SECOND GENERATION ACTIVE NETWORK MANAGEMENT ON ORKNEY

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

Robert JOHNSTON
Smarter Grid Solutions – UK
rjohnston@smartergridsolutions.com

Frazer WATSON
Smarter Grid Solutions – UK
fwatson@smartergridsolutions.com

Robert CURRIE
Smarter Grid Solutions – UK
rcurrie@smartergridsolutions.com

David MACLEMAN
Scottish and Southern Energy Power Distribution – UK
david.macleman@sse.com

Andrew URQUHART
Scottish and Southern Energy Power Distribution – UK
andrew.urquhart@sse.com

ABSTRACT

The Active Network Management (ANM) scheme on the Orkney Islands in the UK was the first of its kind and remains at the cutting edge of smart grid implementation. The first generation deployment has facilitated the connection of almost 19 MW of new wind capacity to a network that was considered 'full'. The paper describes a range of second generation technologies and initiatives that are now being implemented, illustrating how the ANM scheme provides a foundation for further work and an environment for testing a range of techniques with much broader applicability. This includes enhancements to communications, the introduction of real time ratings and voltage management, a new energy storage park, demand side management, small-scale generators and distribution state estimation. The collaborative nature of the developments on Orkney is noted.

INTRODUCTION

Since 2009, Scottish and Southern Energy Power Distribution (SSEPD) has been successfully operating an Active Network Management (ANM) scheme on the Orkney Isles [1] with the assistance of Smarter Grid Solutions (SGS). The ANM scheme implements a power flow management application that controls the output of multiple generators to resolve multiple thermal constraints on the 33 kV distribution network. The Orkney smart grid is a leading example of innovative technology providing new technical and commercial learning to the power industry and real connections for new generator developers. The technology implemented first on Orkney is now being deployed across the UK in various locations and is receiving interest from utility companies in Europe and North America. KEMA recently conducted an independent review of the Orkney project [2], describing it as "a leading exemplar internationally of a smart grid solution to power network congestion".

The background to the situation on Orkney and an introduction to the ANM scheme deployed have been provided in several CIRED papers in the past [3]. The focus of this paper is to provide an update on this important project and to outline activities that are underway or planned to further enhance the deployed smart grid.

FIRST GENERATION ANM

The ANM scheme was deployed on Orkney in late 2009. This deployment was the first of its kind and has, at the time of writing, facilitated the connection of an extra 18.46 MW of wind generation to the Orkney network, with an additional 5.2 MW expected in 2013. Without ANM, even 1 MW of new connections would have required the provision of a third connection to mainland UK, costing £30million in conventional network reinforcement expenditure. A trial of a dynamic line rating device and a real time thermal ratings application began in 2011 and is expected to benefit participating wind farms, reducing the MWh lost due to curtailment by the ANM scheme while also requiring more advanced voltage management.

SECOND GENERATION DEVELOPMENTS

Since installation, SSEPD and SGS have sought improvements to the ANM scheme and its use of the existing network capacity. This is strongly supported by generation developers, who recognise the benefits made possible with the ANM scheme and are keen to push further with innovative methods of network access and utilisation. The second generation improvements and their benefits are described below.

Communications

Communication is an important part of any control system and the ANM scheme's ability to control the network is affected when there are problems with the communications between the various ANM components and the generators.

Without the communications links, the ANN scheme is not able to provide active management of the network. There are two main communications links:

(1) Between the Central ANM Controller (CAC) and the Local ANM Controller (LAC) installed at every generator
(2) Between the CAC and the Measurement Points (MP) installed at the critical constraint locations of the network

If communications fail then fail-safe actions are taken to fully curtail the affected generator, or curtail all generators associated with a MP where communications are lost. A review of the performance in 2011-12 revealed that communications were responsible for a significant portion of all curtailment suffered by the generators.

- Communications with the generators had a total average availability of 98.89 %. The poorest performance was an availability of 96.3 %, whereas the most reliable link had an availability of 99.95 %. The review found 174 communications failures, with a mean down time of 374 minutes and a mean time between failures below 22 days.
- Communications with MPs were more reliable, with a total average availability of 99.89 %. There were 53 communications failures, 47 of which affected the two MPs monitoring the subsea connection to the mainland and hence fully curtailed all generators.

