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

IEC 60909

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

IEC 60909

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”

ABB

Short Circuit Calculation

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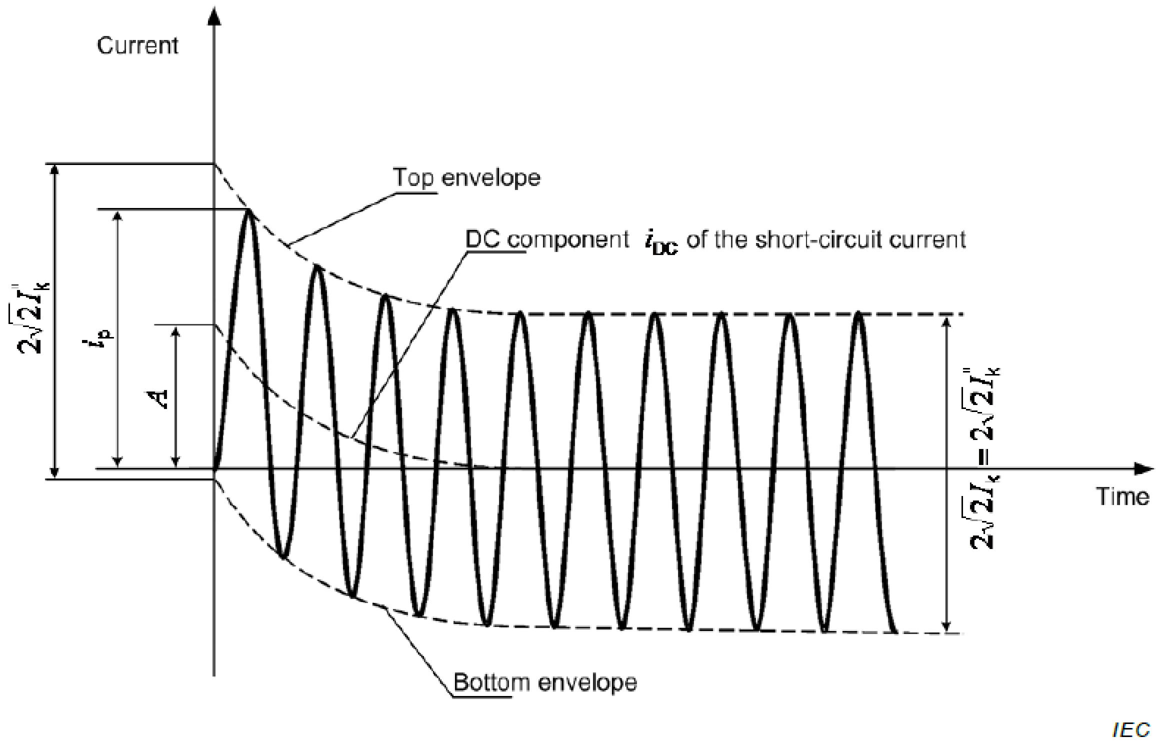
Short-circuit currents



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

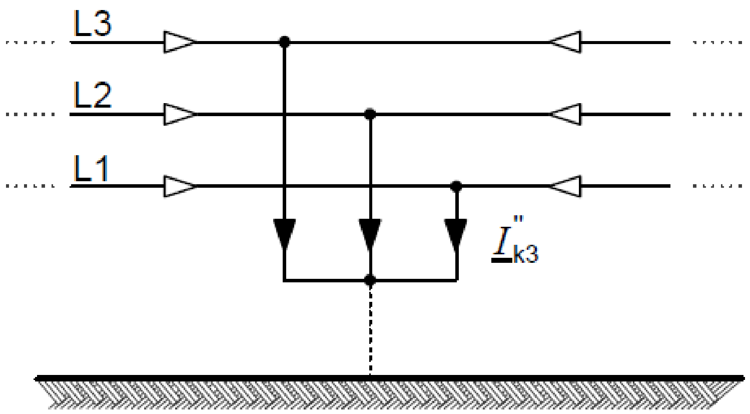

Figure 3a – Three-phase short circuit

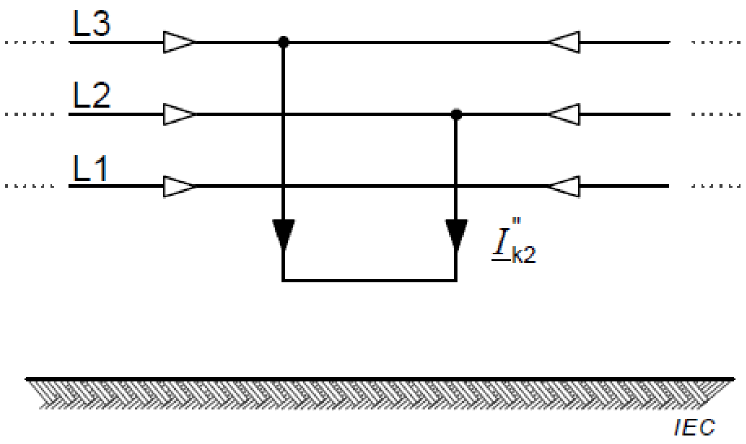

Figure 3b – Line-to-line short circuit

Short Circuit Calculation

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Short-circuit currents

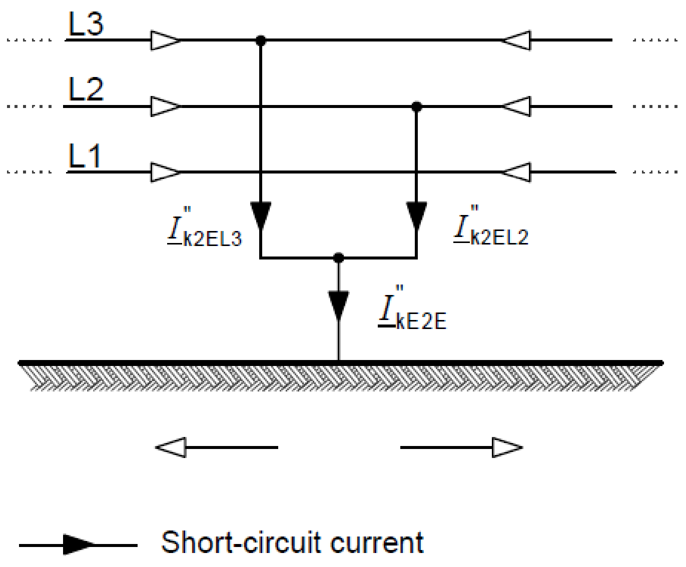

Figure 3c – Line-to-line short circuit with earth connection

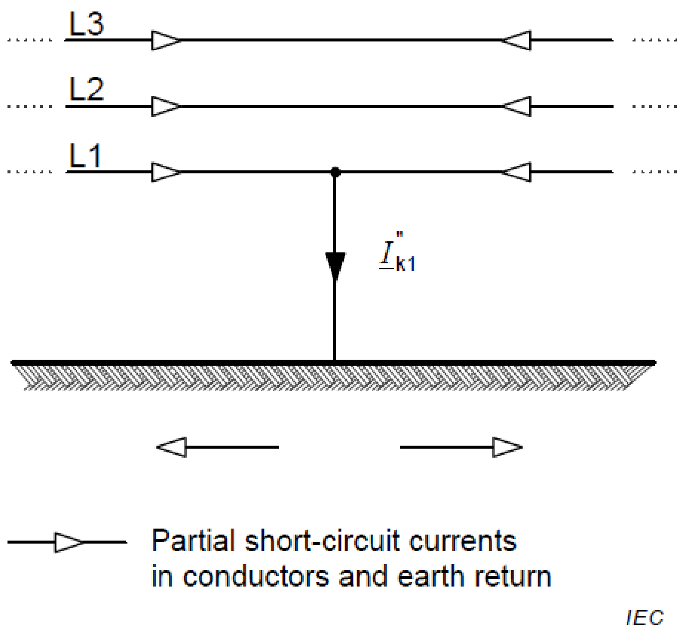

Figure 3d – Line-to-earth short circuit

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

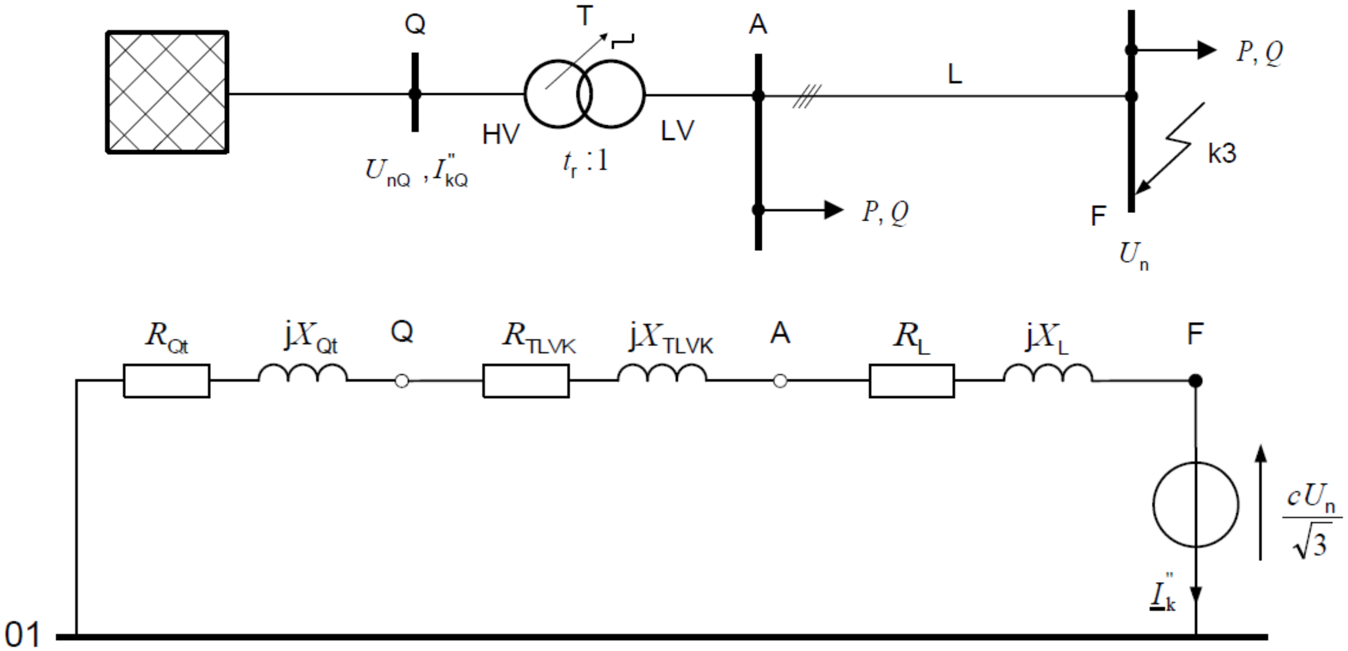

Table 1 – Voltage factor c

Nominal system voltage U_n	Voltage factor c for the calculation of maximum short-circuit currents c_{max} [a]	Voltage factor c for the calculation of 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 ±6 %, for example systems renamed from 380 V to 400 V.

