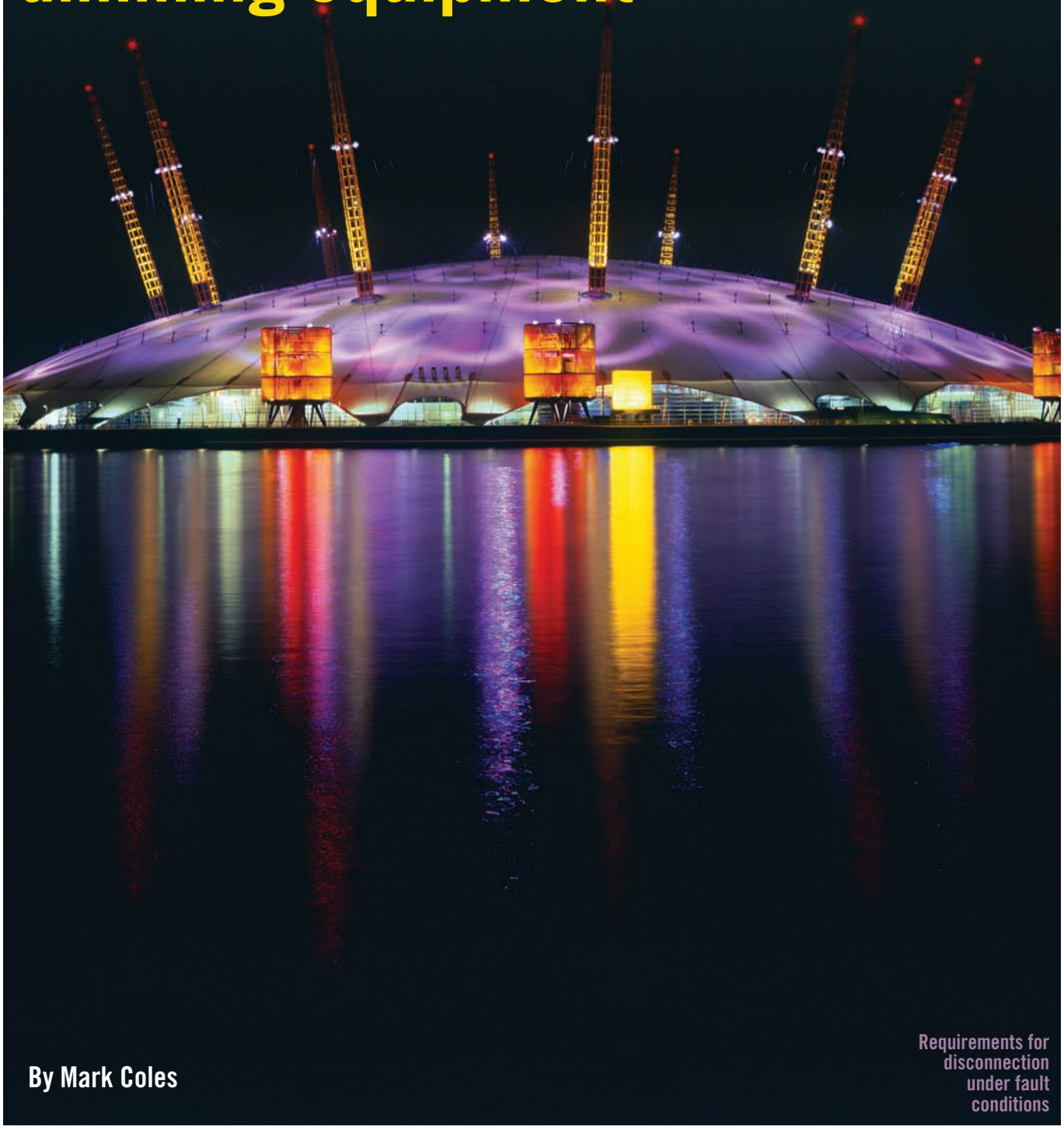
Automatic disconnection of lighting circuits from dimming equipment



By Mark Coles

Requirements for disconnection under fault conditions

Introduction

With the inclusion of dimming or control equipment within a lighting circuit, values of earth fault loop impedance at different parts of the circuit may be affected by the variation of the electrical supply to the load and the inclusion of electronic circuitry. With the variation of electrical supply, the load will see a differing voltage, in magnitude and/or waveform, depending on the type of dimmer or where the dimming control is set at any point in time, i.e. between 0-100%; 0 being in the off state and 100% being full-on. At any point between, a supply will be available at the load. Should a fault occur, the circuit would need to disconnect. This article looks at dimming equipment and the requirements of BS 7671:2008.

