Reduced low voltage systems

OBJECTIVE

_BS 7671_ permits the use of a range of supplies to equipment on construction sites. This article summarises the requirements for the use of reduced low voltage supplies in such locations. This article follows on from articles in the previous issue of _Connections_, which looked at the environmental factors on construction sites and the use of low voltage to supply electrical equipment on-site. You may find it helpful to refer those articles when reading this one. An article describing the requirements for the use of low voltage supplies on construction sites appears elsewhere in this edition and may also be of interest.

Introduction

Section 704 of *BS 7671* permits the use of a range of electrical supplies on construction sites. This article concentrates on the requirements for reduced low voltage (RLV). When considering the use of RLV, it is important to comply with both the requirements of Section 411.8 of *BS 7671* and those of *BS 4363: 1998 (2013) – Specification for distribution assemblies for reduced low voltage electricity supplies for construction and building sites*.

Where, for functional reasons, the use of extra-low voltage is impracticable and there is no requirement for the use of SELV or PELV, an RLV system may be used (411.8.1.1). This system has been used on construction and demolition sites (and indeed some industrial and commercial premises) in the United Kingdom for more than 50 years. It has been highly effective, reducing the risk of death and severity of injury from electricity while providing an adequate supply voltage for the majority of site equipment to function properly. It is for this reason that Note 1 of Regulation 704.410.3.10 expresses a strong preference for the use of RLV for the supply to portable hand lamps for general use, portable hand tools and local lighting up to 2 kW.

RLV is a form of supply in which the nominal circuit voltage does not exceed 110 V AC between lines. In the case of three-phase circuits, voltage should not exceed 63.5 V between a line and earthed neutral and, for single-phase circuits, 55 V between a line and earthed midpoint (411.8.1.2). It is this reduced voltage level which provides the primary protection against electric shock in the RLV system. Indeed, historically, a disconnection time was not specified.

Permitted sources of supply

The supply to an RLV circuit should be derived from one of the following sources:

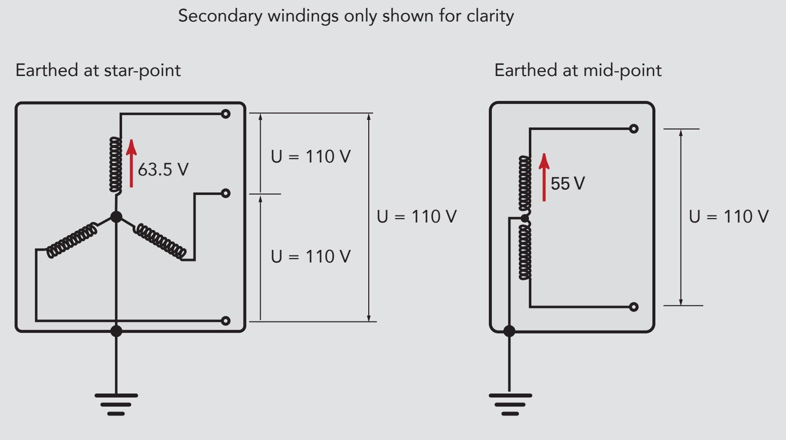
- A double-wound isolating transformer meeting the requirements of *BS EN 61558-1* and *BS EN 61558-2-23*
- A motor-generator in which the windings provide a degree of isolation equivalent to that provided by the windings of an isolating transformer
- Some other source independent of other supplies, such as an engine-driven generator (411.8.4.1).

The secondary windings of a transformer or generator providing the supply to an RLV system must be connected to Earth. As can be seen in Fig 1, for three-phase supplies, the connection is made at the neutral (star) point and for single-phase supplies the connection is made at the midpoint (411.8.4.2).

Basic protection

Basic protection must be provided by either basic insulation suitable for the maximum

Fig 1 Single-phase and three-phase RLV supplies



system nominal voltage or by the use of barriers or enclosures (411.8.2).

