MEDIUM VOLTAGE REINFORCEMENT TECHNIQUES AND ROLE OF THE COMMUNICATION NETWORK

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ABSTRACT

Ofgem (UK Electricity & Gas regulator) has estimated a need for £32 billion of electricity network investment in the next ten years, a doubling of the rate of investment over the last 20 years. Investment needs to be smarter, drawing on a range of new, innovative intervention techniques as an alternative to, or to supplement conventional network reinforcement.

Western Power Distribution, Cisco and Alstom are working together on the Flexible Approaches to Low Carbon Networks (FALCON) project. This is a UK Government funded initiative to look at ways of improving understanding of the UK infrastructure needs in a low carbon future. This is focused on the provision of networks to support energy demand for the future. This project is aimed at reducing the cost of reinforcing the 11kV network

Within this presentation we will discuss four of the intervention (reinforcement) techniques that are being deployed. The four intervention techniques that will be discussed along with the communication solution are:

- *Dynamic Asset Rating*
- *Automated Load Transfer*
- *Meshed networks*
- *Energy Storage*

We will examine how a wireless IP communications network based on WiMax has been designed to accommodate the different requirements including, monitoring, control and low latency applications such as tele-protection.

INTRODUCTION

The Flexible Approaches to Low Carbon Networks (FALCON) project is a UK Government funded initiative to look at ways of improving understanding of the UK infrastructure needs in a low carbon future. This is focussed on the provision of networks to support energy demand for the future. A number of techniques are being trialled, which it is hoped, will enable network operators to better manage investments in the future.
This project is aimed at reducing the cost of reinforcing the 11kV network to practically deliver the benefits indicated in the Imperial College/ENA study `Benefits of Advanced Smart Metering Demand Response Based Control of Distribution Networks' thus enabling the Government's climate change targets to be met. Ofgem has estimated a need for £32 billion of network investment in the next ten years, a doubling of the rate of investment over the last 20 years. Investment needs to be smarter, drawing on a range of new, innovative intervention techniques as an alternative to, or to supplement conventional network reinforcement.
The Project will generate improved load forecasting information to inform load-related reinforcement analysis, especially on the hitherto unmonitored but essential 11kV network.
This project is designed to provide the following:

- Provide a better understanding of the applicability and costs associated with alternatives to conventional 11KV Grid reinforcement techniques
- Enable tuning of the common set of evaluation criteria
- Enable the addition of new criteria (e.g. % network utilisation)
- Provide better asset information, enabling a greater focus on minimising total lifetime cost
- Support investment decisions made within longer term investment timeframes
- Base network investment decisions on a broader range of criteria including managing uncertainty, ensuring deliverability and minimising risk.

FALCON will design and deploy four technical intervention techniques, which are designed to address network constraints:

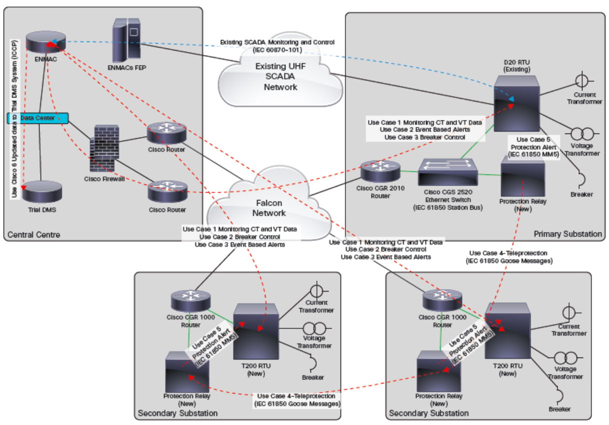
- Dynamic Asset Rating
- Automated Load Transfer
- Meshed networks
- Storage

The combination of techniques will be defined as part of the project. FALCON will also develop a prototype Scenario Investment Model (SIM) using data from the above trials. The SIM will include a network-modelling tool that models the MV network to identify potential constraints. It also provides a decision support system that helps identify the most cost effective network intervention in planning for the relief of capacity constraints. In addition to the above, industry data will be utilised to assess the effectiveness of using industry created load estimates as an alternative to physical substation monitoring.

