Electrical Protection: Limits to Reliable Operation

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INTRODUCTION

A properly designed and maintained protection system with appropriate settings applied to its protective devices is fundamental to operation of any electrical power system. In fact, according to a well respected protect text " … *without discriminative protection it would be impossible to operate a modern power system."*[1]

In the context of the mining industry … safety, quality & reliability of supply are important objectives.

Maintaining electrical protection systems in mining environment provide a particular challenges because of:

- High safety standards to be observed
- Particularly dynamic nature of mine electrical networks - as the mine work-face moves forward the electrical network is extended to follow it.
- Use of high-impedance ground fault limitation by application of transformer NERs to limit maximum earth faults to, typically, 5 or 10 amp.
- Loads are predominantly motor loads.
- Linkage between mine production and reliability of electrical supply
- Frequent lack of full electrical data on the mine electrical network

REQUIREMENTS FOR "RELIABLE OPERATION"

BASIC PROTECTION OBJECTIVES

Basic objectives of the protection coordination process are to design protection systems and determine protection system settings that will:

- Reliably & selectively detect faults & initiate prompt disconnection/isolation. Promptness implies operating quickly enough to avoid, or acceptably limit, any risk to personnel or the public, damage to plant and equipment, or the stable operation of the network.
- Disconnect only the smallest part of the network necessary to isolate the fault
- Operate only for prescribed fault conditions (i.e. will operate stably for through-faults)
- Provide backup - in event of failure of a primary device then a backup device should clear the fault still within an acceptable, though longer, time.
- Aid fault diagnosis & location[2]

PROTECTION ZONES – PRIMARY AND BACKUP PROTECTION

For the foregoing objectives to be met, it is a pre-requisite that every part of the network must be included within the protection zone of one or more protection devices.

Most zones also need be adequately covered by backup protection This is to ensure that if any protection device fails to clear a fault in its primary protected zone, there is a backup device that will have also detected the fault – even under adverse conditions e.g. if it a high impedance fault at the extremity of the zone and that will operate to ensure that the fault is disconnected, albeit with a loger – but still acceptable – time delay.

RELIABLE OPERATION

For reliable operation it is necessary that the design of protection systems - and the choice of settings applied to the protection devices - will cope not only with normal, every-day operating conditions of the network, but also at the extremes of operating conditions. Such extremes include both maximum and minimum fault level conditions.

Maximum Fault Conditions

Maximum fault conditions generally occur when:

- Network impedances are at a minimum – both source impedances (e.g. utility connections) and internal impedances (e.g. transformers operating in parallel, feeder rings closed, etc.)
- All sources of fault current are connected and able to contribute to fault currents

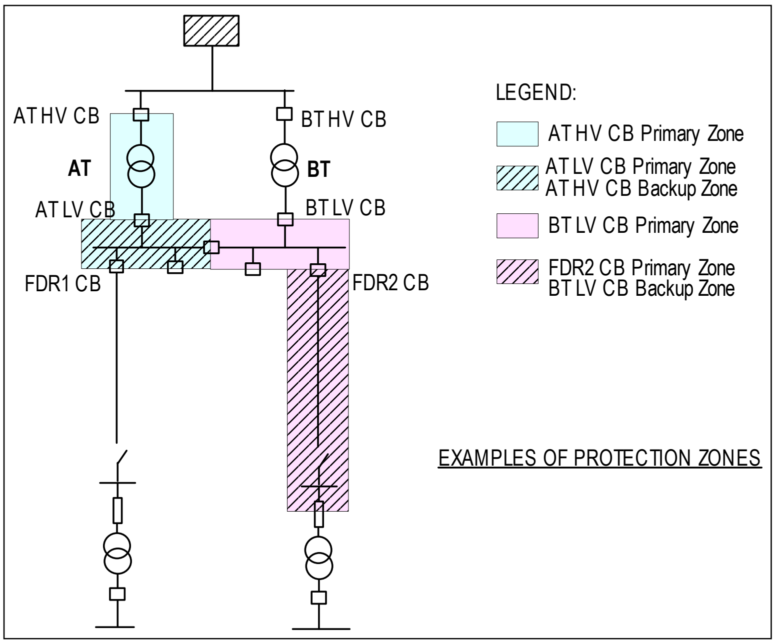

Figure 1: Illustration of Protection Primary and Backup Zones

- Operating voltages are high

Under <u>maximum fault conditions</u>, the main issues to be addressed for reliable operation are:

- Achieving sufficient discrimination times between devices that need to be coordinated
- Clearing faults sufficiently quickly before:
  - Plant and equipment subjected to the fault currents are subjected to thermal or mechanical stresses beyond their capabilities (ratings). For example, cable conductor, or screen, thermal limits; busbar and switchgear mechanical stress limits.
  - Personnel in the vicinity of electrical equipment exposed to excessive "Step & Touch Potentials".