[d] For low-voltage systems with a tolerance of ±10 %.

[e] For nominal system voltages related to $U_m > 420$ kV, the voltage factors c are not defined in this standard.

Short Circuit Calculation

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Short-circuit impedances of electrical equipment

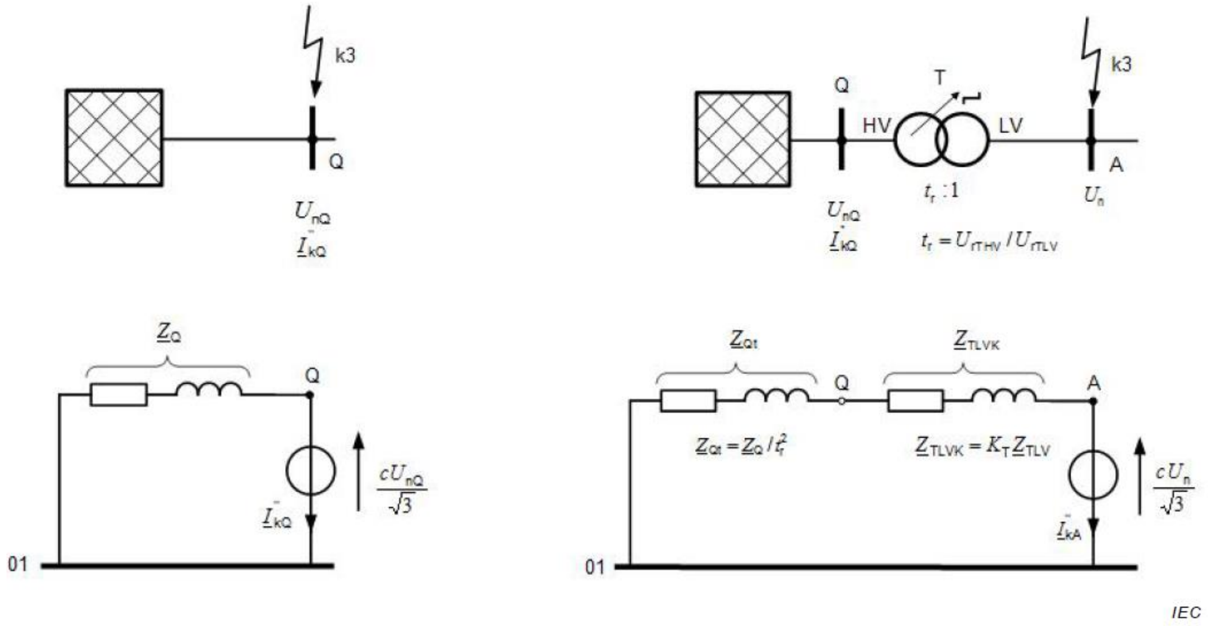

Figure 5a – Without transformer

Fig. 5b – With transformer

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

Short Circuit Calculation

IEC 60909

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.

Short Circuit Calculation

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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 $r_B = \sqrt[n]{nrR^{n-1}}$, where R is the bundle radius (see IEC TR 60909-2);

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

μ_0 = $4\pi \cdot 10^{-4}$ H/km.

Short Circuit Calculation

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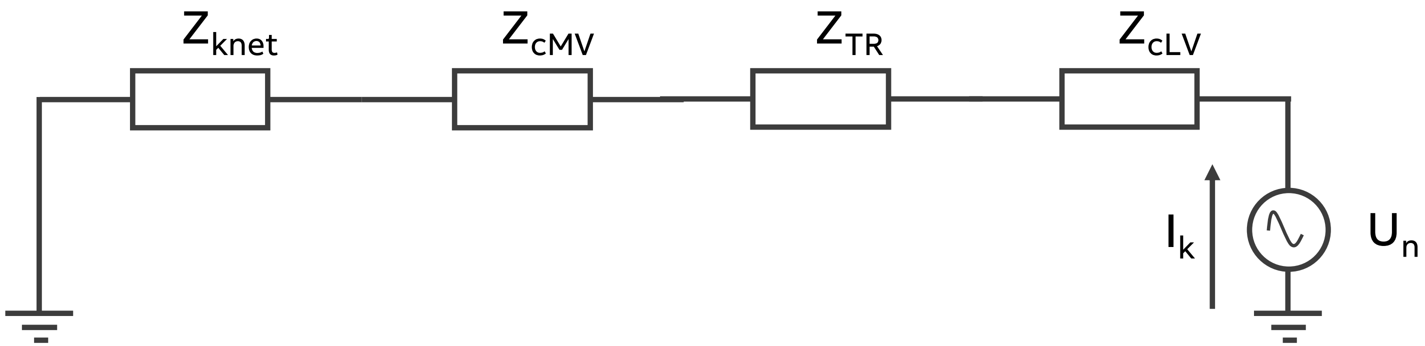
Calculation of Short circuit currents

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

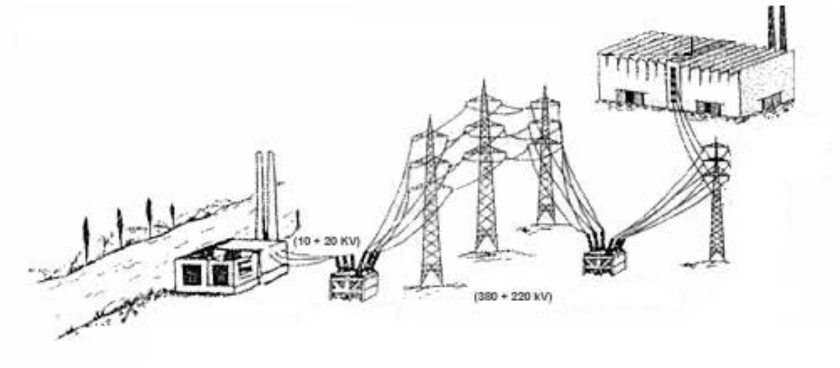
Calculation of Short Circuit Currents

Distribution network

– It is necessary to know the network short-circuit power

- From 250MVA to 500MVA $U_n \leq 30kV$
- From 700MVA to 1500MVA Un > 30kV
- According to IEC 60076-5

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



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

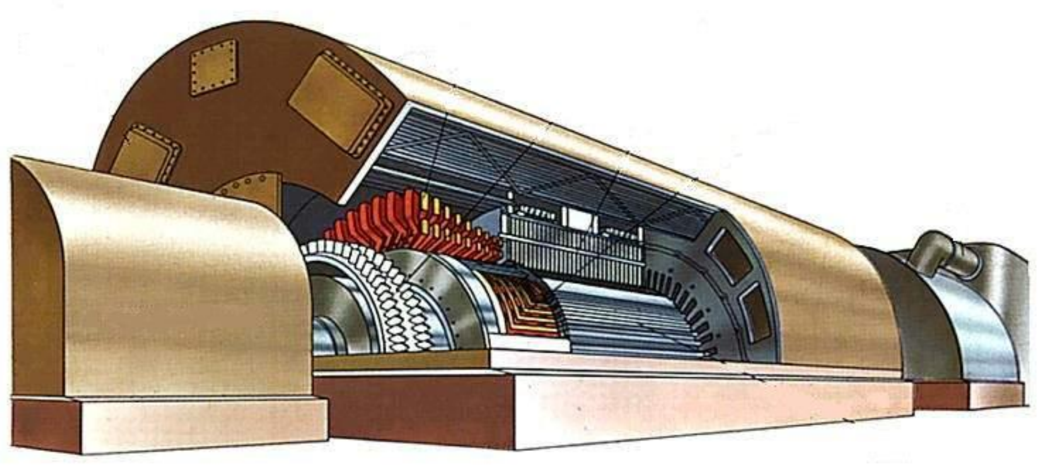
Generator short circuit impedance

– 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

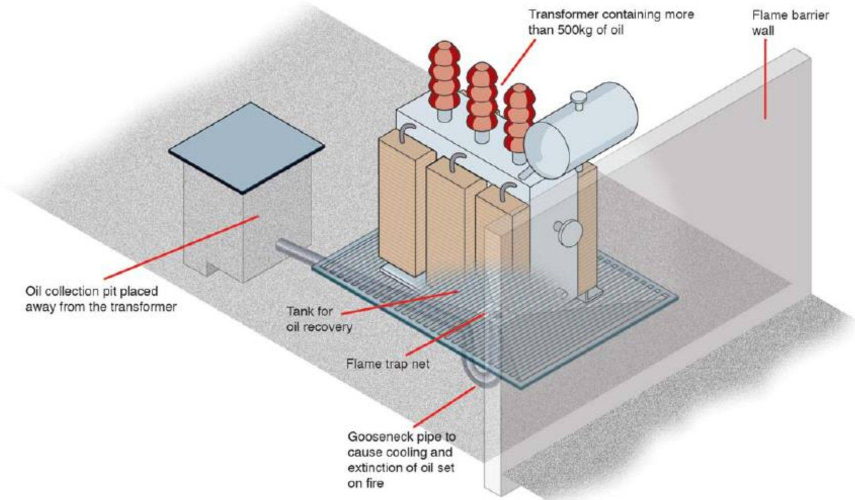
Basic Principles

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 ≤ 1250	5
1250 < S_n ≤ 2500	6
2500 < S_n ≤ 6300	7
6300 < S_n ≤ 25000	8

Short Circuit Calculation

Basic Principles

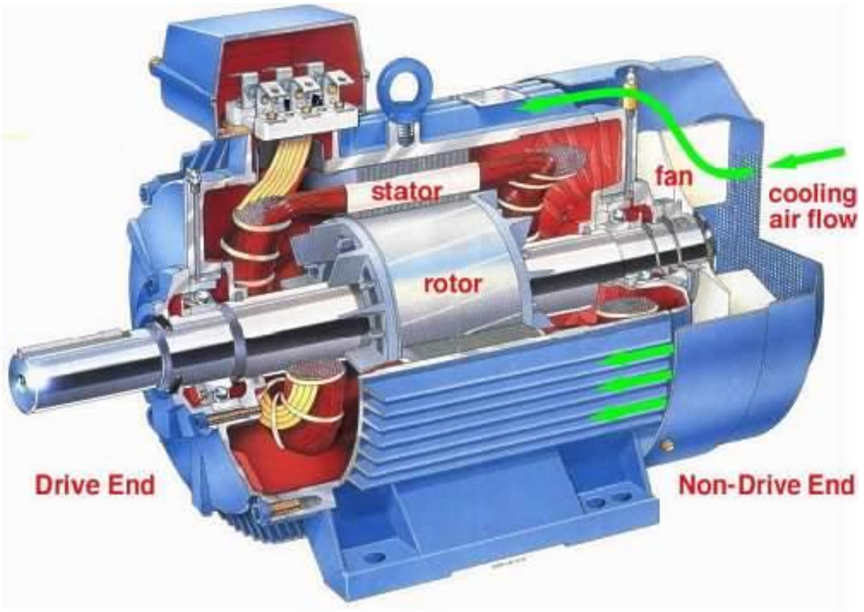
Calculation of Short Circuit Currents

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

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

(Ik short-circuit without motor contribution)



Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Example

S_k = 500 MVA
U_{MV}= 20 kV

Z_{cMV} = 0.01 Ω

S_n = 400 kVA
U= 20/0.4 kV
$u_{k\%}$ = 4 %

Z_{cLV} = 0.06 Ω

Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

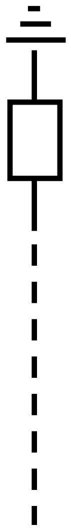
Example

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

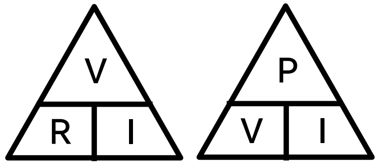
$$Z_{u400V} = Z_{u20kV} \cdot \frac{(400)^2}{(20000)^2} = 3.2 \cdot 10^{-4}\,\Omega$$

S_k = 500 MVA
U_{MV}= 20 kV

$$\frac{V1}{V2} = \frac{N1}{N2} = \frac{I2}{I1}$$



Z_u = 0.32 mΩ



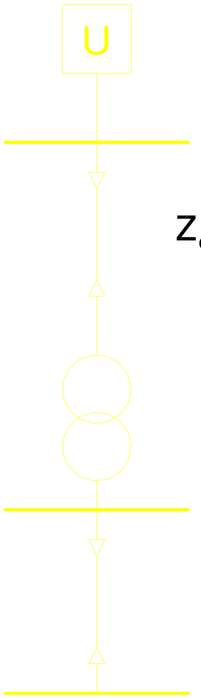
Short Circuit Calculation

Basic Principles

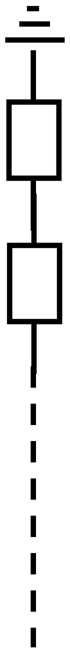
Calculation of Short Circuit Currents

Example

$$Z_{cMV400V} = Z_{cMV20kV} \cdot \frac{(400)^2}{(20000)^2} = 4 \cdot 10^{-6}\,\Omega$$



Z_{cMV} = 0.01 Ω



Z_u = 0.32 mΩ

$Z_{cMV} = 4 \cdot 10^{-3}$ mΩ

Short Circuit Calculation

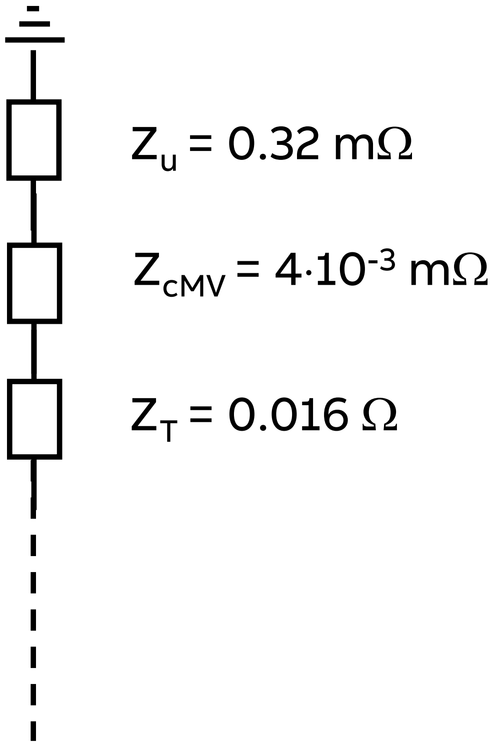
Basic Principles

Calculation of Short Circuit Currents

Example

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

S_n = 400 kVA
U= 20/0.4 kV
$u_{k\%}$ = 4 %

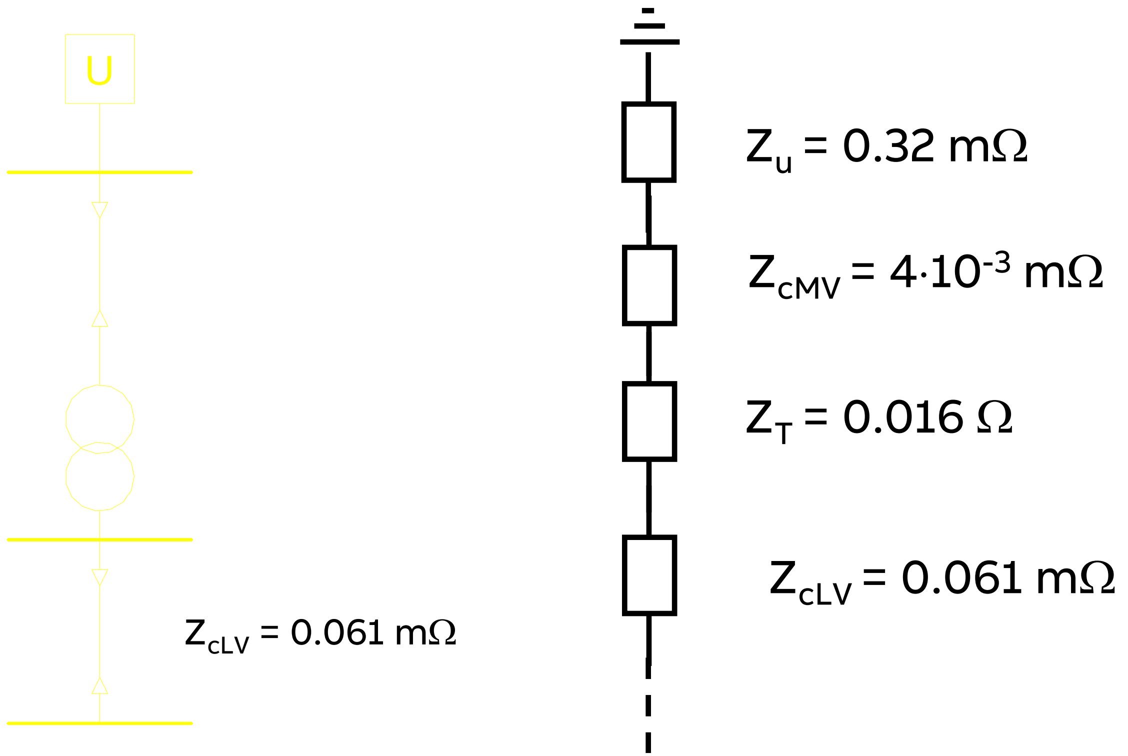


Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Example

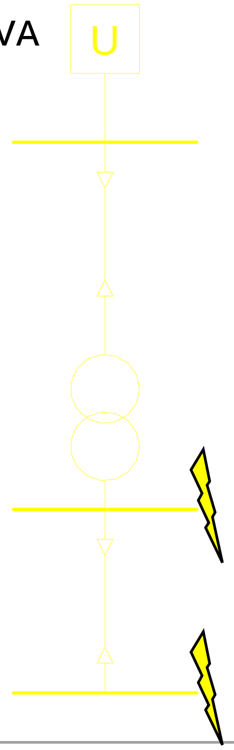


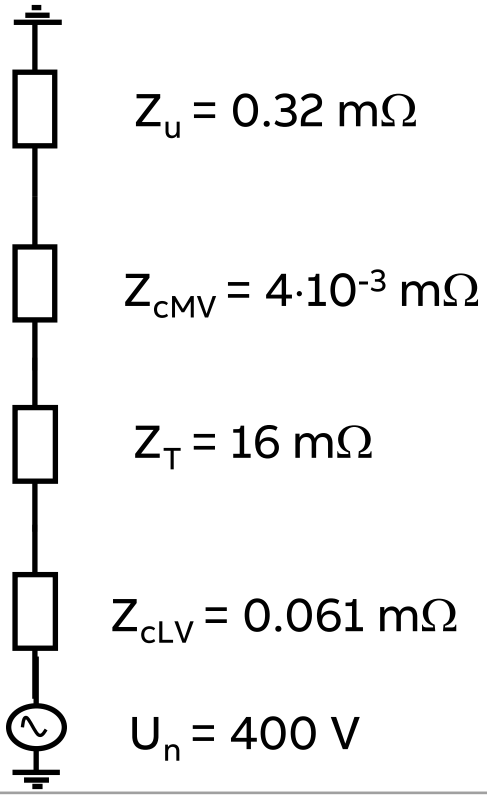
Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Example





