

JUNE 2021

Welcome

Technical Sharing Session

Lionel Ng, Global Training Specialist

Short Circuit Calculation

IEC 60909

Short Circuit Calculation

IEC 60909

IEC 60909 Part 0 to 4

- Part 0
Calculation of currents
- Part 1
Factors for the calculation of short circuit currents according to Part 0.
- Part 2
Data of electrical equipment for short-circuit current calculations
- Part 3
Currents during two separate simultaneous line-to-earth short circuits and partial short-circuit currents flowing through earth
- Part 4
Examples for the calculation of short-circuit currents

Short Circuit Calculation

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IEC 60909-0

Short-circuit currents in three-phase a.c. systems

- Terms and definitions
- Short-circuit currents
- Calculating Assumptions
- Short-circuit impedances of electrical equipment



IEC 60909-0

Edition 2.0 2016-01

**INTERNATIONAL
STANDARD**

**NORME
INTERNATIONALE**

Short-circuit currents in three-phase a.c. systems –
Part 0: Calculation of currents

Courants de court-circuit dans les réseaux triphasés à courant alternatif –
Partie 0: Calcul des courants

Short Circuit Calculation

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Terms & Definitions

- Short-circuit

“Accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal or close to zero”
- Short-circuit current

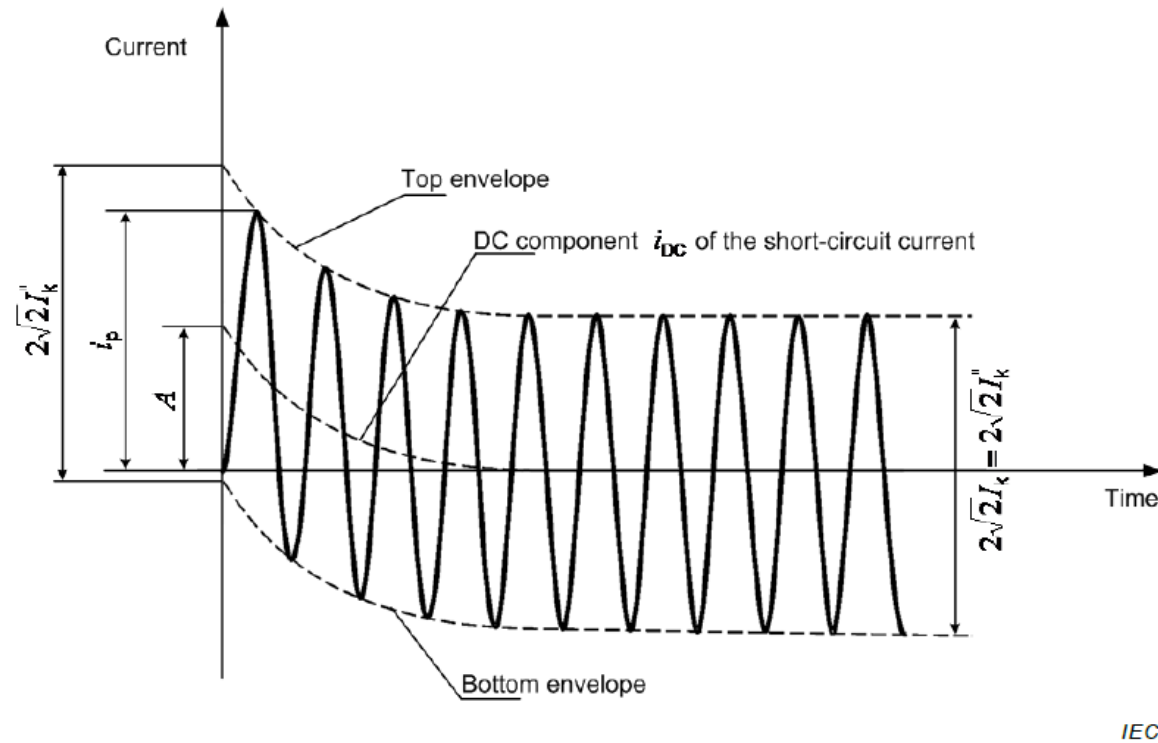
“Overcurrent resulting from a short-circuit in an electric system”
- Prospective short-circuit current

“Current that would flow if the short circuit were placed by an ideal connection of negligible impedance without any change of the supply”

Short Circuit Calculation

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Short-circuit currents



Key

- I_k'' initial symmetrical short-circuit current
- i_p peak short-circuit current
- I_k steady-state short-circuit current
- i_{DC} DC component of short-circuit current
- A initial value of the DC component i_{DC}

Short Circuit Calculation

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Short-circuit currents

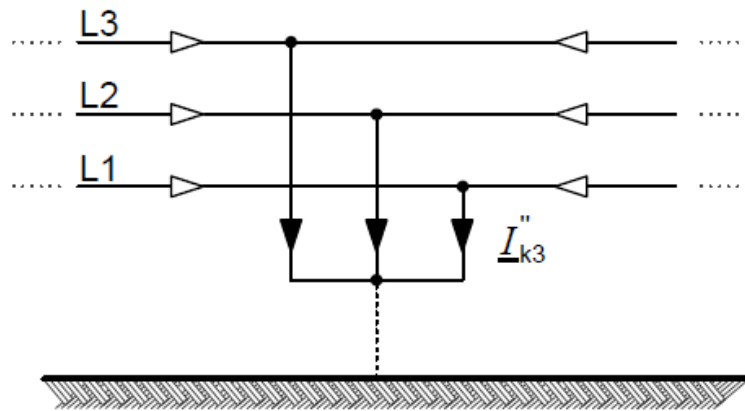


Figure 3a – Three-phase short circuit

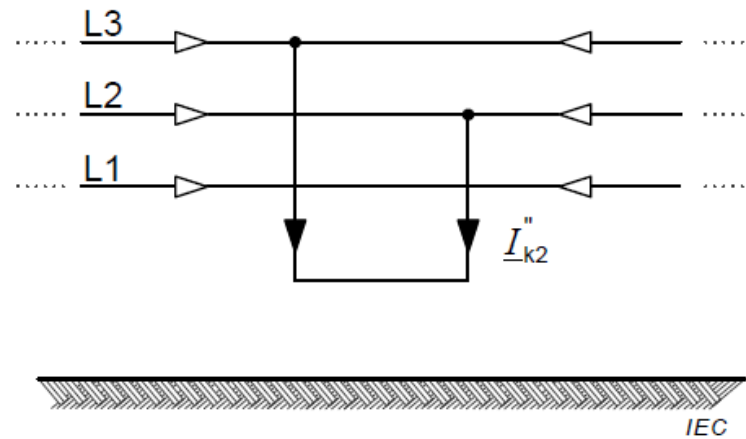


Figure 3b – Line-to-line short circuit

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Short-circuit currents

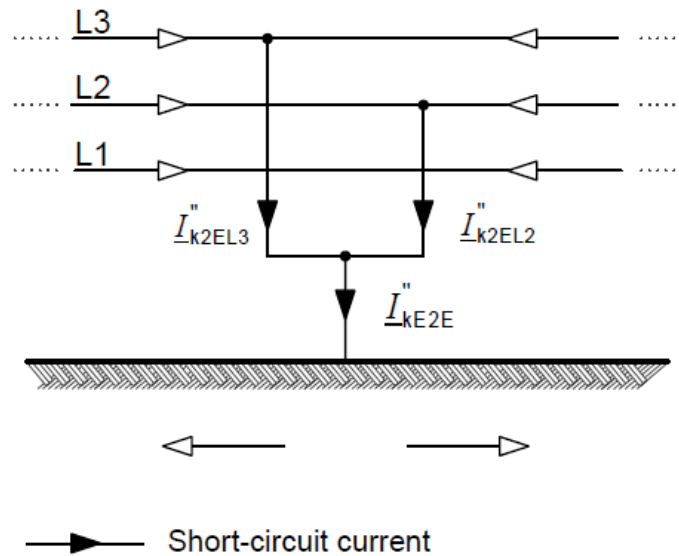


Figure 3c – Line-to-line short circuit with earth connection

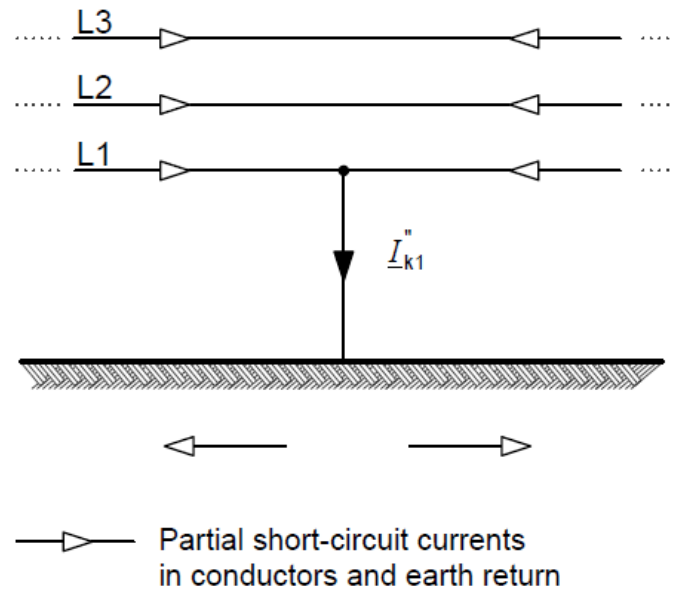


Figure 3d – Line-to-earth short circuit

IEC

Short Circuit Calculation

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Calculation assumptions

The calculation of maximum and minimum short-circuit currents is based on the following simplifications.

- For the duration of the short circuit there is no change in the type of short circuit involved, that is, a three-phase short-circuit remains three-phase and a line-to-earth short circuit remains line-to-earth during the time of short circuit.
- For the duration of the short circuit, there is no change in the network involved.
- The impedance of the transformers is referred to the tap-changer in main position.
- Arc resistances are not taken into account.
- Shunt admittances of non-rotating loads shall be neglected in the positive-, the negative and the zero-sequence system.
- Line capacitances shall be neglected in the positive- and negative-sequence system. Line capacitances in the zero-sequence system shall be taken into account in low-impedance
- Earthed networks having an earth-fault factor (see IEC 60027-1) higher than 1,4.
- Magnetising admittances of transformers shall be neglected in the positive and negative sequence system.

Short Circuit Calculation

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Method of calculation

Equivalent voltage source at the short-circuit location

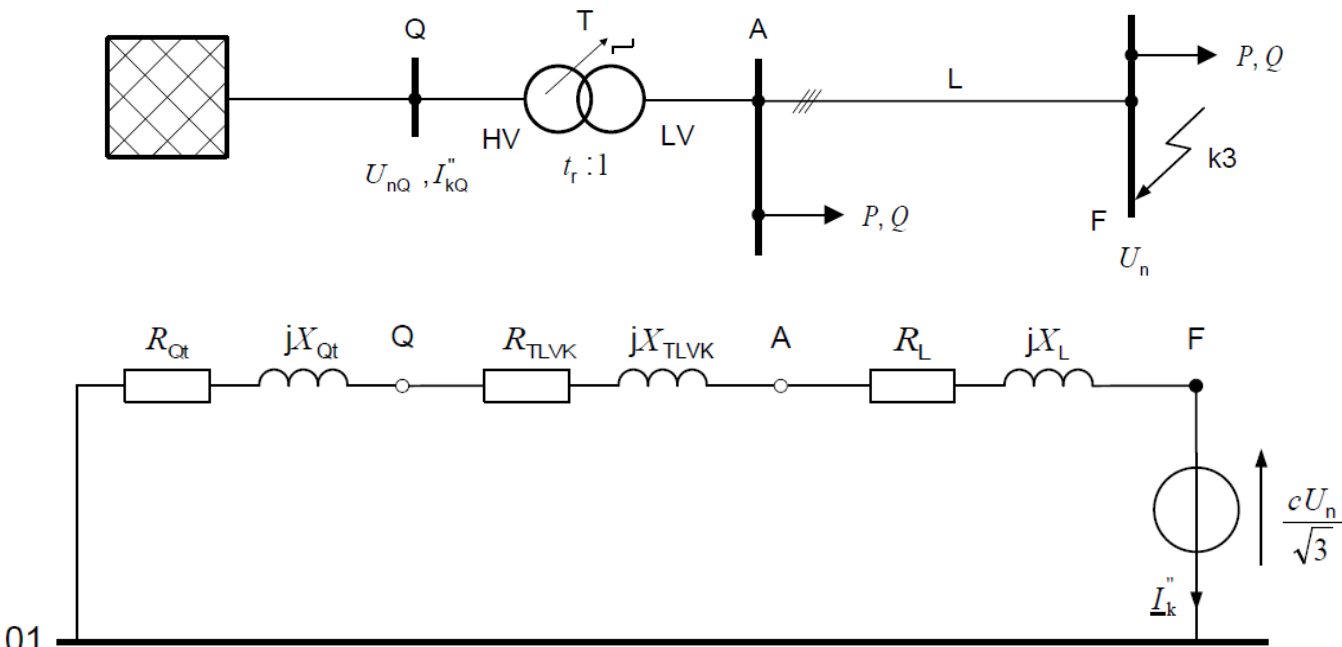


Table 1 – Voltage factor c

Nominal system voltage U_n	Voltage factor c for the calculation of	
	maximum short-circuit currents c_{\max}^a	minimum short-circuit currents c_{\min}
Low voltage 100 V to 1 000 V (IEC 60038:2009, Table 1)	$1,05^c$ $1,10^d$	$0,95^c$ $0,90^d$
High voltage ^b >1 kV to 230 kV (IEC 60038:2009, Tables 3, 4)	1,10	1,00

- ^a $c_{\max} U_n$ should not exceed the highest voltage U_m for equipment of power systems.
- ^b If no nominal system voltage is defined $c_{\max} U_n = U_m$ or $c_{\min} U_n = 0,90 \cdot U_m$ should be applied.
- ^c For low-voltage systems with a tolerance of $\pm 6\%$, for example systems renamed from 380 V to 400 V.
- ^d For low-voltage systems with a tolerance of $\pm 10\%$.
- ^e For nominal system voltages related to $U_m > 420$ kV, the voltage factors c are not defined in this standard.

