LV CONNECT AND MANAGE: A NOVEL SOLUTION FOR LCT INTEGRATION

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ABSTRACT

LV Connect and Manage is a low voltage network intervention that has been pioneered by Western Power Distribution (WPD) and Nortech Management Limited to facilitate the connection of domestic low carbon technologies (LCTs) such as electric vehicles, photovoltaics and heat pumps. The active network management solution allows WPD to control the bi-directional power flow from and to clusters of LCTs. This means that the electricity network is not a barrier to customers adopting LCTs and WPD can manage the LCT connections in an active way, whilst network reinforcement takes place. LV Connect and Manage forms part of WPD's strategy for transitioning from a Distribution Network Operator to a Distribution System Operator.

INTRODUCTION

Background

Network reinforcement can be too expensive and too time-bound to respond to low carbon technology (LCT) connections on the LV network, particularly if rapid clustering occurs (such as with electric vehicles and PV installations) [1]. Due to uncertainties in volume, location and type of LV connections, it is not always possible or efficient for Western Power Distribution (WPD) to plan network reinforcement ahead of need. However, when the need does arise, network reinforcement (traditional intervention solution) can be too expensive and can take too long to deploy, delaying customers' connections to the network.

Technology for LV Active Network Management (ANM), which extends communications and controls beyond customers' meters and is able to deal with bi-directional power flows, is still unproven. There was a need-case for WPD to trial this type of solution in a low-risk way, to assess whether or not LV ANM could be a viable alternative to network reinforcement.

Project Overview

LV Connect and Manage is a low voltage (LV) network intervention that has been pioneered by Western Power Distribution (WPD) and Nortech Management Limited (NML) to facilitate the connection of domestic low carbon technologies (LCTs) such as electric vehicles (EVs), photovoltaics (PV) and heat pumps. Using hardware and software developed by NML, the active network management solution allows WPD to control the bi-directional power flow from and to clusters of LCTs. This means that the electricity network is not a barrier to customers adopting LCTs and WPD can manage the LCT connections in an active way.

LV Connect and Manage is funded by one of the UK's regulatory mechanisms for innovation (known as the Network Innovation Allowance). The project has demonstrated that LV ANM can be used as a short-term measure, whilst network reinforcement takes place, to facilitate the timely connection of customers [2]. The solution can then be redeployed to another area when the need case arises. Moreover, the ANM solution provides a long-term alternative to network reinforcement in cases where the investment in traditional assets is not economically viable or due to other reasons (such as the disruption to customers) preventing reinforcement taking place.

Three objectives were defined at the beginning of the project (in April 2016) to represent a successful outcome:

1. Demonstration of the active management of low carbon technologies (energy storage and electric vehicles) by controlling load profiles and alleviating electricity network constraints.
2. Development of a replicable architecture for the LV ANM solution, which can be utilised by WPD and by other DNOs, more generally.
3. Development of novel business processes for deploying ANM technologies into LV networks. (This included the specification and development of installation guides for the LV ANM technologies in WPD's substations and customers' homes).

As described in the rest of this paper, over the past 18 months, the project has delivered all three outcomes successfully.

SOLUTION ARCHITECTURE

The novel architecture developed for the LV Connect and Manage system is given in Figure 1. This involves the deployment of communications and control infrastructure to allow LCTs to connect to the network in a timely manner and be managed in an active way. The key components of the architecture are:

- Domestic Load Controller (DLC) Boxes;
- LV Substation Monitors; and
- A Centralised Software Platform (iHost).

DLC Boxes

The DLC boxes are compact devices that are installed in customers' homes and integrate with their LCTs (battery inverter systems and EV charge points) allowing the power flows to be monitored and controlled in real time. The DLC boxes have failsafe functions in case of loss of communications. Figures 2 and 3 show example installations of the DLC box in customers' homes controlling battery energy storage and EVs respectively.

