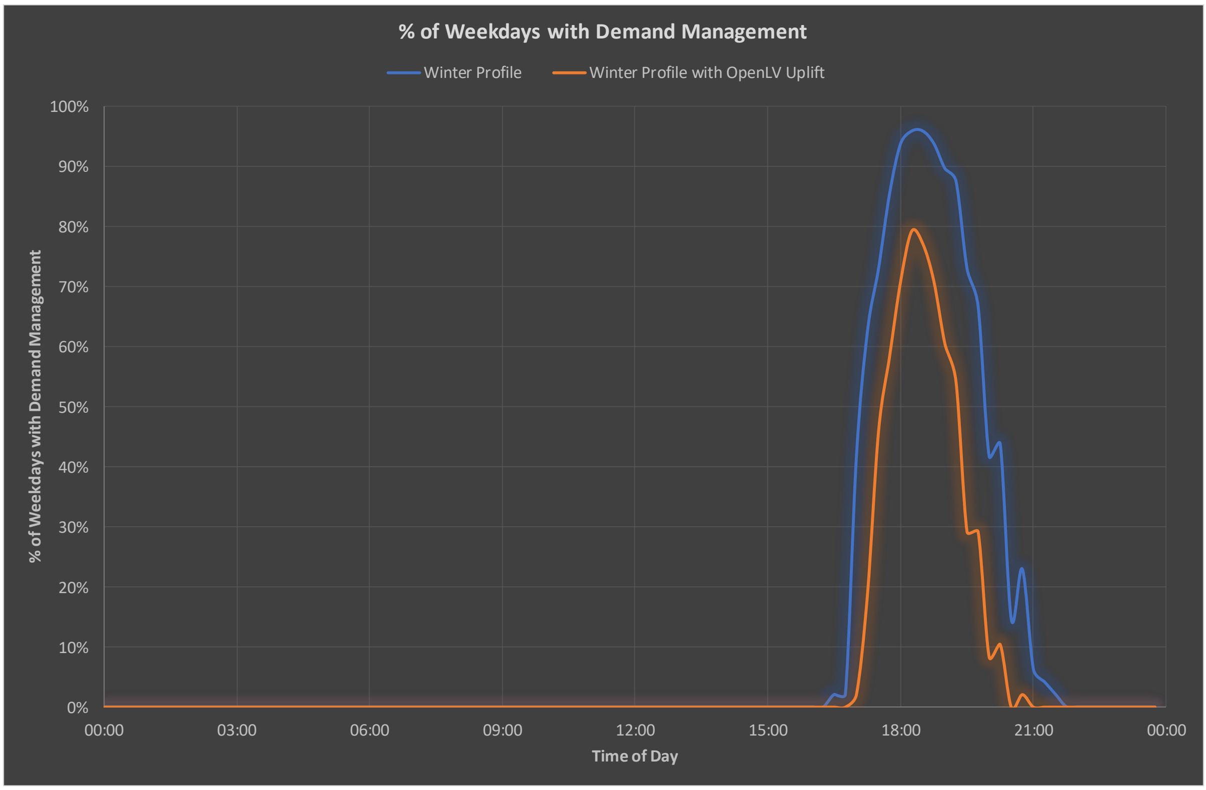


Figure 18. Comparison of EV smart charging events with and without OpenLV (Weekday)

This shows that under a winter scenario, without OpenLV, management would be active on the vast majority of weekdays from 17:30 to 20:30, with occasional management either side of this window. The additional capacity released by OpenLV shortens the window during which management may occur on weekdays and increases the proportion of days where no management would be necessary. With a 'winter' profile (blue) management would be necessary on 96% of weekdays, compared to 79% with the capacity uplift (orange).

Figure 19 shows that management was required less frequently on weekend days during Electric Nation, due to both slightly higher available capacity and lower demand for EV charging. The additional capacity released by OpenLV would virtually eliminate weekend demand management in this scenario.

Reduced charging management would improve the experience of electric vehicle owners as there would be even more opportunity to charge their electric vehicles than with smart charging alone.

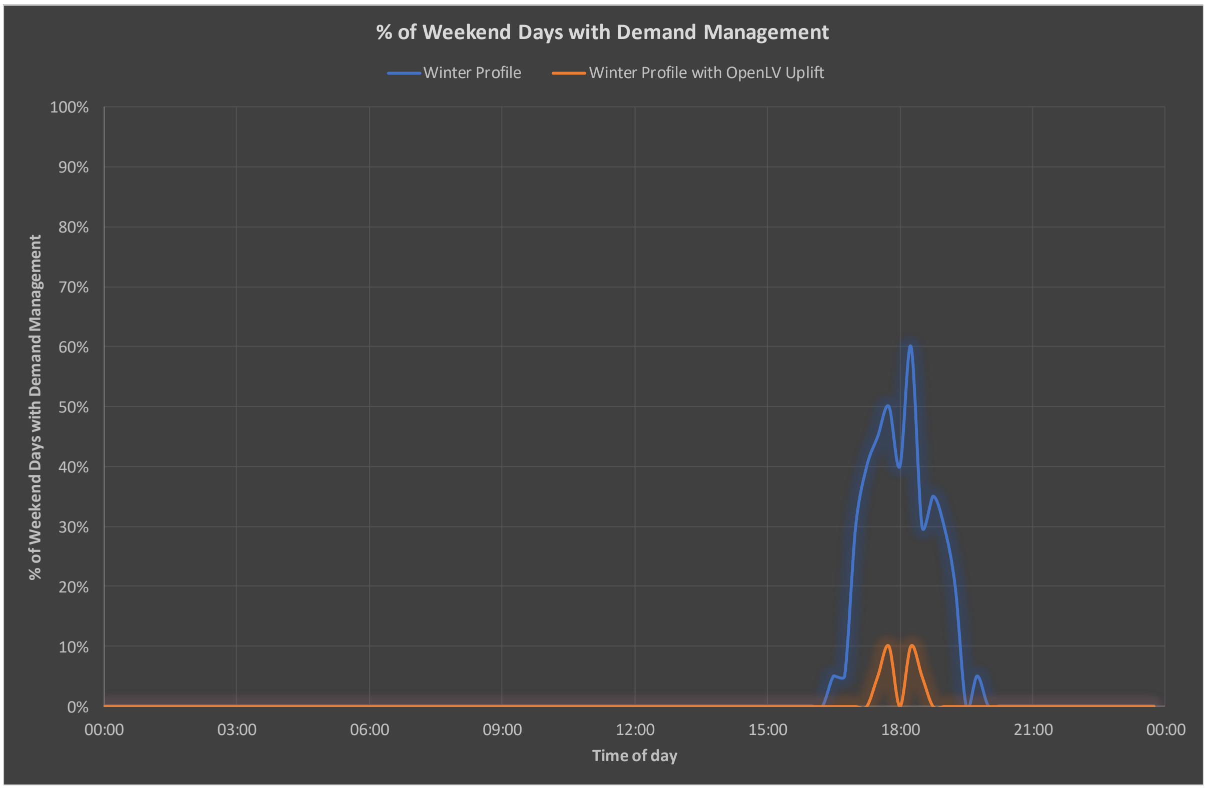


Figure 19. Comparison of EV smart charging events with and without OpenLV (Weekday)

4 Training Needs Analysis

4.1 Enabling works / Method 1

Installation of the majority of project trial equipment was undertaken within WPD's existing work procedures, with specific training being provided for the Alvin Reclose™ units utilised as part of the meshing application trial.

A detailed method statement was created to provide reference information to installation teams and covered the installation and decommissioning of all trial equipment.

Where additional training was necessary, this, along with the appropriate documentation and guidance was provided.

The method statement was maintained as a live document throughout the OpenLV Project, sequentially updated to fully accommodate the necessary work onsite, including the full process for commissioning the individual components. The final version of the document is detailed in Annex A1.

4.1.1 Core trial system hardware

The 'core equipment' installed in all substations utilised in the OpenLV Project was able to be installed under WPD's "Standard Technique: SP2KD. Relating to the Retrofitting of Monitoring Equipment in Live LV Cabinets" [17].

