SP ENERGY NETWORKS

Flexible Networks for a Low Carbon Future

Methodology & Learning Report

Work Package 1: Detailed Network Monitoring

September 2015

Contents

Contents [continued]

Executive Summary

Background

SP Energy Networks under a Tier 2 Low Carbon Network (LCN) Fund project, *"Flexible Networks for a Low Carbon Future"*, investigated several "Smart Grid" solutions to increase network capacity in place of conventional reinforcement. Detailed network monitoring is seen as a pre-requisite for this – as an "enabling" technology. It is the first step towards better risk management, being more "risk aware", rather than simply "risk averse" – a key culture change currently taking place within network operators.

This report presents the work carried out for the detailed network monitoring trials and provides a summary of outcomes and lessons learnt from this activity.

Aims and Objectives

The key aims and objectives of the detailed network monitoring were as follows:

- To assist in the identification of suitable locations for the Flexible Network "Smart Grid" network interventions.
- In conjunction with network models and modelling tools, to assess the potential of specific interventions in specific locations.
- To evaluate the performance of the implemented interventions.
- To improve our understanding of the costs and benefits of detailed network monitoring.

Outcomes of the Project

The key outcomes of the detailed network monitoring exercise are as follows:

Monitoring equipment was installed at the three sites as follows:

Table 1: Monitoring Equipment Installations

	HV and LV substation monitor	LV Substation Monitor	LV supply Monitor	Weather Station + RTU	Transformer Temperature Monitor
St Andrews	✓	✓		✓	✓
Whitchurch	✓	✓		✓	✓
Ruabon	✓	✓	✓	✓	

The monitoring data was brought together in a cloud-hosted database called iHost provided by our project partner Nortech. The monitoring data was also linked to other databases, including our GIS and NMS systems as well as Google Earth, within the Data Analytics portion of the project.

Learning Derived from the Methods Used in the Project

- "Smart MDI" type monitors at secondary substations could provide a cost-effective alternative to conventional MDIs
- "Detailed LV monitoring" is appropriate in areas of high load uncertainly, such as new heat pump or EV charging clusters or clustered PV generation connections.
- Considering "Detailed LV Monitoring" as a temporary installation, with the option to re-locate the equipment makes a significant difference to the business case.
- Data transmission through mobile data networks is not 100% reliable and so allowances must be made to manage this to maximise data availability
- In general, loads should be modelled as constant current rather than the current practice of constant power, except when more detailed information related to the nature of the load is available.
- New rules of thumb were developed for the characterisation of PV generation. The load factor was reduced from 100% to 90% and the daytime minimum load per domestic property assumption was increased from 200W to 300W. This released about 25% of additional capacity for the connection of PV.
- A more statistical and probabilistic approach to data analysis provides a much fuller characterisation of network behaviour, sensitivities and trends.
- Data analytics has the potential to improve our cost efficiency, improve our asset management techniques, and facilitate new or improved services to customers.

Further Development

In order to fully adopt detailed network monitoring into business as usual, the following developments have been identified:

Updating policy documents: The existing technical manuals and policy documents need to be updated to incorporate the application of detailed network monitoring into network planning and operations codes of practice.

Development of a **low-cost replacement for the existing MDIs** (a "Smart" MDI) which is permanently fitted to LV switchboards is likely to provide a greater cost/benefit than the detailed monitoring utilised within this project.

However, the **detailed network monitoring** still has a role to play in instances of less predictable new load types (such as heat pump clusters or EV clusters) or new generation on the network.

1 Introduction

It is critical to develop improved network planning and operations tools and processes to facilitate a future flexible network and make best use of existing assets. These tools will provide a greater understanding of network behaviour and enable a more appropriate response to load growth. In particular, the timing and rate of growth of new demand associated with increasing amounts of low carbon technology including PV, electric vehicles and heat pumps are uncertain and risks must be adequately managed, not least those of

- temporary overloading of the network (leading to accelerated plant aging),
- voltage excursions (affecting customers' power quality), or,
- severe overloading leading to load disconnection (affecting customers' quality of supply).

Whilst network reinforcement can alleviate these risks, such an action introduces the risk of stranded assets in the event that forecasts of demand growth do not materialise.

Network monitoring data has traditionally been analysed consistent with a fit and forget network and satisfaction of simple standards associated with annual peak demand. This will be inadequate for management of the aforementioned uncertainties. Detailed network monitoring is therefore a key enabler for the future Smart Grid. Whilst detailed network monitoring does not create any additional network capacity directly, the analysis of the data can assist in making better use of existing assets. It is the first step towards better risk management, being more "risk aware", rather than simply "risk averse".

This report presents the work carried out for the detailed network monitoring exercise and provides a summary of outcomes and lessons learnt from this activity.

2 Background

The numbers of secondary substations within most DNO license areas are typically in the significant tens of thousands and the majority of these are of an age which spans the last 40+ years. Therefore, monitoring equipment has to be able to be retrofitted across a wide range of various construction types and ages of electrical apparatus. Also, as we wanted to measure the network parameters at primary substations, secondary substations and at remote points on the low voltage network, the monitoring devices need to measure values across a range of voltage and power levels.

