WESTERN POWER DISTRIBUTION

OPENLV

OPENING UP THE SMART GRID

OpenLV Project

Close Down Report

Document Control		
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31.03.21	0.7	Incorporation of WPD comments.
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Contents

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Glossary

Term	Definition
ALVIN®	Automated Low Voltage Intelligent Network
API	Application Programming Interface
APN	Access Point Name
BAU	Business As Usual
CBA	Cost Benefit Analysis
CI	Customer Interruptions
CML	Customer Minutes Lost
CSE	Centre for Sustainable Energy
DNO	Distribution Network Operator
DSM	Demand Side Management
DSO	Distribution System Operator
DSR	Demand Side Response
DTR	Dynamic Thermal Rating
EV	Electric Vehicle
FAT	Factory Acceptance Test
GB	Great Britain
HV	High Voltage
ISD	Intelligent Substation Device
LCT	Low Carbon Technology
LV	Low Voltage
LV-CAP®	Low Voltage Common Application Platform
MoU	Memorandum of Understanding
NOP	Normally Open Point

Term	Definition
NPV	Net Present Value
PV	Photovoltaics
R&D	Research and Development
RTTR	Real-time thermal ratings
SAT	Site Acceptance Test
TRL	Technology Readiness Level
WPD	Western Power Distribution

Executive Summary

The Project Background

The OpenLV Project set out to demonstrate the effectiveness of distributed intelligence platform, utilising EA Technology's LV-CAP® (Low Voltage Common Application Platform), at providing benefits to the LV distribution network.

These benefits were broadly considered to fall into three categories:

- **Network benefits** where a distributed intelligence platform is providing directly measurable assistance to the LV network.

  This can range from real time monitoring and automated alerts to a control room when necessary, to automated control of LV network assets avoiding the requirement of manual intervention.

- **Community group benefits** where a local, independent group can utilise such a platform to assist the community as a whole.

  This may be from little more than using community usage data to negotiate co-operative contracts with energy suppliers, to maximising the benefit of community owned assets, such as local renewable generation, through automated alerts to community members.

- **Third party / innovator benefits** where companies both within and outside of the regular industry supply chain may develop products or services enabled or made more cost effective by the availability of a distributed intelligence platform in LV substations.

  This could cover localised predictions of network load, and the subsequent effect on voltages to aid the DSO in network management, through to control of EV charging as part of a load or frequency response service.

Whilst benefits can be independently achieved for each of the above areas from the deployment of distributed intelligence platforms, it is envisaged that the greatest overall benefit will be realised when deployed platforms benefit multiple stakeholders.

For example, deployment of a platform to solve, or mitigate a network issue creates an opportunity for local communities to benefit from the data available, conceivably in ways that may assist the DSO with the original issue, in ways that would otherwise not be possible.

The trial equipment deployed consisted of a core set of hardware and software, deployed to all substations utilised within the trials, with additional elements utilised depending on the trial requirements for individual locations.

The project trials sought to specifically demonstrate the ability of the LV-CAP® platform to provide benefits in each of the categories outlined above.

The project set out to achieve a large range of objectives that were set at the bid development stage of the project. The objectives have been collated and gathered into the Objective column of the table below. References to details about how the objectives have been achieved are referenced in the Fulfilment comment of Table 1, below.

Table 1: Project objectives

Objective	Fulfilment
Trial and demonstrate an open, flexible platform that could ultimately be deployed to every HV/LV substation in GB.	The OpenLV platform was successfully tested in the field at 80 sites. Details of deployment throughout the SDRCs.
Demonstrate the LV-CAP® solution by: Proving the platform – building on existing development projects to deploy a workable open substation platform for both monitoring and control of the LV network.	SDRC 4 Method 1 Section 2 and 3 show how the OpenLV platform was successfully used to monitor LV network and perform automated network switching (i.e. controlling the network)
Demonstrate the LV-CAP® solution by: Creating an Eco-system – providing third parties / community groups' access to network data.	Details in SDRC 3 Section 2 (for businesses and academics) and SDRC 4 Section 2 (for community groups)
Demonstrate the LV-CAP® solution by: Stimulating a Market – Facilitate a common platform with low-cost entry to a range of new app developers.	Details of the facilitation of the common platform for app developers can be found in SDRC 4 Method 3. A range of businesses took the opportunity to develop apps for the platform which could provide future revenue streams.
Two suppliers providing communications back to separate back-office systems. (Nortech for Method 1 and Lucy Electric for Methods 2 & 3.)	Details of Nortech's involvement is contained in SDRC section 3.4.4. Details of Lucy Electric's involvement is contained in SDRC 1 section 3.4.5.
Four suppliers providing software and algorithms for Method 1.	Software in the form of Apps deployed in Method 1 trials were produced by the University of Manchester, Nortech, Lucy Electric GridKey and EA Technology.

Objective	Fulfilment
Provision of a 'skeleton app' to allow developers a head start through the use of a 'standard code application'.	Details of the skeleton app that could be used by app developers can be found in SDRC 3 section 8.6.
RTTR of the local LV transformer will be provided by a 'DTR App' developed by the University of Manchester prior to this project.	Details if the 'DTR App' for RTTR can be found in SDRC 2.2, section 5.2.2.
Deployment of 60 devices in 30 paired substations	60 substations deployed in 30 paired substations. Details in SDRC 4, section 2.2.
Minimum of 3 of each network type (LVNT) monitored.	Table verifying that at least 3 networks of each relevant Low Voltage Network Type (LVNT) were monitored can be found in SDRC 4, Method 1, Table 1 (section 2.2.4).
Specific outputs of: Detailed description of how LV networks can be assessed.	Details of LV network assessment presented in SDRC 2, sections 2 and 5.
An assessment of how much additional capacity can be delivered.	Details of additional network capacity that could (at substation level, across WPD's license area, and across GB networks) can be found in SDRC 4 Method 1 Section 2.3.
An assessment of the costs and benefits of deploying the OpenLV platform against traditional reinforcement methods.	A thorough CBA is presented in SDRC 5, section 3.
Up to 10 trial devices will be deployed.	Details of deployment of 10 devices for Method 2 found in SDRC 4, Method 2, Section 2.
A more detailed understanding of the appetite of communities in becoming a part of the smarter grid.	Understanding generated by the OpenLV project into the interest of community appetite for involvement can be found in SDRC 4, Method 2 Section 2.

Objective	Fulfilment
Learning generated from development of community apps, including an understanding of the types of services community groups' value.	Details of the learning generated from community app development can be found in SDRC 4 Method 2 Section 2.6.
Economic analysis of the deployed solutions effectiveness.	A thorough CBA is presented in SDRC 5 section 3.
Materials and tools to support the adoption of community benefits across GB.	Materials and tools developed at various stage throughout the project, noticeably the Community guidebook (OpenLV-Community-Guide-A5-SCREEN.pdf) and the CSE web app (Home (openlv-cse.uk)). Additionally, case studies of method 2 participants involvement in the project (Community | Open LV).
Learning collated into reports including an overall assessment of the process of engaging with communities to take advantage of the OpenLV platform and associated LV network data.	Reports include the community guidebook (OpenLV-Community-Guide-A5-SCREEN.pdf), case studies including case studies pdfs available from the OpenLV website (Community | Open LV)
Detailed understanding of the appetite of innovative developers using this solution.	Understanding generated by the project about the appetite by develops to make use of the OpenLV platform is presented in SDRC 3 Method 3 Section 2.2.
A revised API which will be shared with the developer community for future App Development.	The API is discussed in SDRC 2.2 Section 5.4. Documentation is available here: OpenLV LV Common Application Platform Public V1.0.pdf
Learning associated with App validation and verification.	App validation learning and verification is presented in SDRC 4 Method 3 Section 2.4.
Learning how the OpenLV platform and associated LV Network Data can be used by 3rd Parties.	Learning about 3rd party use of LV network data is discussed in SDRC Method 3 Section 2.4.

Objective	Fulfilment
Calculations used to determine anticipated financial and environment benefits of the solution – these need recalculating and comparing.	A full CBA of the OpenLV platform is presented in SDRC 5 section 3.
External funding was expected to develop apps for Methods 2 and 3, with an associated expectation that the total value of the project would increase as well	Discussion of methods used by individual community groups to raise funding is discussed in section 2.7. Group funding for community group app development is discussed in section 2.7.8 and 2.8 of SDRC 4 Method 2. Discussion about Method 3 funding is presented in SDRC 4 Method 3 Section 2.4.2.

Many objectives were set to be covered in specific SDRCs. These are outlined in a similar manner to the table above for all SDRC objectives in the tables below.

SDRC 1

Table 2: Objectives fulfilled in SDRC 1

Objective	Fulfilment
Detailed systems architecture	The detailed system architecture of the OpenLV solution is discussed in detail in Section 3 of SDRC 1.
Requirements specification for the OpenLV ISD hardware	Hardware requirements and technical information is found in section 3.4 of SDRC 1.
Assessment of the development of the ISD control software (LV-CAP®) to identify whether any changes were necessary prior to trial deployment	Assessment of the LV-CAP® control software can be found in section 3.3 of SDRC 1.
Detail the testing approach	The approach to testing in detailed in sections 4.4 and 4.5 of SDRC 1.

Objective	Fulfilment
FAT and SAT documentation	FAT documentation can be found in SDRC Appendix 2 – OpenLV Solution Factory Acceptance Test Documentation SAT documentation can be found in SDRC Appendix 3 – OpenLV Solution Site Acceptance Testing
FAT testing results	FAT testing results can be found in SDRC Appendix 2 – OpenLV Solution Factory Acceptance Test Documentation.

SDRC 2.1 & SDRC 2.2

Table 3: Objectives fulfilled in SDRC 2.1 and 2.2

Objective	Fulfilment
Techniques used to identify target LV Networks	Techniques used to identify target LV network are discussed in section 2 of SDRC 2.2.
Results from assessing market potential for sharing LV network data with communities (and providing an open platform)	Community market potential results is discussed in section 3 of SDRC 2.2.
Results from assessing market potential for sharing LV network data with academics and companies (and providing an open platform)	Academia and business market potential results are discussed in section 4 of SDRC 2.2.
Detailed trial design for all methods	Detailed trial design is covered in section 5 of SDRC 2.2. Section 5.2 discusses the trail design for Method 1, section 5.3 discusses the trial design for Method 2 and section 5.4 discusses the trial design for Method 3.

SDRC 3

Table 4: Objectives fulfilled in SDRC 3

Objective	Fulfilment
An overview of the OpenLV solution (technical specifications and how it works)	Section 2 of SDRC 3 provides an overview of the OpenLV solution.
The installation documentation for the OpenLV trial solution	Installation documentation for OpenLV trial solution is covered in Section 3 of SDRC 3.
Confirmation that the third-party system has been installed and configured to support wide scale deployment	Details of this confirmation is covered in Section 4 of SDRC 3.
An overview of the training provided to installation and operational staff	An overview of the training provided to WPD's Fitting Teams is provided is section 5 of SDRC 3.
SAT for the central IT architecture	A Summary of the SAT is provided in Section 6.2 of SDRC 3. More detail can be found in the SDRC 3 appendices.
Results of SATs on the trial devices prior to wide-scale deployment	An overview of the SATs for the trial devices can be found in Section 6 of SDRC 3. More detail is given in the SDRC 3 appendices.
Standard guidelines to enable third-party organisations to develop new applications	An overview of the App Guidelines is presented in Section 7 of SDRC 3. This refers to further documentation where further details can be found.
App development kit (skeleton application and associated documentation)	The App development kit is covered in Section 8 of SDRC 3.
Quality Assurance Processes / test processes to ensure apps are sufficiently robust prior to being deployed	A document titled "OpenLV Third Party Application Information Form" was produced which detailed the information required by EA Technology to test each application before apps were deployed to WPD's substations. It took the form of sequential questions that developers were required to test themselves before submission.

SDRC 4

Table 5: Objectives fulfilled in SDRC 4

Objective	Fulfilment
Outline of the learning from Methods 1, 2 & 3.	The learning from each of the methods is presented throughout Section 4.1, 4.2 and 4.3 of SDRC 4 for Method 1, Method 2 and Method 3 respectively.
Sharing level of capacity uplift achieved from Method 1	Capacity uplift achieved is discussed in Section 2 of SDRC 4.1.
Sharing which LV networks can benefit from OpenLV and why	Assessment of the LV networks that can benefit from OpenLV is conducted in Section 2 of SDRC 4.2.
Establishing the level of capacity uplift that can be achieved in WPD's licence area, and across GB	Extrapolation to BaU to assess potential capacity uplift across WPD's licence area and GB is conducted in Section 2.3.5 of SDRC 4.1.
Sharing how DNOs can engage with communities who want to become part of a smarter grid to exploit the open and flexible nature of OpenLV	This is covered throughout SDRC 4.2. Case studies of interactions with specific community groups involved in the Method 2 trial are covered in Section 2.4 of SDRC 4.2.
Sharing how community engagement supports the uptake of LCTs	Case studies showing how the trial supported the uptake of LCTs are covered in Section 2.4 of SDRC 4.2.
Outlining routes communities can take to raise funding	Section 2.3.1 in SDRC 4.2 outlines routes communities can take to raise funding.
Sharing the network benefits provided by community engagement	Section 2.9 in SDRC 4.2 shows the network benefits provided by community engagements, split into three areas, transparency value, flexibility value and engagement value.

Objective	Fulfilment
Sharing how DNOs can engage with academics and companies to exploit the open and flexible nature of OpenLV Sharing how DNOs can engage with academics and companies to exploit the open and flexible nature of OpenLV	This is covered throughout SDRC 4.3. Section 2.2. covers interactions with businesses / companies. Section 2.3 covers interactions with academics.
Sharing network benefits provided through Method 3	A range of network benefits were provided by the Method 3 trial. Network benefits are outlined in Section 3.2 of SDRC 4.3.
Sharing how the method facilitates non-traditional business models	Details of non-traditional business model facilitated by Method 3 are covered in Section 2.5.1 and 3.1.3 of SDRC 4.3.

SDRC 5

Table 6: Objectives fulfilled in SDRC 5

Objective	Fulfilment
Assessment of the TRL of the overall OpenLV solution, with specific consideration of BAU roll-out	The natural place to assess the TRL progression in in the closedown report. See Appendix 2 for an assessment of the TRL of the OpenLV platform.
Key learning generated by each Method	Key learnings from each Method are summarised in Section 2 of SDRC 5.
Replicability and scalability of each Method, trials and overall solution	Replicability is covered in Section 3.1.1 of SDRC 5 and scalability is covered in Section 3.1.2 of SDRC 5.
CBA for each method and overall solution	A thorough CBA is presented in Section 3.2 of SDRC 5.
Specification for the overall solution to be taken to BAU	A BaU specification is provided in Section 6 off SDRC 5.
Recommended changes to the security of the system	Security of the system is covered in Section 7 of SDRC 5.

Objective	Fulfilment
Training GAP analysis to enable OpenLV solution to be deployed in GB networks as BAU	These technologies are now BAU with multiple vendors providing them and all DNO's installing similar solutions across their networks.
Summary of key project learning	Key project learning is covered in Section 2 of SDRC 5.
Knowledge and learning dissemination reports and presentations	Details of dissemination conducted throughout the project are presented in Section 8 of SDRC 5.
Network data made available	Data is now hosted on the WPD website.
Project Progress Reports for duration of OpenLV Project	Project Progress Reports are available from the WPD website Western Power Distribution - OpenLV.
Presentations given at industry	Details of these presentations are given in the Section 8, Dissemination, SDRC 5.
Presentations given at LCNI events	Details of these events are given in Section 8, Dissemination, SDRC 5.
Provision of the Loadsense application	Covered in Section 5.1.1 of SDRC 5 with documentation available here: OpenLV: Proposed Operational Logic for Loadsense Application (westernpower.co.uk)
Economic Analysis / Extrapolation for the test community applications in Method 2	Regen were contracted as part of the OpenLV project to assess the value and benefits derived from the community engagement trials. Key findings are presented in Section 3.3 of SDRC 5.
Enduring tools for community groups through GB to utilise beyond the end of the project as an OpenLV style solution is deployed in a BAU scenario	Covered in Section 5.2 of SDRC 5. CSE web app: Home (openlv-cse.uk) Community guidebook: OpenLV-Community-Guide-A5-SCREEN.pdf

1 Details of the work carried out

Demonstrating the ability of the LV-CAP® Distributed Intelligence Platform to provide benefits for GB distribution network stakeholders was undertaken using 80 deployed trial platforms, configured in three different ways, dependent on the site-specific learning being sought.

1.1 Core equipment deployment

All substations utilised within the OpenLV Project trials were outfitted with a consistent hardware / software combination, with specific additional components included based on the general, or specific investigations at that substation.

These core components comprised the following.

- Trial equipment enclosure with an overall Ingress Protection rating of IP64, containing:
  - Ruggedised industrial PC unit
  - 4G Router / Modem
  - Digital I/O unit
- LV Network monitoring device (Lucy Electric GridKey MCU520)
  - Current sensors fitted to active feeders
  - Voltage (and power) links connected to busbars or similar
- Thermal probes for monitoring:
  - Transformer Top Oil Temperature
  - External air temperature
  - Internal air temperature (where the transformer is located either indoors or within a GRP enclosure)
- 4G aerial
- Radiation shield for external temperature probe

The overall project method statement details the installation process and includes photographs of example installations.

The main trial enclosure was powered via 13A sockets available within the substations. The MCU520 was powered through the voltage monitoring connections, and utilised either:

- G-Clamp connections directly to the substation Busbars
- Wiring directly to appropriate connection terminals within the LV enclosure
- Modified Fuse Carriers providing three-phase voltage connections

Substations utilised to support and enable Community Group activities, and development of Third-Party innovations, whilst providing additional data to support the network specific trials, were selected and configured at the point of deployment to serve that purpose, whereas network trial locations were deployed with the potential to upgrade the capabilities later.

1.2 Network trials

During the site selection process for the network trials however, it was not known which substations would only simulate network meshing (passive), or be progressed to actual meshing (active). This decision was made after the project was able to gather good data on network loading and profiles from the affected transformers as the maximum demand data available prior to the deployment of monitoring did not provide enough insight.

Substations utilised for the passive and active network trials were located in pairs, selected for the potential to connect them directly via the radial network and implement active automation trials at the location. All were initially deployed as a 'passive pair' with some subsequently upgraded to an active pair following initial data gathering and network analysis.

Overall, 50 units, (25 pairs) were installed as passive trial pairs, in the arrangement detailed below in section 1.2.1, with a further 10 units (5 pairs) installed with the additional equipment, enabling active trials to proceed, as detailed in section 1.2.2.

1.2.1 Passive network trials

Equipment for the passive network trials was installed as shown below, utilising two LV substations connected via the LV network, although separated by a link box / normally open point at the approximate mid-point of the network.

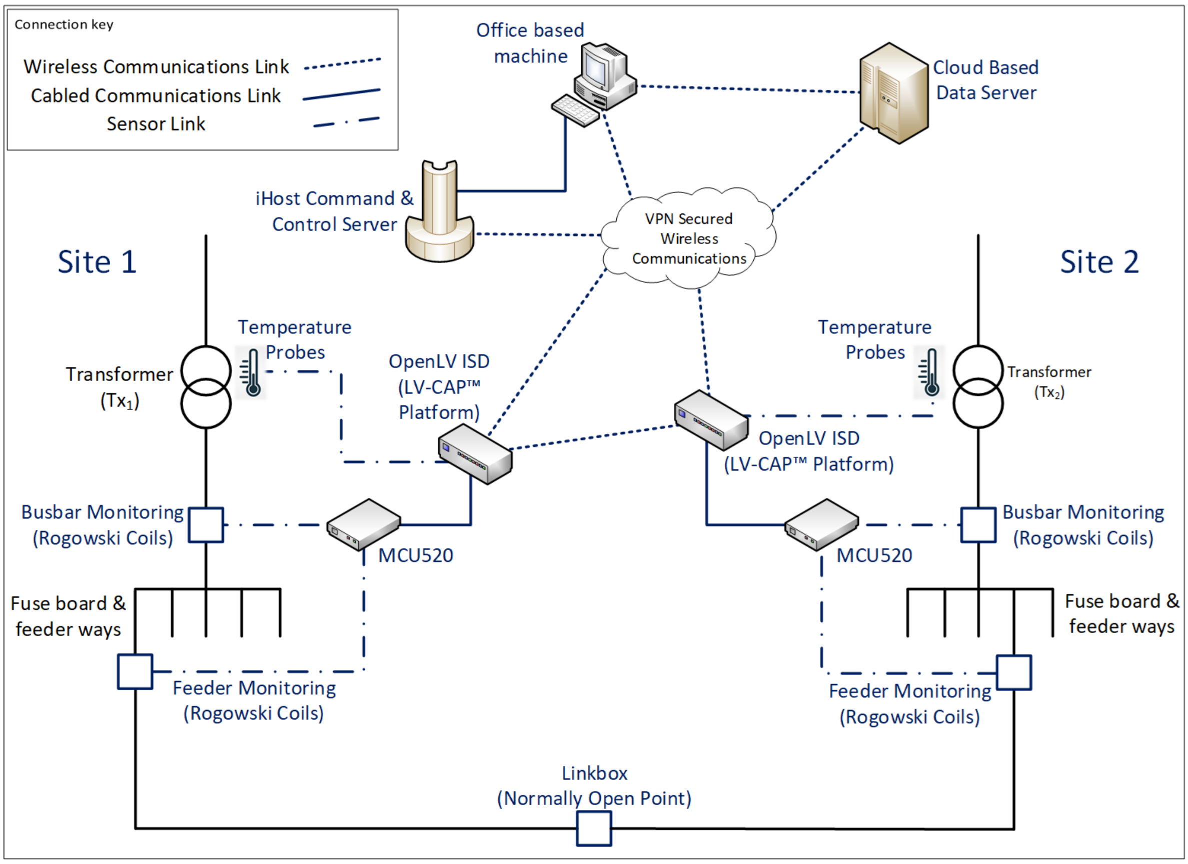

Figure 1: Passive network trial arrangement

In this configuration, at a minimum the connecting feeder from each substation, and the overall transformer load would be monitored, although due to the type of LV enclosure in some substations it proved easier to monitor all feeders and calculate the total transformer load.

