FLEXIBLE PLUG AND PLAY LOW CARBON NETWORKS: AN OPEN AND SCALABLE ACTIVE NETWORK MANAGEMENT SOLUTION FOR A FASTER AND CHEAPER DISTRIBUTED GENERATION CONNECTION

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ABSTRACT

The 'Flexible Plug and Play Low Carbon Networks' (FPP) project aims to facilitate faster and cheaper connections of renewable generation onto the distribution network, by using innovative technical and commercial solutions. In order to move from a passive 'fit and forget' to a more active 'fit and flex' approach, the FPP project have specified an Active Network Management (ANM) platform and will trial it to effectively demonstrate this new approach.

This paper describes the technical solution which will be implemented to dynamically mitigate constraints caused by the connection of generators to existing networks. It details the different smart applications and smart devices which will be deployed to manage power flows and voltage as well as to provide real time rating of overhead lines. Specifically two platforms will be delivered during the project: a pre-production platform to integrate the overall system and a production platform for the trial. The platforms, by implementing the IEC 61850 standard, will aim to demonstrate the capability to develop a vendor agnostic open standards architecture to enable end-to-end communication between distributed smart network technologies and generation.

INTRODUCTION

The problem

UK Power Networks' Eastern Power Networks (EPN) distribution network serves an area of approximately 700 km^2 between Peterborough and Cambridge in the East of England that is particularly well suited to renewable generation. In line the Government's drive for increased renewable generation to meet its Carbon Emissions Reduction Target, UK Power Networks has experienced increased activity in renewable generation development in this area over recent years, and a rapid rise in connection applications, with 121 MW of wind generation already connected and around 200 MW at the planning stage.

The connection of these anticipated levels of wind generation is expected to require significant network reinforcement to mitigate network thermal and voltage constraints and reverse power flow issues.

In order for the FPP project to demonstrate the benefits it can deliver, it is paramount that both the technical solution and commercial framework being developed are adopted by distributed generators.

The FPP project team has been monitoring the generation connections activity in the area, and has proactively engaged with seven generators seeking connections in the FPP trial area. These seven projects are seeking connection at constrained parts of the trial area network and, as a result, their 'conventional' connection quotes include significant costs for provision of expensive sole-use assets. UK Power Networks has identified opportunities to offer cheaper and faster connection through actively managed non-firm connections.

The Technical Solution

In order to transform these opportunities into an effective solution, UK Power Networks specified an ANM solution to monitor network constraints and control the output of the generators connected inside the trial area. The preliminary step was to provide the technical (power systems) analysis to assess the power or voltage constraints that would need to be managed. When the constraints were identified and the level of curtailment assessed (mainly dependent on the commercial agreements in place between UK Power Networks and the generator developers), the project specified the requirements to design the ANM solution. This solution explored the possibility to rollout smart devices (Dynamic Line Rating, Voltage Control Relays and Quadrature Booster) and generator controllers to mitigate the constraints. The ANM infrastructure relies on a Radio Frequency Meshed communication platform and the use of the IEC 61850 protocol to form an interoperable and scalable solution. The use of the IEC 61850 protocol over a wide wireless communication network is one of the main technical challenges of this project.

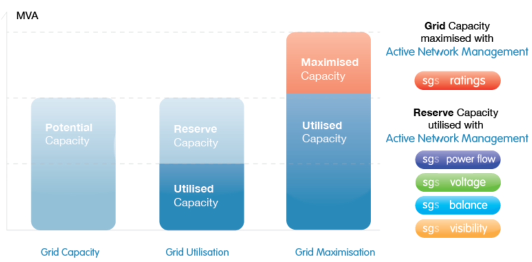
Finally, the ANM solution and its associated components (described in this document) will be installed during the trial period to maximize capacity for renewable generators while maintaining the network within thermal and voltage limits.

