Scottish and Southern Energy
Power Distribution

New Thames Valley Vision

SSET203

LCNF Tier 2 SDRC 9.2(b) Evidence Report
100 Substation Monitoring Installations Installed

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1 Summary

1.1 Criteria 9.2(b)

Successful Delivery Reward Criteria 9.2 (b)

100 Substation Monitoring Installations Installed and learnings presented

SSEPD confirms that this criterion has been met.

This document provides details of the completion of the installation of the 100 substation monitors, and presents the findings identified in line with the evidence criteria specified for the Successful Delivery Reward Criteria (SDRC).

It is confirmed that:

- 100 substation locations have been identified from which data can be interpreted by the University of Reading for their first stage of analysis;
- Substation monitors have been installed and commissioned at each of these substation locations;
- Data has been captured and made fully available to the University of Reading for their assessment
- The substation monitors and associated systems are active
- Unit costs have been reviewed;
- The reliability of the substation monitors since installation has been assessed;
- Photographs of installed Substation monitors have been taken(1);

Note 1 Ofgem representative(s) are invited to visit one or more substations where substation monitors have been installed (by appointment).

1.2 Background

The NTVV project requires half hourly energy data to be captured from substations (and end points) on the low voltage network so that energy usage patterns can be identified, categorised and forecast, and compared with aggregated data from end points. With this information it is expected that meaningful forecasts can be made regarding the future loading of the low voltage network.

Some LV feeders have little or no headroom whilst others have a reasonable amount available for historic network reasons. The substation monitoring will provide real data for comparison with the estimates and forecasts. The substation monitoring will also provide data to support the development of the most appropriate deployment strategy and operating regimes for energy storage as a solution to the network problems identified.

SDRC 9.2 (b) was established to acknowledge the clear focus given to the fitting of substation monitors so that data is captured at the earliest possible stage and made available to our Project Partner the University of Reading. All subsequent stages of data analysis depend upon this data and hence the high priority given to this task.

This document identifies the serial numbers of the devices fitted, and provides a sample of the data collected to ensure that appropriate evidence of compliance with the SDRC is available.

1.3 Link to Methods and Learning Outcomes

Method 3 as defined for NTVV (see SET203 New Thames Valley Vision bid submission) proposes the development of mathematical techniques to reduce the need for new and extensive low voltage network monitoring that might be required to manage and design low voltage networks to meet the needs of the new low carbon technologies. Mathematical models are to be developed by the University of Reading using data from end point monitors now installed in customer's premises, and subsequently from devices measuring the energy profiles of low voltage feeder cables from distribution substations. The substation monitors have been installed in line with SDRC 9.2 (b).

To meet SDRC 9.2 (b) 100 substation monitors have been installed at distribution substations in the Bracknell area, commissioned and data collection established. The substation monitors are GE Digital Energy Multilin DGCM devices. These have been configured for use at distribution substations with up to 6 low voltage feeders, with communications achieved using a Westermo MR-310 modem, and GPRS/3G SIM card connected to the Vodafone network.

The substation data is transmitted to an SSEPD server via a Vodafone access point, and fed into a front end processor (FEP) of the PowerOn Fusion system, established in the shadow environment in the SSEPD control room. From PowerOn Fusion the data is available for storage in SSEPD's PI ProcessBook, and is subsequently available for sharing with the University of Reading.

Successful completion of Learning Outcome 1 requires an understanding of the interaction between the network and individual customers in order to optimise network investment. The selection of the initial 100 substations locations to be monitored was made with guidance from the University of Reading to ensure that the mix of customer types fed from the substations was a representative sample. Combined with end point monitoring data this substation data will be used to predict future demand on the network and better inform investment decisions relating to the low voltage network.

Successful completion of Learning Outcome 2 requires improved modelling to enhance network operation procedures and to provide a management tool for planning and investment on the low voltage distribution network. The University of Reading are using the data from the substation monitors to develop the model.

