DISTRIBUTION CONTROL ROOMS PREPARING FOR SMART GRID COMPLEXITY

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ABSTRACT

This paper describes Distribution network control and how Smart Grid initiatives are changing and complicating that role and identifies some solutions that are emerging.

INTRODUCTION

The electricity distribution control room faces unprecedented change in how it controls the sub transmission networks. The Smart Grid evolution into a multidirectional power flow network at distribution voltages has started modestly but promises to accelerate both in conventional and micro sizes of generator. Also, many initiatives to reduce CO_2 have the effect of increasing electricity usage, therefore maintaining, the rate of load growth. This will increase dependence on the availability of electricity, and levels of network performance that are currently seen as acceptable will require further improvement. All of these changes will cause investment in the physical electricity network and therefore increase planned outage workload, all occurring in the years when the last of the post war baby boomers retire leaving the utilities with skill and experience shortages.

CURRENT SITUATION

MV SCADA Deployment Constraints

A typical MV distribution network has SCADA control and monitoring at the primary substation level but little SCADA applied along the MV feeders. This reflects the cost of deploying SCADA compared to the numbers of customers supplied downstream of these points, below primary substation there is little financial benefit for a DNO to invest in SCADA and make a decent return on that investment. There are exceptions to this:

Major cities where there is a high density network with a high degree of interconnection.

Some western European countries where the social benefits had been costed in to justify the original implementation of MV SCADA, although some of these, now in private company hands are challenged to maintain this level of SCADA by the constraint of business benefits with no mechanism to recognise social benefits.

Some deregulated DNOs where the Regulator has incentivised network performance targets with a risk/reward scheme in effect priming investment in the MV network.

However, the general case is widely accepted that most of the MV networks have little SCADA outside the Primary substation fence.

Compensation for Lack of SCADA

This condition has been manageable these last 70 years because power flow in distribution was largely mono-directional from primary source to load points via normally open rings and radial distribution networks. Control staff learned from experience where it was difficult to parallel or transfer load, and a series of IT applications covering network management and outage management compensated for lack of remote control by driving efficiencies in managing manual switching. Off line network analysis compensates for lack of visibility of measured loads from SCADA monitoring.

Managing a Busy Network

Safety is correctly the top priority in controlling MV networks particularly because MV is a very “busy” network with continual workloads of new connections, reinforcements and refurbishment projects occurring daily. SCADA and manual switching, isolation and earthing and the issuing of safety documents make up a major part of a Distribution operator’s shift. Safe practises have evolved to cover communicating manual switching tasks to crews, ensuring their understanding and confirmation of completion of these tasks. These processes are essential to maintain safety and they typically take up about 37% of an MV control operator’s time, and for each crew undertaking the manual switching, some 7.5% of their working day is consumed by the communication procedures and implementation of MV switching tasks.

Inadequacies of the Current Situation

The current situation therefore is that MV control has dependencies on limited access to SACADA, on experienced staff, the network lacks visibility of loading conditions outside the primary substation, current control methods are dependent on the assumption of mono-directional power flow and significant time is spent ensuring the safety of crews and the safe and accurate implementation of manual switching,

THE CHALLENGE OF SMART GRID

More automated points to assist in optimisation Smart Grid exposes all these inadequacies of current Distribution control operational practice and adds a few new ones. Embedded and micro generation deliver the concept of multidirectional power flows, the usefulness of staff experience is undermined by the combined effects of embedded and micro generation and new green loads, electric vehicle charging etc. which will now dynamically alter load trends per circuit. Near real time visibility of loading information becomes an essential requirement.

Different Switching Tasks

Over and above the traditional MV switching workload, a more optimization based switching model will respond to the dynamic changes caused by embedded generation. This will justify more MV SCADA implementation, so that more optimization options can be realised and reduced losses, however the basic maths relating to customers served per SCADA controlled point still exists and the business case will still not justify 100% SCADA coverage over the mass numbers of secondary substations.

Anticipating Renewable Generation Loads

The changing contribution made by renewables will require to be anticipated and Distribution SCADA will collect data from weather stations per grid or primary substation to feed into load prediction algorithms on near-future embedded generator contributions. Additional voltage and VAr conditions will require to be controlled and strategies to deploy and control storage capabilities will be needed.

Network Reliability

This additional usage of the distribution network to deliver renewable generation and enable green technologies to reduce CO_2 will affect perceptions of network reliability and caused a demand for increased MV and LV network reliability. This will drive the introduction of outage avoidance techniques which will introduce new types of devices to the distribution network, such as partial discharge detection (PDD) and on line dissolved gas analysis (DGA)

The True Load Served

The true load served is becoming hidden to the Transmission system and the EMS calculations on contingency will require access to that true load. The distribution control system will require to identify quantify and correctly synthesize that load at the various grid interconnection points, relating dynamically to the distribution network connectivity, so that generation planning and contingency planning remain effective and efficient.