Under maximum fault conditions it would generally be expected there will sufficient operating current to cause both primary and backup protection device to operate.

Minimum Fault Conditions

Under minimum fault conditions, the main concerns are:

- Will the generally longer clearing times for low fault currents be too long and endanger personnel or equipment?
- Will discrimination still be maintained?
- Will the lower fault currents - especially for faults at the extremities of zones of protection still be sufficient to cause protection to operate at all!

A special category of "minimum fault conditions" that needs consideration in the mining industry is when certain parts of the mining installations are supplied from on-site standby generation. Operating in this mode may require substantial changes to protection settings used when operating from normal supply

Mining Industry Specific Issues

In the mining industry, especially mines that have explosive atmospheres to contend with – such as underground coal mines – the aim is to try and limit faults to ground faults and to clear these before they develop into phase-phase, or other multi-phase & ground combinations.

This because ground faults are generally limited to very low values of ground current (typically 5 or 10A) by the use of Neutral Earthing Resistors (NER) at each step-down-transformer while the multi-phase faults are not limited in magnitude by other than normal network impedances and, unless they are cleared very quickly by overcurrent protection, the resulting very large fault currents – 1,000's of amps (kA's) - can provide a potential ignition source in explosive atmosphere if the fault is not contained within the cable or in explosion-proof enclosures.

Some experts suggest "currents of these magnitudes can cause explosions and fires if permitted to exist even for periods as brief as 1 second".[3]

However, in addition to the underground parts of the network subject to ground fault current limitation, some mines also have significant surface networks that may not be subject to this same limitation. In this case a different set of issues – more like those applying to the more usual coordination of overcurrent devices where grading by choice of current settings as well as time settings - come into play for these parts of the network.

Because of the predominance of motor loads in mines, account also needs be taken of their potential contribution to fault currents and the influence this may have on protection settings.

FAULT CALCULATIONS

Fault calculation provide the foundation for the determination of protection settings, and all fault calculations can only be as good as the network data on which they are based - e.g. source data, network impedance data, etc. The data required may not always be readily available and suitable assumptions may need to be made.

Australian Standard AS3851

Australian Standard AS 3851 *"The calculation of short-circuit currents in three-phase a.c. systems"* provides considerable guidance on appropriate values to use when hard data is missing.

This standard – in line with International Standard IEC909, on which it is largely based, (but with some significant variances to it) also prescribes the use of voltage factors to be used especially when calculating <u>Maximum</u> and <u>Minimum</u> fault currents.

The use of voltage factors is based on the fact that working voltages may differ markedly from nominal systems voltages and the voltage at the fault directly affects the magnitude of the fault current.

For calculating minimum fault currents AS3851 also provides a basis for adjusting conductor data-sheet resistance (often @20^{o}C) to more appropriate values that are consistent with temperatures that may be reached under fault conditions (see later).

NETWORK VARIABLES

UTILITY CONNECTIONS – IMPEDANCE & VOLTAGES

Information that needs to be obtained the operator of the network that supplies the mine site includes:

- Present Utility (Source) Impedance:

1. Three-phase and phase-to-ground fault current available at the supply point – as well as details of any Voltage Factor used in the fault current calculations and, or,

2. Utility positive and zero sequence impedance from the activity metering point to the Utilities infinite bus expressed in ohms, or in percent on a specified base (e.g. 100 MVA), and,

3. Anticipated future changes to the above information, and details of any appreciable variation that may occur in these values according to routine changes in the operating state of the utility's network.

- Single-line Diagram. A useful addition to the above data would be the supply by the network utility of a simplified single-line impedance diagram showing positive and zero sequence impedances between the supply point and the utility infinite bus. This simplified impedance diagram is particularly important if there are alternative ways the mine site can be supplied by the utility.