This enables the project to prove, or disprove the widely used data. The project is based on the network in and around Milton Keynes in the UK and includes testing new "smart" networks in 200 substations.

Use Case Design Approach Overview

One of the key requirements for the project was to ensure that the communications infrastructure was correctly design for the intervention techniques that were to be used. This was achieved by breaking each of the techniques down into a set of use cases or functions. This is essentially the functional decomposition of the technique showing the actors (devices) and each process step. It was then possible to map the communications requirements to each of the functions and each of the process steps within the functions that made up the technique. This ensures that all the communication areas have been considered and can highlight potential issues such as application protocol miss-matches as well the bandwidth, latency and Security requirements.



TECHNICAL INTERVENTION TECHNIQUES

Dynamic Asset Rating Overview

When more electricity flows through a cable, transformer or overhead line than it is designed to carry it causes excessive heat that may result in damage. It takes a finite time for this heating to produce damage. Typically many of these medium voltage assets are not monitored; a prediction of the safe capacity of the assets is used in the network design to limit their capacity. This safe unmonitored rating is the static rating for certain periods. If an asset is monitored then a dynamic rating can be used. This can be higher than the static rating to reflect the time required to heat the asset as long as the asset is allowed periods of cooling after being run at these high temperatures. This approach of using dynamic rating is a way of accommodating peak electricity supply as it uses the cyclical nature of load to provide cooling. The use of cyclic rating creates a trade-off between asset life and its peak handling capacity. By carefully controlling the use of cyclic rating, the impact on the asset's lifespan can be minimised whilst delivering significant additional capacity to the network.

Dynamic asset rating first requires the asset to be monitored to determine its normal operating level. Additional monitoring is then required so that we know exactly what the ratings are at any given time, based on factors such as temperature and recent loads on the asset. Implementing dynamic asset rating involves installing a communications infrastructure and remote monitoring equipment around the asset in question and changing operational procedures to include monitoring of the assets. Dynamic asset rating can be applied to transformers and linear assets (cables and lines). Whilst it can be applied to both overhead lines and underground cables, it is most effective for overhead lines as these are easier to monitor.

FALCON Trial Overview

FALCON will install monitoring equipment enabling dynamic asset rating to be applied to the transformers and cables (both overhead and underground) associated with a single primary substation and six 11kV feeders within the trial area. Additional interventions (e.g. fans, pumps) may also be deployed if appropriate.

Automated Load Transfer Overview

In parts of an 11kV distribution network there are open rings in which there are two or more supply routes from a primary substation to a ring of secondary substations. It is called an open ring because the ring is divided into two sections connected by an open switch. Each substation is normally connected to only one supply route. However each secondary substation has two potential sources of supply as closing the switch provides two routes back to the primary substation.

Automated load transfer uses this feature to dynamically alter the number of secondary substations that are fed from each supply route by closing the open switch and then remotely operating switches introduced between substations. This allows load to be transferred from one supply route to another automatically. If one half of the ring has exceptionally high load whilst the other has spare capacity, load can be shifted between the two by reducing the number of substations on the overloaded side at the expense of the side which has spare capacity. For more complex ring arrangements, consideration needs to be given to the balancing of load across the number of feeders involved.

Automated load transfer requires remotely operable automated switchgear to be installed between secondary substations. This involves installing or upgrading switchgear as required depending on what is already in place and is fully dependent on a resilient and robust communications infrastructure. Deciding when to switch requires visibility of the load at different points on the ring.

This in turn requires installation of remote monitoring equipment such as phasor measurement units. In some cases there may also be a requirement to alter protection settings remotely.

Finally, operational procedures need to be changed to make use of this facility. Automated load transfer is suitable for implementation on open ring 11kV circuits.