Low Voltage Networks

In countries with substantial three phase LV networks, the combination of micro generation and new types of point connected loads applied to a network with near zero oversight from a real time control perspective is a new and real concern. The initial requirement therefore is a per phase connectivity model down to individual premises, an interface to Smart Meter management systems to provide an overview of consumption per phase and per LV feeder.

This creates a demand for an economic solution to providing a near real time monitor of secondary Substations.

IT Architecture

A large amount of new data will be generated by Smart metering, PDD DGA and embedded generation but it is not all needed up front in the control room. It requires to be captured in a data store from where filters identify abnormal trends and violations so that control receives only the items requiring control attention. Expert analysis systems are required to undertake that filtering activity.

RECENTLY IMPLEMENTED SOLUTIONS

Reducing Control Time Spent on Crew Communication

The introduction of Mobile messaging technology to replace control/crew switching instructions/confirmations saves 2 hours per control operator per shift and crews are reducing waiting time and 10% has been saved on planned outage SAIDI. Early adopters have approved, and tested the operational and safety feasibility of this technology and now have operational experience of its proven use since 2006.

Mobile using secure SOAP/XML asynchronous messaging over GPRS (or Tetra etc.) replaces all planned outage switching management, some unplanned switching management and all OMS communication between crews and OMS dispatchers. As the crew completes a switching action, their keystrokes commits the message via the mobile server, directly into the control room switching log, automatically updates the network diagram and pings the operator for the next switching instruction.

Control operators have been reluctant to issue groups of switching instructions in the past due to lack of visibility of how the crew are progressing, but with Mobile, group instruction works well because the crew report per item completed which automatically updates the network diagram and the log.

Improving Visibility of Network Loads

Current use of offline network analysis is not a near real time process and recent developments have now introduced load flow applications as a tool directly used by operators on their live operational network model on demand, in their study mode for outage preparation, and, running cyclically in the background, providing MV controllers with what is in effect an MV state estimator. This application now provides visibility of the load on any cable or overhead line anywhere in the MV network, voltage levels at any secondary substation in the MV network, indications of power flow, and spot loads at secondary transformers. The early adopters of this technology worked with the software developers to overcome concerns of accuracy of the results due to missing network data and scant information on secondary transformer load profiles. Techniques are now in place to ensure that, with continual maintenance the results are 95% in agreement with measured results and therefore operationally useful. Overloads can be avoided, outages can be planned more efficiently, losses can be assessed, networks can be optimized by multiple criteria, embedded generation can be visualized and its field of influence over power flows visualized. DPF (Distribution Power Flow) alarms can be raised as calculated values approach capacity limits, or the combined effect of embedded generation approaches an unwanted export condition.

Of course, some new SCADA deployment is necessary to provide embedded generator control and monitoring, but this actually helps by providing more points of reference for DPF

Smart metering evolution also helps reduce the maintenance workload of managing the load profiles. Embedded DPF therefore is a solution which will be made more effective by Smart Grid evolution

Visualizing embedded generation areas of influence

The same DPF tool applied to analyzing the effect of embedded generation (or proposed embedded generation) can show the area of network influenced by the generator with analogue values of current and voltage per network section/busbar and load flow direction arrows indicating the dynamic position of null points. In continuous background mode any violations indicated from the displayed results can create a limit violation and an associated alarm using the same functions used to create SCADA alarms. For instance an infringement of the low analogue limit at an MV feeder circuit breaker could raise an alarm indicating embedded degeneration is close to causing the feeder to export back up to the primary SS busbar, and the "low – low" alarm could confirm the occurrence of an export condition from an MV feeder. These alarms could invite manual operator attention or invoke an intelligence process interacting with demand management systems, diverting energy into storage, making discretionary loads available etc. or indeed sending constraint messages to embedded generation.

Reducing the impact of unplanned outages.

In regulated environments, distribution network operators may face penalties for poor network performance and poor response times to incidents, and in some instances incentive rewards are also offered for exceeding network performance targets. This additional financial component alters the economics affecting MV SCADA deployment and makes it cost effective to consider some intelligent MV feeder automation at the normally open points and one or two intermediate points along the worst performing feeders. The biggest barrier, other than economic, to the introduction of this technology is concerns over safety. Automation on medium voltage networks requires to recognize the level of crew activity on the MV network and identify when it is inappropriate to attempt an automated response to an outage.

Intelligent Automation For Fault Restoration

Automating the fault restoration using intelligent programmes run from the control room DMS rather than the substation RTUs provides the major benefits of centralised control, centralised maintenance enabling scalability to larger numbers of feeders and the ability to check for the safety related items prior to enabling the automation switching. Optimisation using the generic algorithm has been previously published, Ref 1. Not only does this methodology introduce MV automation safely, it reduces the task of manual fault sectionalising to a shorter section of the feeder, (still involving several manually switched sections) between two automated points which the programme identified and caused to be opened. By default therefore control engineer time required to respond to this fault is reduced because large proportions of the feeder length have already been automatically eliminated as possible fault location sites. Several devices, Power Quality Monitors(PQM)¸Remote terminal units (RTU) intelligent Electronic Devices IEDs and protection relays now boast the capability to capture data fast enough to predict a distance to fault. Given the previous automated sectionalising, the distance to fault can be of further use in assisting manual switching to finalise the fault sectionalizing. Distance to fault visualised on the DMS network diagram provides the control operator with the fastest and clearest representation of the isolation needed for fault isolation.

