INTRODUCTION

This paper presents some simple guidelines for selecting the settings on the protective equipment at a customer’s point of connection (POC). The scenario considered is a customer on a radial supply from a network where time-current coordinated devices provide overcurrent and earth fault protection in both parties’ networks. A single line diagram of such a connection is shown in Fig. 1. It is assumed that the utility network is grounded in such a way as to provide a reasonable level of earth fault current. A case is made for the more widespread use of extremely inverse overcurrent protection characteristics in power supply networks. In this paper the electricity supply network operator is referred to as the utility.

IDENTIFY CONSTRAINTS.

Constraints can be initiated by either the customer or the utility.

Utility Constraints

As the transporter of electricity, the Supply Network Operator or utility is usually in a monopoly situation and is able to dictate the standards of protection performance required at the POC and sometimes within the customer’s network. These standards can govern the types of protection schemes, the critical fault clearance times which must be met by the customer and the levels of dependability to be achieved in the protection design. If these constraints are not identified early then much costly rework should be anticipated.

Customer Constraints

Frequently customers will have precise expectations concerning the manner in which their electrical plant should be protected. It cannot be assumed, however, that these will always be made clear to a consultant engaged to undertake protection work. Common requests include the selection of overcurrent protection settings with pick up currents less than rated current intended to prevent thermal damage due to overloading. Sometimes the dependencies within a customer’s process will mean that if one drive is lost the whole process shuts down. In such cases discrimination between the incomer and the outgoing feeders from a switchboard may be sacrificed to improve the speed of protection. ‘Process critical’ drives, on the other hand, will often have motor protection set for alarm only because the cost of disrupting the process far outweighs the motor replacement cost. After receiving a ‘motor fail’ alarm operators can put an alternative motor into service or implement other contingency plans while the faulted motor runs to destruction.

Cable Ratings

Cable phase conductors and screens have short time ratings. It is desirable to ensure that the overcurrent protection clearance times are fast enough to protect cable cores and the earth fault protection fast enough to protect the cable screens from thermal damage.

SINGLE LINE DIAGRAM

A clear single line diagram is the key to understanding a customer’s power distribution network. Frequently this must be augmented by the schematic diagrams of the relevant protection panel or panels in order to confidently select appropriate relay settings. This is particularly so when you are setting protection which has been specified or designed by others.

OBTAIN UTILITY FAULT CONTRIBUTION

Time-current graded devices using inverse time characteristics will typically grade up to some maximum value of current.

From Utility Supply Network

Utility Circuit Breaker

Utility Protection

Customer Protection

Customer Main Switch

To Customer Plant

Fig 1. Single Line Diagram of Point of Connection

The contribution made by the utility to short circuits at the
POC must therefore be known. You will need to know both three phase and single phase to earth fault levels complete with ‘X/R’ ratios. Maximum fault levels are generally required. Ask the utility if they have any plans that might cause the fault levels to change in the future and if a voltage factor, ‘c’, (as defined in IEC60909-0 Short-circuit currents in three-phase a.c. systems - Part 0: calculation of currents) has been included in the calculations. The ‘c’ factor selected can alter fault levels by up to 10%. When the maximum fault level is in doubt, base your relay settings on the short circuit rating of the primary plant at the POC. Sometimes minimum fault levels will be needed in order to confirm positive operation of protection relays at the minimum value of available fault current.

TO GRADE OR NOT TO GRADE?

Generally, customers and utilities choose to apply a grading step between their respective protection devices so that faults within the customer’s installation will clear at the customer’s circuit breaker only. In this way the customer can restore supply at its own choosing without having to rely on the utility’s attendance.

Where grading margins within the installation are tight you can increase these margins by sacrificing the grading margin with the utility. Such action, however, must have the consent of both parties and is usually considered as a last resort. Eliminating any overcurrent grading margins which might have been applied across the customer’s transformers should be the first means considered for reducing protection operating times.

NUMERIC RELAYS

Modern numeric relays function on an embedded computer code. Codes constantly evolve as is evident from the manufacturers’ regular revisions of relay firmware. Knowing the exact firmware version is necessary to identify a relay’s available protective functions and means of operation. Any relay documentation you are using should be checked for compatibility with the revisions of firmware loaded in your relays.

Software is usually provided by the relay manufacturer for communications between a personal computer and their relays. Use of such communications tends to be the most efficient means of loading settings into a relay. Compatibility between versions of relay firmware and software is often an issue and may need to be addressed with the manufacturer before trying to establish communications.

USE OF INSTANTANEOUS OVERCURRENT

Instantaneous elements (ANSI code 50), or high sets, should be used sparingly. If in the network shown in Fig. 1 there is a short length of conductor between the two circuit breakers a high set on the utility protection is not recommended. Time delayed overcurrent protection (ANSI code 51) is appropriate. If, as shown in Fig. 2, there is a transformer between the two circuit breakers then phase overcurrent high sets should be used at the utility end. The same applies if a fault current limiting reactor or a very long feeder circuit separates the two breakers.
as shown in Fig. 2, then it should not have high set protection selected. If it does, then indiscriminate operation of the high set for faults on the customer’s outgoing feeders can be expected unless some deliberate time delay is introduced. A customer main switch should have high set protection selected if it protects a long cable, a long overhead line, a reactor or a transformer as shown in Fig. 3.