2 Substation Monitor Installations

2.1 Substation Selection Process

To be able to install 100 substation monitors, SSEPD consulted with the University of Reading to identify appropriate locations. Their objective was to achieve substation monitoring for a good mix of properties in Bracknell that were statistically relevant, and to achieve a good coverage of one or more high voltage feeders. Substations were allocated to a matrix of property categories based on density (number of customers per feeder) and homogeneity (mix of types of property connected to the feeder). The matrix of substations is shown in **Appendix 1 Substation Categorisation.**

Actual substations to be monitored were selected from the matrix, taking into account the coincident requirements for end point monitoring (as previously indicated for End Point Monitors, SDRC 9.2(a)) and practical considerations identified during a survey of the substations. A more detailed description of the criteria is found in **Appendix 2 UoR Selection Procedure for End Point Monitor Locations.**

The actual substations selected are listed in **Appendix 3 Substations Selected**

2.2 Engagement with Local SSEPD Depot Team

The NTVV team provided a presentation to the local SSEPD depot team to ensure that:

- The local team were aware of what would happen in the substations for which they are responsible;
- The local team could see the potential future benefits to them and their business as usual activities, and would therefore be more inclined to offer support and avoid misunderstandings;
- Ensure that works in substations are co-ordinated both for safety, and to ensure that appropriate prioritisation could be given to business as usual operational activities.

This approach worked well and all subsequent works proceeded smoothly with regard to interactions with the depot team. Further work is required to give the local team increased visibility of data that is now being monitored, and to manage post installation issues (e.g. substation plant replacement works will require monitoring equipment to be removed and replaced).

2.3 Installation of Substation Monitors by SSE Contracting

The installation work for the substation monitors was awarded to SSE Contracting by competitive tender. For each substation monitor installation the following tasks were required to be carried out.

NTVV Project Team

- Obtain GIS records for each substation and identify the feeder cables connected in terms of number, type and size;
- Obtain the transformer rating from the plant database (PLACAR);
- Establish the maximum fuse rating that can be applied to each feeder from the cable and transformer ratings. This value was used to set the feeder alarm thresholds for each feeder within the monitoring device.
- Obtain G Clamps and fused leads as necessary.

Real Time Systems (RTS) Team

- For each substation, allocate an asset number, modem user name and password, front end processor (FEP) IP address, SIM card username and password.

Telecoms Team

- For each substation establish a communications contract from communications provider (Vodafone) and obtain a GPRS SIM card.

NTVV Control Engineer

- For each substation, create PowerOn Fusion (PoF) template to receive data and link to PI ProcessBook database.
- Apply IP address for remote monitoring device.

GE Digital Energy

- For each substation, supply a Multilin DGCM monitoring device and sufficient Rogowski coils to allow for three per connected feeder cable.
- Supply calibration data for each Rogowski coil.

SSE Contracting

- For each substation, pre-commission each Multilin DGCM monitoring device. This includes the connection of Rogowski coils as necessary, transferring an appropriate configuration file, apply settings for the modem, apply settings for DNP3 communications, apply electrical alarm settings and record settings as agreed.
- Work with NTVV Control Engineer to ensure that all parameters are correctly transmitted, received and displayed in PoF.
- Take monitoring device to site and fit in accordance with work instruction WI-PS-912. (See **Appendix 4 WI-PS-912 Distribution Substation Installation of Monitoring Equipment**)
- Complete site commissioning by establishing two way communication with PoF and confirm that each electrical phase monitored reports information to the correct element with the template on PoF;
- Apply safety and information label to monitoring device.

With all the above items carried out, data can flow into the Pi ProcessBook database, and is available to the University of Reading as necessary.

A complete schedule of the 100 substation monitors installed can be seen in **Appendix 14 SSE Contracting Commissioning Log.**

2. 4 Substation Monitor Configuration

SSEPD specified that the substation monitors to be supplied and installed were required to comply with requirements in the areas of electrical safety, environment, functionality and communications.