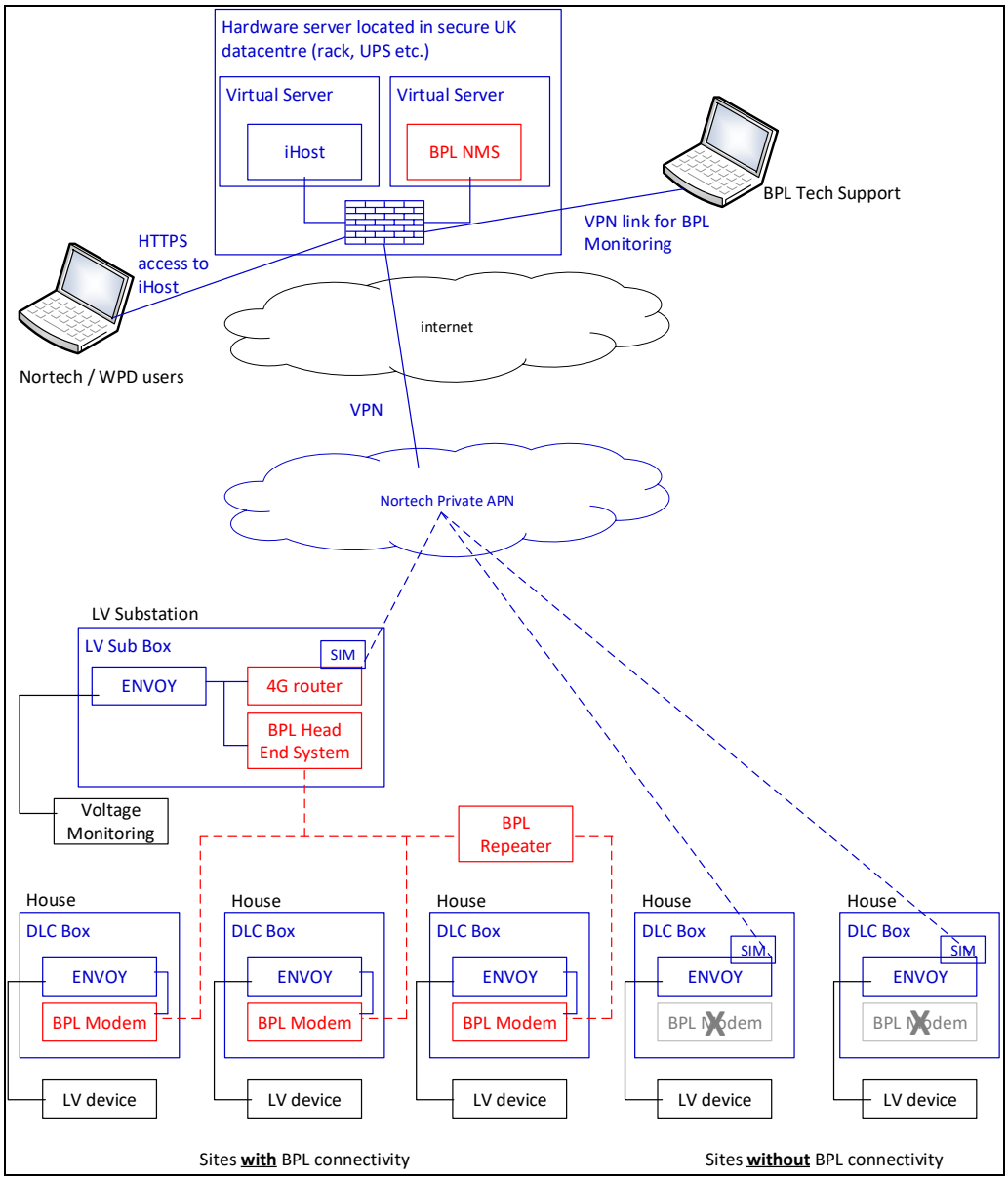

Figure 1: The novel architecture implemented for LV Connect and Manage

Figure 2: Example installation of battery energy storage, smart inverter and Domestic Load Controller devices in a customer's home

Figure 3: Example installation of controllable EV fast charger (0 – 32A single phase) and Domestic Load Controller devices in a customer's home

LV Substation Monitors

The LV substation monitors, as seen in Figure 4, are devices that can be retrofitted into substations, which are upstream of the LCT clusters. The devices monitor substation busbar voltages, transformer and feeder bi-directional power flows and these are reported with a 10s granularity.

