

Guide for fault currents

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1. Scope

This guide applies when electrical industry workers are required to perform work on or near low voltage electrical equipment where fault currents require the following to be considered:

- The correct selection of electrical equipment based on prospective fault current.
- The safety of persons working on or near energised electrical equipment where fault current may be a contributing factor to risk associated with the work.

This guide does not include work on high voltage equipment.

Recommendations in this guide relate to electrical arc flash hazards and electrical hazards.

Other workplace hazards and associated controls required are not covered within this guide but are to be identified and control measures implemented by risk assessment and subsequent application of the hierarchy of control.

2. Introduction

Electricity consumption has increased dramatically in commercial and industrial installations throughout Queensland. To meet this increased demand, it's common practice now for transformers which supply these installations to be installed beside the main switch-room. In some larger installations, additional transformers may be installed to supply specific equipment.

In these installations the prospective fault current is likely to be significantly increased. This hazard needs to be considered prior to any work being performed near energised parts.

The prospective fault current at any point in an electrical installation depends on the total impedance of all conductors, mains, sub mains and final subcircuit, between the transformer terminals and the fault location.

The magnitude of fault currents to be expected at transformer terminals will far exceed the rated output listed on the transformer manufacturer's nameplate. A 500 kVA transformer with a rated output of 695A could supply under certain conditions a short-circuit current as high as 18,500A.

All equipment in an installation including protective devices must be able to safely interrupt the calculated or limited fault currents which may be present. Guidelines to consider in designing an electrical installation are:

- all equipment must have the capacity to operate safely at the prospective fault current available at its installation point

or

- if fault current limiters are to be used, they must be selected to prevent fault conditions from exceeding a predetermined level (e.g. the maximum rating of equipment used in that part of the installation) and installed to comply with recommended standards, e.g. AS/NZS 3000:2018 Electrical installations 'Wiring Rules.'

Whatever method is chosen, the equipment must be able to clear a fault without damage to itself.

There are considerable dangers inherent in incorrect selection of equipment or improper installation of suitable equipment. The high levels of energy dissipated during faults involving high currents can extensively damage plant and could lead to injury for anyone working nearby.

Note: Where a definition has not been provided, refer to Electrical Safety Regulation 2013 section 9 dictionary, and/or AS/NZS 3000 section 1.4 definitions, and/or AS/NZS 4836 Safe working on or near low voltage and extra low voltage electrical installations and equipment section 1.4 terms and definitions, and/or the normative standard applicable to the installation.

3. Guidelines for selecting protective devices

3.1. Overview

Overcurrent protection is the main type of protection used in most electrical installations. Additional protection such as residual current devices or arc fault detection devices may be installed to augment other measures of basic protection at the customer's request or as required by the applicable standards.

Overcurrent protection requires:

- fuses or circuit breakers capable of carrying the rated current continuously
- short-duration low-level overloads should not cause operation
- protection must operate on any overload which persists long enough to cause circuit conductors to overheat
- protection must open the circuit before fault currents cause damage
- protection must be 'discriminative', isolating only the faulty circuit while other equipment remains unaffected.

Overcurrent protection devices may protect against overload or short circuit conditions, both of which must be properly understood and considered when designing new installations or adding to or altering existing ones.

Note: If high current levels could exist under short circuit conditions, it is essential to determine the level of prospective fault currents and install suitably rated protection equipment or use current limiters to reduce fault currents to an acceptable level.

3.2. Overload protection

The current rating of any protective device is determined by the current level it is capable of carrying continuously without deterioration. If the circuit current has been correctly calculated and the proper conductor size selected, then the protective device and conductors would be expected to carry this current continuously without deterioration.

If an overload occurs through an increase in loading, then a higher-than-normal current would flow through the protective device and circuit, causing increased temperature in the protective device which, in turn, would cause it to operate. In overloads, the current increase will be relatively

low compared with currents in a short circuit where the only limiting factors are the impedance before the fault and the fault impedance.

Operating time for protective devices under overloads may vary from 2 hours for a 125 % overload to 3 seconds for a 600 5% overload.

Any circuit protection device selected primarily for overcurrent protection must isolate the protected circuit only after a specific overload has been sustained for a predetermined time. Consider also the protective device's capacity to withstand the fault current which may exist at that part of the installation where the fault occurs. Methods of determining prospective fault currents are discussed later.

3.3. Short circuit protection

Short-circuit fault protection is achieved if the fuse or circuit breaker acts fast enough to open the circuit before the current can cause damage by overheating, arcing or mechanical stress. Furthermore, the protective device must be capable of opening the circuit, under these high current conditions, without suffering irreparable damage itself.

If the selected device can't handle the high fault current conditions, then the outcome normally is explosive and violent, because the very high energy levels cannot be contained within the device and are dissipated rapidly.

When a short circuit occurs in an electrical installation, factors limiting the current at the fault location include:

- capacity of the supply source
- transformer impedance
- circuit impedance (total of mains, submains and final subcircuit up to the fault location)
- whether fault current limiters have been installed.

4. Factors limiting fault current

4.1. Capacity of supply source

The energy released under short circuit fault conditions is governed by the capacity of the supply source.

The capacity of an electrical system and its supply source depends on its size in terms of the generators feeding it. A small portable generating set provides a limited capacity to cause damage under short circuit conditions. A large transmission system fed from several large generating stations provides the capacity to cause considerable damage.

The increased generating capacity of modern supply systems has led to an increase in the prospective current available at an electrical installation under short circuit conditions.

Note: While reference has been made only to short circuit currents, a portable generating set is just as lethal an electric shock hazard as is reticulated supply.

It's not uncommon today for protective equipment in electrical installations to have to withstand the effects of energy released by fault currents of 30,000A (30 kA) or more.

When a fault provides a path of negligible impedance in an electrical installation, large electromagnetic forces are developed, and great amounts of heat energy released due to the large currents flowing.

The operation of an electric welder demonstrates that even relatively low currents of around 100 A are capable of melting metal. It is not hard to visualise the damage thousands of amperes could cause if uncontrolled. This is an important consideration in designing and building electrical equipment and installations.