This provided significant volumes of data of the LV network, enhancing the analysis from the active network trials and allowed the simulation of automated LV switching without requiring additional hardware to be deployed.

There was no requirement for reconfiguration of the LV network as the equipment installed included no capability to affect network assets to any extent.

This was considered the 'default configuration' and as such, the software containers deployed enabled communication between the core hardware components detailed above. They also ensured storage of the data on the local platform, along with compression of the data and regular uploads to a cloud-based data server as a safeguard against equipment failure.

1.2.2 Active network trials

Site verification

In order to run the active trials, it was necessary to reconfigure the LV network as detailed in Figure 2 below, with the understanding that the ALVIN® Reclose™ switches at Site 1 would be autonomously closed, and opened, as determined necessary by the LV-CAP® platform.

The 'active trial' sites were selected from the locations already installed and in operation as 'passive trial' sites. This allowed the Project Team to utilise a combination of the data gathered by the trial equipment and detailed network models were constructed using data extracted from WPD's Data Portal to determine which locations were viable for incorporating the automated network meshing functionality.

Detailed load flow analysis calculations were undertaken, determining the best- and worst-case load flows that could be anticipated on each network, and the corresponding fault currents and fault response times for all possible scenarios.

Trial pairs where in any potential configuration, the maximum fault current was too high, or so low that the fault response time exceeded WPD's design standards, were removed from consideration. This ensured that even when 'active trials' were underway, the network was expected to respond to a fault condition within normal operating parameters.

It is noted that in a number of instances, utilisation of ALVIN Reclose® units decreased the fault response time in comparison to a standard fuse for the same fault current. This is because ALVIN Reclose® units can be programmed to have variable response times and in these cases were set to respond quicker than a traditional fuse.

Multiple networks were investigated until five suitable pairs had been identified.

Additional equipment

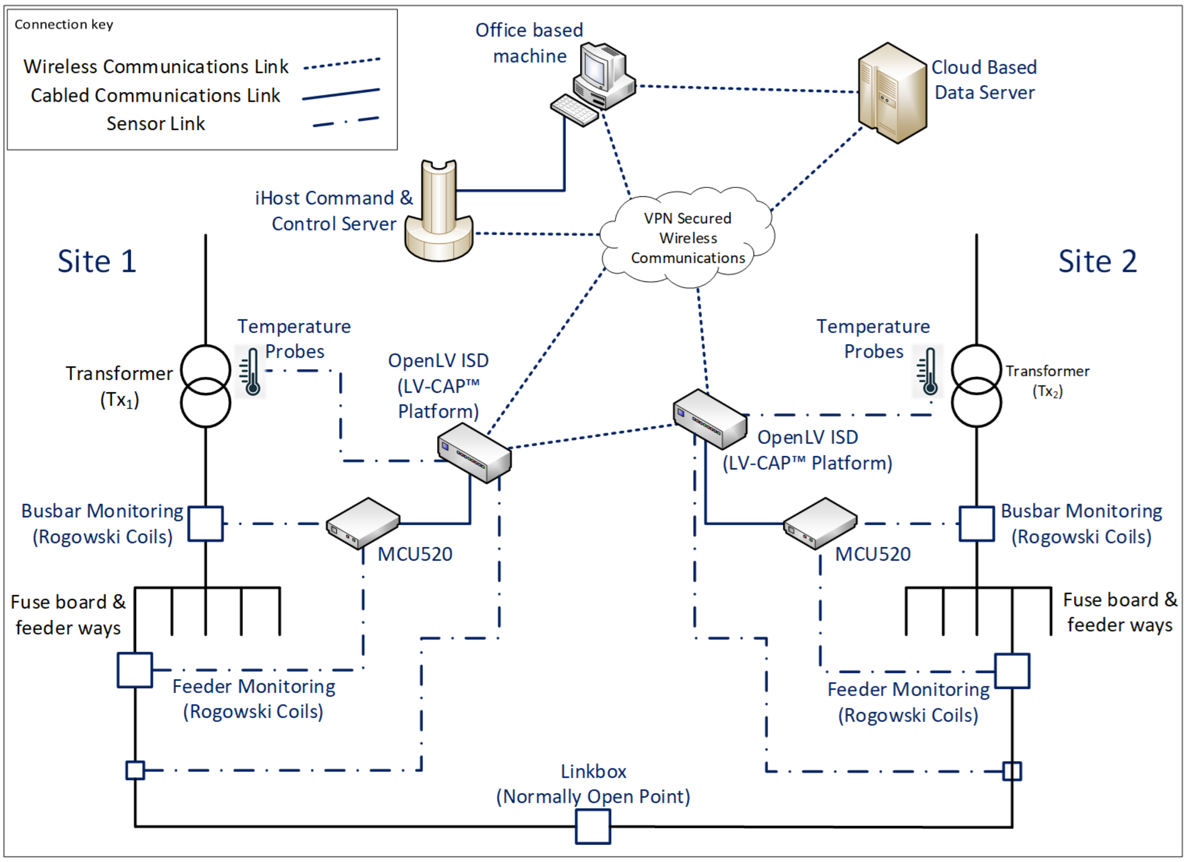

Figure 2: Active network trial arrangement

1.2.3 Community group Methodology

The Centre for Sustainable Energy (CSE) were appointed to engage with communities to promote the availability of the substation intelligence platform and associated LV data. Regen were appointed to assess the longer-term potential and economic impact for the use of the OpenLV devices and to develop enduring tools to assist communities in their engagement with the distribution network.

Before the trial, 51 community groups responded to an expression of interest survey showing an interest in taking part in the Community Engagement trials (Method 2), generating 45 app ideas covering a range of topics from energy consumption displays to using data to aid local planning documents. This initial interest showed there was plenty of interest to proceed to the full recruitment stage. CSE's assessment of the proposed app ideas concluded 22 of these ideas were highly relevant for potential further development in the trial.

In total, 10 full applications were received, of which 8 applicants were selected to be taken forward to interview; 7 of these community organisations were subsequently taken forward to trial.

Ten OpenLV platforms were initially made available to support the OpenLV Community Engagement trials although coverage for this part of the trial was later increased by utilising some platforms for both the Method 2 and 3 trials.

The selection process initially required elimination of potential candidates on the basis of technical feasibility, before selecting from the remainder on the basis of anticipated learning and wider potential benefits.

Community groups were removed from consideration where the network in their area was an overhead line arrangement, as the trial equipment was not suitable for being pole mounted. Other locations were disregarded due to unusable mobile network connectivity when site visits were undertaken.

Many communities would have liked to monitor more than one substation. The trial considered the advantages of using additional units for a community, against the potential disadvantages of doing so, on an case-by-case basis. Consideration was given to the size and area of the community, and their proposed use case. In most cases, it was determined that increasing the total number of communities involved provided greater benefit and additional learning to the OpenLV project.

Of the remaining locations, six community groups were allocated a single OpenLV platform as this was sufficient to meet the stated objectives for the community. One community group was allocated four OpenLV platforms as its use case involved the entire area of a village with one of the locations experiencing a weak, occasionally intermittent mobile signal. This group was an isolated rural settlement with 'energy island' planning potential, which could provide useful insight for a large number of other community groups. As such, the data being gathered would cover the entire community, providing a valuable use case in the Project data, with the weaker mobile network allowing a stress test of the LV-CAP® system, which was designed to handle intermittent data outages.

Feeder maps were useful to communities when selecting the substations to monitor as part of the trial and helped identify target communities for their projects. Participating community organisations were provided assistance by CSE to understand how best to use the LV data generated by the trial, and indeed simply to understand what the data was provided. It was particularly insightful to the organisations to explain that the data was showing net energy demand, rather than net energy consumption[1].

Support was provided to all community organisations involved in the trial by CSE. It was found that the organisations required less support engaging with communities, because of their pre-existing strong community engagement skills that community organisations already possessed. This extra time allowed CSE to focus efforts on developing a web-application for the communities to use. This was important as the trial found that there was a lack of development skills within community organisations to be to either develop software or specifications for software that would allow useful apps to be created to enable analysis of local network data.

[1] This related to a few instances where understanding of how the energy flows in an area would change depending on the interaction of local generation from Solar PV, energy demand by the properties in the area, and energy imported from the grid. There were instances where total energy demanded from the grid was not matching total energy consumed by the community, which initially caused some confusion.

CSE created a web-app that gave communities access to various metrics via easy to understand "front end". Graphs, data tables, and simple smileys were used to communicate information about the local electricity network. The smileys were developed as a particularly easy to interpret method of communicating messages about the local LV network. Support was provided to enable community organisation to make best use of the data in the app. A comprehensive web app user guide was developed, containing a step-by-step guide about how to use the app and a guide to main data points and how to interpret them.

Interest in participating in the project was high across different geographical areas of WPD's license zones, Figure 3 shows the geographical locations of community groups and housing associations who participated in Method 2 of the OpenLV trial.

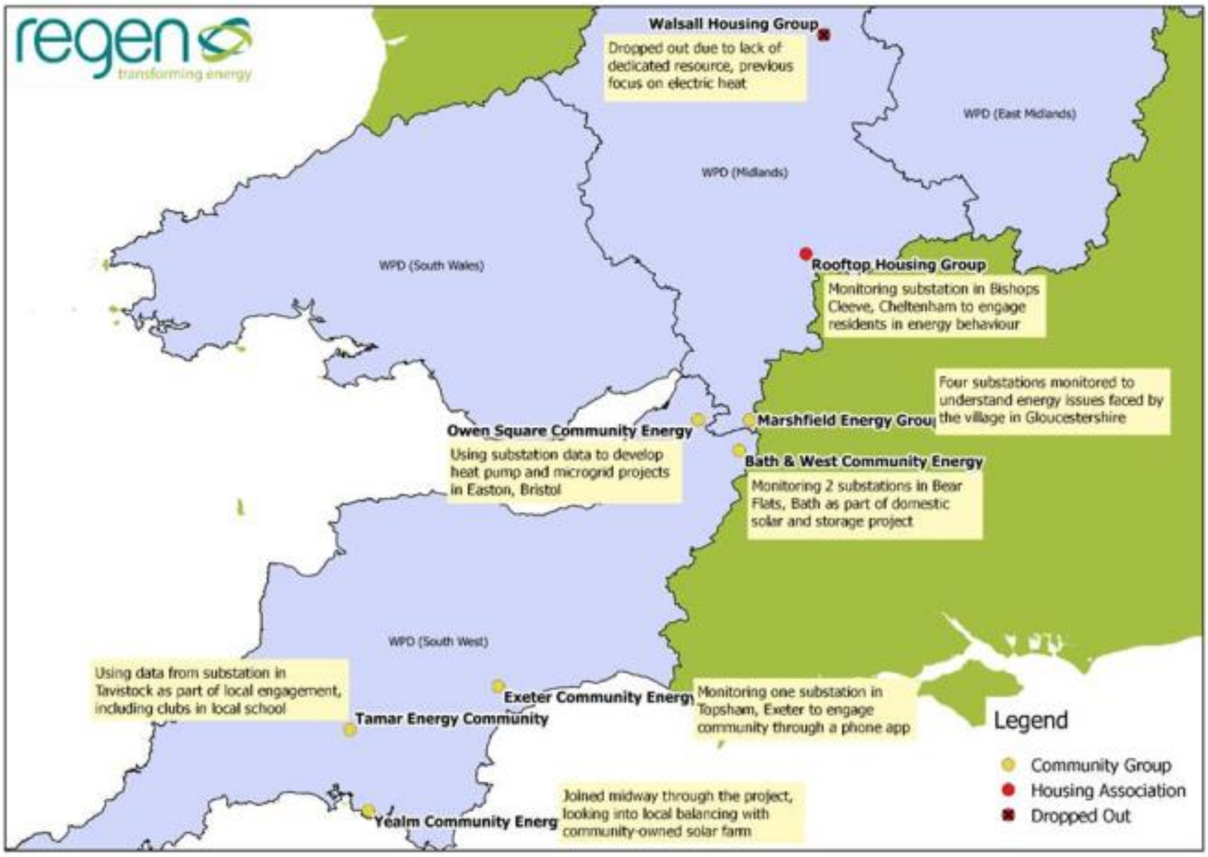

Figure 3: Geographical locations of community groups who participated in the OpenLV trials.

Trial participants were located across WPD's Midlands and South-West license areas, specifically:

- Bath (Bath and West Community Energy Group),
- Bishops Cleeve, Cheltenham (Rooftop Housing Group),
- Marshfield Village, South Gloucestershire (Marshfield Energy Group),
- Topsham, South Devon (Exeter Community Energy Ltd),
- Easton, Bristol (Owen Square Community Energy),
- Tavistock, South Devon (Tamar Energy Community), and
- Yealm, South Devon (Yealm Community Energy).

Unfortunately, Walsall Housing Group based in Walsall, Birmingham, dropped out from the trial. Their place was on the trail was taken by Yealm Community Group, based in South Devon.

Most of the community organisations mainly access the substation data via the web app developed by CSE. Historic data was also of interest to the organisations however some found the large quantities of data provided by this route challenging. One organisation sourced external funding to start the process of developing an app.

1.3 Third Party Developer trials

The purpose of Method 3 of the OpenLV trial, was to investigate the following questions:

1. Whether commercial and academic institutions would be interested in incorporating network data into their operations and what factors condition this decision.
2. Whether data sharing promotes better or easier engagement with academia.
3. Whether data sharing promotes better or easier engagement with stakeholders.
4. Whether data sharing facilitates non-traditional business models in the energy sector.
5. Whether data sharing enables cheaper or more effective network insights or services.

To implement the overall trial, a 5-stage process was implemented as follows:

- **Stage 1:** Assessing market potential.
- **Stage 2:** Inviting applicants to take part in the trials.
- **Stage 3:** Assessing trial applications and selecting trial participants.
- **Stage 4:** Allocate OpenLV to substations and participants and conduct trial.
- **Stage 5:** Evaluate the evidence from Stage 4 with regard to the trial aims.

The conclusions from Stages 1 to 4 have already been discussed within SDRCs 1 to 3. Conclusion from stage 5 have been documented in SDRCs 4 and 5.

Initially market sectors that may be interested in utilising the OpenLV platform were identified. Stakeholders from a broad range of industries were identified including the following industries: Automotive, IT, Large Industrial, Electricity, Renewables, Data Companies, Consultant, Developers, Government, Charities, and Academia.

An online survey was conducted to gauge the level of interest in the project from potential stakeholders. Email, telephone and face to face meetings were channels of communication used to target potential trial participants in the project.

51 out of 79 organisations contacted were potentially interested in developing an app for the platform. Major reasons why some stakeholders were unable to commit to developing an app were internal resourcing and a lack of clear immediate internal investment case. Smaller factors were lack of skill set, uncertainty over WPD's plan for monitoring roll out, and requiring more information before committing resource. A wide range of app ideas were developed from the 59 app use cases survey respondents provided. Most commonly responses included apps for Forecasting (demand or generation), Network Capacity & Resilience, Easier Connection Development and Active Generation Dispatch. A variety of other use cases were mentioned less frequently.

16 business and 7 academic organisations put forward applications to take part in the OpenLV Open Extensibility trials, submitting a total of 37 ideas (27 by businesses, 10 by academic organisations).

In stage 3, the project team held conference calls with the 23 applicants for Method 3 of the trial, in order to review all applications received. Applications were assessed based on the following criteria:

- Quality of idea,
- Technical feasibility,
- Commitment and interest level (as outlined in application form),
- Ability to self-fund and resource software development and research,
- Range of ideas,
- Replicability of proposed idea, and
- Willingness of applicant to share learning from the project trials.

A Memorandum of Understanding (MoU) document was circulated and agreed by all applicants. This outlines the responsibilities of the trial applicant and EA Technology. Additionally, the WPD Data Share Agreement was utilised to cover how the data shared by the project team could be utilised.

Applications were reviewed based on the assessments made using the above criteria and successful applicants were informed. In total, 17 of the 23 applicants were taken forward to the trial, utilising the 10 OpenLV platforms available for Method 3. This was made possible by the approach taken by the OpenLV team seeking to include as many as organisations as possible to maximise project learning.

To answer trial questions 1 to 5; the attitudes, progress and opinions of Method 3 participants were logged throughout development and deployment. This process drew on opinions expressed during update telephone calls, end of trial surveys and measurements taken during any active trials.

The commercial participants and academic institutions who were selected to take part in the trial are summarised in Sections 1.3.1 and 2.3 respectively along with the use case that they explored.

It must be stressed that the use cases that participants championed were of their own suggestion. Participants were responsible for utilising the OpenLV architecture in a manner that suited their use case.

1.3.1 Did commercial organisations express interest in using open data?

There were 16 commercial applicants for this stage of the trial, of which 10 were accepted. Additionally, there were 19 expressions of interest from academia for participation in Method 3, from which 9 academic partners were selected. This proves a strong interest from businesses and academic organisations in using the open data. Since these organisations had to provide their own funding, it is clear in that these organisations see great potential in the value of the technology to provide future revenue streams.

The commercial organisations who participated in the OpenLV trial are summarised in Table 7.

Table 7: Commercial Participant use case summary

Company	Use case	Data link[2]
Depsys	Network Visibility	Data share
Egnida Group	Enable flexibility	API
Energeo	Resource & constraint mapping	API
Equiwatt	Enable flexibility	APP
Haysys	Measurement devices	Hardware
IBM	EV Charging	App
Lucy	EV Charging	App
Nortech	Network Visibility	App
Nortech	Hardware	App
Orxa	Network Visibility	App

[2] The data link may be either:

- an API where data is called from the OpenLV server to a computer that is remote from the substation,
- an App which sits on the substation computer and carries out some form of local processing or decision making before uploading some data to the OpenLV server. This data may then be called from the OpenLV server.

Table 7 shows 10 commercial organisations took advantage of the network data in some form or another and bore the cost of incorporating[3] the LV-CAP® platform into their research and development. This proved that there exists a strong desire from commercial organisations to develop apps for the platform, realising its potential as a future source of revenue.

A range of studies were undertaken, combining data processing on the LV-CAP® platform in the substation, the addition of proprietary third-party hardware and the use of near real time data communications.

The fact that participants were responsible for funding their participation on the trial indicates that interest was linked to some form of longer-term business decision rather than a short term means to revenue. Clearer indication required from WPD about their long-term strategy regarding open data and distributed intelligence was a commonly stated reason explaining why some organisations could not take part in the trial. Therefore, it is concluded with clear strategy, even more organisations would deploy R&D resource into developing products to harness the value of the platform. It was concluded that stronger signals would make this happen as part of BAU. Full details of the organisations and their goals in participating in the OpenLV project can be found in Section 4, SDRC 4.

[3] The OpenLV Project bore the cost of making the platform available and supporting it, but did not fund Method 3 participants to use the app.

2 The outcomes of the Project

Due to the structure of the OpenLV trials, the outcomes are defined within discrete areas of learning relating to the use of distributed intelligence platforms in a wide, business-as-usual capacity across GB electricity networks.

2.1 Method 1 – Capacity uplift

2.1.1 Sharing the level of capacity uplift achieved through Method 1

Method 1 sought to test the hypothesis that having distributed intelligence available within distribution substations would enable capacity uplift through automated analysis and decision making based on observations of local conditions. Although the distributed intelligence does not in itself create capacity uplift, it does instead enable opportunities for capacity uplift.

Network Meshing

Method 1 also sought to demonstrate the ability of the OpenLV platform in instructing the operation of physical devices through a network meshing trial. The network meshing trial sought to allow two substations to run in parallel for a period of network requirement.

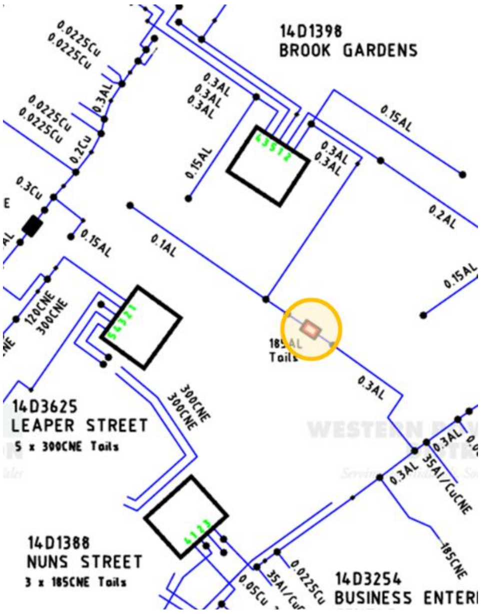

Figure 4: Normally Open Point

To implement network meshing, it should be noted that the OpenLV trial installed intelligent LV devices at the 11kV/LV substations as a means to form Normally Open Points (NOPs) that could be automated. This was an atypical approach as NOPs are typically found midway between substation feeder cables in link boxes on public highways, rather than on the busbars at one of the substations in a pair.

