ECM3
A FRESH LOOK AT EARTH CONTINUITY, SAFETY AND AS/NZS 2081 COMPLIANCE

White Paper

Australian Standard Requirements for Earth Continuity Protection

AS/NZS 2081 and AS/NZS 4871 present competing requirements for the application of earth continuity protection in earth fault limited mining systems. AS/NZS 2081 requires that earth continuity protection operate as fast as possible, with a maximum permissible operating time of 500ms, to quickly protect an outlet in case of live uncoupling. A fundamental requirement in both AS/NZS 2081 and AS/NZS 4871 is that the earth continuity protection is capable of monitoring incremental changes in the resistance of the earth return path to ensure that leakage currents do not result in dangerous touch voltages.

In practical applications, environmental factors often prevent an earth continuity protection system from complying with both requirements of AS/NZS 2081 and AS/NZS 4871. Affecting factors can include coupled noise onto the pilot of the cable, variation in the resistance of the pilot cable due to temperature, and the overall length of the cable.

Cable structure, supply harmonics and installation arrangement are several potential sources of noise on the pilot circuit. Non-symmetrical cables are used in many installations, resulting in the supply voltage from two of the three phase cores being coupled to the pilot core. In addition to this, noise on the phase conductors of a cable can also be coupled onto the pilot core, regardless of cable type. Dirty slip rings in cable reeling systems also provide a source of noise on the pilot circuit.

Noise on the pilot circuit interferes with an earth continuity relay's ability to reliably detect an earth continuity fault. It can also result in nuisance tripping, especially when the healthy pilot/earth loop impedance is close to that of the trip threshold. Such interference erodes the relay's performance and subsequently its ability to meet AS/NZS 4871 requirement to protect against the development of dangerous touch voltages.

Although AS/NZS 4871 notes 45Ω as the maximum tripping threshold for the pilot/earth return path impedance in underground applications, in many surface installations this impedance value is much too low to be practical. It is not uncommon for surface installations to have cable lengths of up to 8km, with the pilot resistance alone on these cables exceeding the recommended underground limit of 45Ω. It is common for surface earth continuity relays have a tripping threshold of 100Ω.

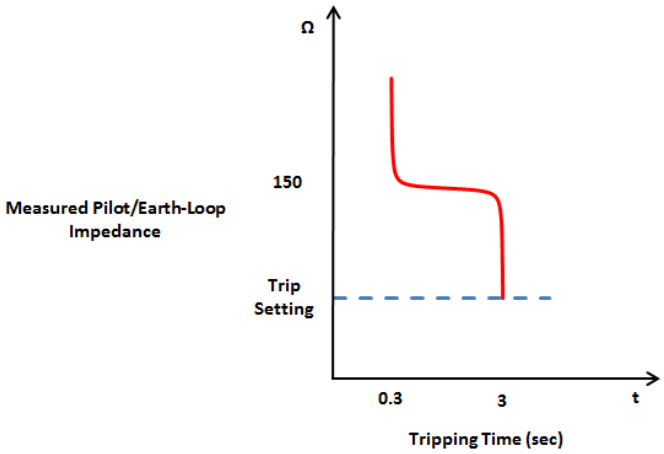
Although the higher tripping threshold of 100Ω allows for installations with long cables, installations that require lower healthy pilot/earth loop impedances have a much larger disparity between the healthy impedance and the tripping threshold. It is common for a fixed trip threshold of 100Ω to result in non-compliant (arguably dangerous) touch voltages.

Present generation earth continuity protection relays use static time and trip settings. Using these relays, it is sometimes not possible to achieve a practical earth continuity protection system that satisfies both the requirements of a fast trip during a live uncoupling, and preventing dangerous touch voltages developing during earth leakage faults.