4.2. Transformer impedance

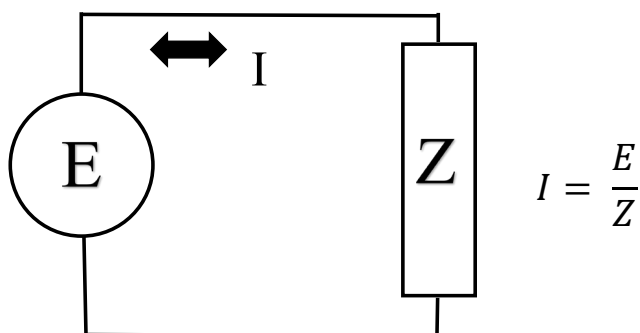
A transformer's impedance usually is expressed as a percentage of the primary voltage needed to circulate full load current in a short-circuited secondary. A 5 % impedance is common. It means that only 5 % of the normal primary voltage will produce full load current in the short-circuited secondary. It follows that, at normal voltage (neglecting any impedance on the line side of the transformer), a three-phase short circuit on the secondary side would result in a current twenty times as great as the full load current of the secondary winding.

4.3. Circuit wiring impedance

To understand why circuit impedance plays a critical a role in limiting current at a fault, let us go back to basic electrical theory. Ohm's law states that current is equal to voltage divided by circuit resistance.

Note: The overall resistance (Resistance, Inductive reactance and Capacitive reactance) in a.c. circuits is Impedance (Z). Some cable data references refer to this as a.c. resistance.

At a constant voltage of 230 volts, substituting various impedance values in this circuit demonstrates how dramatically current levels increase as impedance falls.



E – Electromotive Force in Volts

Z – Circuit Impedance in Ohms

I – Current in Amps

Figure 1 – Ohms Law (ac)

Then if:

Impedance below 0.01 Ohms is normal in industrial installations.

$Z = 10\Omega$	$I = 23A$
$Z = 1\Omega$	$I = 230A$
$Z = 0.1\Omega$	$I = 2300A$
$Z = 0.01\Omega$	$I = 23,000A$
$Z = 0.005\Omega$	$I = 46,000A$

4.4. Fault current limiters

Fault current limiters should be selected to limit instantaneous fault currents to a value within the capacity of the equipment being protected. In selecting suitable fault current limiters, consider:

- short circuit current available from the supply
- ratings and characteristics of the connected equipment
- ratings and characteristics of the protective equipment.

Where protective equipment is selected with a fault interrupting capacity less than the fault level at the installation point, it must be backed up by a device which will limit fault currents to a level the equipment can withstand safely. Typically, a HRC fuse or suitably designed circuit breaker is used as the fault current limiter (FCL) in these situations. Manufacturer data must be consulted, and only recommended devices used for fault current limiting as the devices must be compatible.

5. Determining prospective fault currents

5.1. Source current

Fault levels normally are expressed in megavolt-amperes (MVA) which is $\frac{kVA}{1000}$. This level can be calculated or obtained from the supply authority. When calculating fault levels, it is essential to know the kVA rating and impedance of the transformer supplying the installation.

A 500 kVA transformer with 4% impedance would produce a fault level of:

$$FL_s = \frac{Tr \times 100}{1000 \times Z\%} = \frac{500 \times 100}{1000 \times 4} = 12.5MVA$$

Alternatively, refer to Table 1 which gives details of full load current, short circuit output in MVA, and short circuit current for a range of transformers commonly used in Queensland.

Once the fault level has been determined, the prospective fault current can be calculated using the following methods:

- For a three phase load the prospective fault current in kA for a 500kVA transformer with 4% impedance is:

$$PFC = \frac{FL_s \times 1000}{\sqrt{3} \times VL} = \frac{12.5 \times 1000}{\sqrt{3} \times 400} = 18kA$$

- The prospective fault current can be calculated directly from the transformer rating using the formula:

$$PFC = \frac{Tr \times 100}{\sqrt{3} \times VL \times Z\%} = \frac{500 \times 100}{\sqrt{3} \times 400 \times 4} = 18kA$$

PFC = Prospective fault current in kA

VL = Voltage line – line

FL_s = Fault level at the source in MVA

$Z\%$ = The transformer impedance

Note: These formulas calculate the prospective fault current expected at the transformer terminals and neglects any impedance upstream of the supply transformer.

Alternatively, the prospective fault current in kA can be determined from the fault level conversion graph in Figure 2 or may be obtained from the transformer nameplate if visible.

The total kVA rating of two or more transformers in parallel is the sum of the capacity of all transformers. e.g. Three 500 kVA transformers equal 1500 kVA and the prospective fault current is 54 kA.

Table 1 – Common transformers

Transformer Rating (kVA)	Transformer Type	Transformer nominal impedance (%)	Maximum LV three phase fault current (kA)	Short circuit output (MVA)
25	Pole mount	3.30%	1.1	0.75
63	Pole mount	4.00%	2.3	1.575
100	Pole mount	4.00%	3.7	2.5
200	Pole mount	4.00%	7.4	5
315	Pole mount and pad-mount	4.00%	11.7	7.875
500	Pole mount and pad-mount	4.00%	18.5	12.5
750	Pad-mount	5.00%	22.2	15
1000	Pad-mount	5.00%	29.6	20
1500	Pad-mount	6.25%	35.6	24

