Development and Installation of a Remote Control/Automation System onto an Existing 11,000 / 6,600 volt Distribution Network in the North West of the UK

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INTRODUCTION

United Utilities provides the electricity network for 2.28 million customers in the North-West of England. Supplies are distributed at the following voltage levels: 132kV; 33kV; 11kV, 6.6kV and 400/230 Volts. This network of almost 60,000km together with 32,000 substations delivers 25,444 gigawatt hours of electricity annually from the National Grid to both domestic and business premises. United Utilities charges supply companies for using our distribution network based on rates set by the industry regulator, Ofgem.

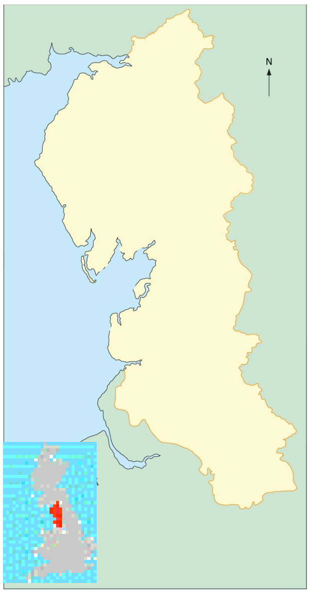

Figure 1
Map of United Utilities Electricity Area

Both underground cables and overhead lines are utilised to distribute electricity. Underground cables (75% of the network) supply dense urban areas, whereas rural areas are predominantly supplied by overhead lines. The United Utilities network covers a diverse range of terrain and customer mix from isolated farms in the Lake District National Park to densely populated industrial areas around the city of Manchester (see figure 1).

Quality of Supply of the electricity network can be measured in terms of security (the number of interruptions experienced by customers connected to the distribution system – Customer Interruptions, CI), and availability (the average number of minutes off supply experienced by customers – Customer Minutes Lost CML). The aim of the Project was to outperform the Quality of Supply targets set by the UK Electricity Regulator (Ofgem) during the previous regulatory period. Over the lifetime of the Project the number of interruptions have fallen from 66.4 CI per 100 customers in 02/03 to 50.98, in 03/04 and availability of supply has improved from 67.7 CML per customer to 59.3 CML per customer.

This paper describes a three-year Electricity Network Improvement Project from 2002/03 to 2004/05 costing £35 million to improve the restoration of supplies following faults on the 11kV or 6.6kV networks. The 11kV and 6.6kV networks were chosen because they were identified as being the major causes of CI's and CML's (50% of total). The programme has involved installing additional protection and nearly 2,000 remote-controlled switches that can be used to quickly sectionalise the network and restore supplies to customers, rather than waiting for an operator travelling to the site. A software driven system has also been introduced to automatically reconfigure circuits and restore supplies during faults on the 11kV or 6.6kV networks. The resulting system acts to minimise disruption to customers by providing greater control of the network.

DEVELOPMENT OF EQUIPMENT AND SYSTEMS

Before the Project was rolled out, a series of trial schemes were initiated to identify the most suitable equipment and its fitness for purpose. Three major areas of development were Communications Media, Mechanical Actuators for existing high voltage switchgear and Retrofit Vacuum Circuit Breakers.

Communications Media

In the trials Low Power Radio was used as the communications media but, in the roll out of the main programme, this was replaced by mobile phone technology GSM and finally by modification of the existing United Utilities PMR (Private Mobile Radio Network) communications system. Whilst Low Power Radio provided a low cost solution for early schemes it became apparent that GSM Radio was more effective and reliable for widespread use of remote control.

In the final phase of the project the development of the communications link between the remote control system and United Utilities PMR system made it possible to use the existing umbrella of 42 Radio base stations located at strategic points across the Region. The United Utilities PMR network is now the preferred communications media as it offers fast communications with minimum running costs and without risk of external interference. A communications management system enables failures in the communication paths to be quickly pinpointed and repaired.

Actuators

United Utilities 11kV/6.6kV electrical network is controlled predominantly by oil filled switchgear. It was not cost effective to change this switchgear for modern circuit breakers, therefore a method of retrofitting electro-mechanical actuators to the switches was developed. These enable the switches to be operated either Remotely, Locally via the electrical actuator, or Locally by manual operation.
In summary, the following mix of equipment was decided upon. For underground cable type circuits a mix of new Vacuum and SF6 switchgear with integral actuators plus retrofitting of existing switches with motorised Actuators was chosen. For overhead circuits a mix of Air Break Isolators with motorised Actuators, auto-reclosing GVRs (Gas insulated Vacuum interrupter Reclosers) and Auto Sectionalising Links (ASLs) was chosen. The use of GVRs and ASLs to replace overhead mounted fuses and links provided greater control of the network through their ability to automatically isolate faulty sections of network to minimise the number of customers affected by a fault.

Retrofit Vacuum Circuit Breakers

Because United Utilities' High Voltage network has been constructed over the last sixty years there is a wide range of equipment installed on the system. To enable remote control and automatic switching to be carried out it is essential that all source circuit breakers are capable of multiple operations during the fault restoration process.

