Guide to working out c

In part two in this series, *Bill Allan* continues his look at the basic steps and provides examples to test your knowledge

In the previous issue of *The Competent Person* magazine, we considered the five basic steps for working out the correct size of cable for a particular load. Due to the importance of this subject, we ought to consider it further. In particular, we'll look at the cross-sectional areas of neutral conductors and protective conductors.

Co-ordination between conductor and protective device

Regulation 433-02-01 in Section 433 contains the requirements for the relationship between the conductor and the overcurrent device which protects it.

The terms included in this Regulation are:

I_b = the load current
I_n = the nominal current rating of the overcurrent protective device
I_Z = the current-carrying capacity (that is, the current rating) of the conductors
I_2 = the current causing effective operation of the overcurrent protective device.

That being said, Regulation 433-02-01 can be summarised as follows:

(i) $I_n \geq I_b$

(ii) $I_Z \geq I_n$

(iii) $1.45 \times I_Z \geq I_2$

Regulation 433-02-02 states that, for the following devices, compliance with condition (ii) above results in compliance with condition (iii). In other words, for the following devices, I_2 is deemed to be less than $1.45 \times I_Z$:

- type (gG) fuses to BS 88-2.1
- fuses to BS 88-6
- fuses to BS 1361
- circuit-breakers to BS EN 60898
- circuit-breakers to BS EN 60947-2
- RCBO to BS EN 61009-1

Regulation 433-02-03 concerns rewireable fuses to BS 3036 and may be summarised like this:

$$0.725 \times I_Z \geq I_n$$

Cross-sectional areas of neutral conductors

Section 524 of BS 7671 contains general requirements for cross-sectional areas of phase conductors and neutral conductors. In single-phase circuits, the cross-sectional area of the neutral conductor must not be less than that of the phase conductor. In three-phase circuits, the size of neutral conductors may be reduced provided that the designer has assessed that the current in the neutral conductor will be less than that in the phase conductors. However this reduction of the neutral conductor is becoming less common due to the harmonic content of modern electrical loads. In any case, the practice is not permitted for discharge lighting circuits.

Cross-sectional area of protective conductors

The requirements for determining the cross-sectional areas of protective conductors are found in Section 543 of BS 7671. The first regulation in this Section, Regulation 543-01-01 contains two basic methods for determining the cross-sectional area of protective conductors:

1 It can be selected using the adiabatic equation, or
2 It can be selected using Table 54G.

1 The adiabatic equation

The adiabatic equation is given in Regulation 543-01-03 and looks like this:

$$S = \frac{\sqrt{I^2 t}}{k}$$

where, S = the cross-sectional area of the protective conductor
I = the fault current
t = the operating time of the overcurrent device corresponding to the fault current
k = a factor which takes account of the resistivity, temperature coefficient and heat capacity of the conductor material

Student Activities

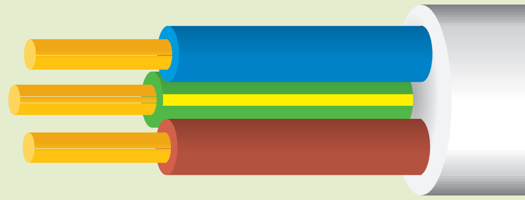
1 Study Regulation 433-02-01 of BS 7671 and summarise the requirements regarding the co-ordination between conductor and protective device.

2 Study Section 524-02 of BS 7671 and summarise the requirements regarding the cross-sectional area of neutral conductors.

3 Study Section 543-01 of BS 7671 and summarise the requirements regarding the cross-sectional area of protective conductors.

4 Use the adiabatic equation to determine the minimum cross-sectional area of a circuit protective

able sizes 2



This might look quite daunting but a worked example is the best way to show how it works.

Worked example

Use the adiabatic equation to determine the minimum cross-sectional area of a circuit protective conductor suitable for use on a radial circuit protected by a 30 amp fuse to BS 3036. The 230 volt circuit is wired in single-core 70° C PVC insulated cables with copper conductors, which are installed in steel conduit. The cross-sectional area of the phase and neutral conductors is 4 mm2. The earth fault loop impedance Z_S is 1.44 ohms.

Answer

Fault current, $I_f = \frac{V}{Z_S} = \frac{230}{1.44} = 160$ amps.

The disconnection time, t, is found by reference to the appropriate time/current characteristic of a 30 amp BS 3036 fuse. This is found in Fig. 3.2A in Appendix 3 of BS 7671. These time/current curves make use of logarithmic scales, which enable large scales to be used in a relatively small area. The disconnection time is approximately 0.8 seconds. The value of k is obtained from Table 54C of BS 7671 and is 115. Now the adiabatic equation can be used as follows:

$$S = \frac{\sqrt{I^2 t}}{k} = \frac{\sqrt{160^2 \times 0.8}}{115} = 1.24 \text{ mm}^2$$

Note
It is only the top line which is square rooted not the whole equation.

conductor suitable for use on a radial circuit protected by a 20 amp fuse to BS 88-2.1. The 230 volt circuit is wired in 70°C PVC insulated and sheathed flat cable with a protective conductor (copper conductors). The earth fault loop impedance Z_S is 1.53 ohms. (Assume k to be 115).

2 Table 54G

If the adiabatic equation looks like too much trouble, then the good news is that you can use Table 54G of BS 7671.

Table 54G
Minimum cross-sectional area of protective conductor in relation to the cross-sectional area of associated phase conductor

Cross-sectional area of phase conductor, S (mm^2)	Minimum cross-sectional area of the corresponding protective conductor	
	If the protective conductor is of the same material as the phase conductor (mm^2)	If the protective conductor is not of the same material as the phase conductor (mm^2)
$S \leq 16$	S	$\frac{k_1}{k_2} \times S$
$16 < S \leq 35$	16	$\frac{k_1}{k_2} \times 16$
$S > 35$	$\frac{S}{2}$	$\frac{k_1}{k_2} \times \frac{S}{2}$

where: k_1 is the value of k for the phase conductor, selected from Table 43A in Chapter 43 according to the materials of both conductor and insulation.

k_2 is the value of k for the protective conductor, selected from Tables 54B, 54C, 54D, 54E or 54F, as applicable.

Reference to Table 54G shows that, where the associated phase conductor has a cross-sectional area up to and including 16 mm^2, the protective conductor can be of the same cross-sectional area. In the worked example above, the cross-sectional area of the associated phase conductor is 4mm^2. This means that, using Table 54G would require the protective conductor also to have a cross-sectional area of 4 mm^2. This size is clearly considerably larger than the 1.24 mm^2 which was selected using the adiabatic equation method. It is however much quicker and easier to use Table 54G.

Conclusion

Student Activities (left) contains more examples, together with the answers, if you need the practice.

Answers to Student Activities from Issue 2:
1, 0.60; *2,* 0.87; *3,* 0.98; *4,* 0.55; *5,* Column 2; *6,* 8.69 amps; *7,* 15 amps.