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

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

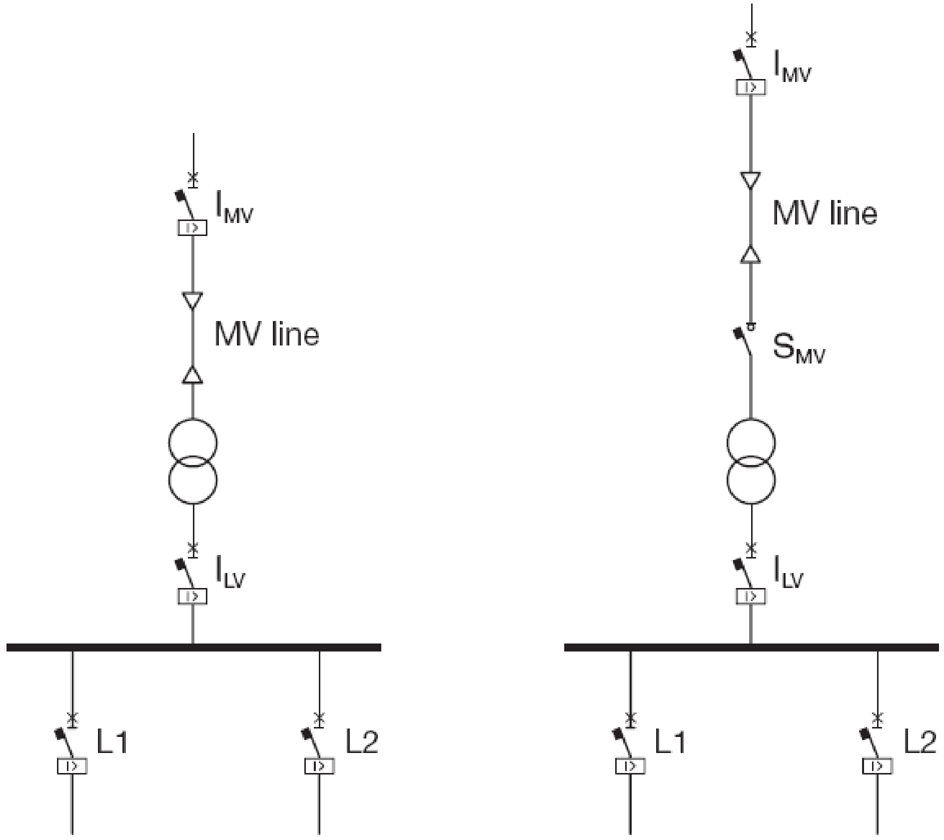
Short Circuit Calculation

Basic Principles

Common Management Methods

Substation with single transformer

Typical single line diagrams

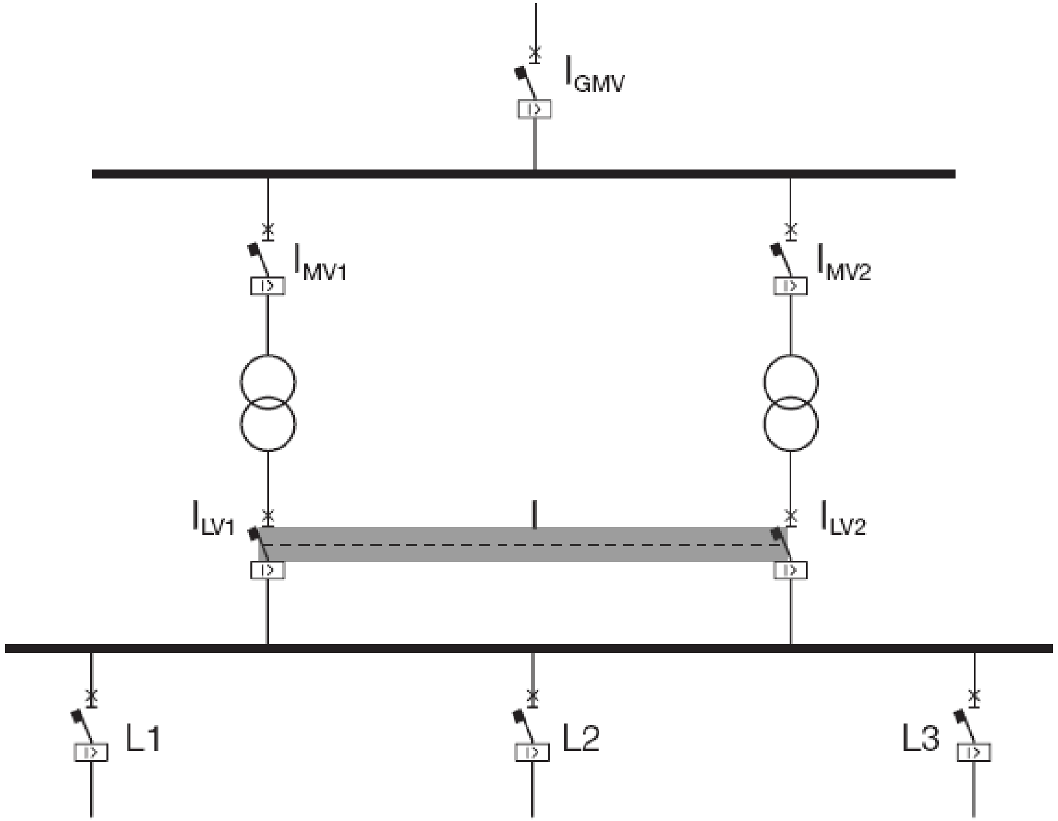


Short Circuit Calculation

Basic Principles

Common Management Methods

Substation with two transformers
(One as spare for the other)
– The use of mechanical interlock between two ACBs