Safety and Environment

The following standards were specified:

ITE Safety – General Requirements

BS EN 61010-1:2001

BS EN 61010-2-032:2002

Surge protection – IEC61000 8kV

WEE Regulations

EMC – CE Mark Directive 2004/108/ec: Electromagnetic Compatibility

IP Rating – Sensors – IP65

The Multilin DGCM conforms to standards in line with **Appendix 5 DGCM Schedule of Type Tests**

Functionality:

The functional requirements of the monitoring device were as specified in **Appendix 6 Specification for Substation Monitoring Equipment**

Communications

Three modes of operation were specified.

Mode 1 Immediate transmission (streaming) of measured values (e.g. current, voltage, power)

Mode 2 Half hourly transmission of calculated values (e.g. energy, maximum and minimum voltage)

Mode 3 Alarms (e.g. high or low voltage)

It was further specified that the communications protocol to be used would be DNP3.0 (Distributed Network Protocol), and the communications medium would be GPRS using services provided by SSEPD’s existing GPRS communications provider, Vodafone.

See Appendix 17 LV Substation Monitoring Whitebook

As product partner for monitoring hardware and integration, GE Digital Energy provided SSEPD with Multilin DGCM monitoring devices. SSEPD accepted the use of these devices for the following reasons:

- Existing Type Approval status (See **Appendix 8 Multilin DGCM Field RTU Instruction Manual** and **Appendix 7 Rogowski Coil Datasheet)**)
- CE Marking achieved
- Known compatibility with GE Digital Energy's control system PowerOn Fusion
- Flexible configuration to achieve the functional requirements
- Commitment by GE Digital Energy to package the device including a separate GPRS modem in an IP65 protective cabinet suitable for safe installation in a live substation environment wall mounted, pole mounted or ground mounted

110 DGCM substation monitors were delivered to SSEPD by the 21 December 2012. This included sufficient devices for each category of substation as advised by the University of Reading to give a representative mix. See **Appendix 9 GE Digital Energy – 110 DGCMs - Delivery Note**.

A prototype DGCM device was received from GE Digital Energy in early October 2012 to allow the NTVV project team to assess compliance with the functional requirements, and to carry out configuration of the device to ensure effective interaction with the Westermo modem, GPRS access point provided by Vodafone and subsequent receipt and handling of the monitoring data within PowerOn Fusion. The product and systems information understood at this stage was seen to be crucial in ensuring that the production devices could be configured correctly and efficiently without having to revisit the monitoring devices after installation in live substations.

See **Appendix 10 – GE Digital Energy DGCM Summary Report**

The experience gained also informed the installation contract tender analysis, and subsequently proved to be extremely useful to the NTVV team in ensuring that the SSE Contracting team could be guided correctly and facilitated to achieve the installation rate required by the project.

2. 5 Substation Monitor Communications

Vodafone provided data SIM cards for installation within the Westermo modem supplied with each DGCM monitoring device (See **Appendix 11 Westermo MRD-310 Datasheet**). These were installed during the pre-commissioning stage and data transmitted via the Vodafone access point name (APN) into PowerOn Fusion. Considerable effort was required to correctly assign IP addresses, usernames, passwords and data points to ensure that data would flow through successfully. A key part of this process was to make it repeatable so that subsequent installations could be carried out efficiently, and to allow it to be repeated in the future if required following upgrades to systems or software. See **Appendix 16 Control Room Procedure for Substation Monitor Commissioning.**

This process for capturing substation data will be fully integrated with the data from the end point monitors through the GE PowerOn Fusion system and subsequent storage in the SSEPD PI ProcessBook database for immediate use and sharing with the University of Reading.

