Notes in Relation to Wideband and Weighted Frequency Modes in ELV-PRO and ELV

Requirements from AS/NZS4871 & 2081

The 2011 revision of AS/NZS2081 correctly recognises that system protection must be assessed in keeping with touch potential curves in AS/NZS4871:2012, but acknowledges that this curve is for 50Hz (power frequency) only. AS/NZS2081 explicitly draws attention to the fact that 50Hz curve sets are not immediately applicable in systems that contain equipment capable of generating non-50Hz components, and that in such instances, touch potential calculations must be supported by individual calculation to determine requirements at the frequency or frequencies of interest.

From AS/NZS2081:2011 Clause 1.1 Scope:

'Whereas this standard is based upon 50Hz supply systems it is envisaged that equipment described may also be installed on systems with higher, lower or variable frequencies, or in DC supplied systems. AS/NZS60479 Part 1 and 2 should be referenced for the consideration of the effects of current at other than supply frequencies on the human body.'

From AS/NZS2081:2011 Appendix B3 Systems at other than 50Hz Cyclic Frequency:

'Where equipment is installed and operated within systems at other than a constant 50Hz cyclic frequency, the characteristics in paragraph B2 are not immediately applicable. In such instances individual calculation to determine requirements at the frequency or frequencies in question will be required.'

Notes in Relation to Wideband and Weighted Frequency Modes in VSDguard and ELV

The vast majority of earth leakage relays approved for use in mining applications are designed to detect 50Hz currents, not DC or high frequency currents associated with a variable speed drive carrier or switching frequency.

A number of protection relays are marketed as suitable for variable speed drive protection as they include a detection bandwidth that covers the synthesised power frequency spectrum of most VSD's (up to 150Hz). When traditional narrowband relays (with a current detection bandwidth below a few hundred Hz) are presented with DC and/or high frequency currents, the relays may not trip, or if they do may take longer than expected.

Whilst a user may have considered higher frequencies (such as the drive carrier frequency) and may have even done so via calculation, the protection system must properly resolve both frequency and magnitude of earth leakage current in order to trip appropriately at the frequency of interest.

Observation #1: A system containing a variable speed drive cannot be assessed as compliant to AS/NZS4871 and/or AS/NZS2081 without fitment of wideband earth leakage protection. The bandwidth of installed earth leakage protection must extend to at least the variable speed drive carrier frequency in order to be argued as compliant.

Wideband Earth Leakage Protection

Traditional wideband earth leakage protection relays typically have a unity characteristic as a function of frequency over their bandwidth. This arguably allows compliance against AS/NZS4871 & 2081 in that the earth leakage current spectrum is within the resolution bandwidth of the protection relay, with two important related caveats:

1. Sensitivity:

Consider the case where a variable speed drive is installed but has no common mode EMC filter, or any common mode filtering installed is only small.

Under normal operating circumstances there will be a circulating earth leakage current from the drive back through the NER. The presence of this current does not indicate a fault and is normal. Its primary current component is at the carrier frequency, not 50Hz or the synthesised power frequency of the drive. The value of the normal standing leakage current depends on the drive output characteristics and the parasitic capacitance of the load motor, but can be relatively high. It is common for the standing earth leakage current to be much higher than traditional earth leakage trip values of a few hundred milliamps, with practical mining cabling and motors it can be as much as a few amperes.

It is not practical to detect small changes in earth leakage current (perhaps 100mA or so) in the presence of a large (a few amps) normal circulating earth leakage current. Invariably, trip settings close to the normal circulating current are prone to nuisance tripping and poor protection reliability. Nuisance tripping often sponsors end users to raise the trip level in an attempt to remove nuisance tripping, but this simply desensitises the protection to high impedance faults, requiring larger fault currents before the fault can be seen by the protection relay.