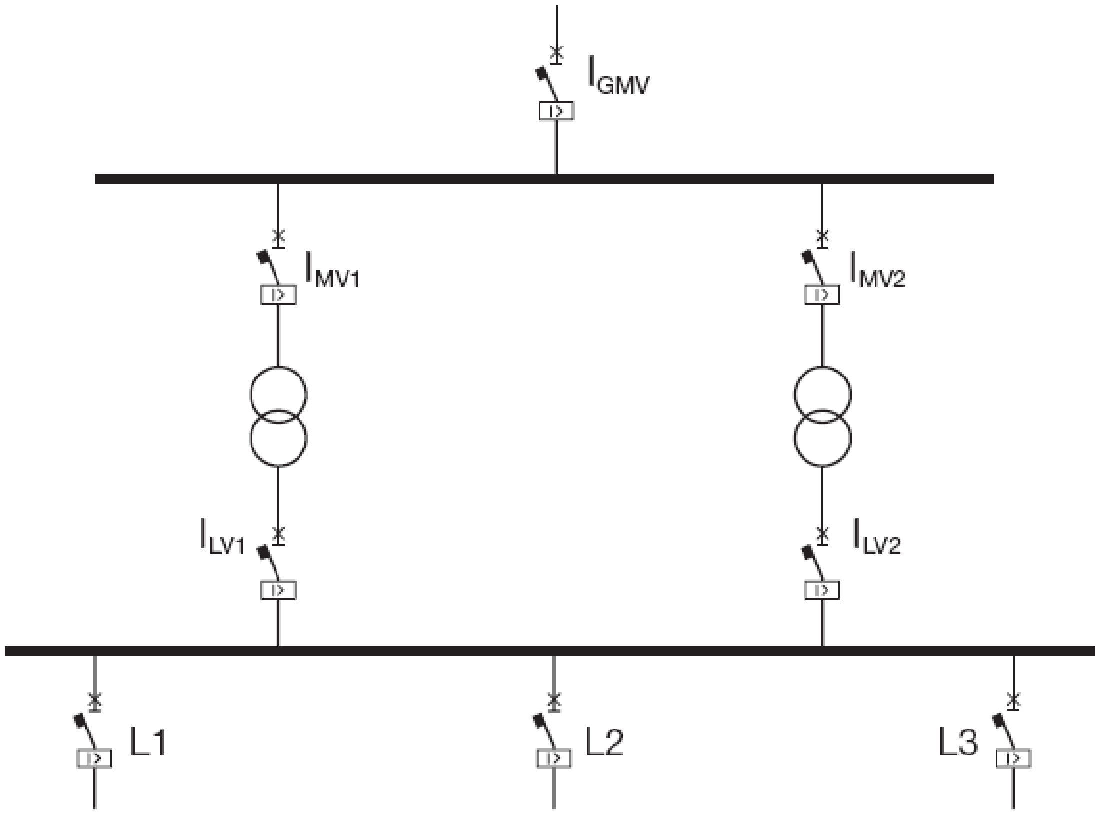


Short Circuit Calculation

Basic Principles

Common Management Methods

Substation with two transformers which operate in parallel



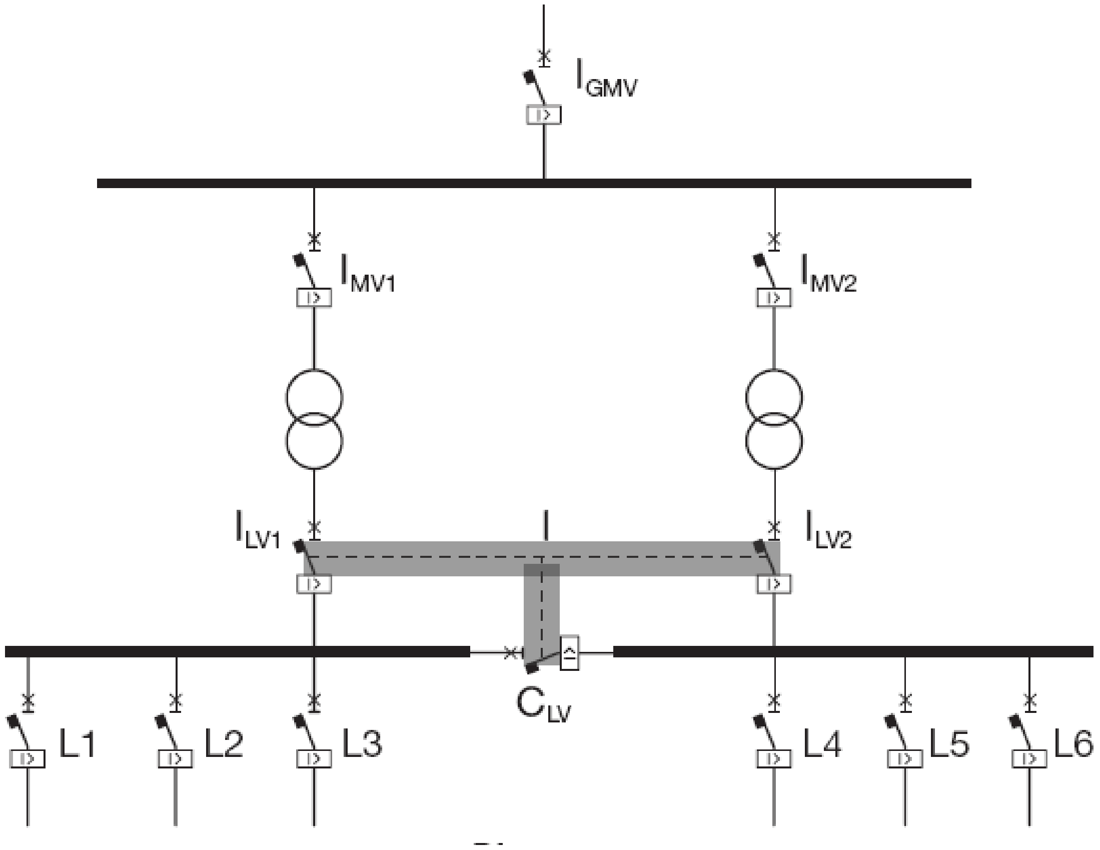
Short Circuit Calculation

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



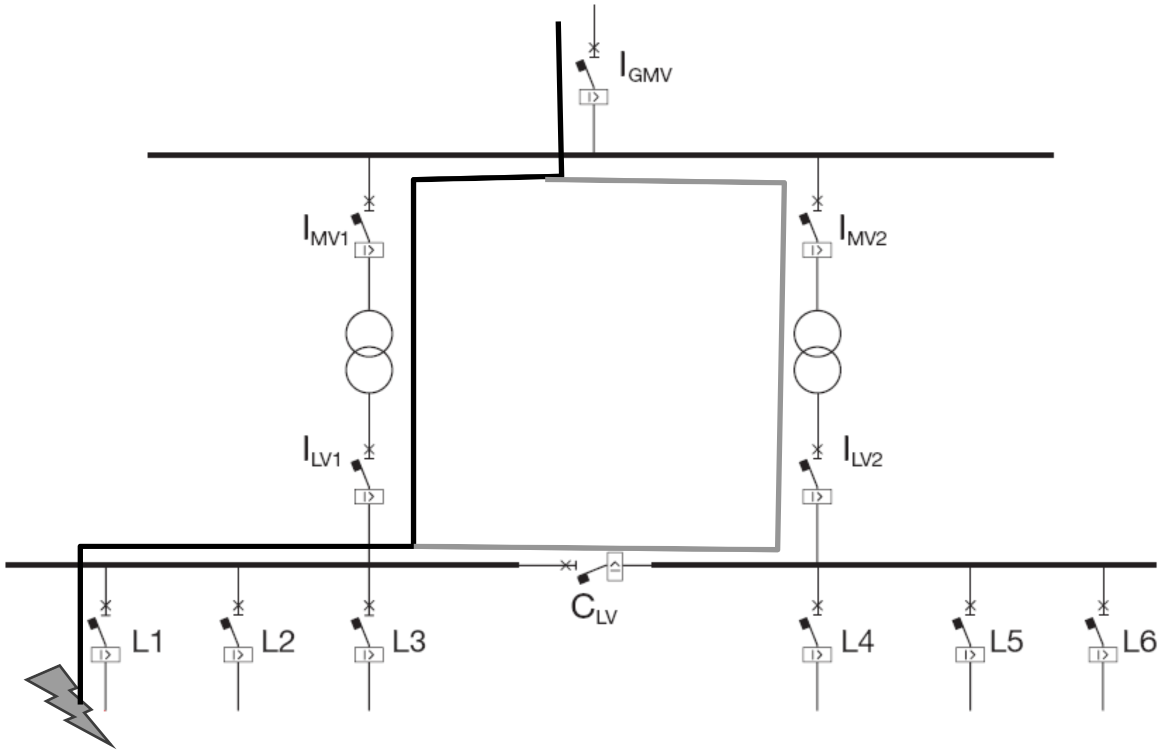
Short Circuit Calculation

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



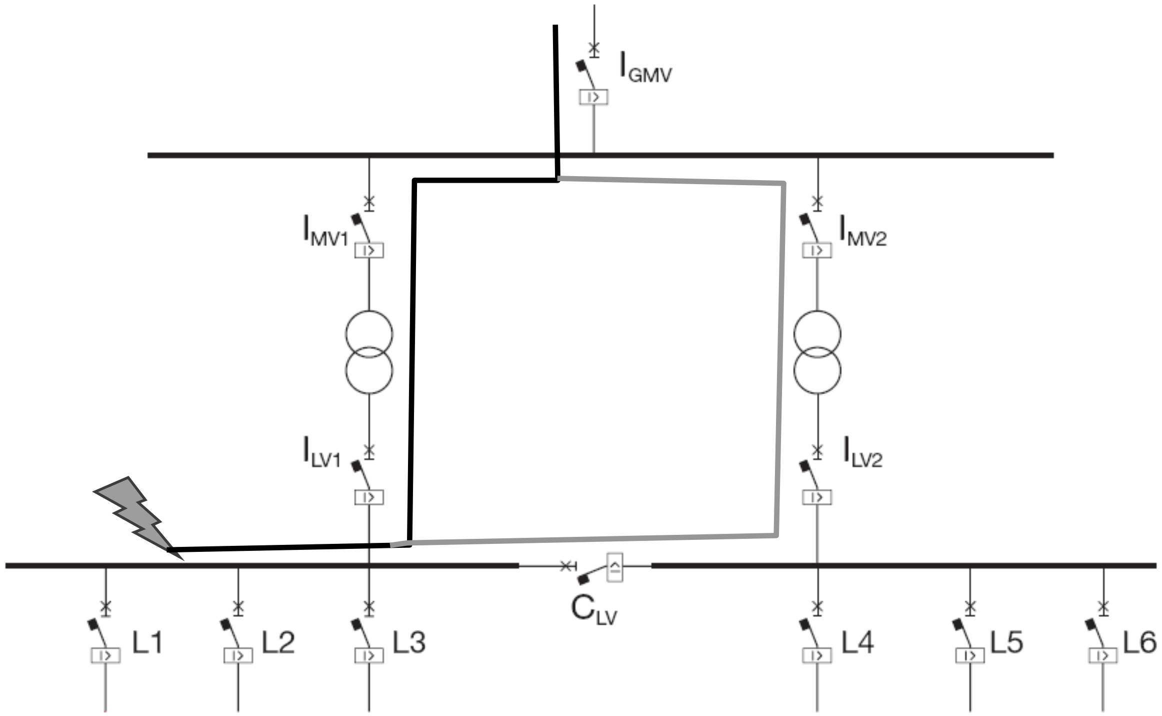
Short Circuit Calculation

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

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
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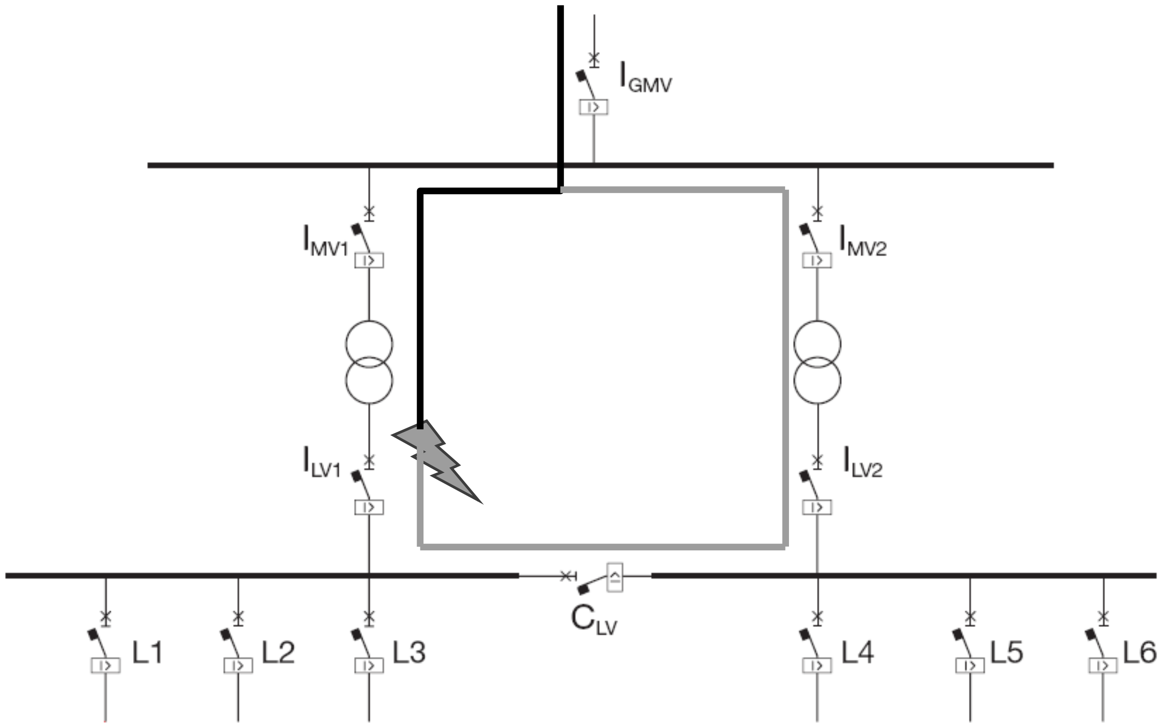


Short Circuit Calculation

Basic Principles

Short Circuit Calculations Single Transformer

MV Level 22kV 750MVA

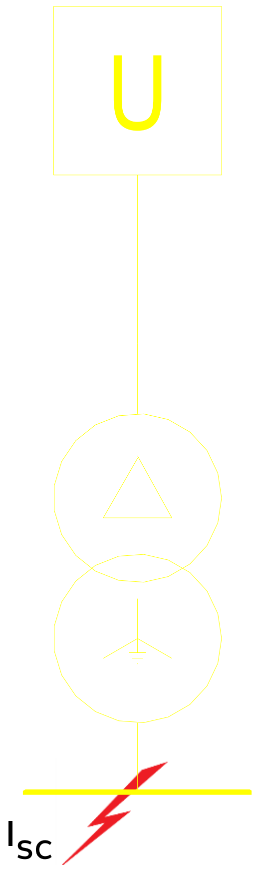
$$Z_{22kV} = \frac{(22k)^2}{750M} = 0.6453\ \Omega$$

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

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

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

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



22kV
750MVA

1600kVA
22/0.4kV
6%

Short Circuit Calculation

Basic Principles

Short Circuit Calculations two transformers in parallel

MV Level 22kV 750MVA

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

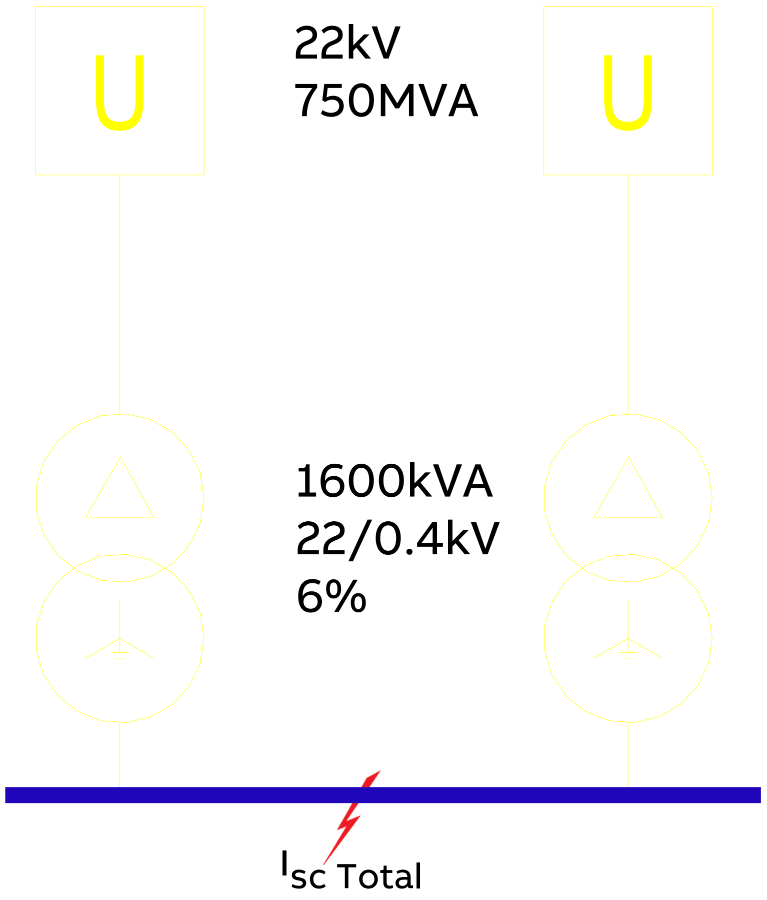
$$Z_{400V} = 0.6453 \times \frac{400^2}{22000^2} = 0.2133\ m\Omega$$