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Short-circuit impedances of electrical equipment

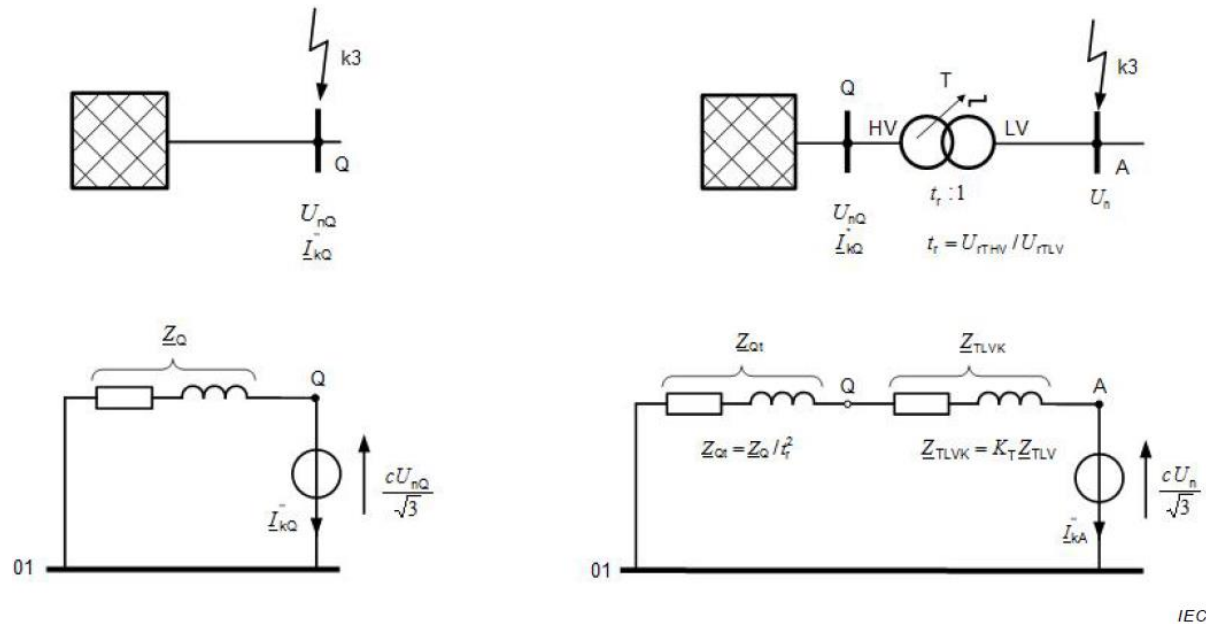


Figure 5a – Without transformer

Fig. 5b – With transformer

Figure 5 – System diagram and equivalent circuit diagram for network feeders

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Short-circuit impedances of two-winding transformer

The positive-sequence short-circuit impedances of two-winding transformers $Z_T = R_T + jX_T$ with and without on-load tap-changer can be calculated from the rated transformer data as follows:

$$Z_T = \frac{u_{kr}}{100 \%} \cdot \frac{U_{rT}^2}{S_{rT}}$$

$$R_T = \frac{u_{Rr}}{100 \%} \cdot \frac{U_{rT}^2}{S_{rT}} = \frac{P_{krT}}{3 \cdot I_{rT}^2}$$

$$X_T = \sqrt{Z_T^2 - R_T^2}$$

where

U_{rT} is the rated voltage of the transformer on the high-voltage or low-voltage side;

I_{rT} is the rated current of the transformer on the high-voltage or low-voltage side;

S_{rT} is the rated apparent power of the transformer;

P_{krT} is the total loss of the transformer in the windings at rated current;

u_{kr} is the short-circuit voltage at rated current in per cent;

u_{Rr} is the rated resistive component of the short-circuit voltage in per cent.

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Short-circuit impedances of Overhead lines and cables

The positive-sequence short-circuit impedance $Z_L = R_L + jX_L$ may be calculated from the conductor data, such as the cross-sections and the centre-distances of the conductors.

The effective resistance per unit length R'_L of overhead lines at the conductor temperature 20 °C may be calculated from the nominal cross-section q_n and the resistivity ρ :

$$R'_L = \frac{\rho}{q_n}$$

where

d is the geometric mean distance between conductors, or the centre of bundles:

$$d = \sqrt[3]{d_{L1L2} \cdot d_{L2L3} \cdot d_{L3L1}} ;$$

r is the radius of a single conductor. In the case of conductor bundles, r is to be substituted by $r_B = \sqrt[n]{nr^{n-1}}$, where R is the bundle radius (see IEC TR 60909-2);

n is the number of bundled conductors; for single conductors $n = 1$;

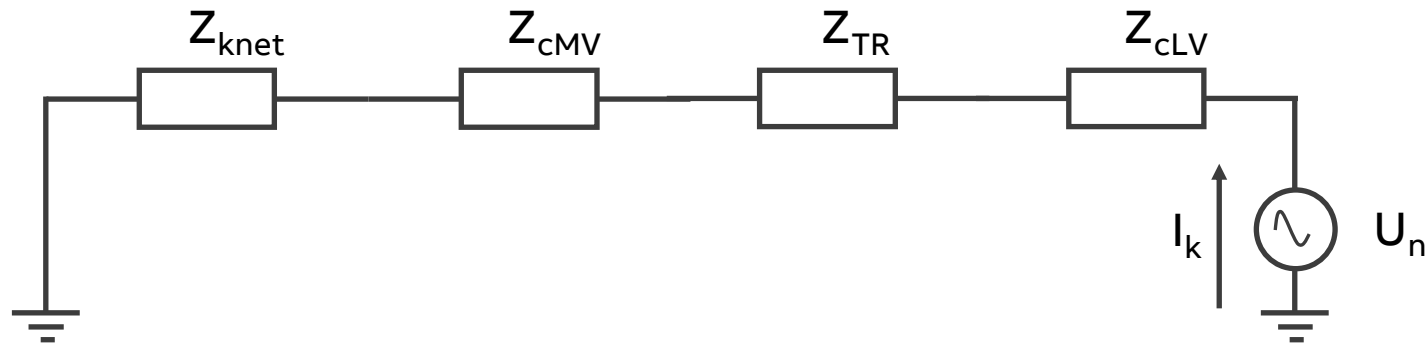
$$\mu_0 = 4\pi \cdot 10^{-4} \text{ H/km.}$$

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Calculation of Short circuit currents

The equivalent network is solved according to standard electro-technical rules (circuits in series / in parallel)



$$I_k = \frac{U_n}{\sqrt{3} \cdot (Z_{knet} + Z_{cMV} + Z_{TR} + Z_{cLV})}$$

Short Circuit Calculation

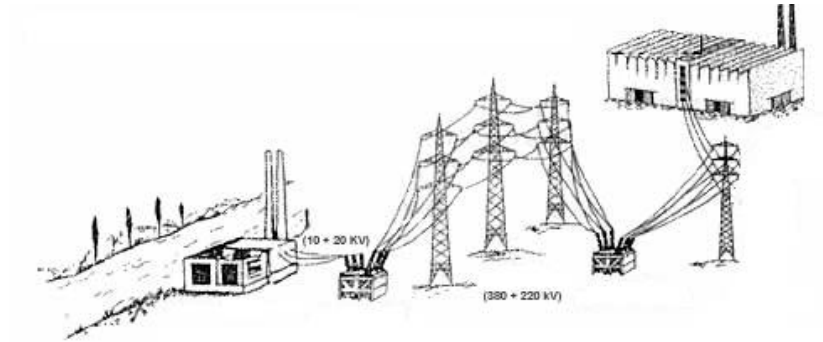
Basic Principles

Calculation of Short Circuit Currents

Distribution network

- It is necessary to know the network short-circuit power
 - From 250MVA to 500MVA $U_n \leq 30\text{kV}$
 - From 700MVA to 1500MVA $U_n > 30\text{kV}$
 - According to IEC 60076-5

$$Z_{\text{knet}} = \frac{U_n^2}{S_{\text{knet}}} = \frac{U_n}{\sqrt{3} \cdot I_{\text{knet}}}$$



Distribution network voltage [kV]	Short-circuit apparent power Current European practice [MVA]	Short-circuit apparent power Current North-American practice [MVA]
7.2–12–17.5–24	500	500
36	1000	1500
52–72.5	3000	5000

Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Generator short circuit impedance

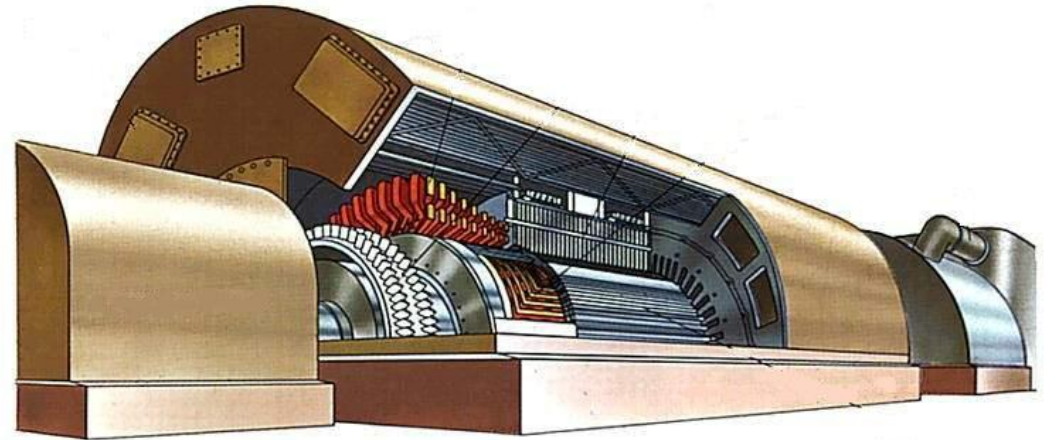
– It is necessary to know the

- Rated apparent power S_n
- Rated voltage U_n
- Subtransient reactance X''_d

from 10% to 20% smooth rotor (isotropic machines)

from 15% to 30% salient pole rotor (anisotropic machines)

$$X''_d = \frac{x''_d}{100} \cdot \frac{U_n^2}{S_n}$$



Short Circuit Calculation

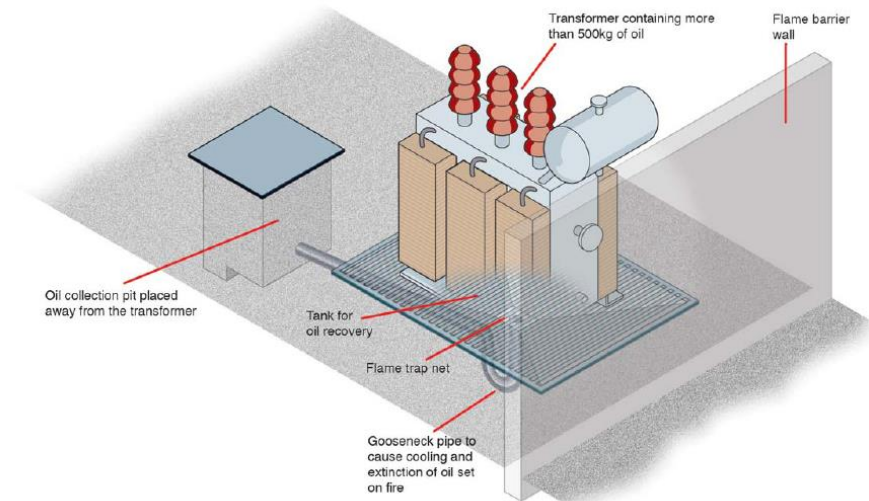
Basic Principles

Calculation of Short Circuit Currents

Transformers

- It is necessary to know the
 - Rated apparent power S_n
 - Primary rated voltage V_{1n}
 - Secondary rated voltage V_{2n}
 - Short-circuit voltage $u_{k\%}$ (Between 4% to 8%)
 - According to IEC60076-5

$$Z_{TR} = \frac{u_{k\%}}{100} \cdot \frac{U_{2n}^2}{S_n}$$



Rated apparent power S_n [kVA]	Short-circuit voltage $v_{k\%}$
≤ 630	4
$630 < S_n \leq 1250$	5
$1250 < S_n \leq 2500$	6
$2500 < S_n \leq 6300$	7
$6300 < S_n \leq 25000$	8