- Utility Supply Point Voltage Regulation. The typical daily voltage regulation of the point of supply should be provided if available. This data can be presented in the form of a graph or as a listing of the nominal supply voltage and the typical daily maximum and minimum voltage. Data on typical summer and winter daily voltage regulation should be provided if they are significantly different. (Note that it may be necessary to supply the utility with a daily load curve for the mine site for them to be able to provide this voltage profile).

Unless a mine electrical engineer, or consultant, is very specific about the fault level information for a particular supply point the utility engineer is likely to provide the ***maximum anticipated fault level*** at that point on the network. This may be an actual calculated level, or be an arbitrary rating simply based on the voltage level of the supply point, or it may take into account long-term planning expectations, that may, or may not, ever be realised.

Depending on circumstances, that fault level provided may be very different to the normal operating fault levels of the present day – and, for that matter, to the present day maximum and minimum anticipated fault.

FAULT IMPEDANCES

Fault calculations are often based on solidly connected faults with zero impedance. This is quite appropriate when assessing maximum fault conditions, because this will yield the highest fault current. But it may not be at all appropriate when considering minimum fault conditions.

Most faults have some finite impedance. Even if, for example, an electrician drops a spanner across live bus-bars, unless the spanner actually "welds" to the bars, a dead short circuit will most likely exist only momentarily as the fault changes to an arcing fault.

Even an arc has resistance. The resistance an arc depends on the current and length of the arc, btu the relationship is non -linear, with the most widely accepted expression for its value being due to Van Warrington, namely[4]:

$$R_f = 2613 \,.\, L / (I^{1.4})$$

Where *L* is the length of the arc in metres and *I* is the current in amp.

Just what fault impedance should be used when calculating minimum fault currents is a moot point. If you are dealing with GFR stings in a NER limited ground fault current network, it is largely irrelevant because the fault impedance is swamped by the NER resistance.

However, when dealing with overcurrent settings, then it does matter. For example, an emerging fault phase-to-phase fault in a paper cable, or surface tracking across inter-phase insulation may initially have quite a high resistance until the fault develops.

For networks with solidly earthed neutral points, a particular issue is the effectiveness of the earthing system. For calculation purposes any resistance in the earth connection should be included in either the fault resistance or neutral earthing impedance. For example, in electricity distribution systems (in NSW) the HV earthing system in certain circumstances may have a resistance-to-ground of up to 30 ohms! The inclusion of a resistance of this magnitude in a fault calculation can have a marked effect on the resulting fault current.

CABLE IMPEDANCES

Published cable data generally gives DC resistances at 20°C. While AC resistances may also be give at 20°C or, alternatively, at maximum recommended operating temperature, e.g 90°C Care needs to be taken when choosing resistance values to use when modelling a network – or, more specifically, what operating temperature should be chosen for the basis for the resistance value to be used.

For maximum fault condition calculations according to AS 3851, resistances for cable and aerial lines use the AC resistance at 20°C, while for minimum fault levels resistance values of 1.5 times the AC resistance at 20°C are prescribed. This factor implies an operating temperature well in excess of the recommended maximum normal operating temperature consistent with overheating due to the passage of short-circuit current.

Cable reactance values are dependent on the spacing between the phase conductors. Values for positive/negative impedances (both are the same) are generally published for 3-core and for various arrangements of single-core cables e.g. trefoil groups, laid flat touching or at specified spacings, etc.

It is the zero sequence impedance that causes most difficulties. The zero sequence impedance is affected by the location of the return path taken by fault currents that flow to ground. And often the return path may have parallel paths it may divide between. Manufacturers can, and frequently do, publish values for 3-core cable on the assumption that 100% of the ground fault current returns via the cable screens/conductive sheath/armouring. This may well be a reasonable assumption - but it all depends of the manner of installation of the cables and, in particular, the method of bonding and grounding the cable sheaths.

For single-core cables the zero-sequence impedance is very much influenced by the installation conditions, so cable manufacturers are unable to publish reliable zero-sequence impedance values and their calculation is quite complex.