THE ROLE OF ANM IN THE FPP PROJECT

In many areas, including the FPP trial area in Cambridgeshire, the network capacity available for new connections to the electricity network is about half of the installed network capacity, as shown in Figure 1. This is due to a network planning methodology based on passive operation which reserves an element of capacity for network outages, or other rare and unforeseen occurrences.

During the FPP trial the ANM will monitor and control the network so that this reserve capacity can be used for new connections. ANM will involve the adoption of a Platform and associated autonomous software applications, from Smarter Grid Solutions, to monitor and control the network in real time to ensure it remains within its operating constraints. Within the FPP project, several ANM applications will be deployed including **power flow management and voltage management applications**. The project also will also trial a **thermal ratings application** which increases the capacity of the network when weather cooling effects allow more power to be transferred, particularly through overhead lines.

Figure 1 – Maximising Network Capacity using ANM



Communication Infrastructure

The principal component to enable the active management of the electricity distribution network is the deployment of a communications platform capable of facilitating the required data exchange in real time. For this project an IEC 61850 based communications system over an IP (Internet Protocol) platform has been deployed. The communications platform enables high speed peer-to-peer communications and provides self-healing capabilities. The use of an IP-based solution using IEC 61850 enables a wide range of vendor products to be integrated onto the network to resolve specific network constraints and demonstrate interoperability.

The ANM system aims to manage the connection of generators in real time. By real time, it is important to clarify that the project does not act in the same timescale as protection systems. The project targets reaction time windows of several seconds. Therefore, the project focused on MMS (Manufacturing Message Specification) messages rather than GOOSE (Generic Object Oriented Substation Events) messages which are more relevant in a protection context. The reliability of the communication link is one of the main challenges in the FPP context, as the ANM system needs to ensure that the network is in a safe state at all times. The communications platform is based on Multi Service Platform (MSP) circuits and an innovative wireless radio frequency mesh network. The terminal nodes of the mesh network are installed at the substation and generator levels. These nodes are connected to the ANM application servers using 61850 protocols over the radio frequency mesh network and captures the work carried with the project partners to design and deploy the communications system [1].

Smart Devices

As well as controlling DG on the network the FPP Project includes several Intelligent Electric Devices (IEDs) which are used to collect measurement data or work along with the ANM to manage the network. These include a Quadrature Booster Controller System, Dynamic Line Ratings (DLR) devices, Automatic Voltage Control (AVC) relays, Frequent Use Switches (FUSs) and **sgs connect** devices to control DG.

The Quadrature Booster is provided by Wilson Transformer (manufacturer) and the Quadrature Booster Controller System by Fundamentals [2]. The DLR devices will be delivered by Alstom and they provide weather information as well as ampacity ratings for the relevant overhead line. The AVC relays are provided by Fundamentals. These provide tap changer functionality at specific transformers on the network. The FUSs use switching capabilities already deployed in Ring Main Unit. The **sgs connect** device is based on a Brodersen RTU32 and includes ANM and fail-safe logic to ensure that the network is maintained in a safe state at all times.

Smart Applications

The ANM solution implemented for the FPP project involves a platform hosting a series of applications that are autonomous, predictable, reliable and deterministic. This technology must be and is reliable, repeatable, transparent and easily understood by all stakeholders (e.g. from control room engineers to generator developers). Operationally, one of the main requirements of the FPP project is the flexibility to configure the platform and applications to scale up the system to handle ongoing additions and changes on the network such as those anticipated within the trial area. The ANM solution also interfaces with existing upstream UK Power Networks' enterprise systems such as SCADA and data historian systems as well as downstream components such as RTUs.