Short Circuit Calculation

Basic Principles

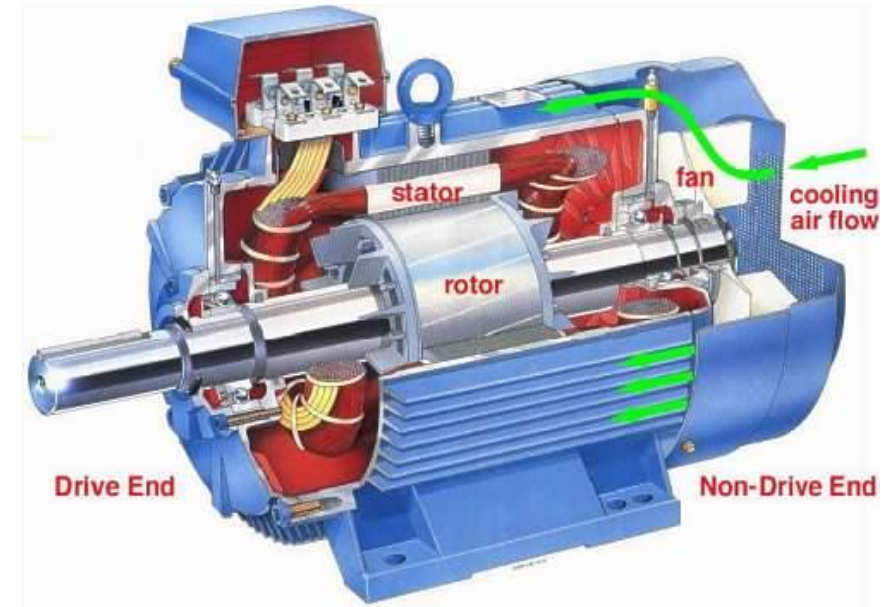
Calculation of Short Circuit Currents

Asynchronous motors

- In case of short-circuit it functions as a generator with a x''_d from 20% to 25%
- a current equal to 4-6 times the I_n can be assumed as contribution to the short-circuit
- the minimum criteria for taking into consideration the phenomenon

$$\left(\sum I_{nM} > \frac{I_k}{100} \right)$$

(I_k short-circuit without motor contribution)

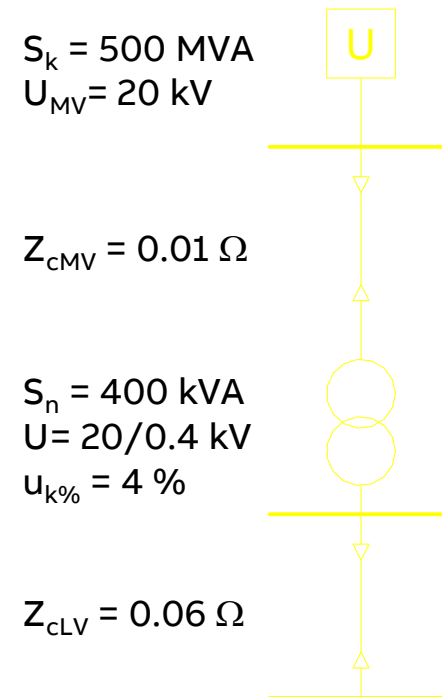


Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Example



Short Circuit Calculation

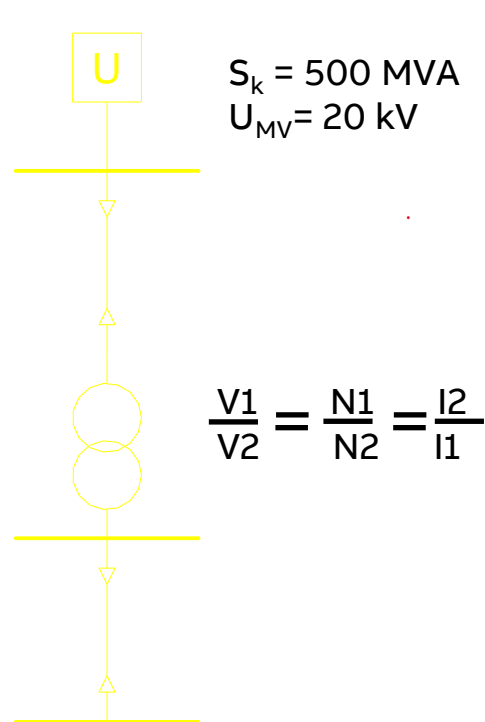
Basic Principles

Calculation of Short Circuit Currents

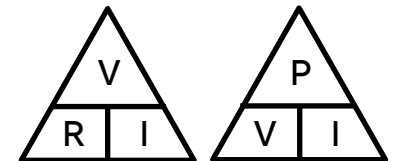
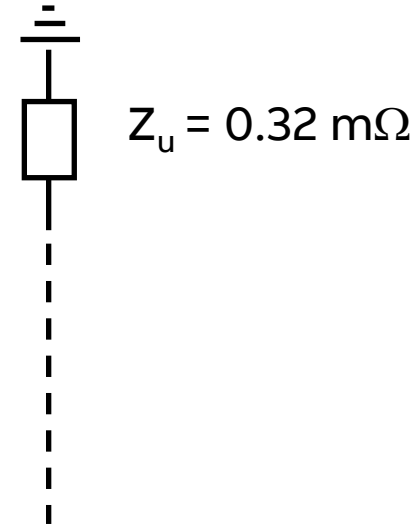
Example

$$Z_{u20kV} = \frac{U^2}{S_k} = \frac{(20 \cdot 10^3)^2}{(500 \cdot 10^6)} = 0.8 \Omega$$

$$Z_{u400V} = Z_{u20kV} \cdot \frac{(400)^2}{(20000)^2} = 3.2 \cdot 10^{-4} \Omega$$



$S_k = 500 \text{ MVA}$
 $U_{MV} = 20 \text{ kV}$



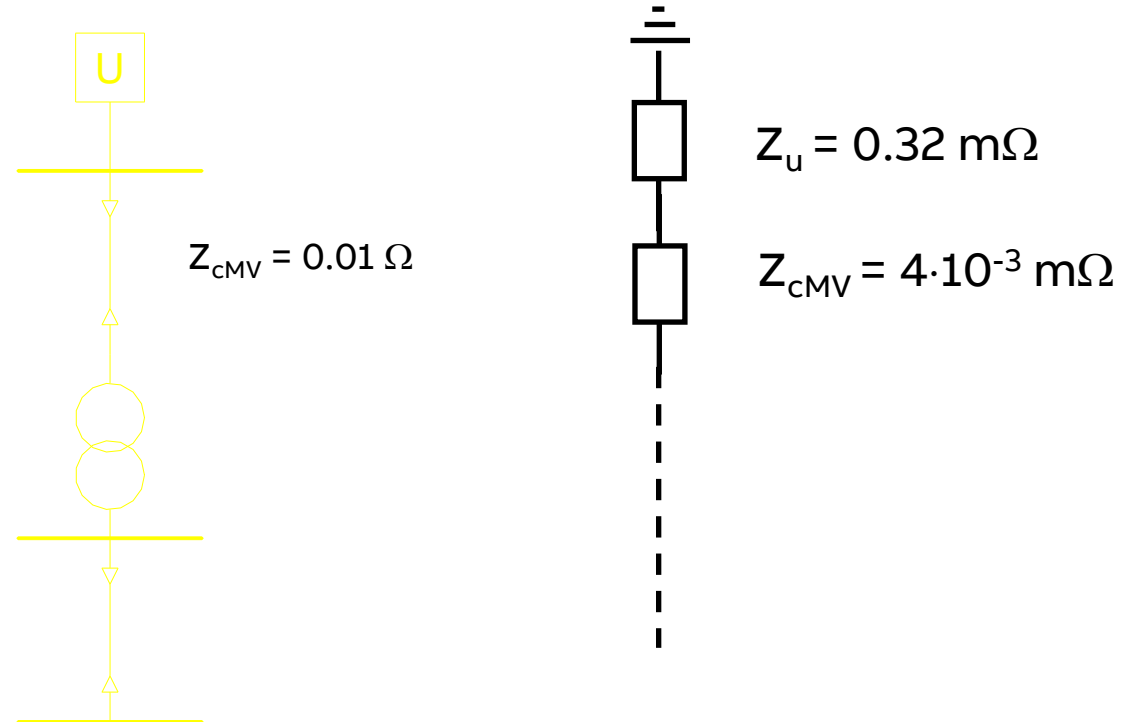
Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Example

$$Z_{\text{cMV } 400 \text{ V}} = Z_{\text{cMV } 20 \text{ kV}} \cdot \frac{(400)^2}{(20000)^2} = 4 \cdot 10^{-6} \Omega$$



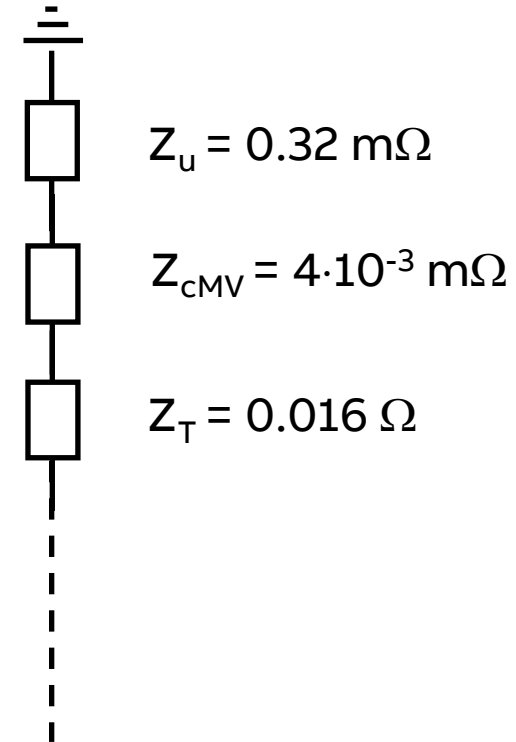
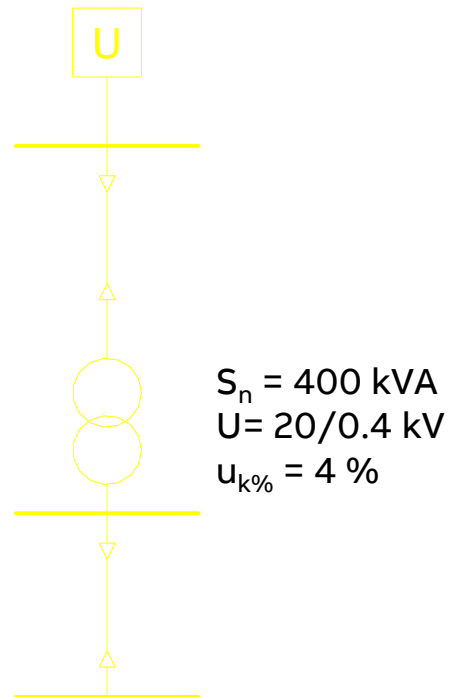
Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Example

$$Z_T = \frac{u_{k\%}}{100} \frac{U_{nLV}^2}{S_n} = \frac{4}{100} \cdot \frac{(400)^2}{400 \cdot 10^3} = 0.016 \Omega$$

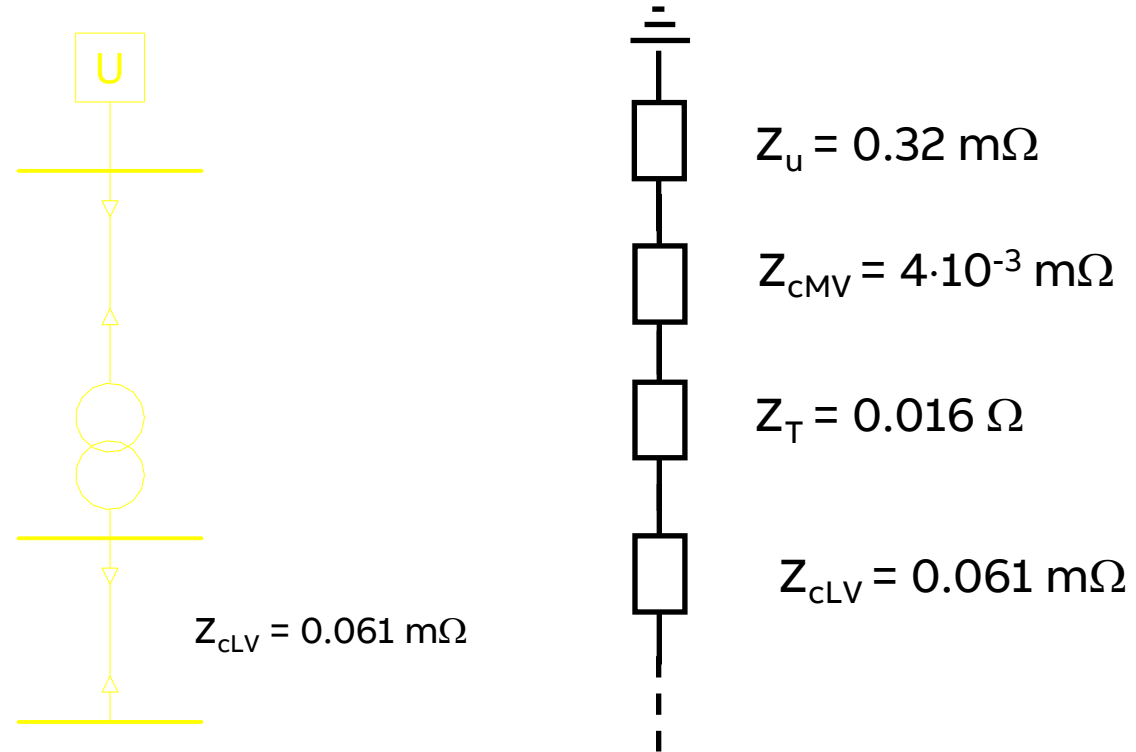


Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Example



Short Circuit Calculation

Basic Principles

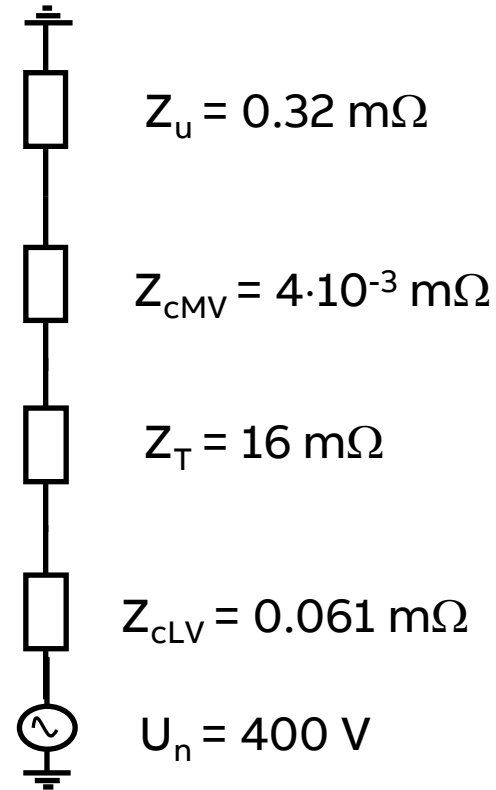
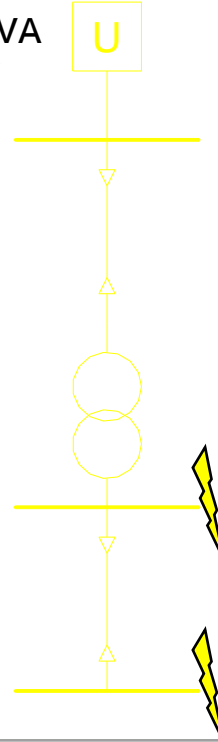
Calculation of Short Circuit Currents

