SUNDAY, 11 APRIL 2021, ABB TALKS 2021

Value Engineering for Low Voltage Networks

ABB Talks 2021: Session 5

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Agenda

Design Verification vs Type Tested Switchboards

Degree of protection (IP and IK degrees)

Operating temperature

Form of segregation

Types of Systems (C.B. & Switchgear) and clearances

Switchboard Front panel operation and Operation modes

Busbar plating

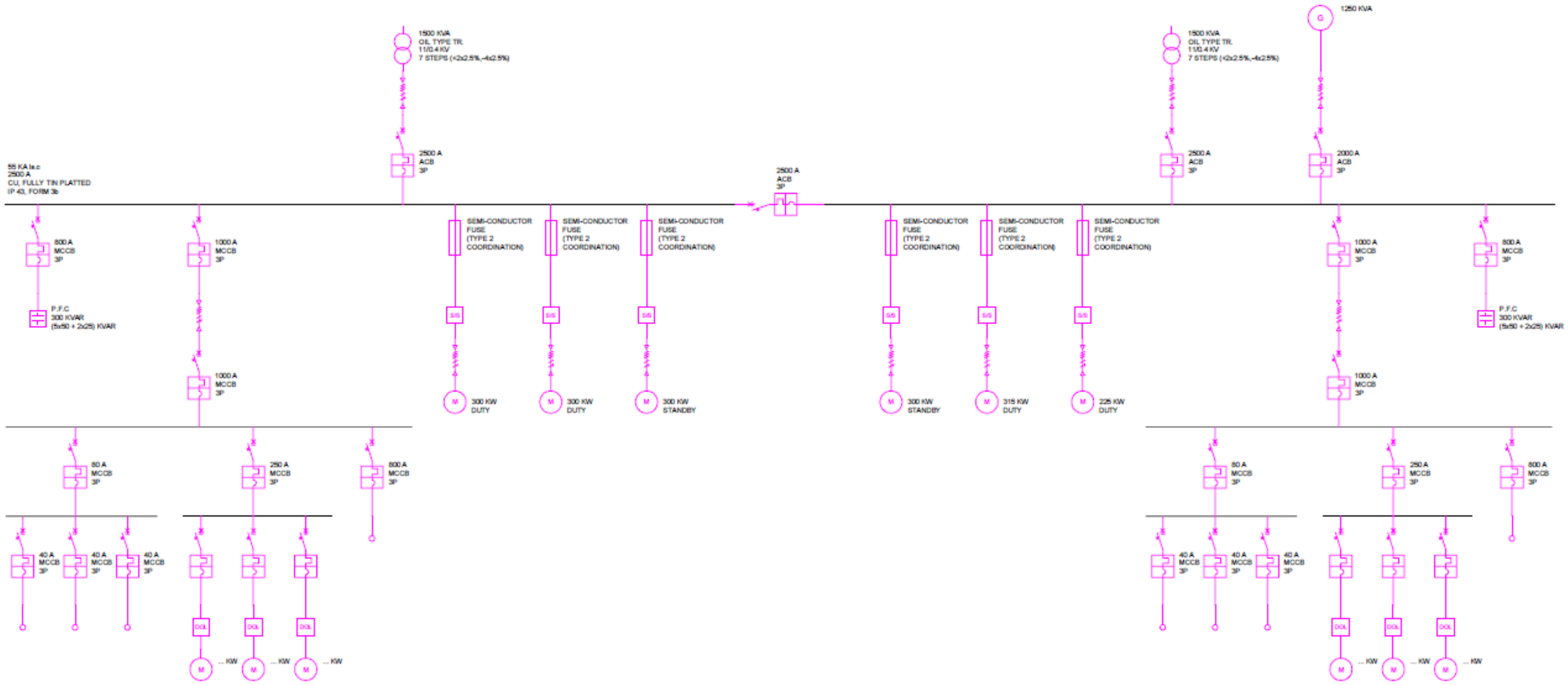
Motor starting Method selection and coordination

Short circuit calculation

Power factor calculation and Harmonics calculation

WWTP Case study

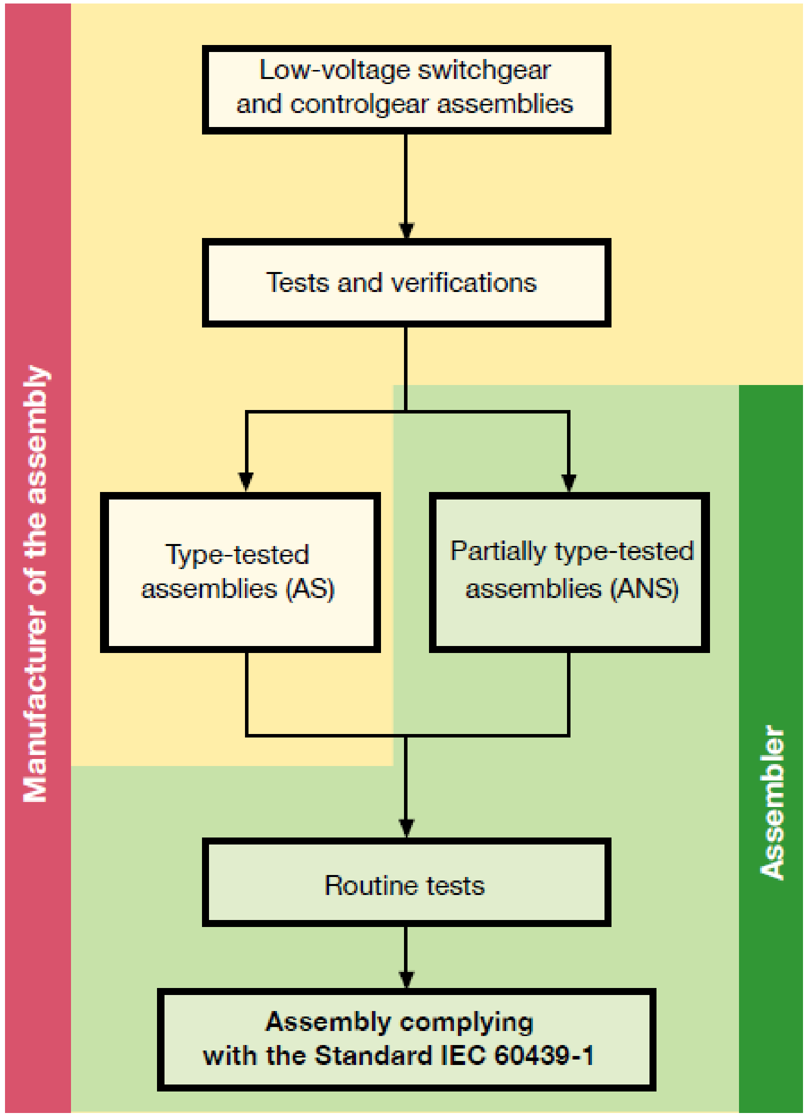
Components' selection and specification preparation



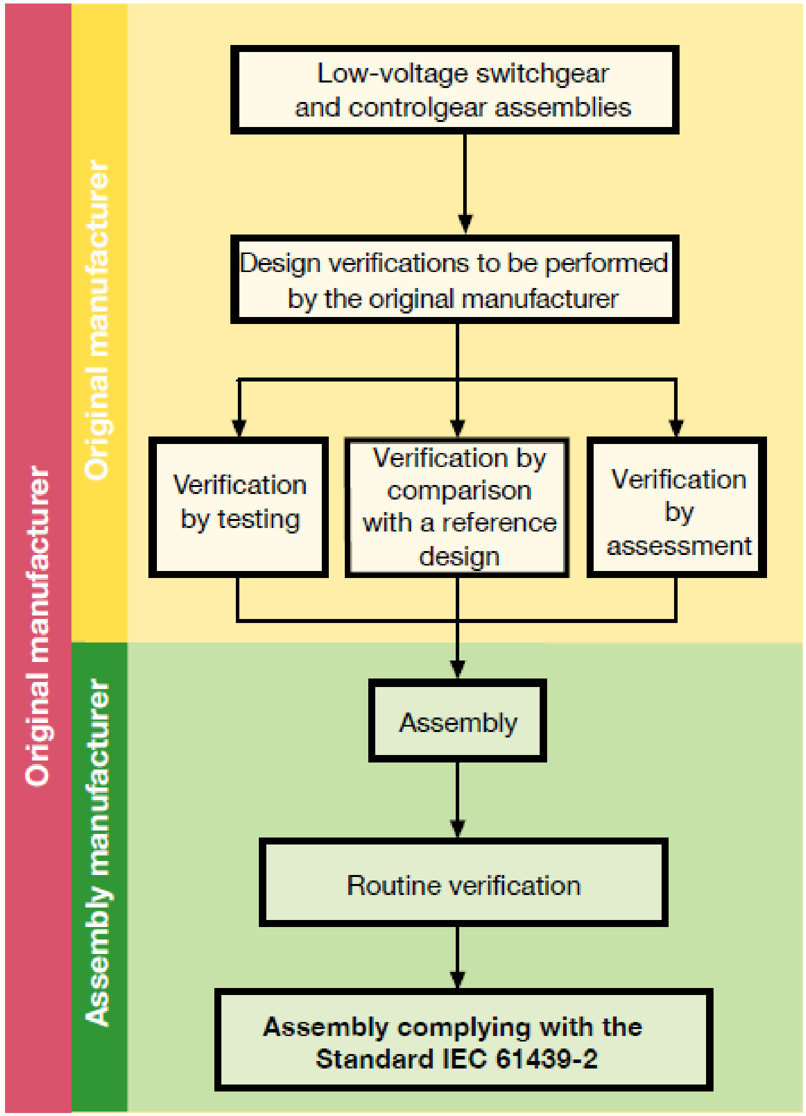
Design Verifications

From IEC 60439-1 to 61439-1

Standard IEC 60439-1



Standard IEC 61439-1-2



Protection Degree (IP/IK)

IEC 60529/IEC 62202

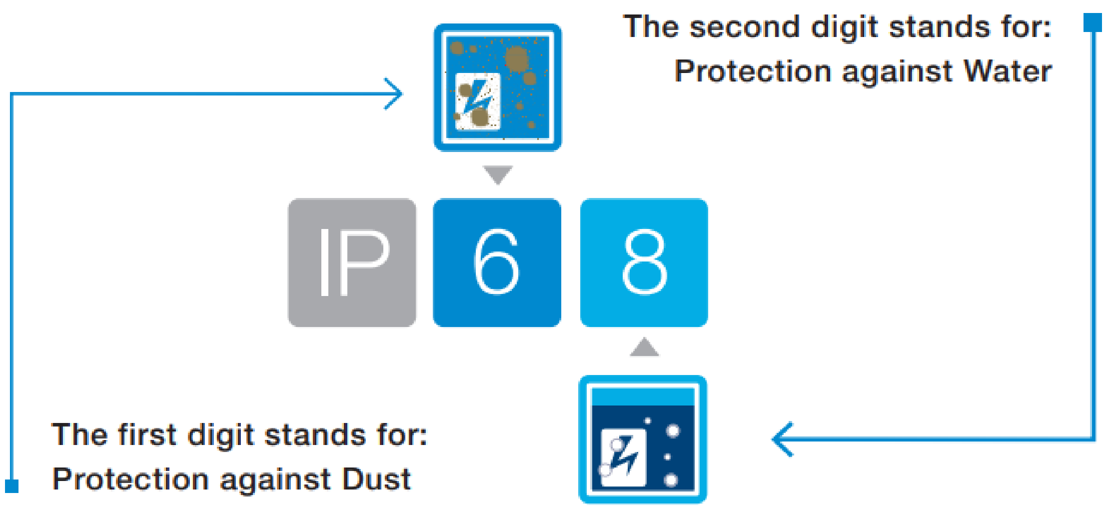
IEC 61439 Low-Voltage Switchgear And Controlgear Assemblies

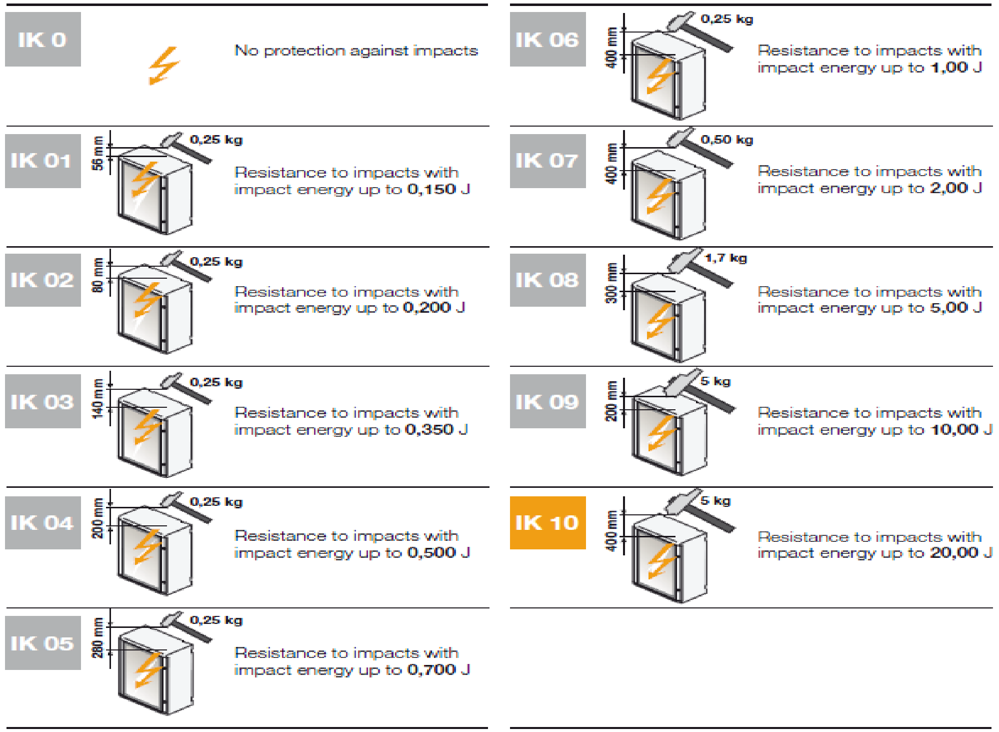
Construction - Design Verification According to IEC 61439-1

2. Degree of Protection

a) Degrees of protection provided by enclosures (IP Code)

b) Degree of Protection provided by enclosures for electrical equipment against external mechanical impacts (IK Code)





IP code

IEC 60529

Element	Numeral or letter	Effect on the protection of the equipment	Effect on the protection of people
First digit		Against ingress of solid foreign bodies	Against contact with hazardous parts
	0	(no protection)	(no protection)
	1	≥ 50 mm diameter	Back of the hand
	2	≥ 12.5 mm diameter	Finger
	3	≥ 2.5 mm diameter	Tool
	4	≥ 1 mm diameter	Wire
	5	dust-protected	Wire
	6	dusttight	Wire
Second digit		Against harmful effects due to the ingress of water	
	0	(no protection)	
	1	Vertical dripping	
	2	Drops (15° tilt)	
	3	Spray water	
	4	Splashing of water	
	5	Water jets	
	6	Powerful water jets	
	7	Temporary immersion	
	8	Permanent immersion (1)	

IEC 61439 Low-Voltage Switchgear And Controlgear Assemblies

Construction - Design Verification According to IEC 61439-1

IP Code According To IEC 60529

IK Code According To IEC 62202

Ambient Temperature

IEC 61439-1

Ambient Temperature

IEC 61439-1

7.1.1 Ambient air temperature

7.1.1.1 Ambient air temperature for indoor installations

The ambient air temperature does not exceed +40 °C and its **average over a period of 24 h does not exceed +35 °C**.
The lower limit of the ambient air temperature is –5 °C.