Fortunately, when dealing with parts of a network that are subject to NER limitation of ground fault currents, the exact zero-sequence impedance is relatively unimportant as this impedance has little effect – even negligible - compared the resistance of the NER. So a substantial error in estimation of the zero-sequence impedance of is likely to little, or no, effect on the calculated value of the ground fault currents.

Cable Capacitances

Cable capacitances are normally ignored in fault calculations, having little effect. However the cable capacitances are quite significant when it comes to determining GFR relay setting in networks with NER limited ground fault current as noted previously. It is also significant in load flow calculations because of its influence on voltage levels.

OTHER NETWORK COMPONENT ISSUES

Multi-winding transformers

While there are recognised methods of modelling 3-winding transformers that fully account for the interaction between all three windings for both load flow and fault calculations there are no similar methods available for four, or five winding transformers.

The use of four winding transformers is, in fact, relatively common in the mining industry – especially on the supply to motor drives where the phase displacement between windings supplying rectifier bridges helps to reduce harmonics.

When it is necessary to include these transformers in a network model whatever improvisation is done will, of course, potentially have an adverse effect on the accuracy of load flow and fault calculations results obtained from the use of that network model.

Shared neutral earthing resistors.

Sometimes a single NER is shared among two, or more, transformers. This is presumably done as a cost-saving initiative, but it introduces another "cost". While such an arrangement can be accurately modelled, the model is quite complex … and the subtleties of the model and its operational behaviour may well be beyond the comprehension of all but the hard-core power system-modelling specialist!

However, one thing that is clear about this arrangement is that any phase-to-ground fault on any circuit supplied directly from <u>any</u> of the transformers sharing the NER, will raise the voltage of <u>all</u> those transformer's neutral points to the equivalent of the faulted phase's phase-to-ground voltage. This will, in turn, increase the capacitive charging current of all cable circuits supplied directly from these transformers (see earlier discussion of the effect of charging currents on GFR settings).

Motor Contributions to Fault Currents

Synchronous motors will act of sources of fault current just like synchronous generators will do, while induction motors will briefly act as induction generators when a fault occurs and will input current to the fault limited only by their own sub-transient reactance and any other network impedances between the motor(s) and the fault. Their contribution is generally only for a short duration – a few cycles – mainly because the magnetic field collapses quite quickly, especially for 3-phase faults. So the motor contributions is not so relevant to protection settings (other than for very fast protection e.g. instantaneous elements), as it is to the rating of plant and equipment that may have to carry these currents, or, in the case of high-speed circuit-breakers where they may actually be called on to interrupt such currents.

Whether DC motors will contribute any fault current depends on the make up of their power supply/control electronics and if any regeneration is possible. Such a possibility is not usual in the drives typically found in mining installations, except for mine winders that may employ regenerative braking.

LONGWALL FAULT LEVEL CASE STUDY

To illustrate the effect of just two major variables on calculated fault levels in a typical coal mine fault a case study was made of a the supply to a Longwall mining machine.

The two variables whose effect on fault calculation results were examined were:

- Source Fault Level:
- Distance to Longwall transformer:

The fault level values at 66kV Supply Point to the mine are used are 1,000MVA and 250 MVA. These could represent, for example, a fault level given by the utility network as the maximum anticipated fault level at the mine site, and the minimum fault level, perhaps under an alternative (backup) supply arrangement.