This covered the following system elements:

- Intelligent Substation Devices;
- LV-CAP™ enabled PC;
- 4G router / modem;
- Thermal monitoring;
    - Transformer Top Oil Pocket
    - Outside Ambient Air Temperature (including radiation shield);
    - Internal Substation Temperature (if an indoor / enclosed substation);
- GridKey MCU520 (including current sensors and voltage connections).

No additional training was necessary for WPD staff to install the core equipment, with the method statement provided as a guide to ensure the most efficient and appropriate installation was achieved in each substation.

4.1.2 LV Automation Components – Alvin Reclose™

Additional training was necessary for WPD staff in relation to the Alvin Reclose™ units, deployed to fulfil the role of automated LV switch.

Installation of the LV automation elements required more detailed planning, and associated sections in the overall method statement due to the need for local network rearrangement and a more complex post-fault restoration process.

Training was provided via two methods, with the principal aim being to ensure that all depot staff were able to safely deal with a network fault occurring on a network where the OpenLV Project had trial equipment installed.

1. **Direct training** at WPD depot, through the use of the presentation provided in Annex A2, followed by hands-on installation and removal of Alvin Reclose™ devices in a test enclosure.
   During this training session, WPD staff were walked through the process that would be necessary to follow in the event of a network fault occurring on a network in use by the OpenLV Project.
   The ALVIN Reclose™ Installation and Removal Guide provided in Annex A3 was also provided as part of the training.
2. **On-site instructions**, providing a step-by-step walkthrough of the post-fault network restoration at each substation.
   The Alvin Reclose™ units were deployed and commissioned in stages, and the on-site instructions were replaced with each change to reflect the required approach. These are provided in Annex A4.

Staff were informed of the trial locations being utilised where they would find Alvin Reclose™ units and the associated LV-CAP™ control platforms deployed as part of the trials.

Commissioning Stages

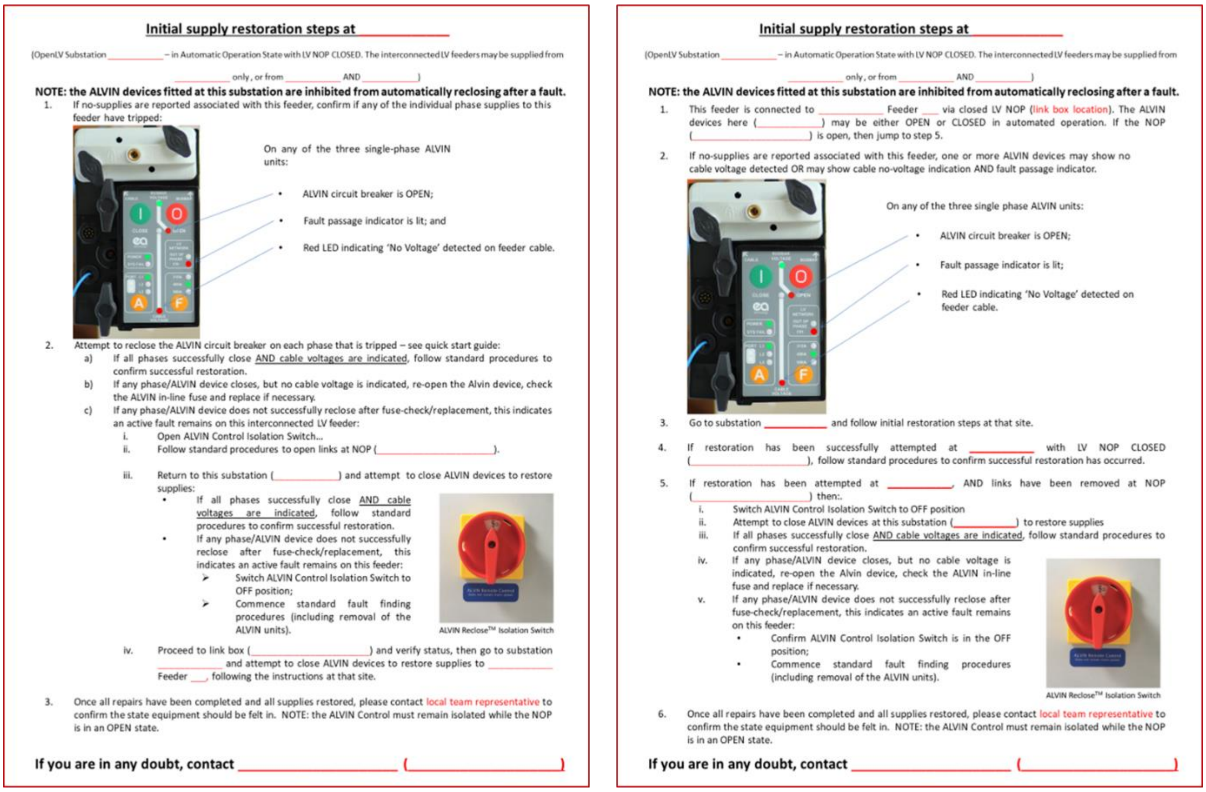
Deployment and commissioning of the LV automation equipment as part of the OpenLV trials was undertaken in three stages.

- Stage 1 comprised replacing the existing, passive fuse holders with Alvin Reclose™ units;
- At Stage 2, the LV network was reconfigured to connect the interconnecting feeders between two substations via the linkbox / normally open point such that one substation energised the previously two feeders; and,
- Stage 3 enabled control of the circuit breakers within the Alvin Reclose™ units by the LV-CAP™ platform.

Figure 20 below depicts the step-by-step instructions left in each substation during Stage 2. Full details of the instructions left in each substation at each stage can be found in Annex A4.

These instructions were clearly mounted on the LV enclosure door in each substation utilised for the LV automation trials. This ensured that in the unlikely event of a member of staff had either missed the training or could not recall the details provided the necessary instructions were available to be followed.

Contact details of responsible persons within WPD were also included in the instructions in the event of unforeseen problems arising.



Initial supply restoration steps at ____________

(OpenLV Substation ________ – in Automatic Operation State with LV NOP CLOSED. The interconnected LV feeders may be supplied from ________ only, or from ________ AND ________)

NOTE: the ALVIN devices fitted at this substation are inhibited from automatically reclosing after a fault.

1. If no-supplies are reported associated with this feeder, confirm if any of the individual phase supplies to this feeder have tripped:

   On any of the three single-phase ALVIN units:
   - ALVIN circuit breaker is OPEN;
   - Fault passage indicator is lit; and
   - Red LED indicating 'No Voltage' detected on feeder cable.
2. Attempt to reclose the ALVIN circuit breaker on each phase that is tripped – see quick start guide:
   a) If all phases successfully close AND cable voltages are indicated, follow standard procedures to confirm successful restoration.
   b) If any phase/ALVIN device closes, but no cable voltage is indicated, re-open the Alvin device, check the ALVIN in-line fuse and replace if necessary.
   c) If any phase/ALVIN device does not successfully reclose after fuse-check/replacement, this indicates an active fault remains on this interconnected LV feeder:
      i. Open ALVIN Control Isolation Switch...
      ii. Follow standard procedures to open links at NOP (________________).
      iii. Return to this substation (__________) and attempt to close ALVIN devices to restore supplies:
         - If all phases successfully close AND cable voltages are indicated, follow standard procedures to confirm successful restoration.
         - If any phase/ALVIN device does not successfully reclose after fuse-check/replacement, this indicates an active fault remains on this feeder:
           - Switch ALVIN Control Isolation Switch to OFF position;
           - Commence standard fault finding procedures (including removal of the ALVIN units).

         ALVIN Reclose™ Isolation Switch
      iv. Proceed to link box (________________) and verify status, then go to substation ________ and attempt to close ALVIN devices to restore supplies to ________ Feeder ___, following the instructions at that site.
3. Once all repairs have been completed and all supplies restored, please contact local team representative to confirm the state equipment should be felt in. NOTE: the ALVIN Control must remain isolated while the NOP is in an OPEN state.

