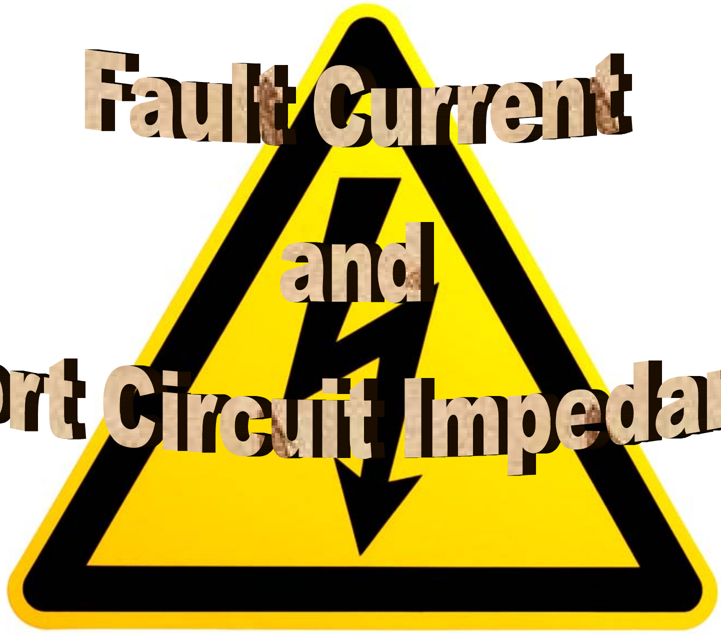
Fault Current and Short Circuit Impedance



An overview, in electrician's terms, with some examples.

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Short Circuits and Fault Levels

Basics

The basic electrical theorem (Ohm's Law) says the amount of current that will flow through a short circuit depends on two variable values,

- the system voltage and
- the connected total impedance of the current flow path from the source to the point of the fault.

The typical system voltages are very familiar to all of us. The connected total impedance of the short-circuit current flow path needs a little clarification, however.

This impedance normally includes the feeder conductors' resistance and reactance, any transformers' impedances (going from the point of fault back to the energy source), and any other equipment connected in the path of current flow.

Fig. 1

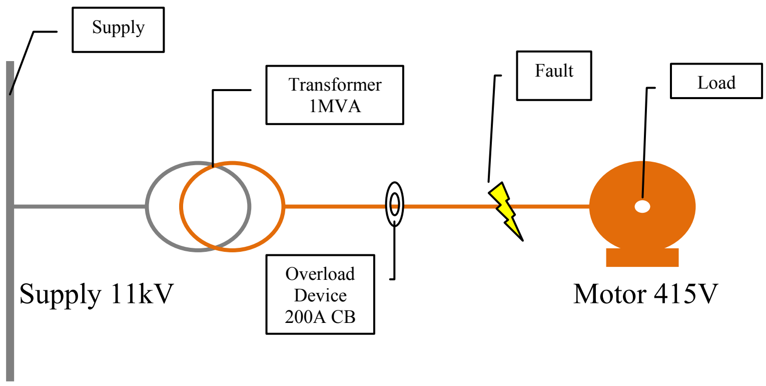


Fig. 1 is a very simplified one-line, with the following: a power source, transformer, and an overcurrent protective device (OCPD) having a specific short-circuit current interrupting rating and a load with a fault.

Let's talk about the power source first. In many short-circuit current calculation examples, you'll see references like "Assume the power source has infinite capacity" or "The source has an infinite bus." What does this mean, and why is it important to our sample calculation?

All that is being said in this case, is: "The source voltage has no or an extremely low internal impedance". Since the source has been assumed to have infinitesimal impedance of its own, the corresponding short-circuit current will be at its worst case.

Now let's look at the transformer. The impedance determining the amount of short-circuit current on its secondary, is made up of two separate impedances: Its own impedance plus that of the secondary conductors which run to the point of the fault.

The transformers own impedance is the amount of its own opposition to the flow of short-circuit current through it. Now, all transformers have impedance, and it's generally expressed as a voltage percentage.

This is the percentage of normal rated primary voltage, that must be applied to the transformer to cause full-load rated current to flow in the short-circuited secondary. (You remember that from TAFE) For instance, if a 11kV to 415V transformer has an impedance of 5%, this means that 5% of 11kV, or ≈550V, applied to its primary will cause rated load current flow in its secondary. If 5% of primary voltage will cause such current, then 100% of primary voltage will cause 20 times (100 divided by 5) full-load-rated secondary current to flow through a solid short circuit on its secondary terminals.

Obviously, then, the lower the impedance of a transformer of a given kVA rating,
The higher the amount of short-circuit current it can deliver.