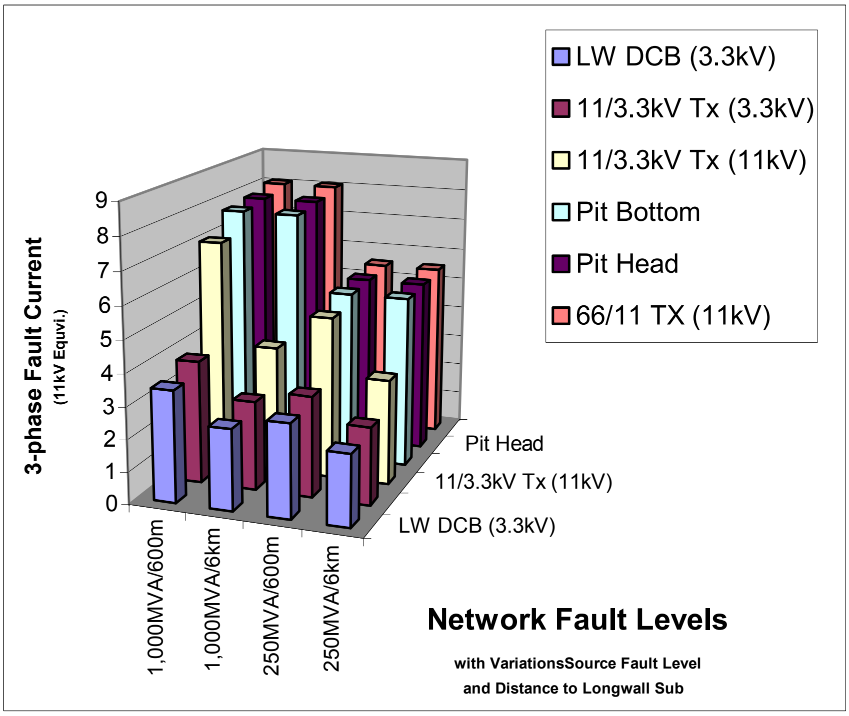

Figure 2: Fault level case study results

The distances used for the cable circuit from the pit-bottom substation to the longwall are 600m and 6 km. The lower figure is an assumed distance at the start of operation of the longwall and the longer is the distance at which it is assumed a new borehole cable will be installed to maintain supply to the longwall as the workface moves further on.

Note that these calculations do not include any effect of changes in the resistance values of the cables, or any other variable.

The results – see following table - show substantial variations in the calculated fault current values at the 3.3kV DCB supplied from the longwall transformer.

Source Fault Level (MVA)	Distance to Longwall Transformer (metres)	Three-phase Fault Current at 3.3kV DCB (kA)	Relative Values
1,000	600	11.56	1.00
1,000	6,000	8.40	0.72
250	600	9.67	0.84
250	6,000	7.42	0.64

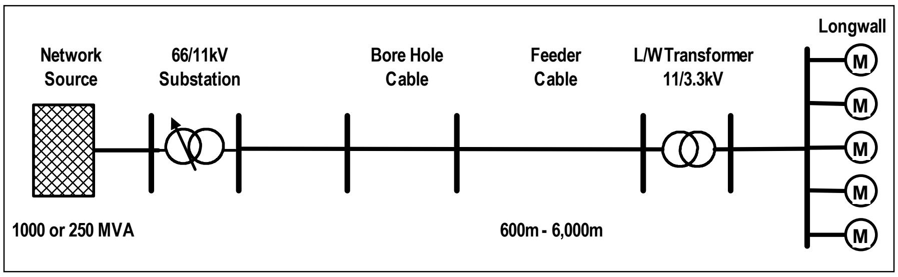

Figure 3: Single-line Diagram of the Longwall Case Study Network

PROTECTION SETTINGS

GENERAL

For predominantly radially operated networks, typical of mining networks, the determination of protection device settings is frequently based on maximum fault level conditions. This is because it is under maximum fault current conditions that successive protection devices with Inverse Definite Minimum Time (IDMT) characteristics will typically have the minimum time margins between them, because they will generally being called on to operate nearer to the define minimum time end of their characteristic curves where those curves tend to converge (i.e. with operating currents that are many times the setting currents). However, it does need to be kept in mind that this is a generalisation about the use of IDMT devices and, as such, is not necessarily universally true – especially when other devices have different, or modified, characteristics.

OPTIMISED PROTECTION COORDINATION VS TIME-GRADED CURVES

There is sometimes an impression that the proper output of a protection study (to determine or review protection settings) is a set of nicely time-graded curves for the various protection devices on the network. But a soundly based protection study aimed at determining <u>optimised</u> protection settings involves much more.

An optimised protection coordination study is one where the best possible settings have been chosen to:

- Minimise fault clearance times
- Cope with single and multiple network operating contingencies
- Meet standards set out in a formal protection setting policy document that lays down such things as:
  - Maximum fault clearance times under "normal" and "contingency" conditions.
  - Acceptable discrimination times between different types of protection device/switch combinations, e.g. numerical relay/circuit breaker and numerical relay/circuit breaker, electro-mechanical relay/circuit breaker and fuse, fuse and fuse, etc.
  - Basis of fault current calculations for assessing maximum and minimum fault current levels.
  - Contingency operating conditions of the network to be taken into account when assessing performance under minimum fault level conditions
  - Minimum operating factors[1] for different circumstances, e.g. for faults at the extremities of the normal "zone of protection" for the device, or at the extremities of its backup zone.
  - Circumstances in which backup protection backup may not be mandatory: eg. if fuses are to be considered to be inherently reliable
  - Margins to be allowed above "normal" maximum load for current settings; allowances for motor starting, cold-load pickup, transformer inrush, capacitor inrush, etc.