Example

$$I_k = \frac{U_n}{\sqrt{3} \cdot (Z_u + Z_{cMV} + Z_T)} \cong 14.1 \text{ kA}$$

$$I_k = \frac{U_n}{\sqrt{3} \cdot (Z_u + Z_{cMV} + Z_T + Z_{cLV})} \cong 13.6 \text{ kA}$$

$S_k = 500 \text{ MVA}$
 $U_{MV} = 20 \text{ kV}$

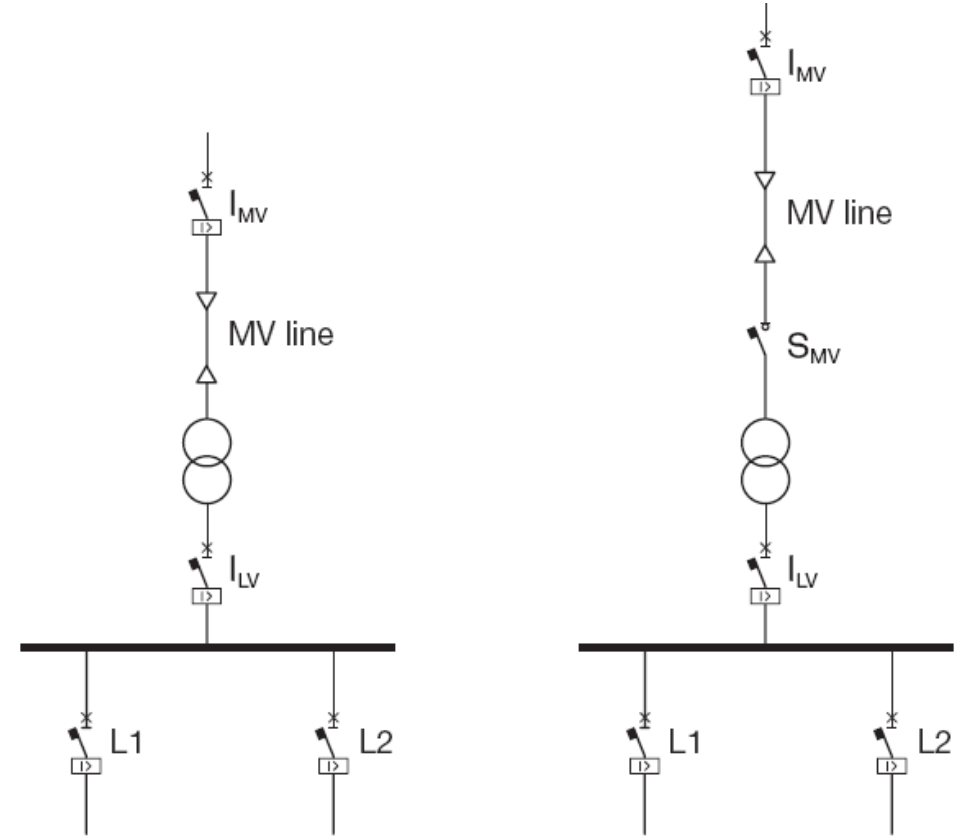


Short Circuit Calculation

Basic Principles

Common Management Methods

Substation with single transformer
Typical single line diagrams



Short Circuit Calculation

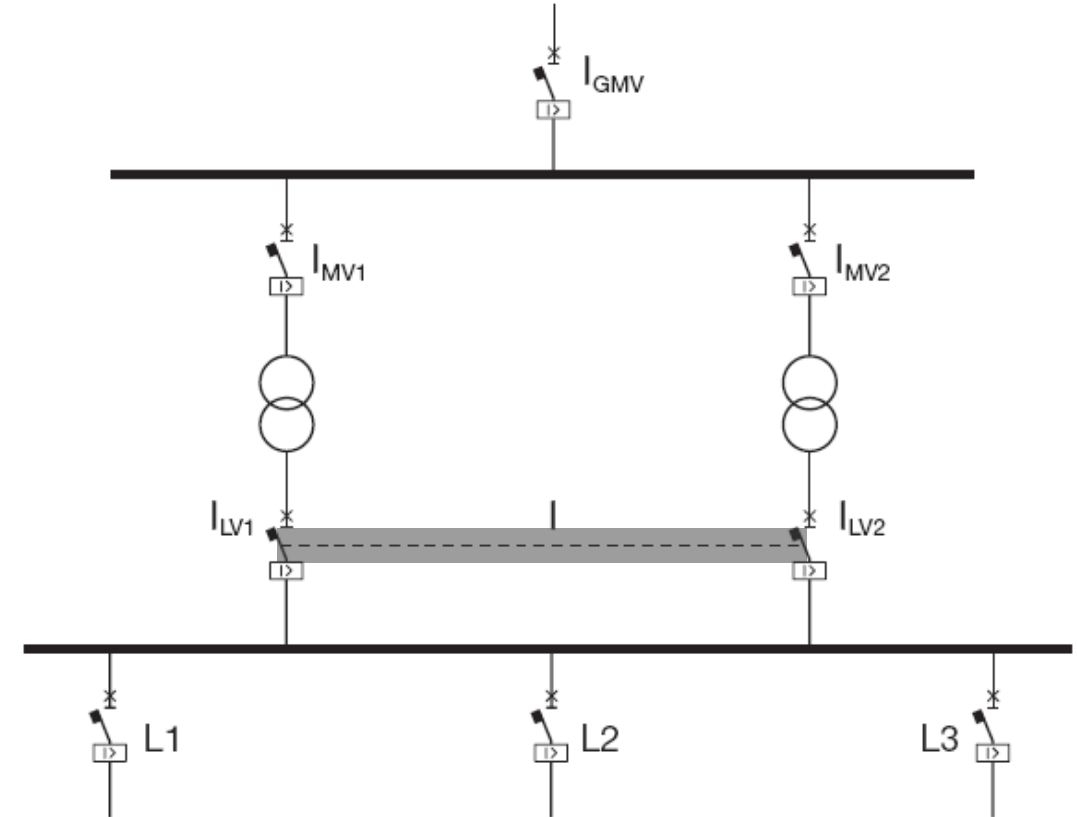
Basic Principles

Common Management Methods

Substation with two transformers

(One as spare for the other)

- The use of mechanical interlock between two ACBs

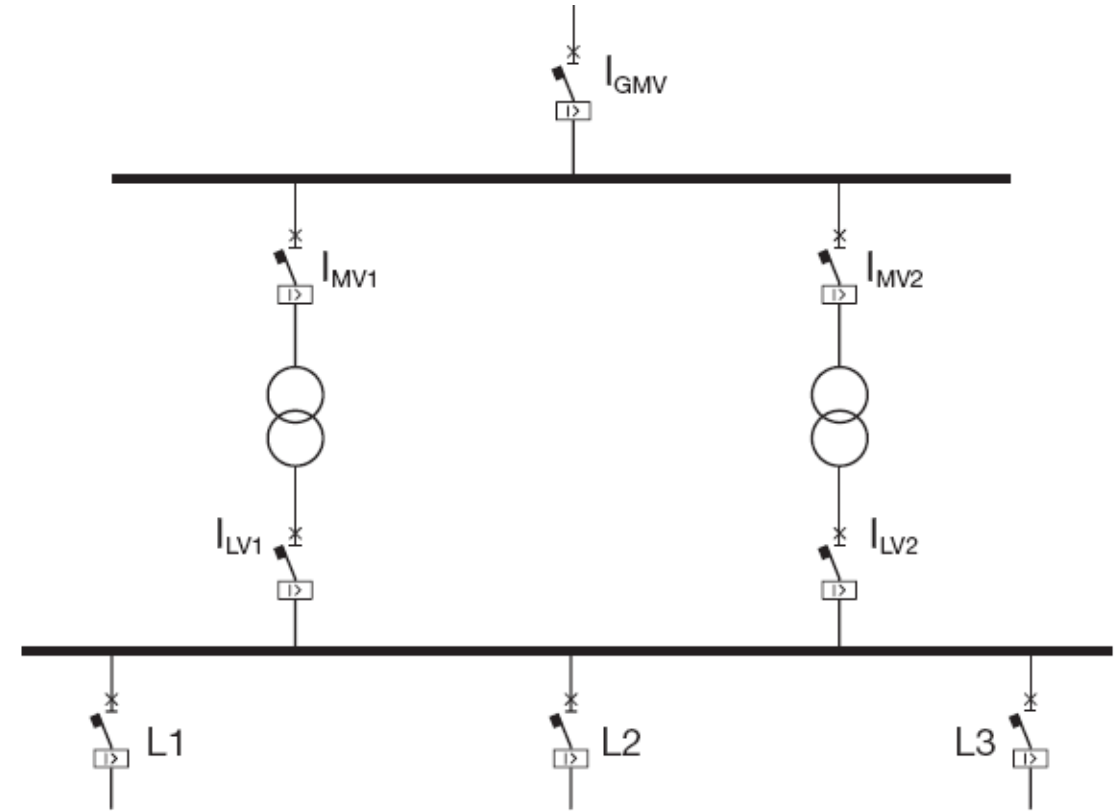


Short Circuit Calculation

Basic Principles

Common Management Methods

Substation with two transformers which operate in parallel



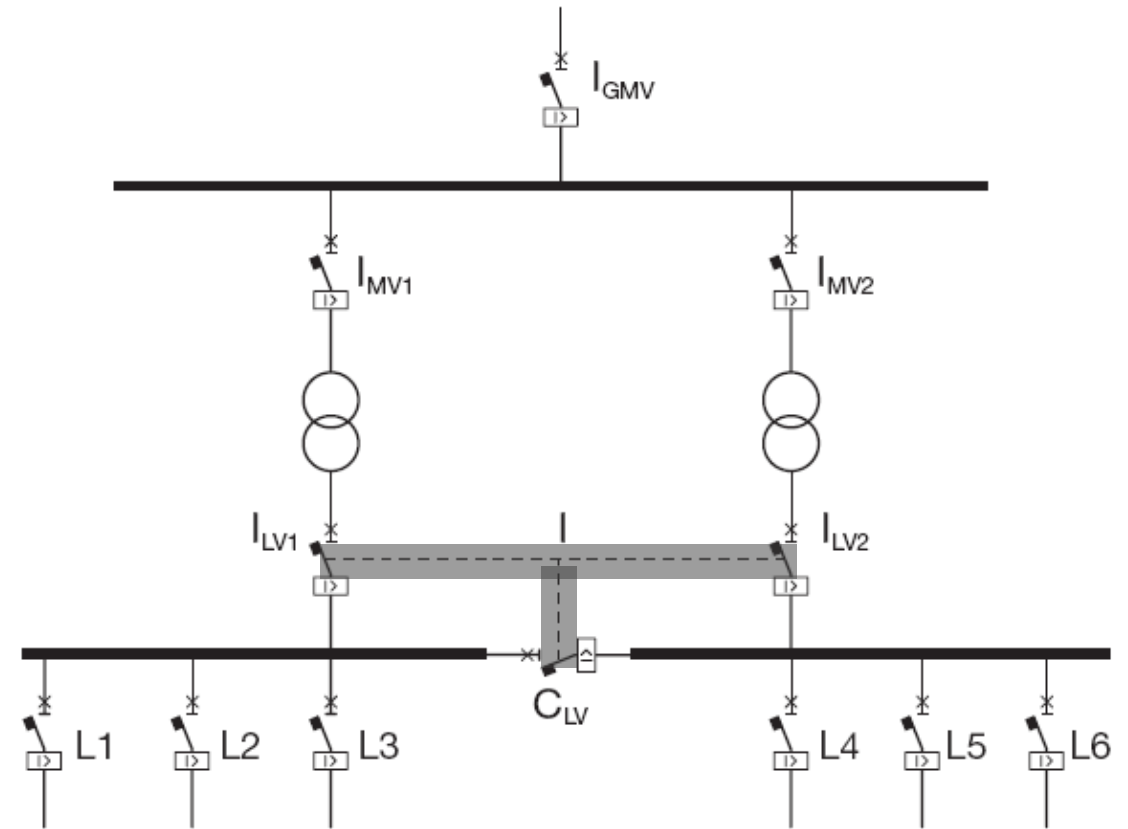
Short Circuit Calculation

Basic Principles

Common Management Methods

Substation with two transformers which operate simultaneously on two separate half-busbars. (Two incoming with bus-coupler)

