CHALLENGES OF ACTIVE NETWORK MANAGEMENT BUSINESS AS USUAL ROLL-OUT

Robert MACDONALD
Smarter Grid Solutions Ltd – UK
rmacdonald@smartergridsolutions.com

Young-Ho KWON
Smarter Grid Solutions Ltd – UK
ykwon@smartergridsolutions.com

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

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

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

Alan GOODING
Smarter Grid Solutions Ltd – UK
agooding@smartergridsolutions.com

ABSTRACT

Active Network Management (ANM) has been successfully demonstrated in the UK as a means for Distribution Network Operators (DNOs) to provide low-cost network connections to generation customers that would otherwise pay for costly reinforcement. Such examples have been supported by innovation demonstration schemes. As DNOs look to roll-out ANM at scale, several challenges arise when transferring to a business-as-usual approach to ANM system deployment and operational support. While there is understandable urgency from network users to achieve momentum and pace in Business-as-Usual (BaU) roll-out, a systematic approach to ANM deployment is proposed as the best means to address the challenges. Pace and a systematic BaU roll-out methodology need not be at odds with each other if suitable planning is undertaken. The evaluation of prospective ANM deployment is presented, where the criteria to assess the feasibility and estimate the impact of ANM deployment in a network area are discussed, providing means of appraising the criteria to efficiently identify priority areas for ANM deployment. The paper outlines the overall ANM roll-out challenge and focuses attention on the early stage feasibility evaluation of ANM deployment in particular network areas.

INTRODUCTION

ANM has emerged as a means to better utilise network capacity and facilitate generator connections on congested networks where previously costly reinforcement would be necessary. The ANM philosophy sees a move away from the fit-and-forget *passive* approach to network planning, towards an *active* approach where autonomous real-time control of parameters maintains the network within secure operating conditions. The most common network constraints that act as a barrier to Distributed Generation (DG) connections are generally thermal and voltage constraints, where control of generator real power export, reactive power generation or absorption, or transformer tap-changer configurations can be used to manage power flow and voltage levels.

In the UK to date, ANM has been successfully deployed and demonstrated at various locations in notable projects such as the Scottish Hydro Electric Power Distribution (SHEPD) Orkney scheme [1], UK Power Networks (UKPN) Flexible Plug and Play project [2], and the Scottish Power Accelerating Renewable Connections (ARC) project [3]. These deployments have been supported by innovation mechanisms such as the Registered Power Zone (RPZ) [4] and Low Carbon Network Fund (LCNF) [5], established by the energy regulator Ofgem. Such support mechanisms provide funding or commercial incentives for Distribution Network Operators (DNOs) to demonstrate innovative network solutions such as ANM. In addition to financial backing, these support schemes can also present DNOs with the opportunity to derogate from elements of grid regulation or standards to facilitate the demonstration of innovative solutions, contracts or processes.

On the back of successful demonstrations of ANM deployment, DNOs are looking to roll-out ANM systems elsewhere on their networks, offering actively managed connections to generation customers in cases where it may defer or avoid costly network reinforcement. Moving towards this Business-as-Usual (BaU) approach to ANM deployment will present challenges to DNOs, where the financial and regulatory support associated with innovation-type projects will not be provided. Although these challenges exist, the commercial and customer-facing benefits of ANM deployment are sufficiently strong that DNOs are planning to roll-out ANM at scale and provide managed connections for generation customers. This paper introduces the typical challenges that network operators will face, and presents an assessment methodology for evaluating areas for ANM deployment.

ANM: FROM INNOVATION TO BUSINESS-AS-USUAL

Typically the aim of DNO innovation projects is to trial a particular technology or system on a particular area of network, providing well-bounded project scope. This approach also allows the DNO to focus resources on the project, which in some cases will be from a team of stakeholders specially tasked with innovation-type projects. As a DNO looks to roll-out ANM on a BaU basis, there will be more sections of network under control, with wide-reaching impacts across the business as the number of stakeholders required to understand and support ANM grows. Table 1 presents some summary challenges related to ANM deployment as DNOs move towards a BaU process.

The challenges that exist can be resolved through the establishment of new business processes and modification of existing processes. The provision of managed network conditions will require DNOs to provide an estimation of the curtailment that the generator will experience, a form of constraint analysis [6]. Performing such analysis in-house may be a resource-intensive process and require additional training or the establishment of new analysis methodologies.