Rarely can an ideal solution be easily found, so adjustments and compromises have to be made, but the determination of these changes requires the exercise of sound engineering judgement to ensure that any changes made do not involve the introduction of unacceptable risks.

CONTINGENCY CONDITIONS

The adequacies of protection settings are generally most strongly tested when the protection devices are called on to operate when the network is constrained by multiple contingencies.

For example, when the network is switched into an unusual operating condition, perhaps because of an isolation of plant for maintenance leading to some other parts being supplied by longer routes than is normal and these parts also be more heavily loaded than usual. These two things in combination – the inclusion of more circuit impedance to more remote parts of the network and the higher loading leading to higher cable operating temperatures (therefore, higher cable resistances) as well as lower than normal working voltages, also due to the loading, may, in combination, lead to much reduced fault levels. Then, if a high-resistance fault occurs somewhere well out towards the mine working face, where the sum of the internal network impedances between the fault and the source is quite high and the

[1] "Operating Factor" can be defined as the ratio of the minimum fault current to which a device needs to respond, to the minimum current that will actually cause the protection device to operate. For example, an operating factor of 2.0 implies that the minimum fault current a protection device needs to respond to is equivalent to twice it pickup current.

voltage relatively low to an extent that there may be excessive long fault clearance times and a breakdown of coordination!

PROTECTION COORDINATION SOFTWARE

A full protection coordination study as described in this paper is a time consuming processing and is rarely done these days without some form of computer assistance. Computer assistance with fault calculations is today almost universal and computer-assisted protection coordination is also becoming much more common.

The level of sophistication of such computer-assistance varies widely – ranging from "home-grown" spreadsheets to perform repetitive calculations and graphing, to integrated fault calculation, protection coordination, and protection databases with integrated single-line diagramming.

Many so-called "Protection Coordination" software programs are basically just curve plotting utilities with no analytical capabilities to assist the user at all. After choosing the device type the user has to manually enter required time and current settings which are then reflected in the positioning of characteristic curves in the graph display (or, in some cases, the plotted curve can be dragged on-screen to a new position with the time and current settings values being adjusted to correspond with the new position).

DataShare's Australian developed protection coordination software *"RELCORD/32 for Windows"*, on the other hand, because it integrates protection coordination functionality with a full-featured fault calculation program with its full model of the electrical network, in addition to the expected curve plotting capabilities, it can also:

- Suggest time settings for modelled protection devices to achieve wanted discrimination times
- Enable the quick and easy testing of existing or proposed protection device settings under normal operating conditions and under multiple contingency conditions. This is done by allowing the user switching or modifying the underlying network model to simulate the required network operating contingencies and then apply <u>any</u> type of fault, <u>anywhere</u> on the network and determine what, if any, protection will operate in response to that fault and the time it will take to operate.

<u>OVERCURRENT AND GROUND FAULT PROTECTION</u>

OVERCURRENT PROTECTION

Because the coordination of Inverse Definite Minimum Time (IDMT) overcurrent relays is fairly well understood, and is generally well covered by standard text books, this paper will pass over this aspect of protection coordination and instead concentrate on other aspects that are less well covered by standard text books.

High-set Instantaneous Elements

Instantaneous elements are used to improve coordination between coordinated pairs of relays by causing a fast trip of the Backup relay for fault currents that have a magnitude that indicates that they can only be located somewhere on the supply side of the Primary relay (i.e. between the Backup and Primary relay). In this case there is no necessity for the operation of the Backup relay to be delayed to give time for the Primary relay to operate, as would be the case if it were possible that the fault was located beyond the Primary relay.

However, high-set instantaneous elements can generally only be usefully employed when there is a appreciable difference in maximum fault current at the locations of the Primary and Backup relays. Or, in other words, there must be some appreciable network impedance between these two points.