A typical normally open point is shown in Figure 4, highlighted by the yellow circle, in the middle of the low voltage feeder connecting the Brook Gardens substation with the one at Nuns Street.

This approach had to be taken as link boxes that could be automated were not commercially or technically mature at the time of project conception.

The Method 1 network meshing trial demonstrated that it is practical to automate low voltage switching devices through the use of the OpenLV distributed intelligence platform.

The sequence of calculation and switching detailed in SDRC 4 was found to operate as expected, based on the control logic programmed into the system. The trigger thresholds were adjusted through the period of active trials to allow for changing ambient temperatures and network loading, whilst ensuring the system would continue to operate.

The network meshing trial also provided evidence that joining together LV substations as demonstrated in the trial was unlikely to lead to significant capacity uplift between transformers. This is due to the load being transferred using the trial approach equating to approximately half the load of one feeder. This is not sufficient to make a material change to the proportional load experienced by a transformer; but it has already been acknowledged that this was an artificial trial approach.

This trial also provided analytical evidence that points to a greater benefit of being able to control NOPs located within link boxes, rather than having automated NOP on the LV bus bars. By investigating the effect of meshing at the feeder link box level, it was shown that there would be viable cases where meshing helped the feeder pairs share load much more effectively, but this approach was unlikely to help create transformer uplift or materially reduce losses. This is due to the load on either side of NOPs in the monitored networks being closely matched – as such there is little realisable benefit from meshing networks in this manner.

It should also be stressed, because of the maturity of automated link boxes at the time of project initiation, that this trial did not demonstrate the effect of transferring customers between substations by using a combination of automated link boxes and equivalent devices to the ALVIN Reclose® units in one of the feeding substations.

Moving NOPs from the middle of feeders between to substations to on the busbars at substation in a pair will always be effective in reallocating 50%-100% of a feeder's load between substations. Having a capability to move NOPs in this manner will also create additional use cases not considered in this trial, an example being the capability to automate LV customer restoration after unplanned outages.

Dynamic equipment ratings

DNOs allow a cyclic rating to be applied to their distribution transformers for limited emergency conditions, during a period of additional back fed load for example, but only for a time-limited period. These are based upon fixed and worst-case assumptions and typically only allow a fixed uplift beyond the continuous nameplate rating.

Method 1 clearly demonstrated that having the ability to be able to apply real-time thermal ratings, based on site-specific measurements of ambient temperature and loading could create a dynamic rating beyond the transformer's nameplate rating. This process was continuous and undertaken locally, operating whilst power was available to energise the OpenLV equipment. If deployed in a BAU scenario, the rating uplift would be available, in effect on an ad-infinitum basis, rather than under emergency conditions.

For such dynamic ratings to be taken advantage of there would need to be the ability to plan the network to remain within the expected dynamic ratings. Because the OpenLV trial gathered site-specific ambient temperature, hot spot forecast and loading cycles, this requirement would be satisfied.

This capacity uplift would be leveraged further when and if distributed intelligence devices are able to instruct smart devices to respond to periods where the transformer was forecast to exceed temperatures without additional intervention.

Such smart devices might include customer flexibility that was demonstrated through some of the Method 3 trials or alternatively some form of network reconfiguration such as changing the network open points.

It is acknowledged that the network meshing trial was inconclusive. Smart link boxes were not technologically available at the time of the project initiation but progress in this field is ongoing.) A next development step may be to prove the concept of LV network load transfers using smart link boxes. If smart link boxes can be proved effective, it provides another means to create capacity uplift for the network.

Network meshing and Dynamic Thermal Ratings

To implement Dynamic Thermal Ratings and network meshing, the trial implemented three different applications running of the OpenLV platform within the substations. These applications were:

- A load forecasting application.
- A transformer Dynamic Thermal Ratings application.
- The Loadsense application. This application reviewed data from the load forecasting application and the Dynamic Thermal Rating application. When the forecast load exceeded the forecast thermal rating, it would instruct the network to mesh.

Over the course of the active trials, across the five active pairs, network meshing was enacted on 792 occasions. Each instance resulting in the automatic activation of network meshing when determined to be beneficial to the network, and subsequently reactivation once the network conditions allowed. On average, each ‘active network pair’ operated 160 times over the 12-month period of active trials.

2.1.2 Establishing the level of capacity uplift that can be achieved in WPD’s licence area and across GB

Method 1 has provided evidence in SDRC 4 regarding the amount of capacity uplift that could be experienced across WPD’s licence areas and across the UK.

This analysis makes a conservative assumption that if dynamic transformer ratings were only applied to transformers of a size 300kVA or greater (which is less than 27% of WPD’s total population of LV transformers) then 6,350 MVA of total additional capacity would be created across 39,500 WPD substations. Extrapolation of this analysis across the total LV substation demographic of Great Britain would see a total uplift of 120,850 MVA in transformer headroom[4].

[4] This value is calculated from the headroom benefits identified from the methodology used in the trial. As such, the calculated benefit is derived entirely from the dynamic thermal rating demonstrated in the trials with the network meshing providing zero benefit, as detailed above.

It should be remembered that Open data platforms have multiple roles and capabilities and as such, there are many other approaches to increase network capacity that can be enabled by a Distributed Intelligence Platform that were not demonstrated within the OpenLV trials. The same platform can provide functionality for multiple actors, such as the network operators, businesses, academics, and community organisations, this is detailed below.

For example, if a community wished to have an OpenLV platform monitor their community, then the incremental cost to deploy Dynamic Thermal Ratings would be minimal as it would simply require the analysis package to be loaded onto the platform. Conversely, in cases where an OpenLV data platform has been loaded into a substation to enable Dynamic Thermal Ratings, then additional applications can be loaded on to create even more value. Examples of these additional use cases may be pre-fault detection of LV faults or apps to track the amount of low carbon technology that has been installed in a LV network. For these reasons, it would be misleading to decide that installation of the OpenLV platform should be justified on solely based on the value created by Dynamic Thermal Ratings.

2.2 Method 2 – Community Engagement

The potential for widespread or targeted deployment of distributed intelligence benefits to benefit communities was tested in the **Method 2 – Community Engagement** trials.

The OpenLV project found that communities, whether through established community energy groups, housing associations or local community organisations, could leverage value at a local level from the information provided by the OpenLV platform.

This was emphasised towards the end of the project trials when participating community organisations requested continued access to the data for their community, requiring an enduring solution to be installed in place of the trial equipment being removed.

Full details of the participating community groups and their data usage are provided in SDRC 4 with highlights of the learning outcomes provided below.

2.2.1 Did OpenLV help engagement with communities?

OpenLV allowed DNOs to engage with communities via the following illustrative cases:

- Community groups have forged closer relationships with WPD via participation in the project. In particular, **Marshfield Energy Group** were able to communicate directly with WPD about outages that the village experienced (which after investigation were attributed to wildlife strikes on overhead lines).
- Access to local data provided an excellent means to start conversations with residents about the energy system, the way that is evolving and saving energy (and money). **Tamar Energy Community** used the data in 'Eco Clubs' that it organised in its local junior school and **Rooftops Housing Association** used the data to start conversations about cost-efficient energy use.
- **Bath and West Community Energy** have installed solar PV and batteries in 16 local homes. Data is being monitored alongside substation data in order to determine substation impact, linked to the future potential of selling aggregated flexibility services based on assets owned within a community[5].

2.2.2 How did OpenLV community engagement support the uptake of LCT?

A common theme among community organisations participating in the OpenLV Project was their desire to support the uptake of LCTs. This was successfully demonstrated by their projects via the following means.

- The data from OpenLV was used by community groups to start conversations with their communities about renewable energy sources. **Tamar Energy Community** were able to do this at their 'Eco Club' at the local junior school. **Yealm Community Energy** used the data to help promote their ownership of a local solar farm.
- **Marshfield Energy Group** were using the data to develop a village-wide energy strategy based on analysis of OpenLV data that would allow them to pinpoint where in their village there is the potential to connect further renewable generation or EV chargers.
- **Rooftops Housing Association** suggested that having this type of data would help them identify where to site renewable schemes in the future.

2.2.3 Outlining the routes communities can take to raise funding

Different funding routes were identified and secured by community groups:

- **Exeter Community Organisation**: Were able to secure in-kind funding worth £10,000 to fund the first stage of a smartphone app.
- **Owen Square Community Energy**: Used data provided via the project as an evidence base to support several funding applications.
- **Bath and West Community Energy**: Used their participation in the OpenLV Project to support their successful application for funding for the Solar Streets project.

[5] https://www.bwce.coop/solar-streets-2/

2.2.4 What were the network benefits provided by community engagement?

An overview of network benefits that were released by DNO engagement with specific community organisations can be found in Appendix 1. An overview of the three potential value streams that the project identified that could be released by providing data to community organisations is presented below:

Transparency Value

Making local network data openly available gives community groups insights into how their local network is performing. In responses to interviews of the community participants in the method 2 trial, when asked to score statements from 1 (completely disagree) to 5 (completely agree), the statement "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." scored 4.3, showing communities hugely valued the transparency provided about local network performance. Further statements suggested further basic support would be required by communities from DNOs to allow communities to interpret the data from the project. There was weak support behind the idea that the data would help support investment decisions in LCTs, suggesting it would be one of multiple considerations taken into account when deciding if to invest and if so where best to locate the LCT(s).

Engagement Value

The trial found that substation data provided interesting, locally relevant data for use by communities to form engaging information on their electricity use and local network. This provided an effective means of engaging with members of the community who took an active interest in their local community, even if they were not specifically interested in energy.

In final interviews with participants in the project, participants were given statements and asked to rate them from 1 (strongly disagree) to 5 (strongly agree). The responses showed that OpenLV information was particularly useful for engagement purposes as it was locally relevant and tangible for members of the communities. There was also strong support for the idea that the project helped people to understand broader energy issues such as the needs of local energy infrastructure and the effects of low carbon transition. It was also found to encourage people to switch to a time of use tariff, but there was weaker support for the OpenLV information helping people understand the need for smart devices such as smart meters and smart EV chargers.

Flexibility Value

OpenLV data supports community level aggregation and coordination of community level demand side response. This could allow communities to realise value (such as payments from DNOs for offering flexibility services) from changing the profile of electricity usage at a substation level. The commercial case for this is emerging but can reasonably be expected to become reality in the short to mid-term future. The OpenLV information and functionality opens up the potential for the substation to act as a community aggregator to remotely prompt actions by members of the community supplied from a particular substation.

By providing demand side response services to the grid, not only can communities benefit from potential flexibility payments in the future, but they can also help remove or delay the need for investment in costly network upgrades. This value saving can be redistributed to the communities contracting the flexibility.

Monitoring substations rather than individual household offers a potentially highly beneficial means to achieving aggregation for demand side response. Individual level demand side response would require costly monitoring at a household level, with complicated individual contracts with associated high administration costs and barriers to participation. Community DSR would require contracts and payments to be made at the community level, which would mean payments should benefit community funds or organisation rather than individual households directly. At a community level these payments could provide a significant revenue stream for schools or other community organisations.

In final interview with participants in the project, participants were given statements and asked to rate them from 1 (strongly disagree) to 5 (strongly agree). All communities were strongly in favour of developing DSR or flexibility business models in the future. Flexibility services to DNOs were recognised as being closest to market. There was also some interest by Rooftop housing association, in selling locally generated solar power to local residents, an idea that regulations do not allow at present.

2.3 Method 3 – Business and Academia

2.3.1 Did OpenLV demonstrate new ways to engage with business?

Even though commercial organisations were required to fund their own involvement in the OpenLV trial, the available spaces for participation were oversubscribed.

The capability for the trial participants to access LV network data created new ways for DNOs and businesses to engage. The exact details of what the trial demonstrated can be found in SDRC 4. There is a clear demonstration of the following use cases:

- **A basis for customer decision making**. We observed a number of organisations being able to optimise control system settings and network capacity utilised on the basis of the load flow data that became available to them as a result of OpenLV. This is a new proposition since DNOs have not traditionally been equipped to stream data to other parties.
- **Basis for supply chain innovation**. We observed some of the trial participants using project data to assess new value propositions or to refine existing products. In some cases, we also observed that the data enabled these parties to conduct testing on these product refinements. Without the development of this data, it would have been harder to obtain meaningful depictions of network behaviour.
- **New network management products.** We observed several organisations creating platforms that enabled end-users or their equipment to respond to network loading information that is geographically specific in near real-time. Whilst it is acknowledged that the participants that demonstrated this did so on a limited basis, extrapolation of this capability would be a significant departure from the traditional business model that assumes customers are passive.
- **New forms of information visualisation.** By making the LV network data available, other parties were able to disseminate this information to their stakeholders alongside other key indicators. One good example of this included electricity network data being presented alongside other information from across other energy vectors which gives the end-user an insight that cannot be obtained from data used in business as usual to date.

2.3.2 Did OpenLV demonstrate new ways to engage with academia?

The OpenLV Project sought to engage with academia and research organisations to see how the platform facilitated their interests. It was found that OpenLV data-sharing features were very popular.

It was commented by participating academics that it is normally difficult for academia to be able to carry out independent research on the distribution network without having the support of the network owner to facilitate measurement and data access.

By making the network data open, the DNO removed a key barrier to academic research. It was notable several academics were interested in obtaining access to the raw data across multiple substations rather than developing an app to sit on a particular substation. This implies that the ability for a DNO to make data open to academic parties may be just as significant as being able to have an open data platform for apps in substations.

2.3.3 Did OpenLV facilitate non-traditional business models?

Within SDRC 4 we reviewed the evidence of whether the OpenLV trial demonstrated evidence of whether the project enabled non-traditional business models.

Evidence was presented that the technology trialled in the OpenLV Project does enable new business models. This evidence was grouped under three headings:

- **Capacity screening and broadcast.** The traditional approach would see DNOs being limited to offering worst-case snapshots of how much capacity is available on a specific network to a customer.
  When local LV network data is made available to customers, they are able to assess the situation for themselves and combine this data with other data streams, creating valuable insights beyond an electricity network's perspective.
- **Mitigation and participation.** The traditional approach to network management has been passive infrastructure measures. This approach is already progressing as DNOs seek to purchase flexibility from customers. These flexibility markets will be underpinned by sets of APIs' through which customers will receive dispatch instructions. To date, procurement of these flexibility products has been focused upon high voltage and extra high voltage systems. The OpenLV platform can contribute to this environment because it enables flexibility markets to be conditioned by the needs or limitations of the LV network.
  The OpenLV platform contributes to this agenda further because it helps minimise the impact of the network on LCT operations. Under traditional business as usual approaches, there is a tendency to use "one size fits all" assumptions in lieu of having detailed information on a specific LV network. These assumptions tend to be the worst case. Because the OpenLV platform enables site-specific visibility it enables a business model for LV network operations to only intervene when a specific network demands an intervention, rather than upon a generic assumption.
- **Platform sharing and competition.** Traditional business models in the supply chain have shown a tendency for smart devices in substations to have a vendor tie in. Vendor tie in means that whilst there may be monitoring or computational capability installed within a substation, utilisation of these resources or data generated from them are not available to other suppliers. The OpenLV trial showed how vendor tie in can be overcome to enable apps from different suppliers to be installed on one platform.
  In addition to simple platform sharing, the OpenLV trial showed how resources or output from individual apps can be shared. For example, a variable from one application process can be utilised by other apps.
  These facts are significant as they indicate that OpenLV enables DNOs to have more control over which processes are deployed to substations (instead of being limited to processes installed by the equipment supplier), and also to be able to procure automated analysis more efficiently because of the features that enable collaboration between apps.
  This trial also obtained evidence that a key barrier to the supply chain engaging with this new commercial model is insufficient signposting from WPD as to where opportunities for App development will be and what the commercial model for procurement would be.

2.4 Which LV networks can benefit from OpenLV and why?

The OpenLV network has shown distributed intelligence within 11kV/LV substations enables a diverse set of benefits cases. The specific benefits are dependent on either the structure of the network or alternatively the needs of customers connected to those networks.

Evidence from Method 1 shows that use of real-time asset monitoring can provide two clear routes to aiding network operations. Use of the data available within the substation to calculate the state of assets in real-time, removing uncertainty inherent in the existing passive network, allows Operators to push assets harder than they can at present, with the knowledge that the asset is able to withstand the additional load. Data confirming the state of network assets, reduces the risks associated with that uncertainty.

Additionally, the ability of distributed intelligence platforms to automate decision making, in accordance with logic agreed by the Control Team can provide the benefits of LV Automation to the DNO / DSO. Automated local decision making reduces data transmission costs, and the risk of information overload in Control Rooms were there a requirement to manually initiate or authorise every LV operation. ‘Reporting by exception’, where the system has identified a situation occurring that is outside of expected operational parameters allows attention to be focussed where it is most effective. Automated decision making could become highly beneficial for neighbouring LV networks with complimentary demand profiles, for example where one network has lots of commercial properties with high demand during the day, and another that has residential properties, with low demand during the day but a high demand for power in the evening. Automated decision making would be able to facilitate sharing of the demand between these networks by utilising, for example smart link boxes, a technology which was not available at the advent of the OpenLV project. Further trials could be conducted to prove this concept, but it is proposed that this would allow greater utilisation of network assets, resulting in a more efficient network that delivers better value to customers.

Evidence from Method 2 shows that the ambitions of local communities can also inform which networks would benefit from having an OpenLV platform, although it should be noted that these benefits extend from within the networks sector outwards across the energy sector. This means that any future cost-benefit analysis for the installation of units will need to have a wider perspective than cashflows within the electricity networks sector.

Evidence from Method 3 shows that there is interest from third parties in the development of an ecosystem of different apps which could be placed on open platforms. These apps will introduce costs benefit cases in their own right. For example, Method 3 demonstrated interest from more than one party in the development of OpenLV apps that can help manage electric vehicle charging. The ability to deploy apps to substation to manage smart devices and smart EV charging will benefit networks with medium to high levels of EVs. By facilitating smart charging according to the local substation constraints monitored in real-time, the uptake of LCTs such as EVs (and heat pumps) can be facilitated while avoiding network reinforcement which would traditionally be needed, by ensuring charging (and heating) take place at times where the substation has spare capacity. This offers huge potential to increase utilisation rates of existing electrical assets, driving greater value for customers. By utilising local LV network monitoring, reinforcement can be focussed only on the local LV networks where it is absolutely essential.

3 Performance compared to the original Project Aims, objectives and SDRC / Project Deliverables

3.1 Issue raised in the full submission

The decarbonisation targets of the UK are clear and remain firm, with goals being revised to further benefit the environment with each iteration of the legislation. At the time of the bid submission for the OpenLV project, the UK was targeting radical changes to electricity generation and usage by 2050, a target now revised to near zero carbon emissions by that date.

Great Britain has approximately 1,000,000 LV feeders, installed on a largely 'fit and forget' basis over the last 100 years. Changes anticipated in the coming years as the industry transitions to a low / zero carbon economy will require adjustments to how the industry operates the network as usage patterns alter.

Increasing uptake of low carbon technologies will result in changing usage patterns, something being exacerbated by the COVID-19 pandemic occurring at the time of writing. Whilst the pandemic was not a factor during project development, or primary delivery phases, the potential benefits envisaged from the use of distributed intelligence platforms can be applied to manage the impact of this situation on the network as well.

3.2 Project Aims

The OpenLV Project aspired to provide a solution to the anticipated problem of multiple proprietary solutions increasing the cost and complexity of the transition to a low carbon economy, requiring separate hardware for each deployment or solution.

LV-CAP® was trialled by the OpenLV project with the objectives of:

- Proving that distributed intelligence devices can provide direct benefit, via both monitoring and control of the LV network.
- Creating an eco-system for third parties such as community groups, individuals, academics, or businesses, to access to network data; and
- Stimulate the establishment of a new product market through providing application developers a consistent core platform for the creation and deployment of new value-add services.

The LV-CAP®, deployed in the OpenLV trials proved successful in delivering the overall aims of the project.

- Method 1 (Network Capacity Uplift) would prove how network control can be implemented in an effective and secure manner using decentralised architecture.
- Method 2 (Community Engagement) would test the value of providing LV network data and an open platform to community groups.
- Method 3 (OpenLV Extensibility) would enable and encourage 3rd party companies to develop applications to improve network performance and facilitate the uptake of low carbon technologies.

Reporting of the above objectives was undertaken through the publication of the SDRC reports. A summary of the objectives covered in each SDRC can be found in the introduction to this report.

3.3 Outcomes

The OpenLV project has shown distributed intelligence within 11kV/LV substations enables a diverse set of benefits cases. The specific benefits are dependent on either the structure of the network or alternatively the needs of customers connected to those networks.