Mechanical Interlock between three ACBs



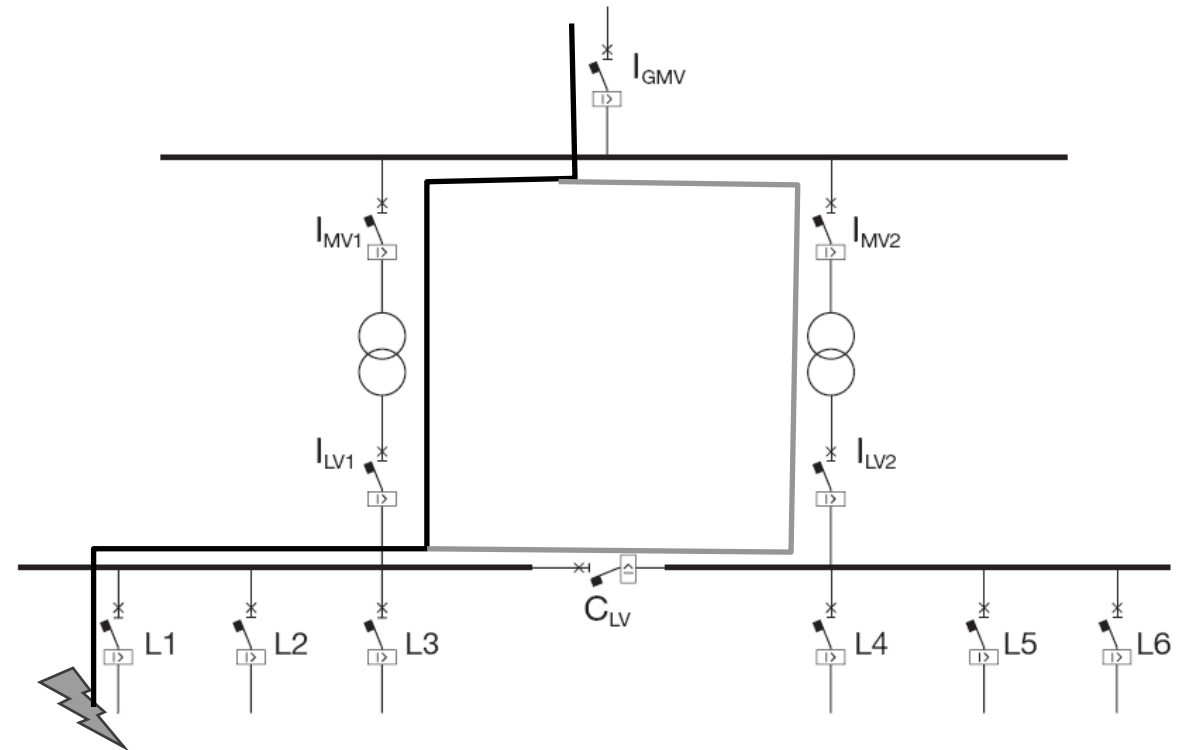
Short Circuit Calculation

Basic Principles

Management philosophy for the protections

To ensure continuity of service to sound parts of the installation

- Circuit breaker L1 must trip and clear the fault



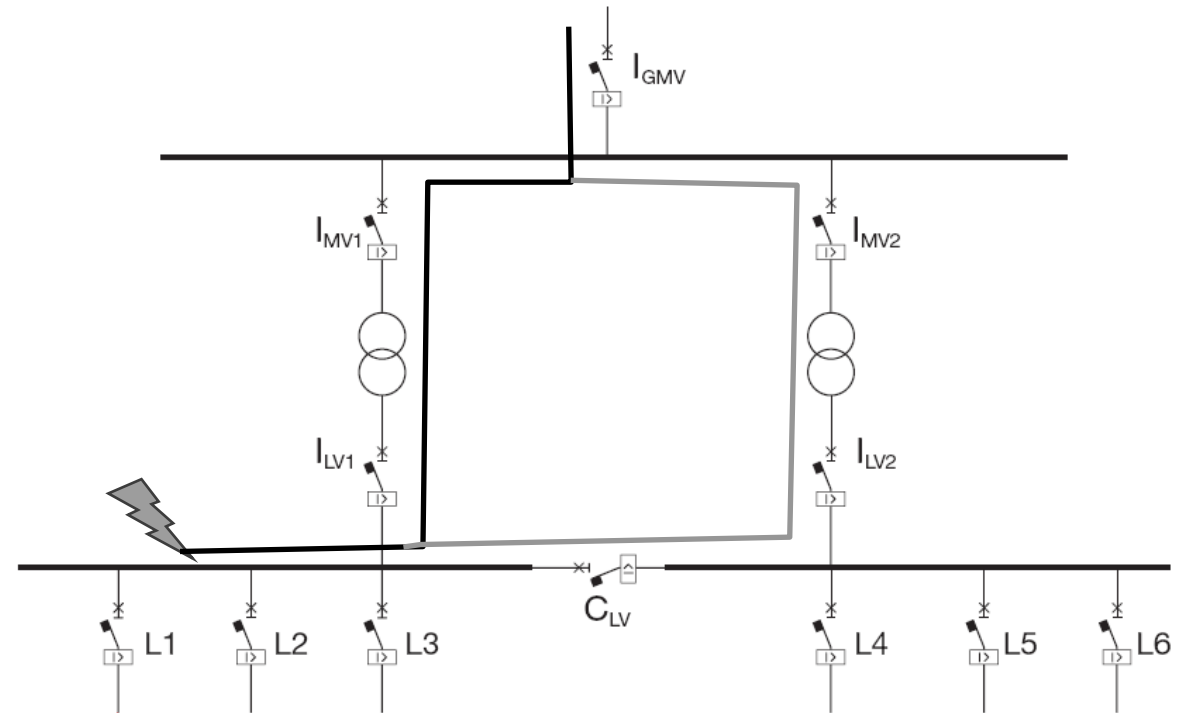
Short Circuit Calculation

Basic Principles

Management philosophy for the protections

To ensure continuity of service to sound parts of the installation

- Circuit breaker I_{LV1} must trip and clear the fault
- If C_{LV} is closed I_{LV2} must trip as well. Depending if C_{LV} is an ACB or just a bus coupler.



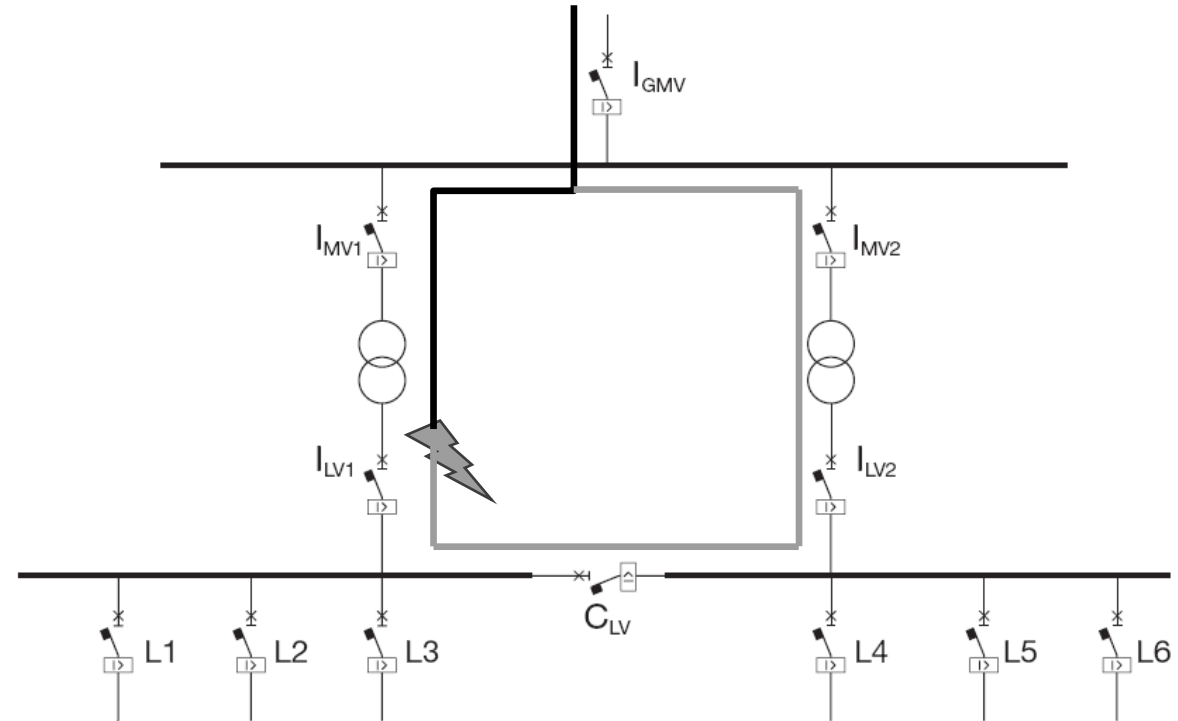
Short Circuit Calculation

Basic Principles

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Short Circuit Calculation

Basic Principles

Short Circuit Calculations Single Transformer

MV Level 22kV 750MVA

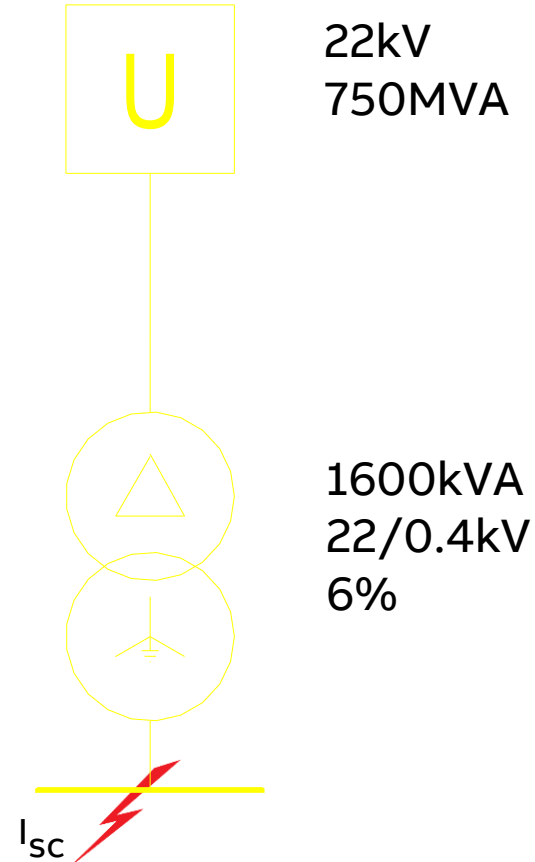
$$Z_{22kV} = \frac{(22k)^2}{750M} = 0.6453 \Omega$$

$$Z_{400V} = 0.6453 \times \frac{400^2}{22000^2} = 0.2133 \text{ m}\Omega$$

$$Z_{TX} = \frac{6}{100} \times \frac{400^2}{1.6M} = 6 \text{ m}\Omega$$

$$Z_{Total} = 6.2133 \text{ m}\Omega$$

$$I_{sc} = \frac{400}{\sqrt{3} \times 6.2133m} = 37.168kA$$



Short Circuit Calculation

Basic Principles

Short Circuit Calculations two transformers in parallel

MV Level 22kV 750MVA

$$Z_{22kV} = \frac{(22k)^2}{750M} = 0.6453 \Omega$$

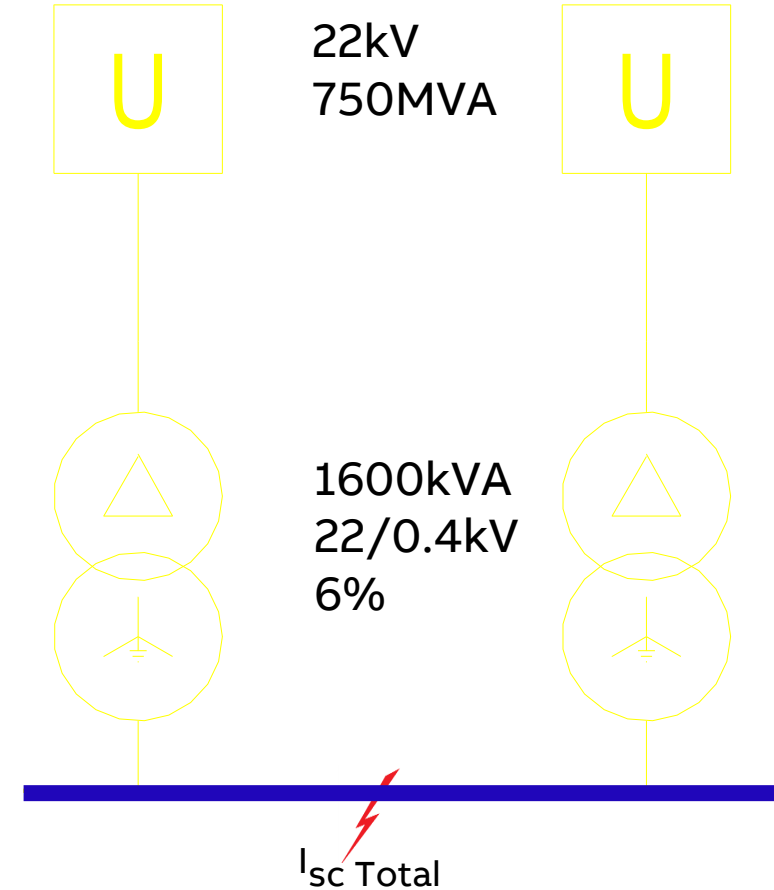
$$Z_{400V} = 0.6453 \times \frac{400^2}{22000^2} = 0.2133 \text{ m}\Omega$$

