ESB NETWORKS

INTELLIGENT SECONDARY SUBSTATION MONITORING (WINTERPEAK) CLOSE-OUT REPORT

Project Owner: Cristina Coleman-Kenny,
Electrification and Innovation Delivery

Report Date: 07th September 2020

Start date: Q4, 2016. End date: Q2, 2020

Contributors: Clem Power, Jonathan Sandham, Noel Ryan

Doc No. DOC-080920-FWK

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Abbreviations

ASHP	Air Source Heat Pump
BaU	Business as Usual
CT	Current Transformer
DNO	Distribution Network Operator
DR	Distributed Renewables
DSM	Demand Side Management
DSO	Distribution System Operator
DV	Dual Voltage
EV	Electric Vehicle
GMS	Ground Mounted Substation
HP	Heat Pump
IERC	International Energy Research Centre
IoT	Internet of Things
IP	Internet Protocol
IP	Ingress Protection
IPC	Insulation Piercing Connectors
IT	Information Technology
kWh	kilo-Watt hour (one kWh is a 'unit' of electricity)
kVA	Kilo-Volt-Amps
LCT	Low Carbon Technologies
LoRaWAN	Long Range Wide Area Network (ESB Networks project)
LV	Low Voltage (<1000V)
MW	Megawatt (one million watts)
MS	Microsoft
MV	Medium Voltage (10kV and 20kV networks)
NSH	Night Storage Heater
OMS	Operations Monitoring System
PID	Project Initiation Document
PMT	Pole Mounted Transformer
PM	Program / Monitoring
PQ	Power Quality
PV	Photo-Voltaic
RESERVE	Horizon 2020 project – Renewable Energy SERVicEs
RMS	Root-Mean-Squared
SCADA	Supervisory, Control and Data Acquisition
SETS	Smart Electric Thermal Storage
V2G	Vehicle to Grid
VPP	Virtual Power Plant

1. PROJECT OVERVIEW

In 2016, an increase in the number of heat pump (HP) and solar PhotoVoltaic (PV) installations was observed in new dwellings, the result of requirements set out in the forthcoming 'Part L' of the Irish building regulations[1] relating to the conservation of fuel and energy. The electrical effect on the LV network as a result of the increased installation of HP's, PV and Electric Vehicles (EV's) connected to the LV network was not yet fully understood. In order to better understand the capabilities of and effects upon our LV network, the WinterPeak project was created.

To fully assess the impact to the network of these Low Carbon Technologies (LCT), the project team needed to identify how to monitor the LV network and how to install a monitoring device safely into a MV/LV substation. The project team targeted new housing developments in order to identify potential trail sites where these technologies where installed. The project evolved as the range, benefits and capabilities of monitoring devices became better understood and so, the project's scope was amended to focus on the assessment of monitoring devices and the data which these devices are capable of providing.

The WinterPeak project collaborated with other projects where suitable trial sites were available. As a result of this collaboration, WinterPeak devices were used to investigate the reduction of peak time energy usage (customer battery), the use and control of LCT's and to understand how new technologies can be used to mitigate network issues (see Section 4 for trial results).

ESB Networks innovation strategy is set out in its 'Innovating for a Brighter Future'[2] document. The strategy commits to using innovative means to solve the challenges on our network brought about by the proliferation of LCT's. The WinterPeak project has been identified as an innovative project as its objectives align to those of the Innovation strategy.

In 2019, the Irish Government published its Climate Action Plan (CAP) targeting a 30% reduction in carbon emissions to be achieved by 2030. This was driven by an EU carbon target of net-zero by 2050. As the generation of electricity itself moves increasingly to renewable sources, using electricity to fuel transport and heating, has the potential to have a major effect in reducing the carbon emissions of the country. The CAP outlines further changes in fuel type/selection for dwellings, eliminating oil-fired boilers from 2021 and gas boilers from 2025, with Air Source Heat Pumps (ASHPs), and smart electric storage heating anticipated to replace them. This additional driver to shift the sourcing of heat energy to renewable sources is likely to further impact the Low Voltage (LV) network, potentially altering usage profiles, leading to constraints and possible overloading of transformers and LV circuits. To avoid sub-standard supplies of electricity, which may lead to customer complaints, ESB Networks need to understand the effects of changing the types of load and usage patterns connected in the future.

Electrification of transport is also targeted in the CAP which estimates that there will be 936,000 Electric Vehicles (EVs) on Irish roads by 2030, further changing the way the LV network will be used. The mix of new demand and generation types is represented in Figure 1 below. Clearly, significant changes to the LV network and the way in which it is used, are likely.

[1] www.housing.gov.ie/sites/default/publications/files/tgd l 2017 for buildings other than dwellings.pdf
[2] www.esbnetworks.ie docs default-source publications esb-networks-innovation-strategy

The publication of the CAP caused a review of the project's objectives and scope, which remained unchanged. The importance of providing a means for cost-effectively monitoring the LV network was, nevertheless, amplified by the issuing of the plan.

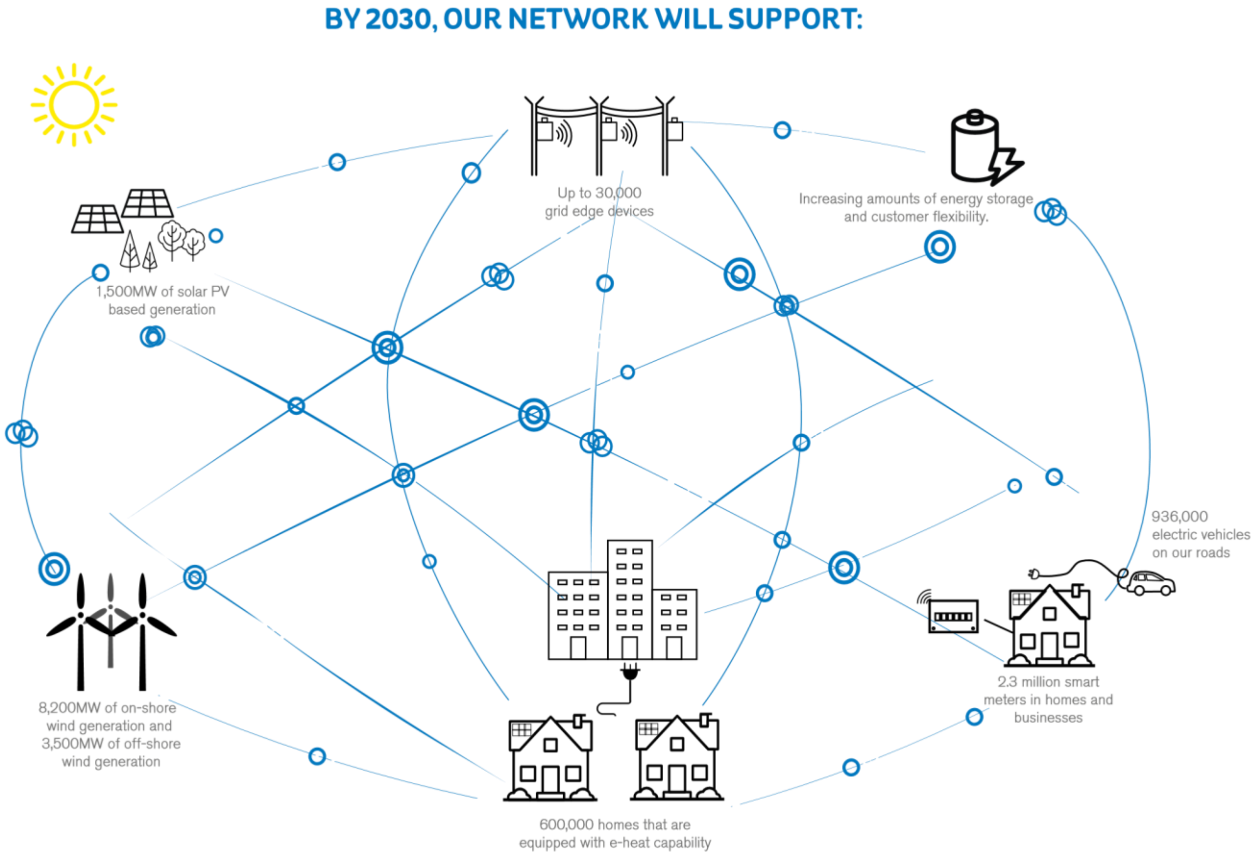


FIGURE 1. ESB NETWORKS INNOVATION STRATEGY

1.1 CONTEXT AND BENEFITS

ESB Networks' Innovation Strategy sets targets that align with the targets contained in the Climate Action Plan, and outlines the work needed to meet these targets. The targets suggest that there will be additional dependency on the LV network with increased connections needed for the electrification of heat and transport. The Irish Building Regulations Part L (Conservation of Fuel and Energy) sets out the statutory minimum energy performance standards that apply to the construction of new dwellings. The standard requires that:

- a 10 kWh/m2/annum contributing to energy use for domestic hot water heating, space heating or cooling needs to be provided by a renewable source and
- a 4 kWh/m2/annum of electrical energy needs to be derived from a renewable source.