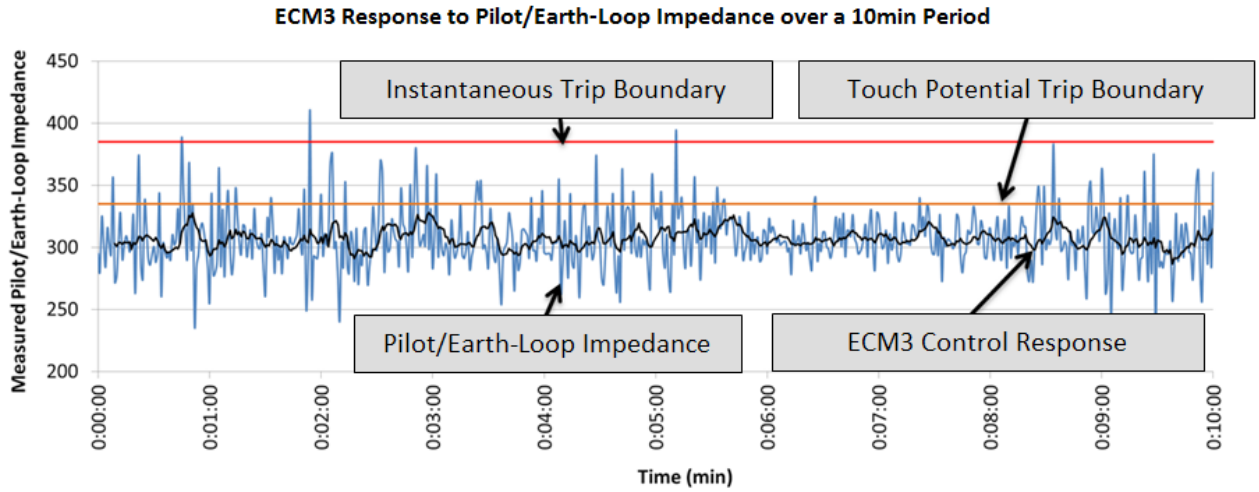
In these scenarios, the use of a dynamic trip threshold in the form of a "dynamic trip time response" would allow a fast trip during a live uncoupling as well as provide a slower trip during high impedance readings, providing noise immunity.

Implementation of an Earth Continuity Relay with a Dynamic Trip Time Response

Ampcontrol has developed an innovative method of earth continuity protection in the form of the Ampcontrol ECM3 Protection Relay. This new relay utilises an “impedance versus trip time response” to provide discrimination between an open circuit and a gradual increase in the measured pilot/earth loop impedance of the protected cable. During an open circuit or large impedance increase, the ECM3 will trip very quickly. If the impedance of the pilot/earth loop exceeds the tripping threshold by a small amount, then the ECM3 will trip at a slower rate. The slower tripping time at the lower earth continuity fault levels allows the tripping threshold to be set much closer to the impedance of the healthy pilot/earth loop circuit, thus allowing the ECM3 to prevent the development of dangerous touch voltages as required by AS/NZS 4871.



The implementation of an earth continuity relay with a dynamic trip time response allows the ECM3 to achieve significantly greater noise immunity than its predecessor, the ECM2 relay. The below graph was created using data taken from a field trial recently performed with the ECM3 relay. On several occasions, due to coupled noise onto the pilot of the protected cable, the instantaneous resistance measurements taken by the ECM3 relay are greater than the trip threshold. At this point, we would have expected the ECM2 relay to have tripped, however the trip response of the ECM3 prevents the relay from nuisance tripping, providing a far more reliable EC monitoring installation.



A Comparison between the ECM2 and ECM3

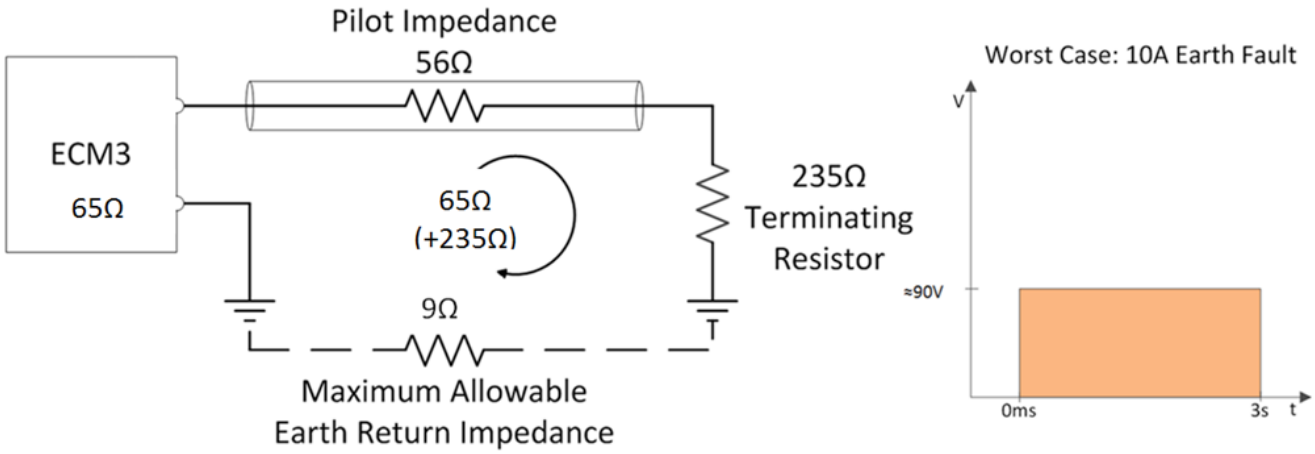
To illustrate the advantages of the implementation of an earth continuity trip curve, this section will investigate the differences between Ampcontrol's ECM2 Relay and the next generation ECM3 Relay.