Let's take another example for clarification. Suppose we have two transformers, each rated at 100kVA. Since they have the same rating, each has the same rated secondary load current.

Suppose one of the units has 10% impedance. It, therefore, can supply 10 times (100 divided by 10) its rated secondary load current into a short circuit on its secondary terminals.

Determine full-load secondary current (I_{Tx1}S). $$ITx1S = \frac{100\,000}{\sqrt{3}\times 415} = 140A$$

Determine the short-circuit current (I_{sub1}SC) at the transformer's secondary terminals per its impedance.

$$Isub1SC = (100\% \div \%Zsub1) \times Isub1S \qquad Isub1SC = (100 \div 10) \times 140 = 1400A$$

Now suppose the second unit has an impedance of 2%. This unit can supply a much greater multiple of its rated secondary load current into a short circuit on its secondary terminals: 50 times (100 divided 2) this value.

Determine full-load secondary current (I_{sub2}S). $$Isub2S = \frac{100\,000}{\sqrt{3}\times 415} = 140A$$ Same as before!

Determine the short-circuit current (I_{sub2}SC) at the transformer's secondary terminals per its impedance.

$$Isub2SC = (100\% \div \%Zsub2) \times Isub2S \qquad Isub2SC = (100 \div 2) \times 140 = 7000A \text{ or } 7kA$$

Comparing both units, the Sub 2 transformer can deliver five times as much short-circuit current as the Sub 1 transformer.

Now that we understand the basic variables that determine short-circuit currents, let's do a sample calculation.

Suppose we have a distribution system with a fault condition on our LV switchboard connected to our 1MVA unit.

For the sake of clarity and simplification, let's assume there are negligible line impedances between the transformer secondary and the fault.

Determine full-load secondary current (I_S). $$Is = \frac{1\,000\,000}{\sqrt{3}\times 11000} = 1391A$$

Determine the short-circuit current (Isc) at the transformer's secondary terminals per its impedance of 5%.

$$Isc = (100\% \div \%Z) \times Is \qquad Isc = (100 \div 5) \times 1391 = 27\,824A \text{ or } 27.824kA$$

Therefore, the Over Current Protective Device OCPD, must be capable of safely interrupting this amount of current, along with the asymmetrical current value (usually a 1.5 times the symmetrical value).
Then a 42kA or higher rating on the MCC would be required.

Admittedly, this is greatly simplified. In reality, the calculation would consider all impedances and the distance of the fault relative to the transformer. Nevertheless, it gives you a feel for what is involved in fault loop current analysis.

Alternate Methods of Calculation

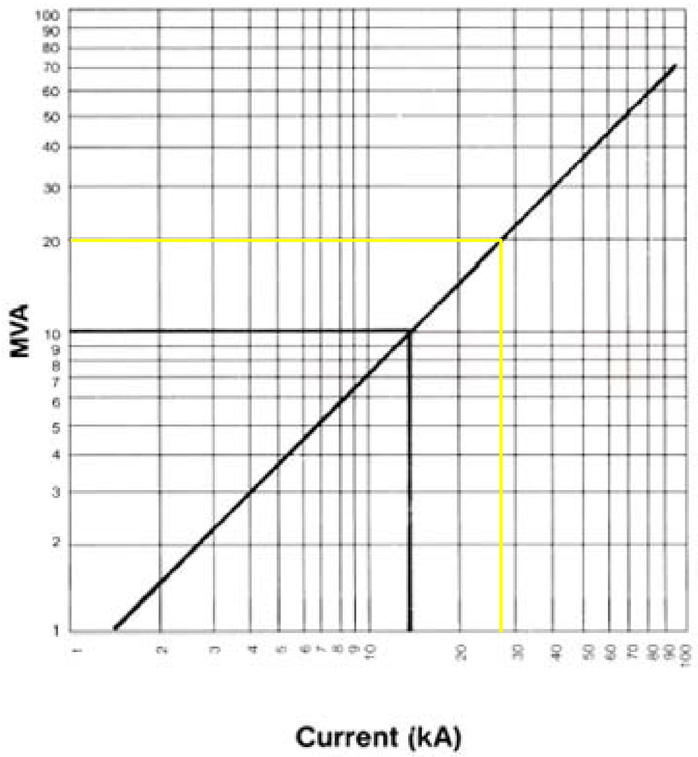
Alternatively, you can refer to the table below which gives details of full load current, short circuit output in MVA and short circuit current, for a range of transformers with 5% impedance.