Ambient Temperature

Average temperatures in different locations*

Cairo - Average temperatures

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Min (°C)	9	10	12	15	18	20	22	22	21	17	14	10	15.9
Max (°C)	19	20	24	28	32	34	35	34	33	29	25	20	27.8

Alexandria - Average temperatures

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Min (°C)	9	9	11	13	17	20	23	23	21	18	14	11	15.8
Max (°C)	18	19	21	24	27	29	30	30	30	28	24	20	25

Luxor - Average temperatures

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Min (°C)	6	7	11	16	20	23	24	24	22	18	12	8	16
Max (°C)	23	25	29	35	39	41	41	41	39	35	29	24	33.5

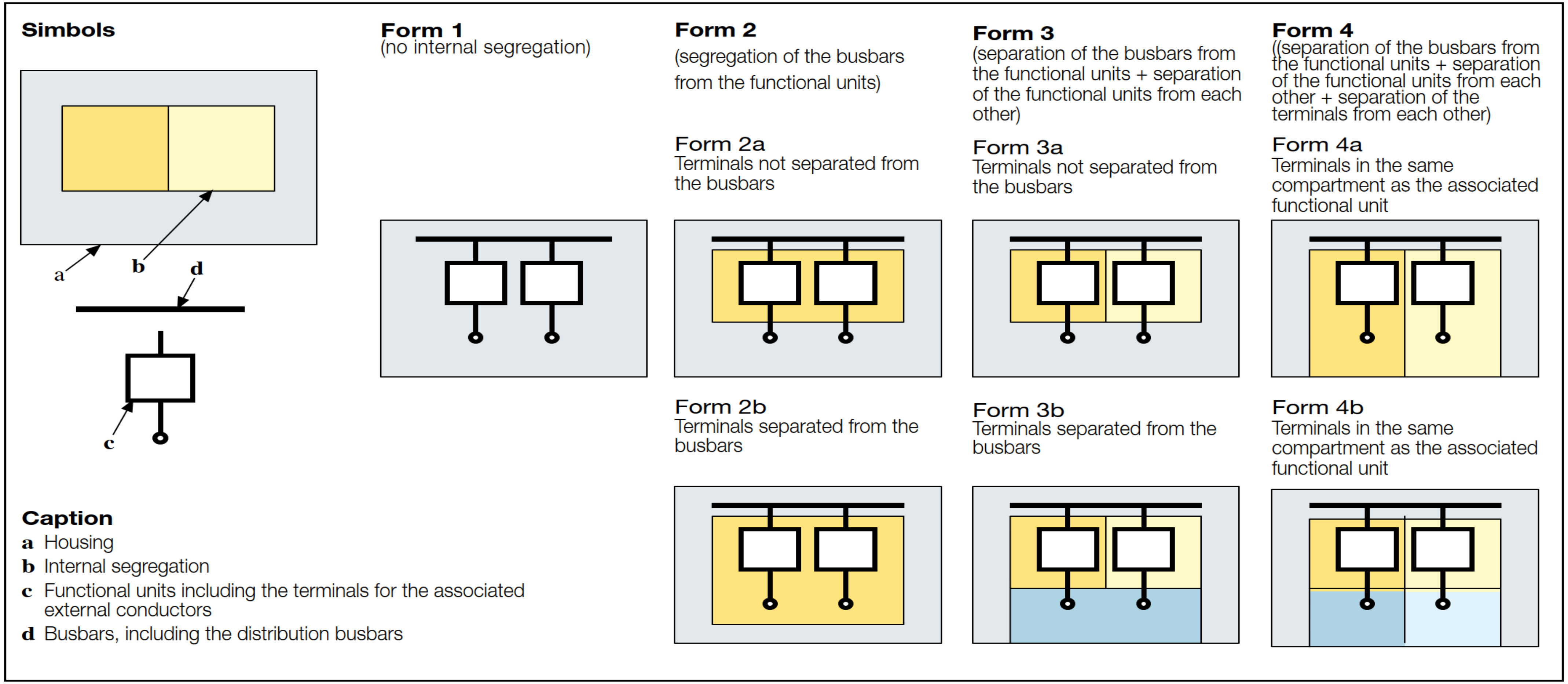
*Source: Egypt climate: average weather, temperature, precipitation, best time (climatestotravel.com)

