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THE USE OF EARTH LEAKAGE CIRCUIT BREAKERS WITH LIGHTING CONTROLS

There has been a substantial increase in the use of Earth Leakage Protection switchgear in conjunction with lighting equipment in recent years. This trend has been promoted by changes in liability legislation and a heightened public awareness of safety in all environments.

The underlying principle of Earth Leakage Protection equipment is to detect electrical current flowing outside its proscribed circuit and, on the assumption that this represents a fire risk or a possibility of electrocution, to disconnect the supply as quickly as possible.

The physiological effects of electric current on the human body are outside the scope of this paper and are well documented in IEC report 479. In simplistic terms, the severity of the effect of an electric shock on a human body is a factor of:

- The current path through the body
- The magnitude of the current flowing through the body
- The length of time for which the current flows

There can be no doubt that Earth Leakage Protection equipment has significantly reduced the incidence of fatal electric shock. However, as with many apparently simple panaceas, there is a risk that the solution is embraced without full understanding of the technical limitations and constraints. Particularly the performance of these devices used in conjunction with the Phase Controlled dimmers.

The purpose of this paper is not to denigrate the use of Earth Leakage Breakers, but to sound a note of caution and to describe some of the known shortcomings so that those responsible for specifying, designing and installing lighting installations will seek guidance if they are not sure of the electrical theory.

The first problem is one of nomenclature: there is an abundance of mnemonic, many similar but not quite synonymous.

The generic title Earth Leakage Circuit Breaker (ELCB) covers two different operating principles: the Voltage-Operated ELCB, and the Current Balance ELCB, also known as the Residual Current-operated Circuit Breaker (RCCB or RCB) or the Residual Current Device (RCD).

Voltage-Operated ELCBs require the earthed metalwork of all the equipment being protected to be electrically isolated from the structure of the building. Separate Earth Continuity conductors are fed back to the ELCB which, in turn, has a connection to an earth electrode of defined impedance.

The concept has several serious disadvantages and the breaker may fail to operate under certain conditions. The 15th Edition of the IEE regulations prohibits the use of Voltage-Operated ELCBs in new installations in the UK. However, they may be encountered in existing installations or overseas.

Current Balanced Circuit Breakers are the devices commonly installed today, and often referred to as RCDs. Here the Line and Neutral conductors pass through a toroidal transformer core. A secondary sense winding is also wound round the core, which is connected to a solenoid trip mechanism. In a "healthy" circuit, current in the Line conductor equals that flowing in the Neutral. Thus no nett magnetic flux is induced in the toroid and the breaker does not trip. This principle holds regardless of the magnitude of load current and demonstrates the first common misconception of RCDs - they do not provide overload protection!

If a fault occurs causing some current from the Line to flow to Earth a nett flux will be set up in the toroid which will induce a voltage in the sense coil and actuate the trip solenoid.

Regarding the use of such equipment in a theatre lighting application, there is no doubt that the cheapest way to provide Earth Leakage Protection is to connect a large TP&N RCD to the dimmer feeder. This is a mistake.

If a single earth fault occurs at any point in the lighting installation the RCD will trip, blacking out everything. In addition to the immediate danger to the cast and the obvious disruption to the performance, it will not be possible to restore power until the fault has been found and cleared. This may take several days in the case of a Neutral to Earth short.

A further problem can arise with a single large RCD: that of nuisance tripping caused by cable capacitance. It is generally accepted that the maximum trip current setting for an RCD which is to provide personnel protection should be 30mA. However, in a sizeable lighting rig currents in excess of this can flow to Earth simply via the distributed capacitance of the load cables. The more cable, the higher the total capacitance value, the higher the Earth leakage current.

The current wave-form from a phase controlled dimmer can be considered to comprise of a fundamental 50Hz current plus a significant current flowing at each of the odd harmonic frequencies (150Hz, 250Hz, 350Hz...). As the current flowing through a capacitor increases with frequency, it follows that the total current coupled to Earth will be higher in a dimmed circuit, possibly causing the RCD to trip as lights are dimmed.

It should be noted that many older dimmers are fitted with suppression capacitors between Line and Earth, which may cause an RCD in the feed cable to trip.