It was identified at an early stage that whilst the existing IT and SCADA systems that exist within SPEN could be developed to perform the network monitoring and data capture, the extensive development work that would be needed would significantly extend the project timescales and require an extensive compatible communications network to be implemented. It was therefore decided to operate a separate system for Flexible Networks from the SPEN SCADA system.

Given the above, a simple solution for the monitoring data transmission was to use mobile network communications and a 3rd party data hosting service. This enabled various types of monitoring devices and protocols to be considered with simplified but secure data access arrangements.

3 Details of the Work Carried Out

This section presents details of the work carried out to implement detailed network monitoring.

3.1 Network Monitoring Trial Sites

The network trials were undertaken across three different areas of the SPEN network; St Andrews (Scotland), Wrexham (Wales) and Whitchurch (England). We undertook a thorough process to identify the best sites for this project. The selected sites encompass a range of different network configurations (radial and interconnected, rural and urban), with different customer types (industrial, commercial and domestic).

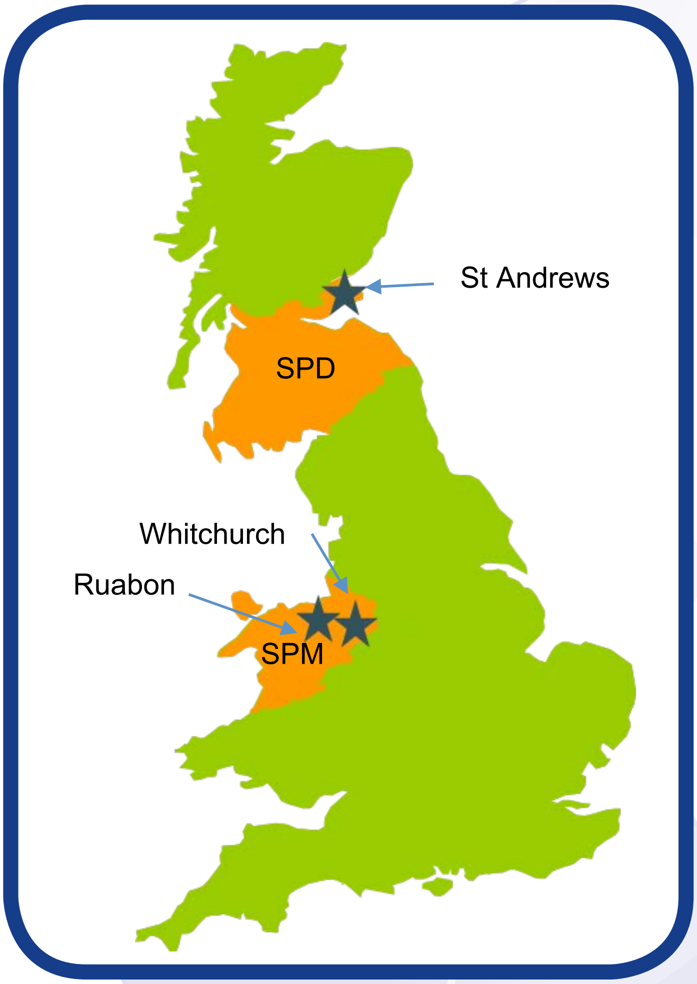

Figure 1: location of the network monitoring trial sites

Further details on the trial sites are given below.

3.1.1 St Andrews

The town of St Andrews is fed by two 15/21MVA transformers. The substation then distributes supplies within the area with ten 11kV radial circuits feeding almost one hundred secondary substations. As the plan for this trial area was to deploy:

i) Flexible Network Control on the 11kV network and split points to adjacent 11kV networks,

ii) Dynamic Rating to the feeding 33kV OHL and 33/11kV transformers, and,

iii) instigate Energy Efficiency measures to local larger customers,

it was necessary to capture full loading and voltage profiles across the 11kV and LV networks. This entailed installing three-phase current and voltage monitors to each 11kV feeding circuit at the St Andrews primary and the three adjacent primary substations (Cupar, Leuchars and Anstruther). On the secondary substations three-phase current and voltage monitors were fitted to the transformers and/or LV fuse board. Monitors were not installed on the smaller sized pole mounted transformers as these only feed low level loads which could be aggregated in the network analysis. A primary transformer temperature sensor and a local weather station were installed to capture data to support the Dynamic Rating analysis and deployment.

3.1.2 Whitchurch

The market town of Whitchurch is fed in a typical SPM semi-rural configuration of three primary transformers at Whitchurch Grid, Liverpool Road and Yockings Gate, which share the load of the town and have the ability to be interconnected subject to the individual circuit ratings.

As the plan for this trial area was to deploy

i) Flexible Network Control on the 11kV network and split points to adjacent 11kV networks,

ii) Dynamic Rating to the 33/11kV transformers, and,

iii) instigate Energy Efficiency measures to local larger customers

it was necessary to capture full loading and voltage profiles across the 11kV and LV networks. This entailed installing three-phase current and voltage monitors to each 11kV feeding circuit at the three primary substations. On the secondary substations, three phase current and voltage monitors were fitted to the transformers and/or LV fuse board. Monitors were not installed on the smaller sized pole mounted transformers as these only feed low level loads which could be aggregated in the network analysis. A primary transformer temperature sensor and a local weather station were installed to capture data to support the Dynamic Rating analysis and deployment.