In many cases, due to the age and type of HV circuit breaker installed on the United Utilities network, it is necessary for an operator to visit site after the closing operation of a circuit breaker to recharge the spring operating mechanism. To carry out a complete replacement of these circuit breakers on associated automated networks would have been very expensive. The solution was to replace the circuit breaker trucks with retrofitted Vacuum Interrupters (see figure 2). This replaced the oil interruption method and enabled the fitting of a motor wound spring operating mechanism to be achieved at a very low cost. Electrical tests were carried out at each site during the initial survey to confirm that Busbars and circuit breaker housings were suitable for continued service.

Figure 2
Retrofitted Vacuum Interruption Circuit Breaker

Central Control System

Remote Control of these units is achieved through Remote Terminal Units (RTUs) which communicate back to a central control System located within the Network Control Centre.

As part of the main programme of remote controlling 2000 switches the initial stand alone central computer control system has now been integrated into the main United Utilities SCADA – Control Room Management System (CRMS). Through CRMS it is now possible to view and operate the entire EHV and HV Networks from one screen. The network is geographically configured on screen and each control point can be operated in real time with indications of Battery condition, Gas Pressure, Sensitive Earth Fault and Auto Reclose operation. The system will also provide voltage and current analogues.

Automation

Various systems were trialed for carrying out Automatic Sequential switching of the Remote Controlled devices. The objective being to restore supplies within 3 minutes. A system of intelligently linking Fault Passage Indicators (FPIs) installed at various strategic locations on the 11/6.6kV network was trialled but finally rejected in favour of a software generated dynamic sequential switching process run from the centrally located CRMS. The process used draws on the knowledge of the current network configuration held in CRMS and uses a series of generic templates to sectionalise the fault without the need for expensive FPIs.

Triggered by the opening of the automatic switch controlling a particular circuit (Source Breaker), the process automatically opens all Remotely Controlled switches down the circuit up to the normally open point(s). Starting from the source breaker it then sequentially closes all Remotely Controlled switches until the faulty section is identified by the tripping of the Source Breaker.

Once identified in this way, the process continues to isolate the faulty section and restore all other supplies by closing the Source Breaker and the normally open point(s). By being driven from CRMS the process is dynamic and takes account of any changes in network configuration.

PLANNING AND DESIGN METHODOLOGY

Prioritisation Modelling

The correct positioning of Protection and Remotely Controlled switching points on the network was vital to achieve maximum CI and CML benefits at optimum cost. To maximise the cost/benefit of the programme a two-stage approach for the positioning of additional Protection and Remote Control devices was adopted. The first stage involved the use of historical performance data for each 11kV/6.6kV circuit within the company to determine a prioritised list of 'worst performing' circuits on a CI and CML per annum basis. Of the 3165 11kV/6.6kV circuits on United Utilities' network this study identified that the worst 205 circuits were responsible for producing 40% of all faults (see figure 3).

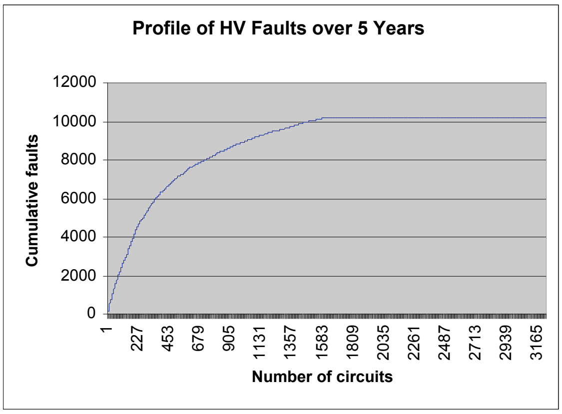

Fig 3
Profile of HV faults

Network Modelling

The second stage of the process utilised a mathematical modelling technique representing the 11kV/6.6kV networks. This was used to optimise the positioning of each device within the circuit. The use of the model allowed the fault probability (based on historical data) combined with known customer distribution to provide projected future CML and CI savings. The particular model used during this project allowed the use of circuit-specific fault rates and distribution patterns to be used during this analysis thus ensuring a highly targeted solution to minimise the CI's and CML's whilst simultaneously minimising costs.

This method together with the use of standard costs obtained via long term contracts allowed for rapid comparison between and identification of, the most cost effective designs.

Prioritising Further Initiatives

As the worst performing circuits were dealt with and further Quality of Supply initiatives recognised, additional more sophisticated modelling techniques were required to identify those initiatives with the highest potential cost/benefit. A modelling technique was developed that provided the functionality to compare the cost/benefit between several such initiatives. This enabled not only the prioritisation of work within a project but also between different projects and allowed United Utilities to optimise investment within a significant proportion of it's Capital Investment Programme.

PROGRAMME MANAGEMENT METHODOLOGY

In order to gain the benefits from this project as soon as possible the Project was managed off line from normal business activities. This involved end to end management of the Design, Approval, Procurement, Installation and Commissioning phases of the project. Bespoke systems were put in place to forward order equipment and project-manage the complex tasks of coordinating materials with specialist installation Contractors and a dedicated team of commissioning engineers. In addition, in order to minimise network outages and fast track the installation of 11kV/6.6kV equipment, extensive use of Live Line working techniques were employed (see figure 4).