Standards and types of dimming equipment

There are very few national standards for dimming equipment, the key reason being that each theatrical production or fixed installation will differ from others which will lead to bespoke designs for that project only. Also, as technology advances, it is difficult for the standardisation process to keep up with recent developments. Primarily, equipment must meet the requirements of the Electrical Equipment (Safety) Regulations 1994 – which implement the Low Voltage Directive. Dimmer equipment would certainly fall within the scope of these Regulations where the fundamental requirement is for the equipment to be safe.

One British Standard – BS 5518:1977 Specification for Electronic variable control switches (dimmer switches) for tungsten filament lighting (withdrawn in 1999) was suitable for the one application but had limited life once low-energy luminaires became more prolific.

There are, of course, standards to which most equipment should adhere, such as:

- BS EN 61000 suite – Electromagnetic compatibility (EMC) which BS 7671 references in Section 332 and Chapter 44
- EN 60335–1:2002 - Household and similar electrical appliances – Safety – Part 1: General requirements
- EN 55015:2006 – Limits and methods of measuring of radio disturbance characteristics of electrical lighting and similar equipment.

The Electromagnetic Compatibility (EMC) Regulations 2005 place a statutory requirement on designers and constructors to design/construct electrical equipment and systems so that they do not cause excessive electromagnetic interference (emissions) and are not unduly affected by electromagnetic interference from other electrical equipment or systems. Harmonic production and interference, electrostatic discharges, mains-borne signals, etc. are all types of EM interference to be considered.

Dimming equipment can vary from simple dimmer switches, used in domestic situations, to large, multi-way dimming units utilising ethernet protocols used in theatrical productions, scene setting in rooms or the illumination of buildings. Large dimmer units can often appear like distribution boards where each outgoing way is protected by a fuse or circuit-breaker with RCDs used to protect the entire board or installed to protect individual outgoing circuits.

The requirements of BS 7671:2008

1. Equipment

Regulation 511.1 of BS 7671:2008 requires that all equipment complies with the relevant requirements of the applicable British Standard, or Harmonised Standard, appropriate to the intended use of the equipment. Where equipment is not manufactured to a recognised standard, as highlighted earlier in this article, Regulation 511.2 requires that such equipment offers the same degree of safety as that afforded by compliance with the Regulations; this is also recognised in Chapter 12.

Fundamentally, the Regulations do not apply to electrical appliances but, as the dimming equipment is controlling outgoing circuits – that can be considered as part of the electrical installation – it would be necessary to make reference to this instance as a departure from BS 7671 in the Electrical Installation Certificate; Regulation 120.3 requires the designer to follow technical requirements intended to ensure that electrical installations conforms to the fundamental principles of Chapter 13 and states:

Any intended departure from these Parts requires special consideration by the designer of the installation and shall be noted on the Electrical Installation Certificate specified in Part 6. The resulting degree of safety of the installation shall be not less than that obtained by compliance with the Regulations.

Therefore, the Regulations are not a barrier to non-standard equipment but designers must ensure the equipment used is just as safe as equipment made to recognised standards.

