EXPERIENCE OF REMOTE CONTROL AND AUTOMATION OF MV (11kV) SUBSTATIONS

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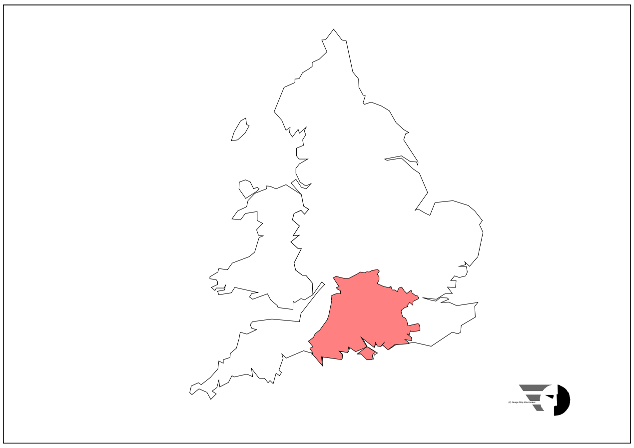
INTRODUCTION

This paper describes the achievements of Southern Electric in improving the availability and continuity of supply for customers supplied via the MV underground network. The success in installing over 1000 remotely controlled ground-mounted ring main switchgear since 1995 is described and the experience of operation is examined. The initial use of remote controlled actuators and a more selective solution using circuit breakers and graded protection is also described.

SOUTHERN ELECTRIC

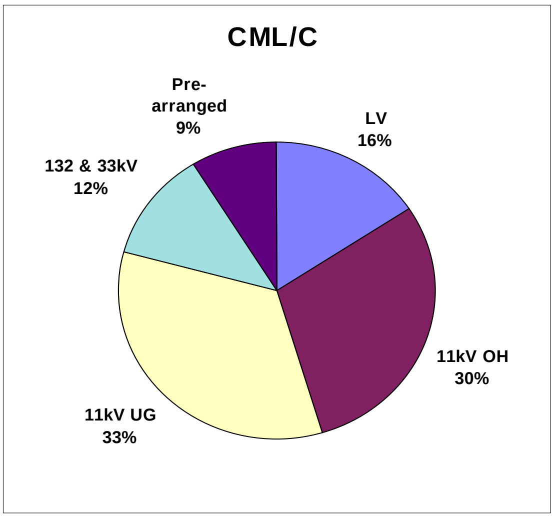
Southern Electric (SE) is part of the Scottish and Southern Energy Group of Companies. Southern Electric is the public electricity distributor to 2.6m domestic, industrial and commercial customers spread over an area of 16,900 sq. km in the central part of southern England. Southern Electric's system comprises some 70,000 km of mains and has an annual maximum demand of 5850 MW. The company has a well established reputation for delivering the highest level of customer satisfaction at economic prices.

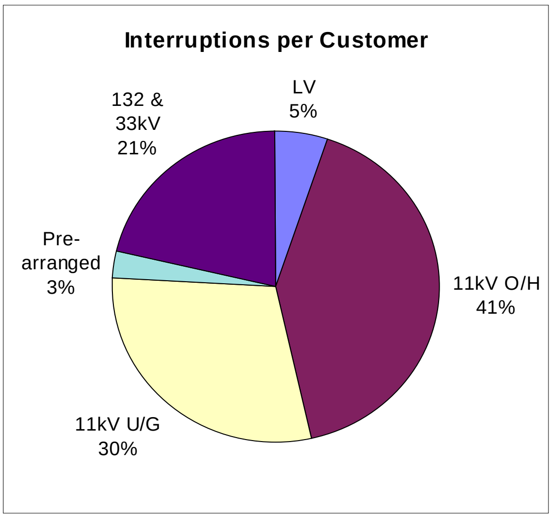


Some 1.7m of customers are supplied via an urban style MV network, principally 13,500km of underground cable and 25,000 11kV/400V ground mounted substations. The project examined in this paper is a good example of the way capital investments have been made to improve customers' level of satisfaction.