The Part L standard was first introduced in 2011 and since then new developments have met the standard by incorporating HPs, PV panels and battery storage into their design. This has increased the quantity and types of microgeneration (PV panels and battery storage) and heating demand (HPs) connected behind the meter and not visible to ESB Networks.

As the integration of these Low Carbon Technologies (LCT) increases, decarbonising the sources of electrical energy distributed over the LV network must be a high priority if the targets contained in the Climate Action Plan are to be met. Their usage is likely to be one of the most economic and practical ways to meet Irish decarbonisation targets. The impact on the LV Network is envisaged to be significant as LCTs (such as HPs, solar PV, EV charging points and Smart Electric Thermal Storage Systems - SETS) are connected, challenging how ESB Networks' designs, operates and maintains the LV network into the future. The effect and consequence of the integration of these new technologies on the LV network is not yet fully understood.

1.2 WINTERPEAK PROJECT FORMATION

In order to improve our knowledge of these technologies and to gain visibility of the LV network, ESB Networks initiated the WinterPeak project with the aim of trailing a number of different monitoring devices in order to understand requirements for effective network monitoring. In December 2016, a Project Manager was appointed who set about identifying the issues and defining objectives. Subsequently, criteria for identifying locations were devices could be installed were identified. Trial locations were selected where it was known that LCTs had already been deployed, allowing ESB Networks to assess installation techniques, usefulness, impact and other criteria relating to the new technologies.

In meeting its objectives and conducting trials, the project collaborated with several other projects, particularly where the installation of monitoring devices was deemed to be mutually beneficial. Partner projects included the Dingle Electrification Project, RealValue, RESERVE and StoreNet. This approach afforded cost effectiveness and project efficiency as well as the inclusion of many other perspectives in the assessment of results. The data from these locations has provided valuable knowledge relating to how some of these technologies would impact the network. The trials allowed a refinement of installation techniques and drove improvements to device specifications, all of which was communicated back to manufacturers, leading to improvements in product design, safety and in their ease of use.

The project also sought to act as an enabler for the smart grid of the future, whereby the LV network must also be included as an integral part of the energy supply equation. To do so cost-effectively requires access to improved products and processes that allow monitoring and data capture of system parameters. The products in question are newly developed, small communications-ready monitoring devices.

1.3 BENEFITS REALISED

The project aimed to trial and deliver standardised easy to install MV/LV monitoring device(s) at a low cost, to provide visibility on the LV distribution network (both pole mounted level and unit substation level). One of the main barriers to installing LV monitors had been the need to schedule outages to local network substations or LV circuits to install some models or types of current monitoring devices such as CT's (Current Transformers). The large-scale deployment of the devices, e.g. to a sizeable proportion of ground mounted substations, would experience outages of between 1-2hrs each time a monitor was to be fitted. The cost benefit to installing

LV monitoring devices trialled in the WinterPeak project relates to the time it takes to plan an outage and the number of customers that would be affected. The estimated saving of installing approximately 2000 monitoring devices would be approximately €350k in avoided costs associated with notifying customers and deploying technicians to implement back-feed arrangements. There are potential extra savings (time and cost) to be realised in the event that monitoring will be required on pole-mounted transformers and indoor substations.
The project developed a novel procedure for installing monitoring devices – while the system remains live, without the need to interrupt customer supply. This procedure document developed as part of the WinterPeak project was reviewed and approved in November 2019, all devices trialled throughout the project are noted within the procedure document.

Challenges to installing traditional monitoring devices on a live substation using traditional CT's and Live voltage connections,

- Schedule outages, alerting all customer effected by an outage
- Planning back-feed arrangements, to ensure critical supplies are not affected by an outage.
- Ensure transformer load is transferable by measuring load daily to access transformer load before back-feed arrangements or offloading of circuits can be completed
- Understanding what is required to be monitored
- Limited capability of remote reading
- Space limitations due to the physical size of CT's
- Increased risk when making voltage connections to live busbars within the substation.

Advantages to installing WinterPeak monitoring devices on a live substation,

- No outage required.
- No planning back-feed arrangements, which can be time consuming.
- Real time data available within minutes of commissioning the monitoring device.
- Visibility of an unknown LV network
- Safety benefits from using Rogowski coils Vs Traditional CT's, (Traditional CT's if open-circuited can generate very high voltages, which does not occur with Rogowski coils)
- Safety benefits from using insulated voltage connection clamps which have fuse protected connections integrated within the clamp in GMS
- Safety benefits from specifying a standardised voltage connection lead for all devices used on the WinterPeak project in GMS
- Safety benefits from specifying a test box for the voltage lead, which tests that the lead is connected correctly to the busbars before being connected to the monitoring device.

2. PROJECT SCOPE AND SCOPE CHANGES

The objective of the project trials was to explore a number of differing principles and concepts surrounding effective secondary substation monitoring of the LV network and to record installation and testing methods that would be included in a procedure document for the installation of the devices.

Over the past 3 years the project evolved as we learned more about the LV network and the devices available to us. Initially, the project aimed to assess the impact of PV and EV technologies on the LV network by installing monitoring devices. When the project started there was no monitoring on the LV network and to understand and assess the impact of LCTs on the network ESB Networks had to investigate how monitoring devices could be integrated into the network. To ensure the safe installation of these monitoring devices the project team had to assess installation procedures and safety policies for installing equipment on live systems to identify and eliminate all hazards while installing the monitoring devices. These learnings were recorded and drafted into a procedure document for the installation, commissioning and decommissioning of the devices (see Figure 3).

The ESB Networks Innovation Team worked on several different innovation projects and through collaboration with these projects, MV/LV substations were identified where network data was a project requirement and not available at LV. By installing monitoring devices capable of providing accurate network data the projects were able to use the data to assess the impact of the different technologies installed along with trailing new novel ways of controlling system parameters (see Section 4 for trial results)

The final scope re-stated the overall aim to uncover and understand what issues or difficulties are associated with the deployment of new LCTs and how network monitoring can facilitate this understanding. The project identified the benefit an LV monitoring device would have for the business providing visibility of the LV network, this started the process to access a device that would be suitable for our network.

The project was sub-divided as follows:

- Identification of monitoring devices suitable for use in Irish ground-mounted substations, block-built substations and pole mounted transformers – meaning a flexible solution.
- Trial devices at locations where there is an anticipated or perceived challenge in relation to LCTs already connected.
- Investigate how the data of the devices could be integrated into the business as an exploitable asset.
- Assess the cloud-based data storage solution accessible by project personnel and others.
- Producing a repeatable and safety focused installation procedure.
- Conduct peer and literature reviews and dissemination activities.

3. OBJECTIVES AND MEASURES OF SUCCESS

The objectives of the project are aligned to the scope above and can be summarised as aiming to conduct suitable trials reflective of the challenges anticipated on the LV network and to enhance knowledge and understanding amongst stakeholders in relation to both the impact of LCTs and the capabilities or limitations of the monitoring devices available. A consequential objective was to identify how visibility of the LV network can be used to facilitate LCT integration into smart grids of the future. It was expected that the project would be deemed successful if it identified a set of requirements, rules, standards, platforms and principles that set the foundation for the design and monitoring of active distribution networks of the future.

The project identified 9 objectives, below, that outlined how the project team would identify monitoring devices suitable to trial. Section 8 details how the project met its objectives and the measures of success listed here. The project also aims to conduct or validate a cost benefit analysis using stated assumptions and information obtained in the course of the projects.