3.1.3 Wrexham/Ruabon

The Borough of Wrexham is divided into many small districts and villages and as the local council had housing stock spread across this large area, the distribution of the properties being fitted with PV were supplied from 28 different primary and then by 192 secondary substations. We identified that the primary substation with the greatest concentration of PV installations supplied from it was Ruabon primary and that 80% of the properties connected to Ruabon were supplied from secondary substations fed by just three of the seven outgoing 11kV circuits. Therefore the secondary substations connected to these three circuits were targeted for monitoring. Where the specific secondary substations being monitored had PV connected to them, all phases of the fuse board outgoing distributors where monitored for current to capture where load was importing onto the LV busbars and being exported to the other LV distributors. Also as the problem PV can create is voltage rises along the LV distributors, monitoring was installed at selected points on the LV network where it was anticipated rises in the voltage would occur. A local weather station was installed to capture data to analyse the relationship between solar radiation, PV output and load changes.

3.2 Methodology for Selecting the Network Monitoring Approach

At the outset of this work package for monitoring it was essential to understand what data would be needed to implement the other work packages of the project, how it would be used and what format it needed to be captured. For this project these broke down into four distinct areas for which data would be needed;

- Dynamic Rating – Asset loading, temperature and weather data
- Flexible Network Control – Power flows and voltages across the network
- Energy Efficiency – Energy consumption and power flows at substations
- Voltage Optimisation – Voltage profiles across the 11kV and LV network

From the above requirements the data values could be derived and site surveys undertaken to determine how the measurements could be practically achieved.

The measurement values it was decided we would collect at various points on the network were:

- Voltage
- Current
- Temperature (of selected transformers)
- Weather information (at selected sites) including;
    - Ambient temperature
    - Wind speed and direction
    - Solar radiation

Tender specifications were produced which set out the measurement and data capture requirements. As this was fairly new territory for DNO's, other LCNF projects which had included secondary substation monitoring were consulted to pick up any learning available.

4 The Outcomes of the Project

This section presents the outcomes of the network monitoring activity. The main outcomes of the project are:

- Improved Use of Primary Substation Data
- A Good Practice Guide for Network Monitoring
- A Guide for the Deployment of Secondary Substation Monitoring
- Monitoring Data Management
- New Planning and Operational Tools and Strategies
- A Visualisation of Data Analytics Functions

These outcomes are explained in more detail in the following sections.

4.1 Improved Use of Primary Substation Data

Primary substation data analysis has conventionally been based on single value maximum and minimum demands and generation extracted from time series data. A more statistical and probabilistic approach to data analysis augmented by appropriate analytical tools provides a much fuller characterisation of network behaviour, sensitivities and trends. It also allows a less conservative forecast of network capacity headroom to be determined.

We have developed and tested our new methodology on the three Flexible Networks trial sites as well as a sample subset of other network groups. Our approach comprises the following interrelated innovations:

- An improved approach to identification and handling of data anomalies for better management of primary substation data uncertainty
- An enhanced load forecasting tool to more accurately forecast future network group load growth trends
- A risk-based methodology to identify additional capacity headroom based on characterisation of frequency and duration of high loading for the network group
- Recommendations to improve management of modelling uncertainty

More detailed information on the above is available in a separate report entitled *"Improved Use of Primary Substation Data"*, but a summary of the findings is given below.

4.1.1 Load Growth Uncertainty

The reduction of load forecasting uncertainty will support a more techno-economic response to the expected increase in low carbon technologies in future years through improved reinforcement prioritisation and planning. Data is already available to better characterise primary asset loading behaviour and trends but has traditionally been underutilised.

Observations of the annual demand peak (P100 percentile) are subject to wide variation due, for example, to weather and unusual network conditions. Our enhanced load forecasting methodology has been developed to reduce the influence of peak demand outliers and thus reduce uncertainty, based on the following two suppositions;

1) Percentile half-hourly measured loads other than the P100 value are less prone to exceptional variation and are more representative of underlying conditions than the P100 value and, hence, are more indicative of underlying behaviour within the group than the P100 value; and

2) There is a consistent, fixed relationship between an observed percentile other than the observed P100 and the 'true' P100 value.

Because high demand periods are critical to reliability of supply, a percentile was selected that represents high demand periods. A simple linear regression based on a number of years of historical data then provides the forecast of 'true' P100 values for future years.

For the six sample primary network groups analysed, the enhanced load forecasting methodology is generally within 10% of the measured peak demand for 1 year-ahead forecasting, whereas the existing approach does not perform so well and is within about 20%. The enhanced methodology also performs better when forecasting load trends up to 4 years ahead.

To summarise, our findings suggest that use of this new methodology provides improvements over the existing forecasting approach through better characterisation of underlying asset loading behaviour and reduced impact of load outliers. The incorporation of local intelligence on new network connections will provide further enhancement. This will help to release available capacity headroom and improve network reinforcement strategy.