Form of separation

IEC 61439-1

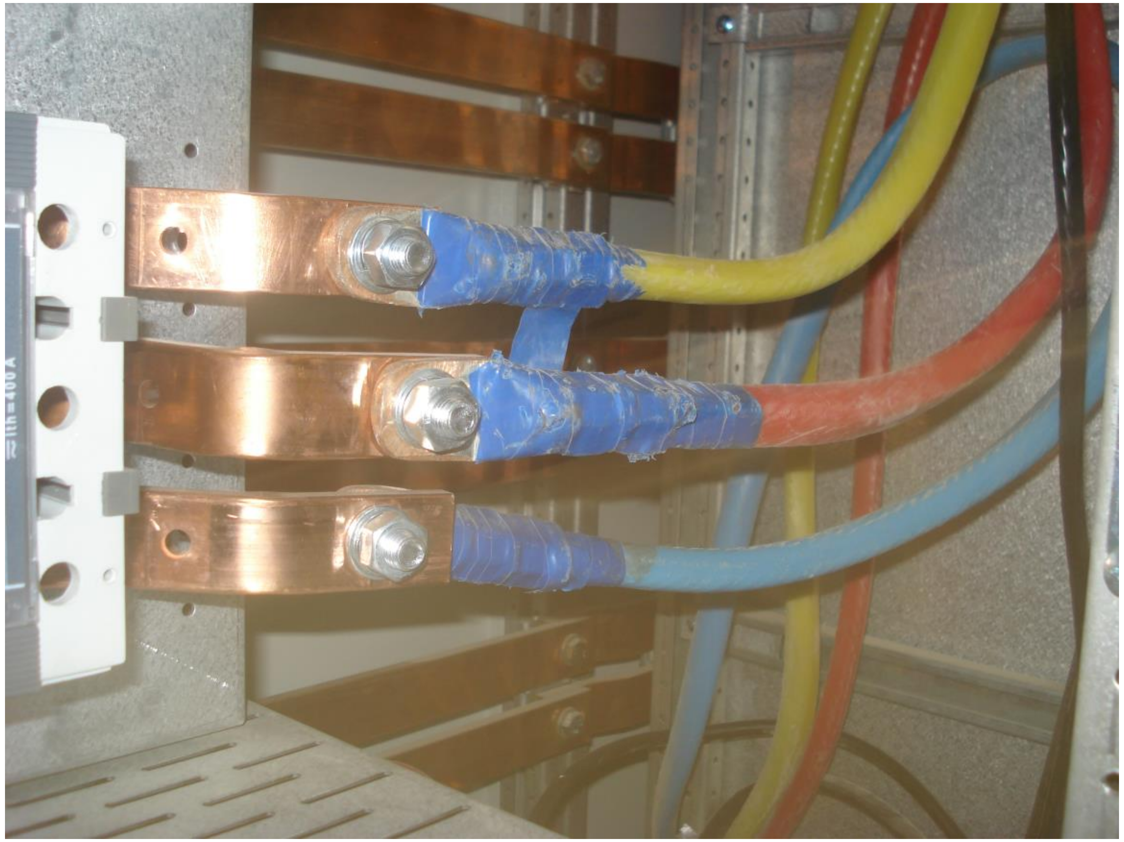
Form of separation

IEC 61439-1



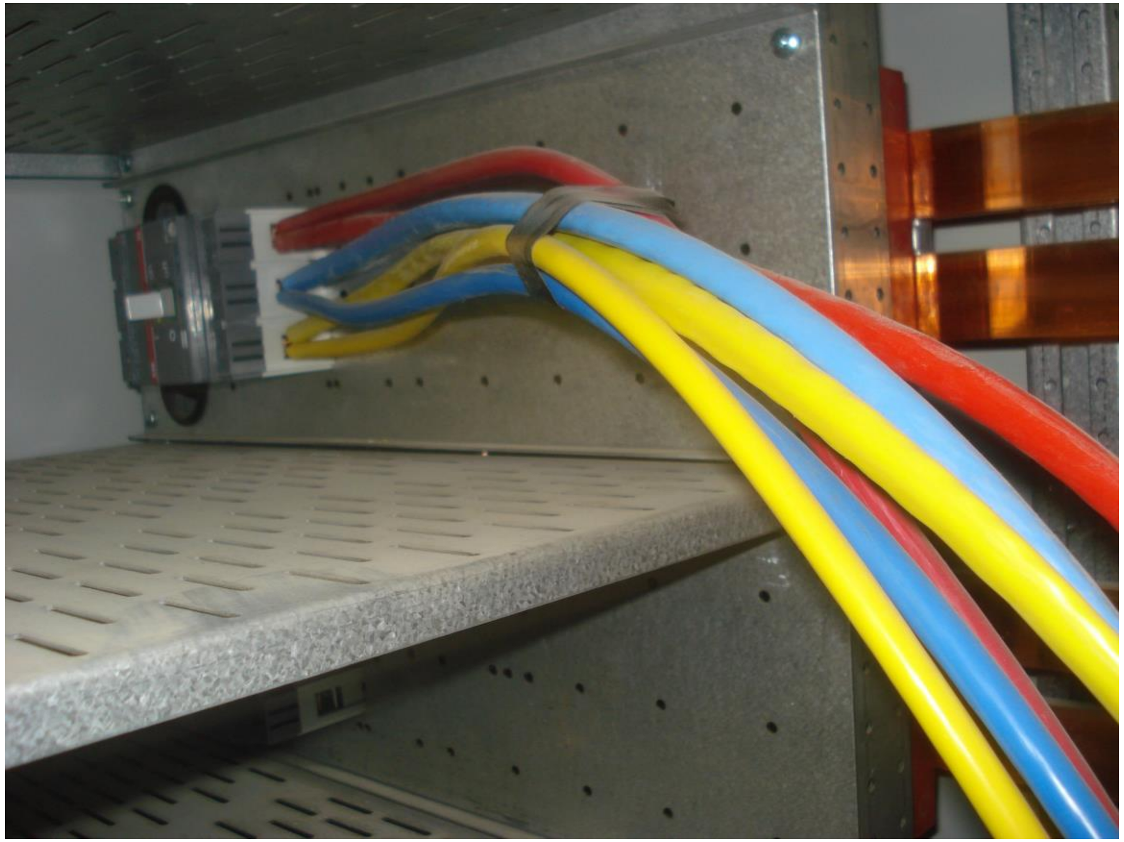
Form of separation

Form 1



Form of separation

Form 1

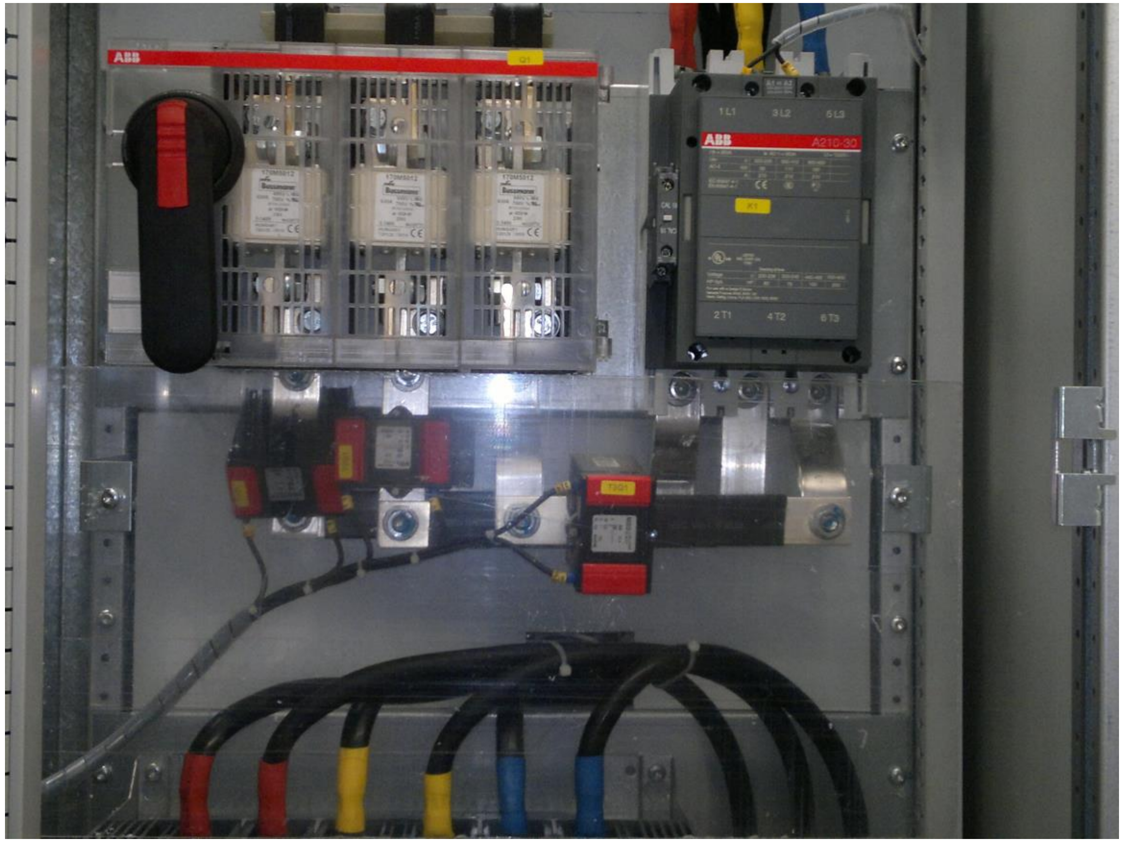


Form of separation

Form 2

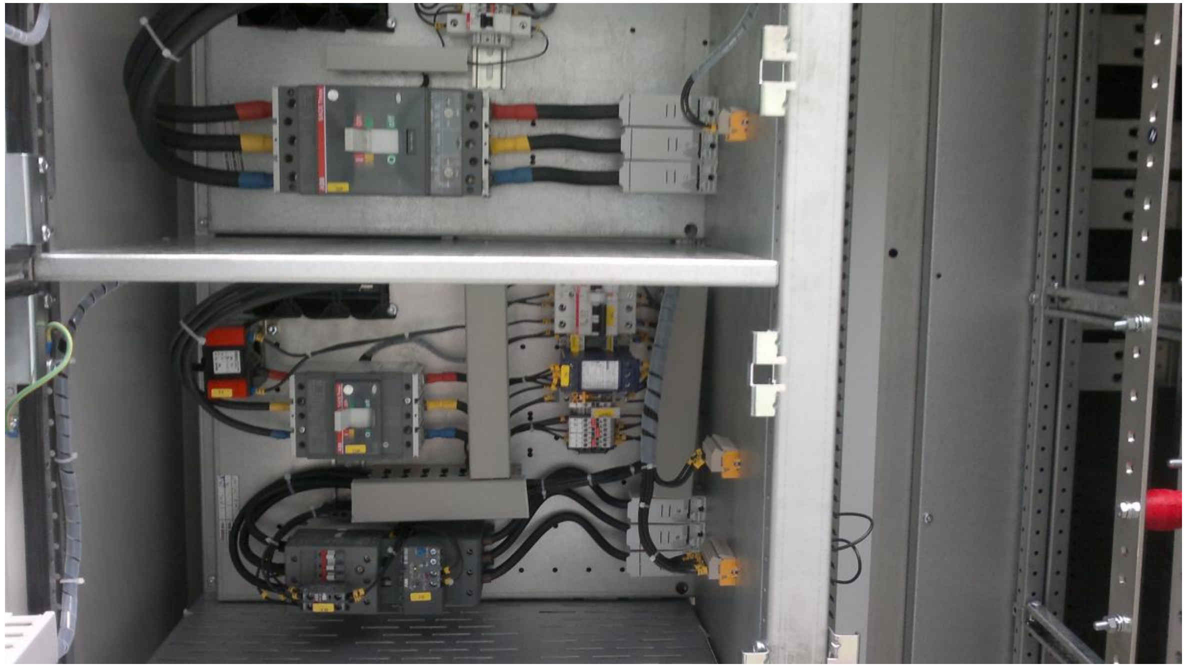
Form of separation

Form 2



Form of separation

Form 3



Form of separation

Form 3

Form of separation

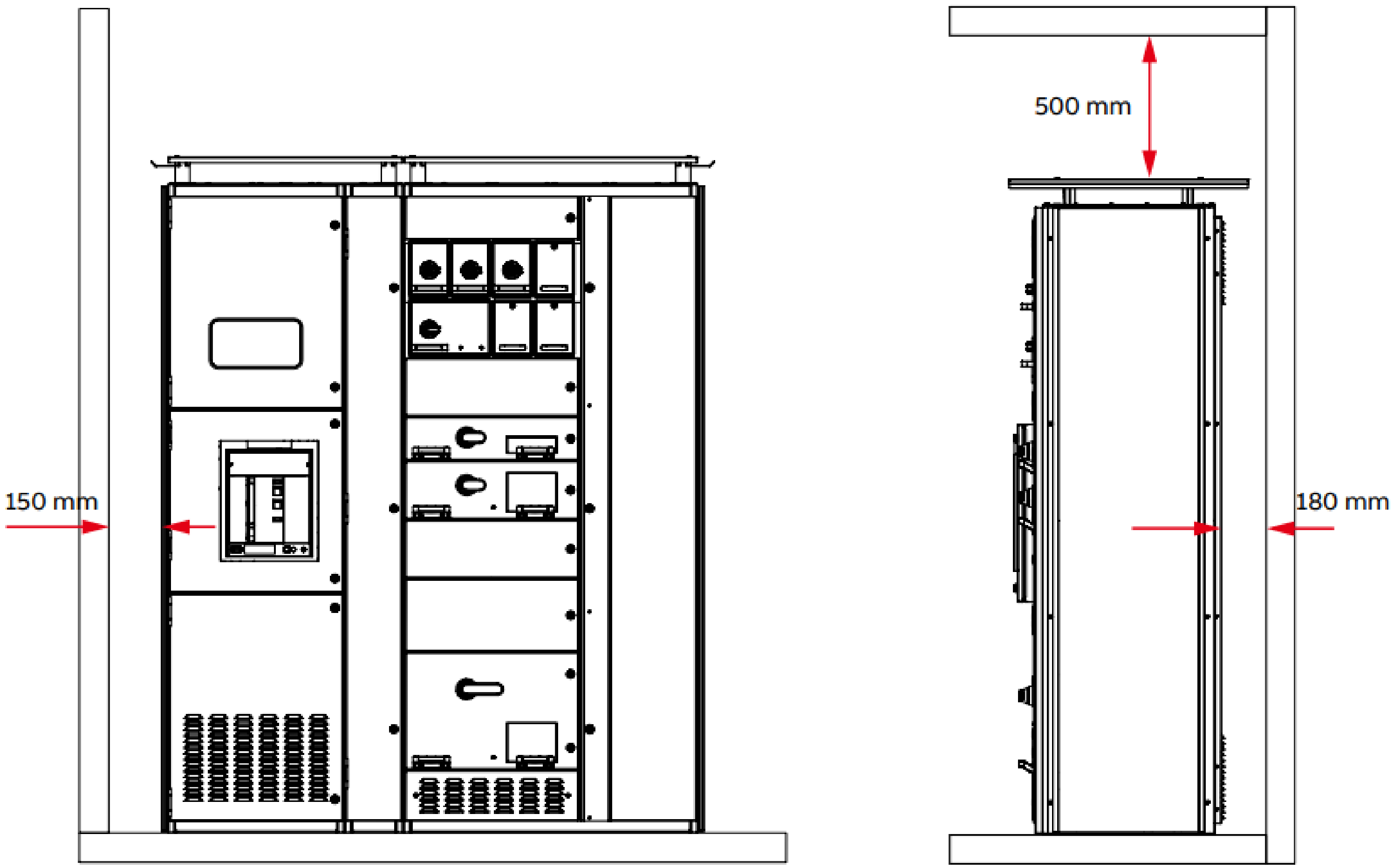
Form 4

Form of separation

Form 4

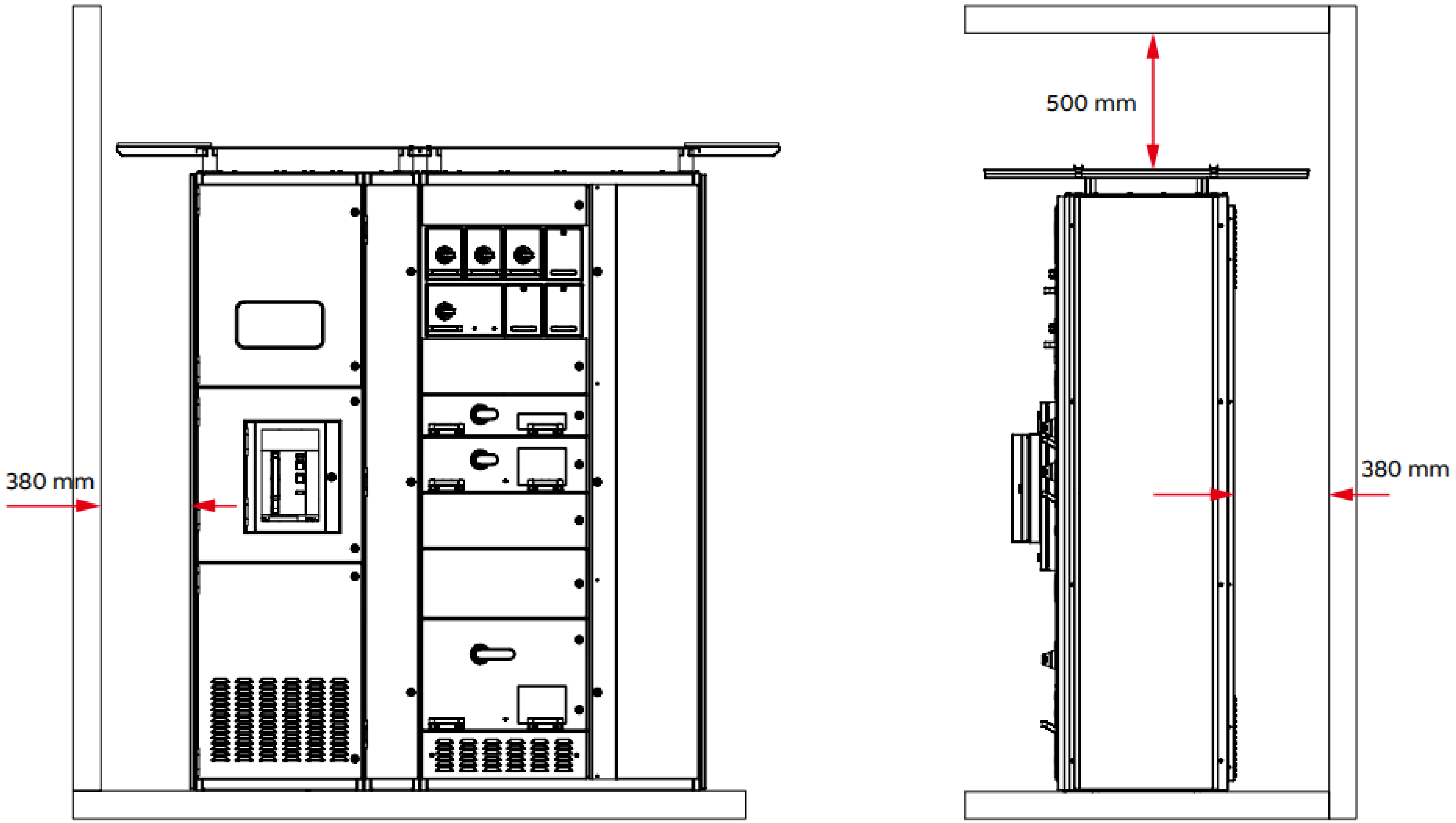
Switchgear Minimum clearance – Front Access

Section minimum clearances for raised roof plate IPx1/IPx2 with left mounted doors IP31-41-42



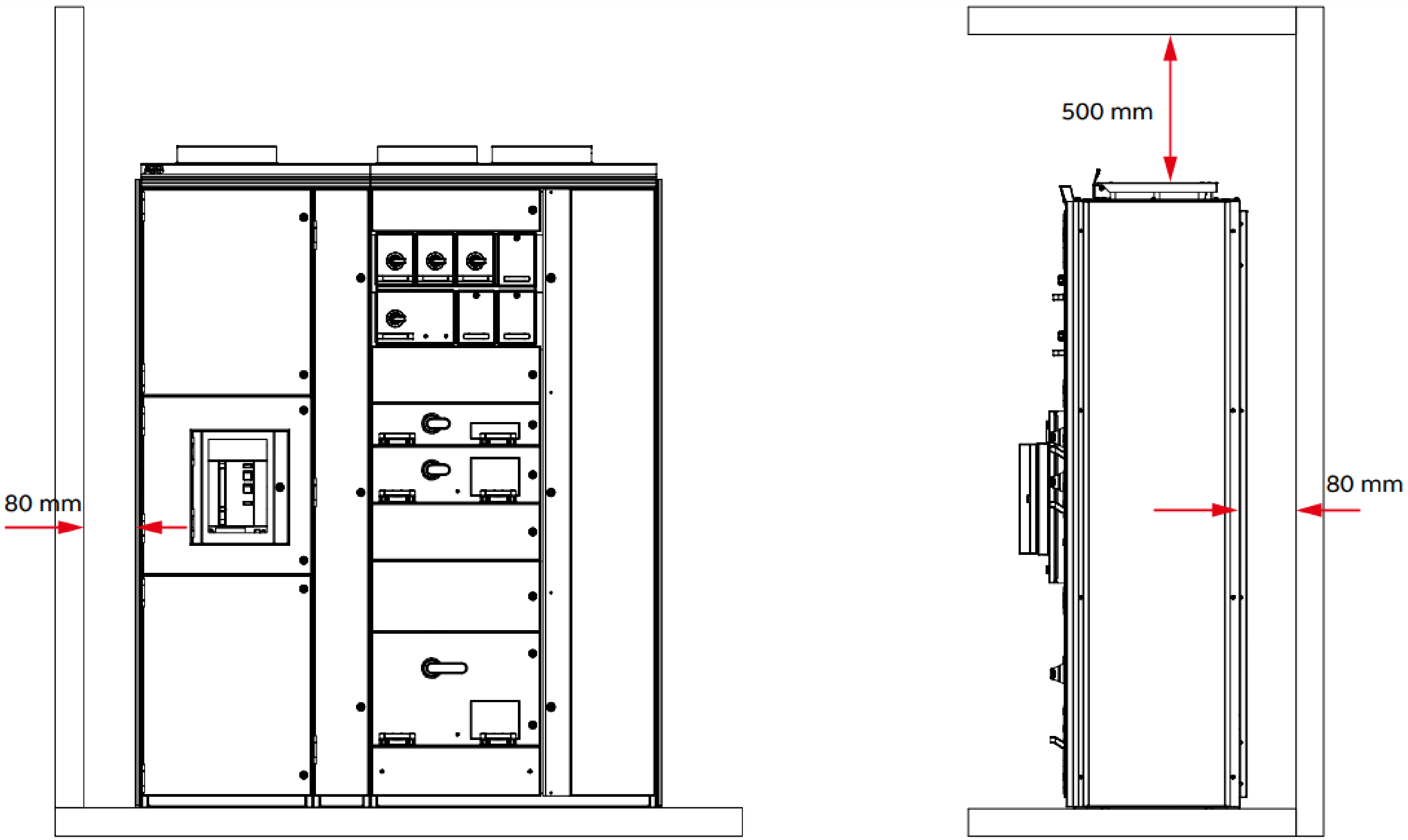
Switchgear Minimum clearance – Front Access