The 9 objectives of the trial were as follows:

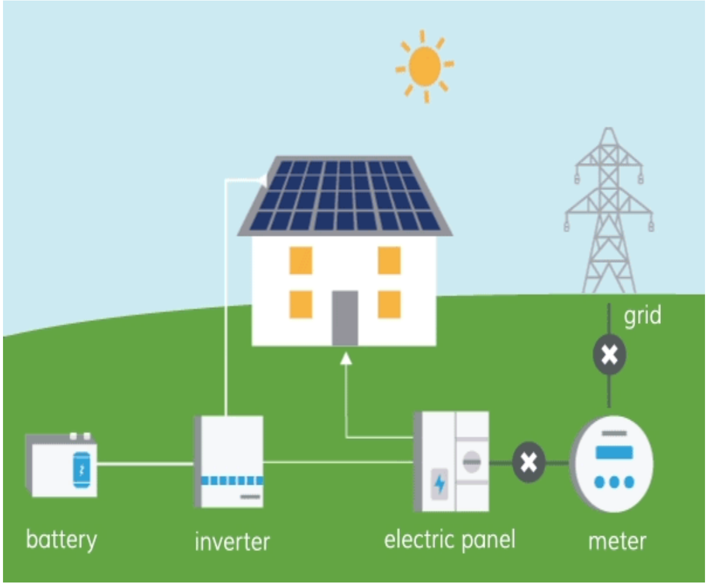
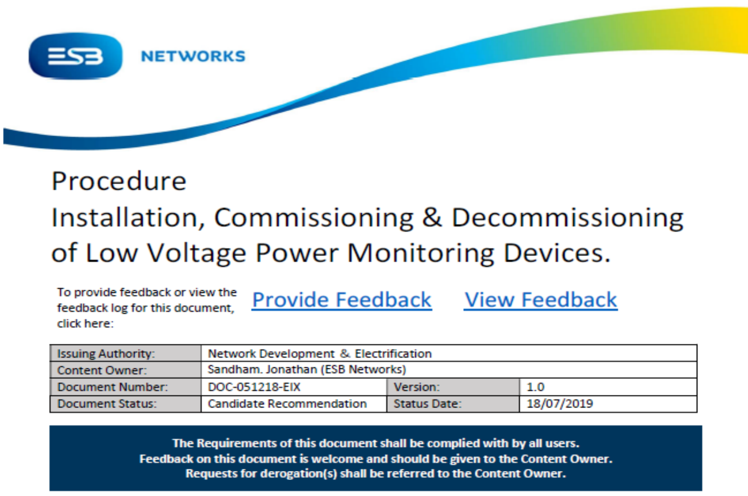


FIGURE 2. LV CONNECTED TECHNOLOGIES

1. To **assess** the techniques and methods for safely connecting devices into the MV/LV substation – which is likely to occur while equipment is live.
2. To identify **standardised** MV/LV monitoring devices so they can be installed consistently and operated by ESB Networks personnel.
3. To **identify** method(s) of efficiently and securely storing the significant quantities of data that will likely result from widespread deployment of monitoring devices.
4. To **understand** the communications technologies available to extract data and to assess how flexible these need to be
5. **Obtain** a greater understanding of the electrical effects of widespread deployment of heat pumps, EVs and solar PV on the LV distribution network.
6. Identify the **monitoring** requirements for LV and assess other monitoring parameters from the following set: - voltage, current, power, reactive power and phase angle of the outlets suppling the trial premises.
7. **Determine** the optimum priority and frequency of data sampling for the visibility of the LV Network.
8. **Review** the total ownership costs of each device / service, including the cost of installation, data transmission and storage.
9. **Produce** an installation procedure documents detailing the installation methods of installing LV monitoring devices onto a live network.

The project identified several Ground Mounted Substations (GMS) in which to trial the installation the monitoring devices. As the project evolved, the requirement for a monitoring device for a Pole Mounted Transformer (PMT) was also identified. Four different devices were trialled throughout the project, each device installed providing learnings, which were reviewed and incorporated into future installations.

The project's measures of success reflect the objectives (see Section 8 Table 2):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Procedure
Installation, Commissioning & Decommissioning of Low Voltage Power Monitoring Devices.

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Issuing Authority:	Network Development & Electrification		
Content Owner:	Sandham. Jonathan (ESB Networks)		
Document Number:	DOC-051218-EIX	Version:	1.0
Document Status:	Candidate Recommendation	Status Date:	18/07/2019

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FIGURE 3. DEVICES INSTALLATION PROCEDURE

1) Assess and trial a number of different devices to identify how to safely install monitoring equipment and determine a set of relevant safety requirements.

   The project team identified the requirement for a standardised and approved method of connection of the monitoring devices within the GMS and at a PMT. The project identified the requirement for a specification for an approved voltage lead that can be installed and connected to the busbar within a GMS. An existing approved method for making connections to live conductors was adopted for connecting monitoring devices on PMT's onto the overhead network. This was trailed and approved as part of the project

   The project team identified a set of requirements for the integration of monitoring devices to ensure that all devices trailed had the option to send or integrate the data to a third-party server, such as Microsoft (MS) Azure platform.

2) Identify a monitoring device that is suitable for MV/LV substations.

   LV visibility is an issue for all DSOs, the network conditions of other DNOs and DSOs are different to the Irish network. We reviewed what other DNOs had implemented on their LV networks and used their reports as reference. Nevertheless, the Irish LV network is made up of a mixture of MV/LV single phase and three phase transformers with metal clad ground mounted substations, making some of the reported LV devices not suitable for the Irish network. Collaboration with different monitoring device manufactures guaranteed that the project was successful in identifying a device suitable for the Irish network.

3) Test, confirm and approve data storage methodologies.

   The data recorded from the monitoring devices was stored on the manufacturer's own server, and available to ESB Networks via the device platform however this increased the cost of the service provided by the device manufacturer.

   The project team along with the innovation team identified the need to reduce this cost associated with storing and gathering data from the devices. Currently the ESB Networks innovation team are investigating the steps required to integrate the data from the devices into an ESB Networks MS Azure platform.

4) Identify and successfully test data communications from devices installed in substations.

   The monitoring devices installed come equipped with a combination of 2G, and 3G technology to communicate back to the manufacturer's server. Initially it was expected that external antennae would be required for monitoring devices installed in GMS, the project recorded that the internal antennae within the monitoring devices were sufficient in the vast majority of locations.

5) Analyse the gathered data and provide an interpretation of results specific to LCT.

   Understanding what parameters should be recorded on the LV network was critical to appreciate how the LV network reacts to the integration of LCTs. The project identified the following parameters as the minimum to be recorded: voltage, current, active and reactive power, harmonics and frequency.

6) Confirm that the identified datasets can be collected.

   Rogowski coil type current pick-ups are used to measure the current on the LV feeders, the project assessed the different methods of how current transformers / Rogowski coils could be integrated safely into a live MV/LV network and provide accurate measurements.

7) Provide a set of lessons learned in relation to the data.

   Through the integration of the MV/LV monitoring devices at the different trial sites ESB Networks learnt how to install and record the data available in the substations and transformers safely and in a timely manner.

8) Assess that monitoring devices can be deployed cost effectively.

   The cost of deploying monitoring devices must include all equipment required to install and operate the devices and systems and the time taken to install the devices on site. Throughout the project the costs of all equipment were tracked to ensure the project had a complete picture of how this project would affect the business, including the following:

   - Time on site to install devices,
   - Monitoring devices,
   - Additional equipment, voltage leads,
   - Licence fees for data storage.

9) Produce an installation procedure to detail how monitoring devices are to be safely installed (See Figure 3 above.)

   The project team developed rudimentary installation guides and wiring job aids for the initial installations but as the request for these devices grew so did the requirement for a fully-fledged and approved business procedure document which would detail the installation, commission and decommissioning of the devices. The project team developed a comprehensive procedure document detailing how to safely install the monitoring devices onto a live network. The procedure document produced by the WinterPeak project team has been briefed to the field engineers installing the devices.

4. RESULTS

At the closing of the project at the end of April 2020, 33 monitoring devices had been installed in a variety of different substation types, (single phase and three phase PMTs and GMSs). The installations were located where LCTs are also present and where there is a mixture of LCTs installed. The trial locations were in counties Kerry, Dublin and Galway. As mentioned in the previous section, when experience was gained in the installation of the monitoring devices, a procedure document detailing the safe, consistent installation, commissioning and decommissioning of the devices was developed. The document has been briefed to installation crews, with particular emphasis on safety and how the equipment can be installed without the need for substation outages. Throughout the project installation times were reviewed, as were installation methods and costs of each device to understand the financial impact of their installation. The ability to install equipment without a power outage, improves both customer experience and acceptance of the new technologies.