4.1.2 Implications for ER P2/6 – Security of Supply

Current methods for the calculation of network capacity headroom, which are based on a simplistic interpretation of ER P2/6, whilst easy to understand, can lead to potentially conservative estimates. This is because current methods do not assess the risks to security of supply directly, but rather apply the discrete P2/6 security levels according to deterministic rules. The techniques proposed here address the uncertainty of the data used in P2/6 assessments and treat it in manner that is consistent with the philosophy of P2/6 to reduce unduly conservative estimates but not add to risk in any material way.

A key consideration for planning of distribution networks is the ability to meet future demand. In the event that future demand is expected to exceed network capacity, appropriate reinforcement should be carried out in a timely manner that takes into account approval, procurement, construction and commissioning lead times. The uptake of low carbon technologies increases the uncertainty associated with network reinforcement timing and need. A key innovation that would permit improved management of the risk of, on the one hand, network overloads, disconnections or failure to facilitate new connections or, on the other, stranded assets, would be the articulation of network 'capacity headroom'.

From a customer perspective, there is no difference between a loss of supply due to a first circuit outage or a second circuit outage. A new design target which takes into account the ability to maintain supply during a second circuit outage, but may result in a small but insignificant increase in the probability of a first circuit outage leading to loss of supply under very high loading conditions, may result in reduced customer minutes lost and a more cost-effective service provision. For example, deployment of low-cost network automation schemes for supply restoration during a second circuit outage event may be better justified than investment in a major reinforcement triggered by P2/6 non-compliance for a first circuit outage event, for example.

Table 2 below illustrates the potential additional capacity headroom that could be accessed for the three Flexible Networks trial sites based on application of our probabilistic risk based approach.

Table 2: Potential Additional Capacity Headroom

Primary Network Groups	Ruabon	Whitchurch	St Andrews
Firm Capacity MVA	10	20	21
Half-hour Maximum Demand MVA	7.12	14.21	19.84
Minimum of 4 Highest Half-hour Loads MVA	7.02	13.94	19.33
% Additional Capacity Headroom	1.1%	1.3%	2.4%

It is noted that a review of Engineering Recommendation P2/6 – Security of Supply is currently under way. P2/6 does not currently define "maximum demand", but our methodology goes some way towards providing new insights into what this might be. We have fed our results into the current review of P2/6.

4.1.3 Reduced Data Uncertainty

If load transfers occur around the time of peak winter demand, this can lift the load duration curve and have implications for peak network loading and load forecasting for future years. Improved, automated algorithms based on robust rules have been developed to reduce the impact of outliers due to atypical load transfer or erroneous readings and zero measurements.

Trend-based techniques can better highlight periods of anomalous behaviour compared to detailed time-series based assessment of loading although informed review of load patterns may still be required to determine whether there is a genuine event of interest. Visualisation of historic behaviour and confidence bands permit the data to be evaluated more easily and changes in load can be shown without being unduly influenced by year-to-year weather variations.

4.1.4 Reduced Modelling Uncertainty

The improved identification, management and mitigation of modelling uncertainties will enhance network modelling for better informed business decisions. Considering the time-varying characteristics of load and generation connected directly to the 33kV network should be relatively simple to implement as part of network model validation process as this data is available and it does not require significant additional analysis time.

It will be particularly important for future voltage management and fault level modelling to better quantify the characteristics of increasing amounts of embedded generation on the HV and LV network and influence on network behaviour.

4.2 A Good Practice Guide for Network Monitoring

Key points from the Good Practice Guide for Data Monitoring include:

- Monitoring specifications should be consistent with required minimum accuracy and reliability, given consideration to scaling across the network at large volumes.
- Practical considerations are also important to ensure an efficient monitoring rollout programme.
- Heuristics based analysis is a powerful technique that can help identify network 'hot-spots' at an early stage.
- Detailed analysis of monitoring data for network trial sites can be used to develop and verify simple rules of thumb for application to the wider network.
- Development of a "common" library will facilitate integration of analysis tools using the same data sources and underlying analysis techniques across planning, operations and connections business processes.
- It is critical to understand the risk associated with a data-based business decision in the context of future load growth increasing rapidly and clustering.
- Metrics which provide a characterisation of the risk associated with a data-based decision should be incorporated.

4.3 Deployment of Secondary Sub Monitoring

A key question for us was the relative cost between the cost of the monitoring equipment itself, and the cost of installation. If the units were low cost, it wouldn't be worthwhile removing to another site to capture the data elsewhere, because of the installation/removal costs. But if the cost of the monitors were significantly high enough and the installation/removal costs were low, then it would make sense to acquire devices which were fairly transportable to other sites.

In the end three different devices were selected, as between them they satisfied the various scenarios for installation and measurement types. However the balance between the costs of the devices and their installation/removal was at a point where it made sense to install them for a period to capture the load and voltage profiles of a particular area of network and then once that was complete to move them to another site which had issues of changing customer demands.

This is illustrated in that the typical cost of a secondary substation monitor was between £1400-£2400 against a typical installation and removal costs of approximately £200 and £100 respectively.