Evidence from Method 1 shows that use of real-time asset monitoring can provide two clear routes to aiding network operations. Method 1 demonstrated that the OpenLV solution successfully provided means by which DNOs could monitor LV networks. The solution was installed on all types of LV network, which provided confidence that this solution could be scaled across the GB network. Use of the data available within the substation to calculate the state of assets in real-time, removing uncertainty inherent in the existing passive network, allows Operators to push assets harder than they can at present, with the knowledge that the asset is able to withstand the additional load. Removal of uncertainty with regard to network assets, reduces the risks associated with that lack of LV data. Monitoring of the LV network allows greater utilisation of the existing network infrastructure, facilitating greater value for customers, while also enabling greater uptake of LCTs. It allows costly network reinforcements to be focussed on areas of the network where this investment is critical, while being smart about where this reinforcement is required ensures excellent value for consumers.

Method 1 also demonstrated that the OpenLV solution could be used to automatically reconfigure LV networks to share load between neighbouring transformers, by using ALVIN® devices, to achieve greater utilisation rates of both assets. Additionally, the ability of distributed intelligence platforms to automate decision making locally prevents introducing further data transmission costs. If the decision-making logic is agreed by the Control Team it can provide the benefits of LV Automation to the DNO / DSO without the risk of information overload in Control Rooms that a requirement to manually initiate or authorise every LV operation could generate. 'Reporting by exception', where the system has identified a situation occurring that is outside of expected operational parameters allows attention to be focussed where it is most effective.

Evidence from Method 2 shows that the ambitions of local communities can also inform which networks would benefit from having an OpenLV platform. It should be noted that these benefits extend from within the networks sector outwards across the energy sector. This means that any future cost-benefit analysis for the installation of any such units will need to have a perspective that is wider than cashflows within the electricity networks sector. Method 2 showed that there was strong appetite from community groups to better understand their electricity consumption, and in many cases generation for their DERs. The LV network data was shown to be highly valuable in engaging with members of the community with no previous interest in their energy consumption. Community groups had wide ranging incentives for getting involved in the project, ranging from wanting to better understand their electricity profiles, to assisting deployment of more DERs and increase utilisation of locally generated electricity, in addition to building local network resilience and facilitating smarter local networks. All these ambitions could be met using the LV-CAP® solution, highlighting the flexibility of this solution. The wide range of use cases shows the huge potential network benefits offered by the solution to consumers.

Evidence from Method 3 shows that there is interest from businesses in the development of an ecosystem of different apps which could be placed on open application platforms. Businesses and academic institutions were responsible for self-funding the development of apps to be deployed to the OpenLV platform. Despite this, there was strong interest from both businesses and academics in participating in Method 3 of the trial. There were more applications than platforms available to support all the applications, so trial participants were selected to maximise project learning. It can therefore be concluded there exists a strong desire for businesses to access LV network data, via an open platform to generate potential new revenue streams. Method 3 has shown to be an effective platform to facilitate the deployment of apps from businesses and academia, eliminating problems associated with vendor tie in.

Therefore, LV-CAP® successfully created an eco-system to allow third parties access to LV network data and simulate a market while doing so. These apps will introduce costs benefit cases; for example, Method 3 demonstrated interest from more than one party in the development of OpenLV apps that can help manage electric vehicle charging. Another 3rd developed an app to control a system containing PV, battery storage and smart devices, showing potential of the platform to help facilitate and optimise the benefits provided by the uptake of a range of LCTs. The development of apps to control customers' LCTs, not only will the network benefit from reduced demand during peak times, but customers will also benefit from the maximisation of value provided by their resources.

The Project has demonstrated that the use of Distributed Intelligence Platforms, similar in operation to the LV-CAP® architecture-based trial equipment offers DNO's a convenient, all in one package for monitoring LV substations. Such an approach will provide a platform for DNO's to enable automated control of the LV Network, whilst application developers have a system with which to provide services to both DNOs and customers.

The potential benefit to end customers from such a system is significant, enabling higher utilisation of network infrastructure and hence more targeted investment where it can provide the most benefit.

4 Required modifications to the planned approach during the course of the Project

There were two modifications to the approach planned during the bid development. These impacted the network capacity and community group trials in the OpenLV Project.

4.1 Method 1

As part of the OpenLV project trials under Method 1, installation of ALVIN® Reclose™ LV network automation devices at 10 11/0.433kV substations within the Western Power Distribution's (WPD) network area was proposed.

These units were to be installed in linked pairs of substations, allowing for automated linking of the substations via the LV network under the control of the connected LV-CAP® platform.

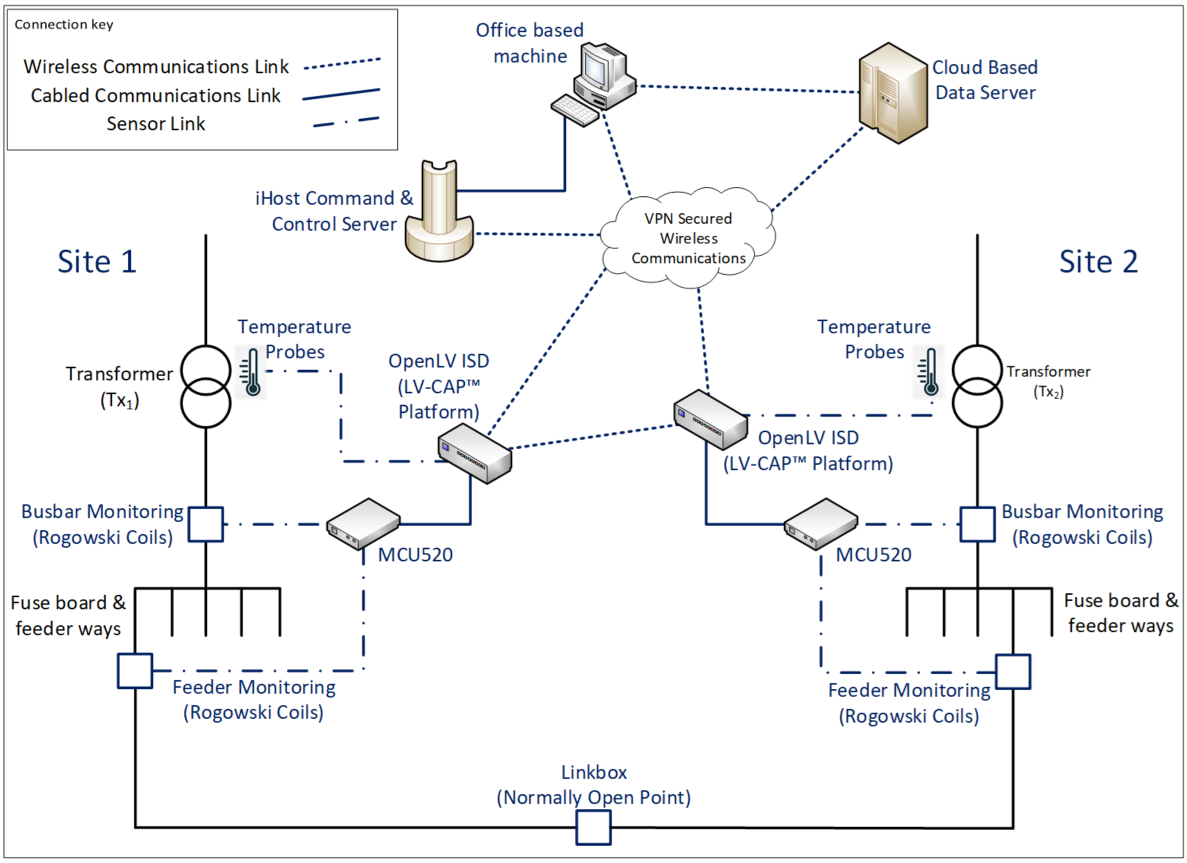

Figure 5: LV network arrangement and LV-CAP® deployment

Traditionally, WPD's LV networks have been designed and operated in a radial manner. Meshing of these networks as part of the network automation offered by the combined LV-CAP® / ALVIN® Reclose™ combination changes the circuits in question from radial to ring operation.

This change in network topology has an impact on the fault level and protection operation on the network. Detailed network studies were undertaken to evaluate the fault level and protection operation performance at a number of 11/0.433kV substations provisionally selected for ALVIN® Reclose™ installation within the OpenLV project.

The purpose of the investigation for each considered pair was to confirm that maximum fault level and protection system operation time would remain acceptable, and within WPD's operational requirements, even in the worst-case scenario.

Although a number of considered circuits were disregarded due to either excessively high fault currents or protection equipment taking too long to operate in the event of the network being rearranged for the project, ultimately five pairs of substations were identified as being acceptable for use in the trials. These trials were self-contained with no links to WPD's SCADA system. Status reporting was via a separate iHost server. If adopted as BAU the system could be interfaced to a DNO's SCADA system if required although this would require consideration of SCADA availability at individual substations, against the additional capability such a connection would provide. It is noted that one of the key aims of Distributed Intelligence in this context is to remove the requirement for direct SCADA connectivity.

Four of the five pairs had been installed and fully commissioned, with the final pair in the early stages of the commissioning process, when the power outage on August 9th, 2019 occurred, causing widespread disruption to GB power networks.

As part of the investigations into the incident, WPD realised that there was a potential unidentified impact on the OpenLV project test locations.

Automated restoration procedures at three of the two trial pairs, although not utilised during the August power outages, had the potential to connect each substation to different primary substations. When investigated further, the resulting impact on protection schemes for adjacent networks was significant and would have necessitated redesign of the processes across a significant area, with no guarantee of it being possible.

Whilst it was expected that in the event of such an occurrence, the ALVIN® Reclose™ devices and trial hardware would operate to separate the two circuits, it was considered an unnecessary risk. This, combined with the temporary nature of any such change resulted in the decision to disable the 'active' elements of the trials at the trial pairs, preventing automated network meshing from occurring.

The project continued to operate the remaining two pairs of network automation substations for the full duration of the active trials. Of the three pairs that were decommissioned, one operated for a period of several months providing a significant volume of data that was utilised in the final analysis.

Despite the need to disable three of the trial pairs, the OpenLV project demonstrated the ability of the LV-CAP® platform to correctly operate devices on the LV network without the need for manual intervention.

4.2 Method 2

It was anticipated during the bid development process that organised community energy groups, or similar community-based organisations, would be able to develop use cases and applications for the data provided by the LV-CAP® platforms.

Whilst community groups and organisations did submit application use cases, their development of them proved to be an optimistic assumption, for two principal reasons:

1. Some community groups did have access through members to the necessary capability for developing an application, or other method of processing and utilising the data, but many did not.

   Furthermore, those with access to the necessary understanding were still limited to the use they could make of the data, as in most cases, community group participation is a voluntary endeavour, and time to be spent on creating community applications is not guaranteed.

2. Most however, simply did not have the expertise available to them that would enable the development of an application 'in house'. This applied particularly to parish councils and housing associations, although the lack of project funding to support them in developing an application or equivalent use case for the data was an additional concern to community energy groups as well.

   This resulted in many deciding that the technical hurdles to participation were sufficiently great, with unreliable expectation of benefits to be achieved, that it was not in their interest to participate in the project.

   One group observed that what they really needed, was "something with the complexity of an emoji to indicate when the network was full up", providing clarity on the level of information desired by the group.

It was determined that the provision of the data in a readily accessible format for all community groups would be beneficial to the project. As such, CSE developed a 'Community Energy App' that processed the information on the LV-CAP® platforms, then uploaded the necessary information to a website for community groups to access. This web-based application was designed to meet the requirements from all the community groups who participated in the trial.

In this way, those groups with a greater level of technical ability were able to download and further process the data to suit their needs, whilst others could benefit from the data visualisation tools built into the website. In doing this, a high level, simple means of accessing and understanding data about the local network was made available to all the community groups. The creation of the single web-based application does not rule out the possibility that in the future community groups with the required skillset could develop their own applications to be hosted on the platform.

4.3 Method 3

The Method 3 trial was very flexible in its design. The intention was to allow businesses and academia to develop applications to be hosted on the LV-CAP® platform to suit their needs for any projects that they wanted to work on. No attempt at prescribing how or what the applications they should develop was made. By its very nature, this method was highly flexible, and as such no modifications to the planned approach was required.

Ten commercial organisations took part in Method 3. Of these ten commercial organisations, six developed an app for deployment. Equiwatt developed and deployed an app on the substation platform capable or reporting network data measurements into their existing digital platform that rewards their customers for allowing electrical appliances to be managed according to the smart grid requirements.

IBM and Lucy Electric independently developed apps that integrated with electrical vehicle chargepoints. These allowed control of EV charging according to the requirements of the substation. These trials demonstrated that electric vehicle charging could be effectively managed according to network requirements measured at the substation.

Nortech developed two apps. The first allowed population of their Smart MDI product by using an app sitting on the OpenLV platform, which demonstrated potential for reducing costs by avoiding having to duplicate monitoring equipment at substations. The second app enabled data to be transferred from the LV-CAP® platform to DNO SCADA.

OrxaGrid developed an app, deployed to the OpenLV platform that forecast future voltage profiles, automatically generating voltage alerts based on those predictions. This presented the DNOs with far greater visibility of their network assets.

Upside Energy’s involvement in Method 3 of the trial demonstrates the disadvantage of relying on commercial organisations funding their own involvement in this Method of the trial. Upside Energy have developed a network flexibility platform, and recognised the potential added value of incorporating data from the OpenLV platform into their flexibility platform. However, their app development had to be curtailed as their limited developer time had to support a different project that was fully funded.

4.4 Impact of the COVID-19 pandemic

The COVID-19 pandemic caused a range of responses by the UK government to attempt to manage the spread of the disease. Lockdowns and limits on social interaction impacted the decommissioning of the project equipment and the methods used to disseminate project learning generated (see section 10 for more information about the impact of the pandemic on the project decommissioning). As a result of the pandemic, the end date of the project was pushed back from July 2020 to December 2020.

5 Significant variance in expected costs

The OpenLV Project was delivered within the anticipated budget, with an overall underspend of 5%.

Three categories experienced a variation from intended budget in excess of 10%.

- **Labour:** WPD did not require as much Labour time in the project as had been anticipated at during the bid development stage. There are multiple causes for this, but the two main ones are believed to be:
    - that EA Technology staff were able to undertake more of the site survey work than originally anticipated, reducing the need for WPD staff time; and
    - WPD did not find it necessary to spend as much time managing the project than had been expected.
- **Travel & Expenses:** WPD do not track their Travel & Expenses separately to Labour, instead covering such expenditure within the Project Overhead. Travel & Expenses are costed on the basis of being, on average an additional 10% of the Labour Cost. As the Labour cost was less than anticipated, this translated into a variation exceeding 10% of budget.
- **Contingency:** It was required to utilise 43% of the Contingency budget across the Project Trials. This is due to the Project avoiding, or successfully managing risks prior to them becoming a significant issue. Claims related to areas of uncertainty at the time of bid submission, with key examples being:
    - the volume of monitoring sensors proved to be insufficient once network locations were confirmed by the site surveys;
    - it was necessary to procure non-standard doors for LV enclosures where ALVIN Reclose® devices were to be installed; and
    - additional security was implemented within the mobile communications contract, firewalling the units within a private network.

Table 8: Project Expenditure

Expenditure Category	Bid Submission Value	Project Completion Value	% Variation
Labour	£267,282.40	£216,882.00	-18.9%
Travel & Expenses	£29,698.04	£21,688.20	-27%
Contractors	£3,775,039.52	£3,705,130.49	-2%
Equipment	£853,617.70	£923,536.82	+8%
IT	£2,500.00	£2,490.00	0%
Decommissioning	£66,000.00	£66,000.00	0%
Contingency	£451,460.68	£196,157.00	-57%
Total	**£5,445,598.34**	**£5,190,294.66**	**-5%**

6 Updated Business Case and lessons learnt for the Method

The business case calculated for the project bid defined the anticipated benefits realisable from the deployment of a distributed intelligence platform across the 14 licence areas within the GB network. These benefits were defined in three categories:

1. Financial benefits to the distribution networks and hence, ultimately, to customers through the reduction or deferral of capital investment.
2. Capacity released in the network through the ability to better utilise both existing and future assets.
3. Reduced carbon emissions attributable to the use of distributed intelligence technology in the distribution network.

Based on the learning generated during the project, the values stated in the anticipated business have been refined, with details provided below, as outlined in the original bid submission.

6.1 Calculation of financial benefit

6.1.1 Method 1 – Network Capacity Uplift

At the bid development stage, an assessment of the financial benefit due to the expected network uplift created by distributed intelligence was performed. Without distributed intelligence, expected network expenditure on network reinforcement ranged from £1,445m to £14,638m, for low and high levels of LCT uptake respectively. Modelling again with the expected network uplift released by the Method 1 solution, the expected expenditure fell to between £1,325m and £12,590m for the same low (Transform Model SC3) and high (Transform Model SC8) levels of LCT uptake. Therefore, expected savings were in the range £120m to £2,048m. Using these models, the uplift solution was expected to be deployed to 16,000 feeders in the low LCT uptake scenario, and 241,000 feeders in the high LCT uptake scenario.

The expected feeder capacity uplift of 25% was revised downwards to 0% as expected network uplift factor failed to materialise in the project trials[6]. However, the expected transformer uplift of 25% was appropriate. This has implications for the expected financial benefits. The capital required to install the LV-CAP® platforms at each substation was also reduced from £5,000 to £2,000 as switching equipment required for meshing became surplus to requirements.

[6] Forecast benefits at the project development phase utilised EA Technology's Transform Model™ to predict the deployment of LV-CAP® enabled platforms based on anticipated network benefits. This required an assessment of likely benefits to be defined, including the headroom benefit to individual feeders, a value that was set as 'a headroom increase of 25%'. The data gathered by the trials demonstrated that whilst LV-CAP® is technical capable of operating network assets, implementing a load sharing system as demonstrating in the trials would provide negligible benefits to feeders.

Annual costs for Opex increased from £50 to £160 due to greater SIM card and mobile network costs than predicted at the bid stage. The Transform Models upon which financial benefits were based underwent significant evolution between 2016 when the bid was submitted, and 2020 at the time of Project Closedown. The cost benefit analysis at closedown moved away from using Transport Models SC3 and SC4, instead using Transform Models SC5 (based on fast transition to high decarbonisation levels) and SC8 (based on a slow transition to low decarbonisation levels).

These models were deemed more appropriate as the discussion has moved away from whether decarbonisation will happen, but instead how quickly that this will occur. The CBA calculated differences in expected with and without the uplift solution. The uplift solution provided a saving of £251m for Transform model SC8 (slow transition), but an additional expenditure of £590m for Transform model SC5 (fast transition). The additional expenditure was a result of the models minimising investment over 5-year periods rather than for the long term to 2050. Minimising 5-year investment costs was an artificial limitation introduced to the CBA to reflect the fact that, despite the Transform Models themselves being well defined (allowing in principle, optimal cost minimisation). In reality, over the long term there exists significant uncertainty in the specifics of LCT uptake rates, and thus it is impossible for perfect investment decisions to be made. By minimising costs over 5 years rather than over the longer term, some of that uncertainty is reintroduced, by removing precise knowledge of the entire Transform model.

6.1.2 Method 2 – Community Engagement

At the bid development stage, it was assumed that average customer savings from the supplier, based upon increased buying power of communities, would be 10%. Scaling up the number of interested communities to 20,000 by 2020 leads to an estimated total saving of £177m. This was based on the average energy bill at the time of the bid development. This financial benefit is received directly by customer, rather than in DNO savings. Its value will of course depend on wholesale energy prices in the future and speed of the uptake of distributed intelligence.

Expected financial benefits for this method are difficult to model as they depend hugely on how widespread the participation in using the open data to deploy apps to the platform becomes.

6.1.3 Method 3 – OpenLV Extensibility

At the bid development stage, the financial benefit of the ability to deploy Apps to the LV-CAP® platform was calculated as £298m assuming a single app deployed on 119,000 LV-CAP® platforms at 119,000 substations. Deploying multiple Apps onto the platform would multiply this benefit, to an estimated £927m in NPV terms by 2050.

In section 6.1.1 it was shown that considering the uplift solution alone, the LV-CAP® platform could potentially increase the investment required in the networks, if the uptake of LCTs is fast (SC8 Transform Model). However, the uplift solution is not the only means the LV-CAP® platform has for creating financial benefits.

For example, LV-CAP® provides a means to monitor transformer headroom in near real time, potentially facilitating Demand Side Management (DSM) for EV's. The Electric Nation project showed that domestic EV charging could be successfully constrained to manage demand on local network, without affecting customer satisfaction. By monitoring the transformer headroom, demand from EV charging can be dynamically managed to ensure that the transformer is not overloaded. This reduces the need for network reinforcements (hence also network investment) required in response to the expected large increase in domestic EVs.

Reducing investments required to facilitate EV charging is hugely incentivised by EV's predicted high uptake rate and high (typically 7kW) demands on the electrical network. Modelling the combined effects of the uplift solution, and EV DSM solution, the net financial benefit for Transform Model SC5 and SC8 is £297m and £390m respectively.

Another benefit comes from the incentivisation of DNOs to reduce customer interruptions under the RIIO-ED1 price control incentive by rewards or penalties for exceeding of failing to reach their target for customer interruptions and customer minutes lost (CI/CMLs). Pre-fault and fault prevention techniques are a key mechanism for reducing the number of CI/CMLs. While typically this has required dedicated hardware, LV-CAP® has opened up the possibility of deploying applications to the platform specifically for this purpose.