The project notes that monitoring devices can provide rich real-time network data. In many cases, the monitoring devices identified serious issues with the quality of the supply, which local NT's and supervisors were unaware of. In most cases, device suppliers offer a cloud solution allowing data to be securely stored and easily retrieved. Data was analysed to improve the understanding of energy demand at the trial locations. While the possibility to continue to use the cloud solution remains, a project recommendation is to stage the data on an ESB Networks IoT platform. This approach has the potential to reduce overall cost, facilitate access to the data by the broadest user base and to allow it to be provided easily to stakeholders. A range of different monitoring devices were assessed and installed at various trial sites allowing the project team to make comparisons between locations.

FIGURE 4. GROUND MOUNTED SUBSTATIONS

Each device trialled had its own pros and cons which were noted as, our experience with various devices increased and as the devices were deployed. All devices provided real time data; although essentially the same data, it was represented differently on each platform. Figures 5, 6 and 9 are sample images of the data available from the platforms available to ESB Networks throughout the trial. This provided the project with an understanding of requirements for any in-house platform that would integrate all the data from the various devices and sources. The development of this platform was outside the scope of this project, however, the learnings obtained are available to developers.

4.1 REALVALUE PROJECT COLLABORATION

The first installation of an real time MV/LV monitoring device capable of remote reading on the Irish LV network was installed as part of the RealValue project, this early installation, allowed ESB Networks to begin to develop the optimum method for installing the monitor devices in a safe and efficient manner. The RealValue trial location selected was where there was existing Night Storage Heating (NSH) installed in an apartment complex and housing development, the NSH systems were upgraded to Smart Electric Thermal Storage Systems (SETS). SETS adapt their charging of stored heat to match owner lifestyle and prevailing climate conditions, delivering heat only when it's needed. The monitoring of this resistive load provided a contrasting data set to those locations with HPs as there were no reactive power or harmonics issues at these locations as a result.

The WinterPeak project, the subject of this report, provided and installed monitoring devices at two locations identified by the RealValue project, the aim of which was to:

- Understand the potential of controlled switching of restive loads on the LV network to contribute to overall grid stability
- Provide a system service utilising the heating load available in dwellings.

1. Location 1 – 39-unit, residential housing development with storage heating.

   Trial site 1 was a housing development where 39 dwellings took part in load shifting trial. The housing development was supplied from two 400kVA DV (Dual Voltage) GMS. A monitoring device was installed into each GMS to monitor the planned load shifting trial, where all the storage heaters in the development were switched on within an agreed timeframe. The total heating load being switched at trial site 1 was approx. 58.5kW. The substation was monitored during the switching trial to assess the impact of the increased load on the transformer. The data recorded during the load shifting trial showed that the increased load on the circuits did not breach any of the transformer or feeder circuit limits. The captured data demonstrated the capability of the monitoring devices to provide real-time data and record it for subsequent analysis.

   The graph below in Figure 5 shows a typical night storage load switched on, the graph indicates the increase in current on the LV feeder circuit supplying the housing development over a 24-hour period. It also shows how the load is distributed over the three phases, the feeder current increases to a maximum of 150 amps on one phase of the 3-phase feeder during the night storage switching and the average current on the feeder under normal conditions is approximately 40 amps.

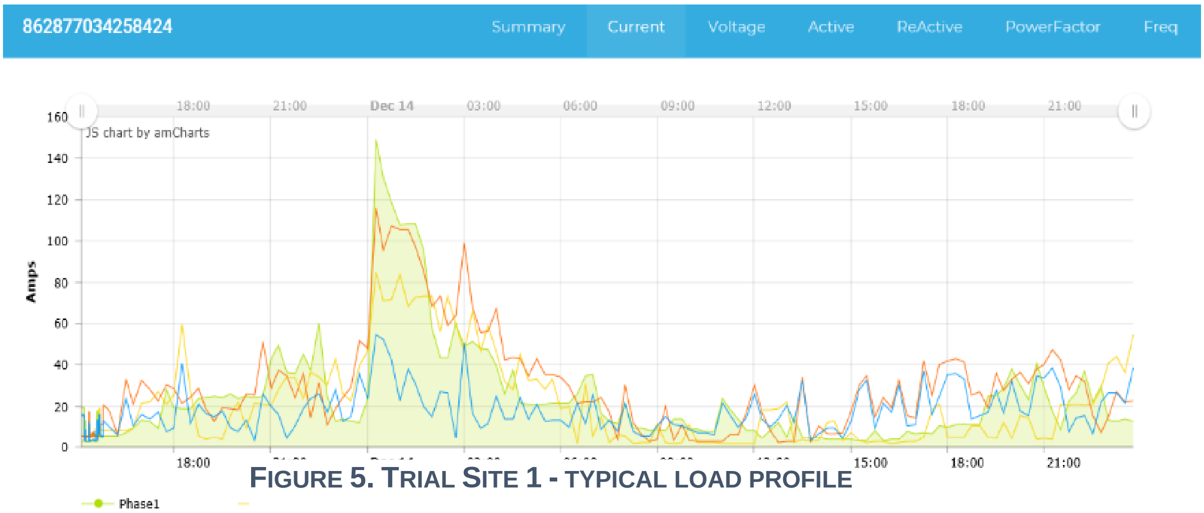

FIGURE 5. TRIAL SITE 1 - TYPICAL LOAD PROFILE

2. Location 2 – 50-unit elderly housing complex with storage heating.

   Trial site 2 was a housing complex of 50 apartments for the elderly, each apartment had storage heating that was upgraded to the SETS as part of the RealValue project. The complex was supplied from a 400kVA DV GMS, a monitoring device different to the one installed at trial site 1, was installed into the GMS to assess the installation methods. Load shifting trials were planned in the complex similar to trial site 1, there was an available heating load of 75kW for the switching trial. Data successfully recorded during the trial showed that the increased load did not breach any of the transformer or feeder circuit limits.

The graph below, Figure 6, shows the recorded data under normal conditions where night storage heating switches on between the night storage hours of a single typical night. The data recorded from the monitoring device graphed below indicates that the load on this LV feeder is not distributed evenly over the three phases of the feeder – a specific insight that would not be known without MV/LV monitoring. The graph shows that the load on T phase (mustard) is not balanced compared to the R and S phases and the S phase (teal) tails off in the early hours compared to the other two phases. This could be a result of some of the apartments switching off the heating load to reduce their energy bills. Separately the behaviour aspect of the complex was researched as part of the RealValue project.

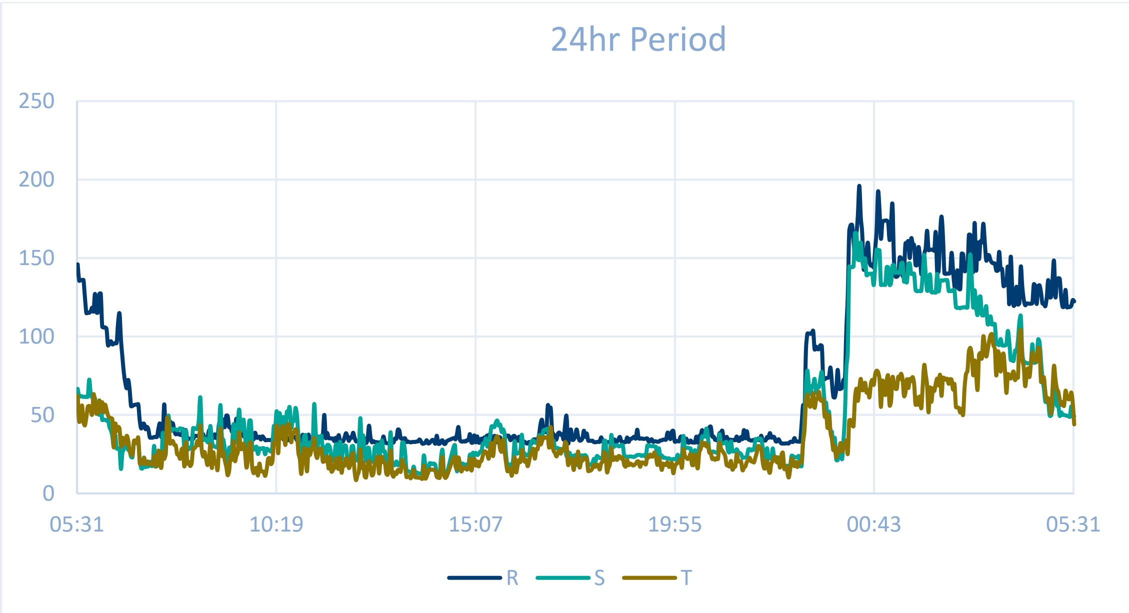

FIGURE 6. TRIAL SITE 2 - MONITORING DEVICE SAMPLE DATA

The RealValue Project demonstrated how local small-scale energy storage could be optimised to bring benefits to the electrical market and the customer, while investigating how to provide a solution to DR at LV level and allow energy users of all kinds to act as “Virtual Power Plants” (VPP). The monitoring devices performed reliably at both locations allowing the project team to compare the outputs of the different devices installed. The RealValue project used the data to model the impact of the SETS on the local LV Network to simulate a demand respond service.