To provide a margin of safety against errors in fault calculations, and current transient offset effects on relay operation, the setting of the Backup relay's high-set instantaneous element needs to have a setting that is, perhaps, 20-30% above the maximum fault current available at the location of the Primary relay. Then it needs to be considered if such a setting is feasible (i.e. is less than the maximum fault level at the Backup relay) and provides "reach" over a worthwhile portion of the network between the Backup and Primary relays (see Figure 2).

GROUND FAULT PROTECTION

There is only limited scope for the coordination of ground fault relays when the maximum ground fault current is limited to a small value by transformer NERs. This is

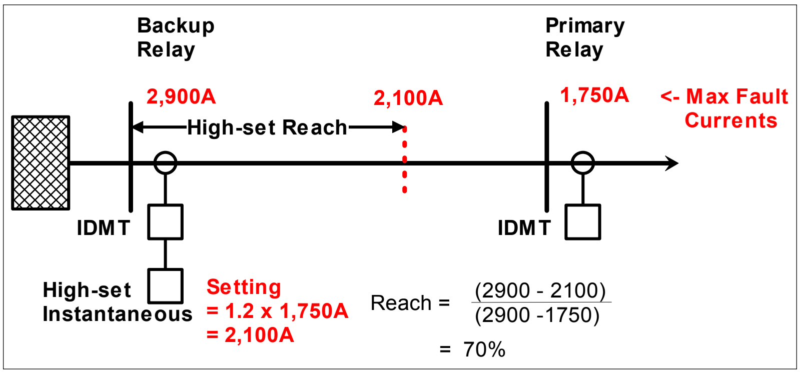

Figure 4: Example of Application of High-set Instantaneous Elements

primarily because grading can only be achieved by time settings alone, because there is virtually no variation in the ground fault current along the network, because the network zero-sequence impedances are so greatly swamped by the resistance of the NER.

Core Balance vs. Residual Connected C.T.

In NER ground fault current limited networks it is almost mandatory to use core balance CTs for the GFRs. Using residual connection of individual phase CTs, though technically feasible (and sometimes necessary) suffers from the problems that can arise because of differences in the performance of the CTs, even where they are theoretically a matched set.

The resulting "spill" of current into the residual (star point) connection of the CTs when, in theory, the three currents should sum to zero, can cause unintended trips unless the protection is made less sensitive by the use of higher settings than would otherwise be necessary. One authority[5] suggests setting GFRs operating from residual connected CTs to not less than 6% of the CT rating at best (in the case of well matched CTs) or even as high as 15 or 20% of the CT rating in the most unfavourable cases. Moreover, this same authority points out that where transformer protection is involved, if an earth fault occurs in the winding near the neutral point of the star connected winding, then the maximum fault current will only be a fraction of the maximum fault current permitted by the NER. For this reason, he suggests the GFR current setting is usually set 20% of the NER current to provide protection to 80% of the windings.

Naturally, where residually connected CTs are involved, these alternative requirements can be in conflict.

Effect of capacitance charging currents on settings

To reliable operation the Ground Fault Relay (GFR) setting must be:

- Only a fraction of the maximum available ground fault current
- Greater than the maximum charging current for the maximum network supplied through the GFR - remembering that the charging current increases at the time of a phase-ground fault anywhere on the NER controlled network causing an increase the voltage across the capacitances to earth of the healthy phases to phase-phase voltage (i.e. normal charging current is increased by a factor of 1.732, i.e. a 70+% increase) See diagram below.[6]