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

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

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

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



ABB

Short Circuit Calculation

Basic Principles

Short Circuit Calculations two transformers in parallel

MV Level 22kV 750MVA

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

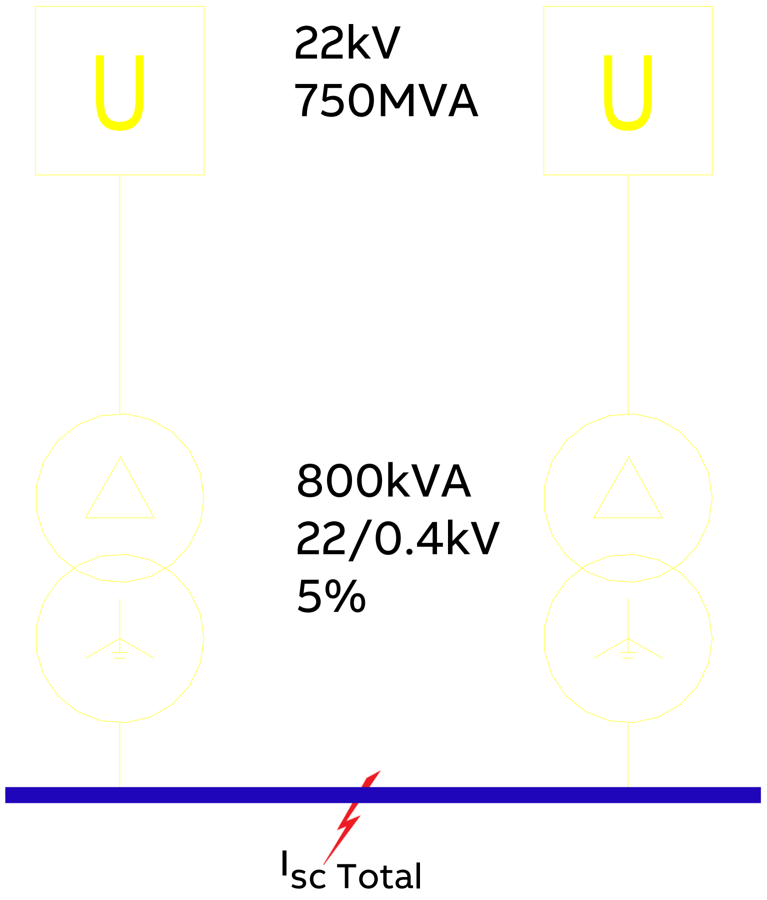
$$Z_{400V} = 0.6453 \times \frac{400^2}{22000^2} = 0.2133\ m\Omega$$

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

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

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

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



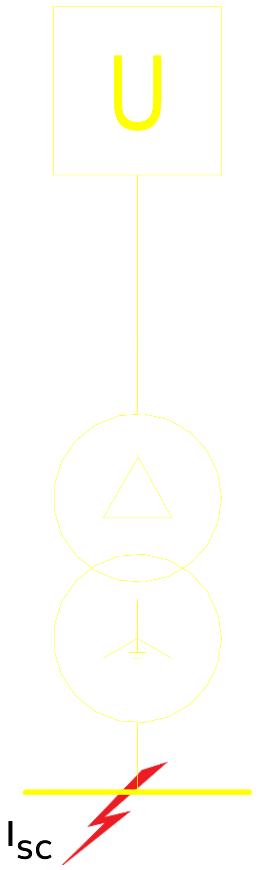
Short Circuit Calculation

Basic Principles

Short Circuit Calculations Single Transformer

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

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



22kV
MVA = ???

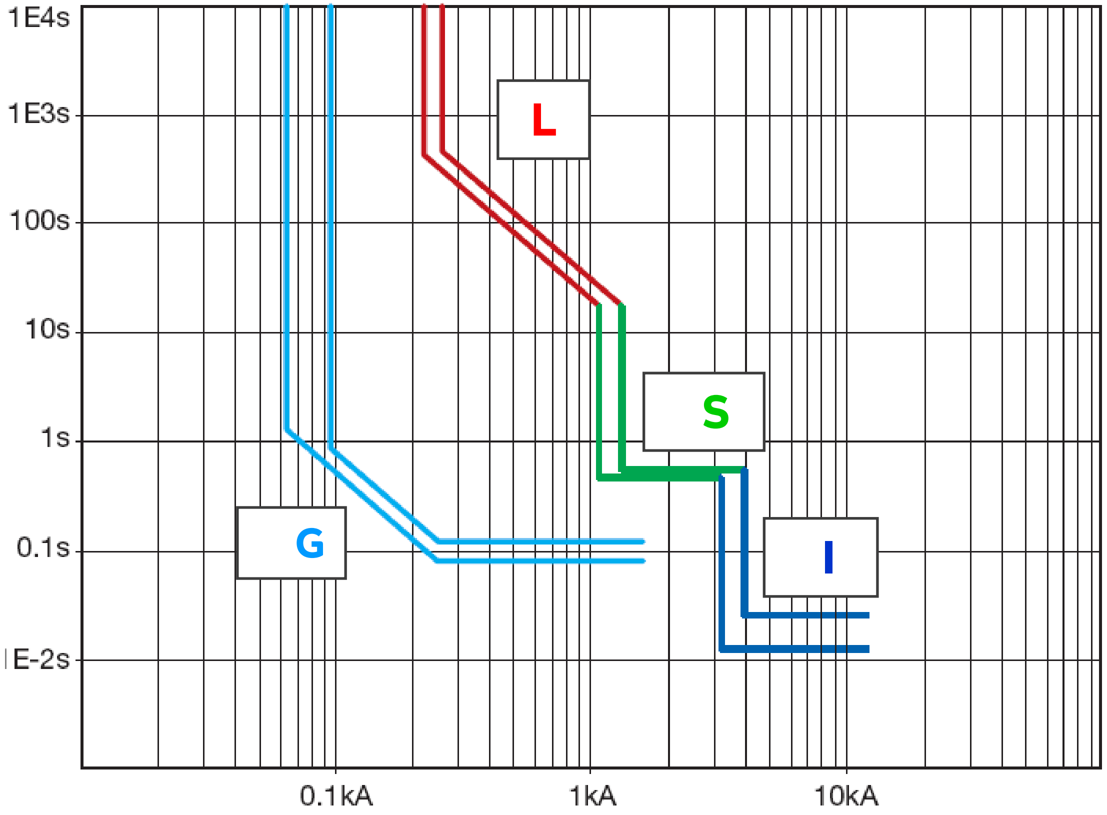
1600kVA
22/0.4kV
6%

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

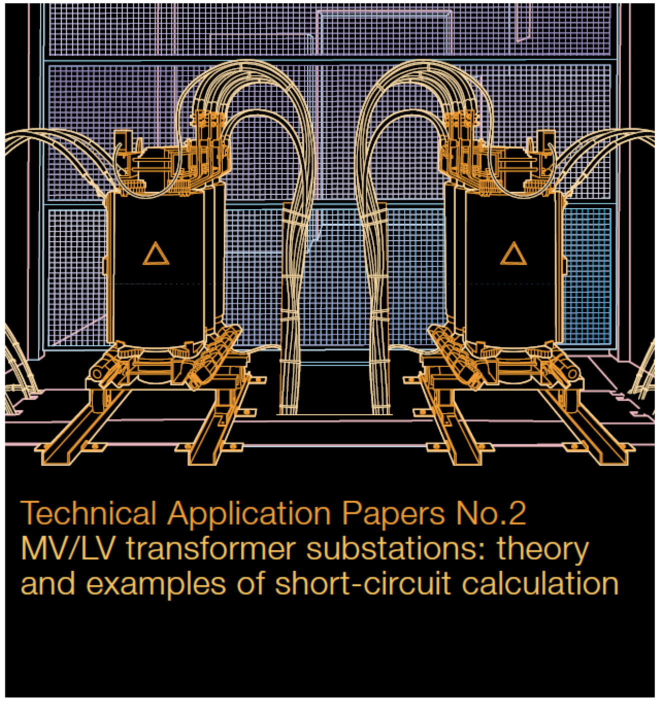


Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Technical Application Paper



Technical Application Papers

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

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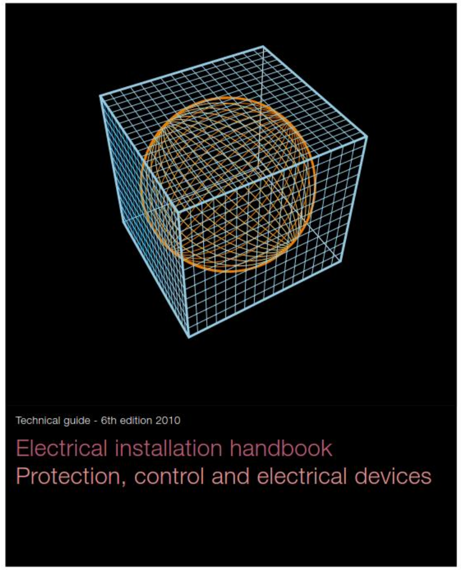
Short Circuit Calculation

Basic Principles

Calculation of Short Circuit Currents

Electrical Installation Handbook



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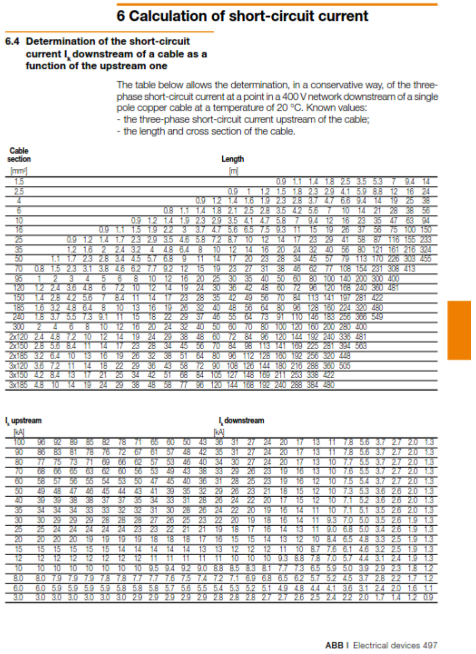


Determination of short-circuit current downstream of a cable as a function of the upstream short-circuit current (Table 6.4).