To enhance scheme performance, SSEPD is introducing a new, primary communication link between the central communications hub and some key measurement points. The previous communications link has been retained as a backup. In addition to this, individual generators have commissioned improved communications links, creating a more robust communications network across the ANM scheme. These upgrades have resulted in a significant improvement in communications availability when compared to the 2010-2011 period, increasing the ability of the ANM scheme to control the network to its maximum capacity.

SGS experience on other ANM projects confirms that communications is often the primary source of problems in new projects and represents a significant portion of the total cost of smart grid innovations.

Real Time Ratings and Voltage Management

The established ANM infrastructure, and the familiarity and enthusiasm of the SSEPD personnel involved, means that Orkney is an excellent location for trials of other new technologies. A dynamic line rating device [4] has been under trial since 2011 together with complementary software for fuller assessment of real-time thermal ratings (RTR).

SGS's real time ratings application collects all available information on meteorological parameters, conductor temperature and communication state. It then uses a thermal model of the power system and industry-standard line rating calculations [5][6] to estimate the current-carrying capability of the grid across a wide area. This addresses the limitations of single-point DLR devices and manages more fully the risk of failure and loss of measurements.

Making use of the increased real-time current carrying capacity of the network means that it will become necessary to manage network voltages in real time. The first generation ANM scheme is concerned with power flow management only. Network voltages remain within limits in all feasible operating conditions, with a DVAR at Scorradale providing fast-acting reactive compensation. By using DLR/RTR to relax the power flow constraints, voltage will become the binding constraint on some parts of the network. The ANM software will be extended to monitor voltage at the critical constraint locations and impose curtailment on generators as necessary to ensure all voltages remain within limits.

Previous analysis has explored how voltages on the 33 kV network vary under different loading conditions, recognising that the limits at 33 kV are dynamic as they depend on the power flow through 33/11 kV transformers with on-load tap changers and line drop compensation. Figure 1 shows some example results. New studies are being performed to examine more fully the interaction between real-time ratings and voltage management on Orkney.

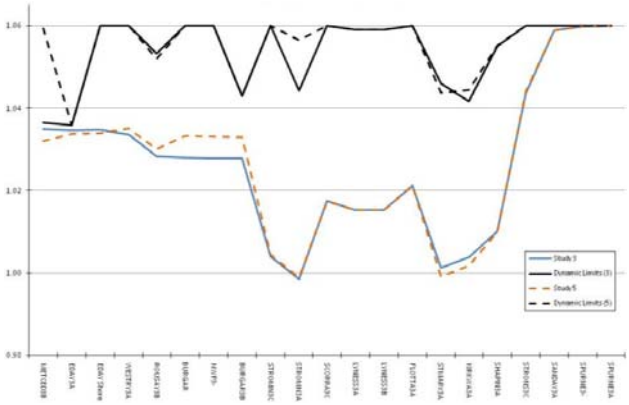

Figure 1: Busbar voltages and limits under different study conditions for Orkney

Energy Storage Park

SSEPD has created the Orkney Storage Park, a dedicated installation area for energy storage devices. Third-party organisations are invited to install their own devices within the Park and test a variety of potential uses, including using storage to offset generator curtailment. This provides a further tool to allow the ANM scheme to reduce curtailment of the Orkney generators. The ANM scheme is being updated to include an energy storage module to handle the various contractual rules for availability, impact on curtailment, the releasing mechanism and usage limits.

To support system testing, a representative data profile was created to simulate a diverse range of operating conditions and dynamic behaviour. This profile is being used to test the calculation engines that will determine the payments received by energy storage service providers. An example of the test profile, showing periods of charge and discharge, is presented in Figure 2.

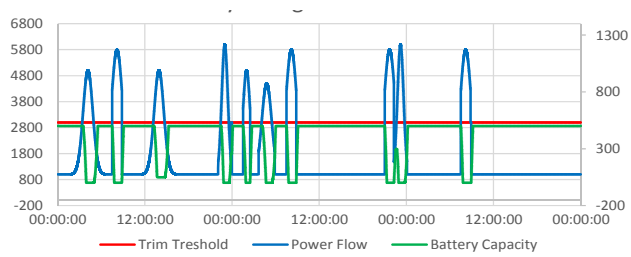

Figure 2: Example profile for ESS testing

Platform Upgrade

As part of SGS's ongoing product development, the underlying platform for implementation of ANM is moving from PLC-based hardware to a server-based platform running real-time Java software applications. The new server-based platform is already deployed in Shetland with different ANM applications [7]. It is now being rolled out on Orkney, initially in 'open loop', allowing SSEPD and SGS to monitor and compare the actions of the server-based and PLC-based platforms. The confirmation process is ongoing and the plan is to close the loop later in 2013. This new platform provides greater flexibility and scalability for new ANM applications to be deployed.