The above problems are relevant to installations where one RCD is used to protect the feed to a large number of dimmers. There are, however, several factors which must be considered both in this case or when small RCDs are fitted to individual dimmers. Although the principle of current balance applies to all RCDs there are numerous "variations on a theme" and it is imperative to select versions which are appropriate for use with phase control.

Most RCDs are designed to operate in circuits carrying continuous 50Hz sinusoidal AC mains currents. Phase controlled dimmers present a current which is neither sinusoidal nor continuous. In addition, a significant proportion of the current comprises of harmonics; therefore the wave-form cannot be considered to be simply 50Hz. Finally, it is possible for a dimmer to become faulty and conduct only in alternate half cycles. This results in a Direct rather than Alternating current in the load circuit. All these factors must be considered in the selection of an appropriate RCD.

Some suppliers offer "Electronic Trip Control". This expression usually implies an active electronic stage interposed between the sense coil winding and the release solenoid. The electronics is powered from the line conductor to the RCD. Clearly, if these devices are fitted after a dimmer, the voltage available to energise the internal electronics will be reduced as the dimmer is faded down and the breaker may not trip. This type of RCD should not be used with dimmers.

"Standard" RCDs are also unsuitable for use with dimmers. Tests performed on a limited number of samples from a few manufacturers gave varying results, although all complied with BS4293. The trip threshold current of all samples tested increased as the dimmer output was reduced. The degradation was not large, most nominal 30mA devices tripping at under 40mA fault current when the dimmer output was reduced to 50v. The time to trip under these circumstances was not measured, and it is possible that some degradation occurred in this vital factor also.

It must be noted, however, that RCD manufacturers do not endorse this type of RCD for Phase control applications.

In all cases the test push failed to trip the RCD as the dimmer output was reduced.

Further tests were performed on standard RCDs to quantify the effect of asymmetric dimmer conduction. Here the degradation was extremely severe. All the standard RCDs tested failed to trip, at any dimmer level, when a dimmer was made to conduct only in alternate half cycles. Earth fault currents were drawn exceeding 1A under these circumstances.

Several manufacturers produce a special version of RCD known as a "pulsating DC RCD". These respond in the normal manner to symmetrical wave-forms but in addition should trip on phase controlled or asymmetrical pulsing wave-forms.

The principle of operation is similar to the conventional RCD with the following exceptions.

- Toroidal core material changed to give better coupling at higher frequencies.
- Turns ratio increased to give higher voltage on the sense coil.
- Differentiating capacitor connected in series with the sense coil to produce a pulse on the trip solenoid each time the fault current rises or falls. Needless to say, there is a cost penalty associated with these variants.

Tests were performed on three sample Pulsed CD RCDs from different manufacturers. In all cases there was a slight increase of trip current threshold as the dimmer conduction fell. However, two samples continued to trip at fault currents inside their nominal thresholds until the dimmer output voltage was well below 50V. The third sample showed a greater degradation: With the dimmer output set to 50V the RCD failed to trip when a fault current of 1A flowed.

In conclusion, the limited tests performed to date have shown that the selection of RCDs for use with phase controlled dimmers is not a simple task.

- Installation of RCDs on supply feeders should be avoided at all costs, and there is little point in installing them for personnel protection if the trip threshold has to be set above 30mA to avoid nuisance tripping.

- Voltage-operated ELCBs are totally inappropriate for the entertainment lighting application.

- RCDs which use the line voltage to power an electronic trip mechanism require very close scrutiny before use.

- Conventional RCDs designed for 50Hz sinusoidal currents will not trip should an earth fault occur whilst the dimmer is conducting in alternative half cycles. Their performance regarding harmonic and non-continuous currents is such that their manufacturers will not endorse their use in dimming applications.

- Pulsating DC RCDs from some manufacturers installed on the output of each dimmer appear to offer an approach whereby fault currents of 30mA will trip the RCD at all dimmer settings above 50V. However, it should be noted that the quantity of samples tested is inadequate to confirm consistency and also that variation of tripping time as a result of dimming has not been examined.

Finally, there is a risk that increased use of RCDs may lead to complacency regarding the safe use of electricity. The use of RCDs is an additional safeguard and in no way forms a substitute for good electrical practice, whether in the field of installation, operation or equipment maintenance.

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The paper above is a summary of a presentation given at the Safe-T '91 Conference.