Transformer capacity kVA	Secondary		
	Full load current A	Short circuit output MVA	Short circuit current A
200	278	4	5,560
250	348	5	6,950
315	421	6	8,690
400	556	8	11,120
500	695	10	13,900
750	1,043	15	20,860
1,000	1,390	20	27,800
1,500	2,086	30	41,700
Higher MV.A ratings (paralleled transformers)		25	34,700
		31	43,000
		35	48,700

Based on average 415V distribution transformer impedance of 5%

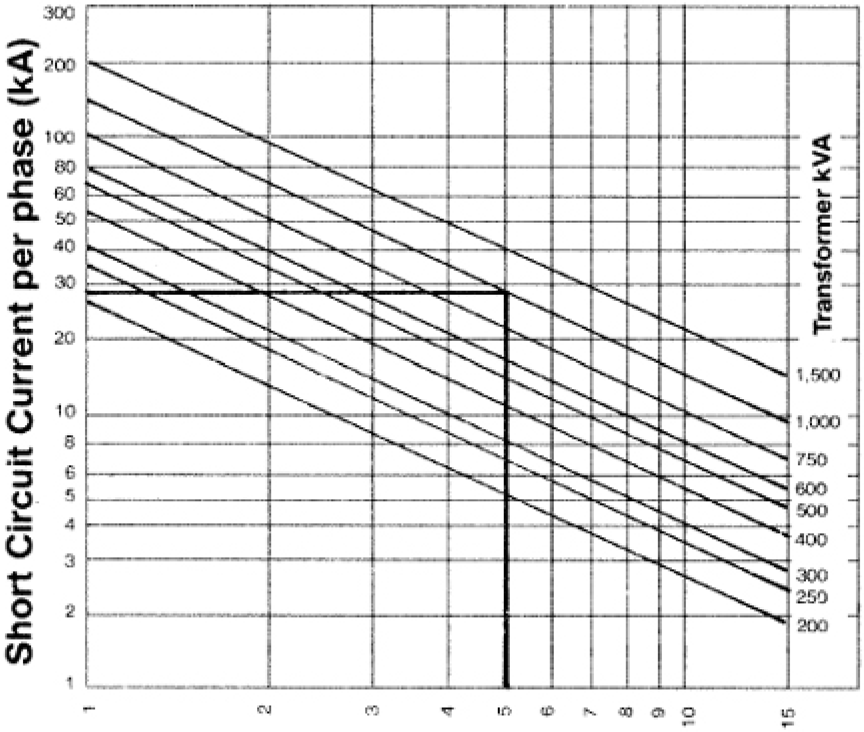
Alternatively, the prospective fault current in kA can be determined from the graph.

Conversion graph MVA Vs kA at 415 volts



Prospective short circuit levels of transformers

If the only information available is the transformer's kVA rating and impedance, maybe from the name plate, the prospective fault current can be determined from this graph.



Transformer impedance (percent)

For example a 1000 kVA (1MVA) transformer with 5% impedance could supply a fault current of approximately 28kA.

NOTE:
These are fault currents at the transformer terminals; the current will be affected by:
- cable impedance and
- installed current limiting devices.

The total kVA rating of two or more transformers, of the same type and impedance, in parallel is the sum of the capacity of all transformers

e.g. Three 500 kVA transformers equals 1500 kVA and the prospective fault current is 41.7 kA.

Limiting fault currents due to Circuit Impedance

The prospective fault current at any point in a 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 (e.g., aluminium rather than copper).

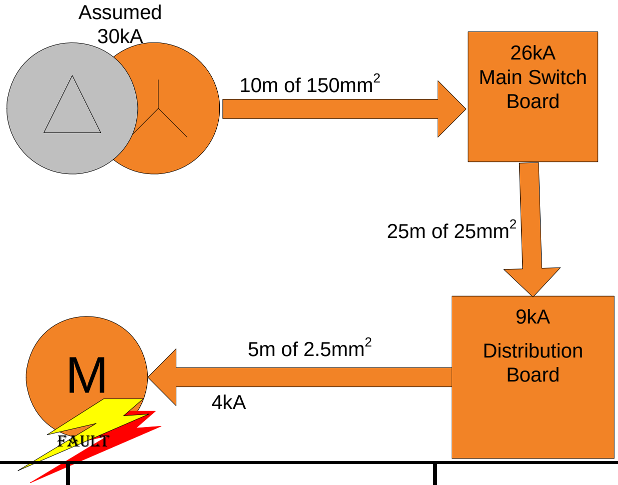
These factors may introduce other difficulties such as reduced current carrying capacity or increased voltage drop in the installation.

Appendix A, provides cable impedances for various lengths of copper conductors.