CAUSES OF FAULTS IN SOUTHERN ELECTRIC

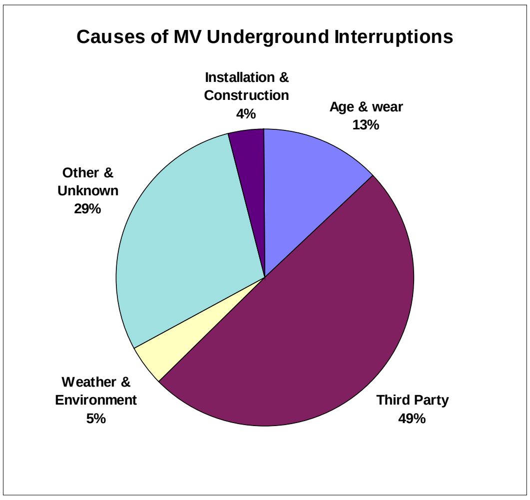
The reliability of supply for customers served by SE is extremely good ; availability of 98.99% and continuity being only 0.7 interruptions per customer on average. The causes for unavailability of supply and discontinuity are indicated on the charts below:





It is clear that the MV system has a major impact on both availability, 63% and continuity ,71%.

The chart below indicates the main causes of interruption in MV underground cable systems in SE.



It is clear that the causes of failure are principally owing to third part damage, which is to a large extent outside the distributors control. However, to reduce third party damages we audit contractors who excavate near electricity apparatus and provide suitable publicity.

THE PORTFOLIO OF INVESTMENT DRIVERS - HOW QUALITY OF SUPPLY FITS.

Quality of Supply is one of the many drivers of Capital investment decisions. The main drivers are indicated below:

- Customers needs, such as Quality of Supply and reliability
- Safety of staff and the Public
- Regulatory pressures
- Environmental issues
- Statutory requirements
- Network efficiency, such as loss reduction.

To provide a balanced programme of investment it is necessary to consider all of these drivers. The programme of installing remote controlled switchgear is typical as it involved more than one driver, as listed below:

Customer needs: Based on information from market research and comments that have been received directly from customers, and groups such as the Consumers Consultative Committee.

Safety/Asset renewal: Replacing old switchgear.

Network Efficiency: Using SF6 switchgear has lower maintenance costs than the oil equipment it replaced.

QUALITY OF SUPPLY STRATEGY

To meet customers expectations regarding Quality of Supply, the company set two main objectives**:**

- To improve reliability of supplies,
  - Reducing the number of interruptions per customer
  - Reducing the average duration customers are without supply
- To integrate improvement programmes with existing asset renewal plans to maximise synergy.

Having considered options, Southern Electric's has implemented programmes of work to met its Quality of Supply objectives:

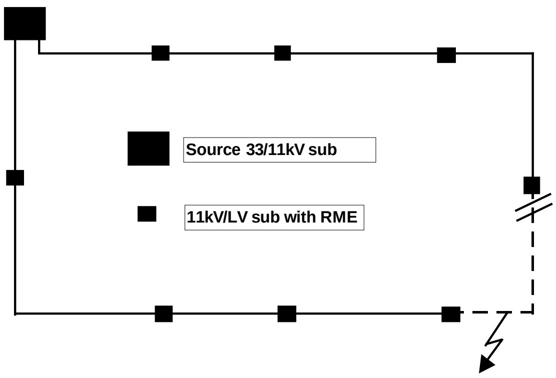
In Urban areas, where the distribution network comprises short lengths of a few hundred metres between well loaded substations there is a relatively low fault rate. However, the impact of loss of supply is quite acute with loss of traffic controls, public lighting etc. After examination of the network, it was decided that it would not be practicable to reduce the fault rate of the existing components, therefore, a programme of installing remote controlled and automatic switchgear was initiated to provide rapid restoration of supply to a large proportion of customers - this is the subject of this paper**.**

In more rural areas, due to the relatively high incidence of faults , it was considered appropriate to improve the inherent reliability of the network; reducing the fault rate by replacing bare wire by covered conductor MV overhead lines. This was the subject of a previous conference Paper [1].

These programmes of work have delivered a 30% reduction in average of loss of supply period.