If you are in any doubt, contact ________________ (________________)

Initial supply restoration steps at ____________

(OpenLV Substation ________ – in Automatic Operation State with LV NOP CLOSED. The interconnected LV feeders may be supplied from ________ only, or from ________ AND ________)

NOTE: the ALVIN devices fitted at this substation are inhibited from automatically reclosing after a fault.

1. This feeder is connected to ________ Feeder ___ via closed LV NOP (link box location). The ALVIN devices here (__________) may be either OPEN or CLOSED in automated operation. If the NOP (________________) is open, then jump to step 5.
2. If no-supplies are reported associated with this feeder, one or more ALVIN devices may show no cable voltage detected OR may show cable no-voltage indication AND fault passage indicator.

   On any of the three single phase ALVIN units:
   - ALVIN circuit breaker is OPEN;
   - Fault passage indicator is lit;
   - Red LED indicating 'No Voltage' detected on feeder cable.
3. Go to substation ________ and follow initial restoration steps at that site.
4. If restoration has been successfully attempted at ________ with LV NOP CLOSED (________________), follow standard procedures to confirm successful restoration has occurred.
5. If restoration has been attempted at ________, AND links have been removed at NOP (________________) then:.
   i. Switch ALVIN Control Isolation Switch to OFF position
   ii. Attempt to close ALVIN devices at this substation (________) to restore supplies
   iii. If all phases successfully close AND cable voltages are indicated, follow standard procedures to confirm successful restoration.
   iv. If any phase/ALVIN device closes, but no cable voltage is indicated, re-open the Alvin device, check the ALVIN in-line fuse and replace if necessary.
   v. If any phase/ALVIN device does not successfully reclose after fuse-check/replacement, this indicates an active fault remains on this feeder:
      - Confirm ALVIN Control Isolation Switch is in the OFF position;
      - Commence standard fault finding procedures (including removal of the ALVIN units).

   ALVIN Reclose™ Isolation Switch
6. Once all repairs have been completed and all supplies restored, please contact local team representative to confirm the state equipment should be felt in. NOTE: the ALVIN Control must remain isolated while the NOP is in an OPEN state.

If you are in any doubt, contact ________________ (________________)

Figure 20: Post-Fault Restoration Instructions (Commissioning Stage 2)

4.2 Training provided to community organisations

Centre for Sustainable Energy (CSE) provided a range of support for the community organisations participating in the OpenLV Project. It was identified that different community organisations needed varying levels of assistance. The support required included:

- Clarification of the functionality of the web app;
- Understanding of the practicalities of the distribution network and its assets;
- Explanation of data points;
- Suggestions about downloading and manipulating huge quantities of data; and,
- Advice on communicating complex data and messages to communities.

CSE provided:

- The 'OpenLV App User Guidance' document;
- A number of webinars;
- Face-to-face workshops;
- Phone tutorials; and,
- Email support.

CSE continued to receive requests for assistance throughout the length of the project.

‘OpenLV App User Guidance’ document

This document was created to provide a User Guide for the community groups participating in the project. It was designed to familiarise the groups with the app functions. It provides information on how data fields are calculated and what engineering terms mean. As the app developed over the course of the project and in response to ‘Frequently Asked Questions’ from participating organisations, the User Guide was expanded.

The User Guide can be found in Annex A5.

Webinars

CSE held four webinars to demonstrate the functionality of the web app. These included:

1. App design workshop – 21 May 2018;
2. Online App Demonstration – 26 June 2018;
3. App development update – 31 July 2018; and,
4. App launch – 4 September 2018.

These webinars were very useful however it was noted that the conversation tended to become more specific focusing on how the data and the web app could be used for each group’s purpose as the webinars progressed.

Face-to-face workshops

The project organised a number of face-to face workshops which were used to update attendees on wider project news and progress. They provided opportunities for community organisations participating in the project to compare strategies that had worked for them, and ones had been less successful. The workshops also allowed members of community organisations to discuss technical difficulties about the web app, network queries or other technical questions with WPD, the CSE team or EA Technology as appropriate.

The slides from these workshops are available on the project website [1].

Phone tutorials

The team at CSE took frequent ad hoc phone queries from the groups about items such as:

- How to use the data to achieve what they wanted;
- The basic principles of power network engineering; and,
- Web app functionality.

Email queries

The project team at CSE, supported by EA Technology when necessary, also received and responded to emailed queries from participating community groups. Some of these were quite detailed technical questions on topics including:

- Network configuration;
- Explanation of power engineering or measurement terms; and,
- Accessing or processing data.

3rd Party application Development Tools

The documentation provided by EA Technology and the OpenLV Project was written specifically for the LV-CAP™ software and associated hardware deployed within the project. It is however provided as guidance of tools and documentation that proved highly effective at enabling 3rd party application developers to produce applications for deployment to the LV-CAP™ platform.

The documentation provided to app developers is summarised below:

- **OpenLV Measurement Points** provided information on the data gathered, to what resolution and accuracy. This is provided in Annex A6.
- **LV Common Application Platform Public API** details the application programming interface (API) for developers intending to write applications for deployment to the LV-CAP™ platform. This is provided in Annex A7.
- **Developing for LV-CAP™ using the Virtual Machine** provided application developers with the necessary knowledge to utilise a virtual system for initial application testing. This is provided in Annex A8.

5 Enduring Tools

The delivery of the OpenLV Project has resulted in the creation of various resources, either created to aid the delivery of the project, or that bring together valuable learning from project experiences that can be used as enduring tools by GB DNOs, community organisations, businesses and Universities.

These enduring tools are detailed below, grouped by the Method that the tool was developed under.

5.1 Distribution Network

Method 1 developed two distinct outputs that provide the potential to benefit GB networks.

1. Loadsense, the automated LV switching control application, was developed to utilise outputs from elsewhere within the system and enact changes to the LV network; and,
2. Analysis of the transformer load and thermal data allowed the development of simple formulae for the calculation of transformer hot spot temperature.

5.1.1 Loadsense

The Loadsense application was developed within the OpenLV Project to demonstrate the ability to make decisions based on multiple input sources.

Loadsense, as deployed in the Method 1, Phase 2 trials, considered the likely state of both transformers in the pair for both possible states of the LV switch, and opened or closed the switch accordingly.

The full logic behind this process is defined in the report titled “OpenLV Loadsense Operational Logic” previously published as part of SDRC 2.2, and is available on the Project Website [1], and via WPD’s Project Portal [7], but Figure 21 below illustrates the principle.

The process for deploying Loadsense on the OpenLV trial utilised IBM’s Node-RED development tool [18], providing an event driven programming model that it is simple to modify as and when required.

Whilst the OpenLV Platform utilised a series of inputs as shown above in Figure 21, these could easily be replaced with variables from other applications.

When deployed in the OpenLV Platforms an application container on the platform undertakes the calculations and determines the necessary action, if any, as determined in the Loadsense Operational Logic Report, previously published as part of SDRC 2.2. The container also requires a configuration file where the thresholds for initiating, or blocking LV switching operation are defined.

