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OPENLV

OPENING UP THE SMART GRID

SDRC 4

Learning Generated from the OpenLV Project trials by all Methods.

ea technology

RIIO NIC NETWORK INNOVATION COMPETITION

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Contents

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Glossary

Term	Definition
API	Application Programming Interface
BWCE	Bath and West Community Energy
CSE	Centre for Sustainable Energy
DNO	Distribution Network Operator
DSO	Distribution System Operator
DTR	Dynamic Thermal Rating
ECOE	Exeter Community Energy
FAT	Factory Acceptance Testing
LCT	Low Carbon Technology
LV	Low Voltage
LV-CAP™	Low Voltage Common Application Platform
NIC	Network Innovation Competition
NOP	Normally Open Point
OSCE	Owen Square Community Energy
PV	Photovoltaics
RTTR	Real Time Thermal Rating
SAVE	Solent Achieving Value from Energy Efficiency [project]
SDRC	Successful Delivery Reward Criterion
TEC	Tamar Energy Community
Tx	Transformer
UPS	Uninterruptible Power Supply
WPD	Western Power Distribution
YCE	Yealm Community Energy

Executive Summary

Background

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

The OpenLV platform

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

Uniquely, the OpenLV platform provides a substation monitoring and operating system (EA Technology's LV-CAP™) that has been designed to be hardware agnostic and, in a Method analogous to a smartphone, to be able to host multiple apps. The trial system allows hosted apps to share monitored data and each other's outputs. LV-CAP™ was designed so that calculations and decisions can be made locally, speeding up reaction times and reducing the amount of data that needs to be sent to central aggregation servers. It provides a secure environment for the maintenance and management of apps, while continuing to ensure the security of the electricity network.

The OpenLV trial

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

The OpenLV Project is seeking to prove the technology and assess how it enables benefits to the DNO (Distribution Network Operator), community groups, business's and academia. The trial was organised to:

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

Further information on the overall project can be found in the Full Bid Submission, which is available on the OpenLV Project website [1].

Report Purpose

In this report we present the results and learning from Method 1, Method 2 and Method 3 of the trial. Subsequent reports will analyse the opportunities and benefits of implementing the platform into business as usual.

Key Findings

Within this report we outline the following key findings from Method 3 that investigated the feasibility and use cases of business's and academia sharing the OpenLV data and also using the open platform functionality to build their own apps that could reside in substations. This report presents the learning points described in the following bullet points.

- There was a great deal of interest in the OpenLV Project from business and academia with the number of trial applicants exceeding the number of available platforms. This was especially notable considering that trial participants were responsible for funding their own engagement on this project.
- Academic participants suggested that access to shared data from across a wide sample of substations overcame perceived data barriers to independent network research.
- This part of the trial demonstrated that commercial business's saw the prospect of open data and open data platforms to be a strategic opportunity. Many existing DNO supply chain members indicated that open data platforms enable them to offer even more value to DNO's.
- By virtue of the trial participants being willing to develop apps that reside on 3rd party hardware it was perceived that this part of this trial demonstrated that the OpenLV platform enables industry to overcome vendor tie in that has been encountered on monitoring hardware traditionally encountered in substations.
  This has been further supported by the OpenLV Project developing a set of cyber security draft standards that protects the network owner and also the app providers. These draft standards will be made publicly available to the industry as a OpenLV deliverable.
  This part of the trial also demonstrated how apps from different vendors could work together on the platform to create efficient network outcomes without breaching security protocols.
- A number of the Method 3 participants put significant effort into developing apps that supported the transition to electric vehicles. These participants demonstrated how the platform could support a diversity of technological approaches to this problem.
- Specific feedback from Method 3 participants includes the following points:
  - There was a perception that the OpenLV data platform provided suppliers with an easier route to market from analytics packages because it avoids the distraction of having to manage hardware and communications.
  - Whilst there was a willingness to invest their time in this trial, for the market to develop efficiently, suppliers sought signposting from DNO's about their intentions for open data platforms and procurement of any associated apps.

1 Introduction

1.1 Project Background

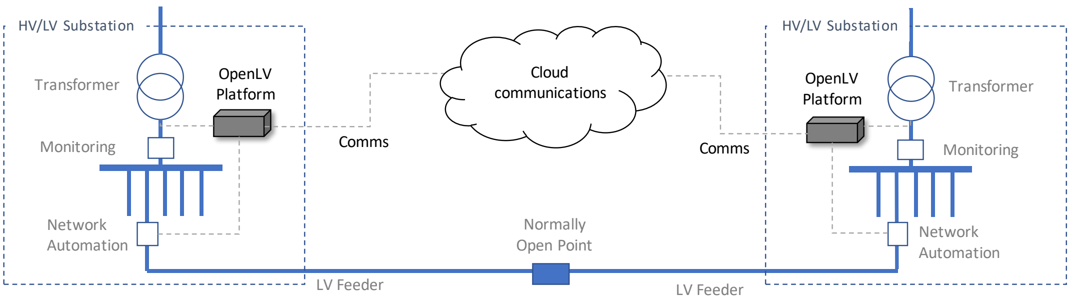
Great Britain has about 1,000,000 Low Voltage (LV) feeders; these have largely been designed and operated on a fit-and-forget basis for the last 100 years, but things are set to change. LV networks are expected to see radical change as we, as customers, alter our behaviour and requirements, stemming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

The technology to be trialled as part of the OpenLV Project provides a new, open and flexible solution that will not only provide the DNO, community groups and the wider industry with data from the LV network, but will also enable these groups to develop and deploy apps within LV substations through a common hardware platform. The OpenLV Project is seeking to prove the technology and assess how the provision of LV network data and the ability to develop and deploy apps can provide benefits to the DNO, community groups and the wider industry. These Methods used to achieve this objective are outlined below.

1.1.1 Method 1: Network Capacity Uplift

Figure 1 provides an overview of the systems architecture that will be deployed to complete Project trials for Method 1 – Network Capacity Uplift.

As part of the Project trials for Method 1, apps will be used to increase the capacity of existing LV assets through the application and implementation of Dynamic Thermal Rating of the LV Transformer and through meshing LV feeder(s) on the LV network.



What

- Check network capacity against thermal rating of transformer; when breached, close two radial circuits to mesh the LV network
- Deploy two proven techniques
  – 'Dynamic Thermal Ratings App' and
  – 'Network Meshing App'.
- Together with a 'Network Control App' to operate/configure the network

How

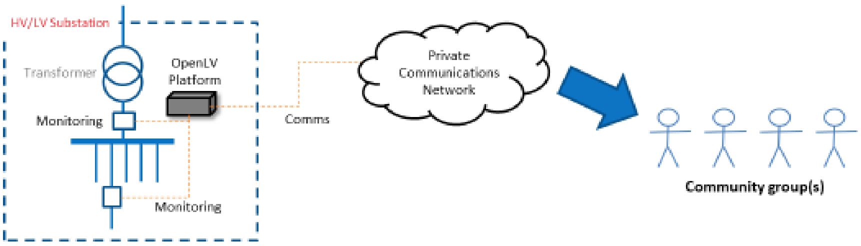
- Assess WPD's network to identify candidate circuits
- Deploy LV-CAP™ to 60 substations
- Monitor how the solution would operate over several months
- Install actuators on 5 circuits (2 ends each) to prove end-to-end control
- Assess and report on performance

Figure 1: Method 1 – Network Capacity Uplift

1.1.2 Method 2: Community Engagement

Figure 2 provides an overview of the systems architecture that will be deployed to complete Project trials for Method 2 – Community Engagement.