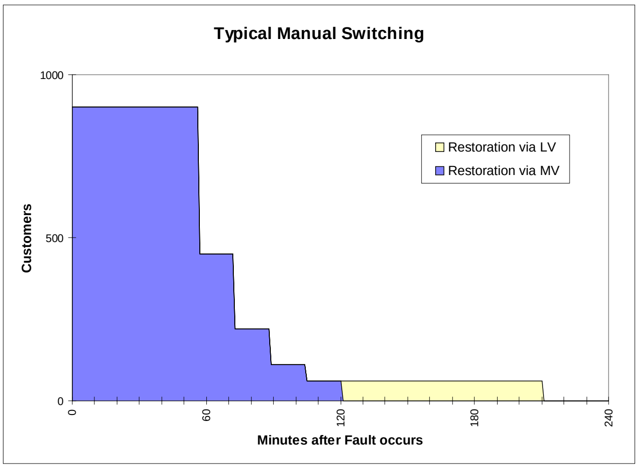
EXISTING MANUALLY OPERATED NETWORK

The basic design of the Urban MV system, comprising ground mounted substation and underground cable, has not changed in over 40 years. 11kV/400V ground mounted substations are linked together via underground cable. Typically, half of the substations are 'looped' using Ring Main Equipment (RME) comprising two manually operated isolators and a fuse-switch to which is connected the 11kV/400V transformer. The remaining substations are 'teed' and have MV fuse switches. A typical network is indicated below.



In the event of a cable fault the entire circuit is automatically disconnected at source by the operation of protecting circuit breaker. At that stage alarms are relayed to a central control point from which Operators are dispatched to operate the switches manually to isolate the faulty section of cable.

The diagram below indicates the rate of restoration of customers, using manual switchgear for a typical fault. Typically the first switching operation restores only half of the disconnected customers, some 60 minutes after the fault has occurred. In some more remote areas, or in areas of high congestion , this initial restoration can take up to several hours. The diagram indicates all supplies being restored from the MV network after 120 minutes and the supplies to a teed substation being restored after a further 90 minutes.



ATTRIBUTES OF REQUIRED SOLUTION

Our objective has been to improve availability of supplies to customers in Urban areas. The solution needed to have the following attributes:

- Existing technology, available for immediate installation
- Compatibility with existing network components,
- Suitable for outdoor installation
- Easy to install
- Costs to be justifiable in terms of cost/benefit case.
- Robust and proven basic technology.

REMOTE CONTROL OR AUTOMATION ?

It was recognised that Quality of Supply objectives in Urban areas could be achieved by reducing restoration times below that which could be achieved by manual switching. To reconfigure the network, post-fault, either remote control or a fully automatic solution would be suitable. After careful consideration we decided that a remote control solution would be implemented as:

1. The technology was readily available without significant development.

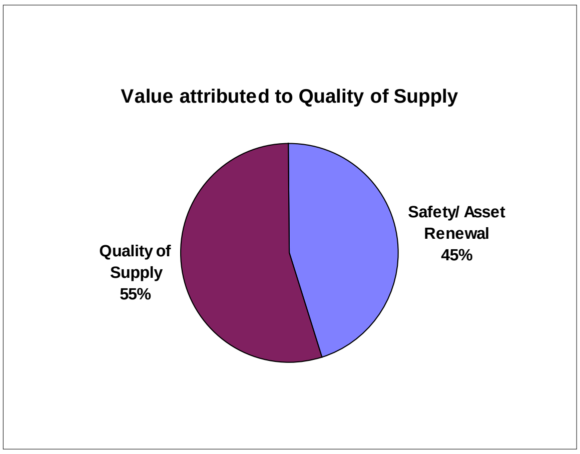
2. In SE there is considerable development and redevelopment, with new substations and cables being regularly connected. It was, therefore, considered that a fully automatic system of network reconfiguration would become difficult to manage and would risk operating errors.

SOLUTIONS IMPLEMENTED

The chosen solution has been the replacement of MV switchgear at the normal open point and, typically, at another substation situated halfway along each feeder.

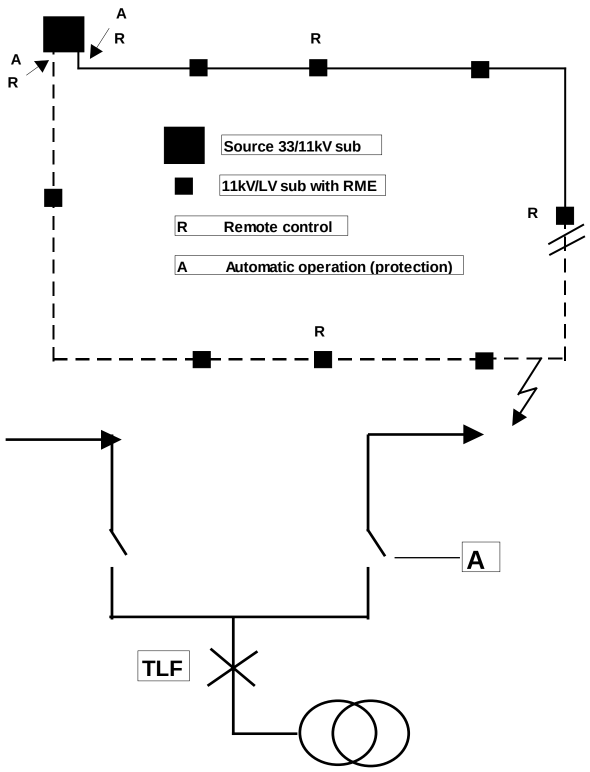
The improvement in quality of supply will vary depending on the frequency of faults on a particular circuit and the number of remote control points being installed on that feeder. Clearly there is a relationship between the cost and benefit. For this reason, the project team individually assessed the number of remote control positions that could be justified on each circuit in question. Generally, however, we found that no more than one control point could be justified between the normal open point and the source.