$$Z_{TX} = \frac{6}{100} \times \frac{400^2}{1.6M} = 6 \text{ m}\Omega$$

$$Z_{Total} = 6.2133 \text{ m}\Omega$$

$$I_{sc} = \frac{400}{\sqrt{3} \times 6.2133m} = 37.168kA$$

$$I_{SC \text{ Total}} = 37.168 \times 2 = 74.336kA$$



Short Circuit Calculation

Basic Principles

Short Circuit Calculations two transformers in parallel

MV Level 22kV 750MVA

$$Z_{22kV} = \frac{(22k)^2}{750M} = 0.6453 \Omega$$

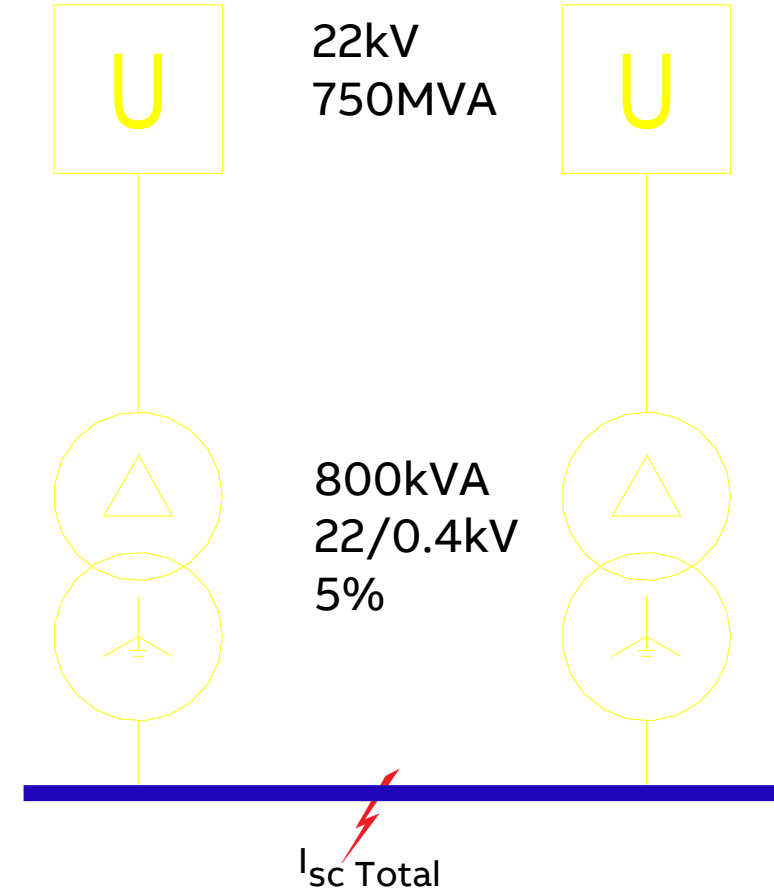
$$Z_{400V} = 0.6453 \times \frac{400^2}{22000^2} = 0.2133 \text{ m}\Omega$$

$$Z_{TX} = \frac{5}{100} \times \frac{400^2}{800K} = 0.01 \Omega$$

$$Z_{Total} = 10.2133 \text{ m}\Omega$$

$$I_{sc} = \frac{400}{\sqrt{3} \times 10.2133m} = 22.611 \text{ kA}$$

$$I_{SC \text{ Total}} = 22.611 \times 2 = 45.22 \text{ kA}$$



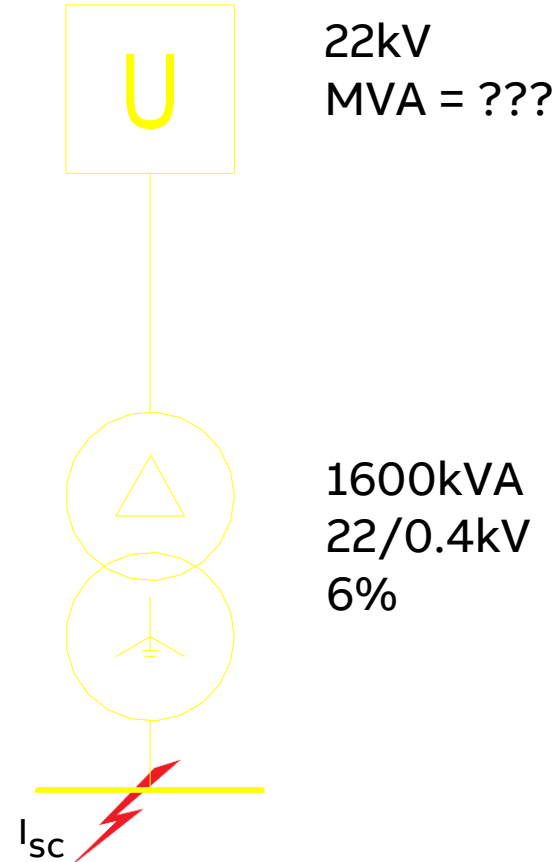
Short Circuit Calculation

Basic Principles

Short Circuit Calculations Single Transformer

$$Z_{TX} = \frac{6}{100} \times \frac{400^2}{1.6M} = 6 \text{ m}\Omega$$

$$I_{sc} = \frac{400}{\sqrt{3} \times 6m} = 38.49kA$$

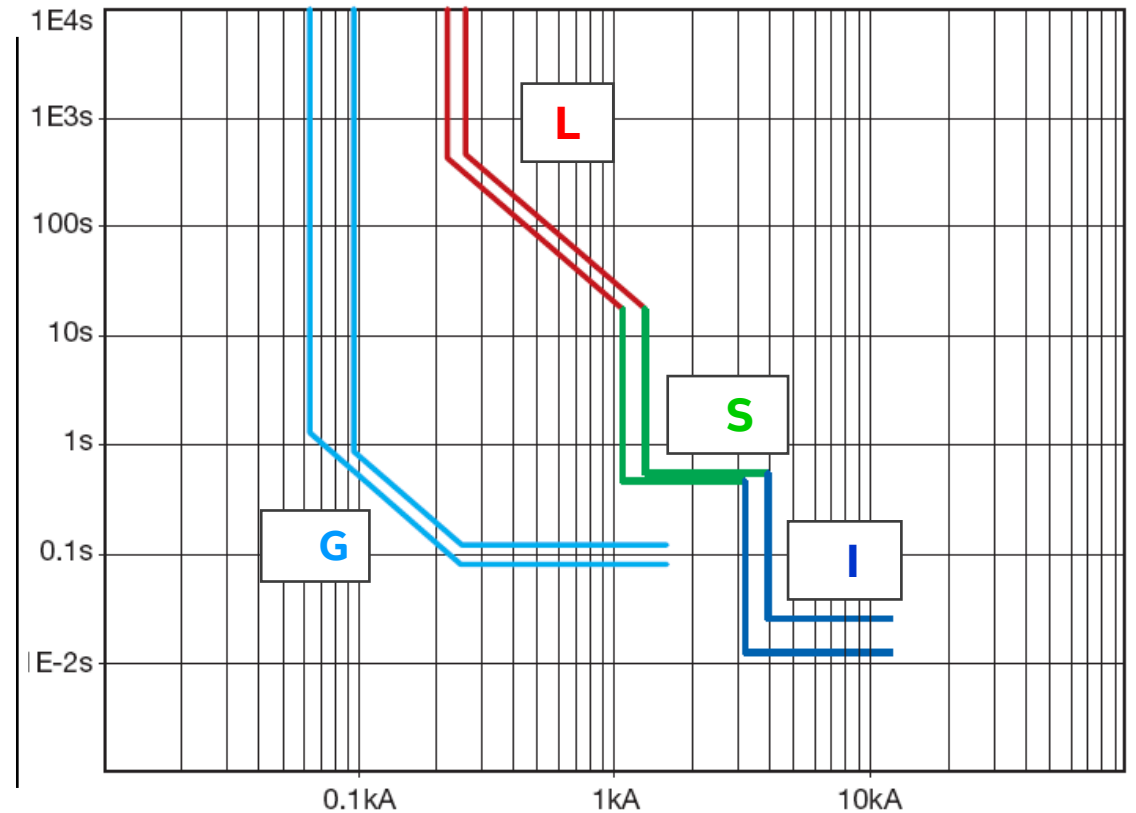


Short Circuit Calculation

Basic Principles

Time Current curves of Circuit breakers

- **L function** protection against overload
- **S function** protection against delayed short-circuit
- **I function** protection against instantaneous short-circuit
- **G function** protection against earth-fault

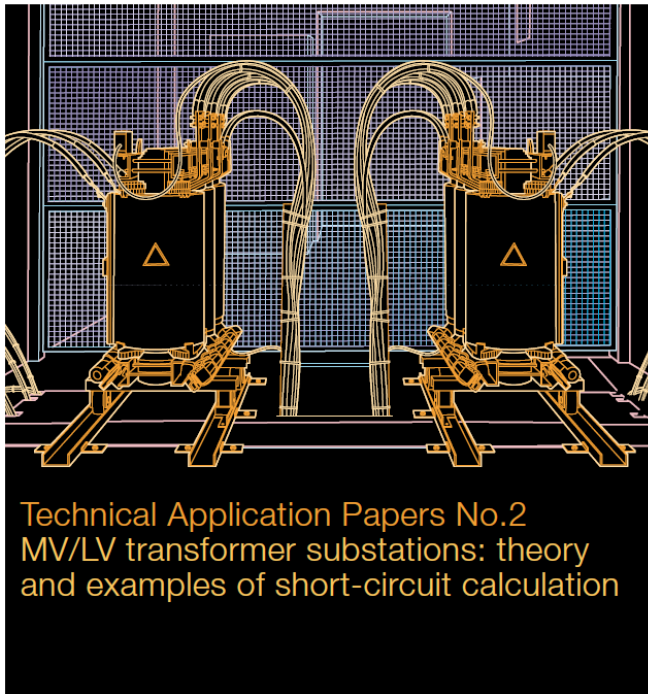


Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Technical Application Paper



<http://new.abb.com/low-voltage>

<http://new.abb.com/low-voltage/business/epc>

MV/LV transformer substations: theory and examples of short-circuit calculation

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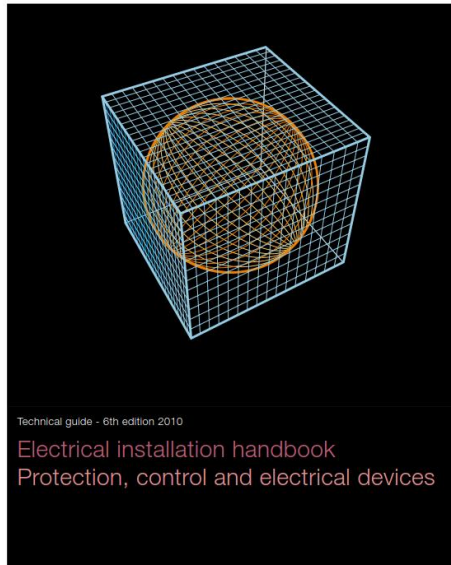
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Basic Principles

Calculation of Short Circuit Currents

Electrical Installation Handbook



Power and productivity
for a better world™ **ABB**

6 Calculation of short-circuit current

6.4 Determination of the short-circuit current I_{sc} downstream of a cable as a function of the upstream one

The table below allows the determination, in a conservative way, of the three phase short-circuit current at a point in a 400 V network downstream of a three pole circuit breaker at a temperature of 20 °C. Known values:

- the three-phase short-circuit current upstream of the cable;
- the length and cross section of the cable.