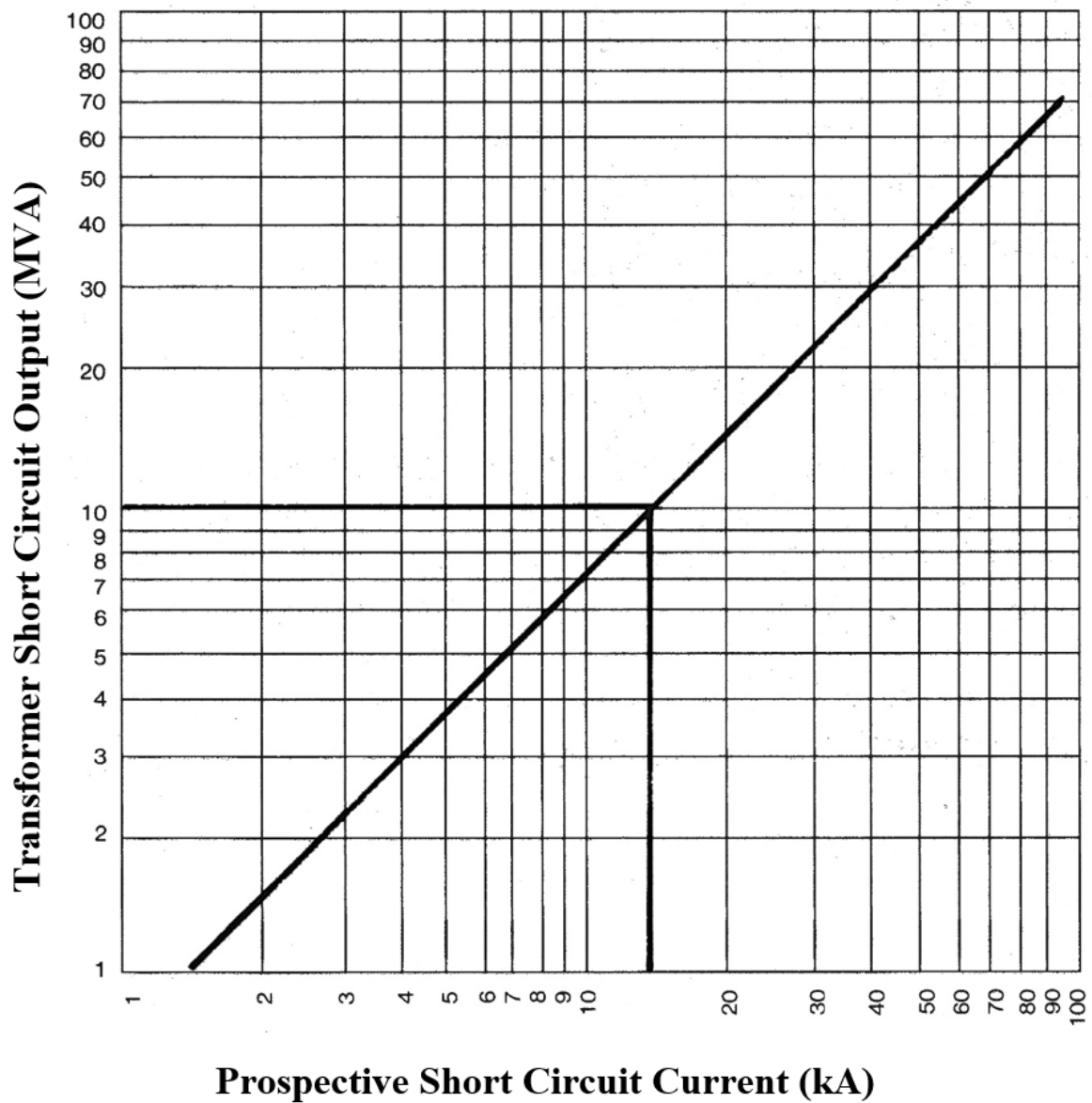


Figure 2 – Fault level conversion graph

If the only information available is the transformer's kVA rating and impedance, the prospective fault current can be determined using the short circuit current for transformer and impedance percentage graph in Figure 3.