As part of the Project trials for Method 2, Community Groups will make use of the LV network data provided by the OpenLV Platform to provide benefits to Communities.



What
- To work with key community groups to understand whether Apps can be developed and installed on the platform
- Identify funding sources that customers / communities can use to develop specific Apps

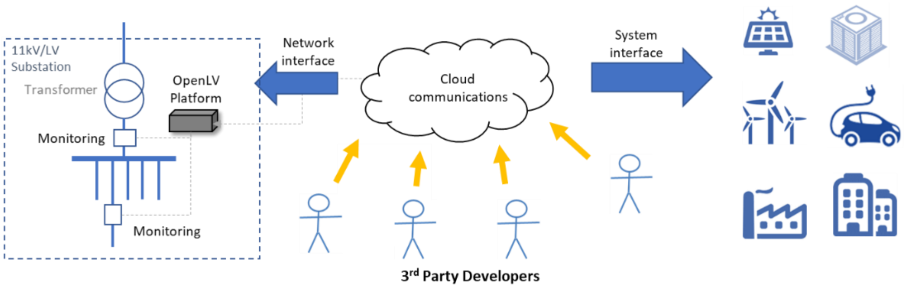
How
- Community engagement to promote availability of platform / LV network data
- Make available 10 LV-CAP™ units for deployment
- Provide communities access to relevant data

Figure 2: Method 2 – Community Engagement

1.1.3 Method 3: OpenLV Extensibility

Figure 3 provides an overview of the systems architecture that will be deployed to complete Project trials for Method 3 – OpenLV Extensibility.

As part of the Project trials for Method 3, the Wider Industry will either, make use of the LV network data provided by the OpenLV Platform, and/or develop and deploy 'apps' to provide benefits to: DSOs (Distribution System Operator), Platform Providers, 3rd Party Developers and Customers.



What
- To enable companies to develop innovative algorithms and applications for either the DNO, or it's customers

How
- Publicise the opportunity to 3rd parties
- Make available standard App 'container' for third parties to use for their development
- Make available 10 LV-CAP™ devices for substation deployment
- Funding to develop specific Apps to be raised outside of the project budget, e.g. private sector

Figure 3: Method 3 – OpenLV Extensibility

1.2 Document Purpose

The OpenLV Project Successful Delivery Reward Criteria 4(SDRC) report 4 was structured to meet the evidence requirements outlined in the OpenLV Project Direction [2].

The primary SDRC 4 report was issued to Ofgem as a single document, detailing the evidence relating to Methods 1, 2 and 3 of the OpenLV project.

1. Sharing the level of capacity uplift achieved through Method 1
2. Sharing which LV networks can benefit from OpenLV and why
3. Establishing the level of capacity uplift that could be achieved in WPDs licence area
4. 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
5. Sharing how community engagement supports the uptake of LCTs (Low Carbon Technologies)
6. Outlining the routes communities can take to raise funding
7. Sharing the network benefits provided by community engagement
8. Sharing how DNOs can engage with academics, companies (including non-energy companies) to exploit the open and flexible nature of OpenLV
9. Sharing the network benefits provided through Method 3
10. Sharing how the Method facilitates non-traditional business models

In this document we present the results and learning relating to Method 3, with matching documents available for Methods 1 and 2.

1.3 Report Structure

The structure of this report is as follows:

- **Section 2: Method 3: Business and Academia –** assesses whether making network more widely data available promotes engagement with academia and stakeholders, facilitates alternative business models, network insights or services
- **Section 3: Conclusions -** outlines how the project has met the Successful Delivery Reward Criteria as set out in Section 1.2

2 Method 3 – Business and Academia

2.1 Trial objectives and Methodology.

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 SDRC's 1 to 3, this document considers the evidence and output from Stage 5.

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 0 and 0 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.

2.2 Did commercial organisations express interest in using open data?

The commercial organisations who participated in the OpenLV trial are summarised in Table 1.

Table 1: Commercial participant Summary

Company	Use case	Data link[1]
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

As shown in Table 1, 10 commercial organisations took advantage of the network data in some form or another and bore the cost of incorporating[2] the LV-CAP platform into their research and development.

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.

Within the next subheadings, we explore the factors that motivated participants to join the trial and fund their effort and their learnings.

[1] 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.

[2] 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.

2.2.1 Depsys

Participant Profile

Depsys is a technology company specialising in devices that optimise the performance of low voltage electricity networks. Depsys already have a number of asset management and network management applications which act upon data gathered by Depsys hardware.

Participant Trial

This trial allowed Depsys to investigate whether they enable their existing apps to act upon data that was measured outside of Depsys systems.

The business reason for Depsys to participate in this trial was to investigate whether the OpenLV platform could open a new route to market for some of their existing products.

DEPSYS Learning

Depsys's trial demonstrated that the OpenLV data stream could successfully be applied to their GridEye platform. This was a small-scale trial which did use shared data and did not progress to software development.

The particular app that the GridEye platform offered in this case was a transformer thermal rating app that was similar in functionality to the University of Manchester thermal rating app that was included on each of the OpenLV trial platforms.

Depsys's trial indicates that there is commercial interest from more than one party to develop similar apps that could be used by a DNO. This is finding significant as it implies that there is the potential for commercial competition to supply software though this medium. The potential for commercial competition is likely to prove beneficial for the DNO, and ultimately the end consumer, as competition will place pressure on supplier costs and also quality offering.

As the OpenLV trial was a technical trial, no investigations were undertaken to discover the impact of competition within the app supply chain.

2.2.2 Egnida Group

Participant Profile

Egnida Group is a specialist energy consultancy and delivery organisation. Egnida has specialist skills in energy, innovative smart systems and mobility. Egnida is able to develop new solutions to problems through their consultancy arm and then physically implement them from within their delivery capability.

Participant Trial

Egnida were responsible for installing low carbon devices within a social housing project as part of a separate effort. Egnida invested its own time and resources into reviewing how having access to real-time LV network data could change the value proposition for LCT connected in social housing.