Power flow management

sgs power flow is the real time algorithm gathering power information from the FPP network and issuing set points to DG units on that network according to the following principles:

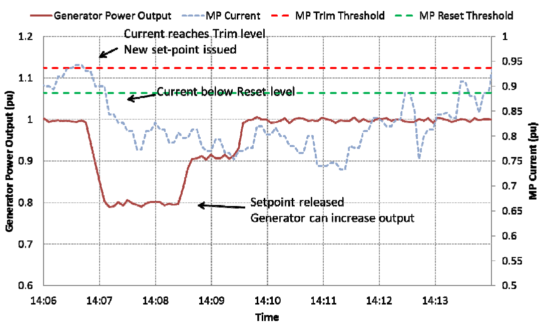
- Power output from DG units is curtailed (i.e.

trimmed or tripped) to ensure thermal ratings are not exceeded;

- Constraints are managed by monitoring relevant measurement points and by issuing setpoints (curtailing) to DG units or by tripping the DG unit circuit breaker in order to reduce the power output at the relevant constraint;
- DG units are curtailed and "released" according to the configured Principles of Access (PoA) mode (e.g. Last In First Off, Shared).

Subject to the above conditions, power output from DG units is maximised at all times. Figure 2 shows a simple "trim" and "release" for a single generator:

Figure 2 – Trim and Release of a Generator



The FPP project identified two thermal constraints to be managed by **sgs power flow**. The first constrained section is on the March Grid Network where at least six developers, with installed capacity ranging from 0.5MW to 16.4MW are seeking to connect their wind energy projects. The second constrained section is on the Peterborough Central network where a 7.2MW generator is seeking to connect on a potentially already overload area.

Voltage management

Sgs voltage is a real time algorithm gathering voltage information from the FPP network and regulating controlled devices to help overcome different network voltage constraints based on the following principles:

- Real and/or reactive power outputs from controllable devices are constrained to ensure that voltages on the network are managed to within upper and lower limits;
- Voltage limits on the network may be static or dynamic;
- Devices may be configured to have any setpoint in their range as their *preferred* setpoint;
- *Continuous* controllable devices are used to resolve constraints by the issuing of (P, Q) or (P, V) setpoints and/or tripping circuit breakers;
- *Discrete* controllable devices resolve constraints by controlling the position of the device;
- When all voltage constraints have been resolved, the algorithm, where possible, releases devices towards their preferred setpoint;
- Controllable devices are regulated and released in a configurable, collective or sequential order.

In the FPP context, **sgs voltage** will be used to mitigate voltage constraints in conjunction to the AVC operation. The voltage constraints may appear due to connections on the 11kV network but such a case has not been identified yet in the trial area.

Real-time thermal ratings

sgs ratings provides real-time rating estimations based on a thermal model, measurements of environmental parameters and measurements of conductor temperature and current. **sgs ratings** provides an estimation of conductor ratings, while identifying and taking into account possible failures in measurements, communications and estimation methods. The algorithm calculates circuit ratings using four different methods. Each method calculates ratings to a certain degree of accuracy according the availability of relevant information. In general, more accurate methods require more time and more information to complete the required computation.

For FPP, **sgs ratings** will use information from weather stations and DLRs to provide dynamic rating for a wider network area than is covered by the individual lines with the DLR devices. These ratings are then used by **sgs power flow** as dynamic ratings for the lines that have thermal constraints.

Smart Commercial Agreements

As mentioned above, the roll-out of the smart applications will allow more distribution to be connected under the existing infrastructure. However, by enabling UK Power Networks the ability to monitor network constraints in real time, it presents the fall-back for generators of having their output actively managed (i.e. curtailed) against those constraints.

Although the FPP project will allow the connection of DG in constrained areas of the network in advance of reinforcement of the network to remove the constraint, these "FPP generators" will need to have a clear idea of the levels of curtailment expected throughout the lifetime of their projects and the rules that determine the order in which ANM will curtail the different generators.

UK Power Networks has developed appropriate commercial arrangements to govern the access rights of generators in the event that the limit of a network constraint is reached.