Prospective short circuit levels of transformers

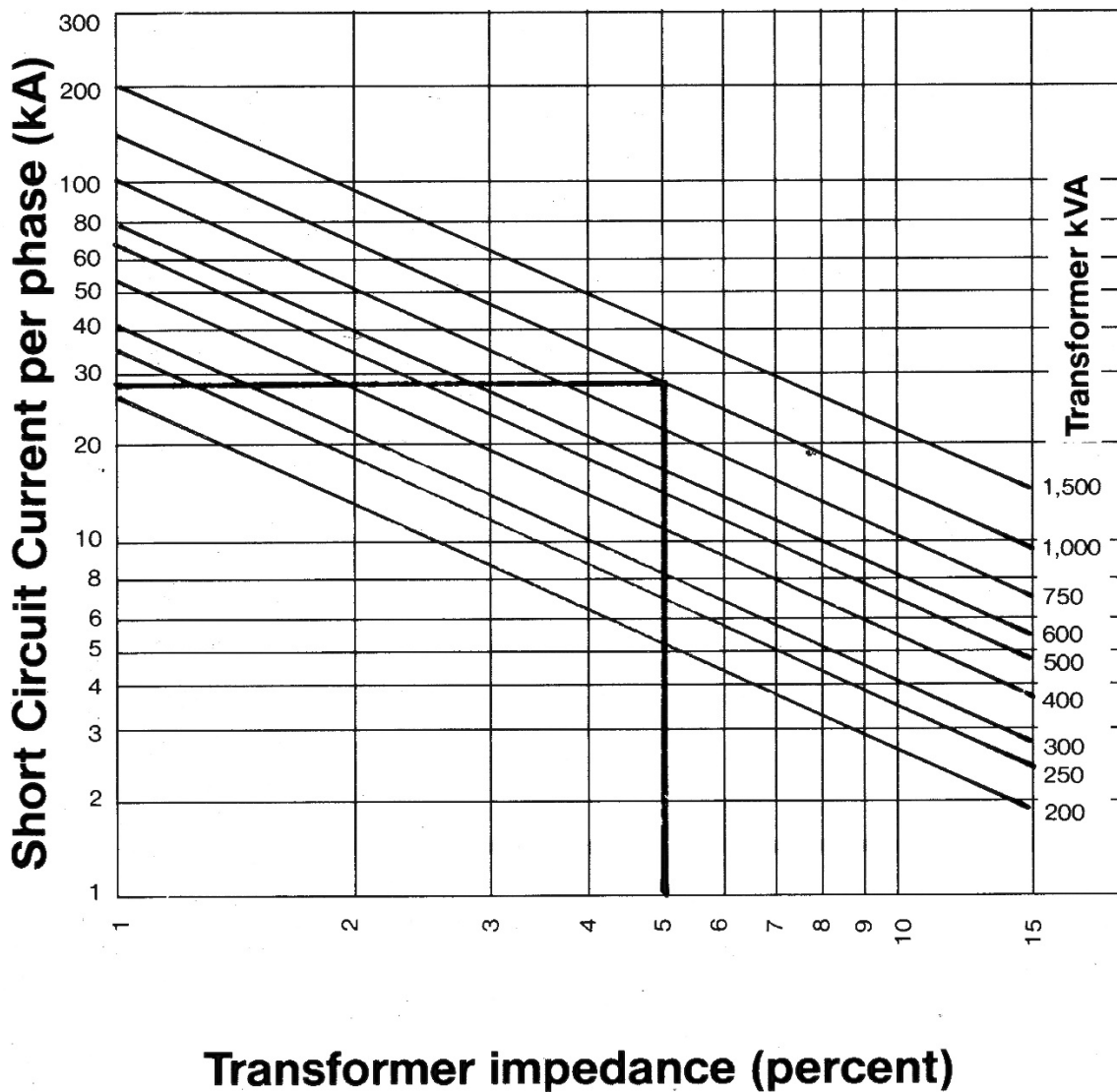


Figure 3 – Short circuit current for transformer and impedance percentage

5.2. Motors

Motors may contribute to short circuit current. Where a significant portion of the load is motor load, the motor short circuit contribution should be taken into account. A practical estimate of motor short circuit contribution is to multiply the total motor current in amps by 4.

6. Protecting electrical installations against damage from short circuit faults

Fault currents in an electrical installation are subject to limiting due to circuit impedance and/or the selection and installation of suitable fault current limiters.

6.1. Limiting fault currents due to circuit impedance

The prospective fault current at any point in an electrical installation depends on the total impedance of all conductors, mains, sub mains and final subcircuit, between the transformer terminals and the fault location.

Prospective fault currents are effectively lowered when circuit length is increased, cross sectional area of the conductors is decreased, or conductors of a higher impedance are used (for example: aluminium rather than copper).

These factors may introduce other difficulties such as reduced current carrying capacity, or increased voltage drop in the electrical installation. Excessive reduction may also increase fault loop impedance, where automatic disconnection used as a method of fault protection.

Appendix A provides cable resistance for various sizes of copper conductors at 20°C. Adjustments must be made as noted if aluminium cables are used (20°C is used as conductors may not be heavily loaded, and likely to be near ambient temperature. If conductor temperature is >45°C a.c. resistance values may be obtained from AS/NZS 3008.1.1:2017 Tables 34 - 39). Conductor reactance can be neglected for cable sizes under 150mm². If a more accurate result is required, or for larger cables, impedance may be calculated using the value of resistance at 20°C and reactance from AS/NZS 3008.1.1:2017 Electrical installations - Selection of cables, Table 30.

In a 3-phase circuit short circuit current at any point is given by:

$$I_{sc} = \frac{U^{20}}{\sqrt{3} \cdot Z_t}$$

I_{sc} = 3 phase short circuit current.

U^{20} = phase-to-phase voltage of the open circuited secondary winding of the power transformer. (For 400V system use 420V).

Z_t = total impedance per phase of the installation upstream of the fault location in Ω .

It is generally considered that three-phase faults provoke the highest fault currents. Calculation of I_{sc-3} phase is therefore essential for selection of equipment (maximum current and electrodynamic withstand capability). In the case of a fault between 2 phases, the fault is likely to develop into a 3-phase fault, thus the 3-phase calculation should be used.

Single phase to neutral faults can be calculated by:

$$I_{sc}^1 = \frac{U^1}{Z_1 + Z_n}$$

I_{sc}^1 = single phase line to neutral short circuit current.

U^1 = line-to-neutral voltage of the open circuited secondary winding of the power transformer.
(For 230V system use 243V).

Z_l = total line impedance of the installation upstream of the fault location in Ω .

Z_n = total neutral impedance of the installation upstream of the fault location in Ω .

Fault currents can be determined at any point in the customer's installation using Figure 4, a graph showing how prospective fault currents decrease as the conductor impedance increases.