Section minimum clearances for raised roof plate IP43 with left mounted doors IP43



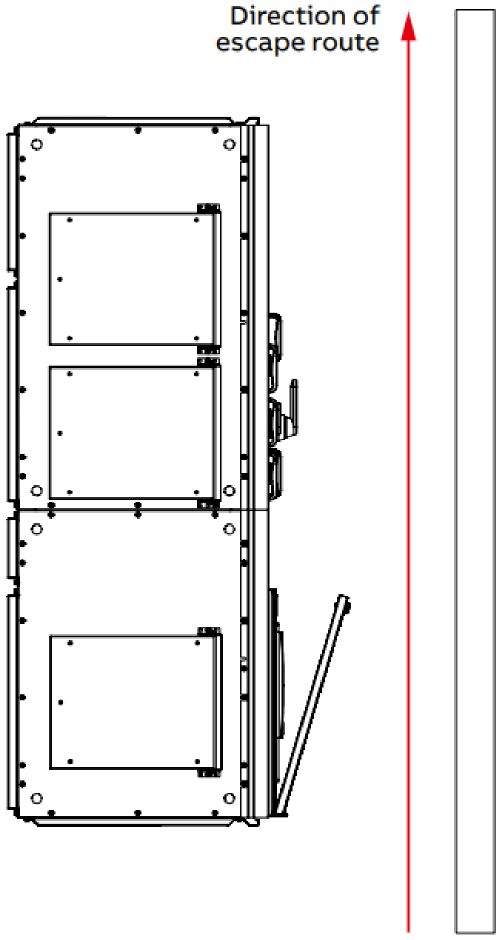
Switchgear Minimum clearance – Front Access

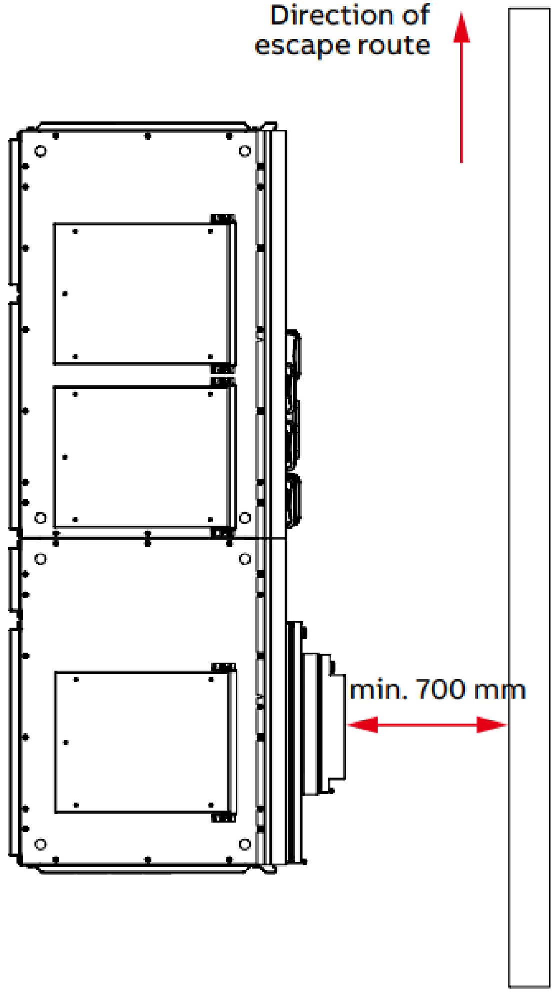
Section minimum clearances for pressure relief roof (flap roof) with left mounted doors or IP54



Switchgear Minimum clearance – Front Access

Minimum clearances according escape route direction

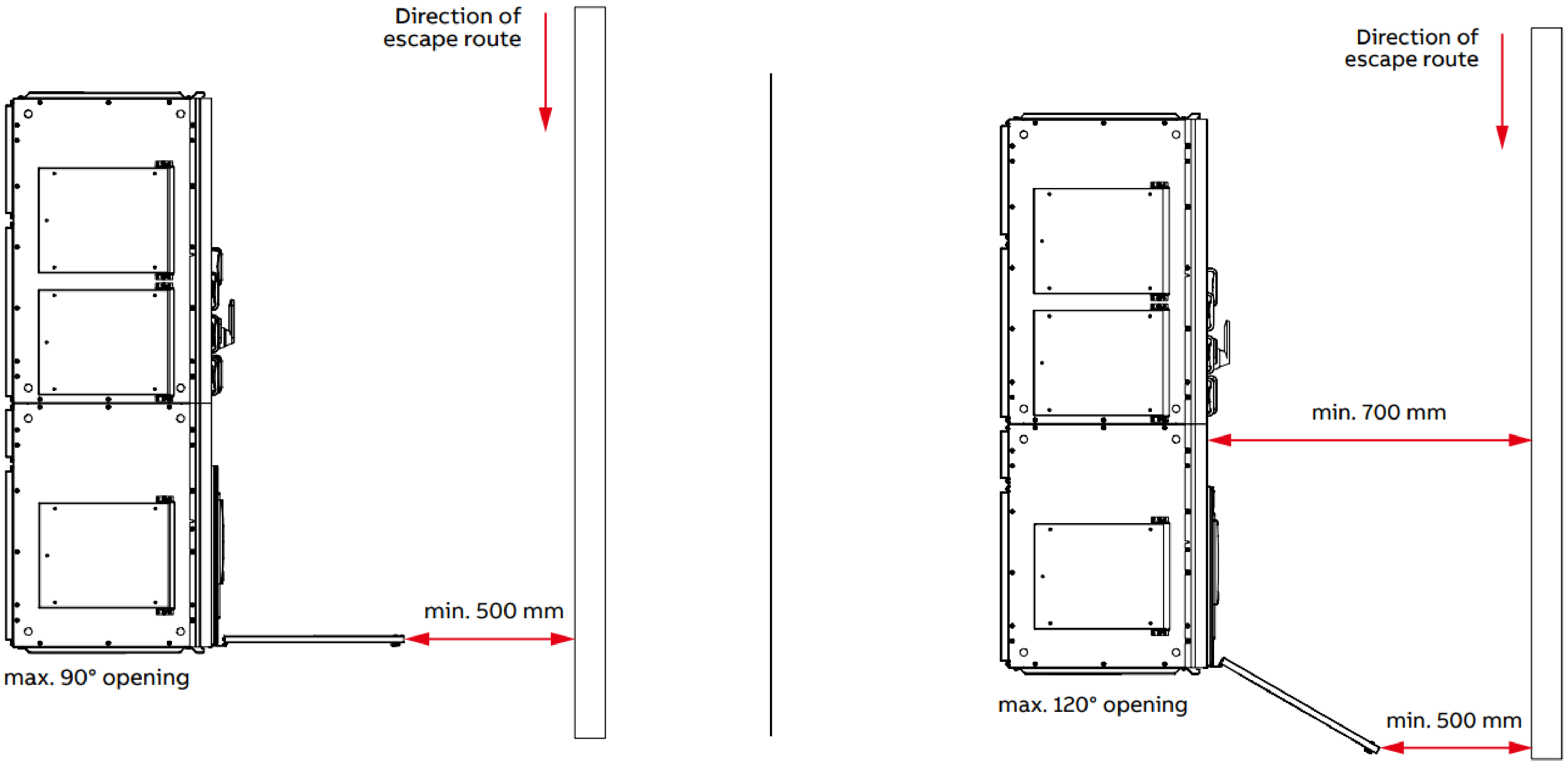




When calculating escape routes, always consider direction of escape route and the worst case of switchgear with opened doors.

Switchgear Minimum clearance – Front Access

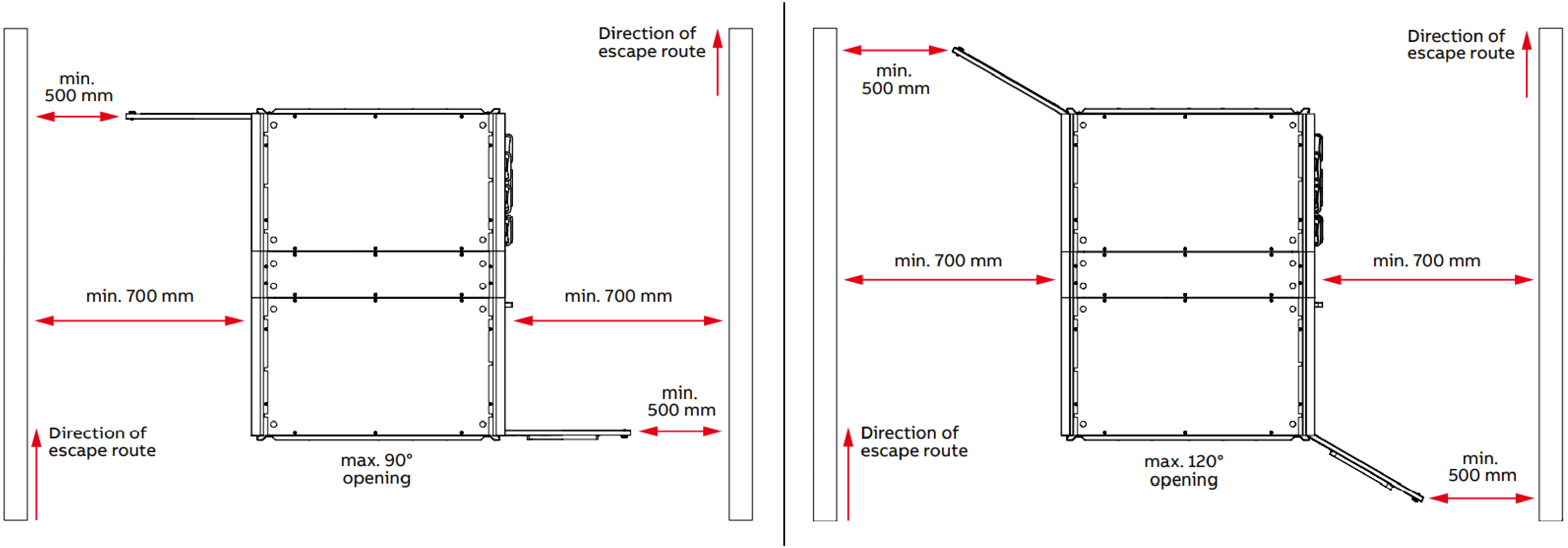
Minimum clearances according escape route direction



When calculating escape routes, always consider direction of escape route and the worst case of switchgear with opened doors.

Switchgear Minimum clearance – Rear Access

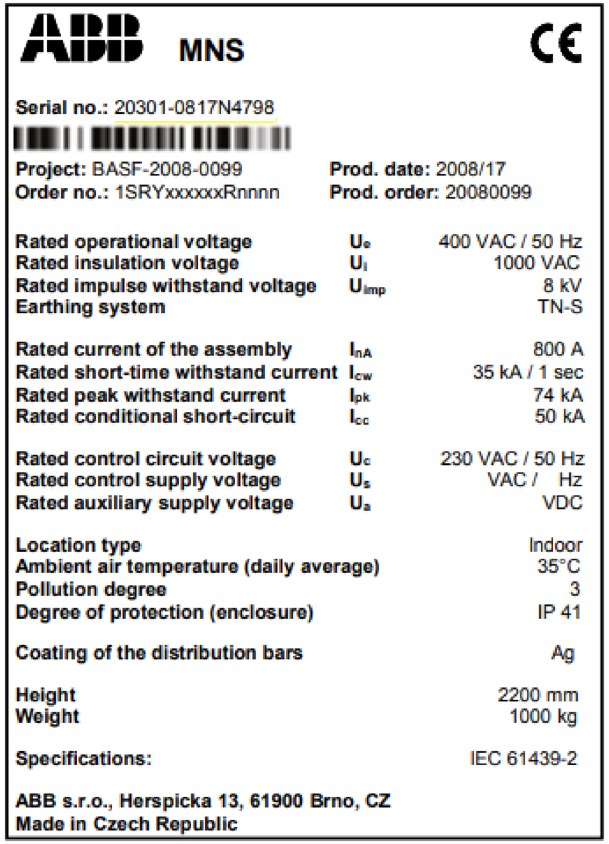
Minimum clearances according escape route direction

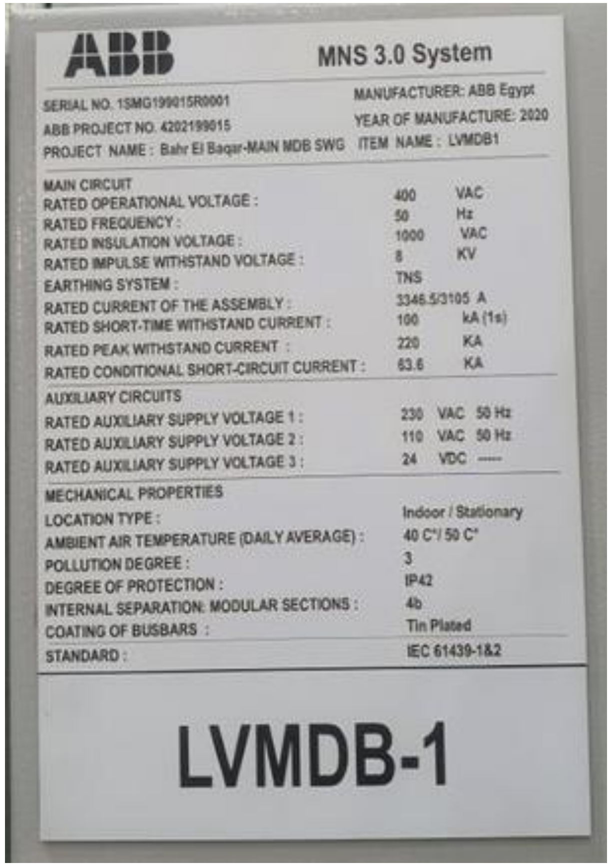


When calculating escape routes, always consider direction of escape route and the worst case of switchgear with opened doors.