The RealValue report detailing the project trials and learnings can be found on ESB Networks innovation projects under [Flexibility on Our Network](#).

4.2 RESERVE PROJECT COLLABORATION

ESB Networks involvement in the Reserve project sought to evaluate the provision of system services to the local distribution network using technological innovations associated with inverter-based Demand Energy Resources (DER). The WinterPeak and Reserve projects collaborated to collect data from locations where DERs were installed and to employ data analytics to assess their impact on the local distribution network.

Again, there were two trial sites where monitoring devices were installed to analyse the various data and evaluate device installation methods. The Reserve project trialled two different technologies to investigate voltage control using inverters.

1. Location 1 – 7.28kW, PV installation.

   In trial site 1 a new monitoring device was installed in a 400kVA DV indoor MV/LV substation to investigate voltage control using inverters from the PV system. The monitoring device was successfully installed on the LV disconnects which supplied an LV distribution board, providing the project with a new installation method. The PV project involved installing two strings containing 14 modules providing a total of 7.28kW, the PV inverters where controlled remotely by the Reserve project team to investigate if the voltage could be improved by altering the active and reactive power from the PV system. The substation was monitored during the project to understand the impact of the PV on the local LV network. This trial also served to facilitate the deployment of a new monitoring devices that could validate the data recorded on site in real time and the projects monitoring and control platform.

Figure 7. PV Installation at ESB Networks Training Centre, Portlaoise

2. Location 2 – 10kW Vehicle to Grid (V2G) charger installation.

As part of the Reserve project, a Vehicle to Grid (V2G) charger was installed, the objective of which was to assess the system's potential to impact voltages at local level and to test the concepts of voltage control and system controls developed.

A monitoring device was installed into the V2G charger in order to understand the impact on the local network as the car battery charged and discharged. The installation of the monitoring device allowed sufficient amounts of data to be collected to allow for charging and discharging profiles to be graphed and analysed.

Monitoring revealed no significant impact on the LV network, though the Reserve project successfully evaluated the control systems involved and this is reported separately by the Reserve project.

Figures 9 and 10 graph the available data from the V2G charger which was gathered by the monitoring devices installed. Figure 9 shows the load increase as the V2G charger is operated and Figure 10 shows the charge for the car's battery discharging and exporting onto the local grid.

FIGURE 8. V2G INSTALLATION

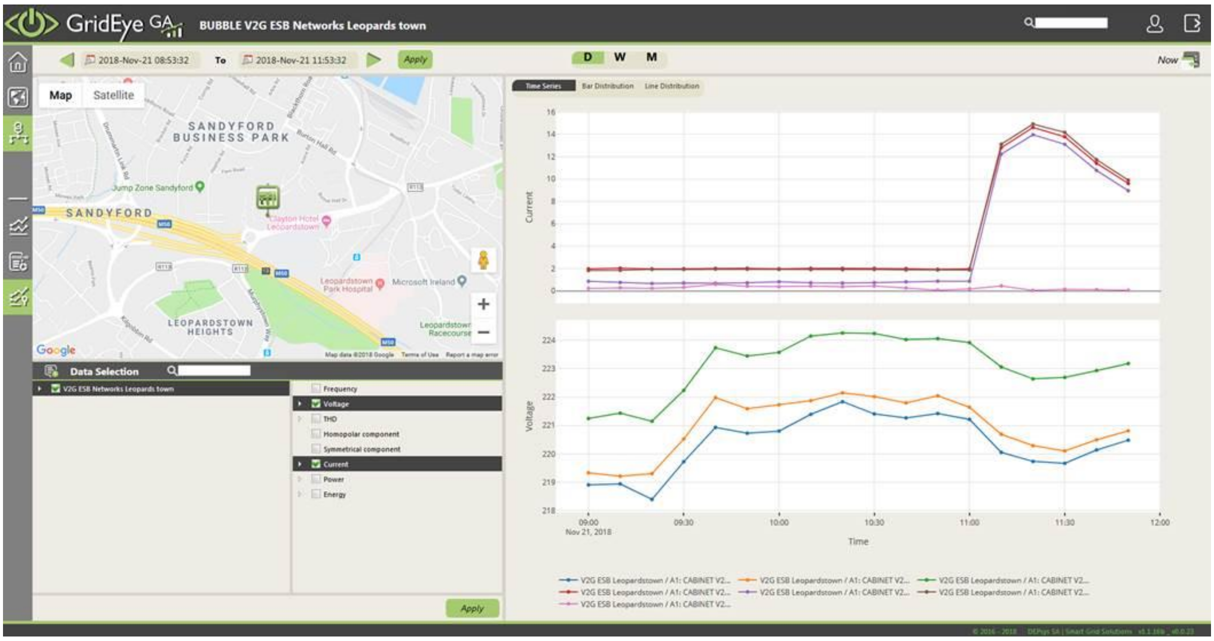

FIGURE 9. DEVICE DATA, V2G CHARGING AT 8.8KW

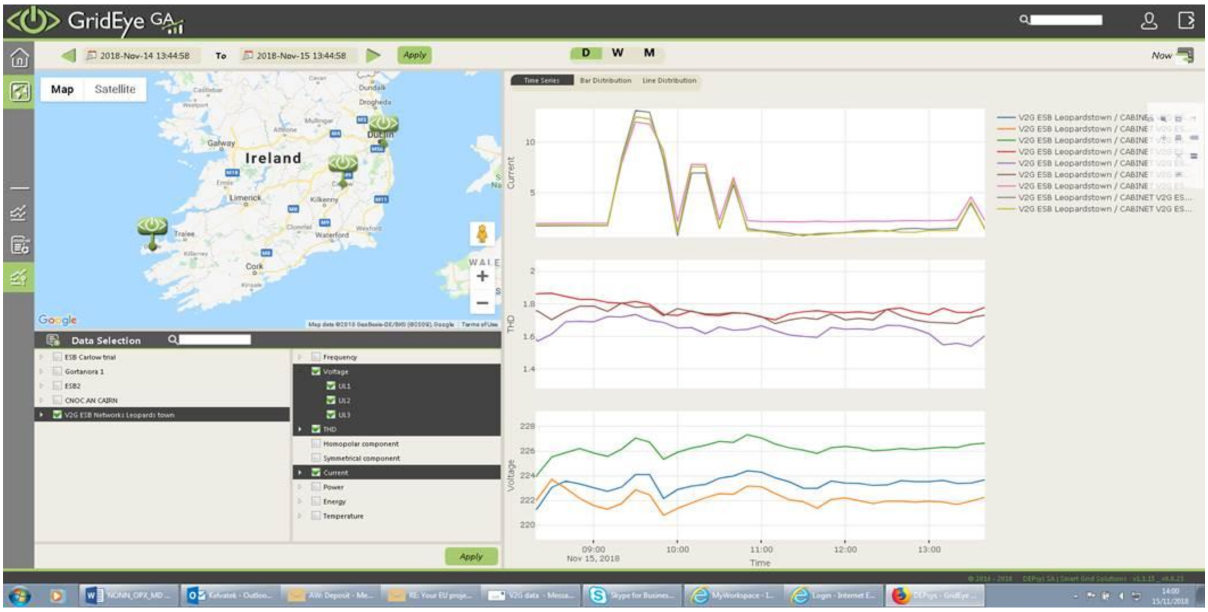

FIGURE 10. DEVICE DATA, V2G DISCHARGING AT 9.6KW

The Reserve report detailing the project trials and learnings can be found on ESB Networks innovation projects under Flexibility on Our Network.