FALCON Trial Overview

The FALCON Project will trial three automated load transfer schemes using six existing 11kV feeders within the trial area, comprising both overhead and underground circuits. For overhead circuits, pole mounted automated re-closers and sectionalising devices will be used. In the case of underground circuits, automated equipment will be installed where they do not already exist.

As previously stated the Automatic Load Transfer intervention technique will require a resilient and robust communication infrastructure to be deployed at both primary and secondary substations. It will also require automation of pole tope sectionalisers such as the Schneider RL27, which are already deployed and use GPRS communications. Additional pole sectionalisers will also be required. This may also require new RTU to be installed.
The RTU will also be used to measure the current and voltage as well as control the sectionaliser. The role of communications is critical because the control of these devices is a centralised function with no local automation.

For this intervention technique, a Phasor Measurement Unit (PMU) will also be deployed in each primary substation and at several secondary substations along the trial network. PMUs can have a significant impact on the communications network and can generate a 100kpbs data stream per feeder. When we consider that multiple existing RTU can communicate using 9.6kbps data lines we can see the step change in infrastructure that is required. The communication infrastructure is vital for both control of the sectionaliser and also for ensuring that the RTU and PMU data reaches the control centre in a timely fashion so appropriate control action can take place.

Meshed Network Overview

As with automated load transfer, meshed networks utilise the fact that each secondary substation on an open ring circuit has two potential sources of supply. However, rather than shifting load operationally between routes using switches, the meshed network is a passive solution in which a permanent closed ring is created. To do this, a set of "protection zones" needs to be designed and implemented to ensure that the network can operate safely. The number of "protection zones" is a balance of practicality, cost, and improvements against customer impact in minimising the number of customers off supply in the event of any given fault on the ring. In this solution, the power flow is improved as the mesh allows the current to choose the path of least resistance. Protection zones that minimise loss of supply in the event of a series of fault scenarios must be designed and implemented by installing circuit breakers in strategic points around the ring circuit. As with automated load transfer, meshed circuits are suitable for implementation on open ring 11kV circuits

FALCON Trial Overview

To date, meshed network implementations have been largely limited to high-density load areas such as city centres. In FALCON, the intent is to explore the benefits of meshed networks applied to suburban and rural areas. We will trial three meshed networks comprising six existing 11kV feeders within the trial area.

The existing protection devices are located at the primary substation and use over current protection. The additional scheme that will be deployed is direction overcurrent with blocking. This requires the transmission of blocking messages between the secondary substations within the intervention ring. Unit protection in the form of differential current protection is also being investigated, however the latencies currently required cannot be achieved using a WiMax infrastructure.

The directional overcurrent protection scheme will use IEC61850 GOOSE messages which are layer 2 multicast messages. This protection scheme is less time critical than the unit protection scheme however there are still quite stringent latency (delay) requirements. This is especially true as the inter-substation communication is a WiMax network. A maximum latency of 80ms is required for this and the project is anticipating 40ms can consistently be achieved with a potential minimum of 20ms.

Energy Storage Overview

Storage involves installing one or more batteries onto the network, charging these at times of low demand and discharging them at times of high demand. The effect is to reduce the demand on the network at peak times thus accommodating additional power flows within the same available network capacity. It can be highly effective in addressing periods of high demand, which may be very limited in duration.
Batteries are installed within ground mounted secondary substations on the LV side of the transformer. The charging/discharging regime is controlled by a set of algorithms that respond to network demand. The secondary substations require monitoring to be installed to drive the charge/discharge algorithms. Power conditioning units (PCUs) are typically installed with the battery arrays to optimise the performance and provide communications. Storage can be installed virtually anywhere on the 11kV network, where space and support requirements can be met. It can be highly effective in addressing constraints that only appear for short periods of the day (e.g. one or two hours at times of peak consumption). One of the advantages is that the battery solution that is being trialled can be relatively quick to deploy/redeploy.
The solution can then also be used as a short term solution, either where there is uncertainty in future demand or as a stop gap whilst a more permanent technique is implemented.

