8 Worked example of cable calculation

Worked example of cable calculation (see **Fig. G65**)

The installation is supplied through a 1,000 kVA transformer. The process requires a high degree of supply continuity and this is provided by the installation of a 500 kVA 400 V standby generator and the adoption of a 3-phase 3-wire IT system at the main general distribution board. The remainder of the installation is isolated by a 400 kVA 400/400 V transformer. The downstream network is a TT-earthed 3-phase 4-wire system. Following the single-line diagram shown in Figure G65 below, a reproduction of the results of a computer study for the circuit C1, the circuit-breaker Q1, the circuit C6 and the circuit-breaker Q6. These studies were carried out with ECODIAL 3.3 software (a Merlin Gerin product).

This is followed by the same calculations carried out by the method described in this guide.

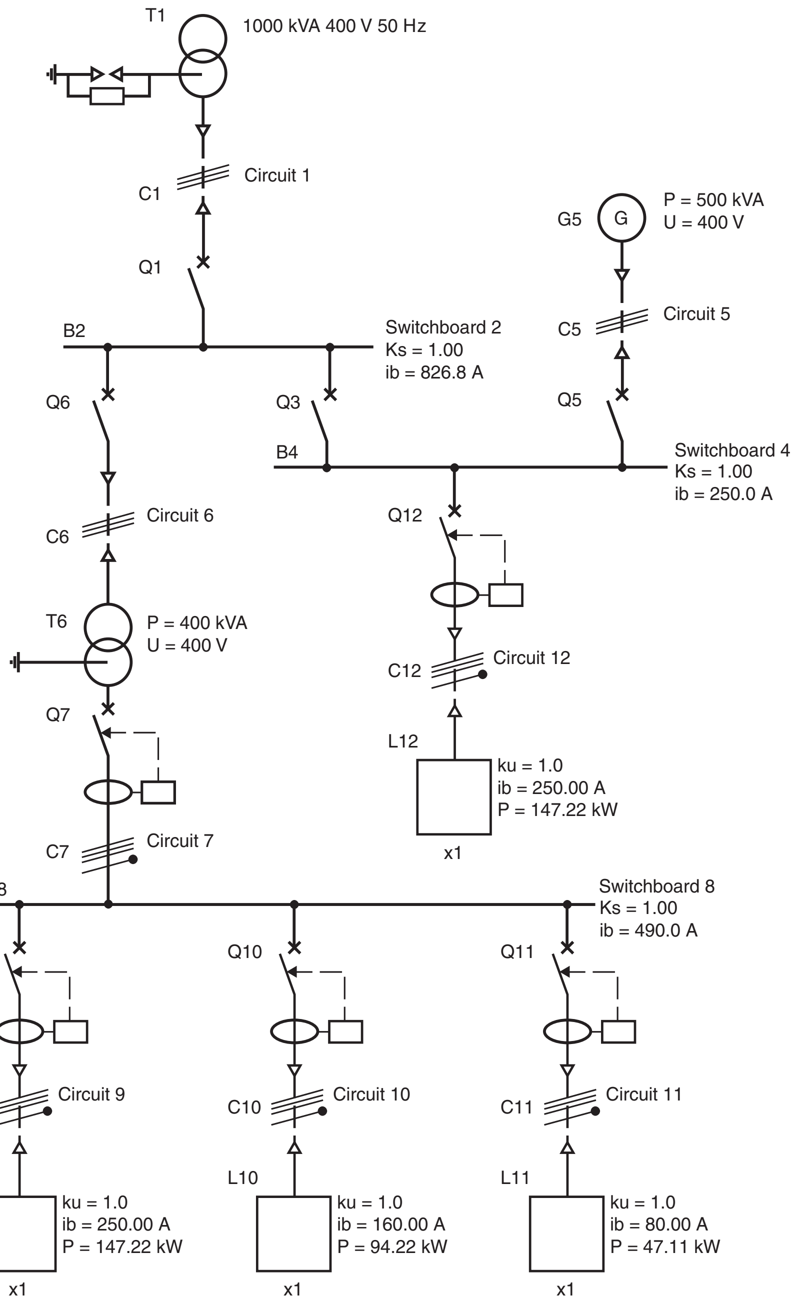

Fig. G65 : Example of single-line diagram

8 Worked example of cable calculation

Calculation using software Ecodial 3.3

General network characteristics	
Earthing system	IT
Neutral distributed	No
Voltage (V)	400
Frequency (Hz)	50
Transformer T1	
Number of transformers	1
Upstream fault level (MVA)	500
Rating (kVA)	1,000
Short-circuit impedance voltage (%)	6
Resistance of MV network (mΩ)	0.0351
Reactance of MV network (mΩ)	0.351
Transformer resistance RT (mΩ)	2.293
Transformer reactance XT (mΩ)	10.333
3-phase short-circuit current Ik3 (kA)	23.3
Cable C1	
Maximum load current (A)	1,374
Type of insulation	PVC
Conductor material	Copper
Ambient temperature (°C)	30
Single-core or multi-core cable	Single
Installation method	F
Number of circuits in close proximity (table G21b)	1
Other coefficient	1
Selected cross-sectional area (mm²)	6 x 95
Protective conductor	1 x 120
Length (m)	5
Voltage drop ΔU (%)	.122
Voltage drop ΔU total (%)	.122
3-phase short-circuit current Ik3 (kA)	23
1-phase-to-earth fault current Id (kA)	17
Circuit-breaker Q1	
3-ph short-circuit current Ik3 upstream of the circuit-breaker (kA)	23
Maximum load current (A)	1,374
Number of poles and protected poles	3P3D
Circuit-breaker	NT 16
