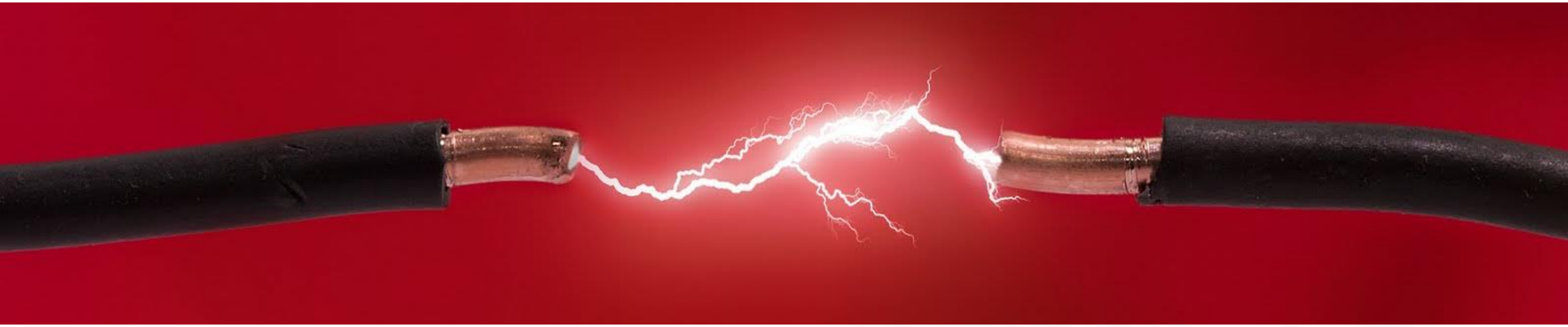
# Order of Engineers and Architects – Beirut Lebanon

# Short Circuit Calculations, Based on Methods Outlined in the IEC

## A More Practical Method to Adopt



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# Risks Associated With Short Circuit Currents

- The reliability and safety of electric power distribution systems depend on accurate and thorough **knowledge of short-circuit fault currents** that can be present, and on the ability of **protective devices to satisfactorily interrupt** these currents.
- Knowledge of the **computational methods** of power system analysis **is essential to engineers** responsible for planning, design, operation, and troubleshooting of distribution systems.

# Why Do I Need a Short Circuit Analysis?

- To ensure that existing and new equipment ratings are adequate to withstand the available short circuit energy available at each **point in the electrical system**
- A Short Circuit Analysis will help to ensure that personnel and equipment are protected by establishing proper **interrupting ratings of protective devices** (circuit breaker and fuses)

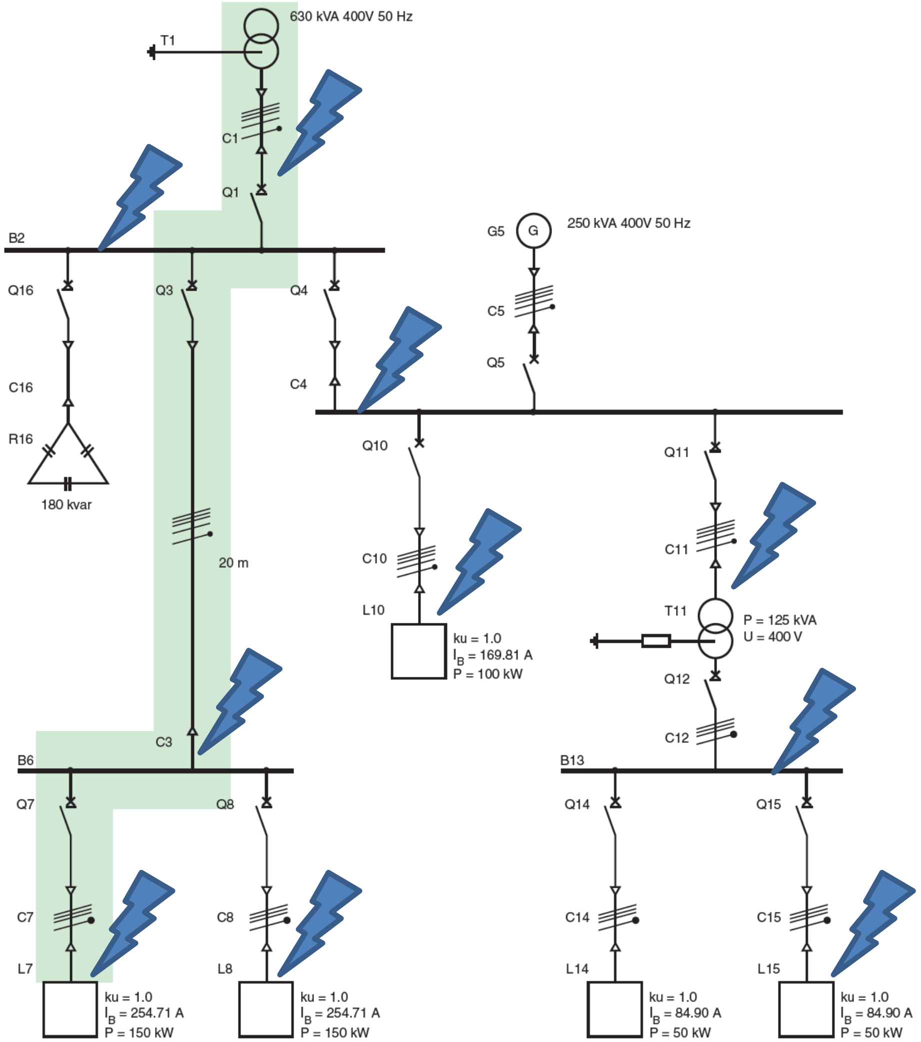


*Fig. G65: Example of single-line diagram*

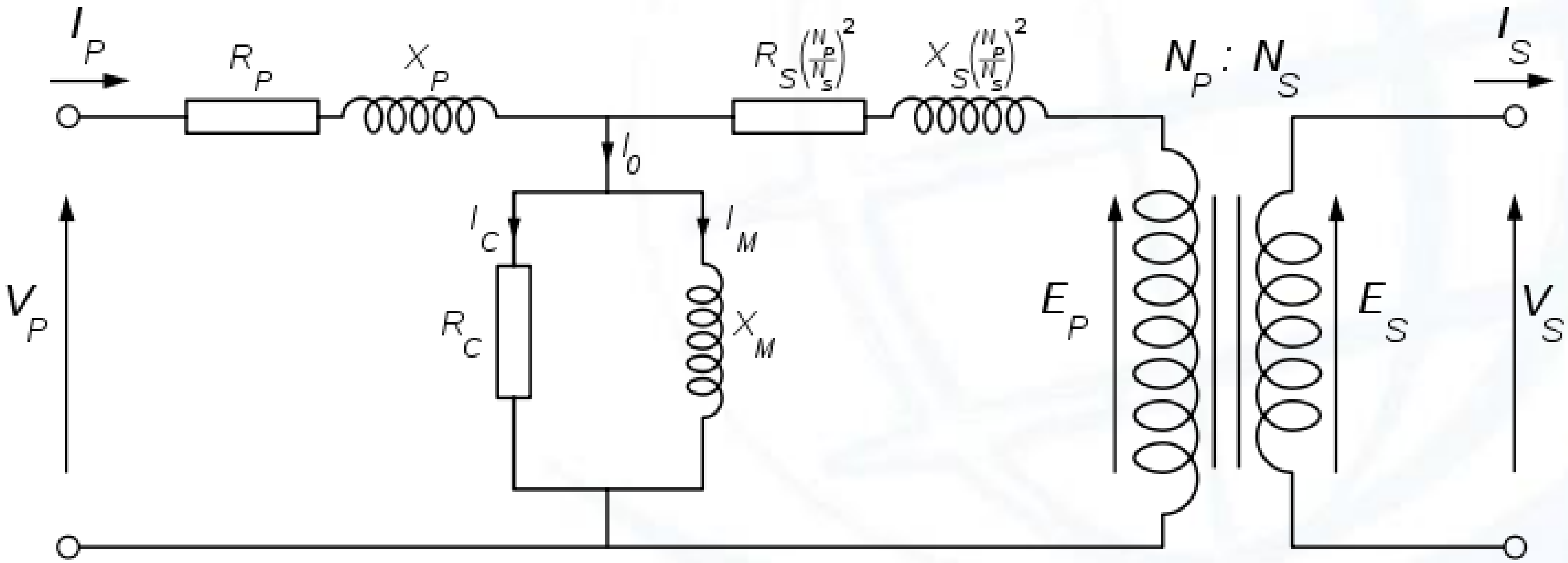
# Why Do I Need a Short Circuit Analysis?

- The short circuit calculations must be maintained and **periodically updated** to protect the equipment and the lives.
- It is not safe to **assume** that new equipment is properly rated.