Cable section [mm ²]	Length [m]	I_{sc}
1	0.9	0.9 1.14 1.28 1.35 1.53 1.57 1.6 1.64
2.5	0.9	1.2 1.5 1.8 2.3 2.9 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 4.0 4.1
4	0.9	1.5 1.9 2.3 2.8 3.4 3.7 3.9 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9 5.0 5.1 5.2 5.3 5.4 5.5 5.6 5.7 5.8 5.9 6.0 6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8 6.9 7.0 7.1 7.2 7.3 7.4 7.5 7.6 7.7 7.8 7.9 8.0 8.1 8.2 8.3 8.4 8.5 8.6 8.7 8.8 8.9 9.0 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 10.0 10.1 10.2 10.3 10.4 10.5 10.6 10.7 10.8 10.9 11.0 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9 12.0 12.1 12.2 12.3 12.4 12.5 12.6 12.7 12.8 12.9 13.0 13.1 13.2 13.3 13.4 13.5 13.6 13.7 13.8 13.9 14.0 14.1 14.2 14.3 14.4 14.5 14.6 14.7 14.8 14.9 15.0 15.1 15.2 15.3 15.4 15.5 15.6 15.7 15.8 15.9 16.0 16.1 16.2 16.3 16.4 16.5 16.6 16.7 16.8 16.9 17.0 17.1 17.2 17.3 17.4 17.5 17.6 17.7 17.8 17.9 18.0 18.1 18.2 18.3 18.4 18.5 18.6 18.7 18.8 18.9 19.0 19.1 19.2 19.3 19.4 19.5 19.6 19.7 19.8 19.9 20.0 20.1 20.2 20.3 20.4 20.5 20.6 20.7 20.8 20.9 21.0 21.1 21.2 21.3 21.4 21.5 21.6 21.7 21.8 21.9 22.0 22.1 22.2 22.3 22.4 22.5 22.6 22.7 22.8 22.9 23.0 23.1 23.2 23.3 23.4 23.5 23.6 23.7 23.8 23.9 24.0 24.1 24.2 24.3 24.4 24.5 24.6 24.7 24.8 24.9 25.0 25.1 25.2 25.3 25.4 25.5 25.6 25.7 25.8 25.9 26.0 26.1 26.2 26.3 26.4 26.5 26.6 26.7 26.8 26.9 27.0 27.1 27.2 27.3 27.4 27.5 27.6 27.7 27.8 27.9 28.0 28.1 28.2 28.3 28.4 28.5 28.6 28.7 28.8 28.9 29.0 29.1 29.2 29.3 29.4 29.5 29.6 29.7 29.8 29.9 30.0 30.1 30.2 30.3 30.4 30.5 30.6 30.7 30.8 30.9 31.0 31.1 31.2 31.3 31.4 31.5 31.6 31.7 31.8 31.9 32.0 32.1 32.2 32.3 32.4 32.5 32.6 32.7 32.8 32.9 33.0 33.1 33.2 33.3 33.4 33.5 33.6 33.7 33.8 33.9 34.0 34.1 34.2 34.3 34.4 34.5 34.6 34.7 34.8 34.9 35.0 35.1 35.2 35.3 35.4 35.5 35.6 35.7 35.8 35.9 36.0 36.1 36.2 36.3 36.4 36.5 36.6 36.7 36.8 36.9 37.0 37.1 37.2 37.3 37.4 37.5 37.6 37.7 37.8 37.9 38.0 38.1 38.2 38.3 38.4 38.5 38.6 38.7 38.8 38.9 39.0 39.1 39.2 39.3 39.4 39.5 39.6 39.7 39.8 39.9 40.0 40.1 40.2 40.3 40.4 40.5 40.6 40.7 40.8 40.9 41.0 41.1 41.2 41.3 41.4 41.5 41.6 41.7 41.8 41.9 42.0 42.1 42.2 42.3 42.4 42.5 42.6 42.7 42.8 42.9 43.0 43.1 43.2 43.3 43.4 43.5 43.6 43.7 43.8 43.9 44.0 44.1 44.2 44.3 44.4 44.5 44.6 44.7 44.8 44.9 45.0 45.1 45.2 45.3 45.4 45.5 45.6 45.7 45.8 45.9 46.0 46.1 46.2 46.3 46.4 46.5 46.6 46.7 46.8 46.9 47.0 47.1 47.2 47.3 47.4 47.5 47.6 47.7 47.8 47.9 48.0 48.1 48.2 48.3 48.4 48.5 48.6 48.7 48.8 48.9 49.0 49.1 49.2 49.3 49.4 49.5 49.6 49.7 49.8 49.9 50.0 50.1 50.2 50.3 50.4 50.5 50.6 50.7 50.8 50.9 51.0 51.1 51.2 51.3 51.4 51.5 51.6 51.7 51.8 51.9 52.0 52.1 52.2 52.3 52.4 52.5 52.6 52.7 52.8 52.9 53.0 53.1 53.2 53.3 53.4 53.5 53.6 53.7 53.8 53.9 54.0 54.1 54.2 54.3 54.4 54.5 54.6 54.7 54.8 54.9 55.0 55.1 55.2 55.3 55.4 55.5 55.6 55.7 55.8 55.9 56.0 56.1 56.2 56.3 56.4 56.5 56.6 56.7 56.8 56.9 57.0 57.1 57.2 57.3 57.4 57.5 57.6 57.7 57.8 57.9 58.0 58.1 58.2 58.3 58.4 58.5 58.6 58.7 58.8 58.9 59.0 59.1 59.2 59.3 59.4 59.5 59.6 59.7 59.8 59.9 60.0 60.1 60.2 60.3 60.4 60.5 60.6 60.7 60.8 60.9 61.0 61.1 61.2 61.3 61.4 61.5 61.6 61.7 61.8 61.9 62.0 62.1 62.2 62.3 62.4 62.5 62.6 62.7 62.8 62.9 63.0 63.1 63.2 63.3 63.4 63.5 63.6 63.7 63.8 63.9 64.0 64.1 64.2 64.3 64.4 64.5 64.6 64.7 64.8 64.9 65.0 65.1 65.2 65.3 65.4 65.5 65.6 65.7 65.8 65.9 66.0 66.1 66.2 66.3 66.4 66.5 66.6 66.7 66.8 66.9 67.0 67.1 67.2 67.3 67.4 67.5 67.6 67.7 67.8 67.9 68.0 68.1 68.2 68.3 68.4 68.5 68.6 68.7 68.8 68.9 69.0 69.1 69.2 69.3 69.4 69.5 69.6 69.7 69.8 69.9 70.0 70.1 70.2 70.3 70.4 70.5 70.6 70.7 70.8 70.9 71.0 71.1 71.2 71.3 71.4 71.5 71.6 71.7 71.8 71.9 72.0 72.1 72.2 72.3 72.4 72.5 72.6 72.7 72.8 72.9 73.0 73.1 73.2 73.3 73.4 73.5 73.6 73.7 73.8 73.9 74.0 74.1 74.2 74.3 74.4 74.5 74.6 74.7 74.8 74.9 75.0 75.1 75.2 75.3 75.4 75.5 75.6 75.7 75.8 75.9 76.0 76.1 76.2 76.3 76.4 76.5 76.6 76.7 76.8 76.9 77.0 77.1 77.2 77.3 77.4 77.5 77.6 77.7 77.8 77.9 78.0 78.1 78.2 78.3 78.4 78.5 78.6 78.7 78.8 78.9 79.0

Determination of short-circuit current downstream of a cable as a function of the upstream short-circuit current (Table 6.4).

Cable section [mm²]	Length [m]																			
	0.9	1.1	1.4	1.8	2.5	3.5	5.3	7	9.4	14										
1.5																				
2.5											0.9	1	1.2	1.5	1.8	2.3	2.9	4.1	5.9	8.8
4											0.9	1.2	1.4	1.6	1.9	2.3	2.8	3.7	4.7	6.6
6																				
10																				
16																				
25																				
35																				
50																				
70																				
95																				
120																				
150																				
185																				
240																				
300																				
2x120																				
2x150																				
2x185																				
3x120																				
3x150																				
3x185																				

I_k upstream [kA]										I_k downstream [kA]									
100	96	92	89	85	82	78	71	65	60	50	43	36	31	27	24	20	17	13	11
90	86	83	81	78	76	72	67	61	57	48	42	35	31	27	24	20	17	13	11
80	77	75	73	71	69	66	62	57	53	46	40	34	30	27	24	20	17	13	10
70	68	66	65	63	62	60	56	53	49	43	38	33	29	26	23	19	16	13	10
60	58	57	56	55	54	53	50	47	45	40	36	31	28	25	23	19	16	12	10
50	49	48	47	46	45	44	43	41	39	35	32	29	26	23	21	18	15	12	10
40	39	39	38	38	37	37	35	34	33	31	28	26	24	22	20	17	15	12	10
35	34	34	34	33	33	32	32	31	30	28	26	24	22	20	19	16	14	11	10
30	30	29	29	29	28	28	28	27	26	25	23	22	20	19	18	16	14	11	9.3
25	25	24	24	24	24	24	23	23	22	21	21	19	18	17	16	14	13	11	9.0
20	20	20	20	19	19	19	19	18	18	18	17	16	15	15	14	13	12	10	8.4
15	15	15	15	15	15	14	14	14	14	14	13	13	12	12	12	11	10	8.7	7.6
12	12	12	12	12	12	12	12	11	11	11	11	11	10	10	10	9.3	8.8	7.8	7.0
10	10	10	10	10	10	10	10	10	9.5	9.4	9.2	9.0	8.8	8.5	8.3	8.1	7.7	7.3	6.5
8.0	8.0	7.9	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.4	7.2	7.1	6.9	6.8	6.5	6.2	5.7	5.2
6.0	6.0	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	4.9	4.8	4.4	4.1
3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.7	2.7	2.6	2.5	2.4	2.2

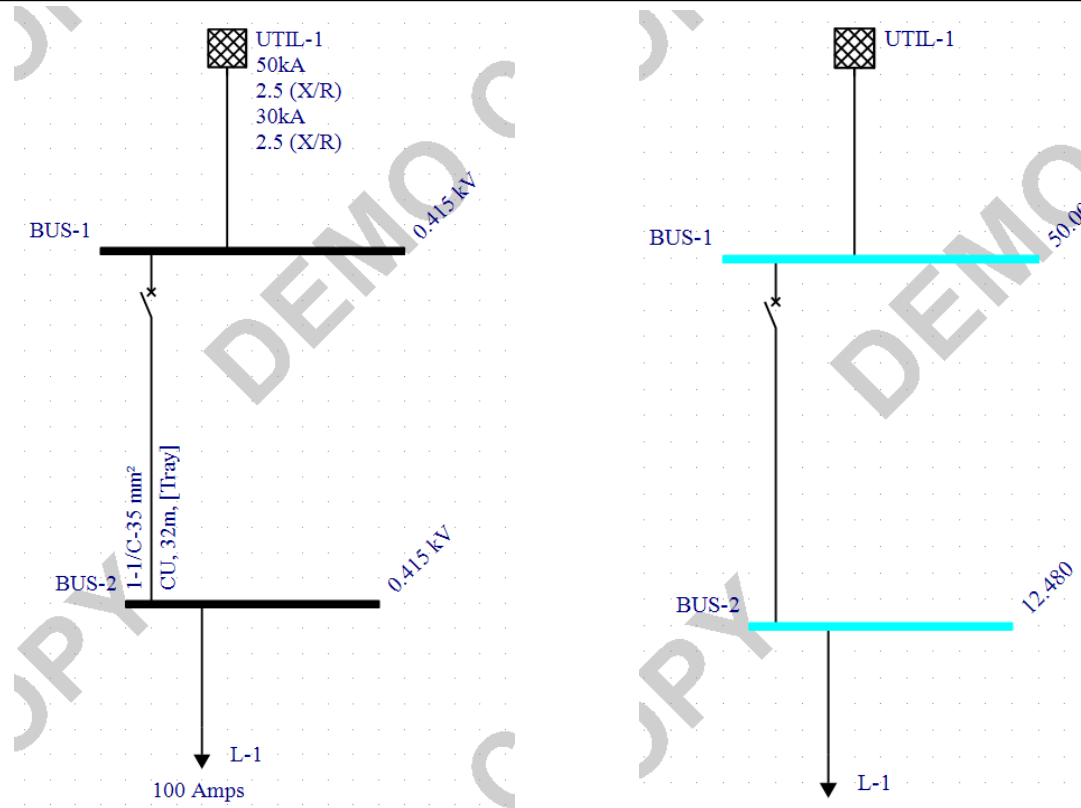
Determination of short-circuit current downstream of a cable as a function of the upstream short-circuit current (Table 6.4).