4.3.1 Monitoring Equipment

The monitoring equipment selected for use in the trial were:

- EMS - Subnet (HV and LV substation monitor)
- Selex-ES – Gridkey (LV Substation Monitor)
- Landis & Gyr – E650 Smartmeter (LV supply monitor)
- Skye Weather Station with Nortech 'Envoy' RTU

EMS - Subnet (HV and LV substation monitor)

The key features of the device for which it was selected were:-

- Cost
- Wide measurement capability, e.g. HV apparatus, LV apparatus, other analogues
- Up to 12 x three-phase circuits
- Digital I/O functionality
- Communication options
- Size

Selex-ES – Gridkey (LV substation monitor)

The key features of the device for which it was selected were:-

- Cost
- Specifically designed for LV fuse boards
- Up to 5 x three-phase circuits
- Ease of installation & simple connections
- Size
- Suitability for outdoor installation – IP rating

4.3.1 Monitoring Equipment [continued]

Landis & Gyr – E650 Smartmeter (LV supply monitor)

The key features of the device for which it was selected were:-

- Low cost
- Voltage & Load measurement (trial as substation monitor)
- Communications
- "Meter like" design for customer installations

Skye Weather Station with Nortech 'Envoy' RTU

The key features of the device for which it was selected were:-

- Low cost and small numbers required
- Simple 'used-before' design that staff had experience installing
- No compatibility issues for data communication to iHost

Ashridge 852plus Transformer Temperature Monitor

The key features of the device for which it was selected were:-

- Transducer output of measured temperature values
- Low cost replacement for existing Winding Temperature Indicator unit
- Simple design, size and existing approvals

More detailed information is available in the separate report entitled *"Enhanced Substation Monitoring Deployment".*

4.4 Monitoring Data Management

The high level system architecture of the monitoring data management system is given in Figure 2, showing how the various system components communicate with each other.

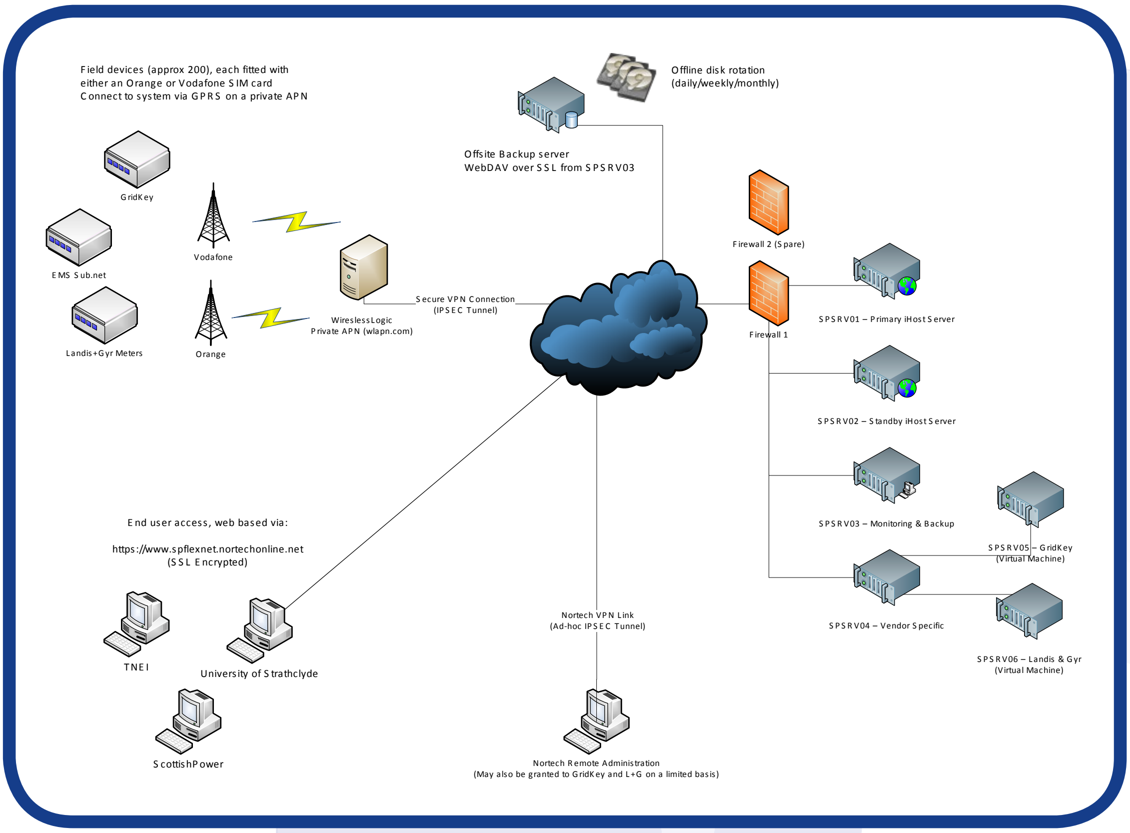

Figure 2 – Monitoring Data Management – System Architecture

Key features of the system include:

Firewall - Security was an important consideration for the project. A firewall was selected to ensure that only very specific services were accessible from the public Internet, whilst allowing remote access to the servers for support and administration.