Assembly designation marking

Nameplate example





Types of Systems (C.B. & Switchgear)

Fixed/Plug-in/Withdrawable

Circuit breakers types

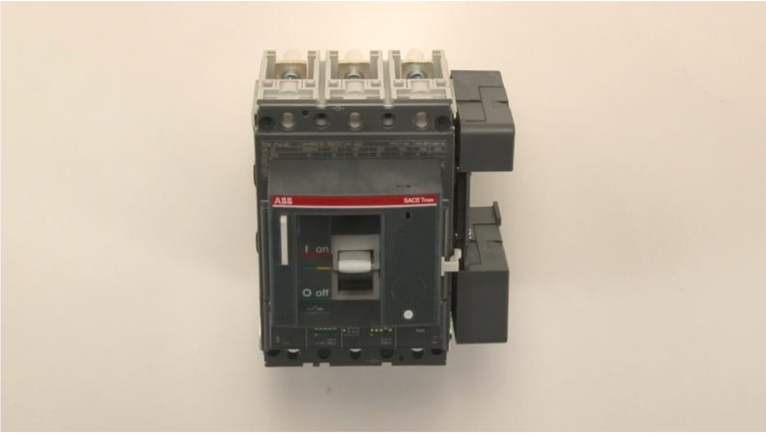
Moulded case Circuit Breakers versions

Fixed

Plug-in

Conversion into moving part of Plug-in - XT4 Video

Withdrawable



Conversion into moving part of Withdrawable - XT4 Video

Circuit breakers types

Air Circuit Breakers versions

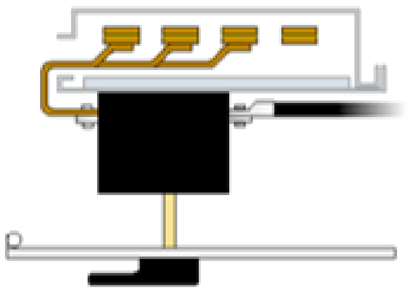
Fixed Circuit Breaker

Withdrawable Circuit Breaker

Switchgear module technology

Electrical connection definition acc. IEC 61439-2, 8.5.101

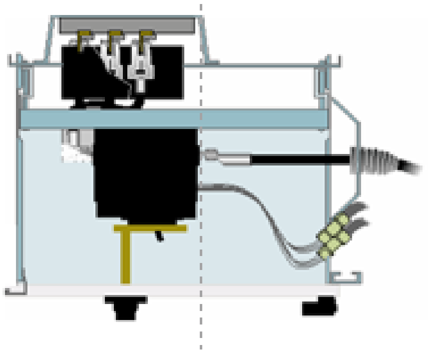
Fixed



Main contact incoming	Fixed
Main contact outgoing	Fixed
Auxiliary contacts	Fixed

Long MTTR, switchgear must be shutdown for maintenance

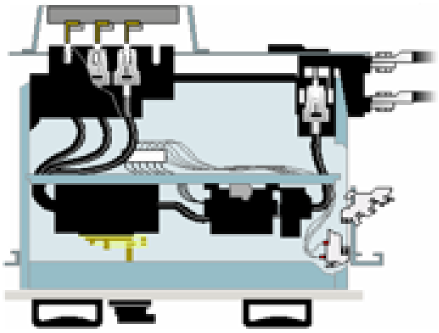
Plug in



Main contact incoming	Withdrawable
Main contact outgoing	Fixed
Auxiliary contacts	Fixed / Disconnectable

Medium MTTR, switchgear can remain life but area of work must be secured according to safety instruction (high PPE etc.)

Withdrawable



Main contact incoming	Withdrawable
Main contact outgoing	Withdrawable
Auxiliary contacts	Withdrawable

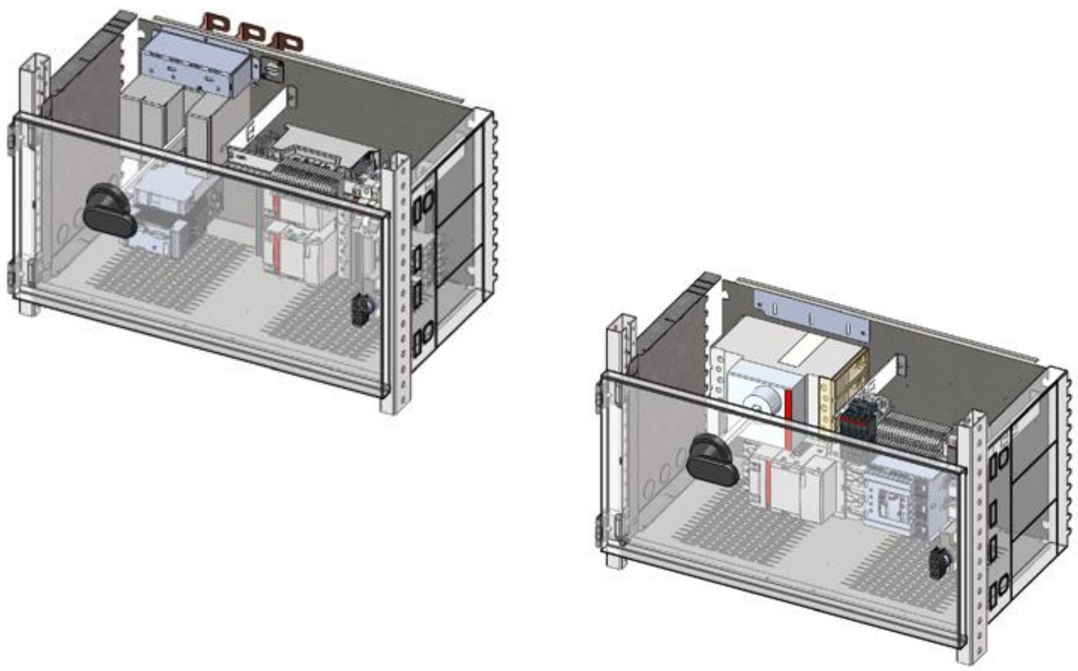
Shortest MTTR, remove drawer for maintenance from life switchgear

Fixed – Tool required for connection & disconnection
Disconnectable – No tool (hand) required for connection & disconnection
Withdrawable – No tool required, automatic connection & disconnection

Switchgear module technology

Fixed technology

Typical modules



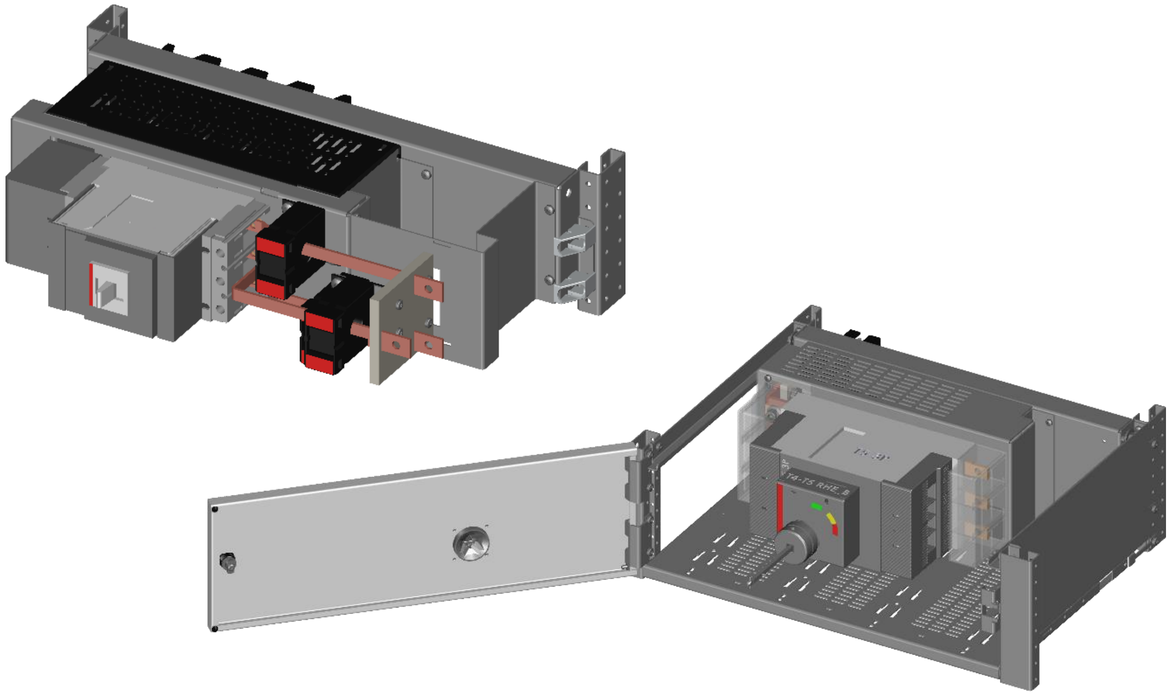
MNS Benefits

ABB

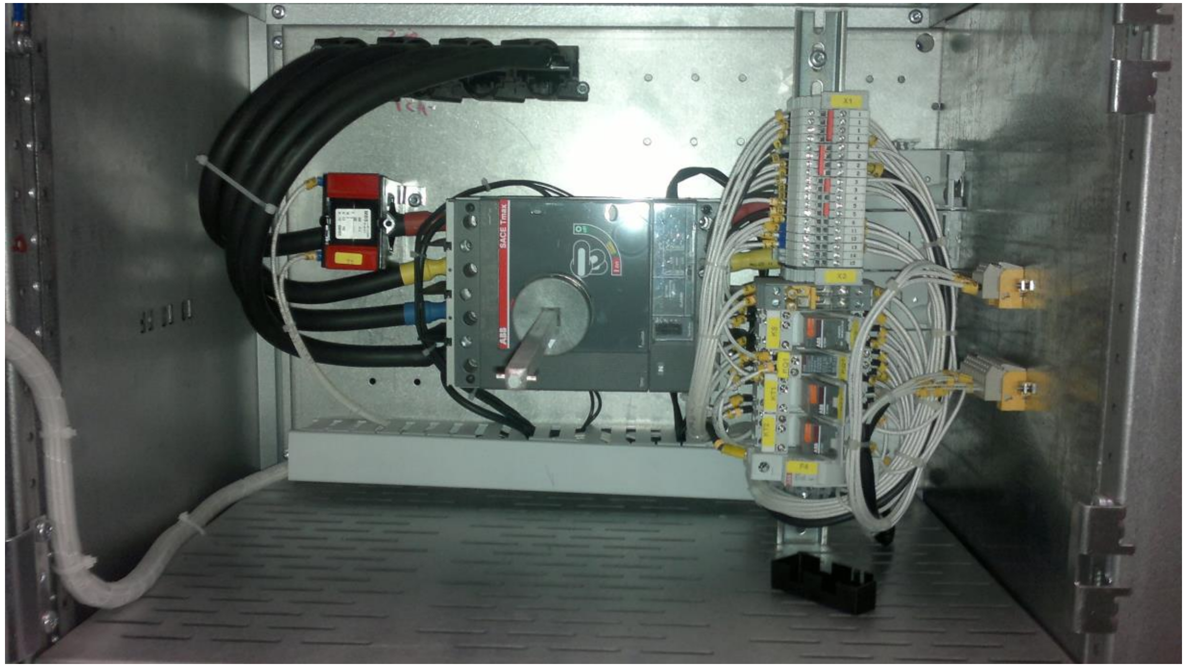
Switchgear module technology

Plug-in technology

Typical modules



MNS Benefits



* Plug in and withdrawable modules can be utilised in the same section
** Refer to ABB and EPES HSE instruction 'Working on LV switchgear'

Switchgear module technology

Withdrawable technology

Typical modules

MNS Benefits

* Plug in and withdrawable modules can be utilised in the same section
** Refer to ABB and EPES HSE instruction ‘Working on LV switchgear

ABB MNS® iS and the IEC 61641 Standard

Internal Arc Protected Switchgear

[(1) ABB MNS® iS and the IEC 61641 Standard Video]

Front panel operation

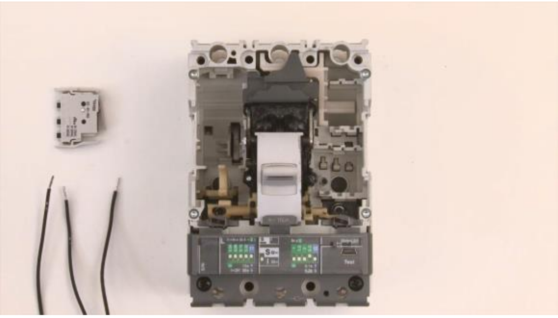
Commonly used accessories

Front panel operation

Electrical Accessories

Auxiliary Contacts

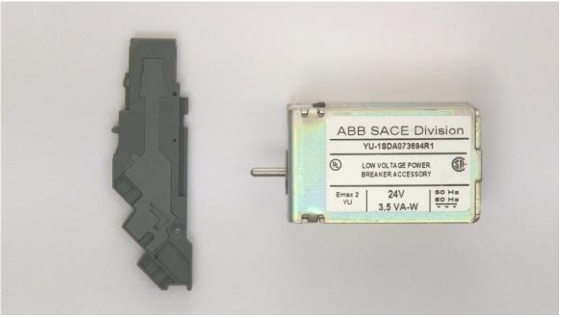
Auxiliary contacts are used to signals CB status:
ON/OFF - Trip



[AUX - Auxiliary contacts not cabled Video]

Under-Voltage Coil

UVC is used to open the circuit breaker if a control signal is cut or interrupted



[SACE Emax 2 - Undervoltage release for E2.2…E6.2 Video]

Trip Coil/ Shunt trip

SOR is used to open the circuit breaker if a control signal is received

[SACE Emax 2 - First opening contacts for E2.2…E6.2 Video]

Shunt closing coil

SCR is used to close the circuit breaker if a control signal is received

[SACE Emax 2 - First closing release for E2.2…E6.2 Video]

- Mechanical Interlock through electrical control is sufficient to achieve the interlocking
- Additonnal Interlock through Wires or key locks can be added
- ** Key lock is not compatible with automatic mode of operation

Front panel operation

External Operation Accessories

Rotary handle

RHD - Rotary handle direct mechanism - XT4 Video

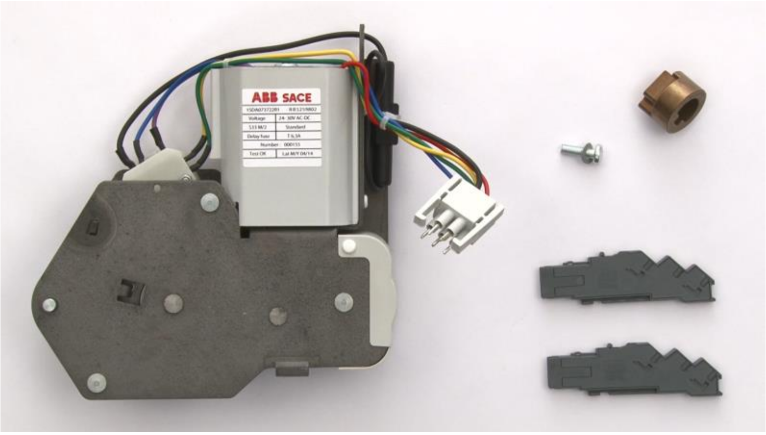
MCCB Motorization

MCCB motor includes SOR+SCR

MOE - Stored energy motor operator XT2-XT4 Video

ACB Motorization

ACB motor needs additional SOR+SCR



SACE Emax 2 - Motor for E2.2…E6.2 Video

Switchgear Operation modes

Interlocking system and Control Options

Switchgear Operation modes

Electro-Mechanical Interlock- Control options

Electrical- UVC

Configuration applicable
All combinations of interlocks
All circuit breakers range
madatory for all types of interlock