Table 1: Summary of ANM BaU Challenges

Areas	Challenges
Procurement	• What is the trigger for deploying ANM in an area? • How will the ANM scheme be designed and procured? • How is the capital cost for ANM deployment apportioned across customers?
Commercial Contracts	• What form will contracts for a managed connection take? • Will a conventional unmanaged connection be offered as well? If so, can both offers be prepared within regulated time-frames?
Analysis	• Constraint locations will need to be identified for prospective or specific connection requests. • System design methodologies must adapt to simulate ANM system behaviour. • The network operator must provide customers with an approximation of the curtailment experienced under a managed connection. • Is there sufficient in-house skill and resource to perform such analysis at scale?
Installation	• Who is responsible for ANM system installation? • What tools and training are required?
Growth and Expansion	• How is this incremental cost of ANM growth apportioned across customers?
Customer Support	• Managed connections may require greater customer support requirements or more resources to respond to customer queries. • DNOs may opt to provide participating customers with operational data from the ANM scheme.

A SYSTEMATIC APPROACH TO BAU ANM DEPLOYMENT

Given the described challenges that DNOs face in deploying ANM at scale, a more manageable approach to deploying ANM is for DNOs to roll-out ANM in a systematic, phased manner. This would see the DNO *ANM-enabling* particular areas of network, offering managed connections and ensuring that the stakeholders are not overly-burdened in the early stages of ANM deployment. Such an approach allows a more organic growth of ANM, allowing the DNO to develop the new and modified business processes that will be necessary to support ANM as the scheme grows.

In taking a phased approach to ANM roll-out, it is vital for the DNO that the areas that are best suited to ANM are prioritized for deployment. Initially deploying ANM to areas with significant grid congestion will increase the likelihood of customers accepting offers for a managed network connections, reducing the risk of the DNO deploying stranded assets. A further motivation for identifying the best suited high-impact areas for ANM deployment is linked to standards and regulation.

In the UK, DNOs must treat all customers in a fair and consistent manner, regardless of location, size or generation type. If some customers are to be prioritized over others, there must be sufficient justification. Providing managed connections for generation customers in areas that initially receive ANM roll-out ahead of others may be perceived as showing bias. Therefore, even though it may be clear to the DNO where the high-impact areas for ANM deployment are located, there may still be a requirement to fully evaluate all possible locations to fairly justify prioritization of ANM roll-out. Such a feasibility assessment must initially consider all network areas and by applying criteria equally and consistently across all prospective network areas, the DNO can justify the prioritization of ANM deployment in areas ahead of others.

One of the greatest challenges in evaluating the expansion and roll-out of ANM to network areas is managing uncertainty over the location and size of generation that will emerge in the future. The size, locations and types of generation that wish to connect to a network will all affect the emergence of network constraints and their severity. Both the location and severity of network constraints will influence the volume of curtailment experienced by ANM participating generators and have a bearing on the commercial feasibility of managed connections and ultimately the additional capacity that is provided via ANM. Uncertainty in these factors presents a significant challenge in determining the suitability of network areas for ANM deployment; as will be shown, by assessing past trends in generation activity and identifying important network characteristics that often lead to the emergence of constraints, it is possible to lessen the impact of this uncertainty.

In identifying and justifying the best suited areas for ANM deployment the DNO must decide upon the criteria to evaluate prospective roll-out areas against. The number of prospective areas to be assessed may influence the type of analysis performed to support the application of criteria. Some types of analysis may involve detailed power systems analysis studies that are time-intensive, whereas the identification of more high-level network characteristics may allow a quicker assessment against criteria. If a large number of areas are to be considered, the DNO may opt to adopt a higher-level analysis to discount areas that are clearly unsuitable for ANM deployment, allowing the more focused analysis of a smaller number of candidate areas.

EVALUATING ANM DEPLOYMENT AREAS

When evaluating proposed ANM deployment in an area, or across a number of prospective roll-out areas, the assessments can focus on two high-level features: the *feasibility* of ANM deployment, and the resultant *impact* of ANM deployment. In assessing the feasibility of ANM deployment, the DNO is concerned with identifying whether the deployment of ANM will succeed in providing low-cost connections to generators connecting in the area. Such analysis is generally high-level and does not focus on local issues but rather those affecting the entire network area. In assessing the impact of ANM deployment, the DNO is concerned with assessing the likelihood of constraints emerging in the network area and if so, ensuring that ANM will present commercially viable connection offers for generation customers. By investigating these factors the network operator can identify the network areas where the introduction of ANM will make the biggest contribution (while minimizing risk) to the DNO.