4.3 POLE MOUNTED TRIAL SITE - DUBLIN

As part of the Building Regulations, new houses must have a Building Energy Rating (BER) which is based on the overall energy efficiency of the building on a scale of A to G, with A1 being the most energy efficient rating possible. ASHP and PV panels are installed into new homes to provide greater energy efficiency, thereby improving the property's energy rating.

The WinterPeak project was asked to investigate an issue in a housing development in Dublin, where there are 11 houses, each fitted with 8kW heat pumps connected to a single phase 33kW pole mounted transformer, with some houses having EVs adding to the demand on the local network. The housing estate had experienced a few outages resulting in the 33kW PMT having to be replaced due to suspected damaged by overload. However, the estate experienced more unexplained outages. It was assumed that the load on the LV feeder was higher than expected so the transformer was up rated to a 66kW (2 X 33kVA transformers connected in parallel) , it was at this stage that a monitoring device was installed to understand what was happening to the LV network.

The site met the criteria for a trial site with the installation of ASHP and EVs on the network, this site was the first site to identify the requirement for a pole mounted monitoring device and was where the first installation of a monitoring device at a PMT occurred. In order to fit the devices, a prototype enclosure was developed by the project that housed the equipment securely and safely while allowing communications to be established with the equipment within. The prototype installation developed as part of this trial has now been fully developed and is now a produced product by the manufacturer, with 32 PMT monitoring devices installed on the LV network using this design as of August 2020.

FIGURE 11. POLE MOUNTED TRANSFORMERS

There are approximately 230,000 Pole Mounted Transformers, of which approximately 180,000 are single phase transformers, on the Irish network. The successful deployment of this initial PMT monitoring device in the Dublin trial site reinforced the requirement for a monitoring device suitable for PMT installations at other trial sites. The learnings gained from this installation were recorded and were incorporated in the procedure document, which dealt with the installation, mounting the devices on the pole and connecting the device, which is powered by voltage supplied from the overhead network and commissioning. These steps were included in the procedure document in greater detail and briefed to the teams installing the devices.

4.4 DINGLE ELECTRIFICATION PROJECT COLLABORATION

The Dingle Electrification Project comprises of a cluster of different trials in the Dingle Peninsula where different LCTs (ASHPs, PV panels, battery storage and controllable switches) are installed at the LV level. The results from the project will support investigations into what the future electricity network will look like with increased integration of LCTs and will examine the impact of renewables, battery storage and greater use of electricity for heat and transport.

Within the Dingle Peninsula there are 5 different trials where different LCTs are installed, to understand and gain experience of these technologies. The Dingle Project has installed monitoring devices on the LV network in both PMT and GMS to understand the impact of the LCT integration on the network and to investigate the new PMT monitoring devices that was deployed.

The installation of these devices assisted the WinterPeak project with the understating of what data would be required from each trial site. Previous monitoring device installations identified the data required from ASHP and PV installations, the Dingle Project introduced this project to battery storage and the data that should be recorded at these sites. Each monitoring device records the same set of parameters voltage, current, active and reactive power, harmonics and frequency, providing an understanding of the LV network that did not exist previously.

On the Dingle peninsula, there are approximately 1229 pole mounted transformers providing that project with the opportunity to deploy monitoring devices on different types of transformers (different ratings). As of August 2020, there were 27 PMT monitoring devices installed and 4 GMS monitoring devices installed throughout the Dingle area network.

As part of the Dingle Project it is also planned to integrate the data from the monitoring devices into an ESB Networks IoT server. The development of this server will then follow on from the Dingle Project.

4.5 STORENET PROJECT COLLABORATION

ESB Networks involvement in the StoreNet project is to validate the performance of domestic behind the meter battery energy storage on the LV network. This project was a collaboration between ESB Networks and other partners such as the International Energy Research Centre (IERC), Solo Energy and Electric Ireland. The aim of this project is to investigate if the adoption of such battery storage can be used to smooth generation and consumption peaks to increase the energy carrying capability of our network and reduces network losses while developing a "Virtual Power Plant" (VPP) system with the batteries. The project sought to answer if the addition of this storage could add flexibility and reinforce the network by allowing for additional renewable generation to be connected in the future, ensuring that losses are limited and monitoring and controlling the power quality produced (as well as the voltage and reactive power).

The project was deemed to be a suitable candidate for the WinterPeak monitoring devices as the project was tasked to deploy monitoring devices suitable for PMTs at 18 locations, with a mixture or single phase and three phase transformers. WinterPeak devices were used to monitor the impact on the network of using behind-the-meter battery storage as the batteries charge and discharge at certain times during the day. While most devices deployed on PMT's are Single Phase devices, the StoreNet project had a requirement to monitor three phase PMTs, a prototype was developed and installed in two locations, the learnings from these two devices where carried on for other three phase devices that were required. The monitoring devices were installed using the guidelines from the procedure document,. This project is ongoing, and the learnings will be documented for ESB Networks.

5. LEARNINGS

The learnings that were possible by sharing trials with other projects are noted above. Overall WinterPeak project learnings facilitated an understanding for the future needs and requirements of the LV network as LCTs are connected in increasing number, specifically:

1. The cost of monitoring equipment and their value has been assessed – see 'Device Costs' Section 5.1 below.
2. Significant knowledge gained in relation to the nature, type and periodicity of data needed for effective network monitoring has been gained – see 'Communications' Section 5.2 below.

3. The capabilities of network monitoring devices and systems are understood – elaborated upon under the 'Device Functionality' Section 5.3 below.
4. In the future, domestic premises can play a part in Demand Side Management (DSM) – through aggregators – enabled by having data available from the LV network.
5. The challenges associated with the installation of the monitoring devices have been understood and a method for their safe and cost-effective installation has been issued. As part of the project a procedure document has been produced and approved and is used in all trial sites, the procedure document details the installation methods to all devices trialled during the WinterPeak project. The project team completed 2 official workshops where the procedure document and device functionality were briefed to all ESB Networks technicians working on the trial sites.
6. Technical specifications and operational requirements needed by ESB Networks personnel have been identified during many informal consultations with field-based NT's. This ensured that the product and the direction which the procedures were taking remained on track. The results of these, and other consultations have been incorporated into the procedure
7. Specific use cases, as described in this report, have been examined in detail and understood. There of course are many more use cases, but this report provides as an informative guide to the trials and the technologies assessed throughout the project, a list of proposed future use cases for MV/LV monitoring is found in Section 6.

5.1 DEVICE COSTS

The total cost of deploying monitoring devices must include all equipment required to install and operate the monitoring devices and systems. The time taken to install the devices on site must also be factored in. Throughout the WinterPeak project the cost of all equipment was tracked to ensure the project had an accurate representation of how this project would affect the business, including licence fees and data storage. If monitoring devices are to be deployed at large scale on the LV network, the total cost of the device will be a considerable factor in a DNO opting for LV monitoring. Such costs will include;

- Cost of device
- Cost of additional equipment
- Cost to install on a live network
- Cost to access data

With approximately 250,000 MV/LV substations throughout Ireland it is easy to appreciate that the cost of purchasing a monitoring device could impact the decision to deploy the technology. Although it is not envisaged to install monitoring devices at all MV/LV substations, it would be ideal to focus on substations where ESB Networks see constraints emerging on the LV due large integration of LCTs or have predictions where the uptake in these technologies will likely be installed.

Identifying the cost of network monitoring devices proved challenging as there is a significant range of devices available, further complicated by the multitude of add-on services offered by suppliers. The WinterPeak project noted that devices are priced, broadly according to the applications and capabilities of each. Those monitoring devices that allowed harmonics measurements to the 50th harmonic and beyond – to recognised standard(s) – tended to be the most expensive, though still cheaper than full PQ (Power Quality) meters. In general, the project found that most network monitoring needs are met by those devices capable of providing the 'basics' – voltage, current, frequency, active and reactive power.