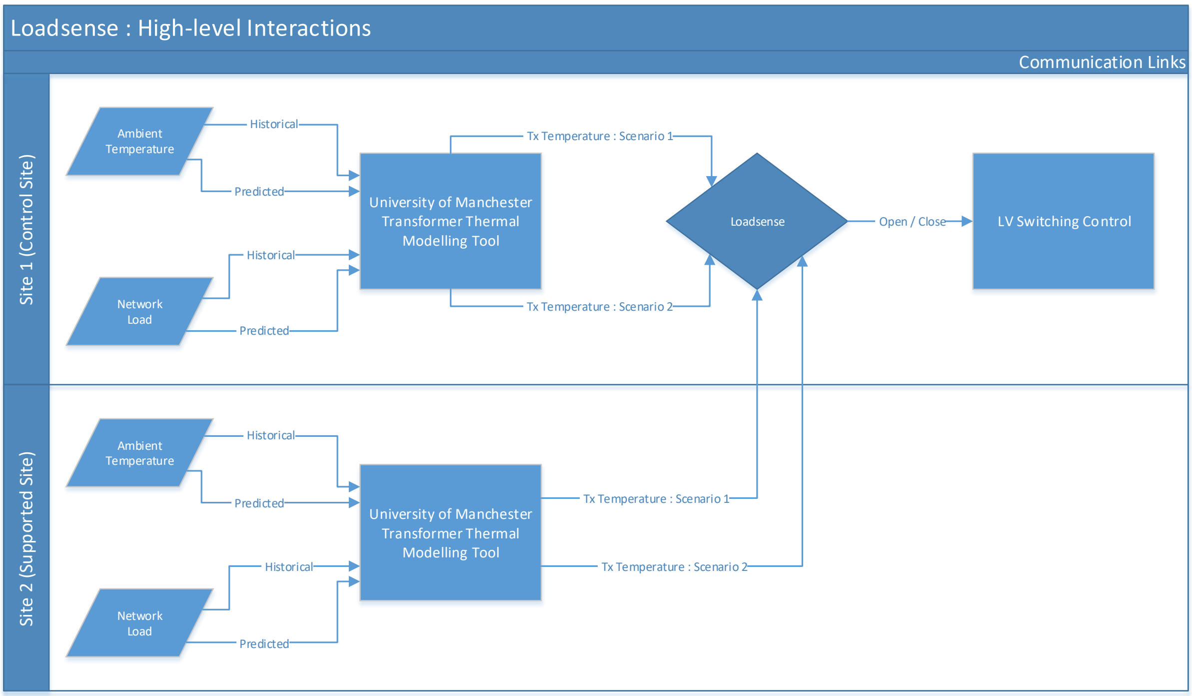


Figure 21 Loadsense: High-level Interactions

Whilst this container will only work on LV-CAP™ platforms deployed in the same configuration as those utilised in the OpenLV Project, and would require some adaptation to function on other distributed intelligence platforms, the code provided ensures such a process will require minimal effort for future deployments. Furthermore, expanding the applications capabilities using the Node-RED platform will also be possible.

Due to the extent of both the source code for the application container and the configuration file, it is not practicable to include them within publication of this report or subsequent Annexes, however, it will be provided in digital format on request.

5.1.2 Transformer Hot Spot Calculations

Using the data gathered from the Method 1 substations, several formulae variants have been created allowing calculation of the Transformer hot spot temperature using information normally available to basic monitoring equipment in a substation. The greater the information available regarding the substation, the more accurate the formula that can be used.

The three formulae are below, in decreasing order of accuracy.

Three variable equations

The first formula utilises three input variables to calculate the Hot Spot temperature.

1. Transformer Load;
2. Transformer Top Oil Temperature; and,
3. Ambient Temperature[4].

This clearly requires, at a minimum, monitoring of the transformer busbars or all connected feeders to determine the total transformer load as well as installation of a thermal probe into the transformer's Top Oil pocket.

Use of weather data from the Met Office can be utilised for a 'reasonable value' of ambient temperature if the transformer at the substation in question is located outside. For indoor or GRP substations, use of this equation also necessitates the installation of a temperature probe for the ambient environment.

Equation 1 : Three variable equation for calculating Tx hot spot

$$Temp.TxHotSpot_E = 2.96 + (0.627 \times Temp.TopOil_M) + (21.5 \times Tx\ \%Load_M) + (0.349 \times Temp.Ambient_M)$$

Two variable equation (Tx %Load and Temp.Top Oil)

The second formula can be utilised where it is not feasible to monitor the ambient temperature (i.e. it is an indoor substation without an internal temperature monitor).In this instance just a Transformer Load and Top Oil are used and provide a less accurate value.

This clearly requires, at a minimum, monitoring of the transformer busbars or all connected feeders to determine the total transformer load, as well as installation of a thermal probe into the transformer's Top Oil pocket.

Equation 2 : Two variable equation for calculating Tx Hot Spot

$$Temp.TxHotSpot_E = 2.92 + (0.913 \times Temp.TopOil_M) + (15.8 \times Tx\ \%Load_M)$$

Two variable equation (Tx %Load and Temp.Ambient)

The third formula can be utilised where it is not feasible to monitor either the ambient or Top Oil temperatures, but loading information is available for the transformer.

Equation 3 : Two variable equation for calculating Tx Hot Spot

$$Temp.TxHotSpot_E = 6.65 + (0.933 \times Temp.Ambient_M) + (34.02 \times Tx\ \%Load_M)$$

[4] Note that in this context 'Ambient Temperature' refers to the environment in which a transformer is located. When a transformer is situated in an outdoor substation the external temperature would be required, but if a transformer is located within a building or GRP enclosure the internal temperature is required instead.

This final equation can also be utilised for 'best guess' calculations for Hot Spot Temperature of a transformer in given conditions, utilising the predicted load profiles generated by industry available tools such as the LV Network Templates tool.

5.2 Community groups

A number of enduring tools have emerged from this part of the project:

- Community web app;
- Training material for the web-app; and,
- Guidebook.

An overview of these resources is provided below.

5.2.1 Web app

Early in the project, a number of barriers preventing community access to substation data were identified, namely:

- Lack of software development expertise in most of the community organisations (to either write software or develop specifications for external developers);
- Lack of funds to procure bespoke software development; and,
- Insufficient time for successful fundraising for software development within the timeframes of the trials.

A review of the project findings about fundraising potential for community organisations to undertake app development of this nature is provided below.

There was significant crossover in the data points that trial participants wanted to access to facilitate their projects and in the features they wanted to include in an app. A change of approach was therefore agreed, and CSE developed a single, customisable, web app featuring a common set of core functions for all trial participants to use. This was the most cost-effective way to provide each group with access to the data, a range of features to manipulate the data, and the ability to tailor functions and visualisations, whilst also avoiding replication of effort and meeting project timeframes.

To achieve this, CSE liaised with the community organisations to scope out their requirements and programmed a single application (the 'm2 collation app') which was successfully deployed to the LV-CAP™ units in August and September 2018. It can access various data measurements from other applications running in the LV-CAP™ unit and collates the 1-minute information for each data point into 5 readings for each data point for every half hour:

- Minimum (i.e. lowest reading in the half hour);
- Maximum (i.e. highest reading in the half hour);
- Mean for the half hour period;
- Number of readings in the half hour period; and,
- Standard deviation.

This information is communicated to the OpenLV Lucy Electric Cloud server. A web app, hosted on a separate server, receives messages from the Lucy Electric server, providing a ‘front end’ for community groups to access the collated half hourly data.

The community trial participants were given access to a set of configurations in the web app where data, time periods and display options are set. In addition to core data from the LV-CAP™ sensors (temperature, voltage, power, energy, etc.), the customised apps can also incorporate external data (carbon intensity data and local generation data) and user defined criteria (e.g. cost of electricity). Some data is extrapolated (e.g. by combining energy with a unit cost or looking at associated carbon emissions for a given time period). The apps can model different time of use tariffs and send alerts to individual members of the community when certain conditions are met (for example, carbon intensity reaches a set level).

The graphs, data tables and smileys[5] are set up by the participating community organisations are in the public domain with configuration restricted to those organisations.

Additional features requested by the community organisations were added during the project trials to improve access to and use of data, including a function to estimate local (domestic) photovoltaic generation, a user controlled feature to amalgamate data from multiple sources, and a means of displaying a time of use tariff (Octopus’ Agile tariff) recently brought to market.

This OpenLV web app is an enduring tool available to community groups after the end of the OpenLV Project.

5.2.2 Training Material for the web app

As mention in Section 4.2 a ‘User Guidance’ document was developed by CSE for the use of community organisations accessing the Web App. The latest version of this (edited in February 2020) is available in Annex A5.