Rather than building an app, Egnida utilised the OpenLV API to help optimise control strategies for the LCT and to understand the effect of different control decisions. Egnida funded this research themselves by directing a member of in-house staff to concentrate on this research for a significant portion of the 12-month period. Egnida were able to design, install, monitor and control suitable smart energy solutions in 6 properties in the vicinity of the WPD LV substation that the OpenLV monitoring equipment was installed in. These smart energy solutions comprised a blend of solar PV, battery storage and smart energy and heating system monitoring and controls. Two OpenLV substation feeders were isolated and monitored separately as each had a single property smart energy installation, one including solar PV (2kW) and battery storage (2kWh) and the other having battery storage only (4kWh), albeit with a tailored "day/night" tariff arrangement in place. This configuration and the relatively low levels of domestic electricity loads on these feeders made it much easier to correlate the control influenced electricity impacts in each property with the corresponding impacts on loads on the associated feeders in the LV substation.

Egnida Group Learning

From post-trial interviews, we gathered the following learning points from Egnida.

- Egnida decided to embark on this trial as they see the OpenLV capability being part of a strategic opportunity in the future rather than being an immediate opportunity
- Egnida believes that the presence and demonstration of this technology in social housing allows the fuel poor to gather some of the value in the energy supply chain rather than leaving big players in the energy industry to access all of this value
- Upon commencing the trial, Egnida compared the potential available capacity on the LV network and transformer in comparison to the available headroom that was initially indicated by WPD. Egnida found that for the large majority of the time, the amount of capacity that was available was much greater than the initial indications made by WPD
- This was a significant learning point as it implies that the OpenLV platform also facilitates the connect and manage agenda
- Egnida investigated how the social home flexibility could participate across industry product lines such as constraint management and frequency response. Egnida did express concern that the latency of the platform (as trialled) might not be compatible with managing the frequency response products that are particularly fast-acting
- At the end of the trial, Egnida considers that the OpenLV platform would enhance the value of the LCT which they install, but this value is presently blocked due to a lack of insight regarding LV data into future plans from the networks sector

2.2.3 Energeo

Participant Profile

Energeo is a privately owned company that develop tools which enable an analysis of the built environment. This analysis is used diverse input data such as satellite imagery, transport data, pollution data and energy efficiency metrics to provide insight.

Participant Trial

The business case for Energeo to participate in this trial was to demonstrate to themselves and to customers that their platform can incorporate grid data if it is made available. The ability to overlay the grid data against all of the other built environment metrics is a very significant enhancement to an existing Energeo product. As a result of being able to participate in the OpenLV trial, Energeo were able to win support from the Datapitch scheme. Winning this scheme enabled Energeo to expand its business offer by being able to increase the breadth of their existing platform. This specific outcome is notable as it is evidence of OpenLV helping new business propositions to develop.

Energeo were given access to data from 10 sites. The site selection was based on potential project locations. Energeo made use of the API and had no need to load an app onto the trial hardware within the substation. Notable sites within the selection were located in Milton Keynes and Plymouth. These sites were notable as they aligned with Business Development initiatives that Energeo are pursuing.

Energeo used both historical and real-time data. The real-time data shows the end-user what is currently going on to give immediate context. But the historical data was the core element as it explains any anomalies or patterns and trends.

This data was used with the Energeo platform. This platform is capable of assessing 1000 homes at a time to assess suitability for solar and how the trends might change (allows scenario modelling against the historic event). Graphical examples of Energeo's platform are shown in Figure 4.

In addition to targeted interventions, this tool also allows local authorities to plan a decarbonisation strategy as it explains the path of least resistance to decarbonisation.

Energeo received support from EA Technology on the use of API support documentation and keys. Having access to the API and the data in the right locations has added relevance to the energy mapping conversation. Eenrgeo commented that this facility has enhanced the business proposition as the conversations are real rather than contextual.

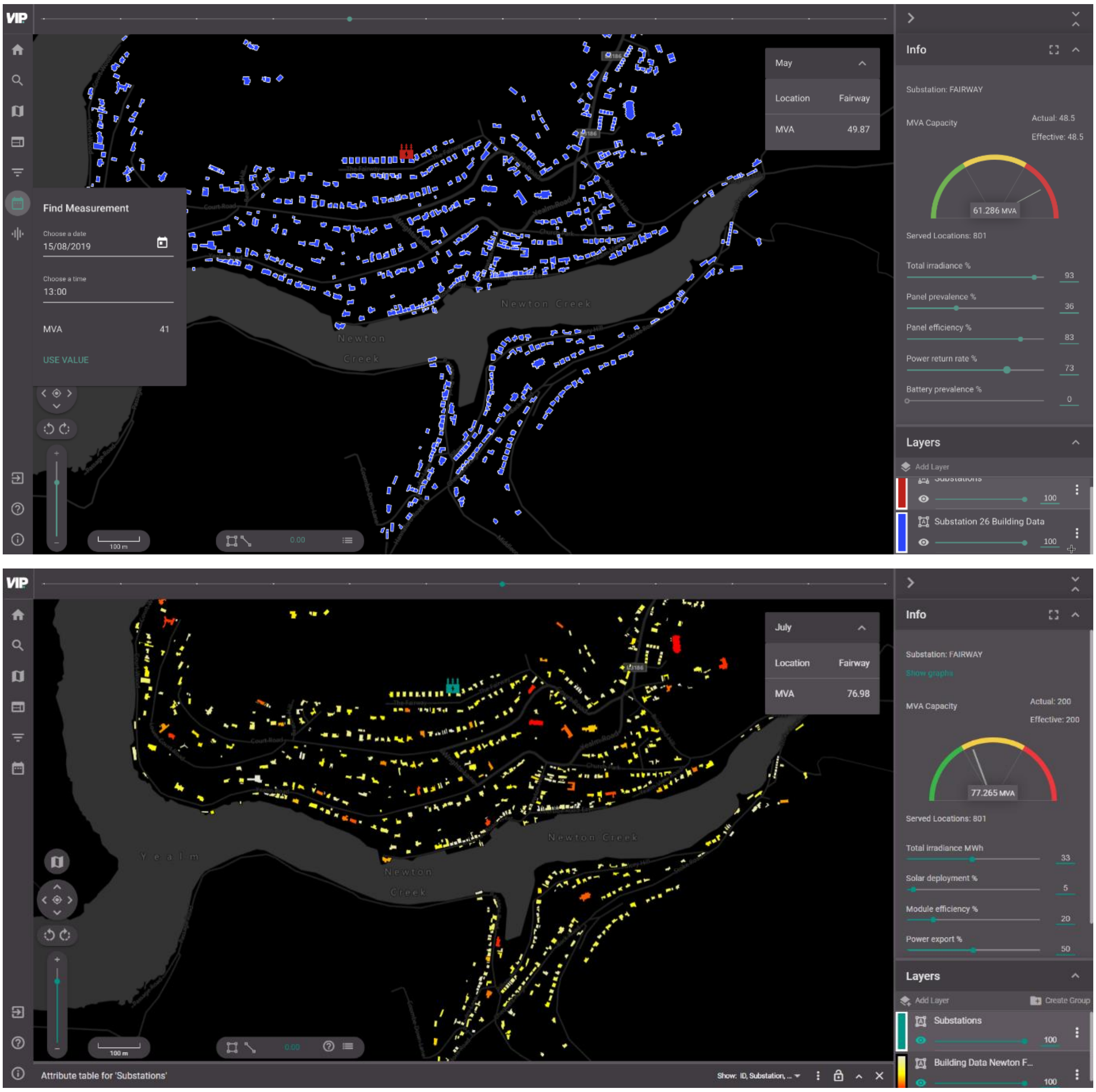


Figure 4: Example of views from Energeo platform

Energeo Learning

Energeo did have some initial difficulties in bringing the data in, as API key took some interpretation, but this was resolved with subsequent releases of the documentation.