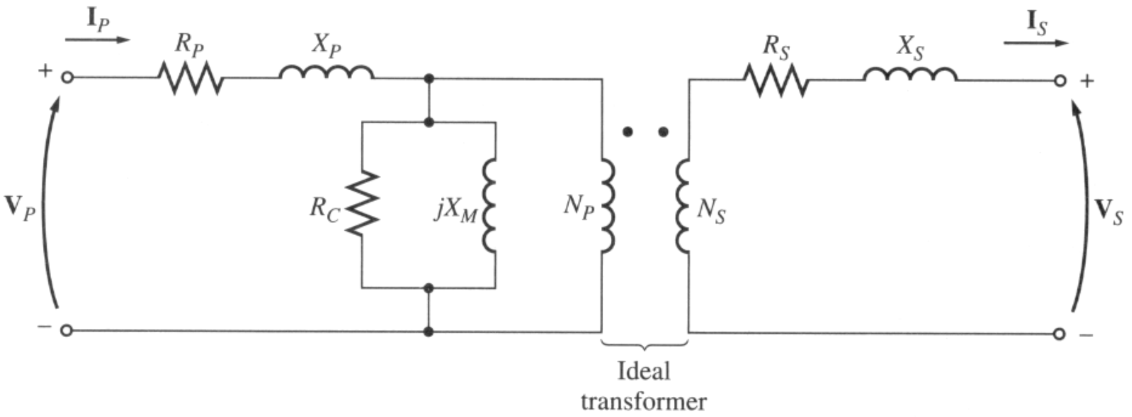
# Benefits of Running a Short Circuit Analysis

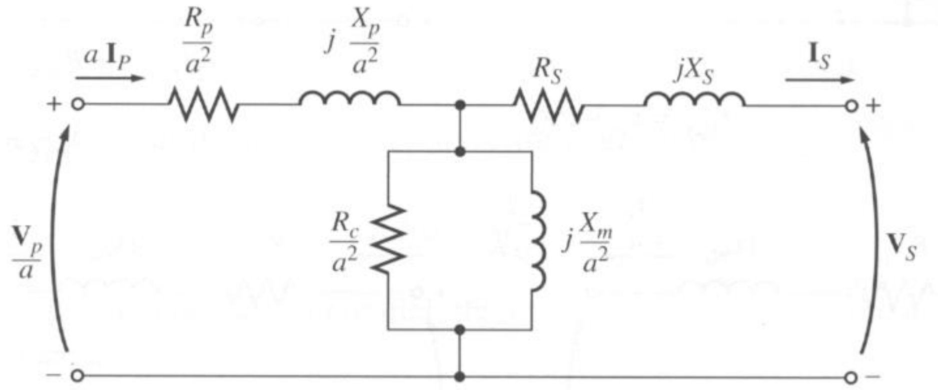
- Reduces the risk a facility could face and **help avoid catastrophic losses.**
- **Increases the safety and reliability** of the power system and related equipment.
- Evaluates the application of protective devices and equipment.
- **Identifies problem areas** in the system.
- Identifies **recommended solutions** to existing problems.

# X-fmr Modeling



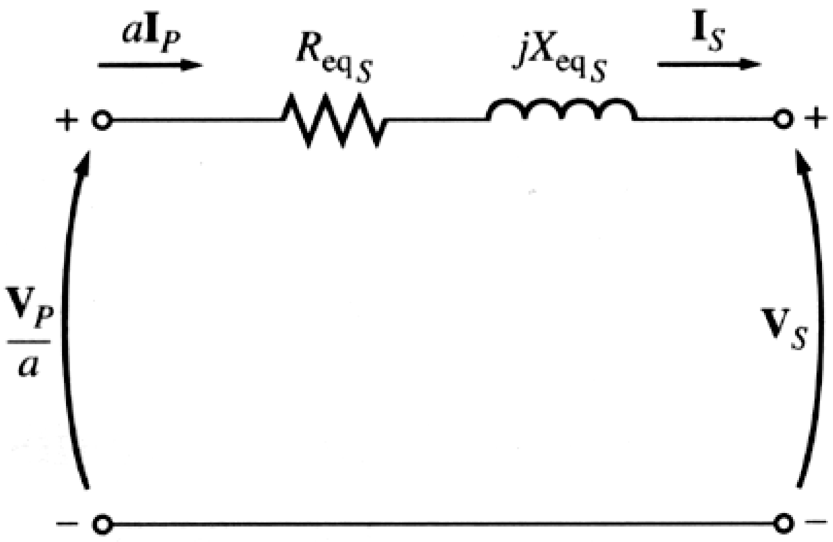
# The exact equivalent circuit of a real transformer





Equivalent circuit of the transformer referred to its secondary side.

# Approximate equivalent circuit of a transformer



Without an excitation branch referred to the secondary side.

**The values of components of the transformer model can be determined experimentally** by an open-circuit test or by a short-circuit test.

# Voltage Impedance

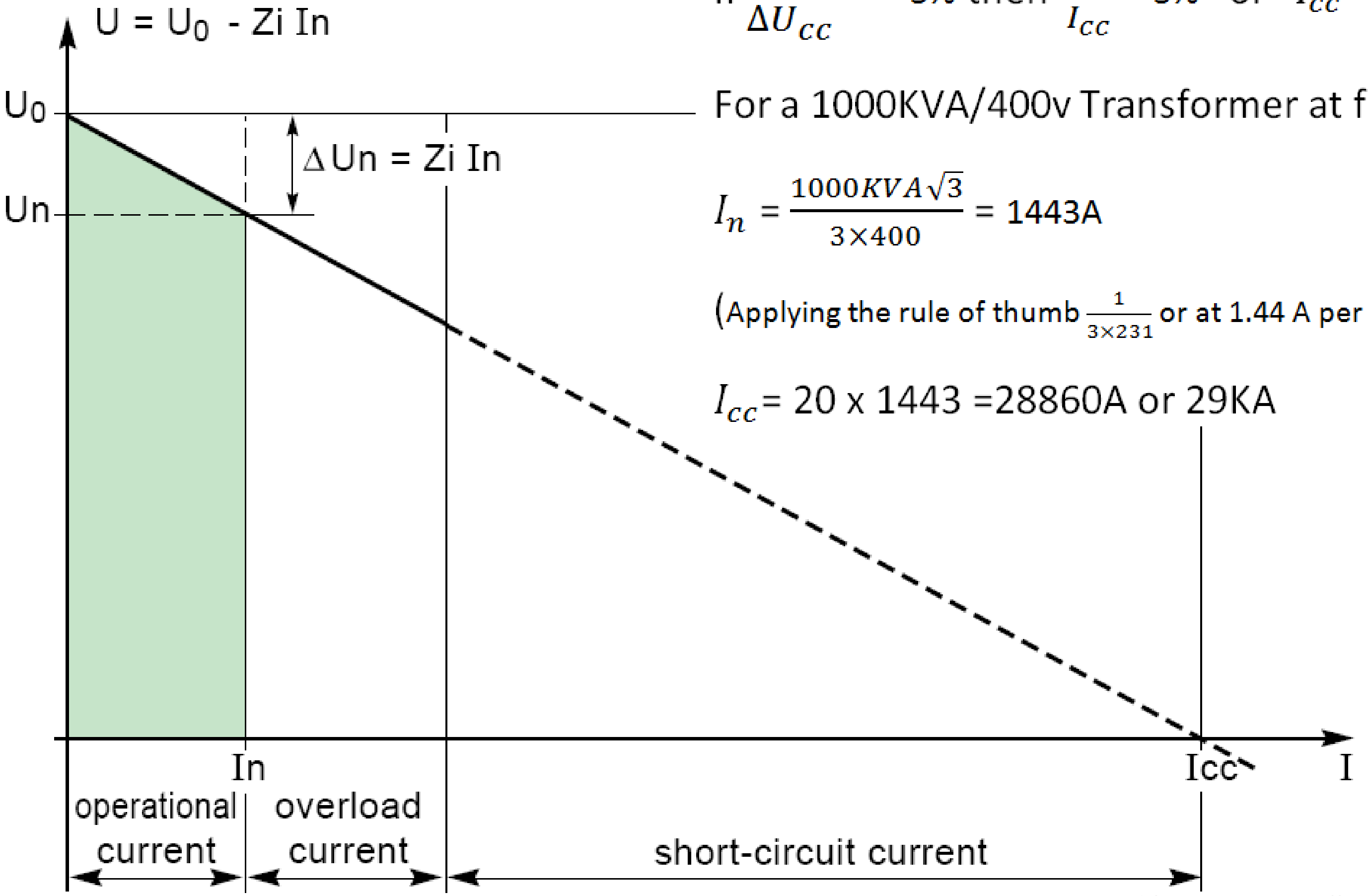
$$U_0 - U = Z_i I$$

$$U_0 - U_n = Z_i I_n$$

$$U_0 - U_{cc} = Z_i I_{cc}$$

$$\frac{U_0 - U_n}{U_0 - U_{cc}} = \frac{I_n}{I_{cc}}$$

$$\frac{\Delta U_n}{\Delta U_{cc}} = \frac{I_n}{I_{cc}}$$



If $\frac{\Delta U_n}{\Delta U_{cc}} =$ 5% then $\frac{I_n}{I_{cc}}$ = 5% or $I_{cc} = 20\ I_n$

For a 1000KVA/400v Transformer at full load the current:

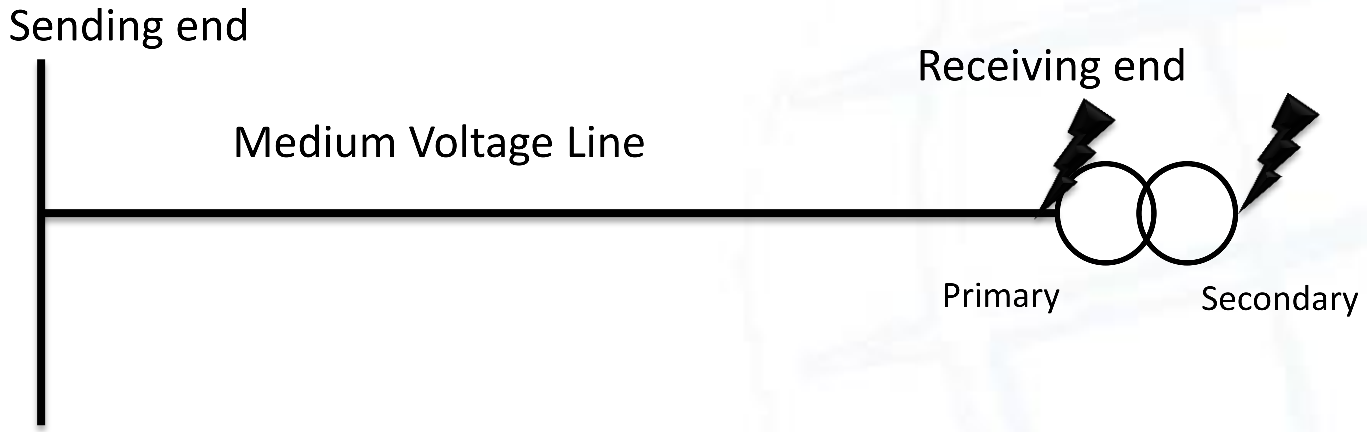
$I_n = \frac{1000KVA\sqrt{3}}{3\times400}$ = 1443A

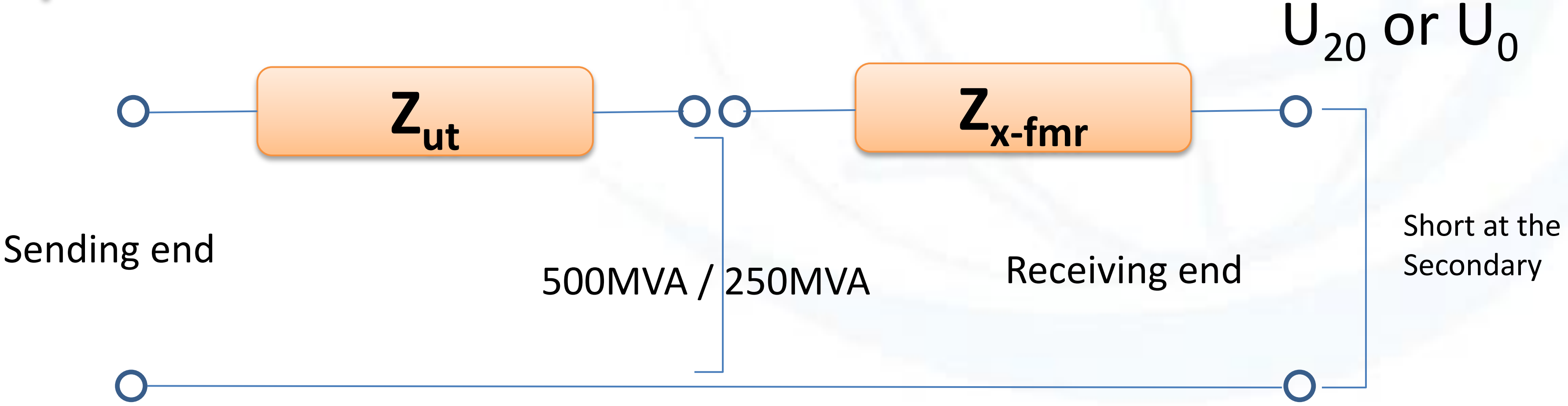
(Applying the rule of thumb $\frac{1}{3\times231}$ or at 1.44 A per KVA, $I_n$ = 1.443x 1000KVA = 1443A )

$I_{cc}$= 20 x 1443 =28860A or 29KA

# Admittance Method

| Psc | Uo (V) | Ra (mΩ) | Xa (mΩ) |
|---|---|---|---|
| 250 MVA | 420 | 0.07 | 0.7 |
| 500 MVA | 420 | 0.035 | 0.351 |





If the short circuit power is infinite then $Z_{ut}$ is zero

# Admittance Method

$S = V^2/Z$ or $S = V^2.A$

or

$A = S/V^2$

$$Z_{eq} = Z_{ut} + Z_{X\text{-}fmr}$$

$$1/A_{eq} = 1/A_{ut} + 1/A_{X\text{-}fmr}$$

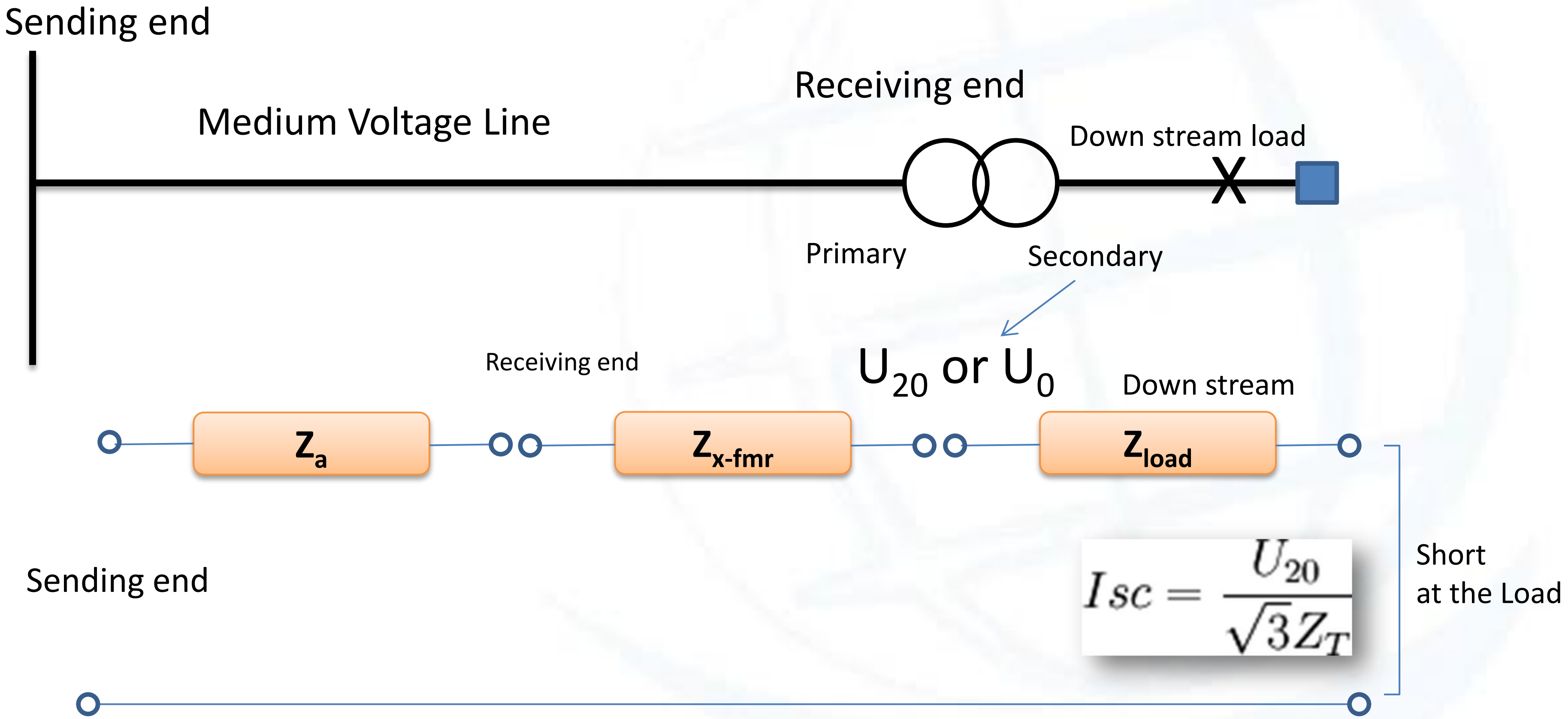
$$V^2/S_{eq} = V^2/S_{ut} + V^2/S_{X\text{-}fmr}$$

$$1 / MVAsc_{eq} = 1 / MVA_{Ut} + 1 / MVA_{X\text{-}fmr}$$

## SYSTEM FAULT CURRENT

- ✓ The MVA method is **fast and simple** as compared to the per unit or ohmic methods.
- ✓ There is no need to convert to an MVA base or worry about voltage levels.
- ✓ This is a useful method to obtain an **estimated** value of the fault current.
- ✓ The elements have to be converted to an **MVA** value and then the circuit is converted to admittance values.

# The Impedance Method
# IEC 60909



$$Isc = \frac{U_{20}}{\sqrt{3}Z_T}$$

$$Z_T = Z_a + Z_{X\text{-}fmr} + Z_{load}$$

# Determination of the impedance of each component

## Network upstream of the MV/LV transformer

The 3-phase short-circuit fault level $P_{SC}$, in kA or in MVA(1) is given by the power supply authority concerned, from which an equivalent impedance can be deduced.

| Psc | Uo (V) | $R_{ut}$ (mΩ) | $X_{ut}$ (mΩ) |
|---|---|---|---|
| **250 MVA** | 420 | 0.07 | 0.7 |
| **500 MVA** | 420 | 0.035 | 0.351 |

The table gives values for Ra and Xa corresponding to the most common MV(2) short-circuit levels in utility power-supply networks, namely, **250 MVA and 500 MVA.**

(1) Short-circuit MVA: $\sqrt{3}\ E_L\ I_{sc}$ where:

- $E_L$ = phase-to-phase nominal system voltage expressed in kV (r.m.s.)
- Isc = 3-phase short-circuit current expressed in kA (r.m.s.)