It is noted that where plain attracted armature type relays are used as high sets, overreaching can be expected due to the DC offset in the fault current waveform. The amount of overreach possible will depend on the system X/R ratio and may approach 100%. This is generally an issue with electromechanical relays where, unless specifically requested at the time of ordering, high set elements are not transient overreach free and respond to the DC component of the fault current.

Possible applications of high set protection on switchboard incomer circuits are as follows.

Logic Discrimination

Also known as blocking, this system is quite readily applied on switchboards with radial outgoing feeders. It does not provide truly instantaneous protection because a short time delay must be applied to allow for the transmission and receipt of blocking signals from downstream relays. The scheme does, however, permit large improvements in fault clearance times. It is suitable for both high and low voltage systems.

Energy Discrimination

This form of discrimination is only available with low voltage switchgear and applies to set combinations of air circuit breakers (ACBs), moulded case circuit breakers (MCCBs) and fuses. It is best compared to the criterion for grading fuses where for successful discrimination the total arcing I²t of the downstream fuse must be less than the pre-arcing I²t of the upstream fuse. Energy discrimination requires that the unlatching energy of the upstream ACB or MCCB is less than the let-through energy of the downstream fuse or MCCB. This restriction of energy stops the upstream instantaneous protection operating for long enough to allow the downstream protection to clear the fault. Manufacturers publish tables indicating which device combinations will give energy discrimination and, if not at all currents up to rated short circuit current, the upper current limit of discrimination. The published tables are manufacturer specific. Therefore energy discrimination between different makes of circuit breakers can not be guaranteed.

USE OF INSTANTANEOUS EARTH FAULT

Instantaneous earth fault (ANSI code 50N) should also be used sparingly. As a rule it is best confined to unit protection schemes. This recommendation is based upon the usual practice of having the earth fault relay situated in the residual circuit of a three phase set of current transformers (CTs).

When one of the CTs saturates the resulting spill current can cause an unwanted operation of the earth fault relay. Where instantaneous protection is required the following schemes are recommended.

Restricted Earth Fault

This is one of the family of circulating current high impedance differential protections. As the name suggests it is a unit protection scheme. It is most commonly applied to transformer windings with one relay being required per protected transformer winding. It gives high speed detection of earth faults and is immune to the affects of CT saturation. The rules for CT selection and relay setting are very clearly laid out in the (British) Electricity Association’s ESI Standard 48-3, ‘Instantaneous High-Impedance Differential Protection’.

Ideally it is applied when the customer’s first item of plant after the POC is a transformer winding as shown in Fig. 3. Both unearthed and earthed transformer windings can be protected, the latter requiring a fourth CT in the transformer neutral circuit.

It is noted that motor circuits with stabilising resistors fitted in series with the earth fault relay element should be engineered to the recommendations for restricted earth fault protection.

Core Balance Earth Fault

Core balance earth fault protection is a scheme in which the earth fault relay is supplied with current from a dedicated CT enveloping all three of the primary circuit phase conductors. A core balance CT responds to the vectorial addition of the three primary currents and is therefore far less susceptible to the effects of saturation due to three phase or phase to phase current flow. Applications at POCs are likely to be very limited as core balance protection, without some additional time delay, does not discriminate with downstream earth fault devices. Core balance protection is mostly applied to motor circuits, at both high voltage and low voltage.

It is noted that low voltage Residual Current Devices (RCDs) also known as Earth Leakage Circuit Breakers or ELCBs) operate on the core balance CT principle but include a neutral conductor to account for the connection of single phase loads.

ALLOWANCE FOR LOAD CURRENT

This is not an interface issue but may affect the choice of overcurrent protection settings at the customer main switch, particularly if the customer requires the overcurrent to provide some degree of overload protection. The ‘background’ load current in the healthy circuits inside the customer’s installation will vectorially add to the fault current in the faulted circuit. This has the effect of shifting the incomer overcurrent curve to the left meaning that it will tend to operate faster. If it operates too quickly then it might not discriminate with the protection on a faulted feeder circuit and supply to the entire switchboard is lost.

TYPES OF OVERCURRENT PROTECTION CURVES

In British and Australian networks it is quite common to find
that utilities apply standard (or normal) inverse IEC curve type A throughout their networks for both overcurrent and earth fault protection. Customer networks favour the selection of the extremely inverse curve type IEC C for overcurrent because these grade better with fuses and moulded case circuit breakers which provide the overcurrent protection at the lowest levels within the customer installation. The matching of the two different curve types frequently leads to problems in the coordination of the protection at the POC as is demonstrated in Fig. 4.

To overcome these problems it is recommended that utilities apply extremely inverse curves adjacent to the POC. The extremely inverse curve matches more closely the $I^2t$ characteristic defining the thermal withstand of metallic conductors. This is considered to be another advantage when selecting IEC curve type C.

The adoption of the very inverse IEC curve type B by utilities at the POC might provide a compromise between the two types of curves discussed above, however, utility use of extremely inverse curves is recommended as the first preference.

WHERE TO START?

To simply grade the protection on a customer’s main switch with the utility’s protection in isolation from the rest of the customer’s network can be regarded as risky. Starting at the lowest level within the plant and working back to the POC gives superior results by providing more control over how protection grading is achieved. When providing relay settings for a customer main switch it is therefore recommended to undertake protection settings for the customer’s entire installation.