OVERVIEW OF ACTIVE NETWORK MANAGEMENT DEVELOPMENTS AND PRACTICES IN GREAT BRITAIN

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ABSTRACT

This paper provides an overview of the current capability of, and methods used by Distribution Network Operators (DNOs) to monitor and control distribution networks in Great Britain. The paper presents the current status of relevant recently completed, ongoing and planned active network management research, development and demonstration activities. The active network management (ANM) operating methodology includes the areas of data acquisition and management, substation and network monitoring, substation and distribution network automation, real-time control, and communications architecture and information models. The most advanced existing and emerging innovative practices as well as the technical areas which are experiencing little activity are highlighted. Due consideration is also given to the identification of the immediate limitations and barriers (technical, commercial and regulatory) in relation to the development and widespread deployment of active management along with the likely consequences for meeting rising consumer expectation and governmental security of supply and environmental objectives. The outcomes presented in this paper are based on completed projects and ongoing work of the Active Management initiative of the DTI/Ofgem led cross-industry Distribution Working Group (DWG) in Great Britain.

INTRODUCTION

The changing demands on distribution systems, and in particular the increased penetration of distributed generation, are causing DNOs to look at new ways of accommodating these schemes. Distributed generators are often located in areas where the infrastructure is sparse, conventional network reinforcement is costly and there are associated planning and environmental challenges. A more interactive approach is regarded as a potential solution in many cases where generation output can be maximized depending on the capability of the distribution system at any point in time. Adopting such an approach requires a change in the way in which networks are currently designed and operated to one where demand and generation connected to the distribution networks are both proactively managed. The change required will tend to move distribution networks from being designed to cater for the most onerous condition which can be ‘passively’ managed (in a system normal state) to an arrangement whereby at least some parts of the network (i.e. those parts with embedded generation or load management facilities) are more ‘actively’ managed or controlled. A wide range of options are available to deliver this method of design and operation including, for example, new technology solutions including devices to assess site specific equipment capability and intelligent switches. Contractual arrangements could also assess seasonal or time of day constraints through to real time interaction of demand and generation, requiring network monitoring, automation, remote control, and communications with both generators and customers.

Several active network management (ANM) solutions have already been identified and some implemented to deal with particular network constraints associated with single generator connections (e.g. power flow management, voltage control, fault level management, demand side management.) However, as the number of generation connections increases and surplus network capacity reduces, several potentially diverse network constraints may need to be simultaneously managed under normal operating conditions. Consequently, advanced functionalities and applications would need to be considered to enable development of a migration path to the future platform. Consideration of the future platform requirements should include the design principles and concepts of the data and communications systems, functions and infrastructures necessary to support integrated and actively managed network operation and control as well as meeting consumer and regulatory demands.

ACTIVE DISTRIBUTION NETWORKS

Many of the effects and implications of ANM are, at least theoretically, well recognized and emphasised in recent studies on future network management and operation. Whilst DNOs do deploy various forms of management techniques that may be considered to be ’active’, the scale of ANM deployment remains unclear. This could be partly attributed to the very lack of a generic definition of ANM. Recent assessment of installed infrastructures and operational practices in the area of ANM has led to a working definition of the term 'ANM' as being 'systems that implement pre-emptive action to maintain networks within their normal operating parameters'. What the active management of networks does not include is post fault automation (returning a network to its normal state or reconfiguring following a fault) or protection systems (operating to manage a fault situation and maintain a safe system.)

The key enabling technologies that would extend the capabilities of a distribution system in the future include

- data management,
- distribution automation (DA) through sensors/monitors and communications systems,
- power electronics and
- demand side management (DSM).

The automation of distribution networks could better utilise installed network capacity, reduce the length of customer interruptions and manage the many constraints that might be a feature of ANM. Introduction of a new generation of digital relays and other Intelligent Electronic Devices (IEDs) enables new monitoring applications (via IEDs and distributed SCADA, substation state estimation, sensors, wireless and optical communications), better coordination of protection and control, distribution automation control, integrated measurement and protection solutions. Cost-effective network diagnostics and maintenance through self–monitoring, self-diagnosis, communication of self-assessment results and ongoing integration of information and data management is also possible. New communication technologies are powerful enablers that make monitoring and control system solutions more effective, with a broader scope of application. Furthermore, an increased application of advanced technologies and infrastructures can enable the development of distribution management systems and distribution control centres used to undertake the active management and operation of networks during both normal and emergency conditions.