Given this basic set of requirements, the project was able to source monitoring devices that cost approximately:

Monitoring device type	Approximate cost
Voltage monitoring only	€300
Single Phase (e.g. 1-ph PMT)	€600
Three Phase (e.g.3-ph PMT)	€650
4-feeder, 3ph (e.g. GMS)	€850 - €2735

TABLE 1 - MONITORING COSTS

There are additional costs in relation to the provision of data capture and storage services. Most suppliers provide this service on a per-device licencing basis and the project experienced costs averaging up to €800 per device per year. These costs can be managed more effectively, if ESB Networks internal IT systems were to be employed. The development of an ESB Networks IoT platform integrating into MS Azure IoT hub is currently underway.

5.2 COMMUNICATIONS

The project found that most device providers use 2G or 3G technology to facilitate the transmittal of real time data to and from their devices. Other options for transmitting the data included Ethernet connections (Ethernet connections s are not available in the ESB MV/LV substations), The project did not trial LoRaWAN or Sigfox communications methods as it was envisaged that the amount of data required to provide real time information would be excessive for these communication technologies. None of the devices offered by any vendor had the option of using either of these platforms as methods for data transmission from the devices trialled.

The project noted that antennae used for communications could pose difficulties:

- Indoor substations – usually located in the ground floor of offices / shopping developments / apartment blocks where the ability of the signal to penetrate steel and concrete resulted in a weak service. Mounting outdoor antennae (which all devices facilitated) often improves signal reception.
- Ground Mounted Substations – located outdoors and in public areas, if external antennae were required, they would have to be mounted outside on the GMS. This would drive the requirement for drilling the GMS which ESB Networks prefer not to do, it could also draw attention to the GMS for antisocial behaviour. The project noted that the internal antennae within the monitoring devices were sufficient once the signal in the area and location was strong.
- Pole mounted installations – transformers are located on a pole with the monitoring device enclosure mounted under the LV network. The location of the monitoring device, high up on a pole and within a fiberglass enclosure meant that communications to these devices was very reliable.

The project did not trial 4G and 5G communication methods as device capability was not available for the trials. The project identifies that suppliers may need to integrate 4G and 5G technology into their devices in the future.

5.3 DEVICE FUNCTIONALITY

Enclosure

During the trials, the WinterPeak project identified a set of basic standards for ESB Networks monitoring devices These standards will form the basis of a technical specification. Whether a monitoring device is installed in a substation or a pole mounted transformer the standard criteria for measuring feeders and form factor of the device are similar. The devices will be installed in a mixture of block built and metal-clad GMS and within an IP (Ingress Protection) rated enclosure suitable for PMTs, highlighting constraints in each installation. The monitoring device will be specified to have a form factor suitable to fit into the full range of existing GMS (older substations often have limited space) and ideally the device should be easy and quick to install.

The project identified the requirement for magnetic fixings for the devices in GMS eliminating the need for using drills or other time-consuming fixings, reducing the installation time which is a factor when installing multiple devices on the network. Equally a monitoring device installed on a pole must be suitable for its enviroment, the device must have a minimum rating of IP65 or installed within an IP 65 rated enclosure that can be mounted on a pole. ESB Networks developed a prototype for the PMT installations during the project, this prototype provides learnings to the project to acceptable assets to be installed on the network.

When installing monitoring devices in a GMS, the device is attached using strong Ferrite magnets to a suitable adjacent interior surface within the Substation, all of which are bonded to the MV earth. The MV and LV earths are normally seperated to prevent an MV fault from becoming imposed on the LV. The project identified a possible risk of inadvertently bridging the MV and the LV earths through the neutral conductor in the voltage lead used for connecting the monitored LV voltage. For this reason we concluded that the monitoring device enclosure needs to be double insulated or otherwise capable of providing isolation from the MV earth. If the device enclosure is fabricated from a conductive material which requires an earth connection, there is the risk that an MV fault could cause a rise in potential on the LV circuits fed from the substation if the devices are not electrically isolated from the MV earth. This issue was identified by the project team at an early stage and this recommendation was implemented at all trial sites.

In accordance with safety policies all devices installed as part of the WinterPeak project comply with international electrical and safety standards and suitable for the enviroment that they will be installed in. All devices have been tested independantly by each manufacturer before any installations on the Irish network.

Voltage leads

Each monitoring device requires a supply from the transformer which is being monitored In a GMS the devices require a 3 phase supply from the LV busbar. To ensure there is a standardised approach to connecting onto an LV busbar, ESB Networks colaborated with a vender to produce a standard voltage lead which will be installed at each GMS. Developing a standarised connection method brings quality control and flexibilty for different devices that can be deployed in the substations. Figure 12 shows the voltage lead, the lead is double insulated, it is terminated at one end to banana plugs which connect to colour-coded Drummond G clamps (shown in Figure 13) and a Female Harting plug on the other end of the voltage lead. All monitoring devices for use in GMS are fitted with a corrosponding Male Harting plug. The Drummond G clamps provide a universal and safe method of connection onto the live LV busbar. These clamps have integral fuses at the point of contact with the Busbar for each of the phase connections.

These fuses are rated to protect the monitoring device, including the connecting voltage lead. Note; fuses are not included in the Neutral or Earth connecting clamps. The monitoring device is powered from one of the monitored phase voltages and is connected internally within the device. ESB Networks will specify that all devices supplied shall have the male Harting plug connection, to provide a standardised connection to the substations.

For ESB Networks a standard voltage lead using the Drummond G clamps and the Harting plug provides us with:

FIGURE 12. VOLTAGE LEADS FOR GMS

- Quality control,
- Easy reliable connections,
- Colour coded for phase identification,
- Drummond G clamps mean no tools are required for connectiong onto the live busbar.

Monitoring devices for use on Pole Mounted Transformers require a voltage connection to the overhead network. To install a monitoring device at these locations the voltage connection is made on the load side of the Black Box fuse unit. This connection is done by using Insulation Piercing Connectors (IPC) which are widely used on the network by ESB Networks.

FIGURE 13. FUSED DRUMMOND CLAMPS

Measuring Equipment

The monitoring devices are intended to be installed at a live substation.While working at and installing equipment in a live substation all possible risks and hazzards have to be identified and control measures are to be introduced to reduce the risks to an acceptable level. This includes making the connections to busbars for the voltage for the devices and fitting the current pick-ups to measure the power on the feeder or transformer. The data recorded from the monitoring device includes the voltage and the current from each phase of the feeder and or the transformer, along with other parameters. The current is measured with the use of Rogowski coils.

Rogowski coils are a type of Current Transformers (CT) that are flexible and come in a range of different sizes and can be easily installed onto a live feeder or LV busbar, using the correct installation procedures. Rogowski coils have the distinct advantage over traditional CT's as they can be open circuited on the secondary side safely as the output voltage is a millivolt repersentation of the output being monitored. This also has the advantage that the Rogowski coils can be disconnected safely from the device while in service. Rogowski coils reduce the need to have an outage of the substation, to disconnect the feeders, install the CT and re-connect the feeder, which would have been required if traditional CTs were to be used. The WinterPeak project identified the requirement to measure all phases of a feeder (RSTN) within a substation, this will be included in the future specification for a LV monitoring device. More than any aspect of the trials conducted, the project felt that it is the use of these Rogowski Coils that enables the widespread adoption of low-cost monitoring of the LV network.

The use of traditional split core CTs in a live substation is not ideal as they have to be hard wired into the substation, and for this the substation would require an outage. Traditional CTs when open circuited have large voltages transferred onto the secondary side, leading to a serious risk of injury to the installer and the equipment.

FIGURE 14. ROGOWSKI COILS

Figure 14 shows three different substations installations where different Rogowski coils were installed. Two types of Rogowski coils trialled during the project, LEM 4 LEM ART-B22-L coils, and the GW100 coils. The two coils provide the project flexibility at installations for indoor or outdoor use and feeder conductor size. The LEM coils used had an output voltage of

22.5mV/kA, and rated for 1000V, 1500Amp (rms), with and accuracy class of 0.5 (IEC61869-2). The LEM coils were installed in indoor GMS and were suitable for measuring the LV cables from the transformer and the LV feeder outlets. The LEM coils trialled during the project are IP57 (Ingress Protection) which meant they were not suitable for outdoor substations as the coils may have been damaged if exposed to the different elements of the Irish weather. Rogowski coils with an IP rating of IP67 or greater are suitable for indoor and outdoor installations and have an output voltage of 100uV per Amp (e.g 0 - 1Vac RMS for selected current range) with an accuracy class of 0.5. The GW100 coils trialled during the project are IP68 which meant they were suitable for both indoor and outdoor installations. Both LEM and GW100 coils are suitable for MV and LV distribution networks.