Fault protection

All exposed-conductive-parts of the RLV system must be connected to Earth.

For automatic disconnection of supply (fault to earth), each line conductor should be protected by either an overcurrent protective device or an RCD. Clause 5.5 of *BS 4363* requires any circuit-breakers used on output circuits to disconnect all circuit conductors simultaneously.

BS 7671 calls for a maximum disconnection time of five seconds for an RLV system (411.8.3). The maximum value of earth fault loop impedance to achieve this disconnection time can be found by the application of one of the following formulae, derived from the expression given in Regulation 411.4.4:

For fuses or circuit-breakers:

$$Z_s max \leq \frac{U_o \times C_{min}}{I_a}$$

Where:

U_o is the nominal AC rms voltage to Earth (55 V for 1Ø RLV or 63.5 V for 3Ø RLV (see 411.8.3))

I_a is the current in amperes (A) causing the automatic operation of the disconnecting device within 5s

C_{min} is the minimum voltage factor to take account of voltage variations depending on time and place, changing of transformer taps and other considerations (typically taken as 0.95)

Alternatively, Table 41.6 of *BS 7671* provides maximum earth fault loop impedance values for the commonly available ratings of circuit-breakers to *BS EN 60898*, for the overcurrent element of RCBOs to *BS EN 61009-1* and for general purpose fuses to *BS 88-2* fuse systems E and G.

It should be noted at this point that *BS 4363* recommends for a single-phase transformer assembly (TA/1) that:

- any single-phase output circuits of rating up to 32 A supplying socket-outlets, and
- any circuits in excess of 32 A, whether supplying or circuits directly or via socket-outlets,

must be protected by double-pole circuit-breakers (Clause 7.1).

Similarly, in a three-phase transformer assembly (TA/3), any three-phase circuit of rating up to 32 A supplying socket-outlets should be protected by triple-pole circuit-breakers (Clause 7.3). This precludes the use of fuses at the origin of circuits in such site assemblies.

Clause 7 also states that any socket-outlets in excess of 32 A rating must be mechanically or electrically interlocked to prevent the on-load removal of the plug.

Where fault protection is provided by an RCD, the following condition must be met:

$$I_{\Delta n} \times Z_s \leq 50\ V$$

Where:

$I_{\Delta n}$ is the rated residual operating current of the RCD providing fault protection.

It should be noted that where an RCD is relied upon for fault protection, for example where the earth fault loop impedance value is high, an appropriate overcurrent protective device must still be provided in each line conductor in accordance with Chapter 43 (411.4.5; 411.5.2).

Particular requirements where the installation forms part of a TT system

BS 7671 permits the use of an enclosure of Class I construction to house an RCD at the origin of an installation forming part of a TT system subject to the use of live conductors having double or reinforced insulation on the supply side of the incoming device (531.3.5.3.2.201).

Similarly, Clause 6.5.4.1 of *BS 7375*[1] states that a metallic enclosure may be used if insulating glands, gland plates or other measures, providing the equivalence of Class II insulation between the incoming supply conductors and equipment metalwork, are taken to reduce the possibility of earth faults. However, this clause also states that, wherever practicable, an insulating enclosure should be used to avoid the

1 *BS 7375: 2010 Distribution of electricity on construction and demolition sites – Code of practice*
2 *Engineering Recommendation G12 Issue 4 – Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks*

risk of earth faults between incoming cables and metalwork on the supply side of the principal protective device(s).

It is important to comply with any specific requirements that may have been imposed by a Distribution Network Operator (DNO) as conditional to the provision of a supply. For example, Clause 6.2.2.2 of Engineering Recommendation *G12, issue 4*[2] does not permit any exposed-conductive-parts before, or enclosing, an RCD. As a result, an RCD at the origin would have to be housed in an enclosure of Class II or equivalent all-insulated construction.

Circuits

Every plug, socket-outlet, luminaire supporting coupler, device for connecting a luminaire and cable coupler used in RLV systems should have a protective conductor contact that is not dimensionally compatible with those used for any other system in use on the particular construction or demolition site (411.8.5).