Outside of the API documentation, Energeo observed that the largest challenge presenting the data from OpenLV in a user-friendly format. This was partly as there was so much data and also because the Energeo platform acts in the geographic domain whereas the OpenLV domain is predominantly time-based. For this reason, additional functionality had to be created to interface the two systems in a meaningful way.

In terms of other observations on the access: Energeo made the following observations:

1. It would have helped if there could have been a better way to explain when the substations were offline to avoid confusion over whether the API was working or not
2. There was so much information, but ultimately what was required is the ability to declare whether capacity on the network has been fully consumed or what opportunities to connect new equipment exists
3. An API token system would have helped make use of the API easier

2.2.4 Equiwatt

Participant Profile

Equiwatt are developing a digital platform that rewards households for allowing electrical appliances to be automatically managed according to smart grid requirements. Through the platform, energy consumption can be managed more efficiently with the potential to realise significant savings for the system operator, DNOs, energy companies and end consumers, as well as delivering environmental benefits.

Equiwatts platform comprises of a user-focussed front end with an analytics package active within the back-end layer of the platform.

Participant Trial

Equiwatt's motivation for participating in the trial was to investigate whether integrating access to the OpenLV platform to their platform was technically feasible.

Work was also undertaken to consider what could be learnt from the data on the platform with regard to the practicality of harnessing domestic flexibility. To conduct this investigation Equiwatt used data from the OpenLV trial to simulate network and DSR events. This data was been translated into signals that sent actionable responses to connected domestic loads, including EV charging and smart household appliances.

Equiwatt also developed an app to sit on the substation platform with the eventual intention to be able to report network data measurements into their platform.

Equiwatt hopes to continue to use the data from the project in research for the coming years. Equiwatt is considering this as a snapshot into the distribution system across several regions of the UK as "it will be an excellent augmentation to other datasets in the distribution system".

Equiwatt invested an estimated 685 work hours of staff and PhD student time into their trial. This effort was not funded by the OpenLV trial.

Equiwatt Learning

Equiwatt developed their own app from scratch and unlike other developers did not take advantage of the skeleton apps provided by the project to developers. Equiwatt were able to progress software development without the use of these aids.

Equiwatt took advantage of the Virtual Machine to test their work before submission for certification. Like OrxaGrid, Equiwatt also presented views that Virtual Machine[3] represented a large development overhead. Equiwatt elaborated that the Virtual Machine was a good test of the finalised app but created difficulty during the app development and debugging stage due to the fact that the Virtual Machine released to users is static and therefore reliant on users updating. To overcome this, Equiwatt adopted an approach that provides containerised machine images.

2.2.5 Hasys

Participant Profile

Haysys are a privately owned equipment manufacturer who makes specialist electronic devices.

Participant Trial

Haysys has developed the FeederNet system, a low voltage substation monitoring solution, which measures a wide range of electrical parameters of interest. An example of the Feedernet unit that was developed is shown in Figure 5.

By participating in this trial, Haysys were able to investigate entry into a new market and test a new product that could be offered to their customers.

[3] The Virtual Machine is a fully software-based version of the LV-CAP™ platform, created to enable application developers to work on applications for the platform without requiring the project hardware.

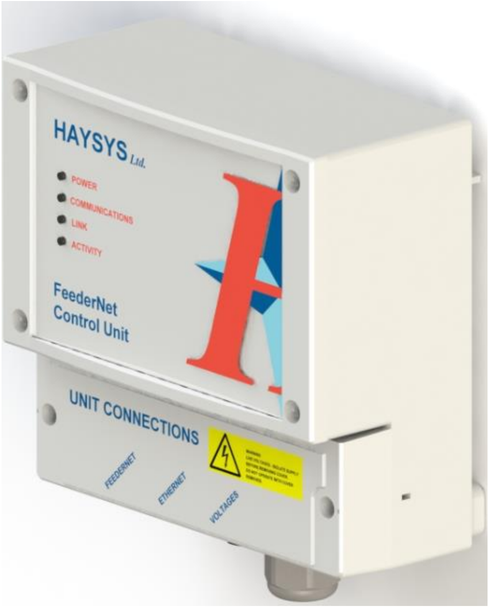


Figure 5: FeederNet unit

Hasys Learning

Haysys's trial demonstrated that it was feasible for a 3rd party to develop and deliver hardware to an acceptable standard that could be used to upload data from the field to the OpenLV platform.

2.2.6 IBM

Participant Profile

IBM produces and sells computer hardware, middleware and software, and provides hosting and consulting services. IBM is also a major research organization.

Participant Trial

For this project, IBM developed an application that could interact with a Jaguar I-PACE electric car and control charging. The purpose of this app was not to develop an app that could be commercialised, but was instead a strategic gesture to help demonstrate the benefit of an Open platform within the energy industry.

IBM's approach utilised three key structures:

1. An OpenLV app, which reviewed the substation loading against a notional limit. When substation loading exceeded this threshold value, a flag would be activated to suspend car charging. When substation loading was beneath this figure, the "suspend charging" flag was reset
2. A back-office application resided on IBM's servers to review the status of the "suspend charging" flag upon the OpenLV platform. Upon a status change of this flag, the back-office app would decide whether to relay a suspend or recommence charging signal to the test vehicle
3. The app and API created by the OEM of an EV tests subject, which was, in this case, a Jaguar I-PACE. By using this app and associated API, the back-office app would be able to control the charging status of the car

To realise this idea, IBM invested the time of a software developer to develop and test the system. IBM successfully tested each of the interfaces from the OpenLV platform to the OEM's app.

IBM Learning

The key learning point for this trial was project management related. This project was contingent on the availability of software development at the same time as an Electric Vehicle being available that had a suitable API offering. Having both of these resources available at the same time, whilst remaining within the trial deadlines was a particular challenge.

This participant's trial does indicate that there are organisations interested in controlling low carbon technologies from the OpenLV platform. This trial shows that the OpenLV platform has a capability to control electric vehicles via the API put in place the by car manufacturer.