A sample screen view from PowerOn Fusion is shown in **Appendix 15 PowerOn Fusion Screen View – Keldholme Substation**

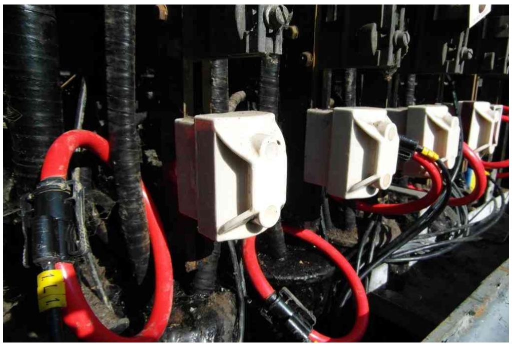
This shows boxes of data for each feeder, and boxes above which represent the summated values representative of the substation low voltage busbar. Values in bold yellow boxes are “real time Mode 1” values, other boxes show calculated “half hour Mode 2” values. The small green boxes are alarms; these fill with a red square when triggered (See feeder 2, phase L2 which had alarmed on “low current”).

Data is now being gathered by over 100 substation monitors.

2.6 Photographs of Installations at Distribution Substations

Substation Monitor at Merryhill Substation

Rogowski Coils wrapped around cable cores:



Substation Monitor at Old Bracknell Lane Substation :

Additional photographs of end point monitors installed on site are shown in **Appendix 12 NTVV Substation Monitoring - Photographs of Installations.**

2.7 Site installation Issues

During the Installation stage it was not possible to install the DGCM substation monitors at all locations as requested by the University of Reading. Particular issues that arose at a small number of substations are described below.

Pad Mounted Substations

Pad mounted substations are designed to be very compact, and in this respect they typically offer very limited access to live low voltage substation busbars. It was found at two locations that a busbar connection could not be made without first isolating the busbars, which would involve disconnecting supplies to customers, or alternatively excavating a joint hole adjacent to the substation and making off a three phase service joint and service installation.

Pole Mounted Transformers

The cabinet containing the DGCM has been designed to be able to fit on a pole, and there is no problem in principle with fitting such a device on a pole. There were two pole locations identified in the initial selection by the University of Reading, but both of these were constrained as access to the neutral conductor could only be achieved at the transformer. For a pole mounted transformer, with live exposed high voltage terminations, access to the low voltage terminations cannot be achieved while the transformer is live.

For both pad mounted substations and pole mounted transformer locations alternative locations were identified by the University of Reading, and these were used in preference so that there would be no delay in the deployment of substation monitoring and provision of data to the University of Reading.

At a number of other substation types, various difficulties were identified with regard to the fitting of G clamps, Rogowski coils or aerial leads. In each case the risks and options were given careful consideration and solutions implemented.

Further observations from SSE Contracting relating to installation works are found in **Appendix 20 SSE Contracting Installation Work Observations.**

3 Active Operation of Systems

3.1 Shadow Environment Development and Commissioning

The IT and communications architecture for the transfer of data from substation monitors to SSEPD Distribution Management System is centred on the establishment of a “Shadow Environment”. This is a copy of the live HV control system, segregated from the actual live system, and prepared for the development of the management system for the LV network. This includes provision for the receipt and display of the substation monitoring data, and subsequent migration of the data into the PI ProcessBook database. The systems have been built in conjunction with Vodafone who are providing GPRS SIM cards for the substation devices, and transmission of data via their access point.

A full description of the commissioning of the Shadow Environment is given in **Appendix 21 NTVV Shadow Distribution Management System Commissioning Report.**

3.2 PI ProcessBook

SSEPD uses Pi ProcessBook extensively for the storage of operational data and it was decided very early at the project conception stage that this was an appropriate database for the storage of substation data for the low voltage network.

Appropriate licences have been purchased for Pi ProcessBook to be deployed for NTVV and software has been configured to receive the substation monitor data that is now available.