(2) up to 36 kV

# Or Analytically

$$Z_s = \frac{U_{20}^2}{P_{sc}}$$

where

- $Z_s$ = $Z_{ut}$ = impedance of the MV voltage network, expessed in milli-ohms
- $U_{20}$ = phase-to-phase no-load LV voltage, expressed in volts
- $P_{sc}$ = MV 3-phase short-circuit fault level, expressed in kVA
    - The upstream (MV) resistance Ra is generally found to be negligible compared with the corresponding Xa,
    - the latter then being taken as the ohmic value for Za.
    - If more accurate calculations are necessary, Xa may be taken to be equal to 0.995 Za and Ra equal to 0.1 Xa.

$$Z_{tr} = \frac{U_{20}^2}{S_n} \times \frac{U_{sc}}{100}$$

**Transformer:** The impedance $\mathbf{Z_{tr}}$ of a transformer, as viewed from the LV terminals (secondary), is given by the formula:

where:

- $U_{20}$ = open-circuit secondary phase-to-phase voltage expressed in volts
- $S_n$ = rating of the transformer (in kVA)
- $U_{sc}$ = the short-circuit impedance voltage of the transformer expressed in %
- The transformer windings resistance $\mathbf{R_{tr}}$ can be derived from the total losses as follows (expressed in milli-ohms):

$$R_{tr} = \frac{P_{cu} \times 10^3}{3\, I_n^2}$$

  - ✓ $P_{cu}$ = total losses in watts
  - ✓ $I_n$ = nominal full-load current in amps
  - ✓ $R_{tr}$ = resistance of one phase of the transformer in milli-ohms (the LV and corresponding MV winding for one LV phase are included in this resistance value).

$$X_{tr} = \sqrt{Z_{tr}^2 - R_{tr}^2}$$

- For an approximate calculation $R_{tr}$ may be ignored since X ≈ Z in standard distribution type transformers.

## Circuit-breakers

In LV circuits, the impedance of circuit-breakers upstream of the fault location must be taken into account. The reactance value conventionally assumed is 0.15 mΩ per CB, while the resistance is neglected.

## Busbars

The resistance of busbars is generally negligible, so that the impedance is practically all reactive, and amounts to approximately 0.15 mΩ/metre(1) length for LV busbars (doubling the spacing between the bars increases the reactance by about 10% only). (1) For 50 Hz systems, but 0.18 mΩ/m length at 60 Hz

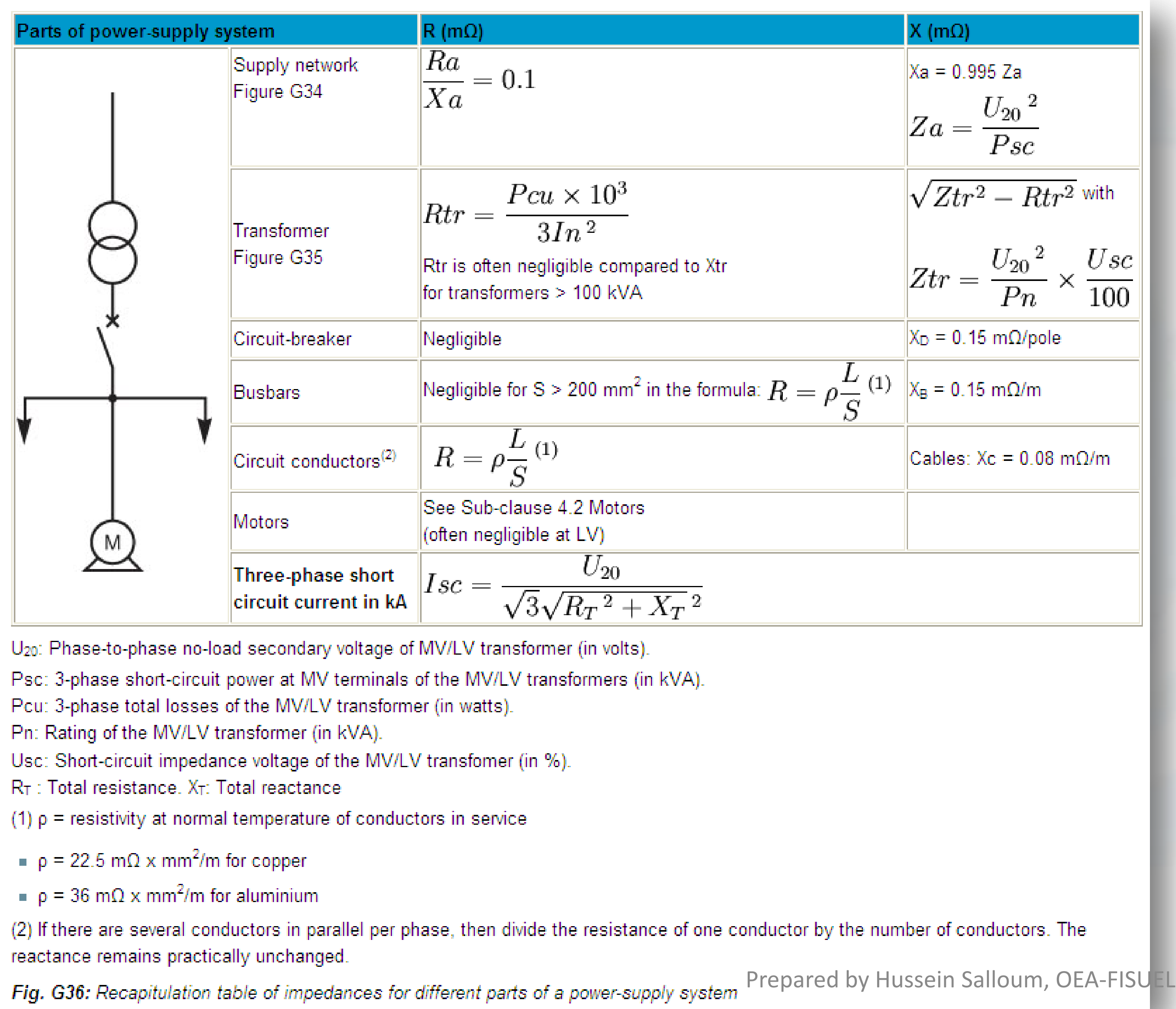
## Circuit conductors

$$R_c = \rho \frac{L}{S}$$

The resistance of a conductor is given by the formula:
where

- ρ = the resistivity constant of the conductor material at the normal operating temperature being:
  - - **22.5 mΩ.mm2/m for copper**
  - - **36 mΩ.mm2/m for aluminum**
- L = length of the conductor in m
- S = c.s.a. of conductor in mm2
- Cable reactance values can be obtained from the manufacturers.
  For c.s.a. of less than 50 mm2 reactance may be ignored.
  In the absence of other information, a value of 0.08 mΩ/metre may be used (for 50 Hz systems) or 0.096 mΩ/metre (for 60 Hz systems).
  For prefabricated bus-trunking and similar pre-wired ducting systems, the manufacturer should be consulted.

# Recapitulation table



| Parts of power-supply system | | R (mΩ) | X (mΩ) |
|---|---|---|---|
| | Supply network<br>Figure G34 | $\frac{Ra}{Xa} = 0.1$ | Xa = 0.995 Za<br>$Za = \frac{U_{20}{}^2}{Psc}$ |
| | Transformer<br>Figure G35 | $Rtr = \frac{Pcu \times 10^3}{3In^2}$<br>Rtr is often negligible compared to Xtr for transformers > 100 kVA | $\sqrt{Ztr^2 - Rtr^2}$ with<br>$Ztr = \frac{U_{20}{}^2}{Pn} \times \frac{Usc}{100}$ |
| | Circuit-breaker | Negligible | $X_D$ = 0.15 mΩ/pole |
| | Busbars | Negligible for S > 200 mm$^2$ in the formula: $R = \rho\frac{L}{S}$ (1) | $X_B$ = 0.15 mΩ/m |
| | Circuit conductors$^{(2)}$ | $R = \rho\frac{L}{S}$ (1) | Cables: Xc = 0.08 mΩ/m |
| | Motors | See Sub-clause 4.2 Motors<br>(often negligible at LV) | |
| | **Three-phase short circuit current in kA** | $Isc = \frac{U_{20}}{\sqrt{3}\sqrt{R_T{}^2 + X_T{}^2}}$ | |

$U_{20}$: Phase-to-phase no-load secondary voltage of MV/LV transformer (in volts).

Psc: 3-phase short-circuit power at MV terminals of the MV/LV transformers (in kVA).

Pcu: 3-phase total losses of the MV/LV transformer (in watts).

Pn: Rating of the MV/LV transformer (in kVA).

Usc: Short-circuit impedance voltage of the MV/LV transfomer (in %).