Cable section [mm²]	Length [m]																								
1.5																0.9	1.1	1.4	1.8	2.5	3.5	5.3	7	9.4	14
2.5													0.9	1	1.2	1.5	1.8	2.3	2.9	4.1	5.9	8.8	12	16	24
4											0.9	1.2	1.4	1.6	1.9	2.3	2.8	3.7	4.7	6.6	9.4	14	19	25	38
6									0.8	1.1	1.4	1.8	2.1	2.5	2.8	3.5	4.2	5.6	7	10	14	21	28	38	56
10							0.9	1.2	1.4	1.9	2.3	2.9	3.5	4.1	4.7	5.8	7	9.4	12	16	23	35	47	63	94
16					0.9	1.1	1.5	1.9	2.2	3	3.7	4.7	5.6	6.5	7.5	9.3	11	15	19	26	37	56	75	100	150
25			0.9	1.2	1.4	1.7	2.3	2.9	3.5	4.6	5.8	7.2	8.7	10	12	14	17	23	29	41	58	87	116	155	233
35			1.2	1.6	2	2.4	3.2	4	4.8	6.4	8	10	12	14	16	20	24	32	40	56	80	121	161	216	324
50		1.1	1.7	2.3	2.8	3.4	4.5	5.7	6.8	9	11	14	17	20	23	28	34	45	57	79	113	170	226	303	455
70	0.8	1.5	2.3	3.1	3.8	4.6	6.2	7.7	9.2	12	15	19	23	27	31	38	46	62	77	108	154	231	308	413	
95	1	2	3	4	5	6	8	10	12	16	20	25	30	35	40	50	60	80	100	140	200	300	400		
120	1.2	2.4	3.6	4.8	6	7.2	10	12	14	19	24	30	36	42	48	60	72	96	120	168	240	360	481		
150	1.4	2.8	4.2	5.6	7	8.4	11	14	17	23	28	35	42	49	56	70	84	113	141	197	281	422			
185	1.6	3.2	4.8	6.4	8	10	13	16	19	26	32	40	48	56	64	80	96	128	160	224	320	480			
240	1.8	3.7	5.5	7.3	9.1	11	15	18	22	29	37	46	55	64	73	91	110	146	183	256	366	549			
300	2	4	6	8	10	12	16	20	24	32	40	50	60	70	80	100	120	160	200	280	400				
2x120	2.4	4.8	7.2	10	12	14	19	24	29	38	48	60	72	84	96	120	144	192	240	336	481				
2x150	2.8	5.6	8.4	11	14	17	23	28	34	45	56	70	84	98	113	141	169	225	281	394	563				
2x185	3.2	6.4	10	13	16	19	26	32	38	51	64	80	96	112	128	160	192	256	320	448					
3x120	3.6	7.2	11	14	18	22	29	36	43	58	72	90	108	126	144	180	216	288	360	505					
3x150	4.2	8.4	13	17	21	25	34	42	51	68	84	105	127	148	169	211	253	338	422						
3x185	4.8	10	14	19	24	29	38	48	58	77	96	120	144	168	192	240	288	384	480						

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	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	19	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

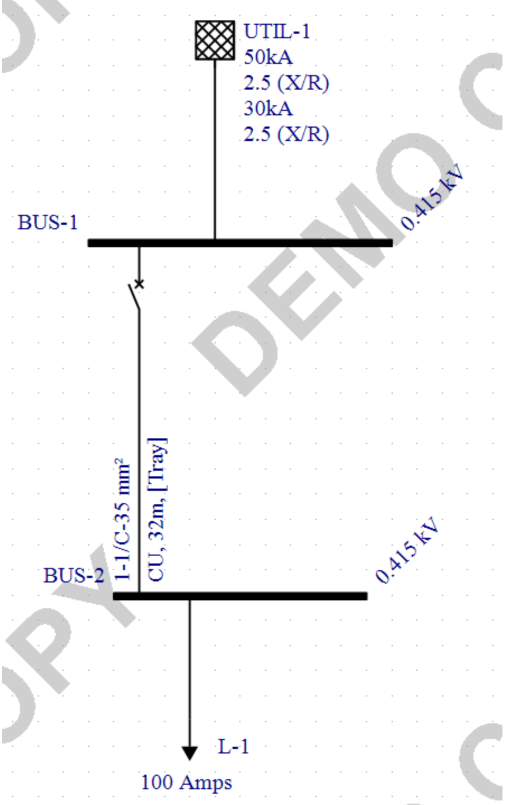
Determination of short-circuit current downstream of a cable as a function of the upstream short-circuit current (Table 6.4).

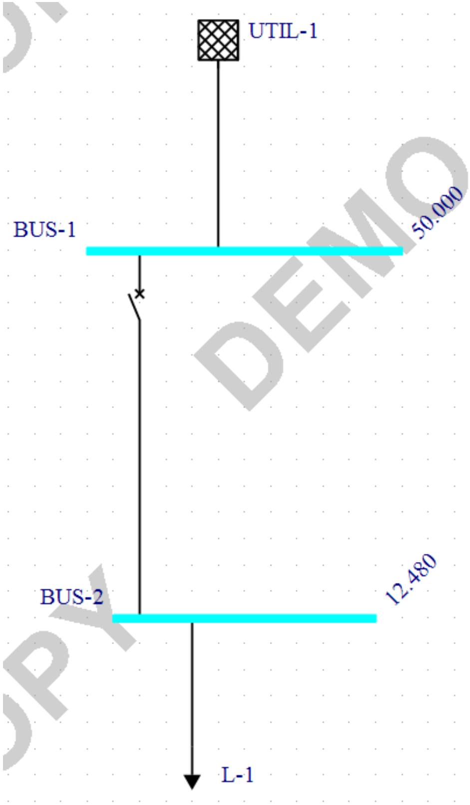
Short Circuit Calculation

Basic Principles

EasyPower Short Circuit Calculation

Example





Short Circuit Calculation

Basic Principles

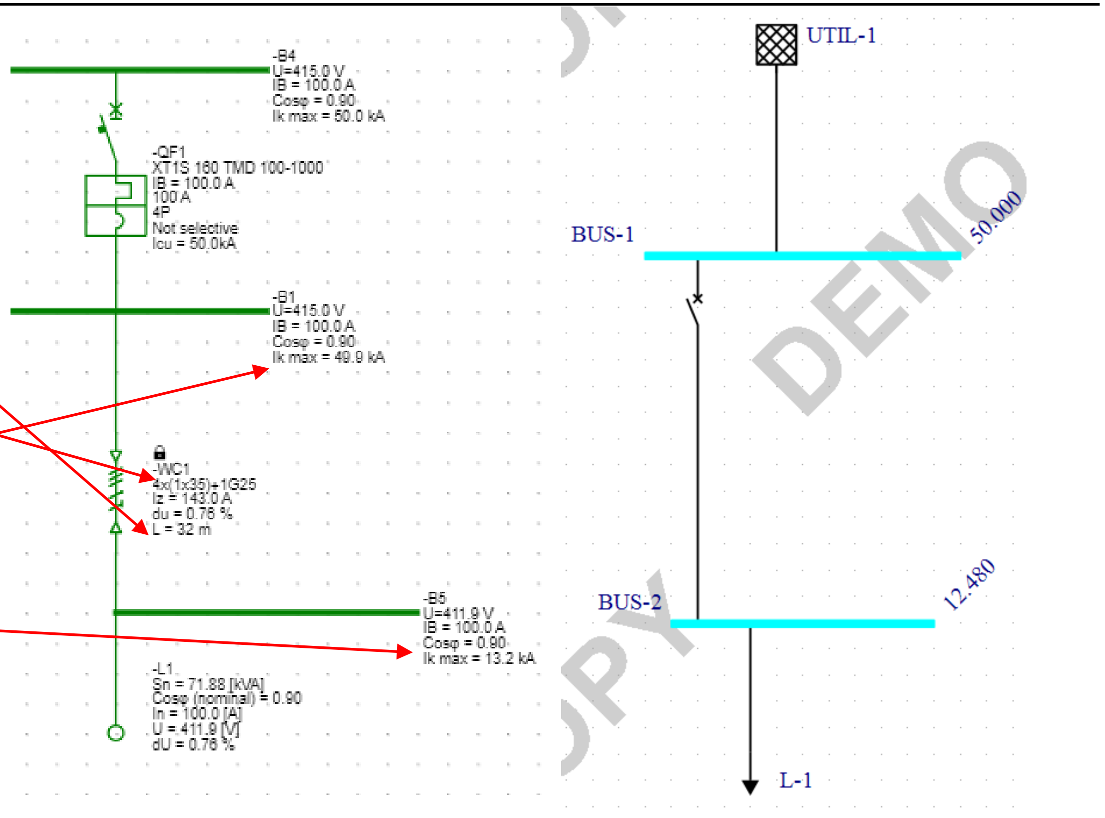
Calculation of Short Circuit Currents

Manual Verification

- Example 1

Cable section [mm²]	Length [m]																								
1.5																0.9	1.1	1.4	1.8	2.5	3.5	5.3	7	9.4	14
2.5													0.9	1	1.2	1.5	1.8	2.3	2.9	4.1	5.9	8.8	12	16	24
4											0.9	1.2	1.4	1.6	1.9	2.3	2.8	3.7	4.7	6.6	9.4	14	19	25	38
6									0.8	1.1	1.4	1.8	2.1	2.5	2.8	3.5	4.2	5.6	7	10	14	21	28	38	56
10							0.9	1.2	1.4	1.9	2.3	2.9	3.5	4.1	4.7	5.8	7	9.4	12	16	23	35	47	63	94
16					0.9	1.1	1.5	1.9	2.2	3	3.7	4.7	5.6	6.5	7.5	9.3	11	15	19	26	37	56	75	100	150
25			0.9	1.2	1.4	1.7	2.3	2.9	3.5	4.6	5.8	7.2	8.7	10	12	14	17	23	29	41	58	87	116	155	233
35			1.2	1.6	2	2.4	3.2	4	4.8	6.4	8	10	12	14	16	20	24	32	40	56	80	121	161	216	324
50		1.1	1.7	2.3	2.8	3.4	4.5	5.7	6.8	9	11	14	17	20	23	28	34	45	57	79	113	170	226	303	455
70	0.8	1.5	2.3	3.1	3.8	4.6	6.2	7.7	9.2	12	15	19	23	27	31	38	46	62	77	108	154	231	308	413	
95	1	2	3	4	5	6	8	10	12	16	20	25	30	35	40	50	60	80	100	140	200	300	400		
120	1.2	2.4	3.6	4.8	6	7.2	10	12	14	19	24	30	36	42	48	60	72	96	120	168	240	360	481		
150	1.4	2.8	4.2	5.6	7	8.4	11	14	17	23	28	35	42	49	56	70	84	113	141	197	281	422			
185	1.6	3.2	4.8	6.4	8	10	13	16	19	26	32	40	48	56	64	80	96	128	160	224	320	480			
240	1.8	3.7	5.5	7.3	9.1	11	15	18	22	29	37	46	55	64	73	91	110	146	183	256	366	549			
300	2	4	6	8	10	12	16	20	24	32	40	50	60	70	80	100	120	160	200	280	400				
2x120	2.4	4.8	7.2	10	12	14	19	24	29	38	48	60	72	84	96	120	144	192	240	336	481				
2x150	2.8	5.6	8.4	11	14	17	23	28	34	45	56	70	84	98	113	141	169	225	281	394	563				
2x185	3.2	6.4	10	13	16	19	26	32	38	51	64	80	96	112	128	160	192	256	320	448					
3x120	3.6	7.2	11	14	18	22	29	36	43	58	72	90	108	126	144	180	216	288	360	505					
3x150	4.2	8.4	13	17	21	25	34	42	51	68	84	105	127	148	169	211	253	338	422						
3x185	4.8	10	14	19	24	29	38	48	58	77	96	120	144	168	192	240	288	384	480						