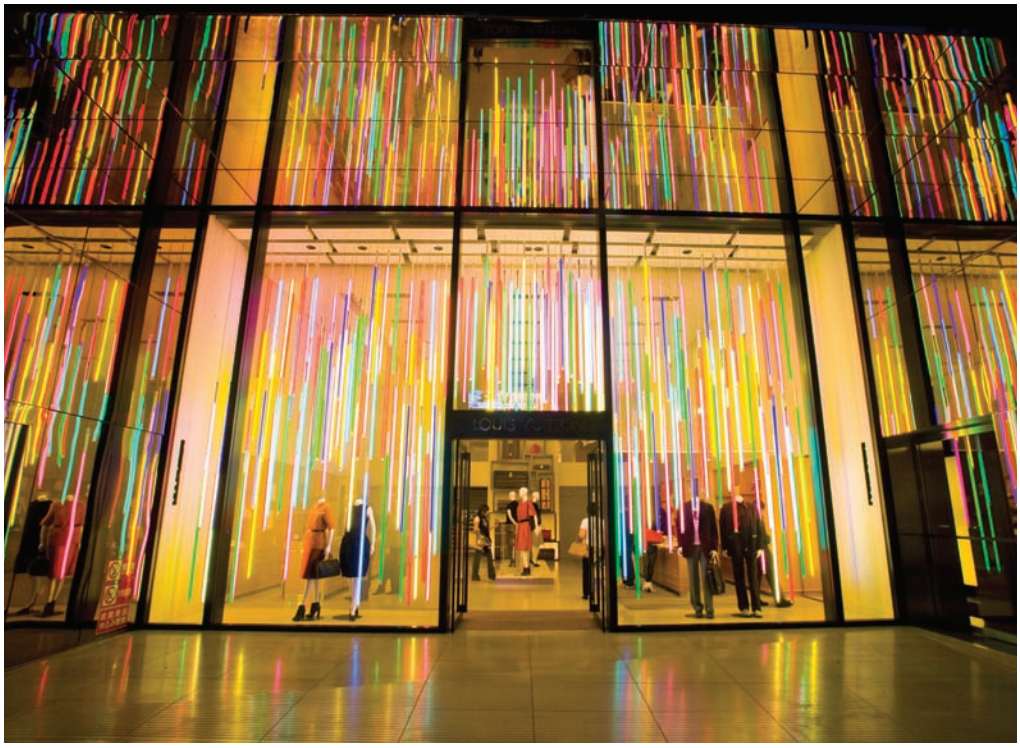
Regulation 515.1 requires that there be no harmful effect between electrical and other installations. The best approach, where practicable, is to arrange that the installations are kept separated. Elevated temperatures from hot-running dimmer units in hot environments need to be considered and such sources of heat kept separate from susceptible parts of the building fabric or theatrical properties.

Regulation 515.2 requires that where equipment carrying current of different types or at different voltages is grouped in a common assembly (such as a switchboard, a cubicle or a control desk or box), all the equipment belonging to any one type of current or any one voltage shall be effectively segregated wherever necessary to avoid mutual detrimental influence.

It is necessary to keep Band I and Band II circuits separate, often by different wiring systems or segregating by the use of multi-compartment trunking but, where this cannot be avoided, Regulation 528.1 requires that every cable or conductor is insulated for the highest voltage present or each conductor of a multicore cable is insulated for the highest voltage present in the cable.

In relation to the segregation of Band I and Band II circuits, The Lighting Industry Federation (LIF) has issued the following information in their Technical Statement No.21:

Keep mains & HF cables separated



Bespoke lighting design in a retail environment

When installing dimming or control systems the mains wiring and ELV control wiring must be mains (500V) insulated, must be segregated in separate screened and earthed channels/conduits and must not be positioned parallel to each other within the luminaire due to the risk of radiated electrical interference. The exception to this is to use an electromagnetic compatible bus system i.e. one that is non-corruptible and that does not emit interference, with 500V insulation sleeving that can then be run adjacent to the mains voltage wiring. External wiring leading to the luminaire can be adjacent for up to 5 metres (i.e. switch lines) but otherwise must be separated permanently by at least 50mm.

Regulation 559.6.2.3 states that where groups of luminaires are divided between the three line conductors of a three-phase system with only one common neutral conductor, at least one device shall be provided with that simultaneously disconnects all line conductors, such as a multi-pole circuit-breaker.

2. Protection against electric shock

The fundamental rule of protection against electric shock, according to BS EN 61140, is that hazardous-live-parts shall not be accessible and accessible conductive parts shall not be hazardous-live, either in use without a fault or in single-fault conditions. According to 4.2 of BS EN 61140, protection under normal conditions is provided by basic protective provisions and protection under single-fault conditions is provided by fault protective provisions. Alternatively, protection against electric shock is provided by an enhanced protective provision which provides protection in use without a fault and under single-fault conditions.