$R_T$ : Total resistance. $X_T$: Total reactance

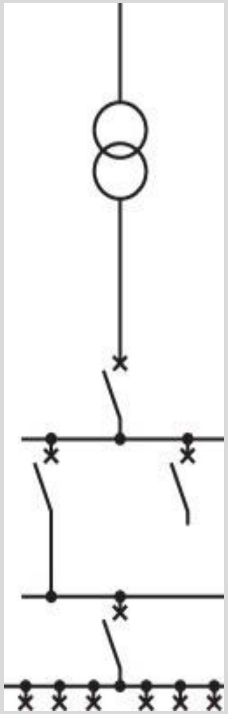
(1) ρ = resistivity at normal temperature of conductors in service

- ρ = 22.5 mΩ x mm$^2$/m for copper
- ρ = 36 mΩ x mm$^2$/m for aluminium

(2) If there are several conductors in parallel per phase, then divide the resistance of one conductor by the number of conductors. The reactance remains practically unchanged.

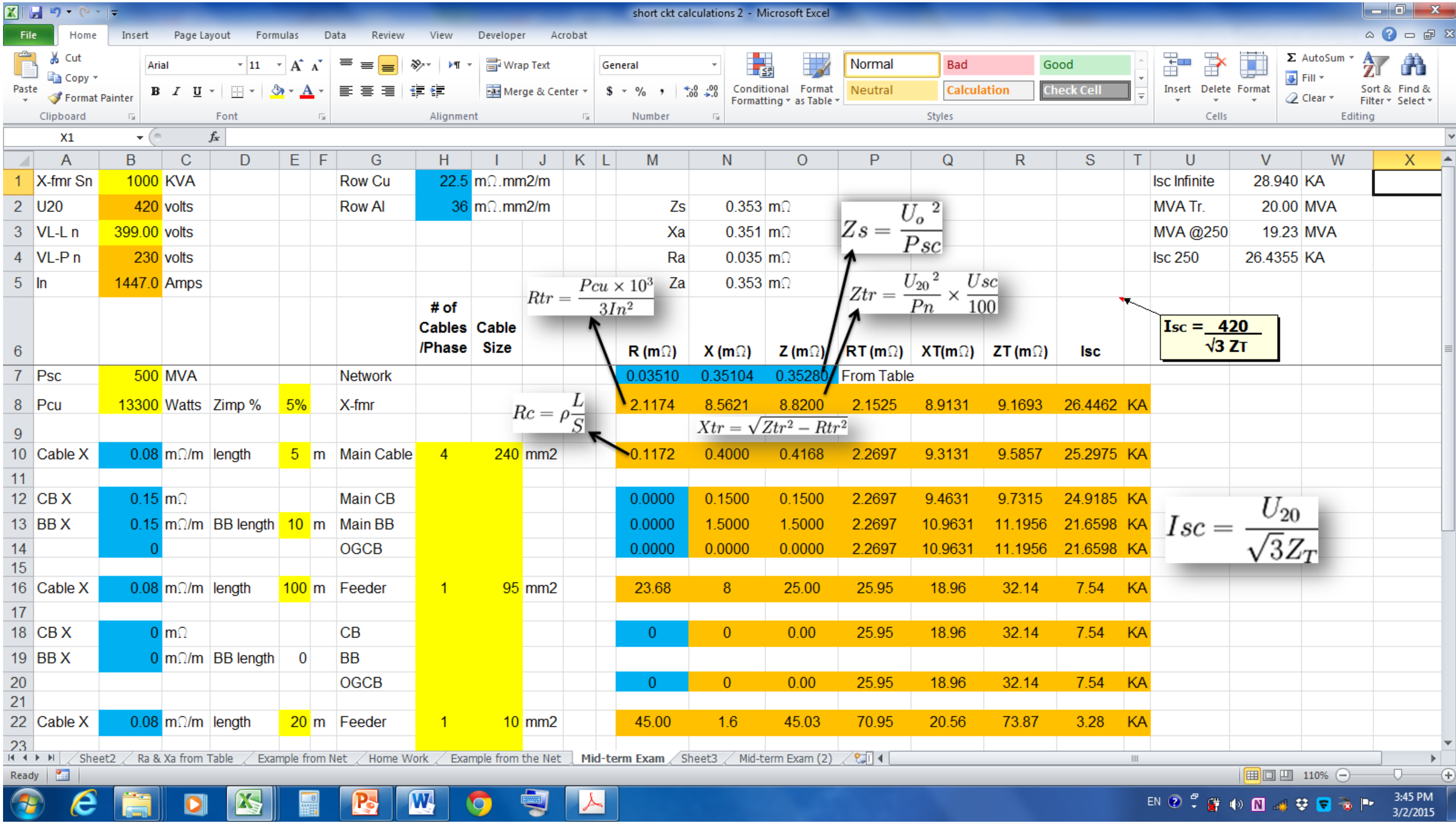
*Fig. G36: Recapitulation table of impedances for different parts of a power-supply system*

# Example of short-circuit calculations



| LV installation | R (mΩ) | X (mΩ) | RT (mΩ) | XT (mΩ) | |
|---|---|---|---|---|---|
| MV network<br>Psc = 500 MVA | 0.035 | 0.351 | | | $Isc = \frac{420}{\sqrt{3}\sqrt{{R_T}^2 + {X_T}^2}}$ |
| Transformer<br>20 kV/420 V<br>Pn = 1000 kVA<br>Usc = 5%<br>Pcu = 13.3 x $10^3$ watts | 2.12 | 8.56 | 2.15 | 8.91 | Isc 1=26.4KA |
| Single-core cables<br>5 m copper<br>4 x 240 mm$^2$/phase | $Rc = \frac{22.5}{4} \times \frac{5}{240} = 0.12$ | Xc = 0.08 x 5 = 0.40 | 2.27 | 9.31 | Isc2 = 25.3kA |
| Main<br>circuit-breaker | RD = 0 | XD = 0.15 | 2.27 | 9.46 | Isc3= 24.9KA |
| Busbars 10 m | RB = 0 | XB = 1.5 | 2.27 | 10.96 | Isc4 = 21.67 kA |
| Three-core cable<br>100 m<br>95 mm$^2$ copper | $Rc = 22.5 \times \frac{100}{95} = 23.68$ | Xc = 100 x 0.08 = 8 | 25.95 | 18.96 | Isc5 = 7.54kA |
| Three-core cable<br>20 m<br>10 mm$^2$ copper<br>final circuits | $Rc = 22.5 \times \frac{20}{10} = 45$ | Xc = 20 x 0.08 = 1.6 | 70.95 | 20.56 | Isc6 = 3.28 kA |

*Example of short-circuit current calculations for a LV installation supplied at 400 V (nominal) from a 1,000 kVA MV/LV transformer*



| | A | B | C | D | E | F | G | H | I | J | M | N | O | P | Q | R | S | T | U | V | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | X-fmr Sn | 1000 | KVA | | | | Row Cu | 22.5 | mΩ.mm2/m | | | | | | | | | | Isc Infinite | 28.940 | KA |
| 2 | U20 | 420 | volts | | | | Row Al | 36 | mΩ.mm2/m | | Zs | 0.353 | mΩ | | | | | | MVA Tr. | 20.00 | MVA |
| 3 | VL-L n | 399.00 | volts | | | | | | | | Xa | 0.351 | mΩ | | | | | | MVA @250 | 19.23 | MVA |
| 4 | VL-P n | 230 | volts | | | | | | | | Ra | 0.035 | mΩ | | | | | | Isc 250 | 26.4355 | KA |
| 5 | In | 1447.0 | Amps | | | | | | | | Za | 0.353 | mΩ | | | | | | | | |
| 6 | | | | | | | | # of Cables /Phase | Cable Size | | R (mΩ) | X (mΩ) | Z (mΩ) | RT (mΩ) | XT(mΩ) | ZT (mΩ) | Isc | | | | |
| 7 | Psc | 500 | MVA | | | | Network | | | | 0.03510 | 0.35104 | 0.35280 | From Table | | | | | | | |
| 8 | Pcu | 13300 | Watts | Zimp % | 5% | | X-fmr | | | | 2.1174 | 8.5621 | 8.8200 | 2.1525 | 8.9131 | 9.1693 | 26.4462 | KA | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | |
| 10 | Cable X | 0.08 | mΩ/m | length | 5 | m | Main Cable | 4 | 240 | mm2 | 0.1172 | 0.4000 | 0.4168 | 2.2697 | 9.3131 | 9.5857 | 25.2975 | KA | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | |
| 12 | CB X | 0.15 | mΩ | | | | Main CB | | | | 0.0000 | 0.1500 | 0.1500 | 2.2697 | 9.4631 | 9.7315 | 24.9185 | KA | | | |
| 13 | BB X | 0.15 | mΩ/m | BB length | 10 | m | Main BB | | | | 0.0000 | 1.5000 | 1.5000 | 2.2697 | 10.9631 | 11.1956 | 21.6598 | KA | | | |
| 14 | | 0 | | | | | OGCB | | | | 0.0000 | 0.0000 | 0.0000 | 2.2697 | 10.9631 | 11.1956 | 21.6598 | KA | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | |
| 16 | Cable X | 0.08 | mΩ/m | length | 100 | m | Feeder | 1 | 95 | mm2 | 23.68 | 8 | 25.00 | 25.95 | 18.96 | 32.14 | 7.54 | KA | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | |
| 18 | CB X | 0 | mΩ | | | | CB | | | | 0 | 0 | 0.00 | 25.95 | 18.96 | 32.14 | 7.54 | KA | | | |
| 19 | BB X | 0 | mΩ/m | BB length | 0 | | BB | | | | | | | | | | | | | | |
| 20 | | | | | | | OGCB | | | | 0 | 0 | 0.00 | 25.95 | 18.96 | 32.14 | 7.54 | KA | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | |
| 22 | Cable X | 0.08 | mΩ/m | length | 20 | m | Feeder | 1 | 10 | mm2 | 45.00 | 1.6 | 45.03 | 70.95 | 20.56 | 73.87 | 3.28 | KA | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | |

$$Rtr = \frac{Pcu \times 10^3}{3In^2}$$

$$Rc = \rho\frac{L}{S}$$

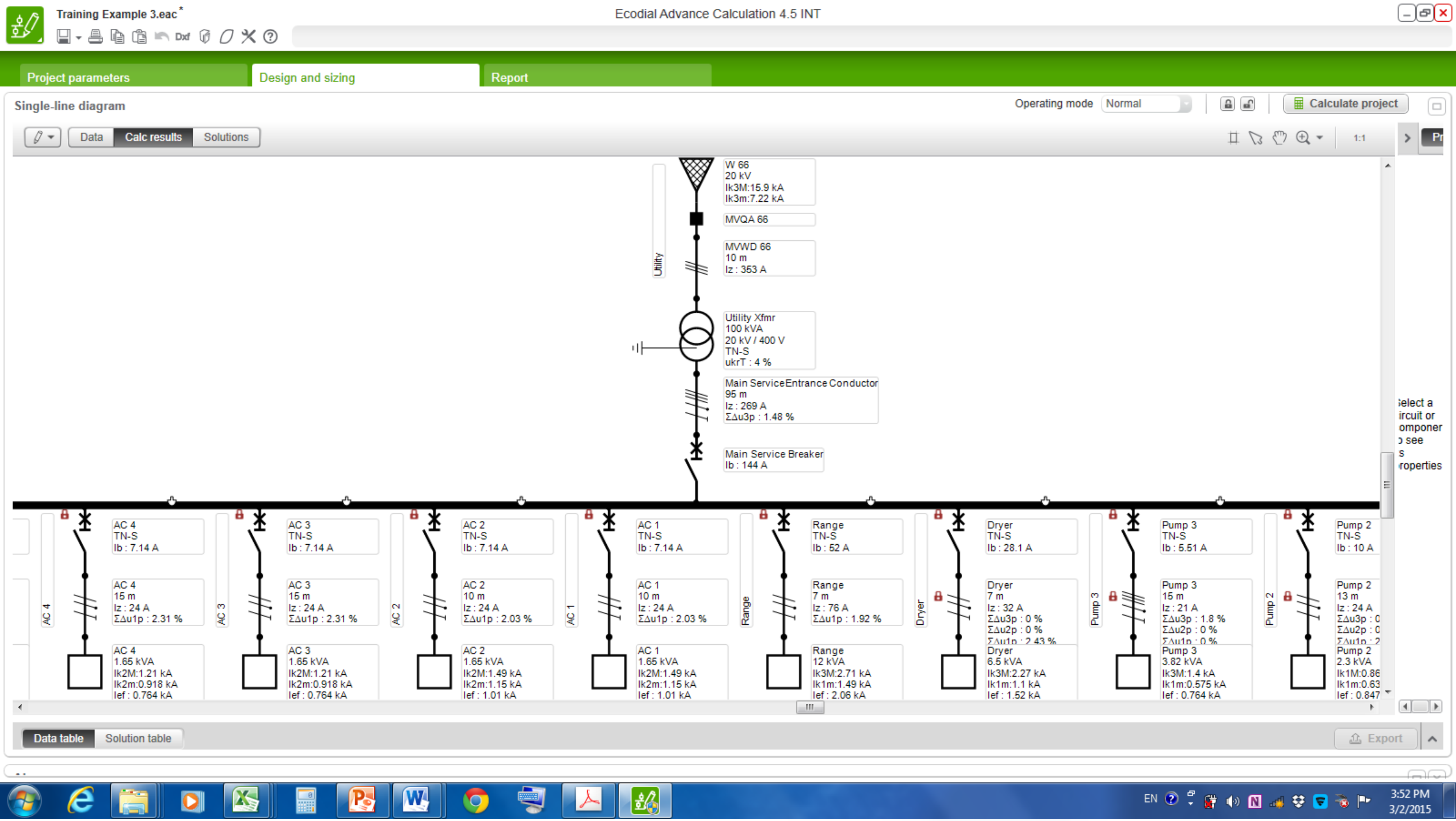
$$Zs = \frac{U_o{}^2}{Psc}$$

$$Ztr = \frac{U_{20}{}^2}{Pn} \times \frac{Usc}{100}$$

$$Xtr = \sqrt{Ztr^2 - Rtr^2}$$

$$Isc = \frac{420}{\sqrt{3}\,Z_T}$$

$$Isc = \frac{U_{20}}{\sqrt{3}Z_T}$$



W 66
20 kV
Ik3M:15.9 kA
Ik3m:7.22 kA

MVQA 66

MVWD 66
10 m
Iz : 353 A

Utility Xfmr
100 kVA
20 kV / 400 V
TN-S
ukrT : 4 %

Main ServiceEntrance Conductor
95 m
Iz : 269 A
ΣΔu3p : 1.48 %

Main Service Breaker
Ib : 144 A

AC 4
TN-S
Ib : 7.14 A

AC 4
15 m
Iz : 24 A
ΣΔu1p : 2.31 %

AC 4
1.65 kVA
Ik2M:1.21 kA
Ik2m:0.918 kA
Ief : 0.764 kA

AC 3
TN-S
Ib : 7.14 A

AC 3
15 m
Iz : 24 A
ΣΔu1p : 2.31 %

AC 3
1.65 kVA
Ik2M:1.21 kA
Ik2m:0.918 kA
Ief : 0.764 kA

AC 2
TN-S
Ib : 7.14 A

AC 2
10 m
Iz : 24 A
ΣΔu1p : 2.03 %

AC 2
1.65 kVA
Ik2M:1.49 kA
Ik2m:1.15 kA
Ief : 1.01 kA

AC 1
TN-S
Ib : 7.14 A

AC 1
10 m
Iz : 24 A
ΣΔu1p : 2.03 %

AC 1
1.65 kVA
Ik2M:1.49 kA
Ik2m:1.15 kA
Ief : 1.01 kA

Range
TN-S
Ib : 52 A

Range
7 m
Iz : 76 A
ΣΔu1p : 1.92 %

Range
12 kVA
Ik3M:2.71 kA
Ik2m:1.49 kA
Ief : 2.06 kA

Dryer
TN-S
Ib : 28.1 A

Dryer
7 m
Iz : 32 A
ΣΔu3p : 0 %
ΣΔu2p : 0 %
ΣΔu1p : 2.43 %

Dryer
6.5 kVA
Ik3M:2.27 kA
Ik1m:1.1 kA
Ief : 1.52 kA

Pump 3
TN-S
Ib : 5.51 A

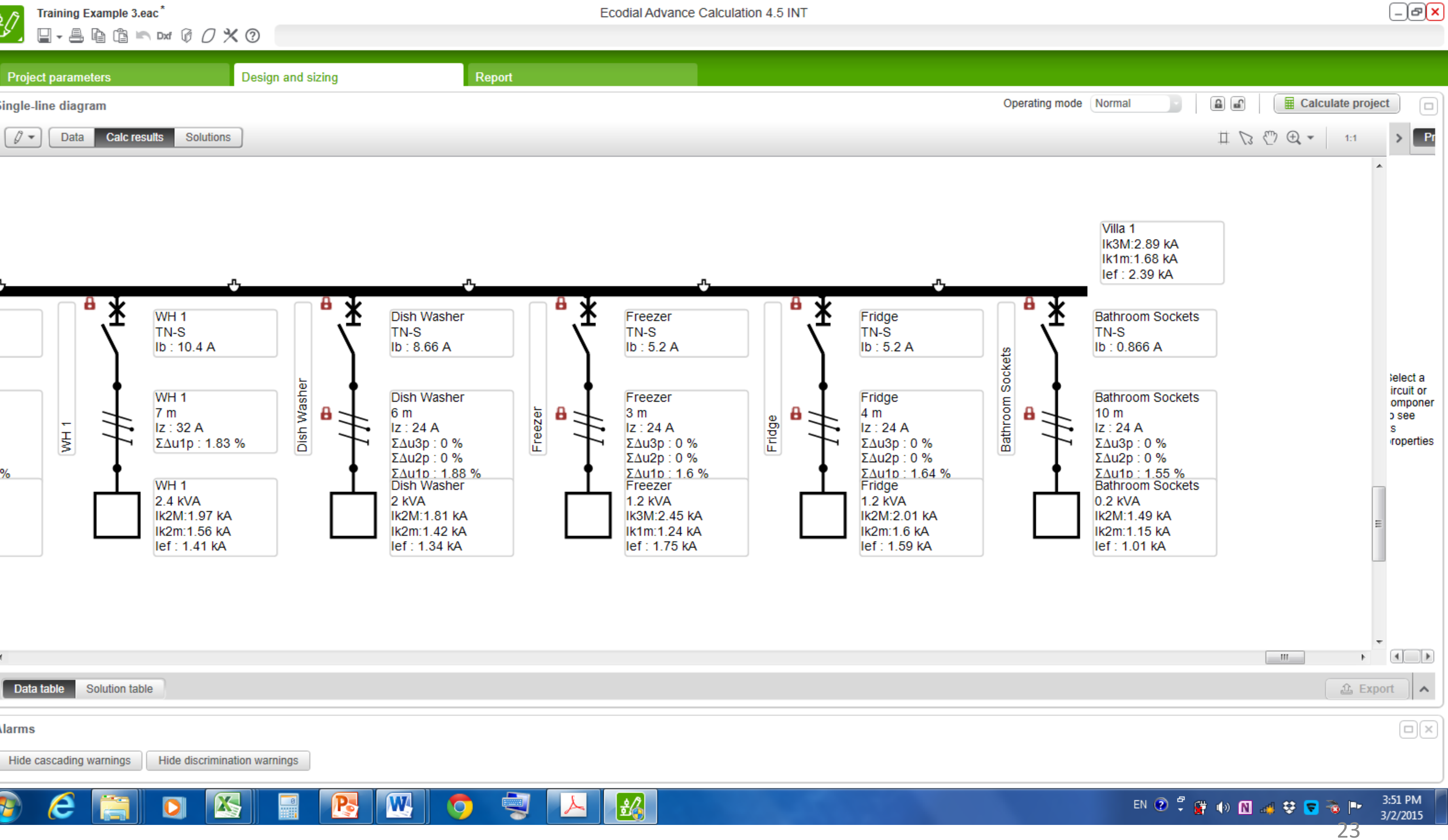
Pump 3
15 m
Iz : 21 A
ΣΔu3p : 1.8 %
ΣΔu2p : 0 %
ΣΔu1p : 0 %