Avoiding Unplanned Outages

Unplanned outages, faults, are themselves an avoidable consumption of control operator's time. Faults disrupt planned activities; introduce inefficiencies and delays into what would otherwise be an efficient planned approach to their days work. The Smart Grid focus therefore moves beyond unplanned outage MANAGEMENT towards outage AVOIDANCE techniques.

The installation of partial discharge detection (PDD) for bushings switchgear and cables can monitor and trend normal patterns of PDD and capture the early stages of abnormal behaviour. Similarly the installation and integration of on line dissolved gas analysis, (DGA), for important transformers provides a different technology but the same end result, a continual trend of normal behaviour and an early awareness of abnormality developing. The full value of these devices is only achieved when the DMS console is integrated in the process of acquiring an expert 24 x 7 and the expert report is made immediately available back to control to assist in the decision making process of how best to proceed to avoid unplanned events from this developing situation. Just as the control engineer has gained access to protection experts when needed, they now also need access to PDD and DGA analysis experts as a specialist service preferably available on demand.

NEW AREAS OF CONTROL

The above discussion indicates emerging areas where control time is being freed up by automation of communication with crews, by better managing faults and by providing better visualisation of loading. NMS network management systems and OMS outage management systems also provide embedded best practise methodologies for managing switching, managing faults and major emergencies such as storms, and in doing so enable younger age profile staff to copy the best practices that evolved from the experienced staff who are now close to retiring.

LV Network

Smart Grid initiatives are creating a major new area of increased control attention to the low voltage network. Some increases in oversight of the LV network have been required in recent years due to the increased use of contracting staff as well as utility employees. Now the approaching impact of micro generation and the needs to instal demand side management techniques require the connectivity model to expand to a complete per premise per phase connectivity model. It becomes essential to understand the net effect at the secondary substation, is it still a net importer of energy to the LV network or is it a net exporter of energy generated at various LV premises and passed up to the MV network. Is the dual effect of per phase micro-generation and per phase point loads caused by heat pumps or electric vehicle charging sites really understood, is it balanced across all three LV phases, is it blowing LV fuses.

Conditions of Connection

New connection conditions may well be needed to give the utilities time to assess and reinforce LV networks prior to point load or micro generation connection requiring more frequent and faster interaction between control, design offices and construction.

Smart Meters

Installing smart metering per connection point and a meter management system MMS will assist in both demand side management and in providing data that the DMS can access as required to understand LV and secondary substation loadings and losses. Installing smart metering/monitoring at secondary SS level will enable the DMS to understand and quantify losses and optimise their reduction

Grid Interface

At the distribution/ transmission interface there is a growing need to help the EMS understand the true load; that served by the traditional top down route, plus that load served internally from embedded generation within the distribution networks, so that accurate contingency allowances can be kept in place. Additional measures for managing the effects of embedded generator connections imply that DMS must use more integrated voltage and VAr control techniques, optimization algorithms and dynamic thermal rating functions to optimise the usage of existing infrastructure and minimise the cost of connection of embedded generation. Understanding the dynamic sphere of influence of embedded generation and the deployment of very fast control mechanisms to avoid cascade outages as assets are driven closer to their limits.

Changing Roles

The control engineer and OMS operators will require to be trained for new tasks. Control engineers will spend less time in communication with crews, with that work becoming more automated via Mobile; however their tasks will now include load dispatching network optimization elements in response to embedded generation effects on the MV network. It is tempting to view this as a role similar to transmission dispatching however the distribution network includes many differences from the transmission network, not the least of which is the proximity to customers, and their roles will continue to be different from transmission operators.

OMS staff similarly will see their traditional tasks becoming more automated with automatic incident creation and preconfigured crew selection however their work will evolve towards LV monitoring and response.

The new monitoring and diagnostic equipment added to the network requires to be integrated into the control room environment. Control however does not descend into a data processing role, the essence of the data processing is in the filtering of that data, identification and extraction of the abnormal trend and presenting that to the 24 x 7 control environment so that expert interpretation can be deployed to contribute to the response strategy.

The OMS operator can deploy tasks to experts in the same way they deploy tasks to repair crews, this ensures an overview and process control mechanism will also cover the new tasks and ensure the findings from the masses of new data are properly identified and implemented.

Integration is the key to maximizing the benefits and reacting to the new challenges presented by Smart Grid. Distribution control requires to avoid proliferation of multiples of new systems, the added value of the new data and techniques is more than the sum of its individual parts only when the data is managed and selected items become integrated into a sensible workable and integrated control room environment.

References

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