Regulation 411.3.2.1 requires that when a fault of negligible impedance occurs between the line conductor and an exposed-conductive-part or a protective conductor in the circuit or equipment, the protective device should operate in the required time. Table 41.1 of Regulation 411.3.2.2 requires a disconnection time of 0.4 s on a final circuit not exceeding 32 A where supplied by a TN system at a nominal voltage of 230 v; the table shows other disconnection times depending on the nominal voltage or earthing arrangements of the system. Should the final circuit be in excess of 32 A, Regulation 411.3.2.3 permits a disconnection time of 5 s where supplied by a TN system at a nominal voltage of 230 v.

As highlighted earlier, where a dimmer control is set somewhere between 0-100%, the voltage and waveform appearing at the load may be somewhat different to that of the 50 Hz sine wave at 230 v nominal supplied to the controller. As no product standard for dimming equipment exists, it is uncertain how dimming units will react under fault conditions.

Where disconnection will not occur in the required time, Regulation 411.3.2.5 states that the output voltage of the source is reduced to 50 V a.c. or 120 V d.c. or less in that required time. In this case, supplementary equipotential bonding shall be installed where appropriate. Also in such cases consideration shall be given to disconnection as required for reasons other than electric shock, such as overheating of cables and other equipment. As a fundamental requirement, this is also recognised in Regulation 410.3.7.

Consider the following as an example - an outgoing circuit from a dimmer control unit is protected by a BS 1361 fuse rated at 15 amps. The table, figure 3.1, is extracted from BS 7671:2008 and shows the time/current characteristics of fuses to BS 1361. In the diagram, the red lines show that disconnection is assured within 0.4 s where the fault current is at a minimum of 70 amps.

The purple lines show that any fault current of less than 70 amps will result in a disconnection time in excess of 0.4 s. As can be seen, 30 amps flowing for 400 seconds on a 15 A rated circuit would result in dangerous overheating of the equipment. This is the reason that Regulation 411.3.2.5 requires that the output voltage of the source is reduced to 50 V a.c. or 120 V d.c. or less within the stated disconnection time.

BS 7909:2008 Code of practice for temporary electrical systems for entertainment and related purposes also makes

reference to this situation in clause 7.10 and states that designers should take account of the characteristics for all electronic units used for control and power-processing when designing sub-circuit overcurrent protection and earth fault disconnection.

The standard continues by stating that in practice, such devices should be supplied by the manufacturer/supplier with integral fuse or circuit-breaker protection suitable for normal conditions of use. The manufacturer/supplier should be consulted to obtain the characteristics of the protective devices used. Interpretation of the measured values of earth fault loop impedance requires knowledge of the nature and characteristics of the source of supply. Caution needs to be observed when verifying systems incorporating power-processing equipment such as UPS, inverters or similar electronic control devices.