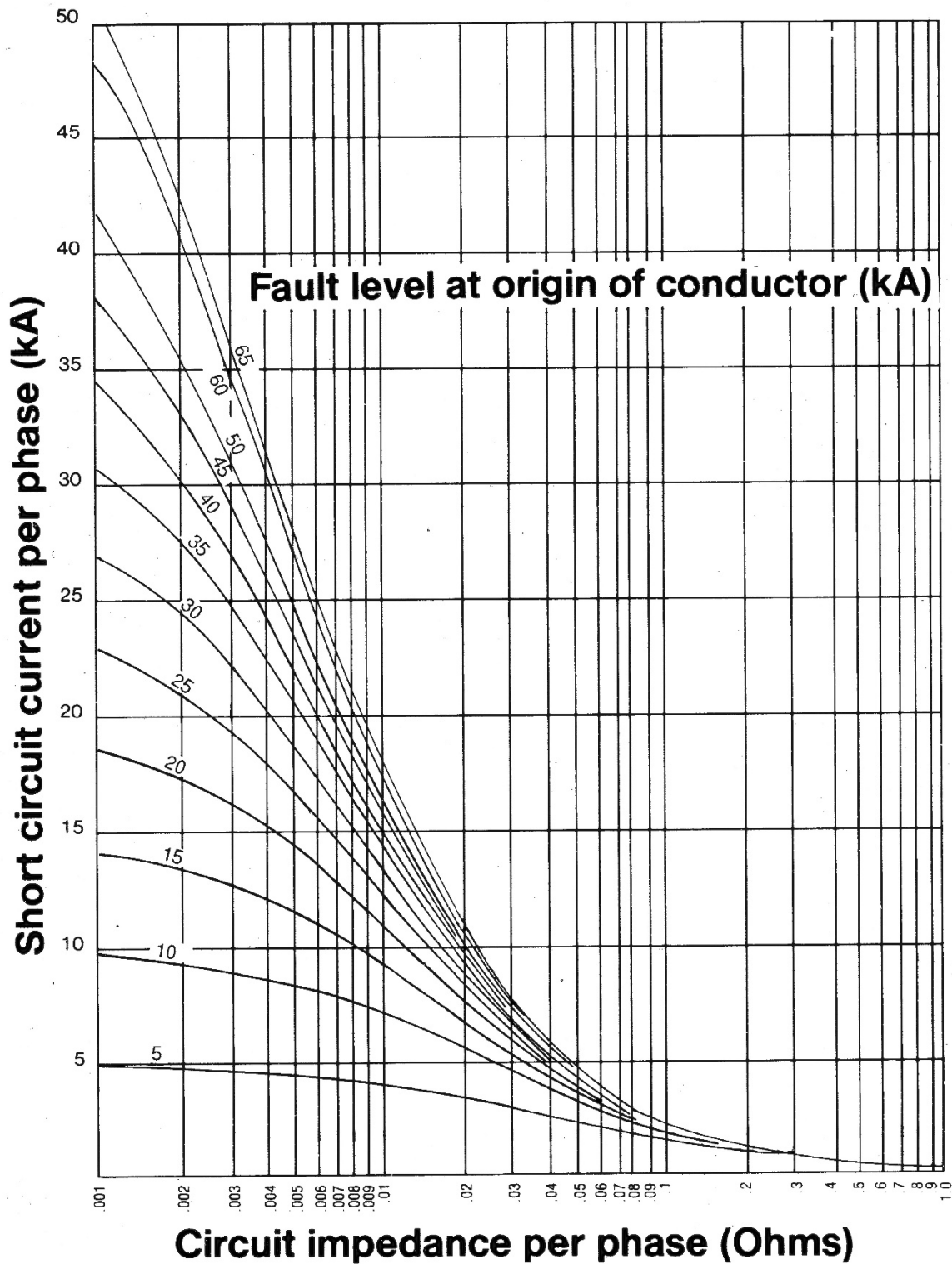
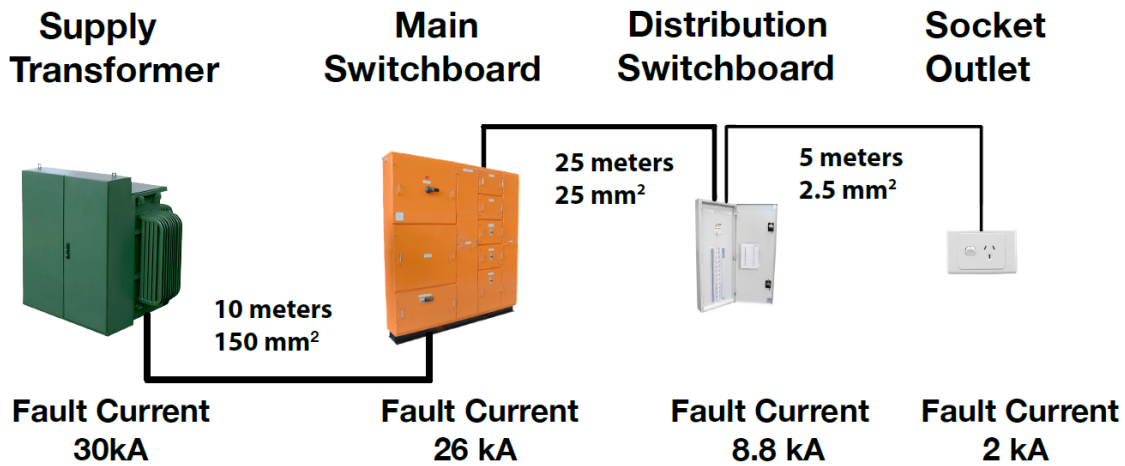


Figure 4 – Prospective short circuit levels

Example: Where the prospective fault current at the point of supply is 30 kA, what is the fault current at the end of a 5m final subcircuit consisting of 2.5mm² copper conductors, given that the consumer's mains consist of 10m of 150mm² cable, and the submain consists of 25m of 25mm² cable.



Section	Z_{SC} Ω	Z_{Ln} Ω	I_{SC} Single phase $I_{SC} = \frac{\frac{U}{\sqrt{3}}}{Z_{SC} + Z_{Ln}}$	I_{SC} Three Phase $I_{SC} = \frac{\frac{U}{\sqrt{3}}}{Z_{SC}}$
Supply Transformer phase $\frac{U}{\sqrt{3}} = \frac{420}{\sqrt{3}}$ $S_{SC} = \frac{30000}{\sqrt{3}}$	0.00807 *(sum of upstream resistance)	0.00	30kA	30kA
Mains (10m – 150mm ²)	0.00124 (0.00931)	0.00124	23kA	26kA
+ Sub Main (25m – 25mm ²)	0.01818 (0.02749)	0.01818 (0.01942)	5.16kA	8.8kA
+ Final Subcircuit (5m – 2.5mm ²)	0.03705 (0.06454)	0.03705 (0.05647)	2kA	3.75kA
Total Impedance	0.06454	0.05647	2kA	3.75kA
Note: Calculations based on cable resistance at 20°C from Appendix A. This calculation provides a conservative value as cable reactance has not been considered. Conductor reactance is neglected for cable sizes under 150mm². If a more accurate result is required, or for larger cables, impedance may be calculated using the value of resistance at 20°C and reactance from AS/NZS 3008.1.1:2017 Table 30. e.g. 150mm² $Z = \sqrt{R^2 + X^2} = \sqrt{0.124^2 + 0.0718^2} = 0.143\Omega/\text{km}$ I_{SC} = 3 phase short circuit current. U = phase-to-phase voltage of the open circuited secondary winding of the power transformer. (For 400V system use 420V). Z_{SC} = The impedance equal to all the impedances through which I_{SC} flows from the source to the fault. Z_{Ln} = The impedance of the neutral conductor through which I_{SC} flows from the source to the fault S_{SC} = Short circuit current available at the source (transformer).				

The fault current limiting effect of the consumer's mains is negligible because of larger cross-sectional area and shorter length, illustrating that the smaller the cable, the higher the impedance and greater the reduction in fault current.

6.2. Selecting suitable fault current limiters

HRC fuse backup protection

Equipment manufacturers provide technical details of the maximum HRC fuse size to use to limit fault current energy to a level that their protective equipment can withstand safely.