Recent technical review and assessment of current and proposed active network management practices in British distribution networks [1] revealed that network control and monitoring systems used by DNOs are typically based on centralised systems. A hierarchical SCADA scheme is used by DNOs to collect information from the Primary and Secondary levels of the network via remote telemetry units (RTUs). Typically measured network parameters are voltage, phase, current, power, circuit breaker status and wind speed at selected locations. Data is then fed into some form of management system (DMS or NMS) of which the ENMAC (GE Harris) system was seen to be a common product which was either in use, or being considered. In future, a larger number of data concentrators could allow rapid collation of RTU data, typically supported by the ENMAC, or similar system to facilitate the automatic network reconfiguration and generator dispatch for active power flow and/or fault management.

The technical review has however highlighted some functional and operational limitations of the monitoring and control infrastructures deployed. These are primarily related to monitoring of network parameters and network conditions which are considered to be key to providing a flexible and adaptable ANM solution either on a local or centrally managed basis. More specifically, whilst the higher voltage levels (132kV, 33kV) down to 11kV primary circuits are covered by SCADA systems, the secondary monitoring and control schemes for the 11kV typically cover a small proportion of those networks. The controllability of network parameters is normally limited to voltages and loads using automatic voltage controllers, tap changers and circuit breakers using RTU commands on 132kV, 33kV and selected secondary 11kV systems. Whilst the use of IEDs is not widespread, electronic protection relays are being increasingly deployed during plant construction or replacement. These modern relays can, in addition to their protection role, execute and respond to logic scripts, monitor the network, perform load shedding and switching, and communicate the data to selected locations. HV & LV automation is providing a platform to assess the inter-operability of automated and operator controlled power networks, with the installed devices providing information that could also be used to support the requirements of ANM. The continuing growth in IEDs is naturally beneficial as it significantly increases the availability of network information.

The assessment of current communications technologies has revealed a diverse range of solutions, with the selection being based on reliability and cost. DNOs use both their own and third party telecommunication circuits, with the majority providing secure high speed communication to primary concentrators; these are connected to substation RTUs in a radial or multi-drop configuration circuits operating down to low bandwidth (data rates of 1200/2400 baud). Readily available high bandwidth telecommunications technology has the capability of meeting the requirements for some ANM applications, and the expanding availability of commercial satellite telecommunications may further increase ANM opportunities. The synergies with communication media and protocols used for automation purposes could also be explored as some can be used to provide links for ANM processes.

Existing ANM in DNO networks

The extent of schemes that have been implemented to actively manage load and generation connections varies between DNOs. In general schemes have been designed to accommodate distributed generation in areas where renewable resources are plentiful and the distribution system is sparse.

Early schemes tended to be designed to constrain a single generator, or demand customer, for local system abnormal conditions. These schemes mostly considered power flow, although voltage monitoring was also utilised. An increase in requests for connection of generation in areas of sparse infrastructure, where the cost of providing conventional reinforcement was uneconomic, led to the evolution of more complex schemes. This involved the use of signaling to constrain generation for unacceptable system conditions remote from the generation site, and in some cases applied to more than one generator. In general these schemes utilised protection equipment and signaling designed for fault situations, and could operate far more quickly than the network required; protection equipment and associated signally was however regarded as robust and had proven performance. The piecemeal construction of these schemes resulted in complex systems using a multitude of signaling channels

However, the current ANM schemes have demonstrated the potential for facilitating increased levels of distributed generation without expensive network capital expenditure through either active voltage control or application of generator constraints via an extension of inter-tripping to meet network thermal limits [1]. The number of these schemes is however still too low to assess their full potential with respect to their suitability for future widespread adoption and improved overall network reliability.

POSSIBLE ROUTES TOWARDS MORE ACTIVELY MANAGED NETWORKS

Innovative control structures and strategies

The existing primary electrical infrastructure and the communications and control infrastructure of distribution networks in Great Britain are capable, to an extent, of supporting active management of generation and demand. This infrastructure is being shown to be suitable for the integration of individual ANM schemes (some of which are described below). However, the integration of control of individual generation and demand customers, multiple generating units or a combination of more advanced generation and network devices is likely to be more challenging.

If more advanced communication and control infrastructures emerge in distribution networks as a result of individual and specific needs, the possibilities for wider application of ANM are increased. The implementation of network analysis to inform control decisions at a local level and the application of distribution state estimation to inform system control are then more achievable. These will aid the optimal utilisation of network assets to maximise access for demand and generation customers. Inevitably, such an approach will increase the demands on communications, control and data management facilities, but active management might then extend to the monitoring and subsequent operation of assets according to their assessed condition. Conversely, there is a real requirement to contain the level of sophistication and associated complexity. The maintenance of system security for all connected customers is the primary concern of distribution network operators, and the integration of new approaches requires careful planning and implementation.