2.2.7 Lucy Electric

Participant Profile

Lucy is a privately-owned technology company who specialises in the development and manufacturer of electricity distribution technology.

Participant Trial

Lucy GridKey has been working with Kaluza, a subsidiary of OVO Group who have developed a range of both smart chargers and V2G chargers all of which have the capability of providing remote control of the chargers. Lucy Gridkey and Kaluza funded and organised this trial themselves.

This charger has a novel feature insofar as its the charge level (or in the case of the V2G charger the level of charge and discharge) can be varied rather than just turned on and off.

Kaluza already offers end customers a proposition that pays a fixed price for exports from the V2G charger (30p/kWh), which is controlled by Kaluza within the constraints set by the user (the time they need the car ready by).

For the Method 3 OpenLV Demo, Lucy Gridkey wrote an OpenLV app which was installed upon the substation platform. The purpose of this app was to issue a car charging control signal based on information regarding transformer temperature and remaining capacity.

The car charging control signal generated by the app was then relayed to the Kaluza back office system via the existing OpenLV API.

The car charging signal that was generated was conditioned by the app to indicate a requirement to commence charging, a requirement to commence export from vehicle to grid or to become dormant.

Upon receipt of this car charging signal, the Kaluza back office system instructed the trial car's rate of charging accordingly.

Due to trial constraints, the V2G test subject was located at premises that were not fed by the OpenLV app. This was due to the fact that Kaluza already had their V2G infrastructure installed at this premises and it was not feasible to relocate an OpenLV unit to this site. This dislocation is not considered to undermine the fact that the OpenLV platform was able to send signals to a customer's data centre which could then be used by a 3rd party to control an electric vehicle charger.

Learning

This trial demonstrated a number of learning points.

Firstly, it demonstrated that OpenLV architecture enables a 3rd party to control LCT in response to network requirements. This trial also demonstrated the benefit of the open platform nature of OpenLV. Because Lucy Gridkey's app took advantage of data from a separate app (the transformer thermal model) it demonstrated how open platforms enable different apps to support each other rather than forcing each app to be self-sufficient. Apps that are forced to be self-sufficient would tend to take up more memory and system resources.

This trial also demonstrated a case of two separate commercial entities working together to research a proposition based on the OpenLV platform. Without the OpenLV API structure, it would be more costly for these two parties to have embarked upon their initiative.

Finally, this trial shows a second electric vehicle focused app, that uses an approach that is technically distinct to IBM's trial insofar as it is based control of the EV charger and demonstrates a contrasting suite of functions.

2.2.8 Nortech

Participant Profile

Nortech is a private technology company specialising in communications equipment for electricity distribution networks. Their equipment includes RTU's for primary substations, fault indicators and also the iHost software that was used as part of the OpenLV trial.

An example of Nortech's existing ihost system is shown beneath in Figure 6.

Figure 6: Example of views from Ihost and Smart MDI platform

Participant Trial

Although Nortech is an OpenLV Project partner, Nortech also asked to participate in the Method 3 trial and developed two apps. The development effort for these two apps was funded by Nortech and not by OpenLV funds.

Nortech's business case for investing their resources into the development of these two apps was strategic rather than linked to an immediate business case. Nortech explained that they wish to help develop a marketplace where non-proprietary apps can be placed on DNO owned equipment in substations. Nortech believes that the benefits of this model include cheaper overall network costs because avoiding vendor tie-in will reduce equipment duplication but also create a new network or asset insights that improve the network business model.

For Nortech to be able to be a part of this future marketplace, they believe that they need to help DNO's understand the opportunities offered through the use of open substation platforms, in effect encouraging DNOs to ask their supply chain for this capability. For this reason, they developed two apps which they believe showcase the strength of the model.

The first app was an extension of their Smart MDI product (see screenshot shown in the bottom of Figure 6), investigating the viability of populating their existing smart MDI user interface with data from a Nortech app sitting on the OpenLV platform rather than Nortech's direct channels.

Nortech successfully demonstrated that their app worked and uploaded data onto the iHost server. Nortech concluded that their existing smart MDI user interface could be reconfigured with minimal effort to present OpenLV data should a commercial opportunity arise.

Nortech's second trial developed an app which enabled data to be transferred between the LV-CAP™ platform to DNO SCADA by enabling the information to the OpenLV platform to be encoded into the DNP3 protocol. This app would allow any future app developer to be able to offer the DNO a DNP3 interface without the vendor having to develop the interface themselves. The app was developed and demonstrated in order to showcase the kind of benefit the LV-CAP platform offers both DNOs and vendors alike.

Nortech Learning

Nortech's trial demonstrated that there are participants in the DNO supply chain committed to the vision of open platforms in substations.

We also observed from interviews with Nortech that, to an extent, they are willing to take a strategic view on product development. But, Nortech also explained that their strategic view would be bounded by the transparency of the supply chain. For example, Nortech expended time on developing the DNP3 conversion app which on the face of it, may fulfil a strategic need, but has not been used yet. To foster a healthy future supply chain, it would be beneficial for potential suppliers to understand more about how DNO's expect to:

- Specify equipment in their substations to use the LV-CAP platform
- Incorporate LV-CAP into their wider control and information architecture
- Procure apps that sit on open devices or act open data

2.2.9 OrxaGrid

Participant Profile

OrxaGrid is a technology company who specialise in hardware, software and analytics that help give better insights into electricity networks and asset condition. An example of some of the analytics outputs that OrxaGrid's platform present to users are shown in Figure 7. This platform was developed by OrxaGrid and is dependent on the deployment of OrxaGrid hardware and an OrxaGrid managed communications network.