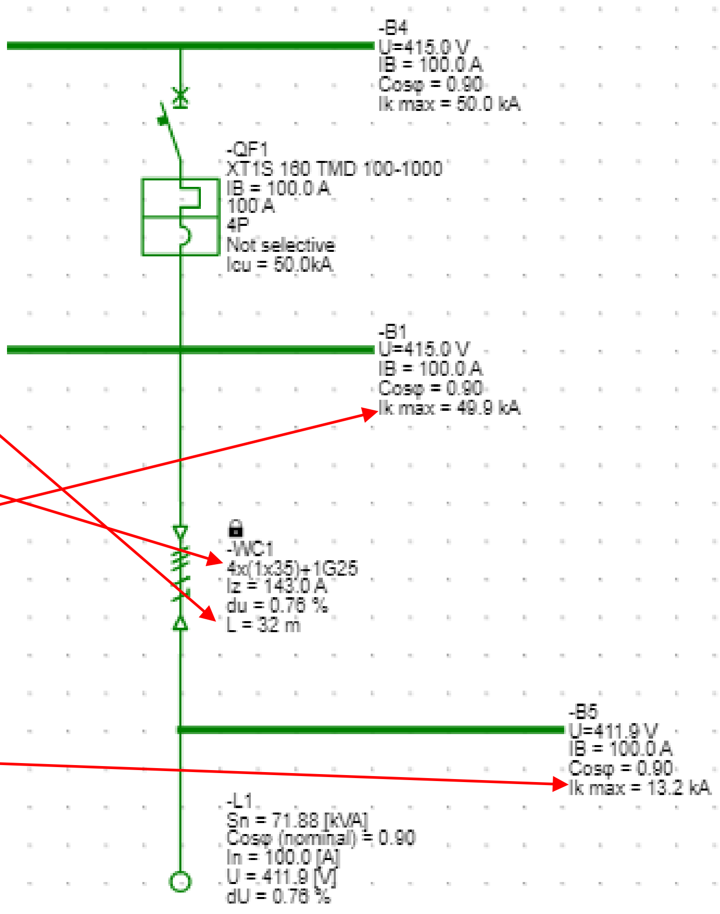
I_k upstream [kA]	I_k downstream [kA]																							
100	96	92	89	85	82	78	71	65	60	50	43	36	31	27	24	20	17	13	11	7.8	5.6	3.7	2.7	2.0	1.3
90	86	83	81	78	76	72	67	61	57	48	42	35	31	27	24	20	17	13	11	7.8	5.6	3.7	2.7	2.0	1.3
80	77	75	73	71	69	66	62	57	53	46	40	34	30	27	24	20	17	13	10	7.7	5.5	3.7	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	13	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	19	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

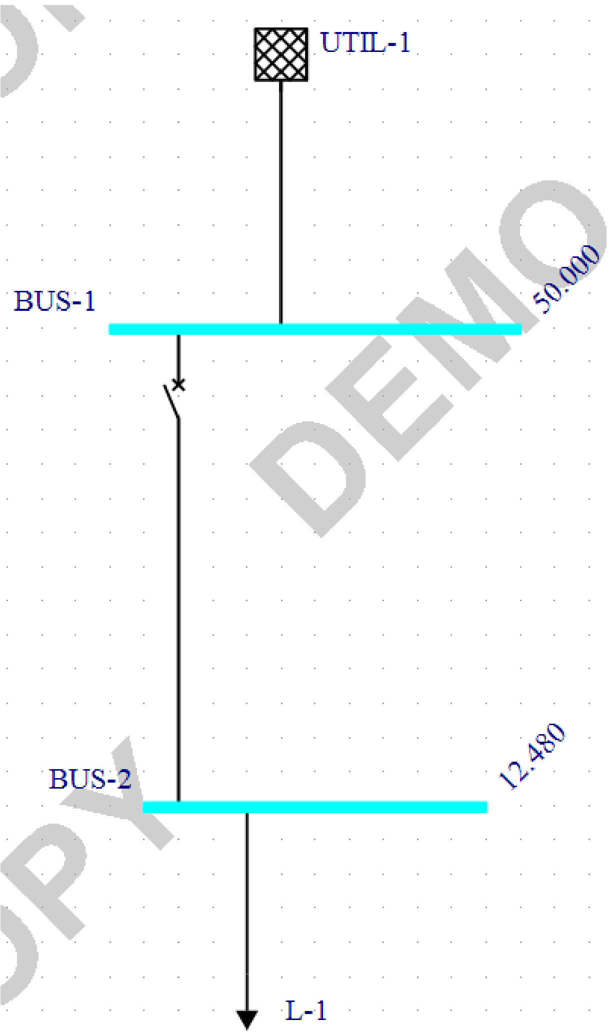


ABB

Cable section [mm²]	Length [m]																							
1.5																0.9	1.1	1.4	1.8	2.5	3.5	5.3	7	9.4	14
2.5													0.9	1	1.2	1.5	1.8	2.3	2.9	4.1	5.9	8.8	12	16	24
4											0.9	1.2	1.4	1.6	1.9	2.3	2.8	3.7	4.7	6.6	9.4	14	19	25	38
6									0.8	1.1	1.4	1.8	2.1	2.5	2.8	3.5	4.2	5.6	7	10	14	21	28	38	56
10							0.9	1.2	1.4	1.9	2.3	2.9	3.5	4.1	4.7	5.8	7	9.4	12	16	23	35	47	63	94
16					0.9	1.1	1.5	1.9	2.2	3	3.7	4.7	5.6	6.5	7.5	9.3	11	15	19	26	37	56	75	100	150
25			0.9	1.2	1.4	1.7	2.3	2.9	3.5	4.6	5.8	7.2	8.7	10	12	14	17	23	29	41	58	87	116	155	233
35			1.2	1.6	2	2.4	3.2	4	4.8	6.4	8	10	12	14	16	20	24	32	40	56	80	121	161	216	324
50		1.1	1.7	2.3	2.8	3.4	4.5	5.7	6.8	9	11	14	17	20	23	28	34	45	57	79	113	170	226	303	455
70	0.8	1.5	2.3	3.1	3.8	4.6	6.2	7.7	9.2	12	15	19	23	27	31	38	46	62	77	108	154	231	308	413	
95	1	2	3	4	5	6	8	10	12	16	20	25	30	35	40	50	60	80	100	140	200	300	400		
120	1.2	2.4	3.6	4.8	6	7.2	10	12	14	19	24	30	36	42	48	60	72	96	120	168	240	360	481		
150	1.4	2.8	4.2	5.6	7	8.4	11	14	17	23	28	35	42	49	56	70	84	113	141	197	281	422			
185	1.6	3.2	4.8	6.4	8	10	13	16	19	26	32	40	48	56	64	80	96	128	160	224	320	480			
240	1.8	3.7	5.5	7.3	9.1	11	15	18	22	29	37	46	55	64	73	91	110	146	183	256	366	549			
300	2	4	6	8	10	12	16	20	24	32	40	50	60	70	80	100	120	160	200	280	400				
2x120	2.4	4.8	7.2	10	12	14	19	24	29	38	48	60	72	84	96	120	144	192	240	336	481				
2x150	2.8	5.6	8.4	11	14	17	23	28	34	45	56	70	84	98	113	141	169	225	281	394	563				
2x185	3.2	6.4	10	13	16	19	26	32	38	51	64	80	96	112	128	160	192	256	320	448					
3x120	3.6	7.2	11	14	18	22	29	36	43	58	72	90	108	126	144	180	216	288	360	505					
3x150	4.2	8.4	13	17	21	25	34	42	51	68	84	105	127	148	169	211	253	338	422						
3x185	4.8	10	14	19	24	29	38	48	58	77	96	120	144	168	192	240	288	384	480						

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	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	19	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





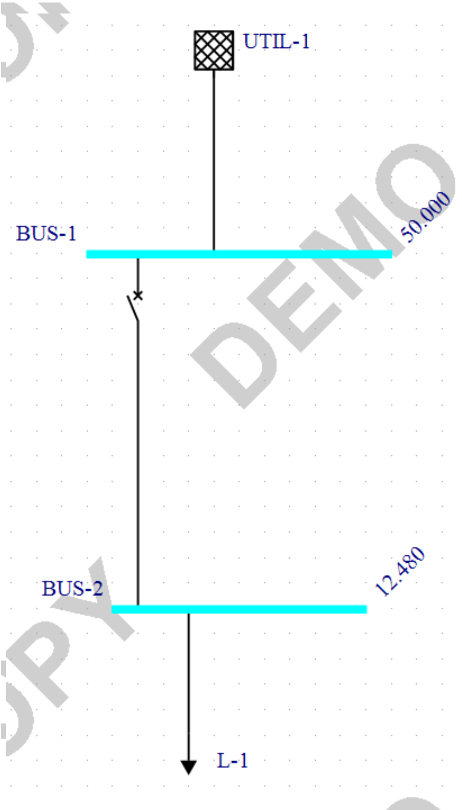
Short Circuit Calculation

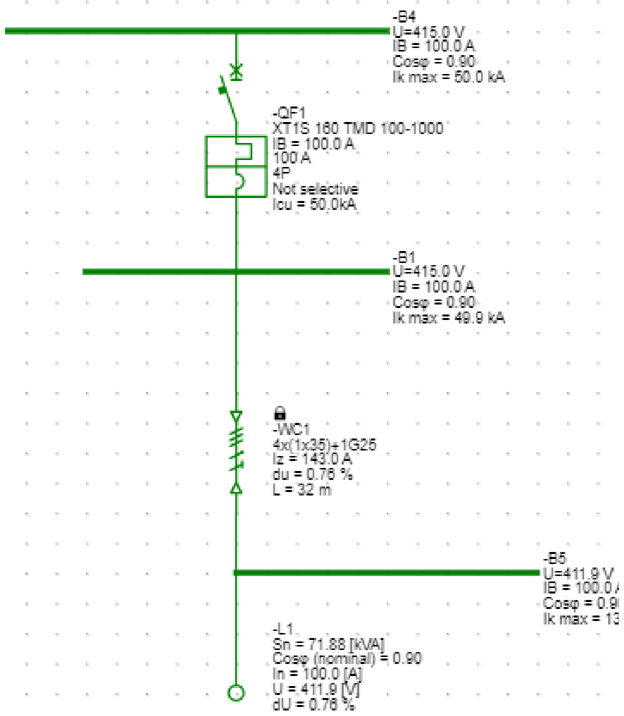
Basic Principles

Calculation of Short Circuit Currents

Manual Verification

- Example 1





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

$I_1 = 50\text{kA}$

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

$R_{cable} = 16.923\ \text{m}\Omega$ (from cable database @ 20^{0}C)

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

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

ABB

ABB