Type	H 1 – 42 kA
Tripping unit type	Micrologic 5 A
Rated current (A)	1,600
Busbars B2	
Maximum load current (A)	1,374
Type	Standard on edge
Ambient temperature (°C)	30
Dimensions (m and mm)	1 m 2x5 mm x 63 mm
Material	Copper
3-ph short-circuit current Ik3 (kA)	23
3-ph peak value of short-circuit current Ik (kA)	48
Resistance of busbar R (mΩ)	2.52
Reactance of busbar X (mΩ)	10.8
Circuit-breaker Q6	
3-ph short-circuit current upstream of the circuit-breaker Ik3 (kA)	23
Maximum load current (A)	560
Number of poles and protected poles	3P3D
Circuit-breaker	NS800
Type	N – 50 kA
Tripping unit type	Micrologic 2.0
Rated current (A)	800
Limit of discrimination (kA)	Total
Cable C6	
Maximum load current (A)	560
Type of insulation	PVC
Conductor material	Copper
Ambient temperature (°C)	30
Single-core or multi-core cable	Single
Installation method	F
Number of circuits in close proximity (table G20)	1
Other coefficient	1
Selected cross-sectional area (mm²)	1 x 300
Protective conductor	1 x 150
Length (m)	15
Voltage drop ΔU (%)	.38
Voltage drop ΔU total (%)	.54
3-phase short-circuit current Ik3 (kA)	20
1-phase-to-earth fault current Id (kA)	13.7
Specific sizing constraint	Overloads

Fig. G66 : Partial results of calculation carried out with Ecodial software (Merlin Gerin)

The same calculation using the simplified method recommended in this guide

Dimensioning circuit C1

The MV/LV 1,000 kVA transformer has a rated no-load voltage of 420 V. Circuit C1 must be suitable for a current of

$$I_B = \frac{1{,}000 \times 10^3}{\sqrt{3} \times 420} = 1{,}374 \text{ A per phase}$$

Six single-core PVC-insulated copper cables in parallel will be used for each phase. These cables will be laid on cable trays according to method F. The “k” correction factors are as follows:

k_1 = 1 (see table G12, temperature = 30 °C)

k_4 = 0.87 (see table G17, touching cables, 1 tray, ⩾ 3 circuits)

Other correction factors are not relevant in this example.

The corrected load current is:

$$I'_B = \frac{I_B}{k_1 \cdot k_4} = \frac{1{,}374}{0.87} = 1{,}579 \text{ A}$$

Each conductor will therefore carry 263 A. Figure G21a indicates that the c.s.a. is 95 mm².