Simulating the use of a fault prevention app in the economic analysis of the benefits of LV-CAP® provided additional financial benefit, increasing the net financial benefit from the combination of the uplift solution, DSM for EVs and the fault prevention app to £672m for SC5 and £734m for SC8. These additional savings are driven by both reduced CI/CML penalties from permanent fault, and prevention of LV feeder faults via pre-fault detection.

This analysis considers only using the app on substation where LV-CAP® had already been deployed for the benefits provided by the uplift and DSM for EV apps. Expanding the analysis to consider installing the financial benefits of installing LV-CAP® on substations where it had not already been deployed for other purposes indicates that net benefits could reach as high as £1,804m for SC5 of £1,864m for SC8. This shows the high value proposition that fault prevention represents.

The CBA conducted shows how the ability to deploy many applications to the LV-CAP® platform provides multiple means of generating financial benefits. The open philosophy will allow further apps to be developed not considered here, many of which are likely to generate even further financial benefits to a variety of different stakeholders.

A thorough analysis of the expected financial benefit associated with network capacity uplift released due to distributed intelligence can be found in SDRC 5, section 3.2.2.

6.1.4 Total revised financial benefit

At bid development stage, using the conservative estimates for the financial benefits from the three methods discussed above, the total financial benefit was calculated to be at least £595m. This is comprised of £120m from Method 1, £177m from Method 2 and £298m from Method 3.

As LV-CAP® is fundamentally an open platform, it is natural new sources of value will emerge over time. The value of the network benefits that expected to emerge depend on the Transform Model used to make the forecast. Section 3.2.4 and section 3.2.5 of SDRC 5 evaluate the estimated value generated from three distinct value stacks that can be facilitated by the LV-CAP® platform. This concludes that the expected NPV term financial benefits are between £1,804m and £1,864m, depending on the uptake rate of LCTs[7].

6.2 Calculation of capacity released

6.2.1 Method 1 – Network Capacity Uplift

The anticipated capacity that could be released by Method 1 at the bid development stage was 25%. SDRC 4 Section 2.3.5 details the total transformer capacity that could be released across WPD's license areas. This was shown to be 6,350kVA, assuming the anticipated capacity uplift figure of 25%. Scaling up for the substation population across Great Britain leads to a potential transformer capacity increase of 42,000MVA. The anticipated thermal cable uplift release from the bid development stage of 25% was not realised in trials. Across the transformer pairs analysed for meshing the highest thermal cable uplift factor was 0.12% (as outlined in SDRC 4 Method 1). This figure could have been higher if networks were selected based upon optimising additional capacity available to the network. However, the primary focus was on demonstrating the ability to safely reconfigure networks using the LV-CAP® platform; the trial was successful in this regard. Alternative methods of meshing, such as meshing at the link box level, were not trialled throughout this project. For the cost benefit analysis conducted post project, an additional feeder capacity uplift factor of 0% was used.

A full explanation is detailed in Section 2, SDRC 4, and section 3 SDRC 5.

[7] The calculations undertaken to derive the above financial benefits take into account the ongoing Operational Expenditure associated with the deployment and operation of individual applications to separate Distributed Intelligence Platforms, and the data transmission and storage costs associated with such systems. These costs will vary dependent on the number and type of applications deployed to each substation in question, the analysis undertaken took this into account when determining annual ongoing expenditure and benefit.

6.2.2 Method 2 – Community Engagement

It was not anticipated that any capacity would be released by Method 2 at the bid development stage.

This assumption was not revised throughout the course of the project. The responsibility for releasing capacity lies firmly with DNOs. Community trial participants' interests in the project were for other reasons, such as understanding the local LV network, using the network data to encourage the uptake of LCTs at the local level and to plan the best location of their installation, or gaining an understanding of the impact of their local network on the environment.

6.2.3 Method 3 – OpenLV Extensibility

The anticipated capacity that could be released by Method 1 at the bid development stage was 10%.

The project showed that LV-CAP® provided a platform to which Apps could be deployed to release capacity. The nature of the applications that will be deployed to release capacity are yet to be realised; as such it is difficult to predict the capacity that will be released on the network due to OpenLV. The 10% estimate made at bid development was based on research that indicated 10% could be released by EV charge management alone. This 10% figure is likely to be an underestimate, especially as uptake of LCTs (distributed generation, EVs, heat pumps and so on) accelerates, and quite possibly innovative time of use tariffs become more widely available to customers.

6.3 Calculation of carbon benefit

6.3.1 Method 1 – Network Capacity Uplift

Bid Development Stage

At the bid development stage, the anticipated minimum (lower bound) carbon savings that could be achieved by the Network Capacity Uplift solution was calculated to be 117,600 tCO_2e (tonnes carbon dioxide equivalent) by 2050. This figure was calculated based on several assumptions.

Firstly, it assumes low uptake of distributed intelligence at LV substations.

In this scenario (Transform Model 3), distributed intelligence is only deployed to 16,000 circuits by 2050.

The average length of an LV circuit was assumed to be 150m, or equivalently 0.15km.

Avoiding cable reinforcement is assumed to save between 49 tCO_2e/km and 75 tCO_2e/km. For calculation of a conservative carbon saving estimate, the lower figure of 49 tCO_2e/km was used.

Taking the product of the carbon saving per kilometre of reinforcement avoided and the average length of an LV circuit in kilometres gives the carbon saving per circuit. Performing the calculation…

$$\frac{CO_2\,Saving}{Circuit} = Average\ Circuit\ Length\ in\ km\ \times \frac{Carbon\ Saving}{km\ of\ circuit}$$

$$\frac{CO_2\,Saving}{Circuit} = 0.15\ km\ \times \frac{49tCO_2e}{km\ of\ circuit} = \frac{7.35tCO_2e}{circuit}$$

…reveals the average carbon saving per circuit is therefore 0.0735 tCO_2e/circuit.

Taking the product of the carbon saving per circuit, and the number of circuits where reinforcement is avoided, allows for a lower limit estimation of the total carbon saving achievable as a result of the solution. Assuming distributed intelligence avoids network reinforcement for 16,000 circuits…

$$CO_2 Saving = 16{,}000\ circuits \times \frac{7.35tCO_2e}{circuit} = 117{,}600tCO_2e$$

…providing total conservative carbon savings of 117,600 tCO_2e.

Assuming higher uptake of the distributed intelligence platform (241,000 circuits), and the higher estimate for CO_2 reduction per kilometre of reinforcement avoided, the total estimated carbon savings rises to 2,711,250 tCO_2e. This placed an upper bound on the expected carbon savings from this method.

Section 3.2.2 of SDRC 5 revised the lower estimate for the number of affected circuits to 259,000 circuits (assuming a slow transition towards the uptake of LCTs, Transform Model SC8). Repeating the calculation above with the revised number of circuits, predicts a carbon saving of 1,903,650 tCO_2e, where the lower figure of 49 tCO_2e/km of reinforcement avoided is used. This represents an increased carbon saving of 1,786,050 tCO_2e compared to the prediction made at the bid development stage, for the lower bound prediction for the carbon saving generated by the network capacity uplift made at the bid development stage.

Table 6 in Section 3.2.2 of SDRC 5 shows a revised upper estimate of the number of affected circuits of 406,000. Repeating the carbon saving calculation using the upper estimate for avoiding cable reinforcement of 75 tCO2e/km, gives the upper estimate for the carbon saving as 4,567,500 tCO2e. This represents an increase in the upper bound prediction for the carbon saving from network capacity uplift of 1,856,250 tCO2e compared to the prediction made at the bid development stage. Table 9 provides a summary of the carbon savings as predicted as bid development stage to as projected at the close of the project.

Table 9: Comparison of Projected Carbon Savings at Bid Development and Project End

	Bid Development Stage	End of Project	Difference
Lower Bound Carbon Saving (tCO2e)	117,600	1,903,650	+1,786,050
Upper Bound Carbon Saving (tCO2e)	2,711,250	4,567,500	+1,856,250

6.3.2 Method 2 – Community Engagement

The anticipated carbon savings that could be achieved by Method 2 at the bid development stage was 31,410 tCO_2e by 2050.

This was derived by assuming customers could use data provided by OpenLV to drive down energy consumption by an average of 175kWh/customer/year. It is assumed each substation supplies an average of 35.9 customers, and OpenLV is rolled out to 20000 substations. Therefore, the total number of customers supplied by the monitored substation is:

$$Number\ of\ Customers = Number\ of\ Substations\ Monitored \times Average\ Number\ of\ Customers\ per\ substation$$

$$= 20{,}000\ substations \times \frac{35.9\ customers}{substation} = 718{,}000\ customers$$

At the time of bid submission (2016), average UK electricity carbon intensity was 412g CO_2/kWh and forecast to fall to 150g CO_2/kWh by 2050. A conservative estimate assuming average UK carbon intensity falls to 250g CO_2/kWh was used to avoid overestimating potential carbon savings. Taking the product average carbon intensity per kWh, and the estimated annual number of kWh saved per customer, gives the average carbon saving per customer per year:

$$\frac{CO_2\ Saving}{Customer} = \frac{175kWh}{Customer \times year} \times \frac{250gCO_2e}{kWh} = \frac{43{,}750gCO_2e}{Customer \times year} = \frac{0.043{,}750tCO_2e}{Customer \times year}$$

The annual carbon saving per customer is therefore the product of the number of customers and the carbon savings per customer:

$$CO_2\ Saving = 718{,}000\ Customers\ \times \frac{0.043{,}750tCO_2e}{Customer \times year} = \frac{31{,}410tCO_2e}{year}$$

However, the UK government committed to net zero emissions by 2050 which will lead to a dramatic decrease in average carbon intensity of electricity. Indeed, carbon intensity has fell significantly since 2016 due to the UK's decreasing reliance on coal and increased utilisation of renewables as part of its fuel mix. This will decrease the effective carbon reductions from energy saving, since that energy saved is produced at a lower carbon intensity.

6.3.3 Method 3 – OpenLV Extensibility

The anticipated carbon savings that could be achieved by Method 3 at the bid development stage was 2,892,901 tCO_2e by 2050. This figure is comprised of the cumulative effect of avoiding network reinforcement (method 1) and energy saving by customers (method 2). It is assumed that Method 3 will enable a broad range of solution to be deployed by third parties. For this reason, it has been assumed that this Method will avoid the need for reinforcement for all 393,592 suitable feeders by 2050. It is likely further benefits will be gathered from energy savings provided by Method 2 solutions, but these have been excluded for this analysis to avoid double counting. Therefore, the lower estimate for the cumulative carbon savings from method 3 is 2,892,901 tCO_2e by 2050. This figure once again assumes the average length of a feeder is 0.15 km, and the carbon saving per kilometre of network reinforcement avoided is taken as 49 tCO_2e/km. This figure has been calculated by the equation:

$$CO_2Saving = 393{,}592\ feeders \times \frac{0.15km}{feeder} \times \frac{49\ tCO_2e}{km} = 2{,}892{,}901tCO_2e$$

6.4 Summary of Benefits

Table 10 shows the expected financial benefits, network uplift and carbon savings expected at the bid development stage, together with the revised expected figures at the project end. This summarises the expected benefits from widespread installation of LV network monitoring across GB's DNOs' distribution networks.

Table 10: Comparison of Projected Financial benefit, Capacity Uplift and Carbon Savings at Bid Development Stage and Project End

	Bid Development Stage	End of Project	Difference
Lower Bound Carbon Saving (tCO2e)	117,600	1,903,650	+1,786,050
Upper Bound Carbon Saving (tCO2e)	2,711,250	4,567,500	+1,856,250
Network Capacity Uplift	42,000MVA	0MVA	-42000MVA[8]
Expected Financial Benefit	£595m	£1,804m (Lower Bound)	+£1,209m

[8] At the stage of Bid Development, it was assumed that implementing Automated LV Network Switching would provide direct benefits to the Network Capacity Uplift. It was found however, that unless the load was imbalanced between LV networks capable of being meshed, the achievable benefits were marginal at best.

This is detailed in SDRC 4.

7 Lessons learnt for future innovation Projects

Many lessons were learnt over the course of the OpenLV project. These lessons are collected in this section of the close-down report, and the lessons learnt will be carried into future innovation projects where relevant. To help the reader find lessons relevant to future innovation projects, the lessons are grouped into categories, namely: hardware, software, network, communities, businesses and academia, and other (project communication, security, safety).

7.1 Hardware

It is better to over specify core components of the system for a solution such as OpenLV, for example the ruggedised PC, thereby ensuring adequate processing power and storage for project trials.

The hardware must fully support all software to be implemented in the project. Specifying specific hardware components can be a useful means to minimise technical risks when implementing software.

It can be useful to over specify sensors used in trials, to ensure the sensors are fit for purpose for potential future applications which might require higher specified sensors than the applications at time of deployment require.

The physical design of the system should consider the variety of physical spaces and conditions that the system might be installed in. Different mounting systems allow for hardware to be deployed in several different ways depending on which mounting system is most appropriate on a site-by-site basis.

Well tested, off the shelf hardware reduces technical risk. For example, the LV monitoring hardware used in the project had already been used by WPD in Business as Usual (BaU) scenarios, as had the ALVIN® Reclose™ devices.

When equipment is installed on the LV network, all possible situations the systems may instigate should be considered, together with the actions required to manage or mitigate them. Training and documentation should be provided where actions are required outside of normal operating practices. There should also be reminders on-site.

A dedicated test rig was extremely useful in the development of the OpenLV platforms. The test rig should include all required sensors and be tested as early as possible to ensure components can be tested for as large a time as possible before installation. A dedicated test rig allowed specific inputs into the system such that system outputs may be verified, in a way that would be technically extremely difficult to achieve in a live deployment. It is clear in this project, that a dedicated testing facility was a highly valuable asset and should be strongly considered for future network innovation projects.

Overall solution system requirements must be formally defined such that the FAT and SAT documents cover testing all Project requirements.

7.1.1 Telecommunications

In project requiring adequate 3G/4G signal strength is required at deployment sites to ensure reliable communications, outdoor antenna should be utilised if doubts exist over the signal strength.

Communication monitoring should be performed with alarms set to report any issues. This allowed hardware issues, commonly with routers, to be detected and rectified.

7.2 Software

Software requirements should be captured using well tested approaches. The MoSCoW approach was the chosen approach for OpenLV.

Single end-user requirements may be delivered by more than one Application. The technical requirements for these Applications must be cross-referenced to ensure compatibility.

The OpenLV solution focussed on building core functionality first, before adding additional functionality later. This method proved effective as it allowed both earlier delivery of the core functionality, and earlier testing, thus minimising technical risk to deployment.

The LV-CAP® operating system was based upon a Docker system architecture. This was effective in allowing Apps (software) from multiple vendors to be packaged into separate “containers”, designed to run on a shared operating system. The environment was designed to allow a variety of programming languages to be used to create Apps, allowing fast development of the overall platform.

Restrictions on technical specifications such as memory usage, processor usage and storage space must be clearly communicated to developers as early as possible. Applications storage size was limited by reliability and cost of deployment to all required sites over the mobile data network. It is clear from this that communicating technical specifications and limitations in any network innovation trial involving software development should be done in detail and at the earliest possible opportunity.

7.2.1 Platform Management

EA Technology performed the role of administrating the OpenLV platform for this trial. This role included ensuring compliance of Method 3 apps against OpenLV protocols, in addition to issuing security certificates to apps once they have passed the process. Certification here refers to compliance of an app with the OpenLV protocol.

The project revealed that where relationships were strong between app developers and the certification team, the certification process went smoothly because small problems were found early and corrected. However, weaker relationships harbouring difference in interpretation of the API rules, slowed down the certification process.

The skeleton app offered to software developers was successful in so far as developers who made good use of the app progressed quickly towards development. Those who did not use the app made progress towards certification more slowly. A common reason for developers not making use of the skeleton app was an unfamiliarity with the programming language that it was written in. Releasing skeleton apps in a wider variety of languages will help to overcome this problem.

It was concluded that greater familiarity with the API rules would have decreased the number of failed certification attempts significantly. Developers attempting to use shortcuts in automation led to serious failed certification attempts due to significant changes to the source code being required before certification could be granted. In BaU context, these issues would be overcome by encouraging greater familiarity with the API rules and creating a culture of constructive feedback in the certification process.

7.2.2 App Development

EA Technology clarified the only requirement was a fully built app and a series of test inputs to confirm its correct application. These tests were only to check correct integration of the application into LV-CAP®, rather than to tests outputs from the application were correct or to demonstrate the app met customer requirements. Access to the source code was not required, avoiding conflicts of interest with potential app developers. Thirdly, the LV-CAP® platform's timestamping of data and data validity flags reduced the need for data cleansing and thus time required significantly. OrxaGrid observed that the architecture of the OpenLV platform enabled them to focus on app development, as valuable time was not taken up for hardware installation of data network configuration and management. Valuable opportunities for commercial development were identified as a result of new data sources being available from the OpenLV platform, as well as greater potential deployment of existing analytics packages.

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.
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.

7.3 Network

The OpenLV trial demonstrated that decentralised analysis and control was able to present a robust Method of automation for the Low Voltage network. Evidence for this came from low voltage networks being reconfigured at times of simulated network stress. This was enabled by OpenLV.

A Smart LV network device, located at one of a pair of substations, allowed the substations to be meshed, enabling the substation to share load. This was an unusual approach, as in BaU LV networks are sectionalised by link boxes located between two substations. In the arrangement utilised in this trial, temporary meshing of two transformers was shown not to be an ineffective method of de-loading substation transformers. However, if cost effective smart link boxes had been available at the onset of the trial, there was potential for significant network uplift.

Method 1 investigated forecasting transformer capacity headroom available at LV transformer, based on real-time measurements of transformer temperature and load duration. This was successfully achieved, and the benefit estimated at a 6,350MVA capacity uplift across 39,500 of WPD’s 140,000 substations. While it would have been possible to carry out these calculations centrally, this would have relied upon reliable communications between the central location and the substations, which would be a costly operation, prone to potentially harmful communication faults. This showed one of the high value propositions enable be decentralised computing, further demonstrated by the results of these calculations being shared with other apps serving the interests of Method 3 trial participants.

One of the main learning points from this stage of the project that seemingly separate decisions combined to restrict the number of suitable substation pairs for use in the project. A combination of decisions made during the initial project development stage together with on-site restrictions limited the number of suitable sites. Each requirement or decisions reduced the proportion of the network suitable for use in the trial. Despite these decisions being made for sensible reasons, they still resulted in unintended consequences. Site selections became a much more time-consuming process than expected for the eventual outcome. The project trial’s system utilising LV-CAP® and ALVIN® Reclose™ devices was more difficult to implement than deployments of different hardware mixtures in the future.

7.4 Communities

As detailed in the section0 above, future projects should be cognisant of the level of technical expertise within community groups and organisations such as parish councils.

During the project planning phase, it was assumed that a level of expertise would exist within communities to enable development of applications, or to make sensible use of the data available. In hindsight, it remained impractical for many communities, especially those without specific domain knowledge, to make practical use of the available data. This was despite the project planning on support for participating communities and designing the interfaces from the distributed intelligence platform to be as simple to use as possible.

It should be remembered by future projects seeking to work with and utilise the local expertise of community groups, that whilst they tend to be highly enthusiastic for anything that would benefit their community, the challenge of their limited technical knowledge must not be underestimated.

The OpenLV project has demonstrated that whilst community groups required assistance to develop workable use cases for the project data, above and beyond that envisaged at the start of the project, once data access was secured a wide range of effective projects were implemented.

Community groups require different engagement approaches. Utilising tailored imagery and communication styles ensured high levels of engagement by communities in the project. Direct engagement with the community groups via telephone or in person contact was crucial to ensuring continued engagement in the project. Having CSE and Regen, companies already trusted by community groups, as part of the project team proved invaluable in successful ‘testing the market’ and recruitment stages for the OpenLV project. The length of the project should be carefully considered, since the timeframes need to be long enough for communities to see real benefits from their network.

The variety of App ideas from community groups was wider than expected. For example, 5 app idea under the banner of “policy, planning and retrofit programmes”, a topic not covered in the suggested app ideas, were suggested. App ideas should be subject to clear assessment criteria to take into account any barriers, issues and risks (in this case set out in the Regen market potential assessment report).

The project showed that there was a strong desire from community groups about accessing local network data to enable a greater understanding of the local electrical system, and particularly the effect their actions had on the local network. High demand led to there being more formal application to participate in the trail than the number of substation platforms available in the trial. It is clear for future innovation projects that community groups have a strong desire to understand the effect of their actions on their local electrical network.

To ensure a wide variety of engagement in the project, targeted marketing is required.

Beneficiaries and value streams from app ideas are not necessarily clear during the development of the idea; these often only became clear after the initial survey which was sent out to the community groups.

The challenge of communicating technical knowledge should not be underestimated; explaining network configuration and topology was a much greater challenge than expected. Network topography meant that some community groups required monitoring of multiple substations to gather the data they wanted (e.g. four substations were monitored in Marshfield village), since neighbourhood boundaries do not align well with the areas fed by single substations. This was a challenge when there were only 10 substations that could be monitored for this stage of the project.

Community groups are generally reliant on volunteers, which results in timescales that often get pushed back as other priorities take precedence.