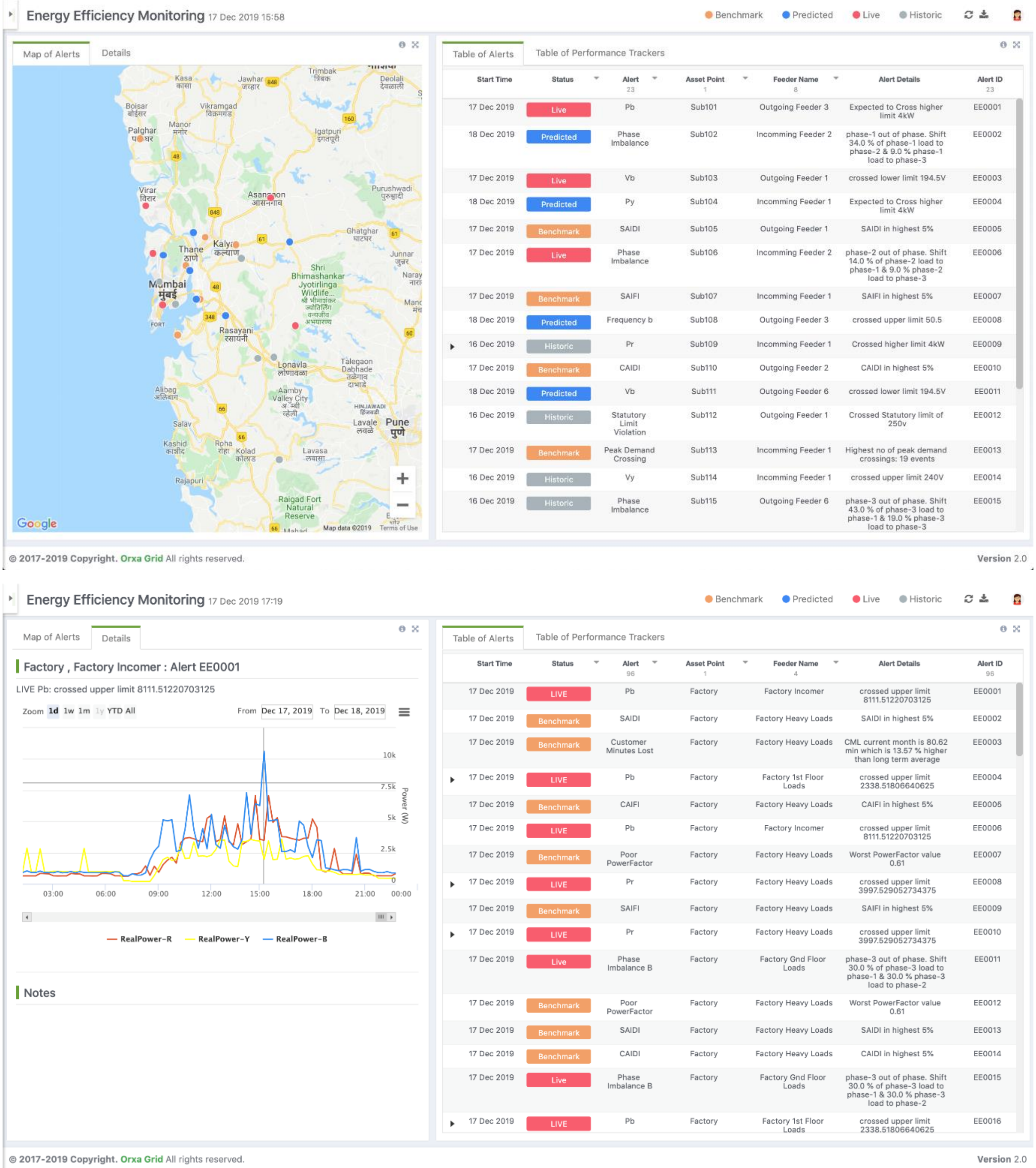


Figure 7: Example of OrxaGrid platform

Participant Trial

OrxaGrid developed an app that ran on the OpenLV platform that forecasts future voltage profiles and generated voltage alerts based on those predictions. The predictions and alerts could provide DNOs with deeper visibility of their low voltage network performance, without them having to manually drill down into low-level data from individual sensors.

OrxaGrid's app used historic data to pre-train its voltage forecasting algorithm before deployment. After deployment on LV-CAP, the algorithm continued to learn from the real-time streaming data in order to fine-tune its forecasts. OrxaGrid's app could be deployed without data and train itself entirely from streaming data, but it would take some months for the prediction model to become accurate.

During the development of the app, OrxaGrid took advantage of the developer guide and the Virtual Machine.

This development was funded by OrxaGrid.

OrxaGrid Learning

Some of the development learning points that were discovered by OrxaGrid were as follows:

- The Virtual Machine was a welcome development tool. OrxaGrid found that if their app worked on the Virtual Machine, it would work in real life
- There was a certain amount of overhead involved in loading a new version of an app onto the virtual platform. But at times, app testing was required without the overhead of loading the app onto the Virtual Machine. OrxaGrid overcame this limitation by developing their own test tools that were used prior to deployment to the Virtual Machine
- OrxaGrid also commented positively upon an approach that the LV-CAP platform took with timestamping of data and data validity flags. These features vastly simplified data cleansing and saved significant quantities of time

In addition to the app-specific learning points, OrxaGrid also observed that the architecture demonstrated in the OpenLV trial enabled them to concentrate on App development. This was because the platform's presence freed up resource as they did not need to make provision for staff to install hardware or configure and manage data networks.

It is considered that OrxaGrid's trial helps demonstrate that an Open platform such as that trialled in OpenLV would enable OrxaGrid to expand their business as it would enable not only new routes to market for their existing analytics packages but also by enabling access to data which they might not normally have access to. It was however noted in conversations with OrxaGrid, that a clear barrier to the continued development of this new business model would be the absence of clear signals from the DNO with regard to the intention to procure any such new apps.

2.2.10 Upside Energy

Participant Profile

Upside energy is an information technology company who have developed a network flexibility platform. The Upside Platform can connect to a wide range of devices, including battery storage systems, electric vehicles, UPS and heating and cooling systems. Providing real-time data and advanced forecasting, it enables our customers to fully optimise their return on investment and market positioning, by dispatching demand-side flexibility in real-time

Participant Trial

Upside energy recognised that adding in grid data to their platform would increase the value it represented as it would allow flexibility to respond to network congestion. For this reason, Upside Energy applied to participate within the OpenLV trial and would fund their own participation.

The fact that Upside energy funded their own participation is significant. This is because during the trial period an opportunity arose when meant that Upside Energy had to choose between OpenLV app development or tasking their developers to support a different project that was fully funded. It was, therefore, a rational business choice from Upside Energy to pause development on their OpenLV development stack.

Upside Energy Learning

The key learning points here would be that for businesses to be able to make a fully committed effort to developing new apps and new business's models, there needs to be transparency from the networks sector as to what the opportunities and commercial arrangements will be for automated flexibility providers. Since the commencement of the OpenLV trial, the DNO sector has begun signposting opportunities for flexibility, one example being WPD's flexible power portal which explains the commercial terms that WPD seeks to procure flexibility with. Further work might explain how the OpenLV API structure can work with WPD's commercial flexibility model.

2.3 Did academic institutions take advantage of the open data?

This question seeks to investigate whether making network data open and available supports research effort by academic institutions. Table 2 summarises the participation of academic participants within the trial.

Table 2: Commercial participant Summary

Institution	Title of research paper	Presentation Events
University of Cardiff	A smart contract oriented whole system regulatory model for electricity networks	Rev. IET Smart Grid, 2018.
Imperial College	Active network management in LV networks: a case study in the UK	Cigre Webinar, October 2019
University of Bristol	Digital and Physical perspectives of the effect of renewables on the LV distribution system	
University of Girona	Detection, Isolation, and Diagnosis of Abnormal Grid Operation with Multilayer Multiway PCA,	Accepted for publication, IEEE Transactions
University of Strathclyde	End-to-end analysis to help improve understanding of how the LV network can be balanced	
South Bank University	Partnership with Orxa Grid (see 0)	An application to present at Cigre has been made.