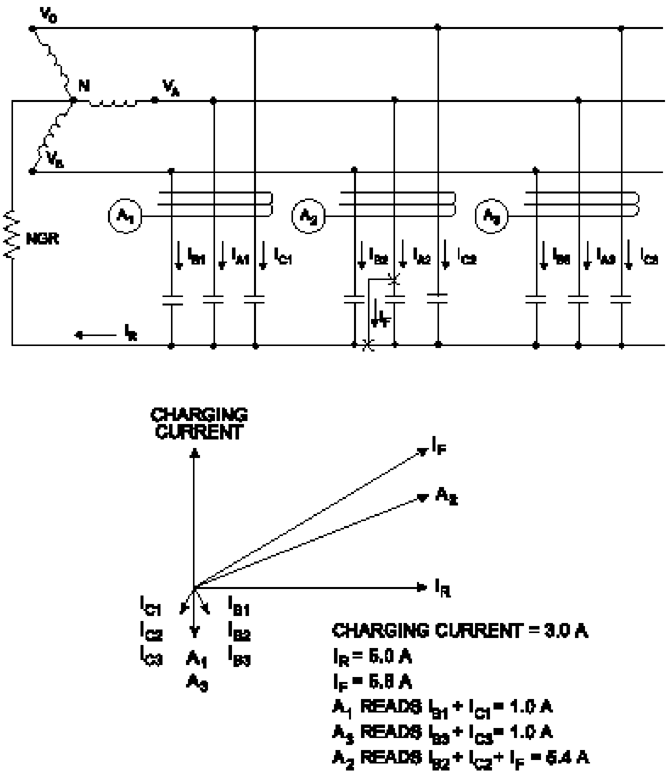

Figure 5: Phase-to-Ground Fault on System with NER Limited Fault Current (From Reference 5)

TECHNICAL ADVANCES IN PROTECTION DEVICES

The following advances in protection relaying technology - mainly associated with modern numerical relays - can substantially influence the determinations of settings – as their advantageous effects often reduce the margin of safety that would otherwise need to be applied with electro-mechanical relays.

Generally they are based on the powerful abilities of digital relays to analyse input signals (e.g voltage and current transformer outputs) by using sampling signal waveforms at very high sampling rates and the mathematical analysis of the sample data.

In fact, the numerical relay has evolved to the point where most of its intelligence is in its software, which means there is practically no limit to what a numerical relay can be programmed to do. The hardware is very much secondary to its software flexibility. This what has basically under-pinned the development of the so-called "universal" relay – a common hardware platform that can be configured by software to perform a wide variety of relaying functions (and not just relaying functions, but also data acquisition, metering, oscillography, communications, etc.).

FILTERING – HARMONIC, DC OFFSET, ETC.

Modern numerical (micro-processor based) relays typically have various filtering circuits to pre-process input currents and voltages before these are applied to the measuring circuits of the relays.

This filtering and pre-processing of input signals from CTs and VTs can effectively eliminate harmonic components (so measurements are made only of the fundamental frequency), remove the DC offset from operating currents, etc.

The use of such filtering circuits means that where formerly electro-mechanical relay settings had to be made less sensitive to avoid unwanted operations due to these effects, some of the past practices and "golden rules" of determining protection setting are no longer be valid when numerical relays are involved!

In general, it is a case of having to "know your relay", so that appropriate decisions are made about what options to activate/deactivate and when safety factors may to need to be applied to relay settings, or when they have been rendered unnecessary, or their impact reduced, by filtering or other pre-conditioning of the input signals.

DISTINGUISHING BETWEEN MOTOR STARTING CURRENTS AND FAULT CURRENTS

A development of particular relevance to the mining industry has been the recent research into methods of distinguishing between motor starting currents and fault currents.

Details of the research carried out in the US and the development of the hardware prototype of a protection relay incorporating this technology is detailed in Reference 3.

COMMUNICATION BETWEEN PROTECTION DEVICES

The ability of modern protection relays to support communication between them can, for example, allow one device to signal to others that it has detected a flow of fault current. Such simple signalling alone can substantially improve protection selectivity and improve protection coordination. However, this and much more complex signalling between protection devices is already possible.

The communication capabilities of modern relays are likely to have a continuing significant impact on protection design and management.

SUMMARY & CONCLUSIONS

The performance of fault calculations and the determination of optimised protection setting can be a intimidating to the un-initiated. But – under present legal regimes – there is little opportunity for mine electrical engineers to remain isolated from these processes. If for no other reason than they need to be able to review the work of others and make judgements as to whether the results or recommendations presented are reasonable! The development of at least a sound working knowledge of these disciplines is a pre-requisite for adequately discharging these responsibilities.

Acquiring an appreciation of basic principles involved – and becoming aware of some of the traps awaiting the unwary - is a good start.

It is in response to this assessed need that this paper has been prepared and presented. It is hoped that it will make some useful contribution towards satisfying this particular need.

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