5.2.3 Guidebook for Community Organisation

A Guidebook has been produced by Regen summarising their observations as the project’s ‘Community Learning Specialist’ supplier. An abbreviated version of this report will be available as a leaflet that can be used by community organisations across GB. The leaflet provides tips suggesting how LV substation data can be best utilised to support organisations aims based around the most common use-cases from the trial. It is illustrated with case studies from the project.

A full-length report style version of the ‘Guidebook’ is available in Annex A9 of this report and will be downloadable from the WPD Innovation website.

[5] Smileys were developed as a function for avoiding graphs and communicating a simple message about current electricity use.

5.3 Business and Academia

As described within SDRC 4, because many of the business and academic focussed participants treated the OpenLV trial as a R&D investigation, there were significant demonstrations of willingness of participants to work towards a long term offering, subject to their being market signals regarding how they can bring their innovation to market.

It is anticipated that where there are sufficient market signals, participants will be in a position to invest further funds to bring their innovation to market readiness and hence release the enduring offer of the OpenLV trial.

When this occurs, the development tools outlined in 4.2 above, created for participants of the OpenLV Project trials are expected to be updated as required to be appropriate for the latest iteration of distributed intelligence software. This would be LV-CAP™ for EA Technology products but it is strongly recommended that any other software platforms developed in a similar manner provide the same tools to aid developers.

6 Business-as-Usual Specification

It is important to distinguish between the LV-CAP™ software platform deployed as part of the OpenLV Project trials and the hardware on which the software is to be deployed.

Whilst onsite, from the perspective of derived benefits, the two elements are effectively a single unit, however the software can be updated, changed, and replaced at a negligible (individual) cost, but the hardware must remain fit for purpose for a reasonable period of time, and for the intended use case.

The OpenLV Project has therefore defined four use cases in which a distributed intelligence platform may be deployed, ranging from minimal monitoring to utilising the full potential of such a platform.

6.1 Operational Tiers

The operational tiers detailed below increase in capability, with the expectation being that each tier builds on the potential of the previous.

With all operational tiers below, data gathered by the core platform (voltage, current and temperature) would be available to any application running on the device, whereas data generated by additional applications would be expected to be restricted, or published, on a case-by-case basis.

A table, summarising the high-level functional requirements for each operational tier is provided in Appendix 1.

6.1.1 LV Monitoring

LV Monitoring deployments are expected to be utilised as ‘early warning’ systems, providing a more useful function than Maximum Demand Indicators (MDIs) currently installed across the LV Network.

Such deployments would prioritise minimal operational costs, utilising the on-board data storage and processing capabilities, allowing the platform to monitor and notify the network operator only if defined criteria are met (e.g. network voltage straying beyond statutory limits). Stored data can be uploaded when 'requested' but otherwise, it will be overwritten once the internal storage is full.

Where a platform raises alerts, software applications can be deployed remotely to determine whether more active measures such as those types detailed below, would be worthwhile, prior to installation of additional hardware.

6.1.2 Limited Control

Limited Control deployments could combine the abilities of the above platform but with additional applications and hardware functionality developed by the DNO / Distribution System Operator (DSO) or trusted 3rd parties.

Local intelligent algorithms would be deployed to analyse the data in real time, determine whether any available actions can benefit the local network, and control the relevant hardware (e.g. Active voltage control, automated network switching, charge / discharge of local battery storage), if available.

Deployments of this type would necessitate a higher operational cost due to a combination of increased data requirements or maintenance of control capable hardware.

The need for enhanced functionality suggests that, at least initially, greater levels of site data will be required before system communications is eventually reduced to a 'by exception' approach as standard for the 'LV Monitoring' deployments.

Data would likely be processed locally, with key information selected by the network operator uploaded on a periodic basis, although alerts for non-standard situations would remain operational.

6.1.3 Enhanced LV Monitoring

Enhanced LV Monitoring deployments will combine the abilities of the LV Monitoring platform but with additional application-based functionality provided by the DNO / DSO (Distribution System Operator) or 3rd parties.

Locally deployed intelligent algorithms would analyse the data in real time, determine whether any available actions can benefit the local network, and transmit necessary information to remote third-party systems for further analysis or implementation of contracted services.

Deployments of this type would necessitate a higher operational cost, due to a combination of increased data requirements, or maintenance of control capable hardware.

The need for enhanced functionality suggests that, at least initially, greater levels of site data will be required, before, eventually reducing the system communications to a 'by exception' approach, implemented as standard for the 'LV Monitoring' deployments.

Data would likely be processed locally, with time critical information being published as soon as possible, and key information selected by the network operator uploaded on a periodic basis, although alerts for non-standard situations would remain operational.

6.1.4 Full Capability

Platforms in this category would be expected to combine elements from those above, and therefore may have the ability to control local LV automation hardware, issue control triggers to third party systems, and issue automated alerts based on key criteria.

Data would likely be processed, with time critical information being published as soon as possible, and key information selected by the network operator uploaded on a periodic basis, although alerts for non-standard situations would remain operational.

6.2 Distributed Intelligence System

The deployment of distributed intelligence devices by network operators (both Distribution and Private) will undoubtedly comprise a mixture of the above categories, with the site-specific requirements determining the level of functionality procured.

There are two broad approaches available with respect to the hardware.

1. Utilise a common hardware platform, capable on a technical level of deployment in a ‘Full Capability’ mode, varying the onboard software packages and ancillary equipment as required; or,
2. Produce a hardware platform suitable for one, or some of the four categories, but necessitating a physical change of the system if the on-site requirements change.

The first approach results in at least some locations being outfitted with hardware being ‘over-specified’ for the on-site requirements but provides greater flexibility as conditions change on the network.

The second approach provides ‘fit for purpose’ hardware with little to no extraneous capacity, sacrificing flexibility for potential savings on capital expenditure.

The OpenLV Project has identified some minimum recommended functional requirements, applicable to every identified use case; these are detailed below.

Where minimum requirements differ between each category, these are identified as such.

It should be noted that the functional requirements below are intended to provide minimum baseline capabilities for distributed intelligence platforms that are applicable in the longer term, without providing hardware specifications. This is to allow for increasing technical capabilities in the future.

6.2.1 Minimum Recommended Functional Requirements

All platform categories

All distributed intelligence devices are recommended to be capable of monitoring electrical network specific readings, key asset status, and ambient conditions.

1. Core hardware
   - LV Network Data, monitoring to at least Class 1 metering accuracy:
     - Five feeders;
     - Measuring Three phases plus neutral; and
     - and three-phase voltages.
2. Ancillary hardware
   - Connectivity for monitoring:
     - Transformer Top Oil / Tank Temperature; and,
     - Temperature in substation environment.

Each platform should have sufficient data storage capability to store:

- 30 minutes averages of monitored data for a period of 30 days; and,
- Application outputs[6] for a period of 30 days.

This data storage capability being appropriate for the number of feeders monitored and applications capable of being deployed to the platform in each scenario defined below.

All distributed intelligence platforms have a minimum set of core functionality based around the monitoring of connected sensor, gathering the relevant data, undertaking basic processing and analysis, before storing the pertinent data for future use and / or transmission.

The applications / processes expected as part of core functionality comprise the following types:

- Measure data;
- Store data;
- Process data;
- Analyse (for the purpose of status alerts);
- Determine state of network assets;
- Raise alerts; and,
- Communicate with command & control servers.

It is emphasised that any distributed intelligence platform must manage limited available resources, and applications must operate effectively within limits assigned by the platform manufacturer. As part of the OpenLV Project, 3rd party application developers were allowed to create applications capable of operating within defined processor and on-board memory

[6] Platform developers will need to provide guidance on the extent to which individual applications are able to utilise onboard resources. This will include access to processing time, operating memory, and data storage, and will be a matter for individual manufacturers to define for their product.

allocations. This effectively limited the system resources each application could utilise and was actively enforced by the core LV-CAP™ application management software.

It is also expected that typical hardware capabilities will increase over time as the cost to achieve a level of system capability decreases, although it would also be reasonable to expect application requirements to increase as more is delegated to remote platforms.