	ECM2	EMC3
Trip threshold (excl. 235Ω terminating resistor)	100Ω	15 - 90Ω Adjustable in 5Ω steps
Trip time	300ms (Fixed)	300ms…3s Dependent upon pilot/ earth-loop impedance

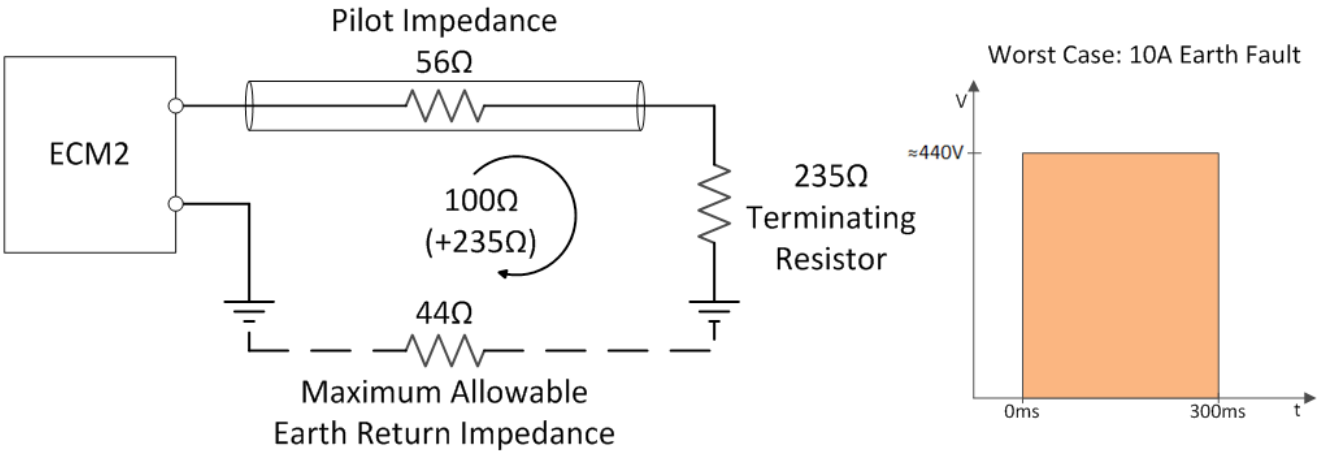
In addition to the dynamic trip response functionality, a significant enhancement in the ECM3 is the ability to adjust the trip impedance threshold in 5Ω steps. This allows the trip threshold to be set just above the measured impedance of the healthy pilot/earth-loop impedance. The advantage in doing this is that by restricting the rise in the pilot/earth-loop impedance, the maximum touch voltage during an earth fault can also be controlled to as low as is reasonably practical – not just compliant to AS/NZS 4871.

For instance in a 10A earth fault limited system, if the ECM's trip impedance threshold is set to 10Ω above the healthy pilot/earth-loop impedance, then the maximum touch voltage that can be present on the system is approximately 100V. For a 5A earth fault limited system, the maximum touch voltage would be approximately 50V for this setting.

A field trial was recently completed where an ECM3 was installed on an outlet within a substation in a surface mining operation. A machine was supplied from this outlet via a 3000m symmetrical cable with a nominal pilot impedance of 56Ω. In the field trial, the ECM3 Pilot/Earth-Loop trip point was set to 65Ω, allowing a maximum earth-loop impedance of 9Ω. The system that the ECM3 was installed on was earth fault limited to 10A, resulting in a maximum touch voltage of 90V at this setting. This touch voltage would only develop if an earth leakage fault was to occur. For very high earth-loop impedance trips, such as those that occur during a live uncoupling, the ECM3 will trip much faster.

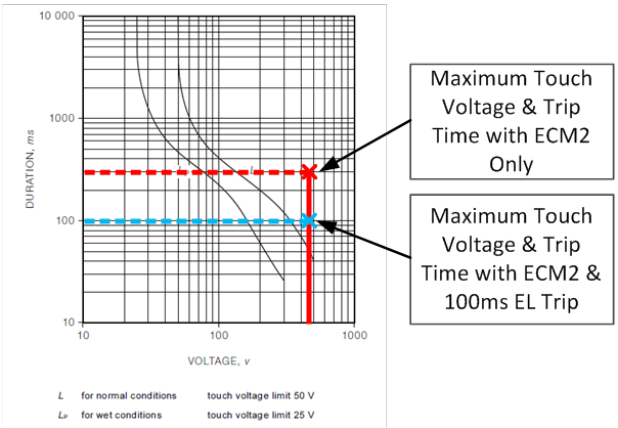


Taking the same practical example, if an ECM2 relay was installed on this outlet, then the maximum earth-loop impedance would be 44Ω (the trip threshold minus the pilot core impedance). The 10A earth fault limited system would result in a maximum touch voltage of 440V if an earth leakage fault was to occur.

