EXPERIENCES FROM AN ACTIVE NETWORK MANAGEMENT TRIAL ON AN URBAN NETWORK

Colin GAULT
Smarter Grid Solutions – USA
cgault@smartergridsolutions.com

David OLMOS MATA
Smarter Grid Solutions – UK
dolmos@smartergridsolutions.com

Tamunosepiribo SOKARI-BRIGGS
Smarter Grid Solutions – UK
tsokari@smartergridsolutions.com

Graham AULT
Smarter Grid Solutions – UK
gault@smartergridsolutions.com

Colin FOOTE
Smarter Grid Solutions – UK
cfoote@smartergridsolutions.com

Michael CLARK
UK Power Networks – UK
michael.clark@ukpowernetworks.co.uk

ABSTRACT

UK Power Networks, who own and operate the urban electricity distribution network within London, was awarded funding for its Low Carbon London project as part of Ofgem's Low Carbon Networks Fund in 2010. The project is due to come to an end in 2014 and, as one of the project delivery partners, Smarter Grid Solutions has amassed valuable experience from the perspective of a solutions provider. This paper presents a summary of this experience and the lessons learned in the provision of Active Network Management (ANM) systems for an urban electricity network.

INTRODUCTION

Ofgem, the UK's energy regulator, established the Low Carbon Network Fund in 2009. This fund, with a total value of £500 million, supports Distribution Network Operators (DNOs) in the trial of innovative technologies and commercial arrangements. Projects eligible for second tier funding must demonstrate that they will improve the DNO community's overall understanding of how to provide value for money for their customers in a low carbon economy. The UK Power Networks led Low Carbon London (LCL) project was successfully awarded £24 million funding and began in 2010. References [3] and [4] provide links to Ofgem's and UK Power Networks' websites respectively, which contain all the public documents on the project.

Smarter Grid Solutions (see reference [5]) has been a key partner in the project, delivering Active Network Management (ANM) systems for the following project use cases:

- Monitor and facilitate distributed generation connections to the LV and HV distribution network.
- Active management of distributed generation to address security of supply and defer network reinforcement.
- Demand response management by regulating electric vehicle charging.

ACTIVE NETWORK MANAGEMENT SYSTEM ARCHITECTURE

The architecture of the ANM system used for the trials conducted as part of the LCL project is presented in Figure 1. The main components of the LCL ANM system are (see reference [5] for more details):

- **sgs core**: Real-time smart grid control platform upon which various smart grid applications can be deployed. It hosts **sgs power flow**.
- **sgs comms hub**: Performs all data handling and processing for **sgs core** via a range of industry-standard communication protocols.
- **sgs power flow**: ANM application that performs real-time management of energy producing or consuming devices to maintain power flows within the constraints of the network.
- **sgs connect**: Receives set-point signals and control instructions calculated by **sgs power flow**, and transmits these to devices under the control of ANM. It also receives status updates from devices being controlled and implements autonomous failsafe mechanisms in the event of non-compliance, loss of communications or abnormal operation.
- **ANM data historian**: An instance of OSIsoft PI software, supplied by Rockwell Automation. It uploads data to the Operational Data Store (ODS) through a PI-PI interface. See reference [6] for more information.

The Central ANM Controller (collectively **sgs core**, **sgs comms hub** and a user interface) was installed within a substation in London, chosen because of its centrality and existing communication links with other substations. Figure 1 shows the interfaces of the Central ANM Controller with: a Remote Terminal Unit (RTU) within another substation, the ODS, UK Power Networks' SCADA, a distributed generator (DG), a Demand Response Control Centre (DRCC) and an electric vehicle charging network operator (EVCNO).