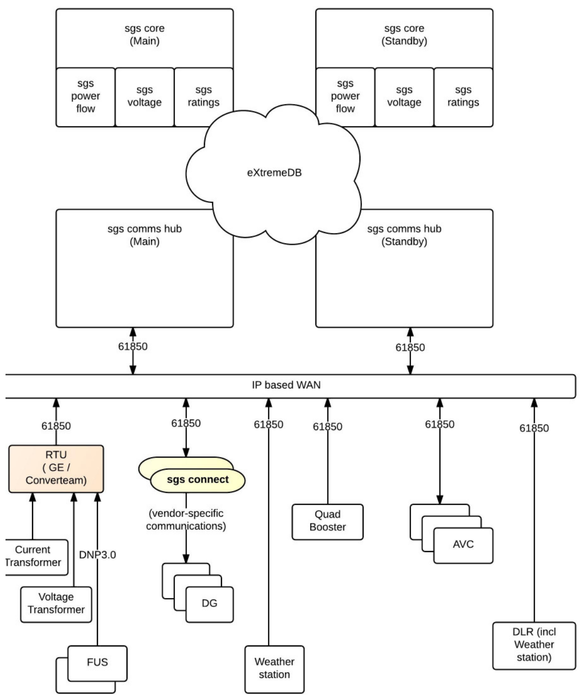
The FPP project adopted a Reinforcement Guarantee Approach based on pro-rata curtailment. This paper presents the findings of the FPP project and the proposed smart commercial arrangement for implementation during the trial [3].

DEPLOYMENT ARCHITECTURE

Principles of ANM Deployment

The ANM deployment is based on a distributed architecture using central servers operating in parallel to the SCADA system used to provide supervisory control of the network. The servers provide the core application logic, data handling processes and an infrastructure to allow IEC 61850-based communications with the IEDs. Distributed **sgs connect** devices interface to the generators. In this architecture, the smart devices have acted as IEC 61850 Servers exchanging information the ANM applications implementing an IEC 61850 Client. The overall architecture is shown in Figure 3.

Figure 3 – ANM Architecture Overview



Pre-Production Platform

The FPP project will roll-out a pre-production platform within UK Power Networks premises to setup an integration environment. This will consist of a central controller unit (including dedicated **sgs core** and **sgs comms hub** servers), **sgs connect** devices and the smart devices to be integrated in the final production platform which will be used for the trial.

Production Platform

The production platform consists of an IEC 61850 communications infrastructure, dual redundant servers and switches within the central controller located at UK Power Networks control centre, seven **sgs connects** located at the relevant generators, four DLRs located on selected overhead lines, two AVCs, and a Quadrature Booster Controller System. This platform will be able to be upgraded to integrate additional smart devices if new generators are planned to connect into the trial area.

Failure Modes and Redundancy

The Central Controller hardware is designed on "dual-redundancy" principles; all hardware within the Central Controller (i.e. the **sgs core** servers, **sgs comms hub** servers, and the network switches) is duplicated such that the failure of a single hardware item does not cause the ANM system to fail. In addition to this dual-redundancy, each of the servers is specified with its own internal redundancy.

In the event of communications problems, the **sgs connect** devices and **sgs comms hub** are designed to "fail safe". This means that **sgs connect** limits the generator output to a pre-agreed safe limit or safe schedule; **sgs comms hub** recognises this and takes this into account during its calculations. When communications are restored these devices synchronise based on these 'fail safe' states.

CONCLUSION AND NEXT STEPS

UK Power Networks and its partners have designed an ANM solution for decentralised monitoring, control and coordination of the distribution network and connected generators. Several ANM applications will be deployed for the trial including **power flow management, voltage management and thermal ratings estimation** in order to dynamically manage access to the capacity of the network.

With the aim to start the trial during the last quarter of 2013, UK Power Networks is commissioning the pre-production platform to demonstrate that the communications infrastructure allows the transfer of IEC 61850-based data between ANM and the smart devices. Different smart devices from different vendors will have to be integrated thanks to the development of a global data model. The use of IEC 61850 for the data modelling and communication protocol will help the integration stage but the interoperability of the overall system will remain a strong challenge.

ACKNOWLEDGEMENTS

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