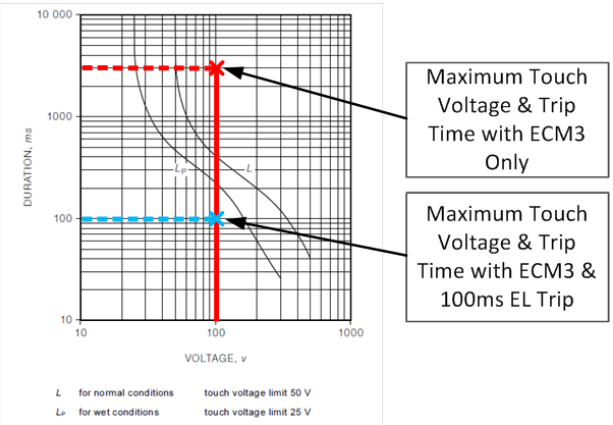


The figures to the right illustrate where the above results fall on the permissible touch voltage graph presented within AS/NZS 4871.1 (2012). It can be seen that when using earth continuity protection only, both the ECM2 relay and the ECM3 relay trip in times that are well into the fibrillation region of the graph. However, it is important to note that when coupled with an earth leakage relay that is set appropriately, in this case with a trip time of 100ms, the outlet protected by the ECM3 clears in an acceptable time frame. Even coupled with the earth leakage protection, the outlet protected by the ECM2 relay will not clear within an acceptable time period due to the higher voltage created by the larger allowable earth-loop impedance.

ECM2



ECM3



Noise Immunity and Thermal Overload Maintaining Touch Potential Compliance

The accuracy and response of the ECM3 is far greater than its predecessor the ECM2. The most substantial improvement of the ECM3, is that it addresses the performance degradation experienced by the ECM2 when subjected to significant noise coupled into the pilot core. Practical tests have demonstrated that when the pilot core connected to an ECM3 is coupled with up to 150VAC of 50Hz noise, it is capable of monitoring the pilot resistance with an accuracy of 5%. Such a scenario is a practical reality given long cable runs and the use of asymmetric cables.

The ECM3 relay is capable of monitoring earth continuity continuously and indefinitely when exposed to voltages up to 45VAC on the pilot core, with internal heating having no effect. If however the pilot is coupled with higher voltages, the relay's thermal overload trip begins to function. The thermal overload maintains an inverse time relationship with induced pilot noise magnitude, as seen in the table below:

Pilot Noise AC (Vrms)	Expected trip time (Seconds)
75	~120
100	~60
125	~40
150	~20

Persistent high AC voltages on the pilot circuit not only stress the relay thermally, but more importantly it is indicative of potentially hazardous step and touch voltages on the installation. When in operation, if the ECM3 repeatedly trips on thermal overload, it is important that steps are taken to reduce the AC voltage coupled into the pilot by either, shortening the cable, replacing the cable with a symmetric alternative or reducing the load.

The applications involving long runs, non-symmetrical or degrading cables, will now have a far greater resilience and detectability to situations that would have previously failed to trip or become hazardous. When limiting the earth impedance, the ability to alter the pilot resistance trip level of the ECM3, further demonstrates the adaptability and compatibility of the ECM3 for even more precise applications without the need for external pilot conditioning.

Summary

The ECM3 is Ampcontrol's next generation earth continuity protection relay. The introduction of the dynamic trip response characteristic allows an electrical protection system incorporating an ECM3 to maintain a much lower touch voltage under earth fault conditions without any degradation of reliability or the introduction of nuisance tripping.

The ECM3 technology in combination with appropriately set earth leakage protection can, in many practical applications, maintain touch potential compliance as outlined in AS/NZ 2081 and AS/NZS 4871, even under high noise applications that were not previously possible with present generation earth continuity protection relays from Ampcontrol or third parties.

Ordering an ECM3

Orders can be made through the Ampcontrol customer service team or through existing Ampcontrol equipment distributors now.

For more information on this product, please contact Ampcontrol Customer Service on +61 1300 267 373 or customerservice@ampcontrolgroup.com