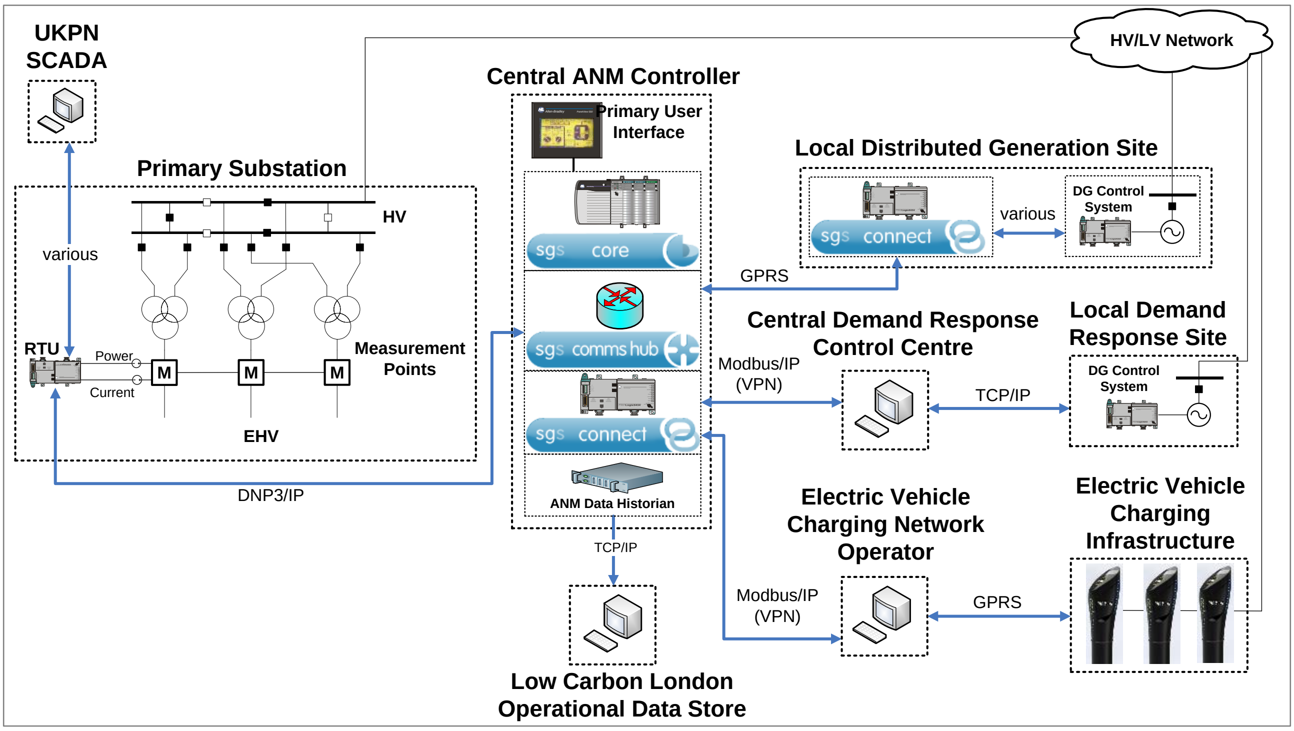

Figure 1: ANM architecture

The connection with the RTU provides measurement information and circuit breaker status to the Central ANM Controller, as well as facilitating a link between UK Power Networks' SCADA system and ANM. The DNP3 communications protocol was selected for communication between ANM and the RTU. UK Power Networks made the decision that the RTU should be set up to operate as a DNP3.0 master ensuring the RTU maintains control over the collection and forwarding of data to ANM.

The ANM system exchanges data and control instructions with controllable devices via **sgs connect**. For the DG, which the ANM system was interfacing with directly and therefore responsible for the failsafe operation during loss of communications, **sgs connect** was located on the same site as the DG.

When the ANM system is indirectly controlling devices through the control system of a commercial demand response aggregator or an electric vehicle charging network operator, it is that control system which has responsibility for ensuring failsafe operation of the end device during a loss of communications event. Therefore, **sgs connect** does not need to be located at the same site as the controllable device and, in this instance, communication with the DRCC and EVCNO was via a **sgs connect** located alongside the Central ANM Controller.

The communications interface between **sgs connect** and the DG, DRCC and EVCNO uses the byte-orientated protocol Modbus TCP. The DRCC and EVCNO are connected to the **sgs connect** through a Virtual Private Network (VPN) managed by UK Power Networks.

The communication medium used between **sgs connect** and the DG site was a GPRS link managed by UK Power Networks. The DRCC and EVCNO have their own communications link to the sites of controllable devices. Although shown as a generator in Figure 1, the device providing demand response can also be a load reducing the net power flow into a constrained or overloaded area of the network.

LOW CARBON LONDON USE CASES

Monitor and facilitate distributed generation connections to the LV and HV distribution network

Within the trials associated with this use case, ANM was used to monitor DG connected to the distribution network. Originally, the intention was for ANM to be used to manage thermal and voltage constraints caused by new DG. This would facilitate less expensive DG connections by deferring or avoiding capital investment in network upgrades.

However, the level of DG penetration in central London was not significant enough to require ANM-style connections at that time. In London, demand is such that reverse power flow caused by DG export is not large enough to breach the thermal capacity of the network; the majority of power generated is consumed locally. Voltage rise is not a problem either due to the relatively short feeder lengths, giving a lower impedance compared with rural networks.

Like most urban electricity networks, London currently does have problems with fault level. This is more difficult to solve because it is not dynamic like voltage or thermal constraints. Regulating a generator's output does not reduce its fault level contribution. Network configuration has a large impact on fault level on the network and often the fault level problem only occurs under certain network configurations. No suitable participants to trial the ANM approach to fault level constraints were identified.