Pump 3
3.82 kVA
Ik3M:1.4 kA
Ik1m:0.575 kA
Ief : 0.764 kA

Pump 2
TN-S
Ib : 10 A

Pump 2
13 m
Iz : 24 A
ΣΔu3p : 0
ΣΔu2p : 0
ΣΔu1p : 2

Pump 2
2.3 kVA
Ik1M:0.86
Ik1m:0.63
Ief : 0.847



Villa 1
Ik3M:2.89 kA
Ik1m:1.68 kA
Ief : 2.39 kA

WH 1
TN-S
Ib : 10.4 A

WH 1
7 m
Iz : 32 A
ΣΔu1p : 1.83 %

WH 1
2.4 kVA
Ik2M:1.97 kA
Ik2m:1.56 kA
Ief : 1.41 kA

Dish Washer
TN-S
Ib : 8.66 A

Dish Washer
6 m
Iz : 24 A
ΣΔu3p : 0 %
ΣΔu2p : 0 %
ΣΔu1p : 1.88 %

Dish Washer
2 kVA
Ik2M:1.81 kA
Ik2m:1.42 kA
Ief : 1.34 kA

Freezer
TN-S
Ib : 5.2 A

Freezer
3 m
Iz : 24 A
ΣΔu3p : 0 %
ΣΔu2p : 0 %
ΣΔu1p : 1.6 %

Freezer
1.2 kVA
Ik3M:2.45 kA
Ik1m:1.24 kA
Ief : 1.75 kA

Fridge
TN-S
Ib : 5.2 A

Fridge
4 m
Iz : 24 A
ΣΔu3p : 0 %
ΣΔu2p : 0 %
ΣΔu1p : 1.64 %

Fridge
1.2 kVA
Ik2M:2.01 kA
Ik2m:1.6 kA
Ief : 1.59 kA

Bathroom Sockets
TN-S
Ib : 0.866 A

Bathroom Sockets
10 m
Iz : 24 A
ΣΔu3p : 0 %
ΣΔu2p : 0 %
ΣΔu1p : 1.55 %

Bathroom Sockets
0.2 kVA
Ik2M:1.49 kA
Ik2m:1.15 kA
Ief : 1.01 kA

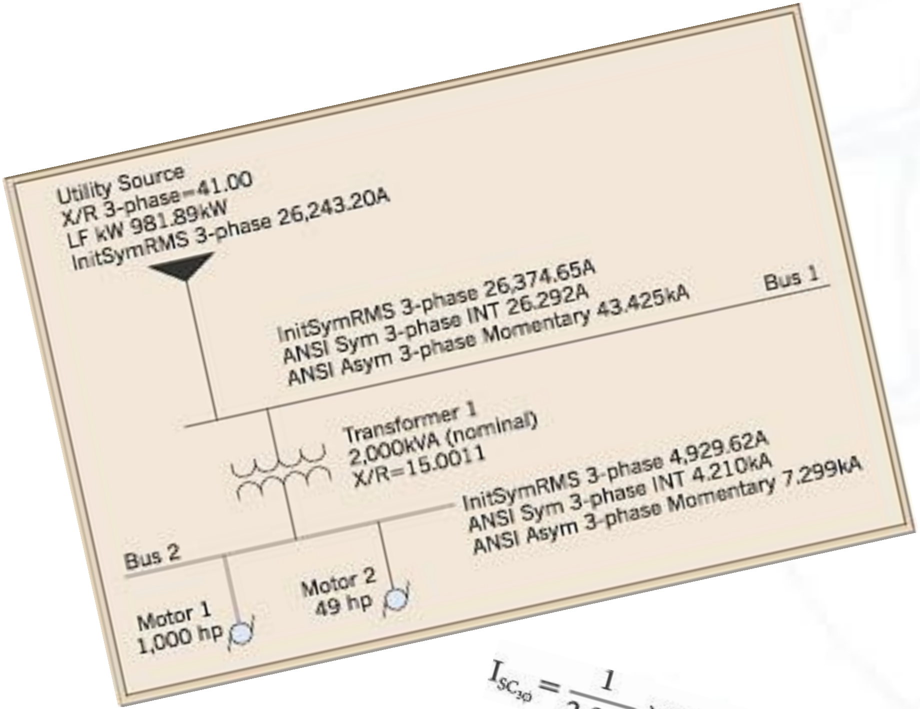
# Conclusions

- All electrical systems are **susceptible to short circuits** and the abnormal current levels they create. These currents can produce **considerable thermal and mechanical stresses** in electrical distribution equipment.
- Therefore, it's important to **protect against fire,** personnel and equipment **by calculating short-circuit currents** during system upgrade and design.
- Because these calculations **are life-safety related, they should be mandated in the National Electrical Codes.**

# Theoretical or Standards method?

- Rather than using a **theoretical approach** to determine short-circuit currents, **published standards** offer **methods** to compute a symmetrical steady state solution to which you can apply a multiplier in order to obtain the peak value of an asymmetrical current.
- The result is **precise enough** to fall within an acceptable tolerance to meet code requirements.
- The classical approach and the method defined by ANSI/IEEE and **IEC** are such industry-accepted methods for calculating short circuits.

# Theoretical Approach - Classical



$$I_{base} = \frac{S_{base}}{1.732 \times V_{base}} = 13{,}879A$$

$$X_{pu} = \frac{X_{actual}}{X_{base}}$$

$$X_{base} = \frac{V_{base}^2}{S_{base}}$$

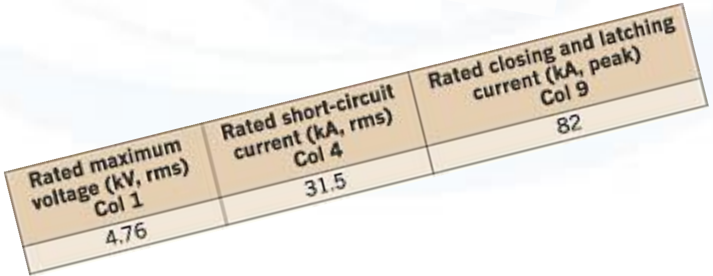
$$X_{pu_{new}} = \frac{1}{X_{base_{new}}} \times \frac{X_{pu_{old}} V_{base_{old}}^2}{S_{base_{old}}} = \rightarrow X_{pu_{old}} \times \left(\frac{V_{base_{old}}}{V_{base_{new}}}\right)^2 \times \left(\frac{S_{base_{new}}}{S_{base_{old}}}\right)$$

$$X = Z \times \sin\left(\arctan\frac{X}{R}\right)$$

$$I_{SC_{3\phi}} = I_{base} \times \frac{1}{Z_{Fault}}$$

$$I_{SC_{3\phi}} = \frac{1}{2.823} \times 13{,}879 = 4{,}916A$$

$$I_{Asym} = \sqrt{2} \times I_{Sym} = \left(1 + e^{-\frac{\pi}{\frac{X}{R}}}\right) = \sqrt{2} \times 4{,}916 \times \left(1 + e^{-\frac{\pi}{\frac{2.817}{0.166}}}\right) = 12{,}692A$$



| Rated maximum voltage (kV, rms) Col 1 | Rated short-circuit current (kA, rms) Col 4 | Rated closing and latching current (kA, peak) Col 9 |
|---|---|---|
| 4.76 | 31.5 | 82 |

# The IEC Method is more practical

- The IEC calculation method is based on the same quantities as used to be calculated before.
- However, it differs from the classical method because it makes it possible to study circuits derived from the original one: one resistive only and one reactive only.
- This is the significant difference between standards methods and the classical calculation procedures.
- **The IEC method proved to have offered a much more practical approach than the others**.