Private APN Link - In order to protect the remote field devices from being internet connected, their GPRS traffic is sent to a Private APN. This provides a gateway from the devices that keeps their communications separate from internet traffic.

iHost Server - The iHost server was the main component of the system. This is responsible for:

- Communicating with the field devices, using the variety of different protocols
- Storing the data in an online database
- Holding metadata about the various sites
- Exporting the data in various formats, as requested by project partners.
- Making the data available via WebDAV for project partners to download
- Making the data available via a user friendly web interface

SIM Cards - A private APN service is added to the SIM cards provided by the network operators. This private APN allows the communications to operate as a closed system, rather than passing the data over the public internet. The private APN also allows static IP address to be assigned to the SIM cards.

4.4 Monitoring Data Management [continued]

A key learning point from the data management exercise has been that better commissioning tests and checks when substation monitoring equipment is installed on site are required. Several problems were found late on in the project after equipment had been collecting data for over a year. This included voltages out by a factor of 10, and CTs incorrectly installed. Whilst it has been possible to correct a lot of the collected data, a more thorough commissioning process, utilizing iHost to validate data on the day of commissioning, would have removed further remedial actions.

More detailed information is available in the separate report entitled *"Monitoring Data Management and iHost System Report"*.

4.5 New Planning and Operational Tools and Strategies

At a high level, the network planning process to assess the suitability of the Flexible Networks solutions for application to constrained networks follows a similar approach to traditional reinforcement techniques;

- Initial identification of constrained networks;
- Definition of a range of potential suitable reinforcement options;
- Calculation of potential capacity release;
- Consideration of cost benefit including capital and operational costs;

Assessment of suitability, capacity release and cost benefit followed by deployment requires a modified approach and/or inputs as described below. Deployment of the technologies also has implications for existing policy on voltage, asset ratings and load index for example.

More detailed information is available in a separate report entitled *"New Planning and Operational Tools and Strategies"*, but a summary of the main points is provided below:

4.5.1 Load forecasting

An enhanced load forecasting and risk characterisation tool was developed that provides a more accurate forecast of future network group load growth trends in comparison to existing practice. The underlying methodology and application is described in detail in *"Flexible Networks – Improved Use of Primary Substation Data"*. This is integrated with the existing SPEN load forecasting tool for use in annual network review during RIIO-ED1.

4.5.2 Improved Secondary Substation Monitoring

A future network monitoring strategy has evolved from the *"RIIO-ED1 LCT Network Monitoring Strategy"* submitted as part of the SPEN RIIO-ED1 business plan to a strategy that captures the most recent learning outcomes from Flexible Networks.

Key features include;

- Install "smart" MDIs in secondary substations at key locations across the LV network identified through application of the LCT Network Monitoring Strategy.
- Install secondary substation monitors with more detailed functionality e.g. monitoring of all LV distributors and phases at a small volume of selected locations of high LCT clustering and network constraints as identified through application of the LCT Network Monitoring Strategy.

The network monitoring strategy is being rolled out during RIIO-ED1.

4.5.3 PV Characterisation

Rules of thumb were developed for characterisation of PV generation at LV based on network modelling and verification with measured load, voltage and weather data as part of Flexible Networks.

Key features include;

- A peak PV generation load factor of 90% for North Wales/Scotland,
- A generic minimum residential demand of 300W during periods of peak PV generation
- Individual LV feeders were found to have a PV hosting capacity of at least 65% for PV systems rated at 1.6kW.

Application of a reduction (possibly seasonal) to the primary substation voltage set point will be applied to release further generation capacity headroom.

The PV connection policy will be updated to reflect these rules-of-thumb and the application of a voltage set point reduction of up to 2% at the primary. This will also be included in the SPEN voltage policy.

4.5.4 Load Modelling

The University of Strathclyde recommended that SPEN should model network loads on a constant current basis, except where knowledge of particular load behaviour dictates otherwise, based on a detailed assessment of load modelling for Flexible Networks. In IPSA, this can be achieved through use of the ZIP load model, configured to act as a constant current load. This new development will be evaluated further beyond Flexible Networks for business as usual integration and further validation.

A study of the level and patterns of load diversity among secondary substations in the three Flexible Networks test areas was carried out . This has provided learning that can be applied to the modelling of load on 11kV networks, to a large extent validating existing assumptions that are used for ground mounted and demand power factor. We recognise that this may change over time however with the uptake of low carbon technology. This learning will be incorporated into future network modelling practice and any interactions with the use of a constant current load model evaluated.

4.5.5 Characterisation of HV and LV imbalance

A simple methodology was developed to allow LV feeders with significant thermal phase imbalance to be rapidly identified based on detailed monitoring data and compared with cable thermal ratings. Feeders can then be ranked and prioritised for investigation of phase rebalancing to improve headroom. Whilst this is only applicable to LV feeders with phase current monitoring fitted, learning outcomes from Flexible Networks suggest LV feeder types that may suffer greater imbalance so can inform network planning during annual review in future.