The technical capabilities of community groups for app production should not be overestimated. This barrier was overcome by appointing CSE to support these projects including app development, focusing on visualising the OpenLV data during the trial period. More support for community groups was required to configure the web app developed by CSE and to interpret the data received from it. Applying for funding to develop apps, in the absence of the skills in house to develop apps, would have been a costly and time-consuming process, leading to little time to use the app to engage with the communities about the information the app generated. Therefore, a single web app was developed by CSE serving the interests of all the use cases the community groups proposed. This was an efficient means of using funding, time and ensuring the communities had time to focus on communicating the findings from their participation in the trial to their communities. Despite training via webinars and 1:1 sessions, some communities still struggled to take full advantage of the web app due to an insufficient skill base to take full advantage.

In general, community groups found that having access to local LV data transformed their ability to discuss their energy use, although data needed to be presented in a simple and easy to understand manner, due to the lack of technical knowledge amongst community group representatives. Access to the local LV data did allow for communities to develop energy use strategies and apply for funding. It was generally acknowledged by communities that wanted to install or deploy or simply encourage the uptake of LCTs that the data was not the driver, but it did facilitate conversations on a local level about LCTs.

Technical requirements for app deployment will be reduced by making the application developed by the Community Groups in the Open available freely available at the end of the trials. Only small configuration changes will be required to ensure this app is suitable for the needs of future Community Groups.

Extensive site surveys prior to site selection were hugely beneficial, as it minimised problems during the installation process. The detailed surveys allowed a plug and play approach to be utilised once installation had been scheduled.

The installation team took detailed photos of the sites once installation was complete. This proved beneficial as it allowed the team to identify issues and incongruities remotely.

Each community participant facilitated different learning points being accrued. Exeter Community Energy (ECOE) highlighted the importance of linking substation data with contextual data such as local energy generation and National Grid carbon intensity to maximise the value from use cases of local LV data. It also highlighted the difficulty in obtaining sufficient resource to fund development of a high-quality phone application in the limited time available as part of OpenLV trial.

7.5 Businesses and Academia

EA Technology sought to manage Method 3 participants towards the eventual goal of exploring the value of the open data platform.

One of the key learnings from the participant management aspect of this project was an effect of the relationship between OpenLV and its Method 3 participants being very different from a supplier and vendor relationship. In this trial, Method 3 participants were responsible for funding their own participation in the project.

This meant that in several cases, the delivery resources earmarked for participation in the trial were prone to become diverted onto other projects that had a more immediate business case for the participant.

This was compounded by the fact that the OpenLV trial was time bounded. This meant it became difficult for some participants to wholly commit to delivery of OpenLV research within the project timescales.

The latter issue is slightly artificial, since if the platform was already part of BAU participants would be able to conduct their research and development at a pace that suited their business context.

It was also observed that the less complex a participants' Method 3 trial, the more likely they were to reach their Method 3 objectives. In contrast, participants who had larger ambitions or complicated resource requirements were more likely to not reach their goals within the allotted time period.

It is therefore worth highlighting for future projects that in the event an area of learning is considered ‘essential’ to the project, there must be adequate budget available within the project to fund it. Reliance on the ‘goodwill’ of third-party companies is unrealistic, as the greater the value of the hoped-for learning, the less likely it is to be provided due to the increased complexity and associated time requirements.

Method 3 showed that there was a high degree of interest in the OpenLV project from business and academic partners. The number of applicants exceeded the number of platforms that were available for deployment, even though participants were responsible for sourcing their own funding. This highlights the fact that businesses saw taking part in the project as a strategic opportunity, and that they believe that open data will enable future revenue streams. However, asking for businesses to find their own funding did have its challenges, because there was no certainty about the commercial viability of the LV-CAP® platform at the start of the trial, and that some businesses were reluctant to alter their R&D commitment without a strong business case for doing so. Businesses involved already in the DNO supply chain stated that they believed open data would allow them to generate greater value for the DNO. Academic participants stated that by accessing data to shared data from a wide sample of substations, data barriers to independent network research could be overcome.

The project showed that participants were willing to develop apps to reside on 3rd party hardware, overcoming vendor tie in traditionally experienced by substation monitoring hardware. This was successfully supported by the development of cyber security standards, which protect both the network owners and the app providers. These standards were made publicly available at the end of the project. The trial also demonstrated that apps from different providers could communicate efficiently, working towards creating efficient network outcomes. The regular workshops throughout the project were an important opportunity for participant organisations to provide updates and to learn from other organisations. These workshops were well attended throughout the project, and feedback received from the project was positive. The relative low priority of organisations involvement in the OpenLV trial due to lack of immediate access route to market prevented full development over the project timescale.

Many participants in the project received funding from other sources, which did not align with the project goals, as it was intended organisations self-funded their involvement in the trial.

Regular workshops were organised by the project team, initially during the application process and then at regular intervals throughout the project. The initial workshop was vital in allowing potential participants to gain an understanding of the project.

Method 3 demonstrated that a variety of different apps technological approaches could be used to manage the transition to electric vehicles.

The OpenLV project utilised Non-Disclosure Agreements (NDAs) to address concerns regarding intellectual property, specifically concerns multiple organisations had with sharing app ideas.

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 simple 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.

7.5.1 Barriers to Participation

Seven organisations failed to commit resource to developing an app for the project. Key learning is that clear investment cases are often required before resource can be committed to the project. These business cases would often need to be rigorously assessed before the resource could be released to enable the work.

Other barriers to participation in the trial were a couple of organisations who thought that they had insufficient information about the project to commit to developing an app, while two other organisations wanted more information about the scale of the potential roll out of the OpenLV platform before committing to app development. Key learning from this is providing as much information as possible to potential participants maximises the chance of obtaining their commitment to participating in the trial. Two further organisations felt they lacked the technical skills required for app development. Specific learning was accrued because of some of the business and academic partner involved in stage 3 of the trial. Egnida's involvement resulted in learning that potential available capacity of the LV network and transformer was higher than that indicated by WPD, indeed capacity was much greater than indicated by WPD for the majority of the time. This indicates the OpenLV platform facilitates the Connect and Manage agenda. Egnida got involved in the trial as a strategic move, rather than to deliver immediate opportunity, suggesting that some businesses are aware of the potential value LV network monitoring will offer in the future. Egnida believed that by using the OpenLV technology in areas of social housing allows the fuel poor to gather some of the value in the energy supply chain, removing some of the value from big companies and organisation in the energy industry. Concerns were raised about how lack of clarity regarding incorporating LV data into future plans from the network sector would prevent the enhanced value of LCTs that the OpenLV has the potential to deliver. Concerns were also raised about the latency of the platform as trialled being a barrier to it enabling fast-acting frequency response products.

7.5.2 Learning from Specific Apps

Lucy Gridkey's app showed that the OpenLV architecture enabled a 3rd party to control LCTs (specifically EVs and EVCPs) in response to network requirements. Since Lucy Gridkey's app took advantage of data from the transformer thermal model (a separate app), it also demonstrated that the open platform nature of OpenLV allowed apps to support each other in a cost effective, as well as memory and processing power effective, way.

OrxaGrid's app development process facilitated the following learning points. Firstly, the Virtual Machine was a useful and effective development tool; if an app worked on the Virtual Machine it was found to work in real life. Secondly, OrxaGrid overcame limitations of the overhead of loading the app onto the Virtual Machine by developing their own test tools used prior to deployment on the Virtual Machine.

The main learning point for Upside Energy's involvement in the project trial, was the importance of transparency in current and particularly future business models around network flexibility. Since the trial was conducted various GB DNOs including WPD have begun signalling opportunities for flexibility providers.

7.6 Other

7.6.1 Project Communication

Animations and short videos were used throughout the project as means to disseminate information about OpenLV and its findings. A short animation to introduce the project was found to be an effective way to engage with potential stakeholders in the project. Similarly, an animation produced at the end of the project to summarise the project's learning was found an effective and engaging way to disseminate the key findings of the project to a wide range of stakeholders, particularly those that traditional means of dissemination would be either too technical or too time-consuming to reach.

Furthermore, a series of short videos involving trial participants speaking about their involvement in the OpenLV project and the lessons they learnt from it was found to be an effective way of communicating. The series of videos allowed people interested in particular aspects of the project a quick way of finding information about that particular aspect of the trial, rather than having to search through large quantities of information to find the relevant aspect. Such was the success of these communication methods; it is recommended that other innovation projects should carefully consider including similar means of communication to inform others about their projects.

These videos' and animations became particularly important when disseminating learning during the COVID-19 pandemic when traditional face-to-face could not be held. Short videos are more likely to grab the attention of an audience when publicised via social media, which can bring material to a wider group of stakeholders.

An important learning point when talking about OpenLV to people from outside the project, or the DNO innovation environment, was that it is important to resist using the 'Methods' terminology. This was confusing and unhelpful to external stakeholders.

It was helpful when discussing the project to non DNO stakeholders to ensure appropriate terminology is used. Overly technical discussions of the electricity network or assets were off-putting to some stakeholders. Different stakeholders, depending on their background and field of interest, found different elements of the project interesting and it was important, especially during recruitment to identify the appropriate 'hook'.

It was very useful to be able to provide examples or case studies illustrating potential uses of network data as a starting point to provoke interest in the project. This helped provoke interest and ideas in potential applications.

Workshops organised by the project were a very useful method of collecting learning from all project participant organisations. This was done by asking the organisations to do short presentations, video recordings and group activities. These organisations found the workshops a useful opportunity to discuss their ideas with each other and the project team.

7.6.2 Security

Security is an essential component when designing systems for innovation trials potentially vulnerable to cyber-attack. This is especially important for any platforms using distributed intelligence, as any attack would be classified as “Major”. Stringent control of access to system controls and digital signing of the measured and generated data is recommended for all deployments to distributed intelligence platforms across the UK’s energy network. Strong monitoring, system logging and automated detection and response controls is also required. Cyber security is a critical consideration that must be taken into account; NCC Group were responsible for ensuring the systems used in the OpenLV project was cyber secure. A dedicated private APN was used by OpenLV project trials to improve the security of the overall solution.

7.6.3 Safety

Safety is another critical consideration in system design. In the OpenLV Platform enclosure, an isolation switch for the ALVIN® Reclose™ was included to ensure these devices could be isolated locally when working on site.

8 Project replication

In order to replicate the outcomes of the OpenLV project, a combination of hardware and software capability is required.

The Functional Requirements Specification document details the necessary functionality of the system deployed in the OpenLV project to demonstrate the capabilities of a distributed intelligence platform to benefit the LV distribution network.

The trial system deployed in the OpenLV Project comprised a combination of software and hardware with a proprietary software platform (LV-CAP®) utilised to provide distributed intelligence capability and meet the functional requirements. This enabled the gathering of data and processing of data, along with decision making and data transmission, utilising the hardware components as required.

The trial hardware comprised 'off-the-shelf components' and whilst a full listing of the hardware used in the OpenLV project is detailed below, it is noted that at the time, alternative devices could have been utilised in place of most, if not all, components of the overall system.

Were the project to be repeated, it is considered unlikely that such an approach would be considered the most effective, from either a financial or capability perspective, given the development of technology and services in the industry during the course of the OpenLV project. Alternative solutions are now able to match or exceed the capabilities of the OpenLV project's trial platform for an equivalent or better price than was possible during the early period of the project.

8.1 Software

It is emphasised that the primary goal of the OpenLV project was to demonstrate the capability of distributed intelligence platforms on the LV distribution network, with EA Technology's LV-CAP® software platform providing the 'distributed intelligence' functionality.

LV-CAP® managed the data gathering, recording, processing and communication capabilities, along with decision making and control functionality, using the hardware devices to achieve the necessary results.

LV-CAP® is a hardware agnostic software environment that in and of itself does not provide any direct functionality but instead makes available a framework environment in which various 'Apps', each designed to provide a specific network benefit (or benefits), can be deployed. The framework provides multiple core services for third party application developers to utilise, including access to data gathered by the platform, communications functionality and data storage, as well as providing access to any ancillary modules connected to the system.

Were replication of the OpenLV project required, it is recommended that the latest iteration of the LV-CAP® software (or equivalent if sourced from an alternative supplier) is utilised, in order to benefit from the ongoing development of the platform and to ensure the available security measures are up to date.

8.2 Hardware

Whilst it is considered unlikely that future replication of the OpenLV project would seek to utilise the same hardware as the project used, due to the increased availability of hardware platforms able to provide equivalent functionality in a single device, or require fewer individual components, information on each component utilised in the trial system is detailed below.

8.2.1 Enclosure - External

The overall solution was deployed within a suitable, non-conducting enclosure, capable of being mounted via multiple methods, including direct wall mounting or magnetic mounting on switchgear or a transformer.

Figure 6 shows an example of the enclosure mounted on a transformer, demonstrating the magnetic bracket and mounting capability. Key features of the enclosure are highlighted in the picture.

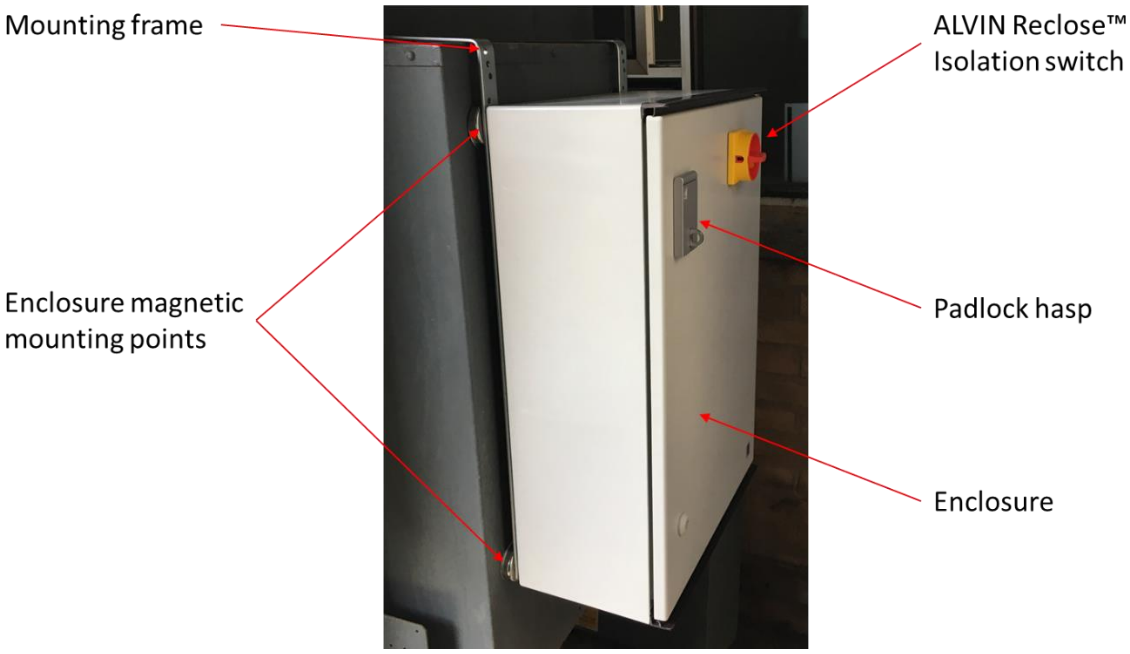

Figure 6: OpenLV Solution - Enclosure

The enclosure is a plastic based enclosure with an IP rating of IP66 and is capable of being mounted via multiple methods. Figure 6 demonstrates the enclosure magnetically mounted on the side of an item of switchgear with a mounting frame supporting some of the weight. If the enclosure is to be wall-mounted, the mounting frame can be removed, and the same mounting points utilised for bolting wall brackets to the enclosure, see Figure 7.

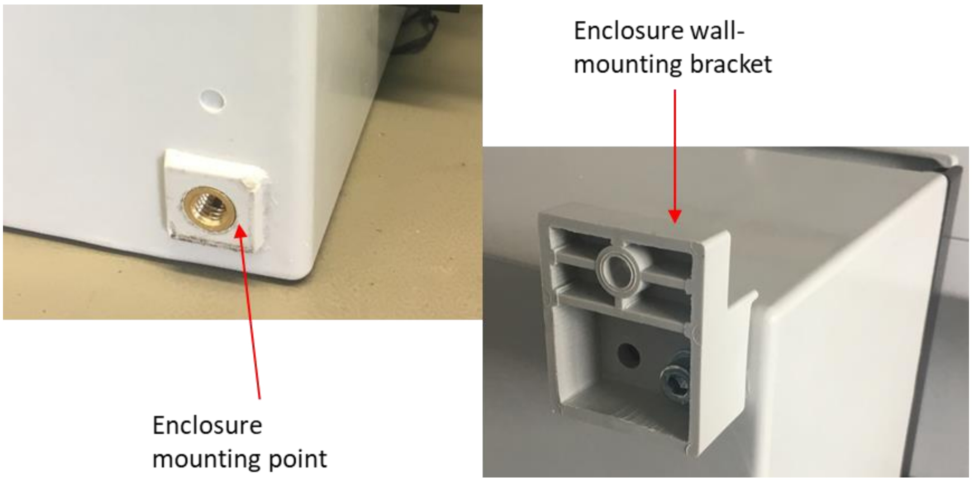

Figure 7: OpenLV Solution – Enclosure mounting points

In the event the unit is to be mounted on top of the LV fuse board enclosure, the magnets will still be utilised to prevent accidental dislodging of the enclosure.

The outside of the enclosure includes an isolation switch to be utilised for disconnecting the ALVIN® Reclose™ devices from the LV-CAP® platform control system if necessary, for safety on-site. This switch can be locked 'off' to prevent inadvertent or unauthorised reactivation of the system.

When deploying ALVIN® Reclose™ devices in the substation to provide automated network meshing, it was ensured that the front mounted isolation switch was readily accessible in the event isolation proved necessary.

A padlock hasp was also included to prevent unauthorised access to the LV-CAP® platform; only the OpenLV Project team will have the ability to unlock the enclosure, once access to the substation has been provided by WPD staff.

8.2.2 Enclosure - Internal

The enclosure contained most of the key components of the OpenLV solution, specifically, the embedded PC on which the LV-CAP® software platform was installed, the digital I/O terminal providing connections to the thermocouples and ALVIN® Reclose™ devices and the power supply for all components.

Communications within the enclosure were provided by an internal network via an Ethernet connected modem, connecting to an Access Point Name (APN) private network, allowing secure remote access to the unit.

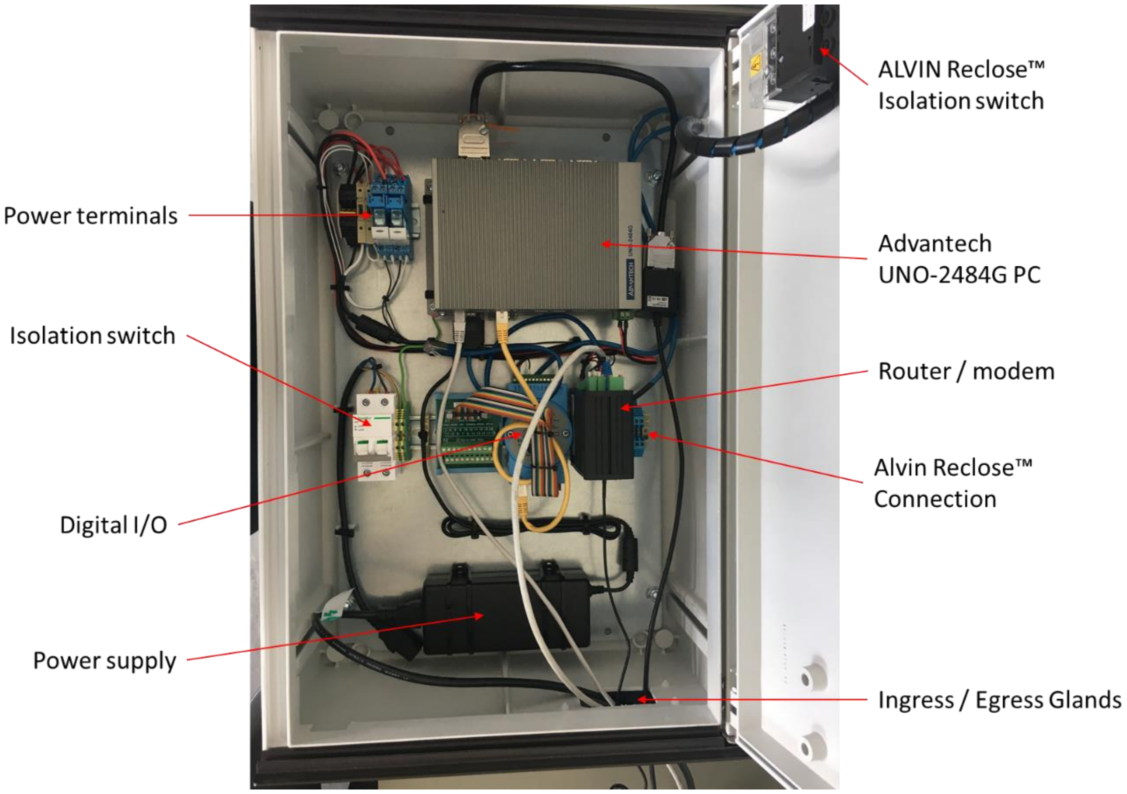

Figure 8: OpenLV Solution – Enclosure Internals[9]

Connections to and from the enclosure passed through the cube glands at the bottom of the enclosure and were routed as appropriate on a site-by-site basis.