A summary table, emphasising the key differences between each tier defined below is provided in Appendix 1.

The minimum cyber-security requirements detailed below were provided by NCC Group[7], following a threat analysis review; the full details of which have been covered in Section 7 below.

Tier 1 – LV Monitoring

Platforms deployed under this utilisation tier are for the purposes of basic LV monitoring only. Minimal data processing will be required, with the primary functions relating to the gathering and temporary storage of data, with alerts triggered if any pre-defined conditions are met.

These would include voltage excursions from statutory limits, and current warnings for individual feeders and/or the transformer.

Data usage will be minimal as unless a specific request is sent to the system to trigger a data upload, communications will only occur for the purposes of system updates and issuing network alerts.

Basic system requirements

The hardware platform should have a processor (CPU) and RAM capable of handling at least 10 application processes.

Software applications

The system is not expected to require any applications addition to the core applications identified above.

[7] https://www.nccgroup.trust/uk/

Tier 2 – Limited Control

Platforms deployed under this categorisation are anticipated to be deployed where enhanced on-site analytics are required, and the application of local intelligent automation has the potential to benefit the network.

Network automation hardware and associated software, provided by trusted third party suppliers can be installed on the local network, controlled by the intelligent device platform based on configurable operational logic.

Network and application data will be stored, with high level network information uploaded on a periodic basis to allow remote monitoring of the asset operation.

Basic system requirements

The hardware platform should have a processor (CPU) and RAM capable of handling at least 10 application processes.

Software applications

In addition to the core applications identified above, applications within the following criteria are expected to be required:

- Communicate with external devices (monitors and actuators);
- Control limited set of devices; and,
- Report on actions taken.

Tier 3 – Enhanced LV Monitoring

Systems deployed in this configuration are anticipated to become more widespread as the marketplace for third-party applications develops. Applications from universities and companies who are not considered to be ‘trusted partners’ are unlikely to be deployed to distributed intelligence platforms with control of critical part of the LV network.

Basic system requirements

The hardware platform should have a processor (CPU) and RAM capable of handling at least 15 application processes.

Software applications

In addition to the core applications identified above, applications within the following criteria are expected to be required:

- Communicate with external devices (monitors); and,
- Communicate with third party servers / control systems.

Tier 4 – Full Capability

There is the potential for systems to be deployed in this configuration as it is possible that significant benefits may be available to the network from applications developed by third-party developers. It will therefore require balance between the level of trust held by the DNO / DSO in the application and platform developers if the distributed intelligence platform has the ability to control any part of the LV network.

Basic system requirements

The hardware platform should have a processor (CPU) and RAM capable of handling at least 15 application processes.

Software applications

In addition to the core applications identified above, applications within the following criteria are expected to be required:

- Communicate with external devices (monitors and actuators);
- Communicate with third party servers / control systems;
- Control external devices; and,
- Report on actions taken.

7 Cyber-Security

Evaluation of the cyber-security of the LV-CAP™ system was undertaken by an independent cyber-security specialist (NCC Group) to verify the overall system was secured to an appropriate level.

The checks undertaken by NCC Group were referenced against four key equipment deployment stages in the project as defined below and discussed in detail in the following subsections.

3. **Design review:**

- A high-level review of the LV-CAP™ system architecture, as planned to be deployed for the OpenLV trials; and,
- As part of this verification a letter from NCC Group was provided to confirm their agreement that the trial system could be deployed.

4. **Penetration testing:**

- Initially a Security Review of the OpenLV trial platform was undertaken prior to a detailed security test, comprising code review, and direct attempts to access trial platforms, the control and data servers, and the communication links deployed in the project from unauthorised users; and,
  A detailed report was provided, outlining all identified areas of interest. EA Technology implemented the necessary changes to the trial system to meet the recommendations for each stage of the trials. *Note that this report was subsequently updated following the code-review stage detailed below.*

5. **Post deployment code review:**

- Following deployment of the trial systems, and the necessary updates to the LV-CAP™ system following the penetration testing, a high-level code review of the changes made was undertaken; and,
- The report initially provided as part of the penetration testing was updated following the post-deployment review, and the revised version is provided along with the report detailing EA Technology's response to the recommendations made.

6. **Business-as-usual recommendations**

- Incorporation of NCC Group's learning over the course of the OpenLV Project, with guidance from industry experts in both EA Technology and WPD, to provide cyber-security advice for the industry when deploying distributed intelligence platforms as part of business-as-usual procedures in the future.

7.1 Design review

Initially, NCC Group were provided with details of the LV-CAP™ platform, specifically relating to the system architecture, and the hardware and communication protocols being utilised.

NCC Group were, based on this initial review, able to approve deployment of the LV-CAP™ platform for the first substations and confirmed so in writing.

This approval was granted on the basis that the trial hardware was:

- Only deployed for LV network monitoring;
- Did not have the ability to implement any changes on the LV network; and,
- Was not connected to existing power control communication networks such as DNP3.

It was confirmed that there was no cyber-security risk to the power distribution networks from deployment of the initial LV-CAP™ platforms in this mode.

The letter provided by NCC Group confirming this statement is provided in Annex A10.

The purpose of this review was to enable initial deployment of the first LV-CAP™ platforms in the OpenLV trial for long-term 'soak testing' on the LV network, prior to widescale roll-out of the remaining devices.

An overall security assurance review was undertaken at this time and is detailed in Annex A11.

7.2 Penetration testing

Following the initial design review, and deployment of the 'soak test' devices, NCC Group provided a code review and penetration test analysis of the complete LV-CAP™ system, covering the hardware platforms to be deployed on the LV network, the 'command and control (iHost) server' located at EA Technology's offices in Capenhurst, and the public facing 'data server' provided to the project by Lucy Electric [19].

The report provided following these tests was up-issued later in the project following a 'post-deployment code review' to verify the implementation of the previously made recommendations and is located in Annex A12.

7.2.1 Risk ratings

NCC Group adopted the Common Vulnerability Scoring System (version 2) (CVSS) for evaluating the OpenLV trial system. CVSS is a vendor independent industry open standard, which provides a universal method for rating IT vulnerabilities. It is designed to convey the severity of vulnerabilities, and to help organisations prioritise their responses.

The table below gives a key to the icons and symbols used through this report to provide a clear and concise technical risk scoring system.

Table 16: CVSS Rating System

Risk Rating	Symbol	CVSSv2 Score	Explanation
Critical		9.0 – 10	A vulnerability was discovered, that was rated as critical. This requires resolution as quickly as possible.
High		7.0 – 8.9	A vulnerability was discovered that was rated as important. This requires resolution in the short term.
Medium		4.0 – 6.9	A vulnerability was discovered that was rated as of medium criticality. This should be resolved as part of the ongoing security maintenance of the system.
Low		1.0 – 3.9	A vulnerability was discovered that was rated as of low criticality. This should be resolved as part of the routine maintenance tasks.
Info		0 – 0.9	A discovery was made that was rated as of informational value. This should be addressed to meet leading practice.
N/A		N/A	Good security practices were being followed or an audit item was found to be present and correct.

It was acknowledged by NCC Group that quantifying the overall business risk posed by any of the issues found in any test was outside their remit.

Therefore, some risks reported as high from their technically focused perspective were, because of other controls unknown to them and the broader business context, considered acceptable or classified as a lower business risk. Where this occurred, the justification behind that decision was clearly detailed in EA Technology’s report, “OpenLV Cyber-Security Response” provided in Annex A13.

7.2.2 Summary of response to NCC Group's findings

NCC Group identified 40 actionable items, with a further 8 items detailed for information, for further consideration by EA Technology across four discrete areas of the project:

- Unauthenticated infrastructure assessment;
- Authenticated infrastructure assessment;
- Docker breakout review; and,
- Code review assessment (OpenLV Environment).