The cost benefit case was made on the basis of an assessed value of the inconvenience of customers being without power. Furthermore, we assumed that in over 80% of cases we would be able to locate replacement RME's in substations where replacement of existing switchgear could reasonably be justified on the basis of age and condition alone. Therefore the cost/benefit was apportioned as indicated below:



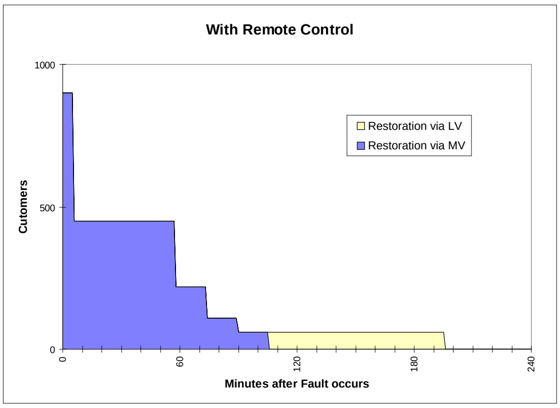
Stage 1- Remote control

The installation project began in 1995 and used equipment we latterly referred to as "Stage 1". This simply involved replacement of switchgear at the normal open point and typically halfway as indicated below. Each newly installed RME is provided with a remotely controlled actuator on one isolator and monitoring facilities via radio link to a central control point. The transformer is reconnected via the circuit breaker which is fitted with Time Fuse Link protection.



Stage 1 Solution

In this system, the entire circuit is automatically disconnected at source following a fault, and the new remote controlled switches are used to restore supply to half of the customers within about 5 minutes. At that stage operators are dispatched to site and , typically, restoration of the remaining customers is commenced some 55 minutes later, or as soon as they reach site.



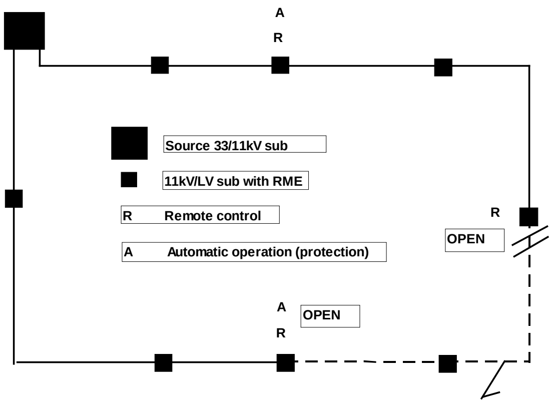
This Stage 1 solution is a significant improvement on the normal manual restoration, however, it suffers the following limitations:

It does not improve continuity of supply to customers, i.e. the number of interruptions per customers remains the same.

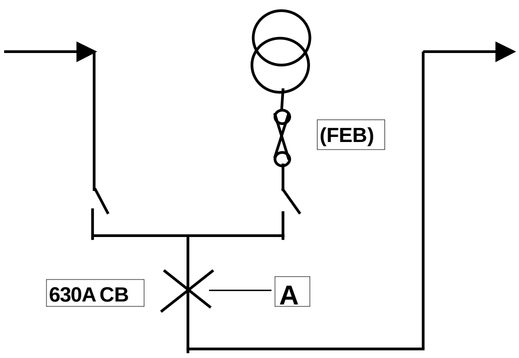
Customers who have been restored after 5 minutes via remote control can be affected by further interruptions when the operative visits site to isolate the remaining customers.