One of the barriers to successful research into distribution networks is to obtain valid and accurate network use data. The OpenLV trial data was used by over 6 academic institutions in their research and publications.

It was noted in the trial that the presence of a shared and open data platform removes barriers from DNO's in engaging academic partners. For example, under the present model, engaging academia to study a network problem would require trial infrastructure that could transmit large volumes of monitoring data. In comparison, the use of an open data platform that is already serving multiple parties removes this barrier to academic collaboration.

By making the data gathered within the trial "Open", the barrier of obtaining reliable network data is overcome. In the case of the OpenLV trial, the academic institutions were then able to pursue research that was already funded by other means. In summary, removal of this data barrier enables greater autonomy in academic thought as research institutions would have less reliance on extracting data from a sponsor.

It is therefore concluded that an Open data platform such as OpenLV does facilitate and enable academic research.

2.4 EA Technology learning

In addition to the learning developed from each of the participants, EA Technology developed learning in its role as the platform administrator as well as the project delivery partner.

2.4.1 Platform management

EA Technology undertook the role of administering the OpenLV platform throughout this trial. This included responsibility for reviewing compliance of Method 3 apps against the OpenLV protocols and issuing security certificates to apps once they had passed this process. It should be noted that within this meaning that certification relates to the compliance of an app with the OpenLV protocol and not a certification of the entire app. Key learning points from this process were as follows:

1. **Working relationships**
   In business as the usual context, it may be envisioned that app developers would need to ensure their apps were certified before they could be deployed into the substation environment.
   Strong working relationships between the certification team and participants developers were observed to be linked to the apps that obtained a smooth certification. When strong links were formed, it was observed that questions were asked earlier in the certification process which avoided small problems becoming bigger.
   In contrast, situations where individuals argued their interpretation of the API rules back to the certification team, the certification process slowed down due to the need to resolve or explain why the features of the platform are the way they are. This latter point could, of course, be mitigated in BAU through more resources for developers to become familiar with the API and the platform.
2. **Use of development resources**
   The OpenLV Project offered software developers resources including a skeleton app that was intended to save development overhead. It was noted that the developers who took good advantage of these resources tended to have a faster route towards a certification that those who choose not to.
   One of the reasons that some developers choose not to use the skeleton app was unfamiliarity with the language it was written in. This could be overcome in the future by releasing a suite of skeleton apps in different languages
3. **Adherence to the API and rules**
   A number of the failed certification attempts were non-intentional transgressions of the API rules. It is not clear whether this was attributable to internal quality control or lack of familiarity.

   It was also observed in some instances that some developers sought to create their own shortcuts using automation, which leads to non-conformities having to be declared in the certification process. These failed certification attempts were of a more serious nature for participants as it meant that:

1. In cases where participants sought to automate build procedures, EA Technology simply could not certify compliance as it couldn't be verified
2. The participants source code would need more significant re-work than correcting a few lines of code before verification and certification could take place

In the BAU context, it is considered that both of these issues would be overcome by fostering greater familiarity by software developers with the API and continuation of the culture of constructive feedback within the certification process. A consistent approach to enforcing the rules of the platform would also avoid debates about what the rules of the platform "mean" to developers.

2.4.2 Participant management

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 the effect of the fact that the relationship between OpenLV and its Method 3 participants was 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 a number of 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 by definition, the OpenLV trial was time bounded. Which meant it became difficult for some participants to wholly commit to delivery of OpenLV research within the project timescales.

This later issue is slightly artificial as if the platform was already part of BAU, then 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 the complexity of 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.

2.5 What was the overall learning?

It was observed throughout the trial that the number Method 3 applications was far greater than the number available platforms for the Method 3 trial. This was despite the fact that each participant would be responsible for funding of their own engagement in the trial. This fact is considered to be an indicator of the amount of commercial interest in this platform.

2.5.1 Non-traditional business models

This section considers whether the OpenLV trial has provided evidence that transition to business as usual would promote non-traditional business models.

For the purpose of this investigation, traditional business models shall be deemed to describe business practices rooted in the following practices:

1. **Capacity screening and broadcast.**
   Traditional network capacity investigations are conducted through "rules of thumb" analysis frameworks, solely by the network operator, with no practical opportunity for 3rd parties to understand the amount of remaining capacity in the LV network.
2. **Mitigation and participation**
   Voltage or loading problems upon the low voltage network are traditionally mitigated through physical interventions. To date, there has been little opportunity for non-network capacity interventions at low voltage; especially when offered from outside the network operator's organisation.
   Also, the behaviour of any flexible devices[4] connected to the LV network may be capped by generic or policy-based limits rather than limits that are based on local observations. The use of generic or policy-based limits may prove to be a barrier to LV connected flexibility helping to resolve upstream problems.
3. **Platform and Data Sharing**
   In situations where there are monitoring devices on the LV network, vendor tie-in[5] or DNO cybersecurity concerns tend to override the opportunity to either: load 3rd party apps into the monitoring device or allowing other parties to access data.

The following sections discuss whether the OpenLV trial provided evidence that these traditional business models can be challenged.

Capacity Screening and Broadcast.

This section reviews whether OpenLV enabled 3rd parties to understand the amount of remaining capacity in the LV network, as per question 1 above.

Within the OpenLV trial, the following participants used LV network data to enable stakeholders to understand how much capacity remained within the network.

- Energeo presented LV network congestion data upon their platform (as shown in Figure 4 in Section 2.2.3.)
- Although not within Method 3, the CSE app from Method 2 did overlap on this use case to an extent

[4] Flexible devices are intended to encompass, Electric Vehicles, Battery Storage, Actively managed space heating, managed hot water heating and potentially PV generation. These devices may form part of a larger portfolio used to help with upstream network flexibility or national energy system balancing.

[5] An example of this would be a case where a supplier provides some form of monitoring device where it is not feasible to load any software onto the device other than that created by the supplier.

- Egnida Group was able to use the data to understand the full context of network utilisation limits, instead of using a snapshot of how much remaining capacity was available

Both of these participants provided feedback that, although they were eventually able to interpret results presented by the OpenLV data in terms of remaining capacity, it would have been easier for them had network data been presented alongside something that enabled contextualisation. This capacity context could have been a remaining capacity metric or even a simple emoji.

Participants also raised the question as to how they could understand whether any remaining capacity metric was reflective of the local LV network, or whether it explained the remaining capacity based on the scope of the relevant upstream network.

It was also notable that Orxa Grid and Nortech, both developed apps that could help the DNO monitor or predict unacceptable loading and voltage. Whilst, in this trial, the output of these apps was not shared with 3rd parties, these apps or similar could be used to inform other 3rd parties of capacity opportunities or issues.

The evidence discussed in this section shows that the OpenLV trial did challenge a traditional business model by enabling end consumers to understand and visualise the remaining capacity in their local area. Learning from the trial also pointed to how the customer experience of this feature could be improved.