4.6 A Visualisation of Data Analytics Functions

There is an exponential growth in data being collected across the business which is often held in separate systems. As a result there is a need for tools to enable us to pull data from different source systems and efficiently analyse it in a way that provides visualisations and reports that provide business benefit. Analytics has the potential to improve our cost efficiency, improve our asset management techniques, and facilitate new or improved services to customers.

The trial has demonstrated that it is possible to extract data that resides in different systems and use this to create new visualisations and reports that benefit the business. Through the trial we have encountered some difficulties in extracting data from existing systems and this has added to our learning. Under a large scale implementation of data analytics it would be impractical to extract data in the highly manual way it was undertaken for the trial. The trial has also highlighted that there are inconsistencies in the way that assets and data are identified between different systems which adds to the complexity of data retrieval.

Overall the trial has been a useful and informative first step for SPEN in the area of data analytics. In particular, it has highlighted some interesting areas, but need further work:

- **State estimation** – estimation of conditions at points on the network that are not monitored. This is an area that may be of interest to SPEN because there is only limited secondary network monitoring to be installed under our ED1 business plan so the ability to compensate for this may be of interest.
- **11kV Network Data** – SPEN have power quality monitors installed at primary substations with the ability to provide large amounts of data. In addition we have large numbers of NOJA pole mounted auto-reclosers on the 11kV network that have data logging as an inbuilt feature. There is potential to examine how this data from these two sources might be retrieved and analysed.
- **Asset risk management** – The potential to analyse data from a number of different systems (including the existing SAP asset management system) for risk management of assets could be considered.
- The analysis of **smart meter data** is another potential application of data analytics

More detailed information is available in a separate report entitled *"A Visualisation of Data Analytics Functions"*.

5 Updated Business Case and Lessons Learnt

5.1 Business Case

A financial evaluation has been carried out to determine the benefit that can be gained by deploying detailed secondary substation monitoring. For this evaluation, the unit costs were obtained from indicative quotations from SPEN's approved suppliers for the new technologies and from SPEN's Unit Cost Manual document for the conventional "base case" solution.

5.1.1 Methodology

The aim is to quantify the cost per kVA of capacity gained by applying an "alternative" or new technology solution against the cost per kVA of the traditional business as usual reinforcement solution.

5.1.2 Future Roll Out Cost of Network Monitoring

Table 3 below shows a breakdown of the trial method costs versus the repeated method cost of deployment for the detailed secondary substation network monitoring. The trial cost shows the cost of undertaking the trial of the monitoring. The repeated method costs illustrate the costs of further deployment to other sites in future. The benefit column shows the capacity gained through the deployment of monitoring and the Cost/Benefit ratio shows the cost of each kVA of headroom benefit, if the monitoring was deployed as a stand-alone initiative.

Table 3: Trial Method Cost versus Repeated Method Costs

Activity	Base cost (£K)	Repeated Method cost	Benefit
Site & Communication surveys	17000	6000	
Monitoring equipment	1175000	180000	
Monitor installation/commissioning	90000	25000	
Data hub/IT support	159000	24702	
Data communication	95000	24000	
Equipment maintenance	20000	3000	
Data quality & performance upkeep	15100	4000	
Engineering & project management	92000	40000	
Totals	1663100	306702*	
*Total repeated method cost is for approximately 100 substation sites			
Per secondary substation		£3,067	
Average Benefit Enhancement (kVA per substation)			39kVA
Average Cost/Benefit Ratio (£/KVA)			£78/kVA

5.1.2 Future Roll Out Cost of Network Monitoring [continued]

Site & Communication Surveys – This is necessary to determine if the sites are suitable for the installation of the monitoring equipment, in terms of space, connectivity, safety and communication medium (e.g. signal strength for GPRS comms).

Monitoring Equipment – Purchase of the monitoring units, measurement sensors and ancillary items.

Monitor Installation/Commissioning – Resources for installation and setup of the monitors.

Data Hub/IT Support – Hosting service and web portal access for the monitoring data.

Data Communication – Data communication costs, which was SIM cards and a monthly data charge.

Equipment Maintenance – Ongoing attendance to monitors and communication equipment which is necessary for a large number of units continually running.

Data Quality & Performance Upkeep – Regular checking of the data collection and quality, to identify and target equipment operation and performance issues.

Engineering & Project Management – Practical aspects of delivery of a monitoring population.

The estimated method cost for replicating the project is £306,702 to the DNO for the installation of approximately 100 substation and network monitors, a data hub with a web access portal and to provide the communications between the monitors and the hub for the data. At the secondary substations on the trial sites where we installed the monitoring, the enhanced load information gave us the confidence that on average, we had additional capacity available from what was previously understood from the maximum demand indicator (MDI) data. The value of the additional capacity at 86 substations with an average rating of 490kVA was 8%, equating to an average of 39kVA* per substation.

In this trial this was assessed from:-

- 86 substations with enhanced monitoring and MDI comparison.
- Transformer capacities varied from 100-1000kVA (averaging 490kVA)
- Substation loading of MDI versus monitoring demand was between -43% and +44% (averaging +8%)

*Note, This was found on a specific group of secondary substations, at another site this figure may be more or less than the average additional capacity figure found to be available in this trial.

5.1.3 Base Cost

The base cost for this capacity is £5,880 for the DNO. This is the typical pro-rata cost for the reinforcement for a secondary substation that is currently at full capacity.