Overview of ANM field pilot and trial, development and demonstration activities

To provide a clear picture of the progress of ANM concepts from research and development through field trial to full implementation, the DWG Active Management Project commissioned a review of ANM activities. The review focused initially on the UK but fanned out to the full international stage. 105 separate initiatives or projects were reviewed and categorised according to their technical focus (voltage control, fault level management, demand side management, etc.) and their current technical status (research, development, trial, pilot, full deployment.) The outcome of the review project was a register of the 105 activities giving summary details of each [2]. In addition an associated report highlights the main findings and proposes actions to maintain momentum for ANM.

The review found that four fifths of the projects were at the research or development stage. This is encouraging from the perspective of a stream of future ANM concepts that might provide benefits in the management of distribution networks. The research and development stage ANM initiatives cover all technical areas from communication and control, power electronics, protection systems, voltage control, power flow management, fault level management, etc. The other side of this finding is that only one fifth (23 in total) of the ANM initiatives had progressed to trial, pilot or full deployment. This finding should be put in the context of existing demand side management schemes around the world and existing arrangements for inter-tripping distributed generation. These existing approaches are not exhaustively covered in the register as they do not readily fall within the definition of active network management as set out by the work group. Many of the research and development phase concepts are enabled by communications and control enhancements and power electronics. This fits with the definition of ANM which seeks to deploy communication, control and new electrical technologies to bring about more effective management of distribution networks that are more accessible to the needs off generation and consumption customers.

It is worthwhile here to give examples of the ANM concepts that have progressed to the demonstration phase through trial or pilot in distribution networks. Only the UK initiatives are discussed here in keeping with the focus of this paper. The interesting new concepts are listed:

- Developments leading to a trial of dynamic line ratings to enhance 132kV network capability are underway in E.ON's Central Networks power network. This approach will enable increased generation connection capacity by allowing overhead line circuits to operate nearer their thermal limits (as calculated from real time measurements of conditions) rather than at more conservatively set seasonal limits as normally applied.

- Scottish & Southern Energy have trialled an active power flow management (APFM) approach in the Orkney Islands 33kV power system to the north of Scotland. This scheme is based around a central PLC controller with communications link from it to power flow measurement points and each generation connection to enable trimming and tripping of units to keep power flows within thresholds while enabling increased generation capacity to access the network.
- Pilot implementation of single phase voltage regulators on LV networks is underway in the Scottish Power distribution network. This improves the effectiveness of existing distribution infrastructure and provides enhanced voltage control to customers with existing or incipient voltage problems. While not actively managed (by the definition introduced in this paper) this trial shows great potential for enhancing network capability with existing primary infrastructure.
- EdF-Energy is planning a trial of the GenAVC voltage control device in closed loop mode following successful completion of open loop trials. The GenAVC device alters the voltage set-point input to transformer tap-change controls (based on current measurements) and allows better voltage regulation for networks with generation connections. The trial is planned for a rural 11kV overhead network in the rural Norfolk area.

Internationally, there is also much activity with NREL in the US trialling DG unit interface controls to enable active management and Encorp deploying control of multiple DG units through their 'virtual power plant' concept. In Japan, the focus of research appears to be on communication and control enhancement for managing demand and supply while pilots are underway for LV integrated demand and generation controls.

Current and emerging commercial and regulatory barriers

Clearly there is continually growing interest in the development of technology for active network management, but the associated commercial issues are equally pertinent. One key question that is repeatedly asked of ANM is 'What's in it for me?' Unless the stakeholder groups understand the opportunities and threats there is likely to be a reluctance to change from current design and operational practices. The identification of current and emerging commercial, regulatory and legislative opportunities and barriers to the widespread implementation of ANM technologies on distribution networks is being undertaken, along with an assessment of materiality and options for addressing them. This work involves an assessment of the generic business case appropriate to each stakeholder group (including Network Operators, Energy Suppliers & Generators, and society a whole) thought likely to be affected by the adoption of an ANM approach. A stakeholder workshop forms one element of the input to this process. A set of desktop models is to be developed to represent the financial and commercial business drivers of each of the stakeholder groups based on a series of generic distribution network models. These models will provide both a baseline and also reflect the commercial implications of the application of ANM. The proposed amelioration techniques can also be modeled so that their impact can be quantified, and used as a basis for wider stakeholder debate.

CONCLUSIONS

The extent of truly 'active network management' of distribution networks in Britain is currently quite limited. There are however a significant number of techniques identified within the research, development and field trial stage, potentially providing a platform for future implementation, either as a final solution, or to postpone network reinforcement. It is believed that the currently deployed technology has sufficient functionality to permit further exploitation. Developments in technology and communications will naturally allow more sophisticated active network management, though the commercial drivers will also dictate the extent of longer term implementation.

The Active Network Management Group of the DWG is continuing its work on both the development of new ideas, and also, importantly the exploitation of existing technology though the identification of current good practice, and communication amongst network practitioners.

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