Although the DG penetration levels were lower than those required to breach thermal and voltage limits, the project's aim was to trial solutions to future problems when penetration levels are expected to be much higher. The ANM solution was still installed such that it could be used to regulate the output of DGs if they caused a network overload. The ANM system also collected measured data from the DGs, typically current, voltage, active power, reactive power and power factor. These values were collected per phase when possible. The ANM system also collects network measurement data and communicates with SCADA and ODS.

The monitoring of DGs in this way accomplishes two objectives: it validates the architecture of the ANM system from end to end and it provides valuable data on DGs correlated with the data collected from the network. This collected data is being used to model more accurately the impact and contribution of DGs to the network performance, to tailor solutions for the future.

Active management of distributed generation to address security of supply and defer network reinforcement

Although UK Power Networks is allowed to include a contribution from DGs when planning for security of supply, this is rarely done. Planning engineers do not have confidence in unregulated DGs being available when needed.

ANM was used in this project to control the output of DGs in response to times of peak load. By increasing the output of DGs when required, peak demand can be reduced. In this way, higher load levels can be served through an existing substation, increasing the secure capacity of that substation.

The use of ANM with real time network measurements (as opposed to day-ahead scheduling based on estimates) allows the DGs to only be requested to provide a response when necessary.

The original intention was to have direct communication between ANM and DGs. However, the initial recruitment phase did not produce suitable DG candidates. As such, the ANM system was adapted to interface with the control systems of commercial demand response aggregators. This was possible because several commercial aggregators were already involved as project partners through a separate use case that was delivering a more traditional demand response, which is scheduled in advance based on times when it was thought demand would peak and dispatched via a phone call or e-mail.

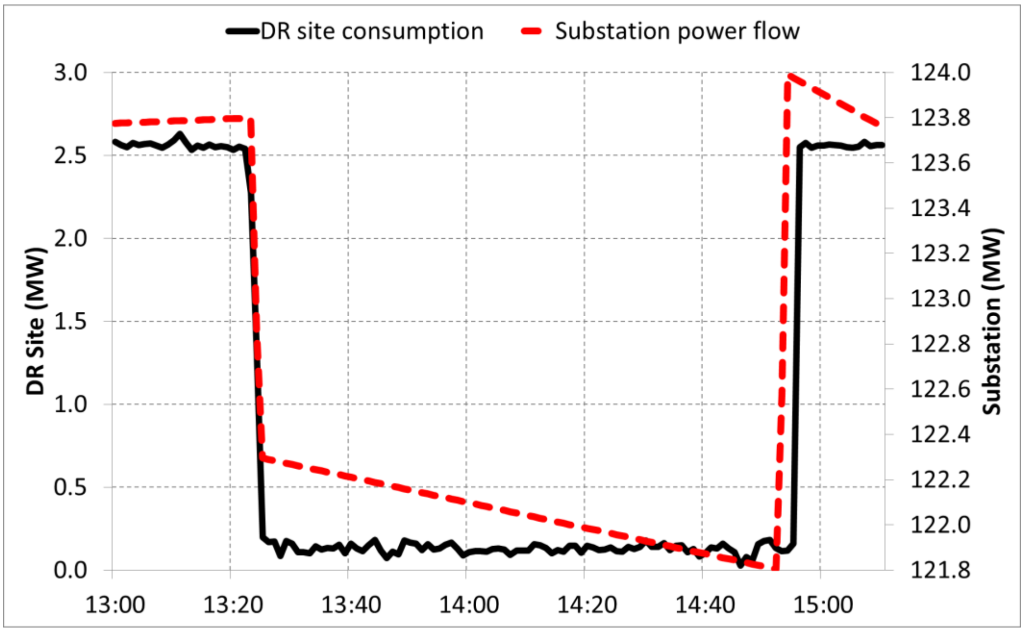

Figure 2: ANM-DR event

Table 1: ANM-DR data transfer

Name	Source	Destination	Description
Watchdog	**sgs connect** / DRCC	DRCC / **sgs connect**	Used to establish health of communications between DRCC and **sgs connect**
Available DR	DRCC	**sgs connect**	Magnitude (kW) of available demand response
DR Request	**sgs connect**	DRCC	1 – ALL available demand response is requested 0 – ZERO demand response is requested
Measured DR	DRCC	**sgs connect**	Real-time measurement of demand response provided (kW)
In service	DRCC	**sgs connect**	1 – DRCC is ‘in service’ and demand response is available 0 – DRCC is ‘out of service’ and demand response is unavailable