Circuit breaker backup (cascading)

The advent of high-interrupting capacity fault current limiting circuit breakers allows the backing-up of circuit breakers with insufficient interrupting capacity by circuit breakers which limit the 'let through' energy to a safe level.

In the event of a fault, both circuit breakers may operate.

This practice frequently is referred to as 'cascading' and, where used, must be installed in accordance with the manufacturer's cascading co-ordination instructions.

7. Determining when fault current limiting is required

Where necessary, fault current limiting equipment must be installed to protect the electrical installation. In general, where a HRC fuse rated up to 100A is installed, no additional fault current limiters need to be connected in the circuit(s) protected by that fuse. A HRC service fuse rated up to 100A will provide suitable fault current limiting to an electrical installation.

The installer of short-circuit protective devices must ensure that the requirements of AS/NZS 3000:2018+A3 Electrical installations 'Wiring rules', clause 2.5.4.2 are met.

Short circuit protective devices shall meet the following conditions:

- The breaking capacity shall not be less than the prospective short circuit current at the point where the device is installed.
- All currents caused by a short-circuit occurring at any point of a circuit shall be interrupted before the temperature of the conductors reaches the permissible limit.

8. d.c. fault current

There are many d.c. systems in use and their use is increasing with the increase in renewable energy systems. Previously d.c. systems were mostly used in industrial settings. With the advent of variable speed drives, it's use in industrial settings has decreased.

Common d.c. sources include, but are not limited to:

- photovoltaic (PV) modules and arrays
- battery Energy Storage Systems (BESS)
- capacitors
- power supplies

During arc flashes on d.c. systems, the current never crosses zero. For arc flashes on a.c. systems, the arc extinguishes each time the current wave goes through a zero crossing and must reignite to maintain the arc. In a d.c. system, there is no need to reignite the arc.

8.1. PV arrays

A domestic PV system may consist of individual strings connected to an inverter. Each of these strings are likely to have an open circuit voltage between 200Vdc and 1000Vdc. The short circuit current will normally be about 10Adc, dependent upon the individual module specifications. Two strings in parallel will produce about 20Adc. Whilst the system does not produce a high fault current, it can still pose a significant risk in the event of an arc fault. As short circuit current is not much higher than normal operating current, the arc will continue until the circuit is isolated or the arcing gap is increased to a point where the arc is no longer sustained.

In larger PV installations several PV strings may be paralleled. These systems generally operate at voltages between 1000Vdc and 1500Vdc. The available current may be 400Adc or more. A basic calculation supports that an array operating at 1500Vdc and 400Adc will dissipate 600kW of energy. Taking into account the duration of the fault, this has the potential to inflict serious injury on any person in close proximity, as well as significant property damage.

8.2. Batteries

Battery energy storage systems (BESS) have many uses, but their use in domestic and commercial settings for the purpose of renewable energy storage has increased. Whilst there are several technologies in use for BESS, the two common ones are Lead Acid and Lithium.

- **Lithium batteries:** These batteries may incorporate a battery management system to limit fault currents. Consult with the manufacturer prior to working on or near these systems. These batteries are configured for various voltage systems. Two commonly used voltages are 48Vdc and 400Vdc. Some lithium batteries are a.c. coupled batteries, where the battery incorporates a charge controller and inverter.
- **Lead Acid Batteries:** These batteries consist of several cells connected in series. Cells in common use, have short circuit currents ranging from 2kA to >16kA. The batteries may be paralleled for greater capacity, which will double the fault current. An arc initiated prior to the fuse will not disconnect and can be very destructive. The arc will have a high energy release and present considerable risk to any person in the vicinity.

AS/NZS 5139:2019 Electrical installations: Safety of battery systems for use with power conversion equipment, section 6.3.2 and Appendix F provide detailed information including calculations and tables regarding arc flash incident energy and arc flash boundary for battery systems.

8.3. Determining d.c. prospective fault currents

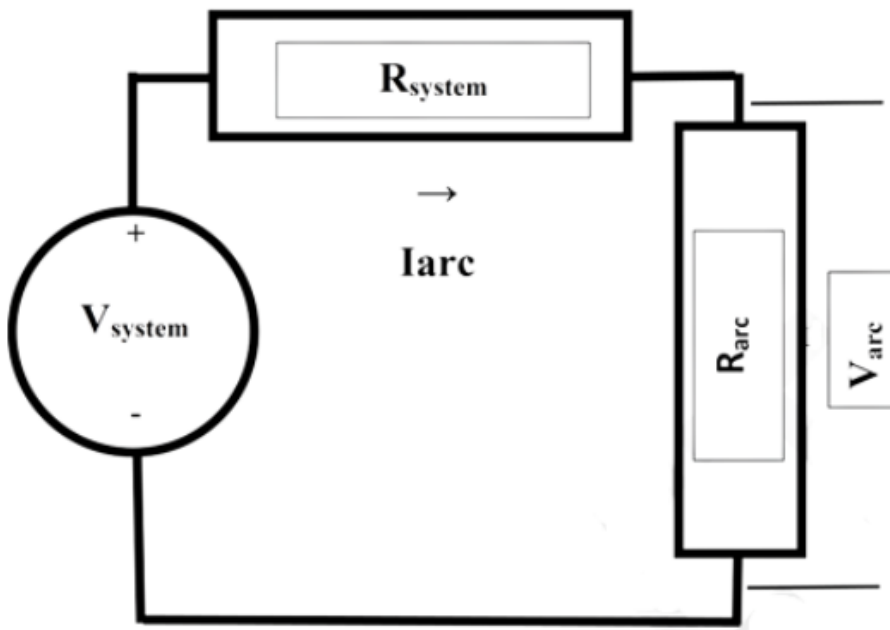


Figure 5 – Basic circuit of a d.c. arc

The power dissipation of a d.c. arc can be calculated as follows.

$$P_{arc} = \frac{V_{arc}^2}{R_{arc}}$$

In general, the maximum power is released when the resistance in the arc is equal to the resistance of the system. An example of this would be an arc resistance equal to the internal impedance of a battery.