Stage 2 Partial automation

To overcome the above limitations. we quickly sought enhancements to the Stage 2 solution Working with the manufacturer we reconfigured the RME to provide an 'in-line' circuit breaker which was equipped with both remote control and self-powered IDMT protection which allowed the 'halfway' point to discriminate with the source circuit breaker. The configuration of the RME and network are indicated below.



The diagram above indicates the benefit of the in-line circuit breaker with protection that is co-ordinated with the source. Fewer customers are disconnected for faults beyond the new circuit breaker.



Stage 2 Solution
Novel use of RME

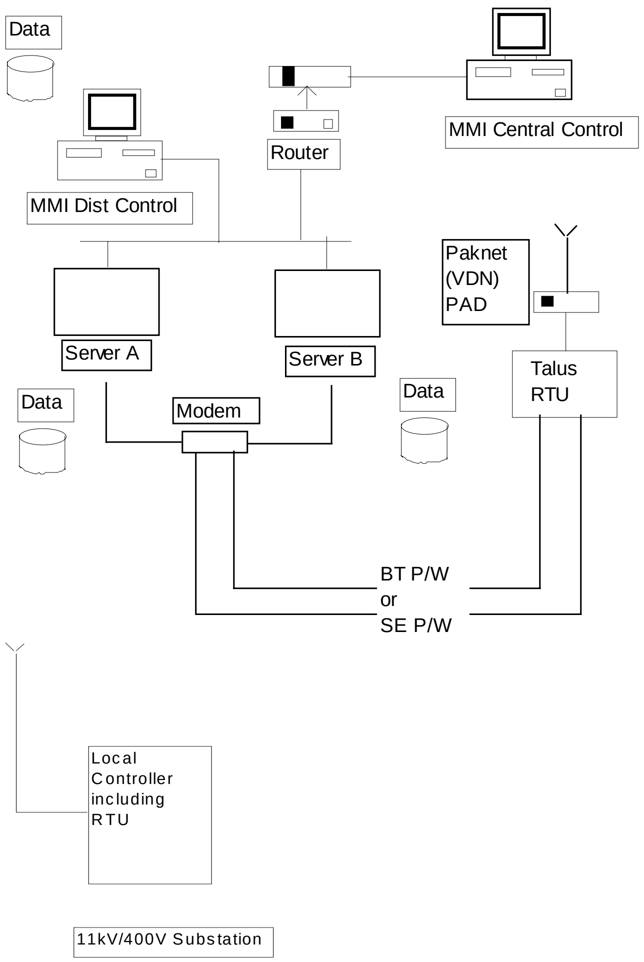
The above diagram shows the inline circuit breaker. To enable this unit to replace a conventional RME, the existing transformer cable box is removed and replaced by a specially constructed Fused end box (FEB) which contains air insulated fuses to protect the transformer**.**

The comparison of performance of the Stage I and 2 solutions is tabulated below:

	Improvement	
	Unavailability	Continuity
Stage 1 Solution	Down by 45%	nil
Stage 2 Solution	Down by 45%	25%

TELECOMMUNICATIONS & CONTROL SYSTEM

Southern Electric is developing a fully integrated Geographic information, fault management, replacement SCADA and screen based control system. Part of this new control system will include control of the MV switchgear referred to in this paper. However, to deliver the benefits of the system, prior to the implementation of the overall control system, an independent interim control system has been established. This control system is shown schematically below:



The control system involves:

1. A local control RTU at each MV substation
2. Communications to each MV substation via Voice Data Network (VDN).
3. Collection of data from about 40 MV ss in a Talus RTU.
4. Communications from each group of MV ss to the central control room via Private Pilot or rented wires.
5. Central processing of data and central Man/machine interface (MMI).

PROGRAMME OF WORK

Selection of circuits

In 1995, Southern Electric approved a 5 year programme to provide remote control facilities on 1000 of its 1900 11kV Urban circuits by April 2000. Analysis was undertaken of all circuits to prioritise the investment programme. This resulted in those circuits with the most cable and greatest customer demand taking priority in the programme.

Resources and Installation Process

In carrying out this programme of work it was essential to optimise the process of removing existing MV switchgear and of installing the replacement RME complete with actuators.

To achieve this a two man civil team carry out preparatory work and deliver new switchgear to site. Then, the installation team completes disconnection of old switchgear and connection of new RME.