The number of issues, and their severity varied between each area, as shown below:

Table 17: NCC Group's High-Level Findings

Phase	Description	Critical	High	Medium	Low	Info.	Total
1	Unauthenticated infrastructure assessment			7	6	3	**16**
2	Authenticated infrastructure assessment		1				**1**
3	Docker breakout review			3	7		**10**
4	Code review assessment (OpenLV Environment)		9	4	3	5	**21**
	Total	**0**	**10**	**14**	**16**	**8**	**48**

With the benefit of available contextual business information and a greater understanding of the LV-CAP™ platform, the identified issues were evaluated by EA Technology, allowing a more accurate risk and impact analysis to be undertaken. EA Technology determined the appropriate response to each issue raised to be one or more of the following:

- Issue is already resolved;
- Resolve for all devices to be deployed as part of the OpenLV Project;
- Resolve for devices yet to be deployed by the OpenLV Project (Method 1 – Phase 2, Method 2 and Method 3 substations);
- Resolve prior to the deployment of LV-CAP™ in a business-as-usual situation but not as part of the OpenLV Project;
- No further action required as either:
    - The issue raised cannot be resolved within the project and will not be an issue for future BAU deployments; and,
    - The initial evaluation is inaccurate and there is no issue to resolve.

Some issues fell into multiple categories, where it can be partially resolved, or mitigated within the project timescales, but full resolution will not be completed before BAU deployment.

This approach has been taken where the identified vulnerability has been mitigated elsewhere within the OpenLV architecture or is specific to the trial hardware and was not applicable to deployment of LV-CAP™ outside the OpenLV Project. Further detail about EA Technology's actions undertaken is provided in Table 18.

Table 18: EA Technology Actions

Phase	Description	Issue resolved	Partial Fix Complete – Full Resolution for BAU	Resolve for BAU	No Further Action Required	Total
1	Unauthenticated infrastructure assessment	10	1		5	**16**
2	Authenticated infrastructure assessment			1		**1**
3	Docker breakout review	1	8		1	**10**
4	Code review assessment (OpenLV Environment)	6	7	7	1	**21**
	Total	**25**	**6**	**9**	**8**	**48**

7.3 Post-deployment code review

Following implementation of the necessary modifications to the system settings and code, NCC Group undertook a high-level code review of the changes made to verify they were implemented as intended.

The penetration testing report was subsequently updated following verification of the updates implemented after the first issue of the report. The final version can be found in Annex A12.

EA Technology also provided a formal response to this report, which can be found in Annex A13.

7.4 Business-as-usual recommendations

Following the design review and penetration testing undertaken prior to the deployment of the trial hardware, NCC Group held a series of workshops with experienced staff at EA Technology and WPD to assess the uses to which distributed intelligence platforms, as trialled in the OpenLV Project, might be deployed. The objective of NCC Group's assessment (see Annex A14 for full details) was to devise and put forward the baseline and enhanced security control standards that are required and expected to be in place for the deployment, management, operation and maintenance of the LV-CAP™ Platform, or similar distributed intelligence substation devices, in BAU use following the conclusion of the OpenLV Project.

- Baseline controls are the minimum set of security controls that are expected to be in place prior to deployment and operation of the distributed intelligence platform. These controls are designed to be mandatory in nature to meet business and regulatory requirements.
- Enhanced controls are additional controls that can be implemented, on top of the baseline controls, to strengthen the security environment of a distributed intelligence platform and to mitigate against Advanced Persistent Threats (APTs). Therefore, these should be considered in-line with changing threat and risk landscape and implemented at earliest opportunity.

The assessment has considered the four operational tiers (or use cases) of an LV-CAP™ style distributed intelligence platform deployment introduced in Section 6.1, namely: LV Monitoring, Limited Control, Enhanced LV Monitoring, and Full Capacity. Each operational tier builds on the previous in terms of connectivity, output and benefits.

With consideration of each operational tier, NCC Group has considered the following in the development of security control standards (i.e. risk mitigations):

- Threat actors;
- Impact of cybersecurity breach; and
- Specific risks.

Initially, in consideration of the baseline and enhanced security controls, NCC Group has assessed a number of threat actors, external and internal, and assessed their capability and motivation to do harm through unauthorised access to the platform and data generated, processed or transmitted. The table below summarises the capabilities, motivation and likely threat rating for each threat actor.

Table 19: Threat actors and their ratings

#	Threat Actor	Capability	Motivation	Threat Rating
1	Organised Crime Group	High	Medium	**High**
2	Opportunist Hackers	Medium	High	**High**
3	Insider Threats	High	Low	**Moderate**
4	Terrorists	Medium	High	**High**
5	Hacktivists	Medium	Medium	**Moderate**
6	State Sponsored Groups	High	Medium	**High**
7	Competitors	High	Low	**Moderate**
8	Hostile Media	Low	Medium	**Low**
9	Partners, Vendors, Suppliers	High	Low	**Moderate**

In addition to the threat actors, NCC Group's study has also assessed the impact to the distributed intelligence platform from a breach to, or loss of, Confidentiality, Integrity and Availability (CIA) of data generated, processed and transmitted.

The impact is measured based on a range of ratings from negligible to catastrophic. In the context of the LV-CAP™ environment, the CIA are defined as follows:

- Confidentiality – protection against unauthorised access or disclosure of data and information generated, stored or transmitted by any distributed intelligence platform;
- Integrity – protection against unauthorised modifications (e.g. changes, deletion, or amendment) of data generated, stored or transmitted by the distributed intelligence platform; and,
- Availability – protection against loss or unavailability of data and information at the time of need and at the frequency required by DNOs and/or third parties.

The following table shows the assessed CIA impact to distributed intelligence platforms based on the four use cases:

Table 20: Use cases CIA impact

#	Use Case	Confidentiality	Integrity	Availability	Maximum Impact
1	LV Monitoring	Medium	Major	Minor	**Major**
2	Limited Control	Medium	Major	Major	**Major**
3	Enhanced LV Monitoring	Medium	Major	Medium	**Major**
4	Full Capacity	Medium	Major	Major	**Major**

As the CIA assessment shows that the impact to any distributed intelligence platform from a security incident originated by any or a number of threat actors is considered as Major, the proposed technical baseline and enhanced security controls would apply to all use cases of the platform equally.

Subsequently, NCC Group examined a number of potential risk vectors, which can be grouped into accidental, adversarial or environmentally sourced. Based on the threats, security impact and risks to such a distributed intelligence platform, NCC Group's assessment has detailed a comprehensive set of technical security controls in the form of Baseline and Enhanced measures to support the mitigation of threats and risks. A summary of these, outlining the security domains and number of controls recommended is shown in the table below.

Table 21: Security controls summary

#	Security Control Domain	Baseline Controls	Enhanced Controls
1	Identity and Access Management	9	2
2	Information and Data Processing	9	0
3	Server Security	9	3
4	Network Security	9	0
5	Application Security	7	2
6	Web Application Security	6	0
7	Cloud Security	5	0
8	End Point Security	7	1
9	Mobile and Remote Working	3	2
10	Threat and Vulnerability Management	5	0

#	Security Control Domain	Baseline Controls	Enhanced Controls
11	Security Operations and Monitoring	6	3
12	Incident Management	6	1
13	Security Testing	5	0
14	Business Continuity	3	2

For a full accounting of recommended security controls see Annex A14, however key recommendations include:

- Adopt role-based access controls with appropriate levels of network segregation through the separation of duties with clearly defined roles and responsibilities;
- Implement multifactor authentication, especially for privileged and third-party users with remote access;
- Implement strong operational security controls for the monitoring, logging and review of events;
- Ensure effectiveness of security incident and recovery processes and plans;
- Adopt strong integrity controls through hashing and signing of data generated and transmitted; and
- Adhere to Open Web Application Security Project (OWASP)[8] best practices for the development of web applications, ensuring there are strong controls around the software development lifecycle and application developments are backed up by appropriate governance and operational procedures.