Fault currents can be estimated at any point in the installation using Appendix B, a graph showing how prospective fault currents decrease as the conductor impedance increases.

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 sub circuit consisting of 2.5mm^2 copper conductors, given that the consumer's mains consist of 10 m of 150 mm^2 cable and the sub main consists of 25m of 25mm^2 cable?



Impedance of	ZΩ	Size and length
Mains	=.0012	(10 metres 150 mm2)
Sub Mains	+.017	(25 metres 25 mm2)
Final Circuit	+.036	(5 metres 2.5 mm2)
Total Impedance	.0542 say .055 ohms	

from appendix b, fault current is reduced to 4ka.

note: fault currents at the end of each conductor in the circuit are: end of consumer's mains (0.0012 ohms) 26 ka, end of sub-mains (0.0182 ohms) 9 ka, end of final sub-circuit (0.055 ohms) 4 ka.

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.

Selecting suitable fault current limiters

When you are faced with the likely hood of installing equipment that may not have a high enough fault level capacity, you may be able to place an upstream high-interrupting capacity fault current limiting circuit breaker or a HRC fuse which will limit the level of fault current your equipment or lower level protection can manage.

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

b. **Circuit breaker backup (cascading)**
The use of high-interrupting capacity fault current limiting circuit breakers allows the backing up of lower level 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 or fuses and breakers may operate.

This practice frequently is referred to as "cascading" and, where used, should be installed in accordance with the CB manufacturer's cascading co-ordination instructions and designed to suit your installation.

I hope this has been of some interest and of some use. Don't forget this was just a brief, simplified outline of how and where the fault current values come from. This document should not be used for the design of an installation. That should always be done using all the engineering principles and by someone who is competent to do so.

Who said, "You can't teach an old dog, new tricks"?

We all learn something new every day!

Appendix A

Typical Cable Impedance = Resistance in straight runs, during Faults (ohms) – Copper

(Data from OLEX Little Orange Handbook and AS 1125)

AS 1125									
Nominal area of conductor mm^2	**Nominal Resistance at $20^oC/km$**	**Length of cable (metres)**							
		5	**10**	**15**	**20**	**25**	**30**	**40**	**50**
1	21.2000	0.10600	0.21200	0.31800	0.42400	0.53000	0.63600	0.84800	1.06000
1.5	13.6000	0.06800	0.13600	0.20400	0.27200	0.34000	0.40800	0.54400	0.68000
2.5	7.4100	0.03705	0.07410	0.11115	0.14820	0.18525	0.22230	0.29640	0.37050
4	4.6100	0.02305	0.04610	0.06915	0.09220	0.11525	0.13830	0.18440	0.23050
6	3.0800	0.01540	0.03080	0.04620	0.06160	0.07700	0.09240	0.12320	0.15400
10	1.8300	0.00915	0.01830	0.02745	0.03660	0.04575	0.05490	0.07320	0.09150
16	1.1500	0.00575	0.01150	0.01725	0.02300	0.02875	0.03450	0.04600	0.05750
25	0.7270	0.00364	0.00727	0.01091	0.01454	0.01818	0.02181	0.02908	0.03635
35	0.5240	0.00262	0.00524	0.00786	0.01048	0.01310	0.01572	0.02096	0.02620
50	0.3870	0.00194	0.00387	0.00581	0.00774	0.00968	0.01161	0.01548	0.01935
70	0.2680	0.00134	0.00268	0.00402	0.00536	0.00670	0.00804	0.01072	0.01340
95	0.1950	0.00098	0.00195	0.00293	0.00390	0.00488	0.00585	0.00780	0.00975
120	0.1530	0.00077	0.00153	0.00230	0.00306	0.00383	0.00459	0.00612	0.00765
150	0.1240	0.00062	0.00124	0.00186	0.00248	0.00310	0.00372	0.00496	0.00620
185	0.0991	0.00050	0.00099	0.00149	0.00198	0.00248	0.00297	0.00396	0.00496
240	0.0754	0.00038	0.00075	0.00113	0.00151	0.00189	0.00226	0.00302	0.00377
300	0.0601	0.00030	0.00060	0.00090	0.00120	0.00150	0.00180	0.00240	0.00301
400	0.0470	0.00024	0.00047	0.00071	0.00094	0.00118	0.00141	0.00188	0.00235
500	0.0366	0.00018	0.00037	0.00055	0.00073	0.00092	0.00110	0.00146	0.00183
630	0.0283	0.00014	0.00028	0.00042	0.00057	0.00071	0.00085	0.00113	0.00142

Appendix B

Prospective short circuit levels

From “High Fault Current Installations” DIR Qld.