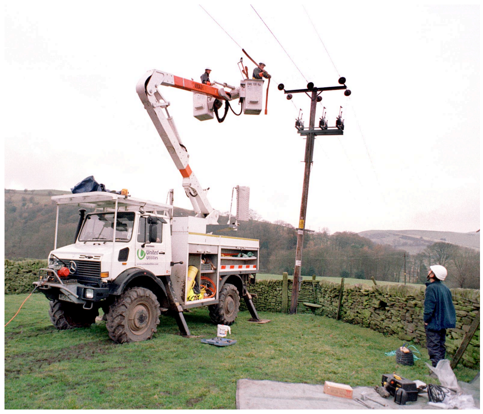

Figure 4
Live Line Working Techniques

RESULTS

We have measured the effectiveness of Remote Controlling the 11kV/6.6kV networks by setting target CI and CML reductions year on year for the 205 worst performing circuits and measuring these on a monthly basis. In order to check that any improvements have not been due to other influences (asset replacement or weather) a control sample of 175 other circuits has also been monitored.

From figure 5 and 6, it can be seen that performance of the 205 circuits improved by 36% over two years whilst the 175 control circuits deteriorated significantly over the same period. The reliability of the installed equipment has also been measured in terms of its availability for use. To date, an availability level of 96% has been achieved for all remote control equipment in service.

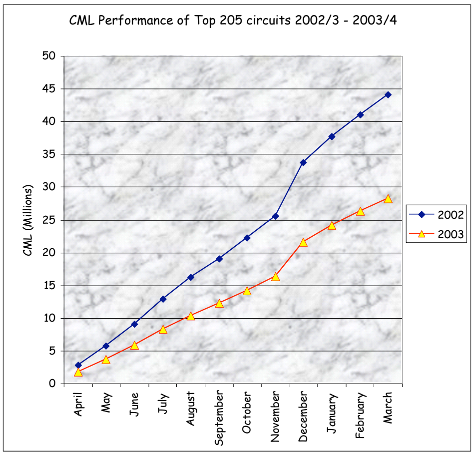

Figure 5
CML Performance of 205 Worst Performing Circuits

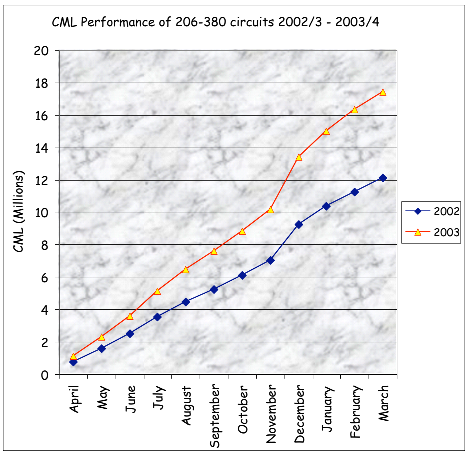

Figure 6
CML Performance of 175 Control Circuits

In order to maximise the impact and reliability of the Remote Control programme we have, wherever possible, used standard equipment and proven techniques to create a package of primary switches, telemetry and communications equipment which has required the minimum of development and trials. This facilitated a fast track installation programme and the excellent performance improvements achieved.

DISCUSSION

By Remote Controlling a significant number of switches on the 11kV/6.6kV network and focusing these on the worst performing circuits, we have been able to achieve a deeper and more effective level of network control – beyond the 132kV and 33kV Primary Networks.

This gives us greater visibility of the network via our CRMS SCADA system and enabled us to isolate permanently faulty sections as well as monitor transient faults through Remote Controlled GVRs and Power Outages Devices (PODs) which monitor customer's supplies. Control Engineers now have a real time 'picture' of events such as lightning storms as they affect the whole electricity network.

Remote Control enables response times to fault interruptions to be improved from typically 1.5 hours (the time to get operators to site) to a few minutes. With Automatic reconfiguration of faulty circuits, restoration times of less than 3 minutes are now possible. Reliable and effective Remote Control of the 11kV/6.6kV network is enabling managers to place less reliance on site operators with consequential savings in manpower costs.

The development of a modelling technique that allowed the comparison of cost/benefits between different projects was found to be crucial in optimising investment in the Quality of Supply programme within United Utilities. Additional development of such modelling techniques will enable United Utilities to further optimise the benefits of their Capital Investment programme.

The correct positioning of Protection and Remote Control switching points is vital to achieve maximum CML and CI benefits at optimum cost. The availability of appropriate mathematical models to analyse networks and allow rapid comparison between design alternatives was found to be a key feature in the success of this programme. It is anticipated that further development of such tools (including the use of dynamic source data) will increase the accuracy and flexibility of this type of network design.

Effective remote control of the 11kV/6.6kV network will become increasingly important to maintain and improve the availability of supply to customers at an acceptable cost, particularly with the likely impact of widespread embedded generation on the 11kV/6.6kV networks. It is anticipated that remote control will play a key role in the development of 'intelligent networks' that will control load flows, manage fault levels and improve the performance of future networks whilst minimising the Capital investment required.