2. Tripping ratio:

AS/NZS4871.1:2012 clause 2.6.2.2 prescribes that 'The ratio of earth fault current to earth leakage protection trip should be at least 10.' This ratio can be lowered to 5 'where capacitive charging currents cause spurious tripping'. A common earth fault limitation value used widely in Australian mining operations is 5A, and the requirement for a 10:1 tripping ratio indicates the earth leakage trip level should be no more than 500mA.

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In all cases the fault current trip level should be set just above the normal steady state background earth leakage so as to be reliable without nuisance tripping. That is, the tripping ratio should be maintained as high as practical. In many practical examples involving protection of variable speed drives with wideband protection relays, tripping ratios are unable to be maintained in compliance with AS/NZS4871.1:2012, or indeed as high as would otherwise be desired.

Observation #2: Tripping ratio and the requirement to maintain sensitivity of earth leakage detection as per AS/NZS4871.1:2012 is problematic when applying wideband earth leakage relays to earth fault limited electrical systems containing variable speed drives. The necessary settings for a wideband relays typically result in nuisance tripping.

Weighted Wideband Earth Leakage Protection

The sensitivity of the human body to electric shock varies with frequency. In general, for any given exposure time, the allowable touch potential rises as frequency increases.

For example, at 1kHz the allowable body current (not touch potential) is approximately 14 times higher than at 50Hz.

As a consequence, it can be shown that the application of wideband earth leakage protection (discussed in the previous section) in an earth fault limited system where acceptable touch potentials are limited to magnitude and durations defined by 50Hz curve sets will be conservative.

Unfortunately, this conservatism in protection settings often results in a significant degradation of system reliability through nuisance tripping and/or trade off of fault detection sensitivity.

Curve sets relating the effect of frequency on likelihood of fibrillation as a function of body current are contained in AS/NZS60479 parts 1 and 2. It is important to note that these curve sets are for body current, not touch potential. It is necessary to relate these curve sets to touch potential by accounting for additional series impedance (be that clothing, human skin resistance and a number of other parameters) all of which vary as differing functions of frequency. Strictly speaking, the impedance to earth at each frequency of interest must be calculated to then determine the resultant earth fault current, and so calculate touch potential at each frequency of interest to then cumulatively apply the curve sets contained in 60479 and so determine the necessary safe clearance time.

It is impractical for the user to utilise these curve sets directly in touch potential calculations. Both Ampcontrol ELV-PRO and ELV relays are capable of weighting the wideband earth leakage current as a function of frequency according to the curve sets in AS/NZS60479. This weighting accounts for the differing effects of frequency on fibrillation risk automatically, and while the actual current measurement is wideband, the weighting produces a ‘50Hz equivalent risk’ touch potential. That is, for a given earth continuity, the weighted wideband current will produce an equivalent risk wideband touch potential as the same magnitude narrowband (50Hz) current.

In practice the user completes touch potential studies using the established (and familiar) 50Hz touch potential curve sets contained in AS4871, AS3007 and AS2067, ultimately choosing the parameters of earth fault limitation, earth continuity and clearance times. The earth leakage trip current is then set in weighted mode to a level that is just above the normal (weighted) circulating current (as would always be the methodology to set the trip level even if the system was 50Hz only).

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Observation #3: Weighted mode automatically applies the curve sets as a function of frequency in AS/NZS60479 parts 1 & 2, and so is fully compliant with AS/NZS2081:2012 for earth fault limited systems with non-50Hz connected equipment.

Weighted mode minimises nuisance tripping often associated with traditional wideband earth leakage protection, by maximising the possible tripping ratio as a function of frequency.

In addition, weighted mode provides increased low frequency earth leakage sensitivity (improving the relays ability to detect high impedance faults) as the protection system is no longer dominated by large (but normal) high frequency circulating currents typical of VSD applications on earth fault limited systems. Similarly, the protection is not simply blinded to ignore high frequency current (as would be the case if the earth leakage signal was simply low pass filtered), and protection properly accounts for high frequency current contribution to fibrillation risk.

Ampcontrol holds an international patent (PCT/AU2011/000705) in regard to the use of frequency discrimination as applied to earth fault protection.