A full description of the commissioning of Pi ProcessBook is given in **Appendix 13 NTVV Pi Commissioning Report.**

4 Data Capture

4.1 Sample Data

Data has been obtained from a number of substation monitors and transferred to the University of Reading. Substation monitors have been installed to suit University of Reading preferences and installation considerations. Substation monitors are only required to store data for a period of 14 days to allow time to resolve communications issues. PowerOn Fusion retrieves the data from the substation monitors and forwards the data to the Pi ProcessBook. PowerOn Fusion does not actually store the data, but it does record alarms and events that occur on the system. All long term storage of substation data is achieved in Pi ProcessBook.

Sample data can be seen in **Appendix 18 NTVV Substation Monitoring Sample Data – Merryhill Substation**. It can be seen that all the required electrical parameters are being measured, calculated and transmitted to the database, although there is work in progress to make a number of refinements to ensure that data flows reliably into the database.

4.2 Review of Data

The University of Reading have received substation data and made some initial observations. These are included in **Appendix 19 UoR Review of Substation Monitoring Data.** They were able to assess samples of the data for suitability for ongoing detailed analysis, and confirm that the data looks realistic.

5 Review of Unit Costs

5.1 Installation Costs

To achieve an efficient installation rate the installation contractor, SSE Contracting, made arrangements to carry out as much as possible of the wiring and commissioning work in their workshop in Theale. This was supported by the SSEPD team by giving them access to the PowerOn Fusion System. This allowed the contractor to carry out pre-commissioning without direct involvement of the SSEPD control engineer. The challenge for the control engineer was to prepare the templates on PowerOn Fusion in readiness for the contractor; this was made more flexible by the establishment of a dummy substation template called “Workshop” to which each DGCM could be pre-commissioned in turn. In this way the contractor was able to establish a production line process with a minimum of constraints imposed.

A typical 4 or 5 feeder DGCM took 3 hours for wiring connections in the workshop (connection of Rogowski coils, labelling of cables etc) and a further 3 hours of pre-commissioning (assignment of configuration file, insertion of SIM card, assignment of usernames, passwords and IP addresses, calibration of Rogowski coils, electrical injection testing, validation of alarm functionality in PowerOn Fusion etc).

Following pre-commissioning, each device was taken to its allocated substation and fitted in accordance with WI-PS-912. This process is inevitably constrained by significant site safety considerations, and requirement to comply with the Operational Safety Rules. Tasks have to be carried out in the correct order, broadly broken down as physical mounting of the DGCM, installation of Rogowski Coils and G Clamps, routing of connecting cables, and final commissioning to PowerOn Fusion. The final commissioning is the last opportunity on ensure that the current measured on a particular phase of a particular feeder is shown against the same phase of the same feeder in PowerOn Fusion, and this involves a telephone dialogue between the site operative and the control engineer. Again, to support the contractor, the SSEPD Control Engineer delegated this role for later installations to the contractor’s supervisor to reduce the time constrained interface. The typical 4 or 5 feeder DGCM took 3 hours for site commissioning.

Actual installation costs for installing these 100 DGCM substation monitoring devices were determined by the outcome of the competitive tender[2]. Further costs were incurred for the resolution of various problems (communications issues, incorrect settings affecting device performance, late choice to provide additional security settings, adjustment to resolution to some electrical values). These issues were no fault of the contractor and may reasonably be regarded as learning outcomes associated with a first time volume installation of monitoring devices, and as such should ensure that subsequent installations may be implemented with these aspects taken into account, and costs minimised.

Total costs of substation monitoring installations need to reflect the establishment of control room diagram templates, generation and control of SIM cards, usernames, passwords, identification of network data to allow alarm settings to be established etc. In other words, there is a significant burden on the first 100 substations. With these systems established, the unit costs of installing subsequent substation monitors would expect to be significantly less. In this case, both the SSEPD team and the Contractor's team learnt much about how to automate the process and reduce actual unit costs to a minimum. Further work is in progress to establish a means of making adjustments and diagnostic checks by remote means to minimise the need to attend site when actual problems arise.

