INFLUENCE OF FAULT HANDLING TECHNIQUES ON SUPPLY SECURITY

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1.0 INTRODUCTION:

The Rural ESB Distribution System consists of 5,500 km of (arc suppressed) 38kV network feeding 320 38/10kV substations ranging in capacity from 2MVA to 10MVA. The rural 10kV network is operated with its neutral isolated from ground and consists of more than 18,000 km of three phase, three wire backbone lines which feed a network of more than 54,000 km of two phase, two wire lines. A 20 year programme to upgrade 10kV to 20kV has recently got under way. Pole mounted distribution transformers, range in capacity from 5kVA to 200kVA and number in excess of 120,000. Average load density is $20kW/km^2$. At low voltage, protective multiple earthing is used.

10kV feeders are protected at source by ground mounted circuit breakers, reclosers or expulsion fuses. Two phase spur lines are generally group fused at the take-off from the backbone line.

Rural 10kV busbar fault levels range from 1kA to 4.5kA (20MVA to 85MVA). Feeder loads range from 1MVA to 5MVA.

2.0 OBJECTIVES AND OPTIONS:

Technological advances have had a major impact on the systems and devices available to electric utilities in providing service to customers. At the same time, such technological change has radically affected the character of loads supplied by rural networks. This has resulted in increased demands in terms of supply security (and quality) being placed on these networks.

In response, a strategic decision has been taken to reduce customer hours lost on rural networks by a factor of 50%. To achieve this over five years, will involve tackling the problem from a number of angles. The options include:

* Prevention of outages - neutral treatment
  - lightning protection
* Minimise outages due to transient faults - autoreclosing
* Reduce impact of permanent faults - location time
  - repair time
* Streamline operational practices, optimise voluntary switching
* Review network configuration.

In addition, more information is required on the nature of faults, behaviour of the system and operation of equipment. This is facilitated by the installation of remotely controlled disturbance (fault) recorders and neutral analysis equipment.

3.0 OUTAGE PREVENTION:

Earth faults and lightning faults are both common occurrences on Distribution networks. Preventing outages in these cases must have a positive impact on supply security.

3.1 Neutral Treatment:

Earth faults are the most common type of fault on overhead networks and with an isolated neutral at 10kV, customer disruption is minimised. Load can continue to be fed while an earth fault is being located. The existence of an earth fault is detected by the measurement of neutral voltage displacement at the feeding substation. Further fault location is aided by a hand held "Pathfinder" device sensitive to the magnetic field associated with the earth fault current. Transient earth faults cause no supply interruption and no equipment or operator intervention.

For safety reasons, on the occurrence of an earth fault, equipment in the feeding substation solidly earths the faulted phase, thereby reducing risk at the fault site (due to step and touch voltages).

The new 20kV system will initially run with resistance earthed neutral. This neutral treatment was chosen to avoid having to change all the line insulators. However, the aim is to change these over time and ultimately facilitate some form of high impedance earthing, e.g. arc suppression or faulted phase earthing.

Arc suppression techniques associated with networks which have potential for large degrees of dissymmetry (single phase spurs, single pole switching) can be difficult to operate. New technology, however, permits monitoring of the degrees of dissymmetry, damping and detuning and facilitates automatic control of the coil setting.

A trial line has been identified where full 20kV line insulation can be provided cheaply, neutral monitoring equipment installed and the feasibility of arc suppression of such a system determined.

3.2 Lightning Protection:

ESB policy has recently been updated, but remains under continuous review. Where pole mounted transformer damage rates are very high, selective application of MOV surge diverters is utilised. These are applied to each transformer or at regular intervals on the network, depending on transformer density.

In other areas, simplex rod gaps are the sole form of lightning protection. The spacing however, has been reduced from 75mm to 50mm. Trial networks are in place to test the performance of 40mm simplex and 40mm cross-cylindrical gaps. While the lower rod gap spacings will not prevent a transient outage due to lightning (power frequency follow current disconnected elsewhere) the lower transformer damage rates will reduce outages due to permanent faults.

4.0 TRANSIENT FAULTS:

As a consequence of using an isolated neutral, phase-phase or three phase faults are the only transient faults which cause disruption.

Consequently, the introduction of steps to reduce the effects of transient short circuits has only recently been embarked upon in any major way.