Advantages of Rogowski coils over traditional methods of current measurement:

- Quick and easy to install
- Intrinsically safe with no open circuit secondary voltages
- Light-weight and flexible

6. NEXT STEPS – BAU, TRANSFER OF OWNERSHIP

The WinterPeak project has identified the benefits of LV visibility to the business. This has been diseminated through workshops and presentations. The installation of the monitoring devices onto the LV network requires a level of safety and knowledge of the equipment and the enviroment that the devices are being deployed in, for this reason a procedure document detailing the safe, consistent installation, commissioning and decommissioning of the devices was developed and shared. The procedure document is available to all field technicans installing the devices and has been briefed to installation crews, with particular emphasis on safety and how the equipment can be installed without the need for substation outages.

Disemination of the project and learnings is an important stage for the project. In March 2020 there were two workshops held with the field engineers from the trial locations in counties Kerry and Dublin. The focus of the workshop was to bring awareness of the devices and what the benefits the project could bring to the business and the field engineers. During these workshops feedback was received from the field engineers who deployed the devices in the trial period. The feedback on the devices was positive as the devices provided the field engineers with real time LV data that was not available previously. Additional future use cases were identified for the integration of the LV monitoring devices during the workshops. These use cases are listed below. It is envisaged that there will be many more use cases when the benefit of LV monitoring is fully understood by other field engineers outside of those involved in the trial sites and it is envisaged that LV monitoring devices will be increasingly installed as BAU where LV data is required. These future use cases have been shared with other delivery teams within the business.

Workshops	Future Use Cases
Awareness	Mobile PM Device
Dissemination	Transformer Capacity
Manufacturer support	Voltage complaints
Feedback	Assessing LCT's for DR

Furthermore, in April 2020 the WinterPeak project and results were presentated to the business to bring awareness of the project and to ensure an understanding to the benefits LV monitoring can bring to the LV network and the operations of the system.

There were many benefits of LV monitoring to the business which wereidentified in this work:

- **Real time data** – Understanding the current and voltage of the networt at a given time can assist network technicans with desgns for new connections, fault hunting after an outage, off loading feeders and maintanance of the network.

- **Monitoring of the network** – The devices that have been deployed have been used during storms to assess the network along with data from the HV network from SCADA and OMS to understand where outages could be minimised by operating controlable devices on the network and connecting customers back.

- **Continuity of supply** –The ability to identify outages before a customer complaint. Future developments of devices could provide a "last gasp" function which alerts the network operator that the device has lost its supply. At present if the device looses supply there will be no data recorded, changes to the algorithms used and the alerts issued could see outage alerts sent to network operators.

- **Flexibility of the network** – As more LCTs are intergtrated onto the LV network there is the potential to create a demand response scheme where HPs , EVs and immersion heaters participate in controlled operations to either reduce demand on the grid at peak hours or to provide load when generation is high but load is low.

- **LV vision and topology** – Monitoring devices along with smart meter data can provide feeder and phasing identification at the MV/LV substation. Some monitoring device platforms have applications that can send a pulse signal to the LV customer smart meter identifying the phase the customer is connected to. Identifying the phasing of the LV customers will assist LV designers with knowledge of any phase imbalance and capacity for further connections. The phasing data along with the transformer data will allow ESB Networks to assess any losses and identify phasing of the LV customers.

In conclusion by the end of the project, the benefits of the monitoring devices had been noted and relayed to the business, particularly the operations sections and within this there have been requests to install a further 38 devices. The learnings gained from the project will assist the business with the production of a technical specification for a LV monitoring device in the future. This technical specification will assist with future specifications and tenders for LV monitoring and may be included in an overall MV/LV and Power Quality specification. A draft functional specification and scoping document have been prepared with the details of all materials and devices used throughout the WinterPeak project.

Technical specification will provide detail requirements for the following which have been trialled as part of the WinterPeak project,

- Measurand requirements – voltage, current, etc
- Communications
- Enclosure
- Voltage leads
- Measuring equipment

The knowledge and learnings gained from the project has enabled a broader based project to be initiated and fed into, which is the 'LV Readiness Project', one of a number of transformation projects being rolled out across ESB Networks.

7. RECOMMENDATIONS

The WinterPeak project recommendations centre around the continued development and deployment of monitoring devices to the benefit of the customer and network.

1. Recommendation 1: to stage data collected from network monitoring activities on ESB Networks IoT platforms.
    - Given the cost of hosting data on 3rd party platforms, this approach has the potential to reduce overall costs, facilitate access to the data by the broadest user base and to allow it to be provided easily to stakeholders. While it will be necessary to develop a 'front-end' for the data, this has been achieved by other applications wishing to leverage ESB Networks flexible IoT hub solution using MS Azure.
2. Recommendation 2: to handover and ensure progression of the use cases that came to the WinterPeak project's attention prior to its close.
    - These use cases provide further opportunity to monitor the network for specific applications allowing the potential of monitoring devices to be further tested. The additional advantage in this approach is the promotion and take-up of the solution amongst network technicians and engineering personnel in need of solutions to issues they observe.
3. Recommendation 3: the project is aware that Smart Meter data will become available to personnel suitably authorised to access it in the coming years.
    - Until this data becomes available, ongoing support for network development and integration of LCTs on a feeder-by-feeder basis will be needed and the use of monitoring devices can provide a cost-effective means of facilitating this objective. To support this, it is recommended that a stock of monitoring devices be held in stores for use by technicians, project managers, planners and others as a means of supporting the widest array of requirements. The issuing of the devices from stores should be accompanied by the Installation Safety Procedure developed by the project.
4. Recommendation 4: to promote the use of cost-effective network monitoring equipment amongst other innovation and non-innovation projects throughout the business.
    - The WinterPeak project identified a range of network monitoring devices with attendant software suitable for a range of requirements and applications. It is likely that devises to suit many of the projects currently ongoing or proposed are available.

8. FINAL TIMELINES

When the project began in Q4 2016 it was anticipated completion by Q4 2019. The over-run of the project to April 2020 was due in large part to increasing enquiries from the business for their use cases to be included as part of the WinterPeak trials. Some of these requests were met and are reported on in this final document. If the project was to continue to be extended further to the end date of April when WinterPeak was concluded, a fuller and more comprehensive set of use cases could in that scenario be presented.

Project Objectives		
1	Assess and trial different monitoring devices to provide a set of requirements for ESB Networks.	✓
2	Identify a monitoring device suitable for ESB Networks MV/LV substations.	✓
3	Test, confirm and approve data storage methodologies.	✓
4	Identify and successfully test data communications from devices installed in substations.	✓
5	Analyse the gathered data and provide an interpretation of results specific to LCT.	✓
6	Confirm that the identified datasets can be collected.	✓
7	Provide a set of lessons learned in relation to the data.	✓
8	Assess that monitoring devices can be deployed cost effectively.	✓
9	Produce procedure document.	✓

TABLE 2 - PROJECT OBJECTIVES

Table 2 highlights the project's objectives and indicates that the objectives were met throughout the trial sites.The installations and findings detailed in this final Close-Down report provide sufficient evidence of the usefulness of LV monitoring devices without the need for further extensive demonstrations.

The WinterPeak project met its objectives and measures of success while also,

A. The project team has informed the business of the results and lessons learnt from the project along with the benefits of real timevision and real time data available from the devices installedthough workshops, presentations and colaboration with other business units.
B. New business cases arising from the workshops have identifed more opportunities for the use of LV monitoring on the network.
C. The results have been fed into the LV Readiness Project, while also informing the business of the benefits to having LV vision and real time data available from the devices installed.

9. FINAL COSTS

Costs associated with the project were in the form of project personnel time and expenses, and the procurement of monitoring devices and associated software and costs associated with device installations. The devices trialled underwent technical approval for the collection and the intergration of the data.

Final project costs are expected to be €95k, dependent on receipts of outstanding invoices. The project budget was €85k, and the over-spend primarily relates to the decision to retain licencing for monitoring device software for an additional year during the period of the project.

If you would like further information/data from this project, please contact us at innovationfeedback@esbnetworks.ie