Demand Side Management

Another positive aspect of the developments on Orkney is that several of the generator connections made possible by the ANM scheme are community-owned. Thus, the ANM scheme has helped spread the financial benefits of renewable energy beyond the normal commercial players. These community-led schemes have been supported by Community Energy Scotland [8], an organisation that supports and promotes all forms of sustainable energy in communities across Scotland. CES is now supporting a project to assess the scope for introducing demand side management into some of the existing community-owned generation schemes. This will seek to add new electrical demand that can be controlled by the customer to consume power as an alternative to the curtailment of generators, thereby exploiting more fully the available energy. This represents an interesting and innovative extension of the ANM scheme and demonstrates the collaborative environment that Orkney enjoys.

Small Scale Generators

The first ANM scheme generation applies only to generators larger than 50 kW. The view was that smaller generators have a smaller impact and the cost of communications and integration into the ANM scheme outweighed that impact. Thus, generators smaller than 50 kW were allowed to connect to the Orkney network without being subject to ANM control as larger generators are.

However, such is the appetite for renewable energy on Orkney, that several MW of new capacity has connected in the form of sub-50 kW generators, being mostly small wind turbines. Each individual generator has a small impact but, in combination, these generators are 'eating' into the constrained capacity and resulting in the larger, ANM-controlled generators suffering additional curtailment.

SSEPD has now imposed a moratorium on all new generation, except the very smallest generators that are exempted by the UK regulations [9]. SGS has assessed the feasibility of including smaller generators within the ANM scheme. The key findings are as shown in Table 1.

Distribution State Estimation

The connection of new renewable sources and other forms of distributed generation, as on Orkney, has led to the requirement for greater visibility of networks. Enhanced visibility is necessary for control operators responsible for maintaining network integrity but it also makes possible new forms of ANM. However, the need for visibility has to be balanced against the cost of additional measurement and telemetry. Distribution state estimation (DSE) offers the possibility of using a reduced set of measurements, augmented with pseudo-measurements, to provide extended visibility of distribution networks. SSEPD and SGS are now trialing the use of DSE on Orkney [10]. This will enhance operation of the ANM scheme, making it more robust to loss of measurements, and facilitate third generation developments of ANM.

Sub-50 kW ANM Characteristics	*Challenge*	*Proposed Solution*
Controlling a much larger number of generators.	High aggregated cost to provide dedicated communications link to all sub-50 kW ANM-controlled generators.	Alternative communications solution to be implemented making use of existing available communication infrastructure.
Controlling generators with relatively low rated capacities.	Curtailment of individual sub-50 kW generators has a small impact on power flows.	Grouping of control actions on clusters of sub-50 kW generators.
Greater diversity in types of generation technology participating in ANM scheme.	Uncertainty over ability of sub-50 kW generators to meet ANM control set-points.	Control of generators restricted to on/off tripping rather than granular curtailment.
Sub-50 kW generator developments have smaller budgets.	Participation in the ANM scheme requires low-cost connection.	Simplified control actions described above require low-cost controller at generator with reduced functionality.

Table 1: Challenges and Proposed Solutions for Integrating Sub-50 kW Generators into the Orkney ANM Scheme

CONCLUSIONS

The ANM scheme on Orkney was the first of its kind and remains at the cutting edge of smart grid implementation. The initial, successful deployment is being supplemented with a range of second generation technologies and initiatives. This demonstrates how an established project can provide the foundation for further work. It is important to note that collaborative nature of the developments on Orkney, where SSEPD has been supported by the local government, communities and generation developers in trailing new approaches. The new developments seek to enhance the existing scheme and exploit more fully the available capacity on the network. In so doing, Orkney will provide an environment for testing a range of techniques with much broader applicability.

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