Table 2: ANM-EV data transfer

Name	Source	Destination	Description
Watchdog	**sgs connect** / EVCNO	EVCNO / **sgs connect**	Used to establish health of communications between EVCNO and **sgs connect**
Total demand	EVCNO	**sgs connect**	Magnitude (kW) of EV group demand
Available demand reduction	EVCNO	**sgs connect**	Magnitude (kW) of available EV group demand reduction
Demand upper limit set-point	**sgs connect**	EVCNO	Magnitude (kW) of EV group demand upper limit
Instantaneous load shed	**sgs connect**	**sgs connect**	Magnitude (kW) of curtailed demand as a result of the upper limit set by ANM

Whereas UK Power Networks, like other DNOs in the UK, has relatively little experience signing up customers to participate in these types of projects, aggregators have many years of experience. In addition, aggregators have access to established ancillary service markets operated by National Grid (UK transmission system operator). The commercial aggregators were successful in signing up participants for trials within this use case.

Table 1 shows the data that was exchanged between the ANM system and the commercial aggregators’ DRCC. This data was exchanged for every demand response portfolio under the control of ANM. A demand response portfolio in this context is a collection of DGs or variable loads grouped together and associated with a specific network constraint. Since the portfolios could only provide their full stated capacity, ANM always requested the full amount that the portfolio could provide.

Figure 2 shows an ANM-triggered DR event in a central London substation. When the power flow at the substation breaches the ANM threshold, ANM sends a request to the DRCC, decreasing the flow through the substation boundary. This is achieved by switching off part of the DR site consumption and switching on their local generator.

UK Power Networks put commercial contracts in place with the aggregators. These contracts stated the capacity of demand response available for each portfolio, the availability time window for each portfolio and speed of response (time from event trigger to capacity delivered). Failure to meet the terms of the contract results in economic penalties.

At the same time, the contract included restrictions on UK Power Networks use of the demand response in the form of a maximum number of calls per day/week/ season, and a minimum and maximum duration for which a response can be requested. The ANM system was configured to respect all of the terms within the contract, so the ANM system tracked the number of requests made and the duration of each request. Whenever a limit is reached for a particular portfolio, the ANM system prohibits itself from using that portfolio for the rest of the day/week/season, depending on what limit was reached.

Demand response management by regulating electric vehicle charging

If penetration levels of electric vehicles meet expectations, many of the transformers within existing substations would have to be replaced to accommodate the increases in network loading. Within the LCL project, a method by which electric vehicle charging could be regulated was trialled.

ANM received power flow measurement data from the network in real-time and curtailed electric vehicle charging whenever the agreed thresholds in power flow were breached.

As depicted in Figure 1, the ANM system communicates via the control system of the EVCNO. As such, the ANM system has no direct link to individual electric vehicle charge points and is reliant on the control system of the

EVCNO for status information and for issuing control signals to the individual charge points.

It was agreed that multiple electric vehicle charge points be grouped according to location and therefore association with a particular network constraint. Each group is represented within the ANM system as a single controllable demand object. The data transfer between the EVCNO control system and **sgs connect** for each group of charge points is detailed in Table 2.

ANM monitors the constraints of the network and manages them by issuing requests to the EVCNO to reduce the total demand of a group of charge points. The EVCNO processes these requests and is then responsible for ensuring requests are met. The ANM system has no control over which charge points within a particular group are affected.

Unlike with ANM-DR, here there were no commercial constraints on agreed availability or number/length of events. When the EVCNO indicated that there was available demand reduction for a particular group of charge points, the ANM system could use it for as long as was required to resolve the constraint.

CONCLUSIONS AND NEXT STEPS

Participation has been identified as the main difficulty encountered in the project, which is shared with many other innovation projects. This highlights the importance of customer engagement at an early stage via workshops or active communication channels.

The flexibility of the technical solution and team involved has been key to the success of the project. Despite the challenges encountered over the project, Low Carbon London has managed to adapt, providing useful learning for the 'Business as Usual' implementation.

One example of how the trials were adapted to the customers participating in DR is the simulated constraints. These EV charge posts and DR sites were supplied from several different substations, which were not constrained. Also, the DR capacity connected to a substation was often too small to have a material impact. Therefore, the constraints had to be simulated and events triggered off relevant, representative substations even if they were not always the ones supplying the DR sites.

Innovation projects trial technologies for constraints that are still rare but expected to be more common in the future. Utilities must think of innovative ways to include real world devices and situations into these trials.

Innovation projects should not be isolated to future networks teams. Internal stakeholders within the DNOs are critical to get these projects and ideas integrated across the DNOs.

Low Carbon London has managed to create new projects being currently developed that build on the existing learning. There are potential projects on fault level, and direct ANM-enabled demand response with generation and EVs.

The project will produce 14 final reports that will address all the expected learning points. They will also provide practical DNO-wide guidance on how to implement the new strategies explored. These reports will be published in September'14 and supported with knowledge dissemination events.

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