The company employs two multi-skilled installation teams on this project, each comprising 4 staff to complete removal and installation of new switchgear at 300 sites per year. They are supported by the two part time civil contractors, a radio survey engineer and two full time staff performing commissioning of control systems. This task includes regular updating of the control system database and drawing of screen displays on the central control system.

To avoid customers being disconnected during the implementation of the new works, mobile generators are often used to maintain continuity of supply, typically for one day.

Progress to date

We are on target to meet the programme goals. By the end of 1998 over 1000 11kV/400V substations have been provided with remote control facilities.

FURTHER BENEFITS FROM THE NEW SYSTEM

At each site with remote control, the passage of fault current is recorded and can be remotely interrogated to provide an indication for operations staff seeking to isolate faulty sections of cable.

Load currents are measured on-line and can be accessed via the communications system. This provides valuable information for the real time control of the network and off-line for medium and long term network development planning. This improved quality of data provides further economic benefit in enabling network reinforcements to be completed 'just in time'.

PRACTICAL LESSONS LEARNT

Pre-installation survey: At the earliest stages of network redesign, we use a radio survey map which has been computer generated, to help us select a suitable site for the remote controlled substation. However we have found that it is essential to carry out radio survey on each site to confirm radio reception. The computer prediction is not accurate on a 'micro' scale. Likewise, mobile phone coverage, or lack of it , is no indicator of VDN coverage.

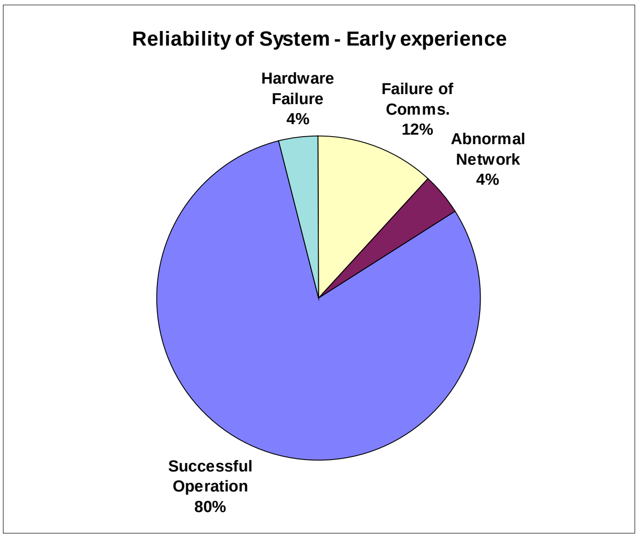
Aerials: the original aerial was a 4m galvanised pole with 1m white aerial. In some cases this aerial was visually prominent and were subsequently painted to match the natural backdrop. To expedite site installation a 3m grey fibreglass aerial is now used. This has the advantage that it can be directly mounted to the free-standing telecontrol cabinet. Where switchgear is housed in buildings a simple whip aerial is attached externally.

RESULTS TO DATE

In the latter months of 1998, typically, remote control is used to restore supplies on about 20 circuits each month. Therefore a good deal of practical operating experience is being built up.

The predicted improvement in availability is being delivered. The chart below indicates the average performance to date.

The new system has performed quite well, however, the average success rate of 80% was not considered satisfactory. Special efforts were made to overcome teething problems with hardware. One unforeseen area of unreliability was the high incidence of communications failures, largely attributable to the private wires linking with the Control centre. A focus on improving reliability and ensuring rapid repair of communications cable faults has now improved overall performance.



THE NEXT STEP

Lower Unit costs: To get best value it is essential to constantly seek reduction in unit costs. Whilst using a multi-skilled installation has delivered benefits there is continuous efforts to reduce costs further. Possibilities for further cost reductions include the integration of the local control unit into the switch enclosure to avoid the need for separate foundations and wiring between the units.

Fault Passage indication: The early installation included earth fault passage indication. Whilst this is adequate, as some 85% of faults are earth faults, we are looking to install full 3 phase fault passage indication.

Continuing the programme: Our success in delivering improvements has led to recommendations to roll the programme forward to the remaining 900 urban feeders in the period 2000-2005.

REFERENCES

[1] D C Mee, Improving Supply Reliability for Southern Electric's Rural Customers, in *Proceedings CIRED 14th International conference and Exhibition on Electricity Distribution (Conference 438),*
Part 1: Contributions, Subject Area 6: Study and Planning of Supply Systems: pp. [6.35.1]