Group fusing and auto-reclosing have been rejected by many Area Boards for a number of reasons, most particularly; inability to achieve selectivity, fuse damageability and incorrect replacement of fuses. The ESB attempt to overcome these problems in the following ways:

Selectivity:

Computer drawn recloser/fuse selectivity plots can be compiled for any feeder. These plots identify what fuse should be used at a given location so as to achieve selectivity with the reclosing device. The relatively low fault levels mean that selectivity is possible for the vast majority of spur lines using between 25A and 100A NEMA K-speed fuses.

Fuse Damageability:

This has been a well known problem, most particularly with certain types of fuses. A long-standing operational policy of not replacing unblown fuses when fuse(s) on neighbouring phase(s) have blown, has been suspended, pending TCC conformance tests on surged fuse links of various constructions.

Fuse Replacement:

To help prevent incorrect fuse replacement, fuse holders are colour coded which leaves the operator in no doubt as to the correct fuse size to use. In addition, fuse sizes used are recorded on the fault report. Fuse blowings due to non-damage faults are closely monitored locally to determine the cause.

As regards the use of electronic auto-sectionalisers in cutouts, the ESB have a limited application for these devices (i.e. close to 38kV substations where selectivity with 100A fuses is not possible) and a small number are currently on field trial. One drawback with these devices is that one level of protection is being removed (i.e. if the reclosing device fails, the sectionaliser cannot interrupt the circuit). This is of concern on ESB networks where backup is not available from earth fault or sensitive earth fault protection (as might be available on earthed neutral systems) and where fault levels are low such that upstream (38kV) overcurrent protection provides very limited backup.

Autoreclosing scheme parameters currently in use are a dead time of 10s, reset time of 5s, 2 instantaneous and 1 delayed trip to lockout and in the case of circuit breakers a maintenance alarm/lockout setting of 30/40.

Trial feeders are being fitted with American reclose relays which record the number of successful reclosures on each shot. Information gathered from these trials will permit fine tuning of the scheme parameters particularly the benefit gained from the second shot and the potential benefits of instantaneous reclosure.

5.0 PERMANENT FAULTS:

While permanent faults are the least common of all fault types, customer disruption can be significant unless the outage duration is minimised.

5.1 Internal Fuses:

As a consequence of group fusing, one faulty distribution transformer would cause an outage to the whole 10kV spur line. Location of the fault may be time-consuming and would often involve breaking/remaking jumpers. The applications of low-rated internal high-tension fusing (IHF) has many benefits, not least in terms of fast fault location. The only customers suffering an outage are those fed from the faulty transformer and only these will initiate no supply calls. In addition, these fuses provide improved transformer protection.

5.2 10kV Busbar Protection:

While the probability of getting a busbar fault is small, the repercussions can be very serious. The provision of any form of busbar protection at 10kV has normally been rejected on economic grounds.

Rudimentary 10kV busbar protection is simply achieved by setting the 38kV overcurrent relay on the 38/10kV transformer with an instantaneous pick-up setting that will detect 10kV busbar faults. In order to prevent operation of this relay for 10kV feeder faults, a blocking signal is derived from the relay on the faulty feeder.

5.3 Fault Indicators:

Flashing light fault indicators have been investigated as a means of reducing fault location time. Field tests were carried out on various types, the most suitable being installed in one Region to gain further experience.

Indicators are applied approximately every 5km on mainlines and long spur lines. Only the mainline units are fitted with voltage resetting.

5.4 Rural Automation:

While permanent mainline faults account for a very small fraction of all faults, they account for around 50% of customer hours lost. Rural automation is currently under investigation as a means to redress this situation, with likely application to only the worst hundred or so lines. Traditional economic justification is very difficult. However, once supply security targets have been set, economic analysis can be used to compare the various options.

A number of schemes have been considered and two trial networks are now being installed. These are both radio controlled, one and a half switch schemes, using air break switch isolators and having local control centres which are independent of, but compatible with, SCADA. One scheme is provided completely by one supplier while the other is a mixture of components from various suppliers. One scheme has a fixed control centre while the other is mobile.

A third scheme using auto-sectionalisers/ACO may also be installed.

6.0 COMMENTS:

Maintaining/improving quality of supply to customers is an ongoing battle for all electric utilities. The ESB system was initially set up in 1927 and the distribution networks have given good service but have probably reached their limit of performance, e.g. in relation to voltage drop, losses and continuity of supply. Consequently developments include the replacement of the 10kV networks by a 20kV system, a review of the existing radial network configuration and appropriate neutral treatment, improved lightning protection and the selective application of rural automation.