Ultimately, due to the inherent risks associated with a distributed intelligence environment, and the impact these may have on the wider energy sector, it is recommended that DNOs and third parties looking to operate, access and develop apps for the LV-CAP™ style platform ensure the following measures are met and in place:

- Treat all four operational tiers of intelligent substation devices as possessing the same threat and risk from a cybersecurity perspective;
- Implement proposed Baseline Security Controls, as a minimum, to ensure secure operation and management of the platform;
- Consider the implementation of Enhanced Security Controls as these will add additional layer of security to baseline controls; and
- Continuously monitor the cybersecurity threat landscape and determine its impact on the platform.

[8] https://owasp.org/

8 Dissemination

Table 22 and Table 23 below list events that the project presented or exhibited at, and the material that it produced to aid this.

An important learning point from this project is that explaining the relevance of the Project and the significance of making LV substation data available to some potential stakeholders from outside the energy industry can be challenging.

Wherever possible, project resources, dissemination material and learning outputs will be made publicly available on the WPD Innovation website at the end of the project. The project Close Down report will signpost where each resource can be accessed from.

Table 22: Events Attended by the OpenLV Project team

Date	Event	Description
June 2017	National Infrastructure Forum, London	WPD presented on behalf of the project.
October 2017	Balancing Act, London	The project team presented an overview of the project.
November 2017	United Nations Climate Change Conference, Bonn, Germany	An overview of the project was presented.
December 2017	Low Carbon Network Innovation Conference, Telford	The project exhibited on the WPD stand and provided an update at a workshop.
February 2018	Potential project Participant Workshop, Bristol	Workshop to provide information about the project to stakeholders from business or academia interested in participating in the project.
June 2018	CIRED Workshop, Ljubljana, Slovenia	EA Technology project manager, Richard Potter, presented a poster “The Development and Implementation of a Common Application Platform to Support Local Energy Communities” at the event attended by over 400 delegates from 33 countries.
June 2018	Smart Energy Place, Exeter	EA Technology project manager, Richard Potter presented about the project.
October 2018	Low Carbon Network Innovation Conference, Telford	The project was featured on both the WPD and EA Technology stands, and an LV CAP™ displayed on the WPD stand.

Date	Event	Description
March 2019	Project participant Workshop, Exeter Castle	Ana Duran, Senior Consultant EA Technology, provided an update about the project to stakeholders at this event.
October 2019	Low Carbon Network Innovation Conference, Glasgow	Exhibited on EA Technology stand, with literature and interactive map highlighting which project participants were accessing data from a particular substation and what project participants were hoping to achieve via the project.
June 2019	Project Participant Workshop, Bristol	The project team provided an update on project progress and an overview on project findings at this event organised by the project team for stakeholders participating in the project. Participants were encouraged to share their progress and interactive sessions were organised to encourage participants to share their experiences.
November 2019	Project participant Workshop, SS Great Britain	The project team provided an update on project progress and an overview on project findings at this event organised by the project team for stakeholders participating in the project. Participants were encouraged to share their progress and interactive sessions were organised to encourage participants to share their experiences.
November 2019	Renewable Futures Event, Bath	OpenLV exhibited at this event hosted some small workshops, including an introduction to the project.
November 2019	Balancing Act, London	The project team including Sam Rossi Ashton from WPD and personnel from EA Technology presented on project findings at this event organised by WPD.
Spring/Summer/ Autumn 2020	Project specific industry dissemination	The project will undertake a range of dissemination activities to be specified later[9].

[9] Measures implemented in the UK to control the COVID-19 pandemic directly affected dissemination activities planned by the OpenLV Project team. The final dissemination events will be planned and delivered in conjunction with WPD once more certainty as to the best possible approach can be ascertained.

Date	Event	Description
November 2020	Low Carbon Network Innovation Conference, Liverpool	The project hopes to present and exhibit at this event.

Table 23: Marketing and Dissemination Materials produced by the Project team

Item	Material	Description
1	Project website – www.OpenLV.net	To provide background information and project progress updates.
2	Project video	Animated video created at the start of the project to provide background and explain its aims and objectives.
3	‘Overview’ leaflet	Brief leaflet to provide background information on the project
4	‘Business and academia’ leaflet	Brief leaflet to provide background information for businesses or Universities considering participating in the project.
5	‘Community organisation’ leaflet	Brief leaflet to provide background information for community organisations considering participating in the project.
6	Case studies	Postcards providing background information about a selection of organisations – community groups, businesses and Universities - participating in the project.
7	‘What we’ve achieved’ leaflet	A4 leaflet produced to coincide with projects attendance at several conferences describing progress of the OpenLV Project up to that point.
8	Interactive map for use at exhibitions	Interactive map that would be used at exhibitions to access substation data, demonstrate which project participants were accessing data from a particular substation and what project participants were hoping to achieve via the project.
9	Short application videos	A group of short videos featuring many members of the project team and Method 2 and 3 participants explaining why participating in the project has been important. The videos are themed around ‘Enabling Net Zero’, ‘Social Responsibility’, ‘Network Benefits’, ‘Benefits to Businesses and Academia’ and ‘Benefits to ‘Community Organisation’.

Item	Material	Description
10	Community Guidebook	Drawing from project learning highlighted by Regen in their final deliverable, this guidebook will be for organisations that wish to use substation data for the benefit of their community.
11	End of project learning brochure	To include summarised project learning.
12	Data set	All the data from the project is available from the website.

8.1 Project dissemination learning points

The following points have been identified as key learning from marketing, recruitment and dissemination of the OpenLV Project:

- The **photography** undertaken at the start of the project was very effective. It was widely used throughout the project and helped create a project image.
- The use of **postcards** to demonstrate the extent of community and third-party involvement in the project was visually eye-catching at exhibitions and helped signpost delegates to further information about the project on its website.
- The **animated project video** produced by WPD provided a very effective tool to explain the technically complex project.
- Recruitment and marketing to **community organisations** was helped by having CSE and Regen as part of the project team. They have very effective communication channels that allowed the project to publicise the project effectively.
- **Twitter** was an effective way of signposting interested parties towards new content on the project website.
- It was much more difficult to spread the word about the project to potential app developers outside the energy sector – placing PR in magazines outside the energy press was challenging with editors finding the project rather dry.
- Regular **six-monthly project partner and supplier meetings** allowed everyone involved in the project to keep abreast of project news.

9 List of Annexes

1. Annex SDRC 5.A1: Method Statement
2. Annex SDRC 5 A2: ALVIN Reclose™ Overview Presentation
3. Annex SDRC 5 A3: ALVIN Reclose™ Quick Installation and Removal Guide
4. Annex SDRC 5 A4: Restoration Notices For OpenLV ALVIN Reclose™ Deployment
5. Annex SDRC 5 A5: User Guide for Community Groups
6. Annex SDRC 5 A6: OpenLV Measurement Points
7. Annex SDRC 5 A7 LV Common Application Platform Public API
8. Annex SDRC 5 A8: Developing for LV-CAP™ using the Virtual Machine
9. Annex SDRC 5 A9: Community Guidebook
10. Annex SDRC 5 A10: OpenLV Security Assurance Letter
11. Annex SDRC 5 A11: OpenLV Security Assurance Review
12. Annex SDRC 5 A12: OpenLV Platform Review
13. Annex SDRC 5 A13: OpenLV Cyber-Security Response
14. Annex SDRC 5 A14: Cyber-Security Business As Usual Recommendations

10 References

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Appendix 1. Functional requirement summary

Category	Distributed Intelligence Platform			Deployed Applications			Additional Capability	
	Processing	Data Storage	Communications	Core Monitoring	DNO / DSO	3rd Party	3rd Party Hardware	Network Control
LV Monitoring	Low		Low data usage High data latency	✓	×	×	×	×
Limited Control	Moderate		Low data usage High data latency (Potentially moderate data usage and low data latency on occasion)	✓	✓	✓ (Trusted)	✓ (Trusted)	✓
Enhanced LV Monitoring	Moderate to High		Moderate data usage Potentially requiring low data latency	✓	✓	✓	✓	×
Full Capability	High		High data usage Low data latency	✓	✓	✓	✓	✓