FALCON trial Overview

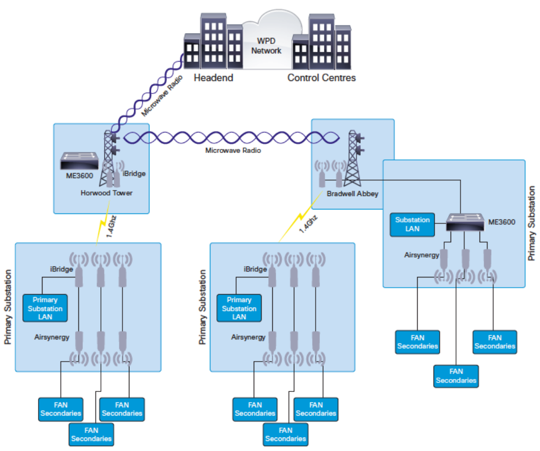
Batteries will be deployed across five secondary substations in the trial area. Each battery array will have a capacity of 10-20% of the transformer capacity over a 1-2 hour period. Battery installations will include a PCU, communications and substation metering. An RTU will be required at each site for measurement and data logging.

The project will look at both local substation control and centralised control, as again the communications to these substations is a vital component.

COMMUNICATIONS NETWORK OVERVIEW

The communications infrastructure is a critical component for the intervention techniques within FALCON and will securely link the 200 sub-stations within the trial area with the Trials Network Manager and Data Storage. To enable communications to all the 200 secondary substation, an IP backbone will be deployed with IEEE802.16e WiMax technology providing the physical connectivity. The traffic will be routed using routers in the primary substations and Field area routers installed at each of the secondary substations. Data from the monitoring devices and relays at each sub-station will be connected to the router via an RTU (for analogues) or directly via Ethernet Station bus.
The trial area covers the following locations:

- 1 x Control Centre
- 9 x Primary Substations
- 200 x Secondary Distribution Substations



The communications network is based on a private network infrastructure and will transport both monitoring and control related traffic for the intervention techniques. The network is based on IPv4 and related technologies. Within the primary and secondary substations, an Ethernet based Station Bus will be utilised.

Existing communications to the substations are based on a UHF radio network. As the new monitoring and control functions are deployed over the IP-enabled WiMAX communication network, it is anticipated that all communications will be gradually migrated from the UHF radio based network infrastructure.

Solution Details

Within the primary substations a ruggedized router will be deployed to provide WAN routing and firewalling. This will be connected to a WiMax node to provide the wireless backhaul. A ruggedized Ethernet Switch will provide the IEC61850 station bus, connecting the substation RTUs and IEDs. Multiple WiMax devices provide Pico cell coverage from the primary substation to enable connectivity to the secondary substations.

Within each secondary substation a rugged field area router with a 1.4Ghz WiMax module will be used. This provides Ethernet connectivity within the substation and uses the WiMax network to backhaul the traffic.

AUTHOR BIOGRAPHYS

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Andrew Longyear is a leading business development for Cisco's Connected Energy Networks service organisation within the EMEAR theatre. He is also responsible for defining utility specific solutions across this region, working with customers, partners and regulators to shape the utility industry.

He has worked in the ICT industry for over 25 years working at both manufactures and end consumers on a variety of technologies from hardware engineering, telephone systems, network management, to systems architecture. He has been with Cisco for 13 years, the last 8 being heavily involved in building specific communications solutions for the utility industry.

Roger Hey

Future Networks Manager
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Roger has worked in the energy industry for over 20 years. He initially trained as an operational engineer delivering networks construction and maintenance activities. Roger subsequently gained experience in Control Room and Telecommunications parts of a DNO business. More recently he spent several years managing the IT functions.

In 2008 Roger was asked to bring together his varied experience and establish a Future Networks strategy and small team of specialist engineers. The department is responsible for the business's innovation strategy, delivery of demonstration projects and implementation of new solutions into core business activities.