Exception: Some energy sources are dynamic in their source impedance. An example of this is PV arrays where the power output is relative to the illuminance received by the array. In this case maximum power dissipation in the event of an arc should be assumed to be the sum of the maximum power point rating MPP of the PV modules capable of feeding the fault.

8.4. Example of energy release during a d.c. arc.

- 48Vdc battery
- 10 kA short circuit current
- Short near battery prior to fuse. Disconnection time is taken as reaction time for the person to move away from fault (2 seconds) as the arc will not disconnect
- Working distance 46 cm.

First calculate system resistance (R_{sys}) from System voltage (V_{sys}) and short circuit current (I_{sc}):

$$R_{sys} = \frac{V_{sys}}{I_{sc}} = \frac{48}{10,000} = 0.0048\Omega$$

Then arcing current (I_{arc}) is equal to:

$$I_{arc} = \frac{V_{sys}}{2 \times R_{sys}} = \frac{48}{2 \times 0.0048} = 5000A$$

In this case arcing time $T_{arc} = 2s$: Incident energy at maximum power (E_m) can now be calculated:

$$E_m = 0.02 \times R_{sys} \times I_{arc}^2 \left(\frac{T_{arc}}{D^2} \right) = 0.02 \times 0.0048 \times 5000^2 \times \left(\frac{2}{30^2} \right) = 2.26 \text{ cal/cm}^2$$

R_{sys} = System Resistance

V_{sys} = System Voltage

I_{sc} = Short circuit current

T_{arc} = Arcing time

D = Distance

E_m = Incident energy at maximum power

In this case the incident energy at maximum power is greater than 2.26 cal/cm^2 .

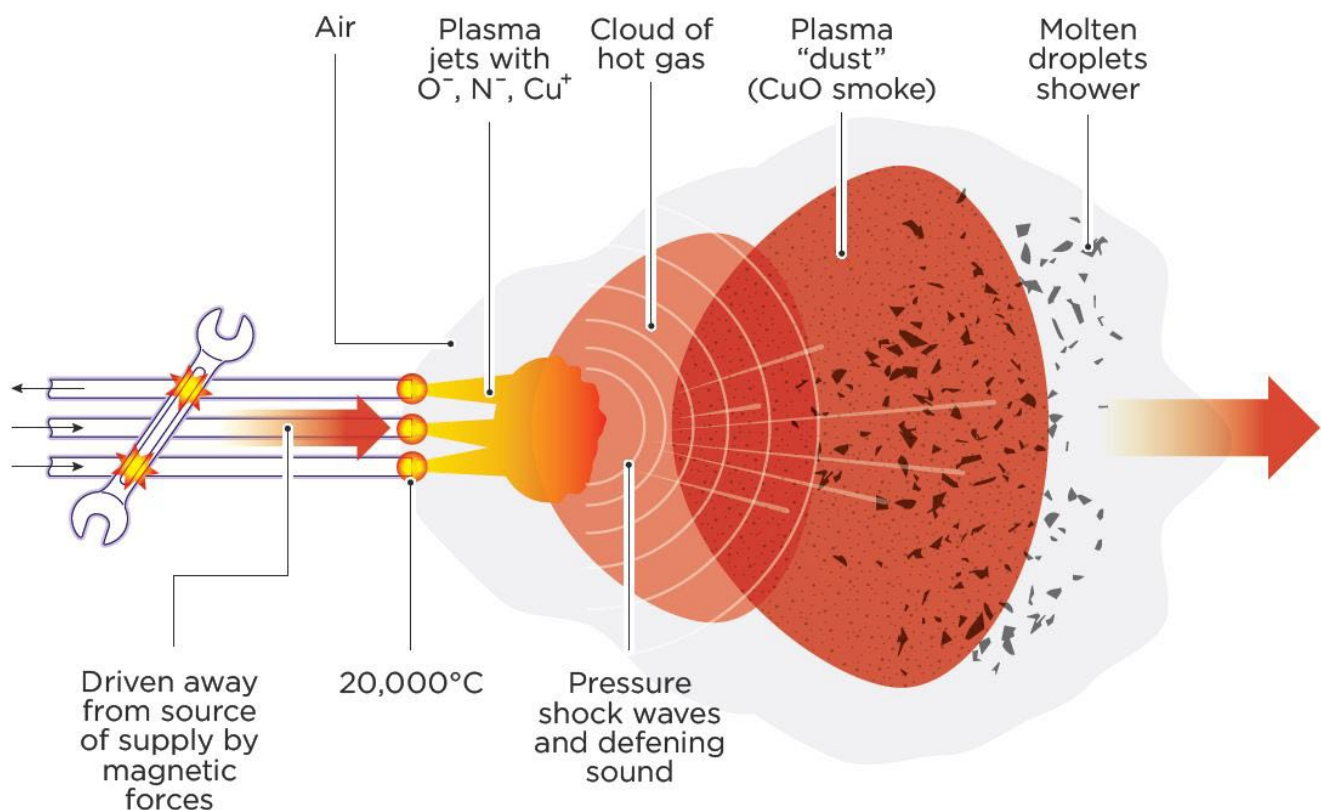
The incident energy as calculated is where the energy is dissipated in all directions. Where the arc is contained within an enclosure such as a battery enclosure preventing dissipation in all directions, the result is multiplied by 3. In this case the result would be $2.26 \times 3 = 6.78 \text{ cal/cm}^2$

If it is not possible to apply mitigation techniques to lower the incident energy, personal protective equipment (PPE) suitable for arc flash exceeding 6.78 cal/cm^2 must be worn.

9. What is an arc flash

Arc faults arise when current flows through the air between phase conductors or between phase conductors and neutral or ground. Put simply, an arc fault could be described as an unexpected, violent, electrical short circuit in the air that produces an arc and associated by-products.

When arc faults occur, the resulting energy released may be enough to seriously burn or otherwise injure nearby persons, ignite flammable materials (including clothing), and cause significant damage to plant and equipment.



Electrical arc flash hazard management guideline 2019 © Australian Energy Council. Used with permission.