Short Circuit Calculation

Basic Principles

EasyPower Short Circuit Calculation

Example



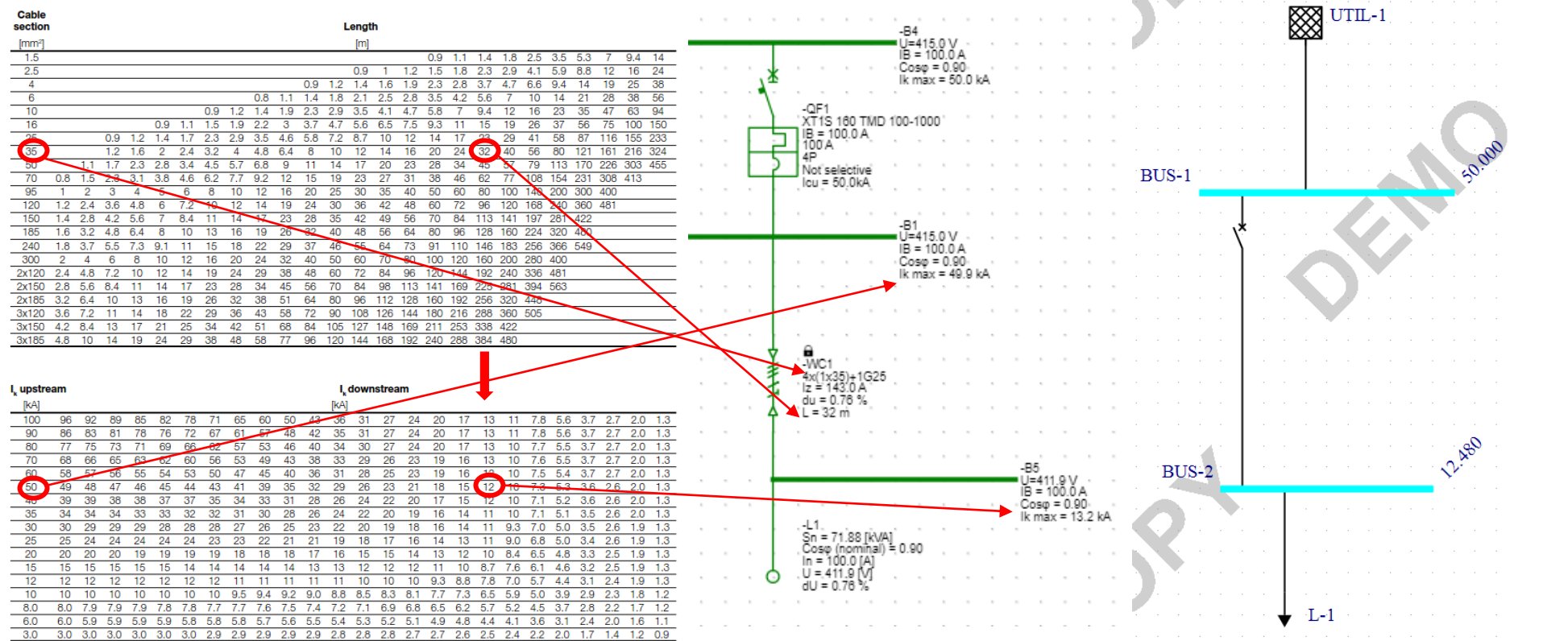
Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

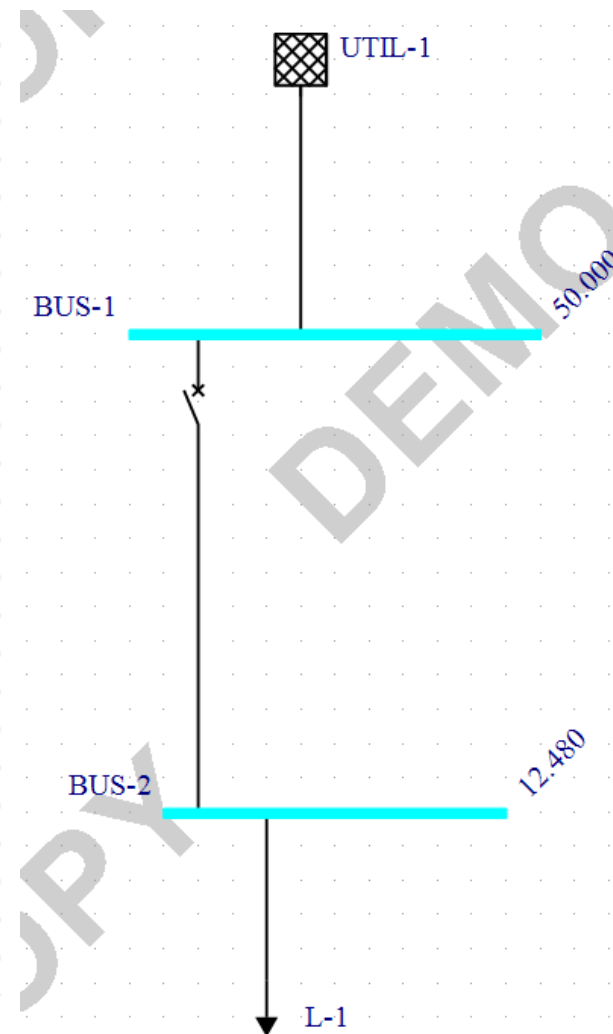
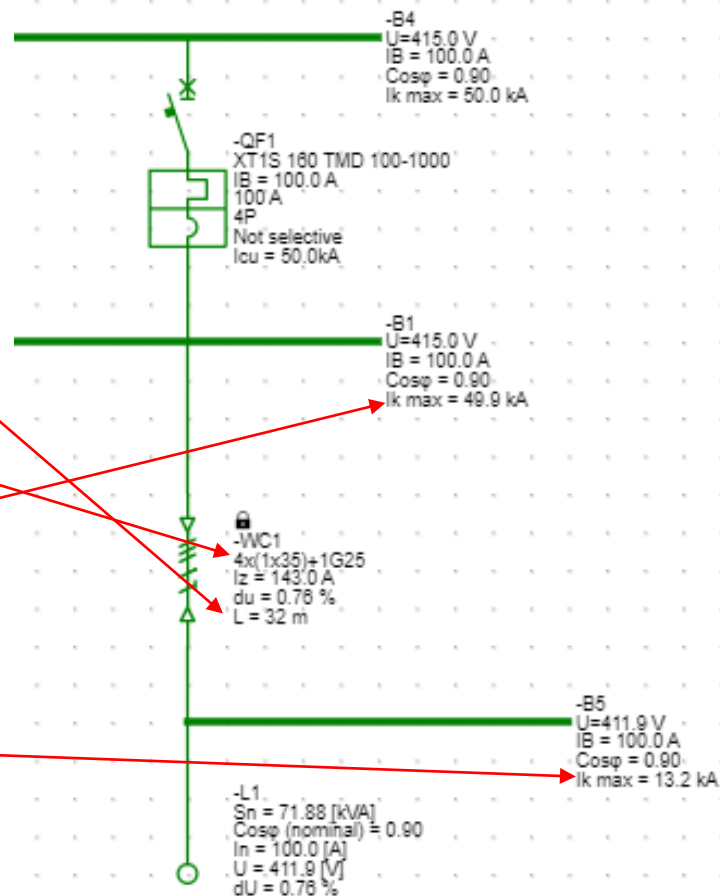
Manual Verification

- Example 1



Cable section [mm ²]	Length [m]															
1.5										0.9	1.1	1.4	1.8	2.5	3.5	5.3
2.5										0.9	1	1.2	1.5	1.8	2.3	2.9
4										0.9	1.2	1.4	1.6	1.9	2.3	2.8
6										0.8	1.1	1.4	1.8	2.1	2.5	2.8
10										0.9	1.2	1.4	1.9	2.3	2.9	3.5
16										0.9	1.1	1.5	1.9	2.2	3	3.7
25										0.9	1.2	1.4	1.7	2.3	2.9	3.5
35										1.2	1.6	2	2.4	3.2	4	4.8
50										1.1	1.7	2.3	2.8	3.4	4.5	5.7
70										0.8	1.5	2.3	3.1	3.8	4.6	6.2
95										1	2	3	4	5	6	8
120										1.2	2.4	3.6	4.8	6	7.2	10
150										1.4	2.8	4.2	5.6	7	8.4	11
185										1.6	3.2	4.8	6.4	8	10	13
240										1.8	3.7	5.5	7.3	9.1	11	15
300										2	4	6	8	10	12	16
2x120										2.4	4.8	7.2	10	12	14	19
2x150										2.8	5.6	8.4	11	14	17	23
2x185										3.2	6.4	10	13	16	19	26
3x120										3.6	7.2	11	14	18	22	29
3x150										4.2	8.4	13	17	21	25	34
3x185										4.8	10	14	19	24	29	38

I ₁ upstream [kA]	I ₂ downstream [kA]																											
100	96	92	89	85	82	78	71	65	60	50	43	36	31	27	24	20	17	13	11	7.8	5.6	3.7	2.7	2.0	1.3			
90	86	83	81	78	76	72	67	61	57	48	42	35	31	27	24	20	17	13	11	7.8	5.6	3.7	2.7	2.0	1.3			
80	77	75	73	71	69	66	62	57	53	46	40	34	30	27	24	20	17	13	10	7.7	5.5	3.7	2.7	2.0	1.3			
70	68	66	65	63	62	60	56	53	49	43	38	33	29	26	23	19	16	13	10	7.6	5.5	3.7	2.7	2.0	1.3			
60	58	57	56	55	54	53	50	47	45	40	36	31	28	25	23	19	16	12	10	7.5	5.4	3.7	2.7	2.0	1.3			
50	49	48	47	46	45	44	43	41	39	35	32	29	26	23	21	18	15	12	10	7.3	5.3	3.6	2.6	2.0	1.3			
40	39	39	38	38	37	37	35	34	33	31	28	26	24	22	20	17	15	12	10	7.1	5.2	3.6	2.6	2.0	1.3			
35	34	34	34	33	33	32	32	31	30	28	26	24	22	20	19	16	14	11	10	7.1	5.1	3.5	2.6	2.0	1.3			
30	30	29	29	29	28	28	28	27	26	25	23	22	20	19	18	16	14	11	9.3	7.0	5.0	3.5	2.6	1.9	1.3			
25	25	24	24	24	24	24	23	23	22	21	21	19	18	17	16	14	13	11	9.0	6.8	5.0	3.4	2.6	1.9	1.3			
20	20	20	20	20	19	19	19	18	18	18	17	16	15	15	14	13	12	10	8.4	6.5	4.8	3.3	2.5	1.9	1.3			
15	15	15	15	15	15	14	14	14	14	14	13	13	12	12	12	11	10	8.7	7.6	6.1	4.6	3.2	2.5	1.9	1.3			
12	12	12	12	12	12	12	12	11	11	11	11	11	10	10	10	9.3	8.8	7.8	7.0	5.7	4.4	3.1	2.4	1.9	1.3			
10	10	10	10	10	10	10	10	9.5	9.4	9.2	9.0	8.8	8.5	8.3	8.1	7.7	7.3	6.5	5.9	5.0	3.9	2.9	2.3	1.8	1.2			
8.0	8.0	7.9	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.4	7.2	7.1	6.9	6.8	6.5	6.2	5.7	5.2	4.5	3.7	2.8	2.2	1.7	1.2			
6.0	6.0	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	4.9	4.8	4.4	4.1	3.6	3.1	2.4	2.0	1.6	1.1			
3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.6	2.5	2.4	2.2	2.0	1.7	1.4	1.2	0.9			



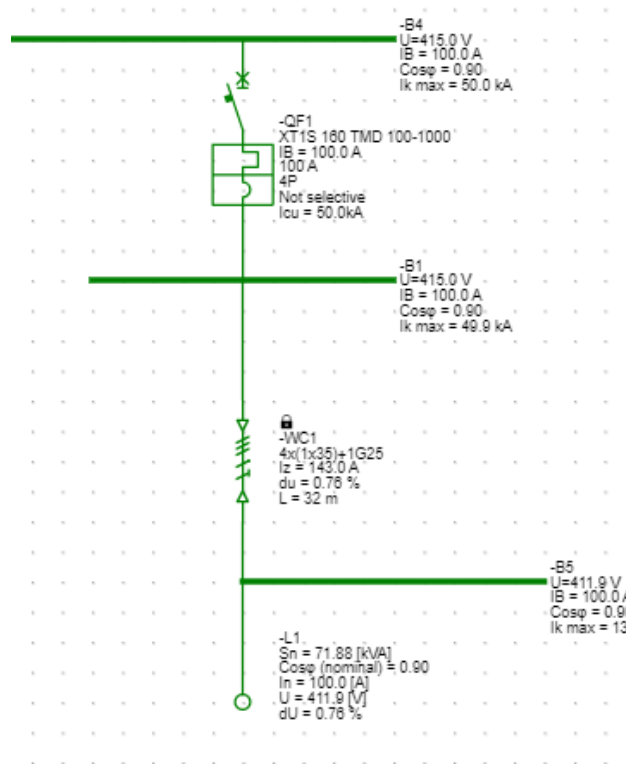
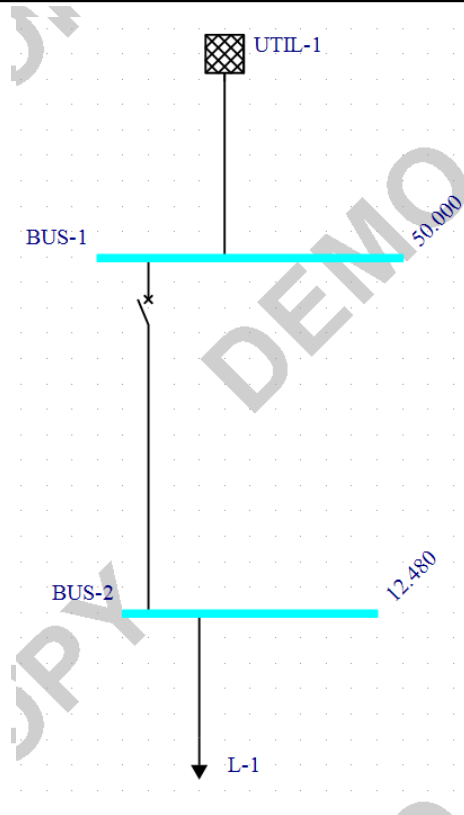
Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Manual Verification

- Example 1



$$\text{Voltage} = \sqrt{3} * R * I$$

$$I_1 = 50\text{ kA}$$

$$R_1 = \frac{V}{\sqrt{3} * I_1}$$
$$= \frac{400}{\sqrt{3} * 50} = 4.618\text{ m}\Omega$$

$$R_{\text{cable}} = 16.923\text{ m}\Omega \text{ (from cable database @ } 20^\circ\text{C)}$$

$$(R_1 + R_{\text{cable}}) = 21.541\text{ m}\Omega$$

$$I_2 = \frac{V}{\sqrt{3} * (R_1 + R_{\text{cable}})}$$
$$= \frac{400}{\sqrt{3} * 21.541} = 10.72\text{ kA}$$



ABB