SACE Emax 2 - Undervoltage release for E2.2…E6.2 Video

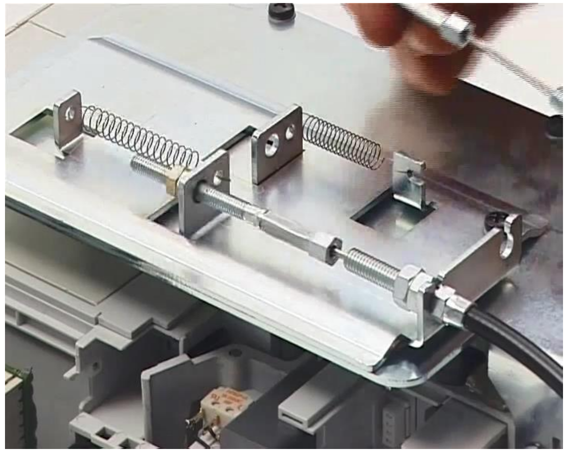
Plates- MCCB- Max 2 CB

Configuration applicable
1 out of two (160A to 1000A)

MIR-H - Mechanical interlock horizontal - XT2 and XT4 Video

Wires ACB- Max 3 CB

Configuration applicable
1 out of two (630A to 6300A)
1 out of three (1600A to 6300A)
2 out of three (2000A to 6300A)



SACE Tmax T7/T7M wired interlock type A - Video

Key lock*

Configuration applicable
All combinations of interlocks
All circuit breakers range

SACE Emax 2 - Key lock in open position for E2.2…E6.2 Video

• * Key lock is not compatible with automatic mode of operation

Switchgear Operation modes

Operation Mode

OFF (maintenance)

Manual (CB or YO+YC)

[SACE Emax 2 - Undervoltage release for E2.2…E6.2 Video]

Automatic (Motor+YC+YO)

Remote (SCADA/BMS)

Motor is mandatory for Automatic mode

Switchgear Operation modes

Automatic Operation Mode

Conventional control

Contactors

ATS Unit 021/022

PLC

Motor is mandatory for Automatic mode

TruONE® ATS

Automatic transfer switch

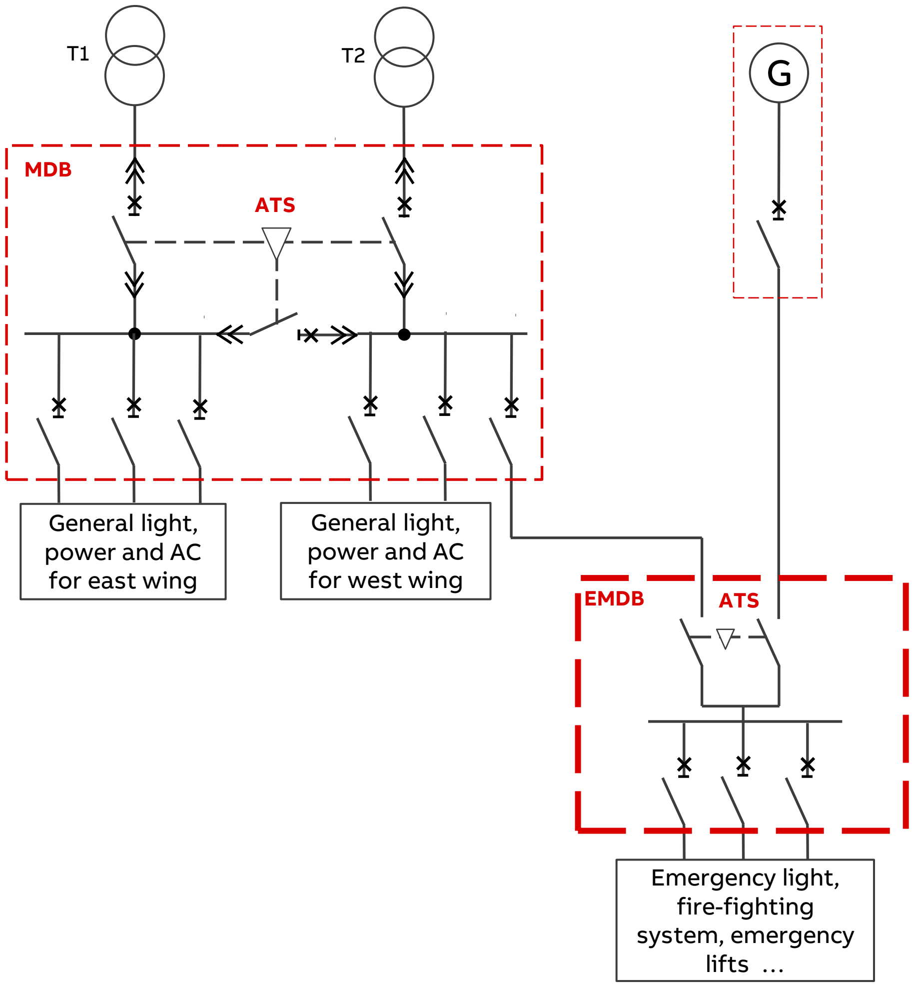
Current range: 200…1600 A (IEC), 30…1200 A (UL)
Rated voltage: 200…480 V AC

- One unit, One wire – just like an ATS should be. Saves up to 60 meters of wire.
- Below 50 ms in-phase transfer
- Readily available emergency manual operation, even under load
- Version with Overlapping neutral
- Power Measurements
- ABB Ability™: EDCS for cloud-based services
- Ekip Com modules for uniform platform (6 com. Protocols)
- Programming via Ekip Connect, without power
- Automatic commissioning capabilities
- Diagnostic and maintenance data
- Predictive maintenance (temperature, contact wear)
- Modular structure to simplify service

Switch based solutions

Common applications

- ATS in the **sub-distribution board or emergency distribution board or ATS panel**, where overcurrent protection is guaranteed by upstream devices
- Electrical installations with **limited space for the transfer switch**
- **UL and IEC enclosed types** directly from ABB
- **Bypass applications** for periodic ATS maintenance
- **Open transition** for UL market with in-phase monitor



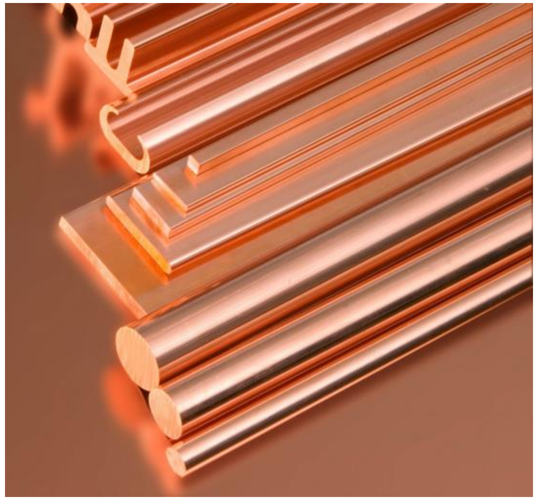
LV Switchboard Busbar

Coating materials

LV Switchboard Busbar

Coating materials

Bare copper busbar



Tin plated copper busbar

Silver Plated copper busbar

Copper busbar with silver plating at joints.

Motor Starting

Basic Motor Circuit Components

Motors Starting

Manual Motor Starters

- ✓ Disconnect
- ✓ Short-circuit protection
- ✓ Overload protection
- ✓ Phase-failure
- ✓ Manual control

- ✓ Disconnect
- ✓ Short-circuit protection
- ✓ Overload protection
- ✓ Phase-failure
- ✓ Manual control

- ✓ Control

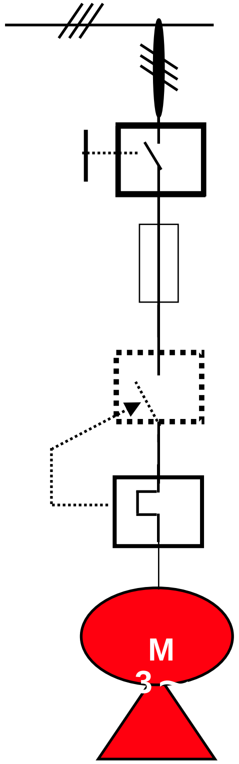
- ✓ Disconnect
- ✓ Short circuit protection
- ✓ Manual control

- ✓ Control

- ✓ Overload protection

Motors Starting

Motor Protection & Control



Isolation
- Disconnector
- Switch disconnector

Short Circuit Protection
- Switch Fuse
- Circuit Breaker (Magnetic)
- Manual Motor Starter