All plugs and socket-outlets – and indeed cable couplers and cable connectors – of current rating exceeding 16 A should meet the requirements of *BS EN 60309-2*[3] (704.511.8.11). Unless otherwise specified in that standard, the requirements of *BS EN 60309-1*[4] are also applicable.

Accessories to *BS EN 60309-2* are non-interchangeable with respect to their current and voltage ratings.

A more complete explanation of the non-interchangeability arrangements is given in the article on low voltage supplies on construction sites which appears elsewhere in this issue of *Connections*.

Clause 7.7 of *BS EN 60309-1* states that the operating voltage of accessories may be indicated by colour. In the case of accessories suitable for operation at 100-130 V, the identifying colour yellow should be used.

While there is no requirement for such, this colour-coding system is often also applied to the outer sheath of flexible cables.

Conclusion

The reduced low voltage (RLV) system has been used in the United Kingdom for more than 50 years. RLV provides both a safe system for use in the tough environment typical of a construction site while providing a supply that is sufficient for the majority of site electrical equipment to function properly.

When an RLV system is employed it is important that all relevant requirements relating to the installation of such systems are met. This will require reference to a number of British Standards, in particular *BS 7671* and *BS 4363*.

3 *BS EN 60309-2:1999+A2:2012 Plugs, socket-outlets and couplers for industrial purposes. Dimensional interchangeability requirements for pin and contact-tube accessories*

4 *BS EN 60309-1:1999+A2:2012 Plugs, socket-outlets and couplers for industrial purposes. General requirements*

Apprentice Corner answers

1. **Correct option is (d)**
   The total calculated value of impedance is:
   $Z_s = Z_e + (R_1 + R_2) = 0.22 + 0.66 = 0.88\ \Omega$.
   This will give a prospective fault current of:
   $I_{pf} = \frac{U_0}{Z_s} = \frac{230}{0.88} = 261$ A.
   From Fig 3A5 in Appendix 3, the disconnection time is about 6 s.

2. **Correct option is (c)**
   The total calculated value of impedance is:
   $Z_s = Z_e + (R_1 + R_2) = 0.22 + 0.66 = 0.88\ \Omega$.
   When compared to Table 41.3, the total impedance should not exceed: 0.68 x 0.8 = 0.54 Ω. The 0.8 correction factor is found in Appendix 3 *BS 7671*. Therefore the circuit impedance is too high to meet the disconnection time of 0.4 s.

3. **Correct option is (b)**
   When determining earth fault current, it is always the voltage to earth (U_0) that is used, even if the circuit is connected to a three-phase supply.
   $U_0 = \frac{U_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} \approx 230$ V
   Therefore: $I_{pf} = \frac{U_0}{Z_s} = \frac{230}{0.5} = 460$ A
   The equation given in 411.4.4 cannot be used in this instance as there is insufficient detail given in the question. Therefore, this current is a prospective fault current (I_{pf}) and not a current causing disconnection of the protective device within the required time (I_a).

4. **Correct option is (c)**
   From Fig 3A2(a) in Appendix 3, the disconnection time is about 0.5 s

5. **Correct option is (d)**
   See page 40 of *BS 7671*, which gives a list of the symbols used in the standard.

6. **Correct option is (a)**
   For a reduced low voltage system, Regulation 411.8.3 permits two methods to be used to determine the maximum value of earth fault loop impedance.
   Method 1: Use Table 41.6, maximum value of impedance is given as 0.33 Ω
   Method 2: By calculation using the equation given in 411.4.4; $Z_s \times I_a \leq U_0 \times C_{min}$
   From the table in Fig 3A4 of Appendix 3, I_a is 160 A
   Maximum $Z_s = \frac{U_0 \times C_{min}}{I_a} = \frac{55 \times 0.95}{160} = 0.33\ \Omega$