In the following sections, criteria for evaluating ANM deployment are presented. Figure 1 illustrates the hierarchical approach to applying the evaluation criteria, where the high-level *feasibility* criteria can be applied to a large number of areas, whereas the more detailed criteria that require time-consuming analysis should only be applied to a small number of candidate areas.

ANM Feasibility

Determining the ANM feasibility in a network area will identify high-level network-wide issues that may act as barriers to DG connections regardless of ANM deployment.

Area-wide issues: The application of high-level feasibility criteria aims to identify and assess the consequences of issues that will influence the success of ANM across the entire network area being considered. In general, ANM can help DNOs overcome thermal and voltage constrains on their networks, which are common barriers to DG connections; it should be noted however that there are other issues that may act as a barrier to DG connections, and ANM may not always be able to overcome these constraints. An example of such a scenario is the case where constraints exist on the local transmission system and affects the distribution network, acting as a barrier to further DG connections. As the constraint is located on transmission infrastructure there may be technical complexities to managing this via a distribution-level ANM system; similarly the commercial arrangements for controlling DG via a distribution-level ANM system to manage a transmission system constraint may introduce undesirable levels of complexity. The existence of such a constraint would rule out an area for initial ANM deployment as DG would not be able to connect on the distribution system regardless of ANM. Other non-technical constraints such as local planning restrictions may act as an obstacle to DG connections and the deployment of ANM would fail to enable DG connections in such a case.

Likelihood of Constraints Emerging

By estimating the likelihood of constraints emerging in the future the DNO can gauge the likely demand for managed network connections and ensure ANM deployments are fully utilised.

DG Connection Activity: The number and total capacity of DG customers that have connected in a prospective network area, or that have attempted to connect, may provide an indication of future DG growth and the potential emergence of constraints. Areas with large volumes of existing generation will also result in a network that is running closer to capacity than those with low penetrations of DG connected. Other indications of future generation growth, such as the available renewable energy resources can highlight areas where constraints may emerge in the future as more generation connects to the network.

Network Location and Circuit Characteristics: The type of network being proposed for ANM deployment and the typical circuit characteristics can reflect the likelihood of constraints emerging. For instance, an urban distribution network may have low levels of DG connection, large areas of dense load and in general short, high capacity circuits. In these types of conditions there is a low likelihood of thermal or voltage constraints emerging as generators appear on the network. On rural networks however, it is more likely that loads will be highly distributed, with long, radial, lower capacity circuits. It is on such circuits that thermal and voltage constraints are much more likely to emerge following the connection of DG. If faced with a large number of network areas to assess, the DNO is able to use quick evaluations to dismiss areas with a significantly lesser probability of constraints emerging.

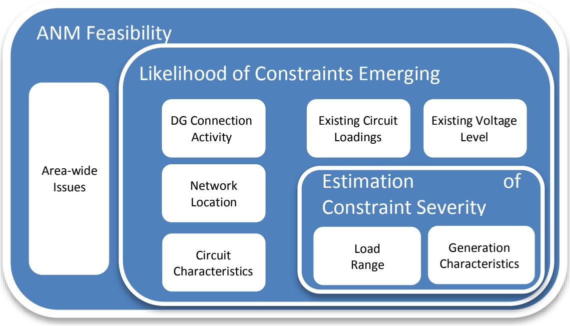

Figure 1: Application of Evaluation Criteria

Loading on Existing Circuits: If a network area has circuits that are already highly loaded or running close to their planning limits, there will be a greater likelihood that constraints will emerge as further generation appears on the network. On highly loaded networks the connection of a relatively small generator can cause constraints to occur.

Existing Voltage Levels: Similarly to circuit loadings, if voltage levels are already close to their planning limits, the emergence of constraints will be more likely as further generation connects to the network. As with circuit loadings, these network characteristics must be identified via power systems analysis simulations, which can be a time-intensive process if required for a significant number of network areas.

Estimation of Exploitable Capacity

If assessment has shown that there is a high likelihood of constraints emerging on a prospective network area, with particular specific constraint hot-spots identified, it is possible to approximate the exploitable capacity that can be harnessed by generators via managed connection. The degree of exploitable capacity that is available to generators will ultimately affect the volume of managed generation that can be accommodated before the curtailment experienced by generations becomes commercially unviable.

Load Range: A proportion of the additional network capacity that can be exploited under an ANM managed DG connection is provided via the range in load that sits behind the network constraint. As traditional network planning is based upon conservative minimum load conditions, in reality the load will be a higher and more network capacity is available to be exploited under a managed connection. In cases with a larger load range there will be more additional capacity available to managed generators. As well as the magnitude of load range, the shape of the load duration curve will also affect the capacity available to managed generators. Figure 2 presents two load curves for normalised sub-station demands, where the lower load curve presents a demand that has a much greater probability of being over half the peak load value when compared to the upper load curve, which is only greater than half of peak load for roughly 20% of the time.