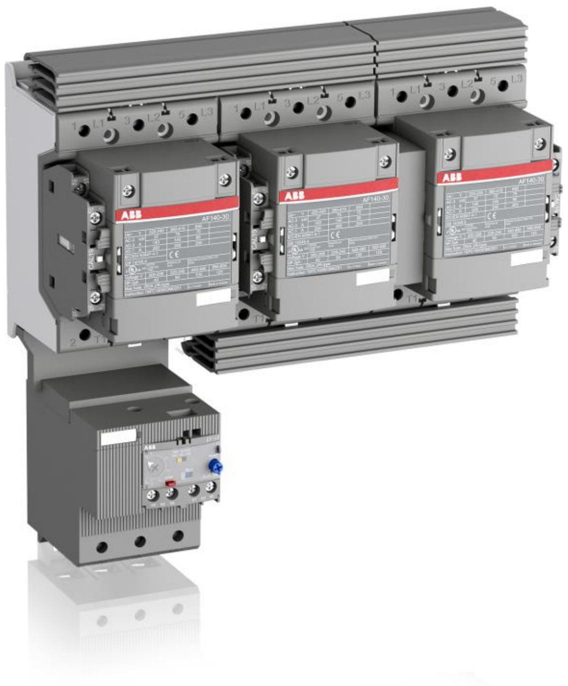
Control
- Contactor

Overload Protection
- Thermal / Electronic Overload Relay

Motor Starting Solutions

Direct Online - DOL

Star-Delta Starter



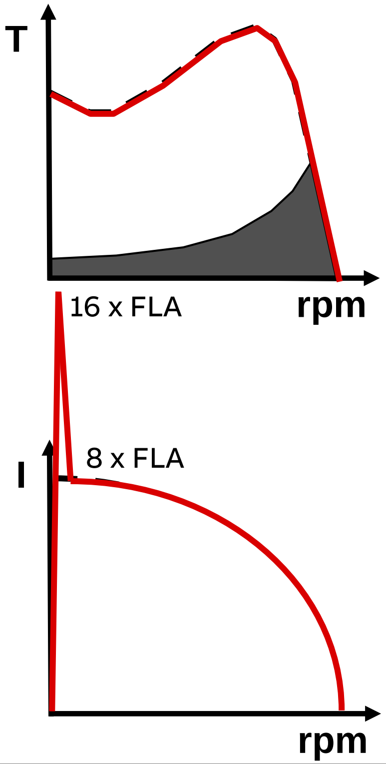
Softstarter

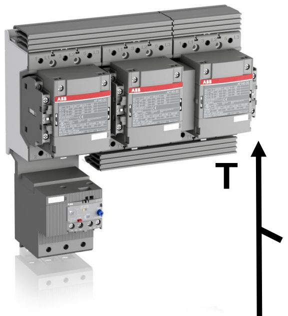
Variable Speed Drive

Motor starting solutions

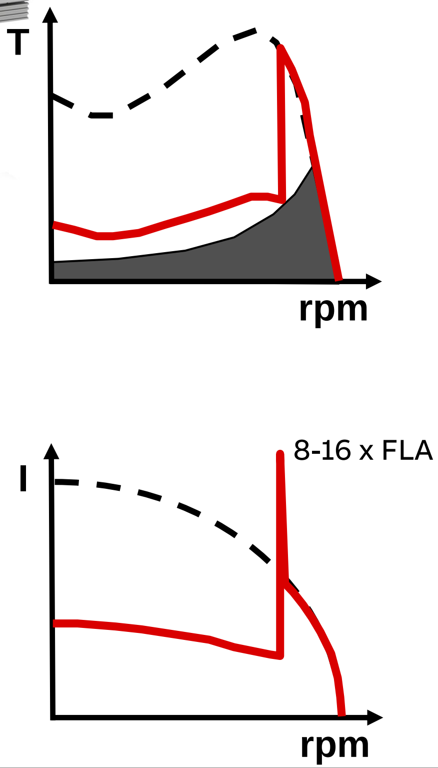
Different ways to start a motor

DOL

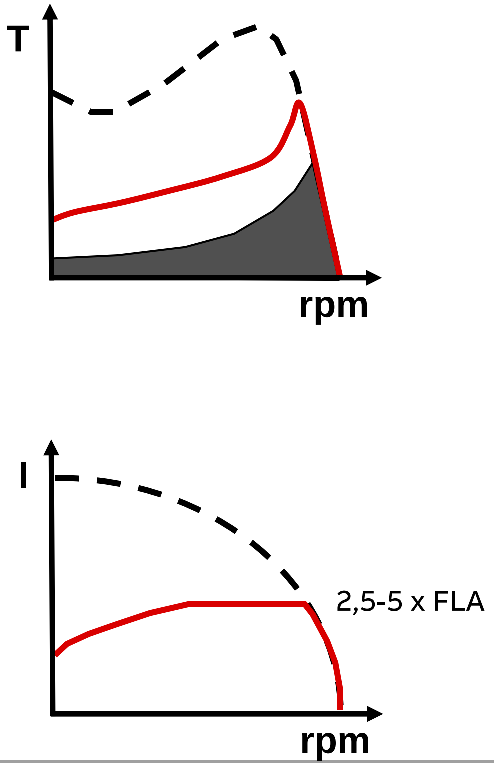




Y/D

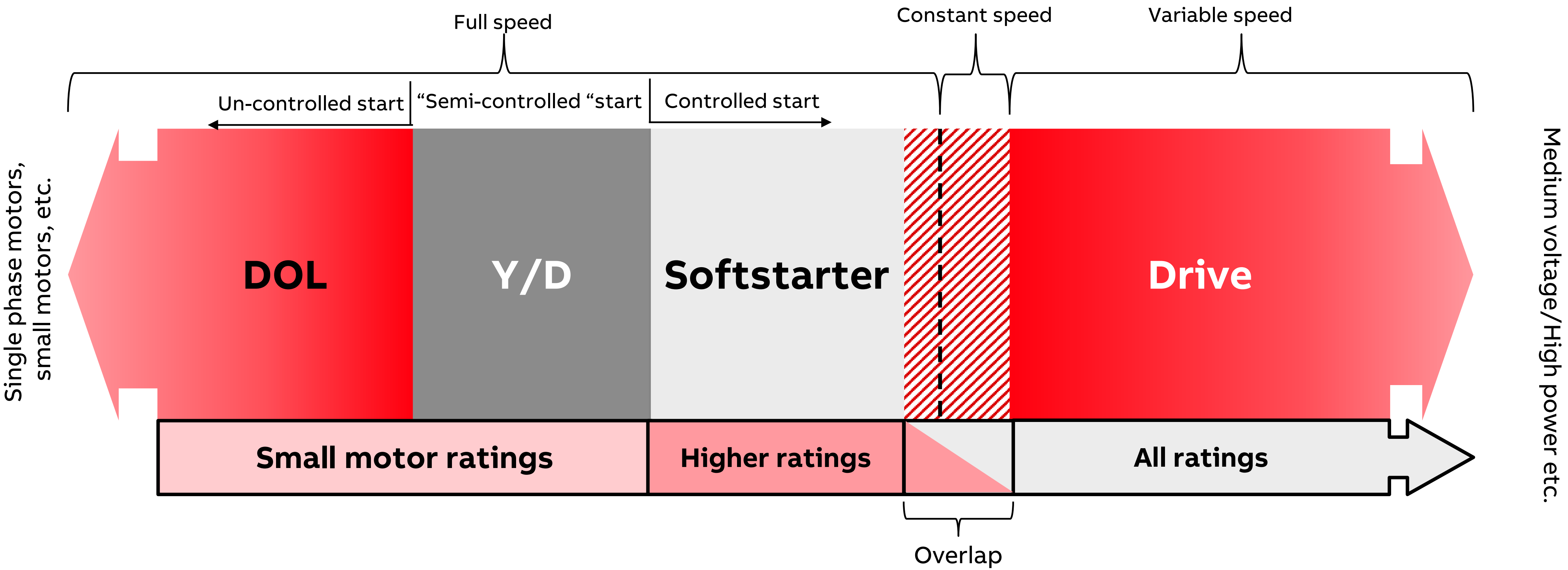


Softstarter



The motor starting market

Which starter shall be select

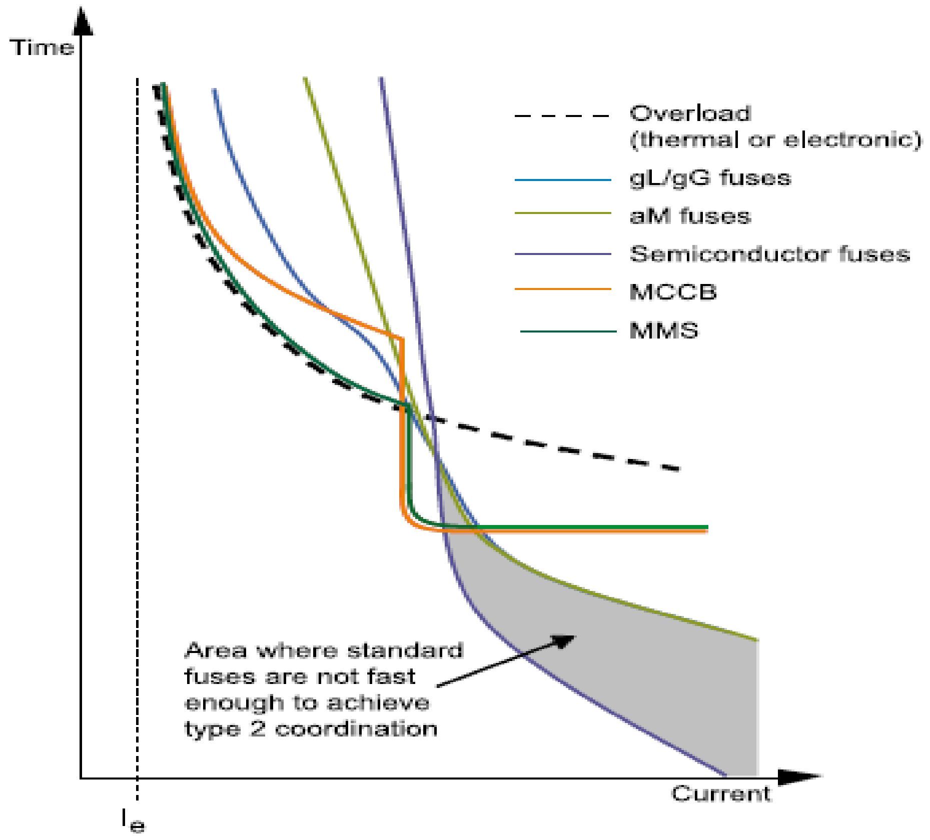


Soft Starters

Coordination of Protection

Coordination Type 2 for Soft starters

Semi-conductor fuses (High speed fuses) are the only type of fuses that are fast enough to achieve a fully type 2 coordination when using a soft starter. A separate overload relay for the motor protection is always required in combination with this type of fuse. If replacing the semi-conductor fuses with an MCCB, MMS or similar, type 1 coordination will be achieved instead.



The motor starting

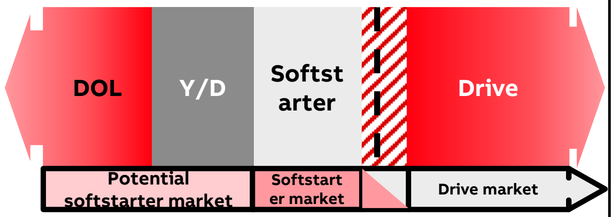
Which starter shall be select

ABB Motor Control Centers (MCC) SLD library

The motor starting

Tips for designing

Full Speed vs Variable speed



Voltage Protections

Voltage Protection functions Preferred to be on Incoming feeders

Measurement with DPMs

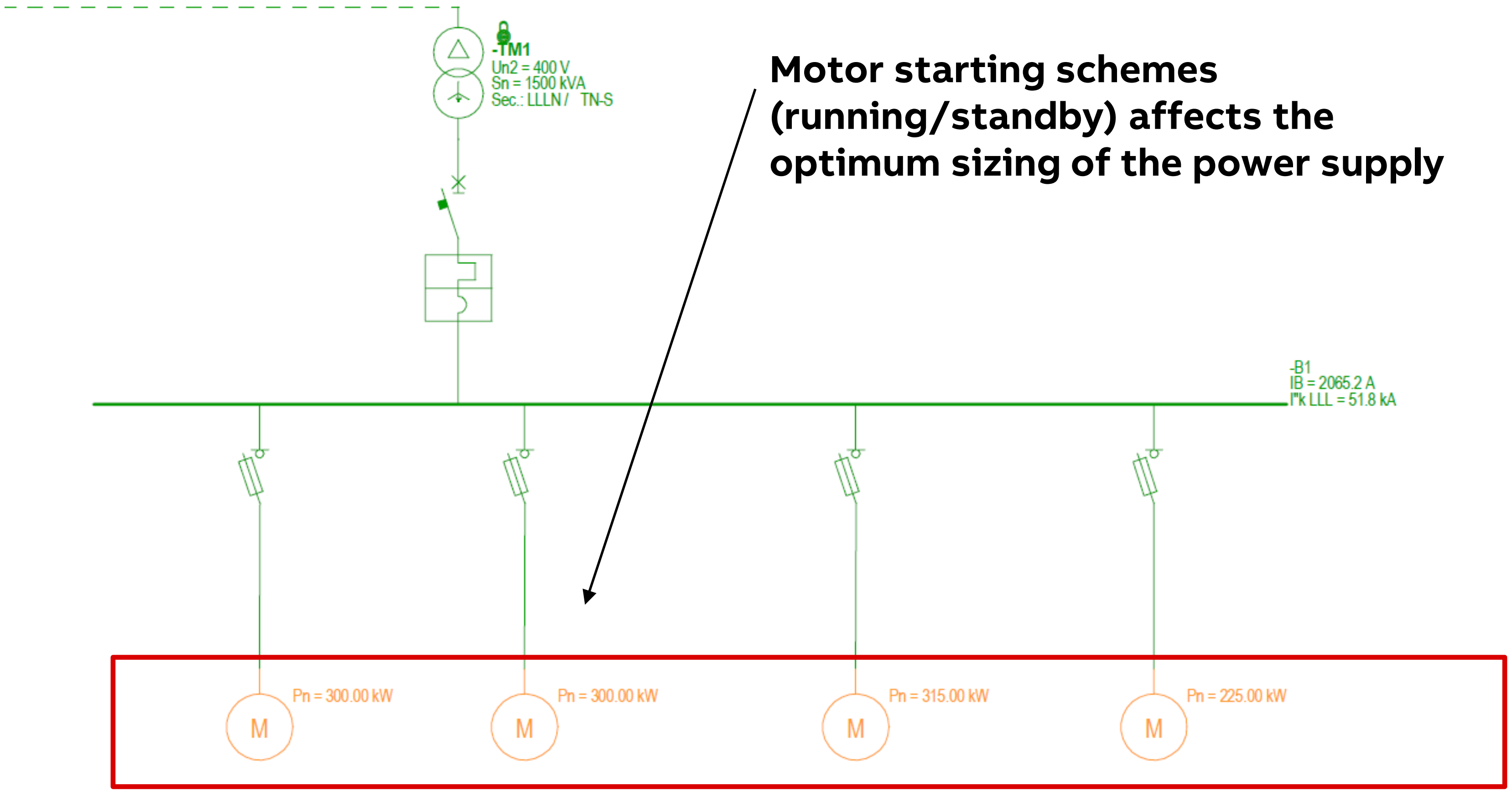
Full measurements preferred to be on Digital Power meter instead of main Circuit breaker

Protections on feeders

Motor Protection functions related to Motor Power

MV & LV Transformer Substations

Theory & Short Circuit Calculations



Motor starting schemes (running/standby) affects the optimum sizing of the power supply

LV Switchboard

Short Circuit Calculations

MV & LV Transformer Substations

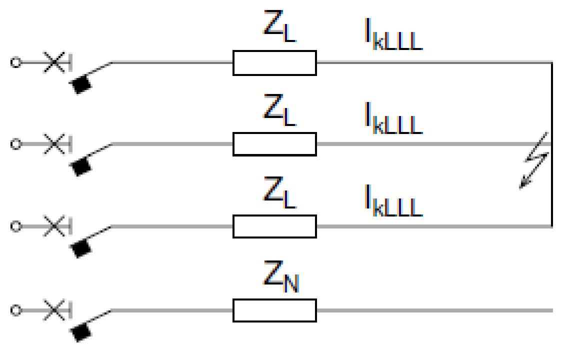
Theory & Short Circuit Calculations

IEC Standard for Short-circuit calculation : IEC 60909-0

- 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”

Three-phase fault

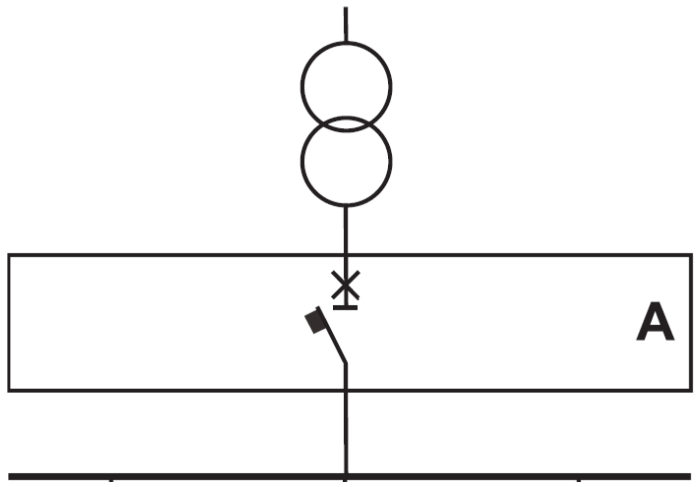


MV & LV Transformer Substations

Theory & Short Circuit Calculations

Protection of 400V transformers at 750MVA (Example)

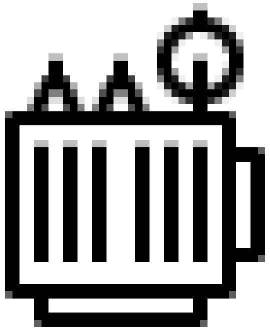
Sr (KVA)	Uk (%)	Rated Current Ir (A)	S.C. Current (KA)
500	4	722	17.7
630	4	909	22.3
800	5	1155	22.6
1000	5	1443	28.1
1250	5	1804	34.9
1600	6.25	2309	35.7
2000	6.25	2887	44.3
2500	6.25	3608	54.8
3125	6.25	4510	67.7



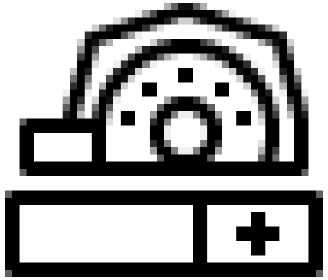
MV & LV Transformer Substations

Network Elements affecting Short Circuit

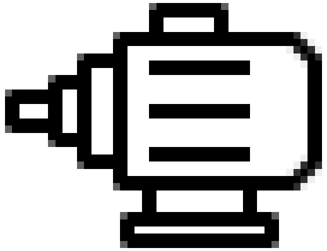
Utility/Transformers



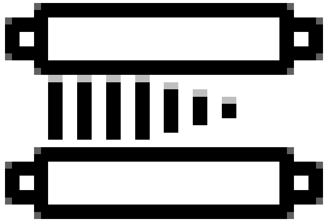
Generators



Motors



Cables/Busway



MV & LV Transformer Substations

Theory & Short Circuit Calculations

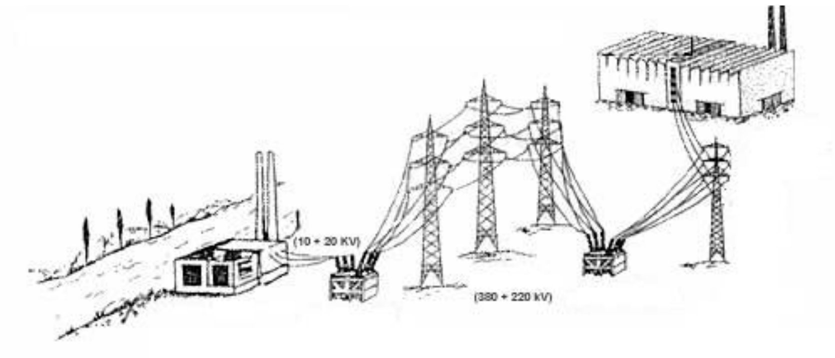
Calculation of Short Circuit Currents

Distribution network

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

- **500MVA** for U_n = **11kV**
- **750MVA** for Un = **22kV**
- According to IEC 60076-5