# THANK YOU

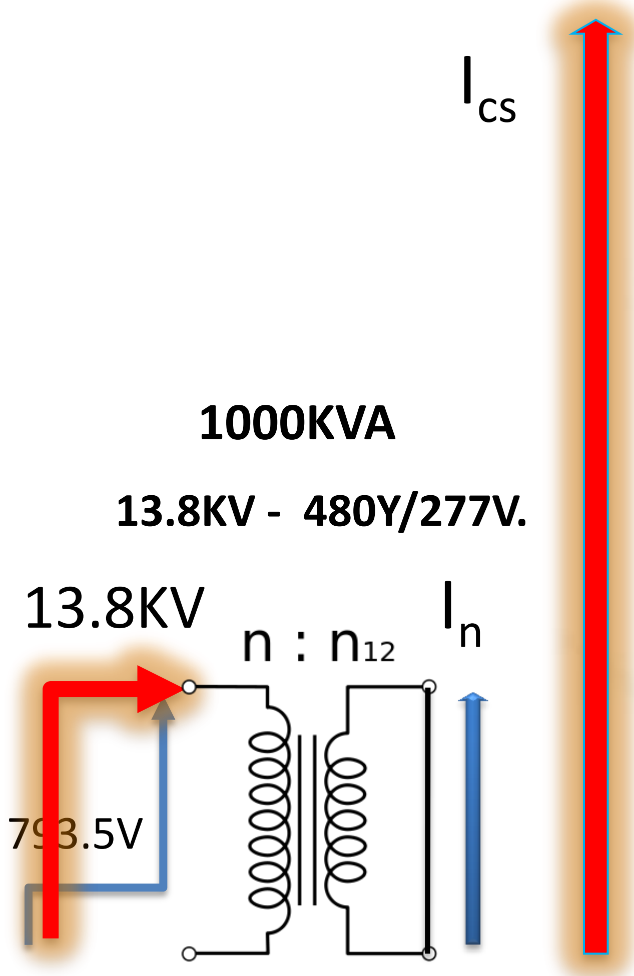
# MERCI

# 감사합니다

# Practically

When the secondary ampere meter reads **1,202A**

the primary Voltage Meter reads **793.5V**.



**1000KVA**

**13.8KV - 480Y/277V.**

The percent of impedance value is

793.5 volts / 13800 volts = 0.0575.

Hence, % Z = 5.75%

And the Short Circuit becomes:

**17.39 x the FLA = 20,903A**

$$\frac{I_n}{I_{cc}} = 5\%$$

Full Load Ampere

$I_n$ = S / √3 x $V_{L\text{-}L}$ = 1000 KVA/√3 x 480V

$I_n$ = **FLA = 1,202Amps**

Therefore the **main breaker**

that is to be installed in the circuit on the **secondary** of the transformer

has to have a **KA Interrupting Rating** greater than **21,000A**.

# Utility MVA at the Primary of the Transformer

## Case of MVAsc = 500MVA

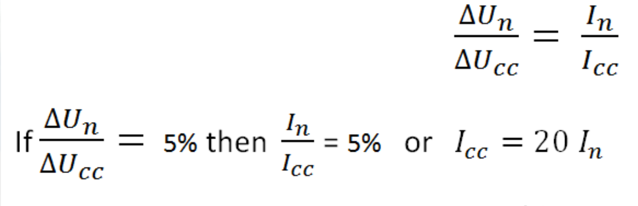
**Which Basically means that the short circuit at the primary of the X-fmr would withdraw a short circuit power of 500MVA.**

Since X-fmr rating is at: **1000KVA = 1 MVA and Z = 5.75%**

**Therefore** on its own would withdraw:

1MVA x 1/ .0575 = **17.39 MVA of short circuit power**

$$\underbrace{\sqrt{3} \times V_{L-L}\ I_{cc}}_{\text{MVAsc of X-fmr}} = 17.39\ \underbrace{\sqrt{3} \times V_{L-L}\ I_n}_{S_n = 1\text{MVA}}$$



$$\frac{\Delta U_n}{\Delta U_{cc}} = \frac{I_n}{I_{cc}}$$

If $\frac{\Delta U_n}{\Delta U_{cc}} =$ 5% then $\frac{I_n}{I_{cc}}$ = 5% or $I_{cc} = 20\ I_n$

# Same Secondary Voltage

$$1 / MVAsc_{eq} = 1 / 500 + 1 / 17.39 = 0.002 + 0.06$$

$$MVAsc_{eq} = 1 / (0.002 + 0.06) = \mathbf{16.13MVA}$$

**which is less than 17.39MV (infinite impedance)**

Therefore,

Short circuit current at 480V $= MVAsc_{eq} / (1.73 \times 0.48) =$

$16.129 / 0.8304 = 19,423A = \mathbf{19.4KA}$

**Case of 500MVA**

# All cases

| Case of Utility Source at Primary | Short Circuit Current |
|---|---|
| Infinite | 20,904A |
| 500MVA | 19,432A |
| 250MVA | 18,790A |

- When the cable and its length is added to the circuit the fault current will decrease to a smaller value. Cable MVA Value MVAsc = $KV^2$ / Z cable.
- Use the cable X & R values to calculate the Z value then add to the Admittance calculation.

## *The impedance of the MV network referred to the LV side of the MV/LV transformer*

| Rated Power (kVA) | Oil-immersed | | | | Cast-resin | | | |
|---|---|---|---|---|---|---|---|---|
| | Usc (%) | Rtr (mΩ) | Xtr (mΩ) | Ztr (mΩ) | Usc (%) | Rtr (mΩ) | Xtr (mΩ) | Ztr (mΩ) |
| **100** | 4 | 37.9 | 59.5 | 70.6 | 6 | 37.0 | 99.1 | 105.8 |
| **160** | 4 | 16.2 | 41.0 | 44.1 | 6 | 18.6 | 63.5 | 66.2 |
| **200** | 4 | 11.9 | 33.2 | 35.3 | 6 | 14.1 | 51.0 | 52.9 |
| **250** | 4 | 9.2 | 26.7 | 28.2 | 6 | 10.7 | 41.0 | 42.3 |
| **315** | 4 | 6.2 | 21.5 | 22.4 | 6 | 8.0 | 32.6 | 33.6 |
| **400** | 4 | 5.1 | 16.9 | 17.6 | 6 | 6.1 | 25.8 | 26.5 |
| **500** | 4 | 3.8 | 13.6 | 14.1 | 6 | 4.6 | 20.7 | 21.2 |
| **630** | 4 | 2.9 | 10.8 | 11.2 | 6 | 3.5 | 16.4 | 16.8 |
| **800** | 6 | 2.9 | 12.9 | 13.2 | 6 | 2.6 | 13.0 | 13.2 |
| **1,000** | 6 | 2.3 | 10.3 | 10.6 | 6 | 1.9 | 10.4 | 10.6 |
| **1,250** | 6 | 1.8 | 8.3 | 8.5 | 6 | 1.5 | 8.3 | 8.5 |
| **1,600** | 6 | 1.4 | 6.5 | 6.6 | 6 | 1.1 | 6.5 | 6.6 |
| **2,000** | 6 | 1.1 | 5.2 | 5.3 | 6 | 0.9 | 5.2 | 5.3 |

*Resistance, reactance and impedance values for typical distribution 400 V transformers with MV windings ≤20 kV*

# THE CONTROVERSY OF ICU AND ICS

## *Definition of Icu & Ics*

The key performances and testing methods for Low Voltage Circuit Breakers are defined in IEC60947-2.

***Icu*** is the abbreviation for Rated Ultimate Short-circuit breaking capacity. This is the current for which the prescribe conditions according to a specified tests sequence do not include the capability of the circuit breaker to carry its rated current continuously after the tests. It is the maximum short-circuit current that the circuit breaker can break and it is checked by the following sequence:

**O – t – CO**

***O*** - *refers to a breaking operation*
***CO*** - *refers to a making operation followed by a breaking operation*
***t*** - *refers to the time separating two operations, equal to 3 minutes or the length of time needed to reset the breaker, whichever is longer*

After the tests, the circuit breaker is simply tested to show that it is electrically safe. This is done by a dielectric test under a testing voltage equal to twice the rated service voltage but at least equal to 1000V.

***Ics*** is the abbreviation for Rated Service Short-circuit breaking capacity. This is the current for which the prescribe conditions according to a specified test sequence include the capability of the circuit breaker to carry its normal rated current continuously after the test. The tests are conducted in the following sequence:

***Ics*** is the abbreviation for Rated Service Short-circuit breaking capacity. This is the current for which the prescribe conditions according to a specified test sequence include the capability of the circuit breaker to carry its normal rated current continuously after the test. The tests are conducted in the following sequence:

**O – t – CO – t – CO**

Following the tests, the circuit breaker undergoes a temperature rise test, a dielectric test and a tripping test to verify that the breaker is qualified to be returned to service.

Ics is expressed as a percentage of Icu (eg 25%, 50%, 75% or 100% of Icu). In a nutshell, this is the maximum current that the breaker can break for 3 times and yet returned to service with its operational integrity intact.

# THE CONTROVERSY OF ICU AND ICS

$I_{cu}$ is the abbreviation for Rated Ultimate Short-circuit breaking capacity.

It is the maximum short-circuit current that the circuit breaker can break and then gets checked by the following sequence.

- **O – t – CO**
  - ***O -*** *refers to a breaking operation*
  - ***CO -*** *refers to a making operation followed by a breaking operation* ***t -*** *refers to the time separating two operations, equal to 3 minutes or the length of time needed to reset the breaker, whichever is longer*

This is the current for which the circuit breaker is incapable to carry its rated current continuously after the tests

proposed conditions according to a specified tests sequence do