Figure 6 – What is an arc flash

Any activity in the vicinity of energised conductors has the potential for arc flash, but arc flash most commonly happens when a person is working on or near an energised circuit or equipment (knowing it is energised or believing it is not). The risk increases by the degree of interaction with the energised equipment.

The safest way of working on any electrical installation is to isolate the work area from all sources of supply (i.e. supply authority mains, emergency standby plants and inverter energy systems). Before work is started, tests at the work location must prove conclusively that the area has been de-energised.

Note: Isolating the supply may involve work on or near energised equipment. An example is testing to prove de-energised as part of the isolation process is work on energised electrical equipment until the de-energisation is proved.

Testing instruments must be suitably rated for the prospective fault current, in good condition and tested to ensure correct operation prior to and after testing.

Working near energised electrical equipment is likely to have the same risk level as actually performing work on energised electrical equipment. The same process should be used to control the risks.

9.1. Identifying an arc hazard

Arcing faults may be caused by human error or equipment failure. Any location where a person is working on or near electrical equipment may present an arc hazard. The level of that hazard is proportional to the amount of energy available.

The amount of energy that strikes an individual from an arc event is referred to as incident energy and is usually measured in Joules/cm² or calories/cm² (cal/cm²).

Arc energy is the energy involved in the arc event. Incident energy is the energy that reaches an individual or surface at a distance from the arc.

A partial thickness (second degree) burn is possible by exposure of unprotected skin to an incident energy level of 5J/cm² (1.2 cal/cm²).

Incident energy, to which an individual may be exposed, should be estimated by one of the following methods:

- Calculations based on formulae in ENA NENS 09.
- Calculations based on the IEEE 1584 Guide for Performing Arc-Flash Hazard Calculations.
- In accordance with AS/NZS 4836:2023 Safe working on or near low voltage and extra low voltage electrical installations and equipment Table 11.2.

Consideration must be given to low fault currents as well as high fault currents as fault clearing times may be greater and result in higher total incident energy.

9.2. Calculating the incident energy

An electric arc has resistance. For low voltage faults the arc current may range between 25% and 95% of the bolted short circuit current. For the purpose of calculation, a value of 30% of the bolted short circuit current should be assumed as per AS/NZS 3000:2018+A3 Electrical installations 'Wiring Rules', clause 2.5.5.3.

The arc duration may be difficult to determine. Disconnection time may be determined from the protective device trip curve with reference to 30% of the bolted fault current.

Generally, a working distance of 450mm (approximately 18 inches) is assumed for calculations. This is used as the typical distance from the torso of an individual to the equipment being worked on or near. Incident energy increases rapidly as distance decreases.

The following is based on ENA NENS 09 and assumes that the individual is located at the end of the electrodes. This location has the highest incident energy.

$IE_{(cal/cm^2)}$ = Incident Energy (cal/cm²)

t = Fault Duration (seconds)

I_{rms} = Prospective symmetrical RMS three phase fault current (Amps)

r = Distance from arc (metres)

Copper electrodes

To calculate the incident energy:

$$IE_{(cal/cm^2)} = \frac{3.8 \times 10^{-4} \times t \times I_{rms}^{1.12}}{r^2}$$

To calculate the distance for specific incident energy:

$$r = \frac{0.01949 \times t^{0.5} \times I_{rms}^{0.56}}{IE_{(cal/cm^2)}^{0.5}}$$

Aluminium electrodes

To calculate the incident energy:

$$IE_{(cal/cm^2)} = \frac{4.4 \times 10^{-4} \times t \times I_{rms}^{1.12}}{r^2}$$

To calculate the distance for specific incident energy:

$$r = \frac{0.02098 \times t^{0.5} \times I_{rms}^{0.56}}{IE_{(cal/cm^2)}^{0.5}}$$

The incident energy for a single phase to earth fault will be approximately 1/3 of the three-phase calculated value.

Note: calories = Joules/4.184, Joules = calories x 4.184.

Incident energy calculation software is available from several sources.

For safe working procedures, refer to the Guide for safe working on or near energised electrical equipment.

10. Appendix

10.1. Appendix A: Cable resistance at 20°C

CABLE RESISTANCE AT 20°C (mΩ)									
Nominal area of conductor mm ²	Nominal Resistance at 20°C Ω/km	Length of cable (metres)							
		5	10	15	20	25	30	40	50
1.0	21.2	106	2.2	318	424	530	636	848	1,060
1.5	13.6	68	136	204	272	340	408	544	680
2.5	7.41	37.05	74.1	111.15	148.2	185.25	222.3	296.4	370.5
4	4.61	23.05	46.1	69.15	92.2	115.25	138.3	184.4	230.5
6	3.08	15.4	30.8	46.2	61.6	77	92.4	123.2	154
10	1.83	9.15	18.3	27.45	36.6	45.75	54.9	73.2	91.5
16	1.15	5.75	11.5	17.25	23	28.75	34.5	46	57.5
25	0.727	3.64	7.27	10.91	14.54	18.18	21.81	29.08	36.35
35	0.524	2.62	4.24	7.86	10.48	13.1	15.72	20.96	26.2
50	0.387	1.94	3.87	5.81	7.74	9.68	11.61	15.48	19.35
70	0.268	1.34	2.68	4.02	5.36	6.70	8.04	10.72	13.4
95	0.193	0.98	1.95	2.93	3.9	4.88	5.85	7.8	9.75
120	0.153	0.77	1.53	2.3	3.06	3.8	4.59	6.12	7.65
150	0.124	0.62	1.24	1.86	2.48	3.1	3.72	4.96	6.2
185	0.0991	0.5	0.99	1.49	1.98	2.48	2.97	3.96	4.96
240	0.0754	0.38	0.75	1.13	1.51	1.89	2.26	3.02	3.77
300	0.0601	0.30	0.60	0.90	1.20	1.50	1.80	2.40	3.01
400	0.0470	0.24	0.47	0.71	0.94	1.18	1.41	1.88	2.35
500	0.0366	0.18	0.37	0.55	0.73	0.92	1.10	1.46	1.83
630	0.0283	0.14	0.28	0.42	0.57	0.71	0.85	1.13	1.42
Calculated using data from AS 1125									

Scan to access other Electrical Safety Office resources



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