Figure 4: Example LV substation monitor

Centralised Software Platform (iHost)

iHost provides WPD with remote visibility of the aggregated LCT devices, including set points, power flows and device status alarms. In this deployment, the control algorithms are running on iHost in a central location. This allows the system to be readily ported from site-to-site and to scale as LCT clustering increases.

LV ACTIVE NETWORK MANAGEMENT

The LV ANM system works by limiting the power imported by EVs and exported by PV/battery systems at times of LV network congestion [3]. This keeps the network within technical limits for both thermal and voltage constraints.

RESULTS

The results of the LV Connect and Manage field trials are shown in Figures 5 and 6 for EV charge control and battery energy storage control respectively.

Considering Figure 5, the blue trace represents the maximum charge set point (kW) for the customer's electric vehicle (EV). The orange trace represents the charge power (kW) of the EV as it responds to the set points issued. From 14:53 to 15:38, manual set points were issued to the EV. From 15:38 onwards, the control was automated by monitoring power flows through the upstream LV substation and controlling the EV charge power according to the headroom available. The results of these trials show that the EV reliably responds to signals that throttle back the charge and then increase it when the substation constraint is relaxed.

Considering Figure 6, the blue trace represents the maximum discharge set point for the customer's battery energy storage system (W), the red trace represents the discharge power output (W) of the battery as it responds to the set points issued. The black trace shows the capacity of the battery (%), which can be read from the right-hand axis of the graph.

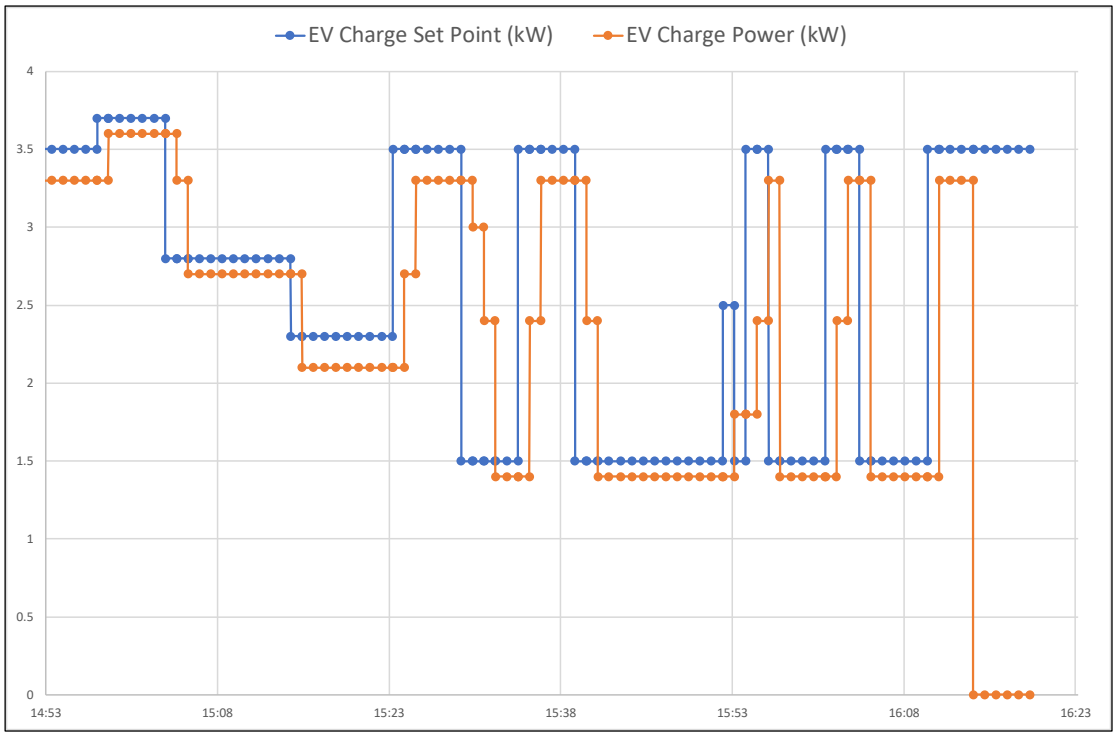

Figure 5: Field trial results demonstrating the control of EV charging in customers' homes