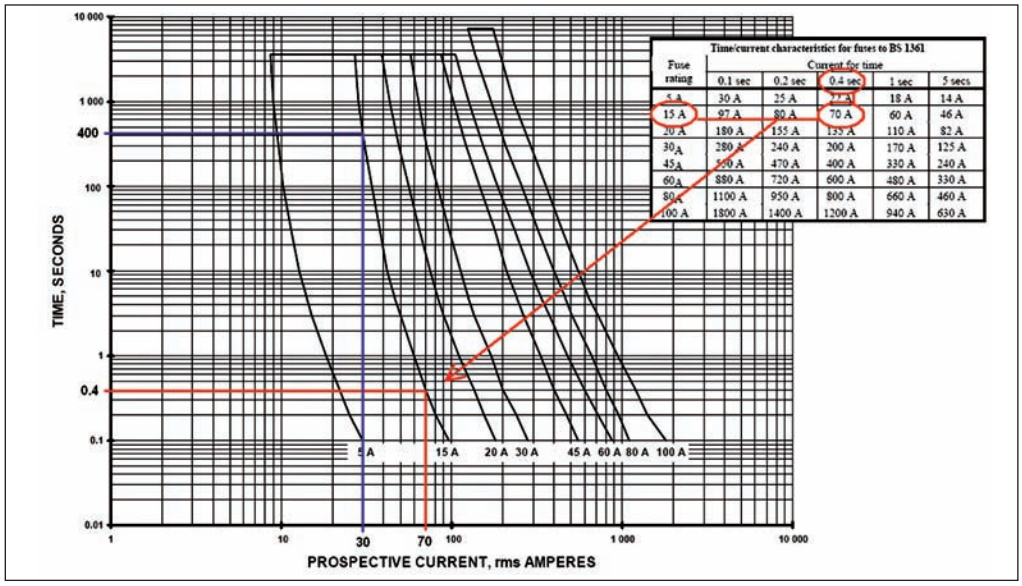


Fig 3.1 from BS 7671:2008

3. Residual current devices

Where RCDs are used with dimming equipment, information from the manufacturer may be required before the correct RCD can be selected by the designer. As no single standard exists, it would be generally unknown how the dimming equipment would affect the electrical installation as different types of semi-

Bespoke lighting design at the Beijing Olympic stadium

conductor switching devices can introduce unwanted signals on the electrical supply.

For the majority of applications, type AC devices are suitable, with type A being used where special circumstances exist. Type B devices are manufactured and tested to IEC 60755, which is a Technical Report, with no BS or BS EN equivalent. There is no requirement for the use of type A RCDs in BS 7671 but type B may be required in a solar photovoltaic (PV) system.

Type A devices are important due to the wide range of electronic equipment available now which may produce a protective conductor current with a pulsating d.c. component and harmonic currents. These RCDs may utilize electronic circuitry or low remanence core material to more closely match the predetermined current/time trip characteristics allowed by the standards to achieve the most suitable performance characteristics.

Type 'AC' RCDs will provide protection against a.c. earth fault currents

Type 'A' RCDs will provide protection against a.c. earth fault currents that contain pulsating d.c. components

Type 'B' RCDs will provide protection against d.c earth fault currents

BS 7909 offers guidance on the use of RCDs in clause 7.6 – RCDs in temporary systems. The standard states that every final circuit should be protected by an RCD with a rated residual operating current (IΔn) not exceeding 30 mA and recommends that no more than six final circuits are protected by a single RCD.

4. Testing

BS 7671 requires that all circuits are inspected and tested prior to being put into service; see Regulation 610.1. The testing sequence is given in Section 612 of BS 761 and will not be reiterated here but there are a number of points worth highlighting.

When undertaking insulation resistance testing, Table 61 shall be applied, e.g. test voltage of 500 v d.c. with a minimum insulation resistance measurement of 1 MΩ, when verifying insulation resistance between non-earthed protective conductors and Earth. Where equipment is likely to influence the verification test, or be damaged, such equipment shall be disconnected before carrying out the insulation resistance test. Where it is not reasonably practicable to disconnect such equipment, the test voltage for the particular circuit may be reduced to 250 V d.c. but the insulation resistance shall have a value of at least 1 MΩ.

Regulation 612.3.3 recognises that where the circuit includes electronic devices which are likely to influence the results or be damaged during the test, a measurement between the live conductors connected together and the earthing arrangement only can be made.

Conclusion

In the event of a fault of negligible impedance, protective devices in all lighting circuits should disconnect the fault within the required time or supplementary provisions are applied to achieve the same degree of safety. The use of non-standard equipment is not a barrier to electrical installation design but the designer must ensure that the level of safety is not compromised.

Further reading

BS 7671:2008 Requirements for Electrical Installations, 17th Edition of the IEE Wiring Regulations
IET Guidance Note 1 - Selection and Erection
BS 7909:2008 Code of practice for temporary electrical systems for entertainment and related purposes
The Lighting Industry Federation (LIF) Technical Statement No.21
Electrical Equipment (Safety) Regulations 1994

Thanks

James Eade – E-mech
Ken Morton – HSE
Dave Roberts – Dave Roberts Associates
JB Toby – Avolites
The Lighting Industry Federation

Live event lighting