This benefit could be measured through greater operational efficiency within DNO's when signposting capacity opportunities or difficulties.

Mitigation and participation

This section reviews whether the OpenLV trial enables non-traditional approaches to LV network problems and also promotes participation of LV connected energy resources into LV or upstream network problems.

The OpenLV trial can cite 5 participants who created apps that facilitated the participation of end consumers in either LV network management or upstream network management.

- IBM and Lucy both demonstrated apps which could control the charging of electric vehicles to ensure that the LV network remained within transformer loading limits
- Egnida Group demonstrated that the API could help them optimise control strategies for LCT
- Equiwatt and Upside energy both put effort into developing an app, but the self-funding nature meant that they could not complete their development within trial deadlines. These platforms would have permitted local energy resources to be balanced in response to grid congestion amongst other signals.

The IBM and Lucy apps were also notable as they enabled smart charging flexibility to be deployed on the basis of local conditions, rather than a fixed time of user profile. The ability to schedule smart charging on this basis overcomes one of the observations from WPD's Electric Nation project [3], which was that the use of fixed policy assumptions for when EV's may charge, will lead to more smart charging interventions for end consumers than if the available windows for smart charging was informed by local capacity observations.

This observation is relevant to OpenLV insofar as the trial demonstrates the capability to share network capacity information with parties that can control car charging. The effect of having this capability would be measured in a reduced volume of restriction events associated with smart charging as part of network management practice.

It is also notable that the car charging apps considered two different Methodologies to control car charging i.e. controlling the charge rate via the car charger and also controlling the charge rate via the car manufacturers car app. This is notable as it shows that the open nature of this trial facilitates technological diversity.

Platform and Data Sharing

This section reviews whether the OpenLV trial provides evidence that 3rd party software can be loaded onto substation devices and data can be shared without compromising DNO cybersecurity.

Almost by definition, the trial has given evidence that hardware vendor tie in can be overcome and network data can be shared with 3rd parties, either by app or publication of an API, without compromising WPD's cybersecurity policies. This was enabled by a set cyber of security features which included one-way data flows (always away from the DNO) and prohibiting 3rd party apps from substations which have active network controls.

The OpenLV trial has recognised that the set of cybersecurity features was reflective of a trial and not the "business as usual" environment. To respond to this, the OpenLV trial is developing a set of draft cybersecurity standards that enable data sharing and platform sharing. This draft standard is to be published to the industry by WPD and the OpenLV Project.

Enable Competition

In addition to the evidence provided in the three questions above, the trial demonstrated that in the Method 3 trials, there was a replication of similar product offerings. For example:

- We observed the delivery of two car charging apps from two different suppliers using two different Methods, namely IBM and Lucy Electric
- We observed the participation of applications from Egnida Group and Equiwatt that could marshal flexibility from domestic properties
- We observed participation from Haysys, a hardware supplier who demonstrated that they could supply hardware which provided an alternative to the measurement hardware system LV-CAP platform that was used during the trial

Although the OpenLV trial was a technical trial rather than commercial, these observations indicate that there could be healthy competition between app and hardware providers in a business as usual context. Competition is an important ingredient in the question of enabling new business models as it ensures that suppliers and vendors end up with a sustainable proposition.

3 Conclusions

3.1 Method 3 – Business and Academia

3.1.1 Did OpenLV demonstrate new ways to engage with business?

Despite the fact that commercial organisations were required to fund their own participation in the OpenLV trial, the available spaces for participation were oversubscribed.

The ability for the trial participants to access the data did create new ways for DNO's and companies to engage. The exact details of what the trial demonstrated can be found across Section 2, but 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 used on the basis of the load flow data that became available to them as a result of OpenLV. This is a new proposition due to the fact that DNO's have not traditionally been equipped to stream data to other parties
- **Basis for supply chain innovation**. We observed some of the trial participants using Open data to assess new value propositions for existing or refined products. In some cases, we also observed that the open data enabled these parties to conduct testing on these product refinements. Without the development of this data being Open, it would have been harder to obtain meaningful depictions of network behaviour
- **New network management products.** We observed a number of 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 passive customers
- **New forms of information visualisation.** By making the LV network data Open, 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 Methods used in business as usual to date

3.1.2 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 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 a number of academics were interested in obtaining access to the raw data across a number of 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.

3.1.3 Did OpenLV facilitate non-traditional business models

Within Section 2.5.1 we reviewed the evidence of whether the OpenLV trial demonstrated evidence of whether it enabled non-traditional business models.

This trial presented evidence 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 upon a network to a customer.
  When LV network data is made open to customers, they become able to assess the situation for themselves and create innovative ways to combine this data with other data streams to create insights and value beyond an electricity networks perspective.
- **Mitigation and participation.** The traditional approach to network management has been passive infrastructure measures. This approach is already changing with the advent of DNO's seeking 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 is positioned to be able to 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 specific information upon an 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 particular 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 become more selective as to what processes they would like to have running in substations (instead of being limited to processes installed by the equipment supply) 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 sufficient signposting from WPD as to where opportunities for App development will be and what the commercial model for procurement would be.

3.2 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 3 shows that there is interest from a supply chain in the development of an ecosystem of different apps which could be placed on open application 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 next SDRC (SDRC 5) will investigate the costs and benefits of fitting OpenLV into substations onto the quantitative basis.

3.3 Next Steps

The next project deliverable will be SDRC 5 which considers the overall cost-benefit case of OpenLV and how it might be best employed to create industry value.

In addition to this next step, WPD has already announced that they are committed to maintaining the offer of community data by installing a number of EA Technology VisNet units that will be installed into substations.

3.4 Criterion Compliance

Table 3 provides a summary of the SDRC criterion that is expected for this milestone and where evidence is provided for its completion.

Table 3: SDRC Criterion & Evidence Compliance Matrix

Successful Delivery Reward Criterion	Section(s)
Sharing the level of capacity uplift achieved through Method 1	SDRC 4 – Method 1
Sharing which LV networks can benefit from OpenLV and why	SDRC 4 – Method 1
Establishing the level of capacity uplift that can be achieved in WPD's licence area and across GB	SDRC 4 – Method 1
Sharing how DNO's can engage with communities who want to become part of a smarter grid to exploit the open and flexible nature of OpenLV	SDRC 4 – Method 2
Sharing how community engagement supports the uptake of LCT	SDRC 4 – Method 2
Outlining the routes communities can take to raise funding	SDRC 4 – Method 2
Sharing the network benefits provided by community engagement	SDRC 4 – Method 2
Sharing how DNOs can engage with companies (including non-energy companies) and academics to exploit the open and flexible nature of OpenLV	Section 2.2 Section 2.3
Sharing how the Method facilitates non-traditional business models	Section 3.1.3

4 References

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[3] “Electric Nation - Customer Trial Final Report,” 2019. [Online]. Available: https://www.westernpower.co.uk/downloads/64378.