[9] The enclosure shown in Figure 8 has a temporary power cable for direct connection to the power supply. When installed on-site, the incoming power feed will be routed through the isolation switch on the left, allowing the power to be disabled for all system components within the enclosure.

8.2.3 Ancillary equipment

ALVIN® Reclose™ devices

ALVIN® Reclose™ devices were only be installed in 10 substations (five pairs) within the project trial.

These devices were connected to the LV-CAP® platform when installed allowing the system to control operation of the circuit breaker within each device.

For the avoidance of doubt, the autonomous protection functionality within the devices continued to operate as normal and it was not possible to override that functionality using the LV-CAP® platform.

Figure 9: OpenLV Solution – ALVIN® Reclose™ devices

A deployment of ALVIN® Reclose™ units, using typical 'off-the-shelf' variants, will automatically attempt to reclose the circuit breaker after opening in the event of a fault. This functionality was disabled, at the request of WPD, for the units installed as part of the OpenLV project.

The installed units were instead configured to open the circuit breaker in the event of a fault but require manual intervention by a WPD engineer to reenergise the circuit, in a similar manner to replacement of a fuse.

LV System monitoring – Lucy Electric GridKey MCU520

Monitoring of the LV network within the OpenLV Project was via a GridKey MCU520 platform that communicated with the LV-CAP® hardware via an Ethernet connector.

Depending on the substation arrangement, the MCU520 monitored either:

- All feeders and summated the values to provide the total transformer load; or
- The LV busbars and the single feeder (to be meshed).

The first option was always applied for Method 2 and 3 substations.

The MCU520 is designed to be installed via the use of magnetic mountings or direct wall-fixings. Each site inspected at the site-survey (phase 2) stage identified the preferred installation arrangements.

Figure 10: OpenLV Solution – GridKey MCU520

Temperature monitoring

The dynamic rating application utilised calculated transformer and monitored ambient temperatures to model the available and predicted capacity of the transformer in question. The ambient temperature was measured using a thermocouple temperature probe installed within a radiation shield to prevent or mitigate the effects of wind and direct sunlight on the thermocouple. (Note that in the picture the probe is partially removed from the shield for information purposes)

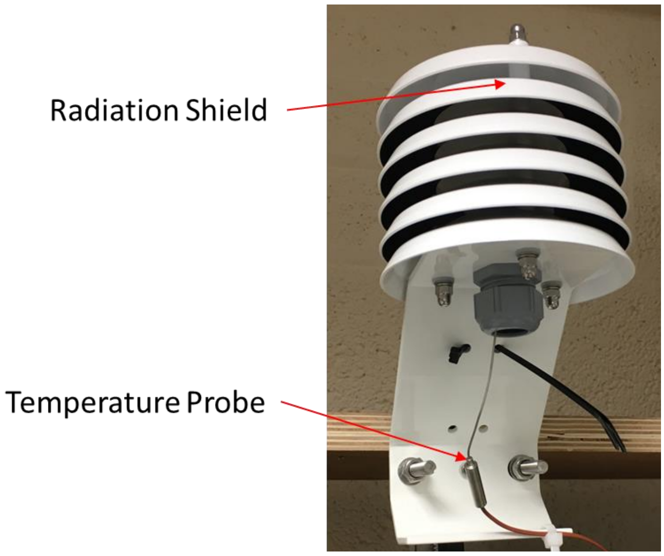

Figure 11: OpenLV Solution – Thermal probe & radiation shield

The internal temperature of the associated transformer was also monitored (to allow comparison of the calculated and actual values), utilising a similar thermal probe. However, a radiation shield was not required in this instance. Instead, the transformer thermal pocket was filled with oil with the probe inserted into this.

Figure 12: Example of a transformer oil pocket and cap.

Figure 13: Example transformer oil pocket and test cap, including thermal probe.

9 Planned implementation

The high TRL of the OpenLV solution, thanks to the comprehensive project trials, means that it is ready for Business As Usual deployment. We have initiated a deployment programme of secondary substation monitoring since the initiation of the OpenLV Project. Some of these monitors will be 'distributed intelligence enabled'.

The project has engaged with communities and learned how useful the provision of local energy data is. As such, WPD has facilitated the ongoing data provision for the project's community participants.

We are also working to provide this service to new community groups and interested stakeholders. Where the deployment of secondary substation monitoring has already taken place, WPD plans to enable local communities to access this data. The means to do this needs to be agnostic of the monitoring solution WPD has deployed, as such there is some work ongoing to enable all monitoring solutions that WPD deploys to be able communicate with the CSE Community App. If a community group wishes to access its local electricity data where WPD has not already deployed secondary monitoring, it is working to come to an offering where this can take place.

In location where we have deployed 'distributed intelligence enabled' substation monitoring, the functionality to host apps which can be deployed remotely and at scale. WPD will consider the deployment of such apps as and when they are developed. These could enable more complex on-site data analytics which could mean lesser data transmission and the costs associated with that.

Actions that we plans to perform to maximise the potential off the OpenLV solution are to:

1. Publish a policy that will enable community groups to request the deployment of a secondary monitoring solution so as to access their local electricity network data. This needs to include considerations around equipment installations, data tariffs, application on-boarding, user training and ongoing assistance with queries.
2. Ensure that data from all existing monitoring solutions used by WPD can be accessed by relevant stakeholders. Different solutions provide data in different formats and ways. WPD will develop a method for these to be presented in a single uniform way.

9.1 Exploiting the findings of the OpenLV Solution further

- Continue to encourage and promote the third-party access and use of both the network data collected throughout the project and network data that continue to be gathered by the solution as it exists beyond the project. This is so that third parties can find new ways to use the data to realise their own use cases. This ongoing work is now undertaken by the WPD DSO and Digitalisation Team.
- Further engagement with community groups to better understand their needs and the functionality DNOs can develop to benefit them and enable to realise their own data use cases. This ongoing engagement work is undertaken by the WPD Innovation Team
- Continue to consider the development of applications that can be hosted by a common application platform to promote on-site analytics and continue to realise additional benefits of this approach.
- The investigation of the benefits of automated control within substations that distributed intelligence can enable beyond meshing which was trialled in Method 1.

10 Learning dissemination

Learning dissemination is critical to share the knowledge accumulated over the course of the OpenLV project. Dissemination was conducted by a variety of different means. The table below outlines the various ways information from the project was disseminated.

It is worth noting that it had been initially planned that end of project dissemination would be carried out via in person workshops or conferences. Due to the impact of the COVID-19 pandemic on both travel and social interaction, plans were changed. The planned workshops were replaced by webinars, which allowed people to attend the dissemination events easily while adhering to the restrictions in place to limit the spread of COVID-19. This alteration did not reduce the effectiveness of project knowledge sharing.

Traditional means of dissemination (such as Presentations, Webinars, Conferences, Workshops etc.) are listed in the table below, with weblinks to the resource where available.

Table 11: Events that the project attended to dissemination project learning

Event	Date	Description
Presentation	28/04/17	An overview of the OpenLV project was presented by a member of the EA Technology team to a representative from SP Energy Networks.
Presentation	01/06/17	A presentation was given to 33 stakeholders in the project on 1st June 2017 in Birmingham.
Meeting with BEIS representatives	15/08/17	Presented an outline of the OpenLV project
Presentation at National Infrastructure Forum	13/06/17	WPD gave a presentation on OpenLV on 13th June 2017 at the National Infrastructure Forum, in London.
Vulnerable Customers Workshop, Birmingham	12/09/17	Short Introduction to the OpenLV project.

Event	Date	Description
Vulnerable Customers Workshop	13/09/17	Short Introduction to the OpenLV project.
Peer Power Feast Event, Dorset	28/09/17	Short Introduction to the OpenLV project.
Official Launch Presentation	05/10/17	WPD officially launched the project at their Balancing Act Conference. A one-hour presentation was given to 170 stakeholders about the OpenLV project.
Smart Community Energy Systems, Nottingham	11/10/17	Short Introduction to the OpenLV project
Smart Community Energy Systems, Cardiff	18/10/17	Short Introduction to the OpenLV project.
Electricity Network Innovation, London Event	01/11/17	Short Introduction to the OpenLV project
Electricity Network Innovation, Newcastle	7/11/17	Short Introduction to the OpenLV project
Peer Power Arts Energy Event	9/11/17	Short Introduction to the OpenLV project
Taking the power back, an energy jamboree about social justice and making our energy system smarter, Plymouth	15/11/17	Short Introduction to the OpenLV project

Event	Date	Description
EWiRE A smart decentralised system, London	16/11/17	Short Introduction to the OpenLV project
Renewable Futures and Green Energy Awards, Bath,	28/11/17	Short Introduction to the OpenLV project
Presentation at UN Climate Change Conference, Bonn Germany	November 2017	Presentation of an overview of the OpenLV project.
Stand at LCNI Conference	December 2017	OpenLV presented at WPD's stand at the LCNI conference. An update was provided at a workshop.
Poster Presentation at Workshop, Ljublijana	June 2018	Paper titled "The Development and Implementation of a Common Application Platform to Support Local Energy Communities" at the CIRED workshop by Richard Potter. This event was attended by over 400 delegates from 33 countries.
Stand at LCNI Conference	October 2018	OpenLV project represented at both WPD's and EATL's stand at the LCNI conference. An LV-CAP® was displayed at the WPD stand.
Community Events	November 2018	Project represented at community events organised by Regen in June.
Workshop, Exeter	March 2019	Presentation given to stakeholders by Ana Duran, senior consultant at EA Technology.
LCNI Conference, Glasgow	October 2019	OpenLV was exhibited at the EA Technology stand. Relevant literature and an interactive map which showed which participants in the project were accessing substation data from which substation.

Event	Date	Description
Workshop, Bristol	November 2019	This event was organised for stakeholders participating in the project. The project team gave an update on the progress of project and an overview of the project findings. Interactive sessions were used to encourage stakeholders to share their experiences.
Presentation at Balancing Act Conference, London	November 2019	The project team including Sam Rossi Ashton from WPD and representatives from EA Technology gave a presentation on the project findings.
Regen Renewable Futures Event, Bath	November 2019	There were some small workshops on OpenLV at this event, including an introduction to OpenLV.
OpenLV webinar: Electricity Networks & Distributed Intelligence	17 November 2020	This was the first of two online webinars hosted by David Russell from EA Technology. Contributions to the webinar were made from David Russell (EATL), Sam Rossi Ashton (WPD), Arun Chiadambaram (NCC Group) and Chris Harrap (WPD). The webinar was immediately followed by a live question and answer session, where questions which had been submitted by the webinar attendees via the question box were answered by a panel. The panellists were Sam Rossi Ashton (WPD), Jon Berry (WPD), Chris Harrap (WPD), David Roberts (EATL), Tim Butler (EATL), David Russell (EATL) and Arun Chiadambaram (NCC Group). 147 people registered to attend the webinar, of which 88 attended the webinar. Amongst these attendees were representatives of GB DNOs Northern Powergrid, UK Power Networks and Scottish and Southern Energy. There were registrants from ENWL and SPEN but these did not attend the event. OpenLV webinar: Electricity Networks & Distributed Intelligence

Event	Date	Description
OpenLV webinar: Making LV network data openly available	26 November 2020	This was the second of two online webinars hosted by David Russell from EA Technology. Contributions to the webinar were made from David Russell (EATL), Sam Rossi Ashton (WPD), Bridget Newbury (CSE), Ana Duran (EATL), Ky Hoare (Regen) and Paul Morris (EATL). The webinar was again immediately followed by a live question and answer sessions where questions that had been asked by the attendees were asked to a panel. This time, the panellists were Sam Rossi Ashton (WPD), Paul Morris (EATL), Dave A Roberts (EATL), Ky Hoare (Regen), Bridget Newbery (CSE). 165 people registered to attend the event, 72 people attended the event, including representatives from GB DNOs UK Power Networks, Northern Powergrid and Scottish and Southern. There were registrants from ENWL and SPEN, but these did not attend the event. (1) OpenLV Webinar: Making LV network data openly available - YouTube
Energy Networks Innovation Conference	08-09 December 2020	Sam Rossi Ashton (WPD) presented an overview of the project at this 'virtual' conference on 9th December
Innovation Lab webinar	08 December 2020	Bridget Newbery (CSE) provided a presentation about the project at this community energy forum

Physical means of dissemination (such as Brochures, posters, postcards, websites, videos, animations) are listed in the table below. Each resource is listed with a description and a weblink to access the resource where a weblink is available.

Table 12: Project dissemination material

Resource	Date	Description	Weblink
Project Website	Launched in August 2017 and updated throughout the project	The OpenLV website went live on 31st August 2017. It was used to host project dissemination and knowledge sharing material, provide background information and contact details. It was updated regularly to reflect project progress and news.	Open LV | The groundbreaking project that's making local electricity data openly available.
OpenLV Explainer animation:	August 2017	Animation produced to explain in an accessible manner the OpenLV project, its motivations, goals and ambitions. Two videos for context were placed on the OpenLV website. One video was developed by WPD giving an overview of Smart Grids, and the other was developed by Ofgem, giving an overview of the energy network.	https://youtu.be/bogJNxOAUfI https://open-lv.net
Twitter	Ongoing throughout project	To disseminate and publicise events, news, learning, knowledge sharing material and other relevant happenings.	
Press Releases	Various point throughout the project	Press Release were created to publicise project milestones, so assist dissemination and to widen knowledge of the project.	
Newsletters	Throughout the project	Circulated by email through the project containing news and progress updates.	

Resource	Date	Description	Weblink
Short leaflets		Three short leaflets were produced early in the project. Each leaflet had a different purpose. They were produced to: • To background information on the project, • To provide information to community organisations interested in participating in the project, or • To provide information to businesses and academics interested in participating in the project.	https://www.westernpower.co.uk/innovation/projects/openlv
Postcards	November 2018	These were produced to outline the range of organisations and project ideas involved in the OpenLV. The postcards were designed specifically for use at conferences and workshops, and pointed the reader to more in-depth information on the project website	
Community Guidebook	September 2020	A guidebook to provide background information for community groups wanting to use network data in the future, based on the learning gathered from the groups that participated on the OpenLV project	https://www.westernpower.co.uk/innovation/projects/openlv

Resource	Date	Description	Weblink
OpenLV - How open access to data from electricity substations could help social responsibility video	October 2020	Short three-minute video featuring the views project partners and participants outlining how open access to data from electricity substations can be used to help social responsibility.	OpenLV - How open access to data from electricity substations could help social responsibility - YouTube
OpenLV – Enabling Net Zero Video-	October 2020	Short three-minute video featuring the views project partners and participants outlining the learning accrued from the OpenLV project and how this knowledge can be used to help with the transition to net zero.	(1) OpenLV - Enabling Net Zero Aspirations - YouTube
OpenLV – Businesses and Universities Video	October 2020	Short three-minute video featuring the views project partners and participants outlining learning accrued from the OpenLV project with regards to use cases of open data from both businesses and universities.	(1) OpenLV - Businesses and Universities - YouTube(1)
OpenLV – Network Benefits Video	October 2020	Short three-minute video featuring the views project partners and participants outlining the benefits released to the network by utilising adopting intelligent monitoring.	(1) OpenLV - Network Benefits - YouTube(1)
OpenLV – Community Involvement Video	October 2020	Short three-minute video featuring the views project partners and participants outlining the learning accrued from the OpenLV project regarding involving and facilitating community involvement in open substation data.	(1) OpenLV - Community Involvement - YouTube(1)

Resource	Date	Description	Weblink
OpenLV End of Project Brochure	November 2020	A brochure was produced at the closedown of the project, containing information about project methodology, what the project achieved, learning and case studies that the achievements of groups and organisations participating in the project. The project brochure is available to download from the project website as well as in a printed version.	https://www.westernpower.co.uk/innovation/projects/openlv
OpenLV Project Summary Animation	November 2020	A short, accessible animation was produced to summarise the achievements of the project. It was previewed during the first webinar and is now available online.	(1) OpenLV - Project Summary Animation | EA Technology - YouTube
OpenLV webinars: Questions & Answers	December 2020	As many questions from the attendees of the first and second webinars as possible were answered in the panel session. Written responses to all questions are available from the project website.	OpenLV-webinar-1-QAs_v1.pdf QAs-Webinar-2.pdf (openlv.net)
Data set	February 2021	The project data is available at the website.	www.westernpower.co.uk

11 Key Project learning documents

OpenLV project documents detailed below are available from the OpenLV project webpage on the WPD website, available at the following link, with specific links provided in Table 13 below: https://www.westernpower.co.uk/projects/openlv.

11.1 OpenLV Requirements Specification

This document provides a record of the requirements for the overall OpenLV solution that were required to support Project trials for the three Methods outlined in the Full Submission Proforma (OpenLV Bid document).

11.2 Loadsense Operational Logic (May 2018)

The Loadsense application is envisaged to ultimately enable the LV-CAP® platform to 'decide' how to best support the LV network through the implementation of a range of Smart Grid solutions.

In a Business-As-Usual (BAU) scenario, this may be using one or multiple solutions connected to the networks in question.

Within the OpenLV Project, the Loadsense application to be developed was intended to be the 'first step' towards this solution. Therefore, the logic that was developed as part of the OpenLV Project was intended to be relatively simple, considering only the status of two connected substations and the impact of network meshing on those assets.

The purpose of this document is to detail the proposed logic to be embedded within the Loadsense application and summarise the rationale behind it.

11.3 Method Statement (July 2018)

The Method Statement was a live document, updated over the course of the OpenLV Project as each stage of equipment deployment commenced. The final document details the individual components installed on the network, including those relating to the automated LV switching, the commissioning process, and the decommissioning process for all equipment.

Annexes to the method statement provided additional detail on the installed equipment where required. They also detailed the precise steps needed to safely commission and decommission the network automation devices.

The Method Statement document along with the documentation described in sections 11.4.1, 11.4.2, 11.5 and 11.6 are available for download in a zip folder from the OpenLV page of the WPD website, by following the link "SDRC 3 Appendices".

11.4 Acceptance Testing

11.4.1 Factory Acceptance Test (FAT) Documentation (September 2017)

All FATs were undertaken at EA Technology's Head Office in Capenhurst, utilising a specialised test rig that allowed for full energisation of the trial equipment and introduction of fault currents to the LV switching units as part of the testing process.

Stage 1

The Stage 1 FATs were undertaken to demonstrate the acceptability of the overall solution to meet the defined requirements, with the exception of elements relating to the automated switching deployed under Method 1 Phase 2.

Specifically, the Stage 1 FATs verified the acceptability of the system hardware, ability to run the LV-CAP® software and application containers, communications, monitoring and remote access.

Stage 2

The Stage 2 FATs were undertaken to test the system capabilities related to the automated switching element of the trials. Specifically, Stage 2 tests were focussed on the capability to predict network load and transformer temperature, and correctly enact LV switching in response.

Post-FAT Loadsense Analysis

Following the Stage 2 FATs, a detailed report was produced to explain the process of data flow through the system, including the calculations performed within the platform and how these translated into the operation of LV network switching.

11.4.2 Site Acceptance Test (SAT) Documentation (July 2018)

The SATs were undertaken at the first pair of installations to verify the complete system was operating as expected following relocation from EA Technology offices to a live deployment.

The tests were performed to verify the successful transfer of data 'end-to-end', from the sensors on-site, through the necessary processing and being made available at both the iHost 'Command and Control' server and Lucy Electric's 'Public Data' server.

Successful verification of this demonstrated the complete system was fully functional.

11.5 LV-CAP® Public API (October 2017)

This document details the Application Programming Interface (API) for developers intending to write Applications to run on LV-CAP®. LV-CAP® uses Docker to overcome dependency problems for third party developers and helps to maintain and manage containers. It uses a MQTT messaging system for the communication of running containers and has a data storage functionality to persist data. This document has details on how a third-party Application can be set-up, run and interact with the core services on the platform.

11.6 Developing with the LV-CAP® Virtual Machine (February 2018)

This document details how to utilise a Virtual Machine image supplied by EA Technology to begin developing applications for the LV-CAP® platform. The Virtual Machine provides a representative environment on which to test and debug applications, prior to attempting deployment to the live system.

11.7 Learning Outcomes

11.7.1 SDRC 1 (October 2017)

This report provided details on the design of the overall OpenLV solution, with specific information included on:

- the system architecture;
- requirements specification for the intelligent substation hardware;
- an assessment of the LV-CAP® platform to determine whether further changes are required to meet the requirements of the OpenLV project;
- detail the approach for testing the overall solution ahead of wide scale deployment;
- Factory Acceptance Testing (FAT) and Site Acceptance Testing (SAT) documentation; and
- FAT results.

11.7.2 SDRC 2.1 (December 2017)

In this report we present the community engagement plan along with the results from testing the market to assess the level of interest from communities and third parties in participating in trials as part of the OpenLV project. The key findings from the work completed to date are broken down under the following headings:

- **Community Engagement –Testing the Market:** Provides an overview of the community engagement that has been completed to date and the market potential for community groups to utilise LV network data and/or develop apps to be trialled as part of the Project;
- **Community Engagement –Market Assessment Review:** Outlines the key findings from assessing the ideas that have been put forward by community groups to date;
- **Community Engagement Plan:** Provides an overview of the approach that will be taken to engage with community groups; and
- **OpenLV Extensibility –Testing the Market:** Provides an overview of the engagement work that has been completed to date to assess the market potential for the wider industry to utilise LV network data and/or develop apps to be trialled as part of the Project.

