



Understanding Earth Fault Loop Impedance

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Table of contents

Table of contents	i
Introduction.....	1
Theoretical background behind fault loop impedance	3
Requirements of the Australian Standards	4
Calculating the actual fault loop impedance (Z_s).....	5
Calculating the maximum allowable impedance (Z_{max}).....	6
Determining earth cable size	7


Introduction

The purpose of this article is to provide a better understanding of Fault Loop Impedance, also referred to as Earth Fault Loop Impedance so that the requirements of AS/NZS 3000 Wiring Rules for safety, design, installation and testing of electrical installation are met.

You can calculate Fault Loop Impedance by hand or using software. Cable Pro software can accurately calculate Fault Loop Impedance.

This document provides:

1. The theoretical background behind fault loop impedance which will lead to a better understanding for those required to perform the designs and calculations.
2. A practical guide to performing the processes and procedures to meet the requirements of the Australian and New Zealand Standard AS/NZS 3000:2018.
3. Information about how the fault loop impedance is used by the Cable Pro software to calculate earth cable size.

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Load

Current (A)
120

Derating factor
1 ☐ Use Wiz Derating Wizard

Power factor
0.9

Supply

Phases
3 ph

Voltage drop (%) Voltage (V)

Length of run (m) Fault level (kA)

Cable

Insulation
Thermoplastic (75 °C)

Conductor
Copper Solid/Stranded

Cores
Single core

Installation

TABLE 7

- ☐ Unenclosed Spaced
- ☒ Unenclosed Spaced from surface
- ☐ Unenclosed Touching
- ☐ Unenclosed Exposed to sun
- ☐ Enclosed Wiring enclosure in air
- ☐ Thermal insulation Partially surrounded
- ☐ Thermal insulation Completely surrounded
- ☐ Buried direct
- ☐ Buried enclosure Combined
- ☐ Buried enclosure Separate

Cable size

Details

- Current-carrying Capacity
 - Circuit rating (derated) 127 A
 - Derating factor 1.00
 - + Current rating (tabulated) 127 A
 - Operating temperature 71.25 °C
- + Voltage Drop
- + Short-circuit Performance
 - Fault Loop Impedance
 - Total loop, Zs 0.3619 Ω
 - Source, Zext 0.0724 Ω
 - + Cables, Zint 0.2895 Ω
 - Max. allowed, Zdevice 0.4619 Ω

Protection

Device Fault time (s) Earth fault time

Rating Curve ☐ RCD

Trip current (A) Trip multiplier

Cable Pro Web
Version 210.0 (22/01/20)

Email: support@elek.com.au
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 Electrotechnik

Figure 1 – [Cable Pro Web](#) for calculating fault loop impedance and earth cable size

Theoretical background behind fault loop impedance

The earth fault loop in an MEN system comprises the following components:

1. The protective earthing conductor (PE) including the main earthing terminal/connection or bar and MEN connection.
2. The neutral return path consisting of the neutral conductor (N) between the main neutral terminal and the transformer neutral point.
3. The path through the transformer winding.
4. The active conductor (A) as far as the point of the fault.

The earth fault loop is normally regarded as consisting of the following two parts:

1. Conductors upstream or 'external' to the reference point.
2. Conductors downstream or 'internal' to the circuit from the reference point.

Figure 2 shows the earth fault loop for an active-earth short circuit. At the instant of the fault current will flow through the earth fault loop with its current magnitude limited by the total path impedance (Z_s) which is obtained from the sum of impedances of the individual elements.