8 Worked example of cable calculation

The resistances and the inductive reactances for the six conductors in parallel are, for a length of 5 metres:

$$R = \frac{22.5 \text{ x } 5}{95 \text{ x } 6} = 0.20 \text{ m}\Omega \quad \text{(cable resistance: 22.5 m}\Omega\text{.mm}^2\text{/m)}$$

X = 0.08 x 5 = 0.40 mΩ (cable reactance: 0.08 mΩ/m)

Dimensioning circuit C6

Circuit C6 supplies a 400 kVA 3-phase 400/400 V isolating transformer

$$\text{Primary current } = \frac{400.10^3}{420.\sqrt{3}} = 550 \text{ A}$$

A single-core cable laid on a cable tray (without any other cable) in an ambient air temperature of 30 °C is proposed. The circuit-breaker is set at 560 A

The method of installation is characterized by the reference letter F, and the “k” correcting factors are all equal to 1.

A c.s.a. of 240 mm^2 is appropriate.

The resistance and inductive reactance are respectively:

$$R = \frac{22.5 \text{ x } 15}{240} = 1.4 \text{ m}\Omega$$

$$X = 0.08 \text{ x } 15 = 1.2 \text{ m}\Omega$$

Calculation of short-circuit currents for the selection of circuit-breakers Q 1 and Q 6 (see **Fig. G67**)

Circuits components parts	R (mΩ)	X (mΩ)	Z (mΩ)	Ikmax (kA)
500 MVA at the MV source network	0.04	0.36		
1 MVA transformer	2.2	9.8	10.0	23
Cable C1	0.20	0.4		
Sub-total for Q1	**2.44**	**10.6**	**10.9**	**23**
Busbar B2	3.6	7.2		
Cable C6	1.4	1.2		
Sub-total for Q6	**4.0**	**8.4**	**9.3**	**20**

Fig. G67 : Example of short-circuit current evaluation

The protective conductor

Thermal requirements: Figures G58 and G59 show that, when using the adiabatic method the c.s.a. for the protective earth (PE) conductor for circuit C1 will be:

$$\frac{34{,}800 \text{ x } \sqrt{0.2}}{143} = 108 \text{ mm}^2$$

A single 120 mm^2 conductor dimensioned for other reasons mentioned later is therefore largely sufficient, provided that it also satisfies the requirements for indirect-contact protection (i.e. that its impedance is sufficiently low).

For the circuit C6, the c.s.a. of its PE conductor should be:

$$\frac{29{,}300 \text{ x } \sqrt{0.2}}{143} = 92 \text{ mm}^2$$

In this case a 95 mm^2 conductor may be adequate if the indirect-contact protection conditions are also satisfied.

8 Worked example of cable calculation

Protection against indirect-contact hazards

For circuit C6 of Figure G65, Figures F45 and F61, or the formula given page F27 may be used for a 3-phase 3-wire circuit.

The maximum permitted length of the circuit is given by :

$$Lmax = \frac{0.8 \text{ x } 240 \text{ x } 230\sqrt{3} \text{ x } 1,000}{2 \text{ x } 22.5\left(1+\frac{240}{95}\right) \text{ x } 630 \text{ x } 11} = 70 \text{ m}$$

(The value in the denominator 630 x 11 = Im i.e. the current level at which the instantaneous short-circuit magnetic trip of the 630 A circuit-breaker operates).

The length of 15 metres is therefore fully protected by “instantaneous” overcurrent devices.

Voltage drop

From Figure G28 it can be seen that:

- For the cable C1 (6 x 95mm^2 per phase)

$$\Delta U = \frac{0.42 \text{ (V A}^{-1}\text{ km}^{-1}\text{) x } 1,374 \text{ (A) x } 0.008}{3} = 1.54 \text{ V}$$

$$\Delta U\% = \frac{100}{400} \text{x } 1.54 = 0.38\%$$

- For the circuit C6

$$\Delta U = \frac{0.21 \text{ (V A}^{-1}\text{ km}^{-1}\text{) x } 433 \text{ (A) x } 0.015}{3} = 1.36 \text{ V}$$

$$\Delta U\% = \frac{100}{400} \text{x } 1.36 = 0.34\%$$

At the circuit terminals of the LV/LV transformer the percentage volt-drop $\Delta U\%$ = 0.72%