5.2 Cost of Substation Monitors

The substation monitors are off-the-shelf products supplied to NTVV by GE Digital Energy. The total cost of the devices includes the provision of a modem, cabinet (suitable for mounting in a substation environment) and Rogowski coils. They were supplied to the NTVV project by GE Digital Energy as part of their overall package of work and it is difficult to breakout individual costs; for a total projected quantity of 325 monitors, which is relatively small compared to the total count of distribution substations within SSEPD's area, a relatively high cost is expected, and this would clearly not be representative if scaled up for a larger deployment.

Note 2 The prices obtained by competitive tender have been provided from commercial organisations and open publication may provide an unfair competitive advantage to their competitors, hence they have not been included within this document. SSEPD will provide direct input to Ofgem should further information be required.

5.3 Cost of Communications and Systems

The provision of communications has been with Vodafone for the use of GPRS data SIM cards. A standard commercially available corporate tariff is currently in use, although this is being reviewed in the light of actual data volumes carried on the network from the monitoring devices. The cost is currently high and this is expected to fall as the tariff is matched more closely to the requirement, and would be expected to fall further if the volume of monitoring devices installed was to be scaled up.

The volume of data transmitted for two substations (Merryhill and Old Bracknell Lane) in one month is shown in **Appendix 22 GPRS Data Communications – March 2013.**

6 Review of Reliability

6.1 Reliability of Substation Monitors

Three DGCM substation monitors have been returned to the manufacturer for rectification of defects. These are currently under investigation. A number of minor wiring issues have been identified and corrected by the contractor. Site issues have generally been identified at the site commissioning stage and were found to relate to minor wiring issues or incorrect settings applied.

6.2 Reliability of Communications and Systems

A number of DGCM substation monitors have experienced communication issues; these have been linked to incorrect settings and no real communication issues are outstanding. Signal strength in a substation environment has not proved to be a constraint other than that the aerial has to be mounted outside of the low voltage pillar or cabinet, even if the DGCM could otherwise be mounted inside the cabinet.

6.3 Reliability of Pi ProcessBook

There have been no reliability issues with the Pi ProcessBook database in the period of operation to date. Pi ProcessBook as a pre-existing system is of proven reliability, and some modifications to the configuration established for NTVV are to be expected over the next few months.

6.4 Reliability of Data Received by the University of Reading

The University of Reading will review the quality of data received in terms of completeness and error checking on an ongoing basis. To date, as more substation monitors have been commissioned refinements have been made to ensure that all parameters are reliably reported, and further refinements are expected to be required as the data is analysed in detail over the next few months. Apart from some initial setting up issues the University of Reading have confirmed their satisfaction with the data.

7 Appendices

Appendix 1 Substation Categorisation

See separate document attached.

Appendix 2 UoR Selection Procedure for End Point Monitor Locations

See separate document attached.

Appendix 3 Substations Selected

See separate document attached.

Appendix 4 WI-PS-912 V1.1 Distribution Substation Installation of Monitoring Equipment

See separate document attached.

Appendix 5 DGCM Schedule of Type Tests

See separate document attached.

Appendix 6 Specification for Substation Monitoring Equipment

See separate document attached.

Appendix 7 Rogowski Coil Datasheet

See separate document attached.

Appendix 8 Multilin DGCM Field RTU Instruction Manual

See separate document attached.

Appendix 9 GE Digital Energy – 110 DGCMs – Delivery Note

See separate document attached.

Appendix 10 GE Digital Energy DGCM Summary Report

See separate document attached.

Appendix 11 Westermo MRD-310 Datasheet

See separate document attached.

Appendix 12 NTVV Substation Monitoring – Photographs of Installations

See separate document attached.

Appendix 13 NTVV PI Commissioning Report

See separate document attached.

Appendix 14 SSE Contracting Commissioning Log V1.5

See separate document attached.

Appendix 15 PowerOn Fusion Screen View – Keldholme Substation

See separate document attached.

Appendix 16 Control Room Procedure for Substation Monitor Commissioning

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Appendix 17 LV Substation Monitoring White Book

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