11.7.3 SDRC 2.2 (May 2018)

In this report we present the results from:

1. Identifying the target networks for the capacity uplift trials (Method 1);
2. An update to the results previously published regarding testing the market to assess the level of interest from communities and third parties in participating in trials as part of the OpenLV project (Methods 2 and 3); and
3. The detailed trial design for the capacity uplift, community and OpenLV Extensibility trials (all Methods).

The key findings from the work completed to date are broken down under the following headings:

- **Community Engagement Trials – Testing the Market:** Provides an overview of the community engagement that has been completed to date and the market potential for community groups to utilise LV network data and/or develop software applications to be trialled as part of the Project;
- **OpenLV Extensibility Trials – Testing the Market:** Provides an overview of the engagement work that has been completed to date to assess the market potential for the wider industry to utilise LV network data and/or develop software applications to be trialled as part of the Project; and
- **Detailed Trial Design:** Provides an overview of the detailed trial design for each of the 3 Methods outlined in the Full Bid Submission: 1) Capacity uplift, 2) Community and 3) OpenLV Extensibility. This also includes the work completed to identify the target networks for the capacity uplift trials.

11.7.4 SDRC 3 (January 2019)

In this report we present the suite of documentation created as part of the OpenLV Project's 'Enabling Works', covering:

- System specifications;
- Site identification details;
- Installation documentation;
- Training information;
- Pre- and post-installation testing;
- Guidance for third parties developing applications for the LV-CAP® platform;
- Learning points identified during the Enabling Works phase.

11.7.5 SDRC 4

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

SDRC 4.1 (January 2020)

- Sharing the level of capacity uplift achieved through Method 1;
- Sharing which LV networks can benefit from OpenLV and why;
- Establishing the level of capacity uplift that could be achieved in WPDs licence area;

SDRC 4.2 (January 2020)

- Sharing how DNOs can engage with communities who want to become part of a smarter grid to exploit the open and flexible nature of OpenLV;
- Sharing how community engagement supports the uptake of LCTs (Low Carbon Technologies);
- Outlining the routes communities can take to raise funding;
- Sharing the network benefits provided by community engagement;

SDRC 4.3 (January 2020)

- Sharing how DNOs can engage with academics, companies (including non-energy companies) to exploit the open and flexible nature of OpenLV;
- Sharing the network benefits provided through Method 3;
- Sharing how the Method facilitates non-traditional business models

11.7.6 SDRC 5 (April 2020)

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.

11.8 Cyber-Security Recommendations

Implementation of an OpenLV style solution, in the form of wider deployment of distributed intelligence devices, is expected to bring many benefits to a cross spectrum of stakeholders within the energy sector. As such the solution should aim to monitor substation performance and electricity demand across regions within the United Kingdom, whilst integrating with third party products and applications. The security of the platform and the data generated, are of paramount value and importance.

The objective from this assessment is 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 distributed intelligence platforms. In addition, it also provides the security controls that are needed to ensure secure development and connectivity from DNOs and other third parties.

The assessment has considered four Use Cases of distributed intelligence platform deployment, namely LV Monitoring, Limited Control, Enhanced LV Monitoring, and Full Capacity. Each Use Case builds on the previous in terms of connectivity, output and benefits.

11.9 Community Group Guidebook (September 2020)

The purpose of the guidebook is to summarise the learnings from the trials into a format that can be used by new communities or organisation who may wish to use a solution similar to OpenLV in the future.

The guidebook is written as a document for community organisations and non-expert audiences to show how having access to local electricity data can be used to support local energy projects, encourage behavioural change or help communities use more renewable electricity. Specifically, the guidebook explains how community organisations might use the substation data for three main use cases:

- to tell a story about their energy usage;
- to plan for the deployment of more low carbon technologies; and
- whether communities could earn additional revenue from the provision of network services enabled by substation data.

The guidebook includes community case studies from the trial, as well as providing an overview of the use of the website application that processed and displayed OpenLV information. This application was developed for the trials by project supplier Centre for Sustainable Energy (CSE) to support the communities who participated in the trials.

11.10 OpenLV Final Project Brochure (November 2020)

The purpose of this brochure is to provide an overview of the key learning points generated by the OpenLV project, in a condensed, relatively simple to understand document. It is written in such a way that it allows people not from a technical background to understand the key learning points derived from the project. The brochure focuses particularly on the benefits provided by the technology to different stakeholders.

The brochure covers the following areas:

- Installation;
- Benefits of distributed intelligence;
- How the technology benefits community groups;
- How the technology benefits businesses;
- How the technology benefits academia;
- How the technology benefits the Net Zero transition; and
- How the technology benefits social responsibility.

The brochure finishes with a discussion of the project legacy, focusing on the development on LV monitoring and its future role in the electricity networks. Its conclusion focuses on the value LV network data provides community groups.

11.11 OpenLV Project Videos

Short videos were produced at the end of the project, featuring participants in the different Methods used in the OpenLV project, discussing the learning outcomes from the project.

11.11.1 OpenLV Explainer Video (January 2021)

This video outlines the motivations for the OpenLV project, discussing the need for open data about local LV networks. It also discusses potential benefits from the project, for communities, network operators and businesses.

11.11.2 OpenLV Network Benefits Video (January 2021)

The purpose of this video it to outlines the benefits of the OpenLV platform to the network. It discusses the possibility of automated network switching using LV-CAP® and ALVIN® Reclose devices. It also discusses interface external products with the LV-CAP® platform. It discusses the potential of the platform to enable the pathway towards net-zero and generate income opportunities for businesses using the platform.

11.11.3 OpenLV Community Involvement Video (January 2021)

The purpose of this video is to discuss the how communities interacted with the OpenLV platform. It discusses the opportunities access to LV network data provide to community groups, for example for monitoring electricity demand and generation. Representatives of different community groups involved in the project discuss how their community groups have used the OpenLV network data, and how they used this data. Representatives of academic partners discuss how they have used OpenLV data in their research.

11.11.4 OpenLV Social Responsibility Video (January 2021)

The purpose of this video is to discuss the implications of the OpenLV platform on social responsibility, focusing on the potential for how open access to network data has the potential to help fuel poor and vulnerable communities benefit from the smart grid.

11.11.5 OpenLV Business and Academia Video (January 2021)

The purpose of this video is to discuss the involvement of businesses and academia in the OpenLV project. It discusses some of the use cases of the open data by businesses and academic partners. Participants from different businesses discuss how they used the open data to develop apps for the platform.

11.11.6 OpenLV Net Zero Video (January 2021)

The purpose of this video was to discuss the role the OpenLV project plays in the pathway towards net-zero. It discusses how open data provided by the project can be used by a range of participants, using the common OpenLV platform. It discusses how the OpenLV network can be used to manage EV charging at a local level, avoiding the need for costly network reinforcement. It also discusses how the platform can help maximise the potential of LCTs such as PV farms, and how battery storage can be integrated to best utilise this energy. The OpenLV network has shown that LV network monitoring is an essential enabler for enabling net-zero.

11.11.7 OpenLV Project Summary Video (November 2020)

This animation presents a short summary of the motivations and need of the project. It outlines the need for LV network data and how OpenLV achieved this. It outlines use cases of the LV network data, highlighting the benefits this provides. It discusses the project legacy, for communities, for network operators, for businesses and academia and for the pathway to net-zero. It discusses the future opportunities provided by the platform.

Table 13: Project Documentation

Title & Weblink	Publication Date	Content
Bid Documentation		
NIC Bid	Submitted in Summer 2016	The formal bid submission to the Electricity NIC, requesting funding for the OpenLV Project.
Formal Project Direction	December 16th, 2016	This Project Direction contains the terms to be followed by WPD WMID as a condition of the Project receiving funding through the Electricity NIC. It must comply with these terms, which can be found in the Schedule to this Project Direction.
Project Progress Reports		
Project Progress Report: Dec 16 – May 17	June 6th, 2017	The biannual Project Progress report provided by the Project Team to Ofgem.
Project Progress Report: Jun 17 – Nov 17	December 8th, 2017	The biannual Project Progress report provided by the Project Team to Ofgem.
Project Progress Report: Dec 17 – May 18	June 13th, 2018	The biannual Project Progress report provided by the Project Team to Ofgem.
Project Progress Report: Jun 18 – Nov 18	December 11th, 2018	The biannual Project Progress report provided by the Project Team to Ofgem.
Project Progress Report: Dec 18 – May 19	June 10th, 2019	The biannual Project Progress report provided by the Project Team to Ofgem.
Project Progress Report: Jun 19 – Nov 19	December 5th, 2019	The biannual Project Progress report provided by the Project Team to Ofgem.
SDRCs		
SDRC1: Detailed Design of the Overall OpenLV Solution	October 17th, 2017	This report provided details on the design of the overall OpenLV solution, with specific information included on: • the system architecture; • requirements specification for the intelligent substation hardware; • an assessment of the LV-CAP® platform to determine whether further changes are required to meet the requirements of the OpenLV project; • detail the approach for testing the overall solution ahead of wide scale deployment; • Factory Acceptance Testing (FAT) and Site Acceptance Testing (SAT) documentation; and • FAT results.

Title & Weblink	Publication Date	Content
SDRC 2.1: Community Engagement Plan & Testing the Market	December 8th, 2017	In this report we present the community engagement plan along with the results from testing the market to assess the level of interest from communities and third parties in participating in trials as part of the OpenLV project. The key findings from the work completed to date are broken down under the following headings: • **Community Engagement –Testing the Market:** Provides an overview of the community engagement that has been completed to date and the market potential for community groups to utilise LV network data and/or develop apps to be trialled as part of the Project; • **Community Engagement –Market Assessment Review:** Outlines the key findings from assessing the ideas that have been put forward by community groups to date; • **Community Engagement Plan:** Provides an overview of the approach that will be taken to engage with community groups; and • **OpenLV Extensibility –Testing the Market:** Provides an overview of the engagement work that has been completed to date to assess the market potential for the wider industry to utilise LV network data and/or develop apps to be trialled as part of the Project.
SDRC 2.2 – Target Networks, Market Potential & Trial Design	May 25th, 2018	In this report we present the results from: 1. Identifying the target networks for the capacity uplift trials (Method 1); 2. An update to the results previously published regarding testing the market to assess the level of interest from communities and third parties in participating in trials as part of the OpenLV project (Methods 2 and 3); and 3. The detailed trial design for the capacity uplift, community and OpenLV Extensibility trials (all Methods).[TS1][TB2] The key findings from the work completed to date are broken down under the following headings: • **Community Engagement Trials – Testing the Market:** Provides an overview of the community engagement that has been completed to date and the market potential for community groups to utilise LV network data and/or develop software applications to be trialled as part of the Project; • **OpenLV Extensibility Trials – Testing the Market:** Provides an overview of the engagement work that has been completed to date to assess the market potential for the wider industry to utilise LV network data and/or develop software applications to be trialled as part of the Project; and • **Detailed Trial Design:** Provides an overview of the detailed trial design for each of the 3 Methods outlined in the Full Bid Submission: 1) Capacity uplift, 2) Community and 3) OpenLV Extensibility. This also includes the work completed to identify the target networks for the capacity uplift trials.

Title & Weblink	Publication Date	Content
SDRC 2.2 - Annex 1: Loadsense Operational Logic	May 25th, 2018	Within the OpenLV Project, Loadsense is designed to utilise information within the LV-CAP® platform, (e.g. monitored data or processed outputs) to determine whether to implement network meshing of two adjacent substations, based on a preconfigured set of logical rules. The purpose of this document is to detail the proposed logic to be embedded within the Loadsense application and summarise the rationale behind it.
SDRC 2.2 - Annex 2: Community Engagement Trial Participant MoU Template	May 25th, 2018	Memorandum of Understanding Template for participation in the community trials.
SDRC 2.2 – Annex 3: Business & Academia Trial Participant MoU Template	May 25th, 2018	Memorandum of Understanding Template for participation in the 'Third Party Company trials.
SDRC 3 – Specific Learning from Deployment and App Development	January 31st, 2019	In this report we present the suite of documentation created as part of the OpenLV Project's 'Enabling Works', covering: • System specifications; • Site identification details; • Installation documentation; • Training information; • Pre- and post-installation testing; • Guidance for third parties developing applications for the LV-CAP® platform; • Learning points identified during the Enabling Works phase.

Title & Weblink	Publication Date	Content
SDRC3 Appendices	January 31st, 2019	Appendix 1 - Site Selection Appendix 2 - Site Survey Guidance Appendix 3 - Site Survey Checklist Appendix 4 - Locations of Site Surveys Appendix 5 - Fault Protection Studies (Method 1 – Phase 2 locations) Appendix 6 - Method Statement Appendix 7 - Alvin Reclose™ Commissioning Documentation Appendix 8 - Fault Restoration Process Appendix 9 - Alvin Installation Training Presentation Appendix 10 - Requirements Specification Appendix 11 - Factory Acceptance Tests (FATs) Appendix 12 - Post-FAT Stage 2 Loadsense Analysis Appendix 13 - Site Acceptance Tests (SATs) Appendix 14 - OpenLV Business and Academia Trials – Guidance for Applicants Appendix 15 - OpenLV Third-party Application Information Form Appendix 16 - OpenLV Third-party Supporting Test Document Appendix 17 - OpenLV Third-party Test Results Document Appendix 18 - Feedback on Standard Guidelines for Application Development Appendix 19 - LV-CAP™ Node-RED Application Developer Guide Appendix 20 - Developing with the LV-CAP™ Virtual Machine Appendix 21 - LV Common Application Platform – Public API Appendix 22 - OpenLV Measurement Points Appendix 23 - GridKey OpenLV Data Centre System Overview
SDRC 4 – Learning Generated from the Network Capacity Uplift Project Trials	January 31st, 2020	In this SDRC report we present the results and learning surrounding the following objectives: • Sharing the level of capacity uplift achieved through Method 1; • Sharing which LV networks can benefit from OpenLV and why; • Establishing the level of capacity uplift that could be achieved in WPDs licence area.

Title & Weblink	Publication Date	Content
SDRC 4 – Learning Generated from the Community Engagement Project Trials	January 31st, 2020	In this SDRC report we present the results and learning surrounding the following objectives: • Sharing how DNOs can engage with communities who want to become part of a smarter grid to exploit the open and flexible nature of OpenLV; • Sharing how community engagement supports the uptake of LCTs (Low Carbon Technologies); • Outlining the routes communities can take to raise funding; • Sharing the network benefits provided by community engagement.
SDRC 4 – Learning Generated from the OpenLV Extensibility Project Trials	January 31st, 2020	In this SDRC report we present the results and learning surrounding the following objectives: • Sharing how DNOs can engage with academics, companies (including non-energy companies) to exploit the open and flexible nature of OpenLV; • Sharing the network benefits provided through Method 3; • Sharing how the Method facilitates non-traditional business models
SDRC 4 Appendices	January 31st, 2020	Appendix 1 - Distribution of LV Network Templates in WPD Licence Areas Appendix 2 - OpenLV Project Locations – LV network Template Types Appendix 3 - Simple Predictor for Transformer Hot Spot Temperature Appendix 4 - Analysis of Calculated Hot Spot Temperatures Appendix 5 - Variation of Calculated Hot Spot Temperature with Surrounding Temperatures Appendix 6 - Headroom Benefit of LV Switching Appendix 7 - Transform Model

Title & Weblink	Publication Date	Content
SDRC 5 – Knowledge Capture, Dissemination and Transferring the OpenLV Solution to Business as Usual.	April 27th, 2020	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.

Title & Weblink	Publication Date	Content
SDRC 5 Appendices	April 27th, 2020	Appendix 1 - Method Statement Appendix 1.1 - GridKey MCU520 LV Monitoring System Guide Appendix 1.2 - Installation Schematic Drawings Appendix 1.3 - Site Acceptance Testing & Commissioning Appendix 1.4 - ALVIN Reclose Installation & Commissioning Appendix 1.5 - Replacement of LV Enclosure Door Appendix 1.6 - ALVIN Reclose Decommissioning Appendix 2 - ALVIN Reclose Overview Presentation Appendix 3 - ALVIN Reclose Quick Installation and Removal Guide Appendix 4 - Restoration Notices For OpenLV ALVIN Reclose Deployment Appendix 5 - User Guide for Community Groups Appendix 6 - OpenLV Measurement Points Appendix 7 - LV Common Application Platform Public API Appendix 8 - Developing for LV-CAP using the Virtual Machine Appendix 9 - Community Guide Book Appendix 10 - OpenLV Security Assurance Letter Appendix 11 - OpenLV Security Assurance Review Appendix 14 - Technical Security Standard
Other		
End of Project Summary Brochure		The purpose of this brochure is to provide an overview of the key learning points generated by the OpenLV project, in a condensed, relatively simple to understand document. It is written in such a way that it allows people not from a technical background to understand the key learning points derived from the project. The brochure focuses particularly on the benefits provided by the technology to different stakeholders. The brochure covers the following areas: • Installation; • Benefits of distributed intelligence; • How the technology benefits community groups; • How the technology benefits businesses; • How the technology benefits academia; • How the technology benefits the Net Zero transition; and • How the technology benefits social responsibility. The brochure finishes with a discussion of the project legacy, focusing on the development on LV monitoring and its future role in the electricity networks. Its conclusion focuses on the value LV network data provides community groups.

Title & Weblink	Publication Date	Content
Community Guidebook		The purpose of the guidebook is to summarise the learnings from the trials into a format that can be used by new communities or organisation who may wish to use a solution similar to OpenLV in the future. The guidebook is written as a document for community organisations and non-expert audiences to show how having access to local electricity data can be used to support local energy projects, encourage behavioural change or help communities use more renewable electricity. Specifically, the guidebook explains how community organisations might use the substation data for three main use cases: • to tell a story about their energy usage; • to plan for the deployment of more low carbon technologies; and • whether communities could earn additional revenue from the provision of network services enabled by substation data. The guidebook includes community case studies from the trial, as well as providing an overview of the use of the website application that processed and displayed OpenLV information. This application was developed for the trials by project supplier Centre for Sustainable Energy (CSE) to support the communities who participated in the trials.

12 Data access details

As a consequence of Western Power Distribution's industry-leading work on Open Data, the OpenLV dataset, which broadly contains 18 months of monitoring data from 80 secondary substations, will be available to our stakeholders without the requirement for a data sharing policy being in place. Instead the dataset will be downloadable from WPD's website. Term of use can be found in WPD's Open Data Licence.

13 Contact details

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Appendix 1. Community Groups

- Bath and West Community Energy are monitoring integrated low carbon technologies installed by the group in their area, combining it with substation data to determine substation impact, with a view to future selling aggregated flexibility services based on assets owned within a community.
- Tamar Energy Community used the data in 'Eco Clubs' to educate the community on energy efficiency measures and Rooftops Housing Association used the data to drive cost-efficient energy use initiatives.
- Marshfield Energy Group are developing a village-wide energy strategy based on analysis of OpenLV data that would allow them to pinpoint where, in their village, there is the potential to connect further renewable generation or EV chargers.
- Rooftops Housing Association suggested that having this type of data would help them identify where to site renewable schemes in the future.

Appendix 2. TRL Assessment

At the outset of this project, the TRL of the LV-CAP® platform was TRL 4. A previous project funded by InnovateUK had successfully progressed the technology from TRL 1 to TRL 4. By the end of this previous trial, the platform had performed successfully in lab-based testing. In regard to the TRL of the platform, the aim of this project was to progress the TRL of the technology from TRL 4 to TRL 8. TRL 8 is achieved when the technology has been demonstrated to work in its operational field. In the case of LV-CAP® this required the platform to be demonstrated working live on LV substations in real world trials.

The project demonstrated that the LV-CAP® platform could be used to autonomously control the network, when combined with technology such as the ALVIN®. Additionally, it was demonstrated that the technology could be used as a platform whether businesses, academics and other organisations could successfully develop applications, eliminating problems associated with vendor tie in. It is becoming increasingly clear that LV monitoring will become an essential element of the transition to net-zero, which has become mandated in law since the outset of this project. Solutions such as LV-CAP® can reasonably be expected to become a much more prevalent feature of GB's electricity networks.

After the first stage of roll-out of the OpenLV platform, EA Technology were convinced by the technology of the platform and thus decided to invest in monitoring technology. Further development outside the project scope by EA Technology, funded exclusively by EA Technology and not project funding, lead to the development of its VisNet® product. This product combines the necessary hardware and software, utilising the LV-CAP® platform for LV Network monitoring. Orders have already been delivered to numerous network operators including SPEN, NPg, SSEN and WPD. This provides evidence that the TRL of the platform to a level where it is beginning to be deployed at scale across GB's LV networks.

While it's not BAU yet to deploy a distributed intelligence platform at LV substations, it is certainly rapidly becoming more commonplace. DNOs are continuing to invest in LV monitoring products such as VisNet®, and are increasingly becoming aware of the need to expand their LV monitoring offering. This indicates that the TRL of the platform has progressed since the start of the OpenLV project and now is at TRL 8 and rapidly progressing towards becoming part of BAU operations.