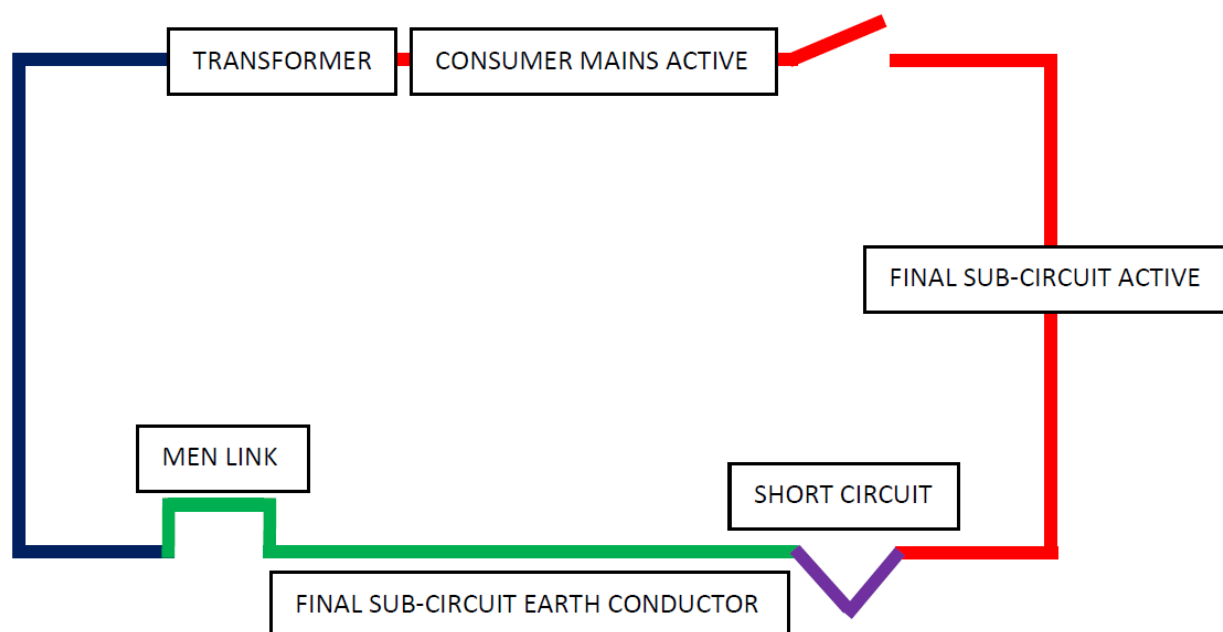


Figure 2 - Fault loop impedance schematic for an active to earth short-circuit

Requirements of the Australian Standards

AS/NZS 3000 Wiring Rules applies throughout Australia and New Zealand and is referenced in whole or in part in legislation in all states of Australia and in New Zealand. Therefore, the design and the installation of all electrical circuits in these regions must meet the minimum requirements of this Standard.

A basic safety requirement stated in AS/NZS 3000 is the protection of people from 'indirect contact' with live parts. Automatic disconnection of the power supply is the most common way of satisfying this requirement. However, there is a bit more to it than that.

To comply with the Wiring Rules each circuit in an electrical installation must be designed such that automatic disconnection of the power supply occurs within a specified time when a short-circuit of negligible impedance occurs between the active and protective earth conductor or other exposed conductive part anywhere in the electrical installation.

To fulfil this requirement of AS/NZS 3000 when an active to earth fault occurs, and this is the important bit, the total impedance of the fault loop path (consisting of all conductors, connections and contacts as well as the transformer windings) must be low enough to allow sufficient current to flow to ensure the protective device will operate within the specified time.

Therefore, the actual total earth fault loop impedance (Z_s) and maximum allowed fault loop impedance Z_{max} must be obtained.

Calculating the actual fault loop impedance (Z_s)

Total earth fault loop impedance (Z_s) is approximately equal to the sum of impedances of all of the circuit components in the fault loop impedance current path shown in Figure 2.

That is the total fault loop impedance is equal to:

$$Z_s = Z_{int} + Z_{ext}$$

The internal impedance (Z_{int}) is calculated as:

$$Z_{int} = \text{impedance of the active conductors} + \text{impedance of the earth conductors}$$

An accurate method that Cable Pro uses of determining impedance of the conductors in the earth fault loop path is to use the resistance and reactance data given in AS/NZS 3008.1 – Electrical Installations – Selection of Cables.

To calculate the external impedance (Z_{ext}) the rule from AS/NZS 3000 that at least 80 % of the nominal phase voltage will be available at the position of the protective device is used.

Calculating the maximum allowable impedance (Z_{max})

The actual fault loop impedance (Z_s) should be lower than the maximum allowed to ensure the circuit protective device will trip during a fault.

The maximum allowed fault loop impedance (Z_{max}) is calculated based on the rating of the protective device as follows:

$$Z_{max} = \frac{U_o}{I_a}$$

Where

U_o = Nominal phase voltage.

I_a = Current ensuring automatic operating of the protective device.

Z_{max} = Maximum earth fault loop impedance.

I_a for circuit breaker is the mean tripping current as follows:

Type B = 4 (typical) × rated current

Type C = 7.5 (typical) × rated current

Type D = 12.5 (typical) × rated current

I_a for fuses are appropriate mean values from AS 60269.1.

Note the actual trip multiplier value may vary and in Cable Pro software this value is changed to match the actual protective device setting.

The value of maximum earth fault loop impedance (Z_{max}) with respect to the actual total impedance (Z_s) may be used to determine the appropriate earth cable size (explained below).

Determining earth cable size

The earth cable size needs to be sufficient to ensure:

1. Appropriate earth fault loop impedance (Z_s).
2. Adequate current-carrying capacity for prospective earth fault currents for a time at least equal to the tripping time of the associated circuit protection (adiabatic equation).
3. Adequate mechanical strength.

The selection of the earth cable size is determined from either:

- (a) Tables in AS/NZS 3000 which provide conservative earth cable sizes with relation to the largest active cable size (or summation where there are parallel circuits).
- (b) By calculation – this requires the protective device details to be known.

Note: Appropriate earth fault loop impedance must always be ensured.

The [Cable Pro Web](#) software performs both (a) or (b). When the protective device details are not entered the program uses the conservative earth cable sizes given in AS/NZS 3000. On the other hand, when the protective information is entered it will use the more accurate calculation methods to determine earth cable size, which is usually smaller than the conservative size.

The AS/NZS 3000 Wiring Rules mandate that the Earth Fault Loop Impedance of a circuit within an electrical installation must comply with specific requirements to ensure safety.

The actual earth fault loop impedance (Z_s) (either measured or calculated) must be less than the maximum permissible (Z_{max}). The earth conductor size is determined with respect to earth fault loop impedance but also adequate short-circuit performance must be ensured by employing the adiabatic equation method from AS/NZS 3008.1.

[Cable Pro Web](#) is used to quickly and accurately calculate earth fault loop impedance and earth cable sizes in full compliance with the latest Australian Standards.