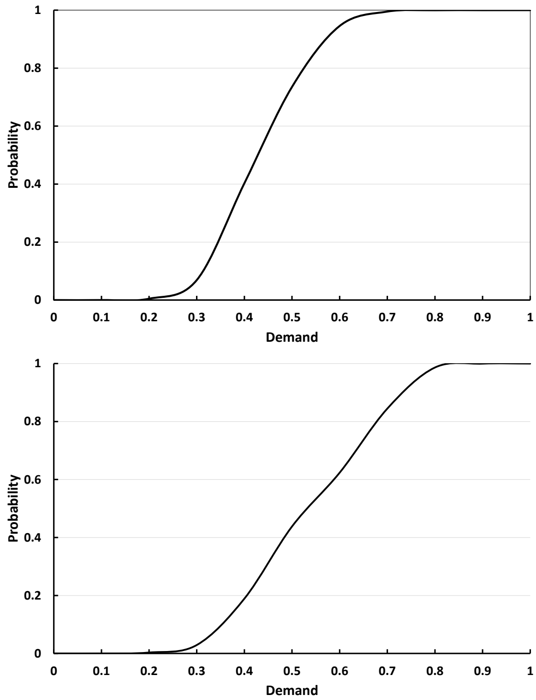

Figure 2: Low load factor (above) and high load factor (below) duration curves

Generation Characteristics: ANM allows the utilisation of network capacity that exists due to the diversity in generation export profiles, as well as that provided from the range in local load. The typical capacity factor of the generation that contributes to a network constraint provides a useful indication of the general likelihood that each generator will be operating at or close to their rated capacity. As the typical capacity factors for wind turbines is between 20-45 %, it is likely that there will be significant periods where generators are not exporting close to rated capacity and there will be network capacity available for managed generation. In addition to the capacity factor of generators, the general diversity between the export profiles of generators contributes to the capacity available to managed generators. A useful quick indicator of diversity in export profiles is to gauge the difference in types of generation in the network area. In cases where only wind generation exists, and it is expected that in future wind generation will look to connect, although the generation has a relatively low capacity factor, the high degree of correlation between export may result in greater curtailment for managed generators than a case where the local generation mix includes wind, hydro and PV generation.

CONCLUSIONS

This paper has introduced some of the challenges that DNOs can expect to face as the deployment of ANM solutions matures and moves away from *Innovation*-type demonstration projects towards *Business-as-Usual* roll-out at scale. In overcoming these challenges, the staged roll-out of ANM through *ANM-enabling* priority network areas is seen as a logical approach to developing and deploying the new processes required to provide and support ANM-enabled managed network connections and provide ANM connections where they have most immediate value.

As the DNO may wish to evaluate a large number of prospective ANM-enabled network areas, a wide range of assessment criteria has been presented. The application of these screening criteria can assist DNOs in identifying the best areas for ANM deployment. The criteria focus on the issues and characteristics that will affect the impact of ANM deployment and would be applied in a systematic manner, whereby high-level identification of area-wide issues can allow the discounting of infeasible deployment areas, and more detailed identification of constraint hot-spots and estimation of exploitable capacity (not covered in this paper) can be performed for a more focused, smaller number of prospective network areas.

REFERENCES

[1] H. Cleijne, J. Scott, 2012, *"Smart Grid Strategic Review: The Orkney Islands Active Network Management Scheme"*, KEMA.

[2] S. Georgiopoulos, C. Marantes, D. Openshaw, 2012, *"Flexible Plug and Play Low Carbon Networks Enabling the Integration of Renewable Energy"*, CIRED Workshop: Integration of Renewables into the Distribution Grid, CIRED, Paper 86.

[3] E. Norris, 2013, *"Accelerating Renewable Connections: Project Progress Report",* SP Energy Networks, Dec 2013.

[4] *"Engineering Recommendation G85: Innovation Good Practise Guide for Energy Networks"*, Energy Networks Association, Issue 2, 2007.

[5] *"Low Carbon Networks Fund Governance Document"*, Ofgem, Version 6, 2013.

[6] R. MacDonald, C. Foote, 2013, *"Constraint Analysis Techniques for Active Networks"*, Proceedings 22nd International Conference on Electricity Distribution, CIRED, Paper 614.