Capacity of 39.2kW @ £150/kVA = £5,880

5.1.4 Financial Benefit:

Base Cost: £5,880

Method Cost: £3,067

Financial Benefit = Base Cost – Method Cost

Financial Benefit = £5,880 – £3,067

Financial Benefit = £2,813

Further details of the business case assessment can be found in report *"Flexible Networks Project Cost Benefit Analysis – Enhanced Network Monitoring"*

5.2 Lessons Learnt for Future Monitoring Projects

This section provides an overview on key challenges encountered and lesson learnt in the course of project.

5.2.1 Monitoring Learning

Since the commissioning of the monitors, they have generally performed well in recording the data and transmitting the data to the iHost database. A few issues have been encountered, such as;

- The detailed site surveys were critical in the identification of sourcing monitors that would be easy to install and connect to the existing network apparatus.
- The selection of a number of monitors meant that we could deploy the most suitable monitor for a given installation scenario and also spread the risk that for any specific monitor or component failure then the entire population of monitors would not be jeopardised.
- A visit was made by the technical team to the selected devices manufacturers. This was of invaluable for all concerned, for the user to fully understand the manufacture and assembly processes and for the suppliers to fully understand the user requirements and intended use methodologies. This also built up a co-operative working relationship between the suppliers and the end users and enabled the units to be configured and tested as much as possible prior to dispatch for installation.
- It was communicated with the manufacturer that the quality checks of the GPRS SIM card installation (where embedded inside the IP65 factory sealed unit) were critical, given that some of these units were being installed at height on the overhead line pole mounted transformers. The consequences of a poor SIM card connection would have meant the unit being taken down, returned to the factory and reinstalled at substantial cost.
- Undertaking test-case installations enabled a fully assessed installation guide and safety method statement to be produced prior to the training of the teams and commencement of the installation program.
- Having the iHost database installed and commissioned ready to receive data as each monitor was installed meant that immediate configuration and testing of data being captured could be carried out without any site revisits.
- The GPRS communications has been a bit intermittent in some weak signal areas. A signal strength meter was used to identify the best signal level position and at some sites the aerials were repositioned outside the substation enclosure.
- The intermittency of the data communications caused the development of a system from monitoring the data completeness being captured in the database in the form of a report. This has helped identify trends in monitor data issues and provided a focus for problem solving.

6 Project Replication

6.1 Anticipated business-as-usual costs

We expect there to be cost reductions and feature enhancements of monitoring in the future. So, the costs below are indicative of the costs in 2012, when the equipment was originally procured, but would expect to pay less than this in the future.

Table 4: Indicative cost for deploying detailed network monitoring in BaU

Item Description	Cost [£]
HV and LV substation monitor (e.g. Selex)	£1500 (LV) - £3,500 (HV)
LV Substation Monitor (e.g. Gridkey)	£1400-£2400
LV Supply Monitor (e.g. L&G E650 Smartmeter)	250
Installation Costs	£100-£200
Weather Station + RTU (e.g. Skye + Envoy)	8,500
Smart MDI (future development)	£250
3G Comms (per node, per month)	£5-10
Cloud Data Hosting	£25000
Data Analytics	£150,000 to potentially £millions

7 Planned Implementation

7.1 Secondary Substation Monitoring in the SPEN ED1 Business Plan

The merits of secondary substation monitoring was assessed as part of SPEN's ED1 business plan and sufficient benefits were recognised to recommend secondary substation monitoring on up to 4 to 5% of the SPEN secondary network during the ED1 price control period. This is likely to be a mix of the "LV Substation Monitor" and the "Smart MDI".

7.2 Future Monitoring

From the data recorded on this project it was learnt that the majority of the useful information came from the secondary transformer loading profiles and that whilst there is additional benefit of the information of the individual circuit/phasing load profiles, that the additional costs of measuring, recording, communicating and storing of this data may not always provide the same level of benefit.

Therefore we believe that a low-cost replacement for the existing MDI's which is permanently fitted with a captured-data communication function would probably give a greater cost/benefit. Should there be less predictable loads or generation which may give rise for the need for more detailed data information, then a more expensive monitor could be fitted to measure all the circuit phase loads as necessary.

8 Further Reading

This methodology and learning report is supported by a series of more detailed reports, as identified below:

1 Improved Use of Existing Primary Substation Data

2 Enhanced Substation Monitoring Deployment

3 Monitoring data and iHost system report

4 Planning and Operations Tools and Strategy

5 Good Practice Guide Monitoring

6 IBM DGA

7 Flexible Networks Project Cost Benefit Analysis – Enhanced Network Monitoring

9 Contact details

Alan Collinson, SP Energy Networks (alan.collinson@spenergynetworks.co.uk);

Kevin Smith, SP Energy Networks (kevin.smith@spenergynetworks.co.uk);

Charlotte Higgins, TNEI (charlotte.higgins@tnei.co.uk);

Ian Elders, University of Strathclyde (ian.elders@eee.ac.uk);

Simon Hodgson, Nortech Management Limited (simon.hodgson@nortechonline.co.uk);