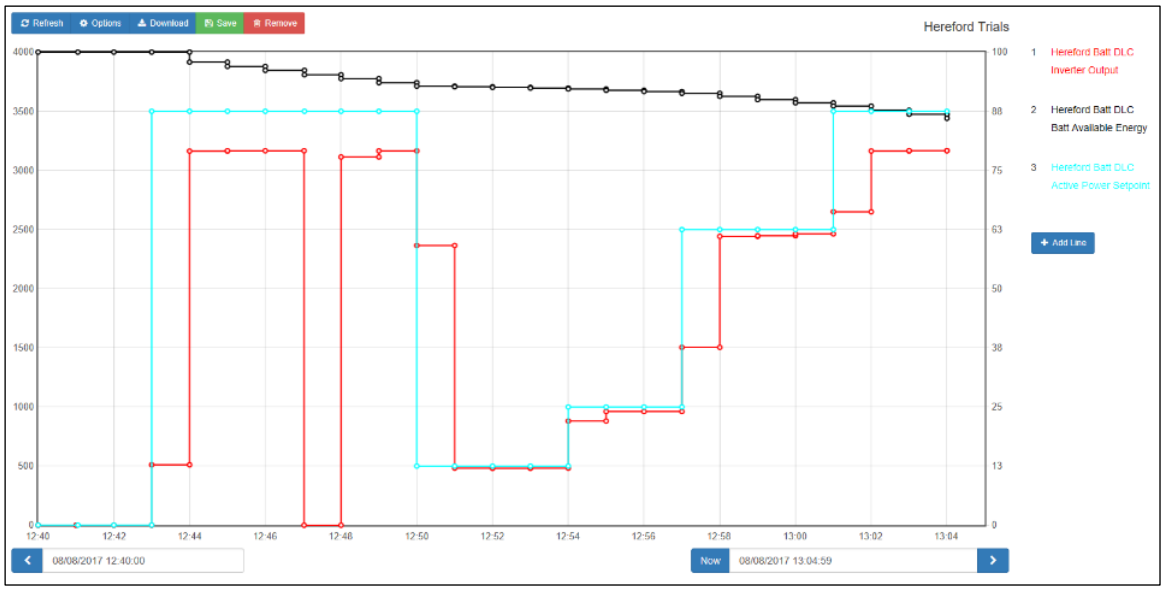

Figure 6: Field trial results demonstrating the control of battery energy storage devices in customers' homes

LESSONS LEARNT

The following learning has resulted from the LV connect and Manage Project:

1. It has proven feasible to manage EV charging rate (from 16 to 32A in 1A steps) via cellular communications;
2. It has proven feasible to manage rate of PV/battery energy storage discharge via cellular communications;
3. Moving forwards to wider-scale roll out, there are likely to be supply chain technology changes, which can be accommodated within the architecture but are outside of WPD's immediate sphere of influence. In this project, both the battery technology and inverter technology evolved during the trial phase;
4. The process for retrofitting substation monitors has been appended to an existing WPD policy. This transfers the knowledge and de-risks future substation installs;
5. The Broadband over Powerline (BPL) equipment was found to be very sensitive to the LV network topology and electric noise. Repeater equipment was required to pass the BPL signal through customers' distribution boards into the home (for technology control). It was not feasible to install repeater equipment in customers cut-outs and so it was concluded that this communications medium was not fit-for-purpose for the LV Connect and Manage application;
6. Having a flexible approach (a willingness to adapt business processes etc.) is more likely to lead to successful innovation.

CONCLUSION

Over the past 18 months, the project has delivered all three objectives successfully:

1. Demonstration of the active management of low carbon technologies (energy storage and electric vehicles) by controlling load profiles and alleviating electricity network constraints.
2. Development of a replicable architecture for the LV ANM solution, which can be utilised by WPD and by other DNOs, more generally.
3. Development of novel business processes for deploying ANM technologies into LV networks. (This included the specification and development of installation guides for the LV ANM technologies in WPD's substations and customers' homes).

NEXT STEPS

LV Connect and Manage forms part of WPD's strategy for transitioning from a Distribution Network Operator to a Distribution System Operator.

REFERENCES

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