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



Net voltage U_r [kV]	Short-circuit power S_{knet} [MVA]
Up to 20	500
Up to 32	750
Up to 63	1000

MV & LV Transformer Substations

Theory & Short Circuit Calculations

Calculation of Short Circuit Currents

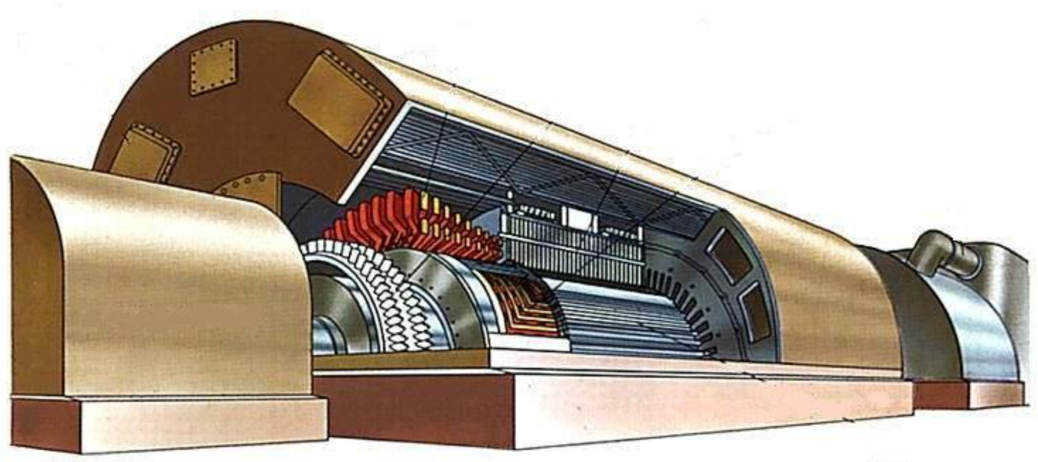
Generators

– 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)

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



MV & LV Transformer Substations

Theory & Short Circuit Calculations

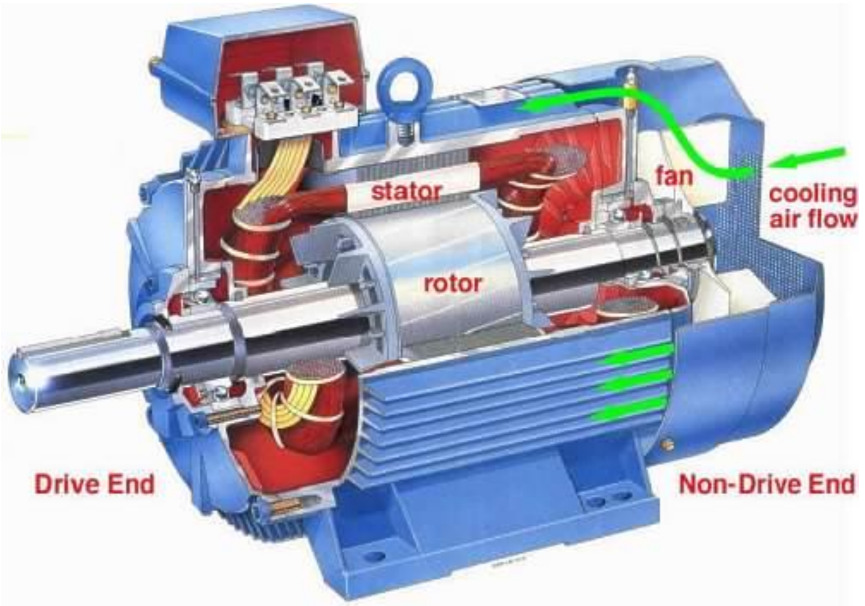
Calculation of Short Circuit Currents

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

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

(Ik short-circuit without motor contribution)



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MV & LV Transformer Substations

Theory & Short Circuit Calculations

IEC 60909-1 : Motor Contribution values

TR 60909-1 © IEC:2002 – 147 –

2.9 Statement of the contribution of asynchronous motors or groups of asynchronous motors (equivalent motors) to the initial symmetrical short-circuit current

2.9.1 General

Asynchronous motors or groups of asynchronous motors (equivalent motors) contribute to the initial symmetrical short-circuit current I_k'', especially in the case of near-to-motor short circuits, and furthermore to the peak short-circuit current i_p, to the symmetrical short-circuit breaking current I_b and in the case of unbalanced short circuits, to the steady-state short-circuit current I_k (IEC 60909-0, 3.8.1). If the contribution to the initial symmetrical short-circuit current remains smaller than 5 % of the total short-circuit current, this contribution may be neglected. IEC 60909-0 gives two equations to estimate whether the contribution is less than 5 % either to a short circuit at the terminal of motors (IEC 60909-0, equation (25)) or to a short circuit fed from motors or motor groups through transformers (IEC 60909-0, equation (28)) without an exact calculation.

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MV & LV Transformer Substations

Theory & Short Circuit Calculations

IEC 60909-1 : Motor equivalent values

7.1.3 Contribution of asynchronous motors to the short-circuit current

Asynchronous motors have to be considered in the calculation of maximum short-circuit current. Low-voltage motors are to be taken into account in auxiliaries of power station units and in industrial and similar installations, for example in networks of chemical and steel industries and pump-stations.

Those high-voltage and low-voltage motors may be neglected, provided that they are not switched in at the same time according to the circuit diagram (interlocking) or to the process (reversible drives).

Low-voltage motors are usually connected to the busbar by cables with different lengths and cross-sections. For simplification of the calculation, groups of motors including their connection cables may be combined to a single equivalent motor.

MV & LV Transformer Substations

Contribution of Motors starters to short circuit value

Starting method	Contribution to S.C.
Direct On Line DOL	Yes
Star-Delta	Yes
Softstarters	Yes
Drives (VSD)	**No**

6.11 Static converter fed drives

Reversible static converter-fed drives (for example, rolling mill drives) are considered for three-phase short circuits only, if the rotational masses of the motors and the static equipment provide reverse transfer of energy for deceleration (a transient inverter operation) at the time of short circuit. Then they contribute only to the initial symmetrical short-circuit current I_k'' and to the peak short-circuit current i_p. They do not contribute to the symmetrical short-circuit breaking current I_b and the steady-state short-circuit current I_k.

As a result, reversible static converter-fed drives are treated for the calculation of short-circuit currents in a similar way to asynchronous motors. The following applies:

Z_M is the impedance according to Formula (30);

U_{rM} is the rated voltage of the static converter transformer on the network side or rated voltage of the static converter, if no transformer is present;

I_{rM} is the rated current of the static converter transformer on the network side or rated current of the static converter, if no transformer is present;

I_{LR}/I_{rM} = 3;

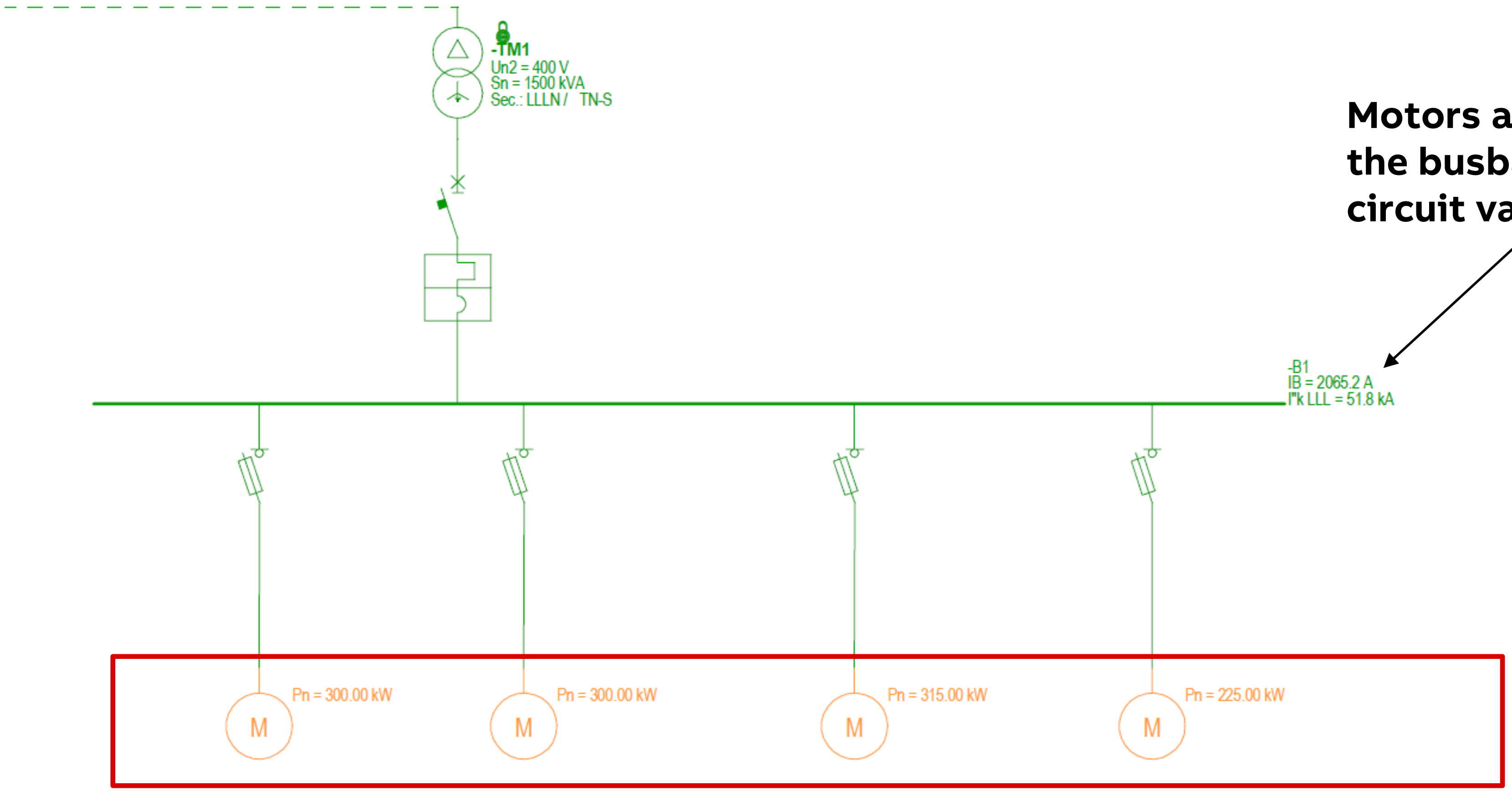
R_M/X_M = 0,10 with X_M = 0,995 Z_M.

All drives short circuit contribution is neglected acc. to IEC 60909-0 clause 6.11

All other static converters are disregarded for the short-circuit current calculation according to this standard.

MV & LV Transformer Substations

Theory & Short Circuit Calculations



Motors affected the busbar short circuit values

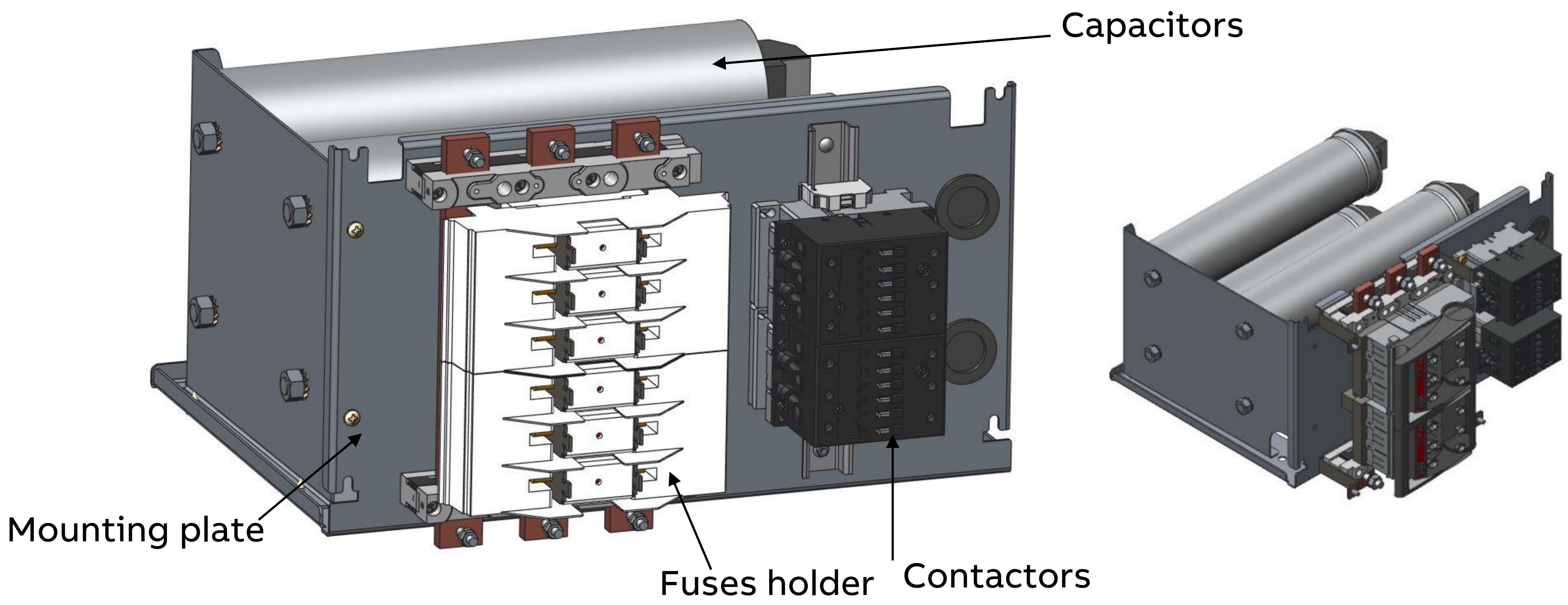
Capacitor Bank

Detuned Reactor Selection

Power Quality – Harmonic basics

Reactor protected capacitor

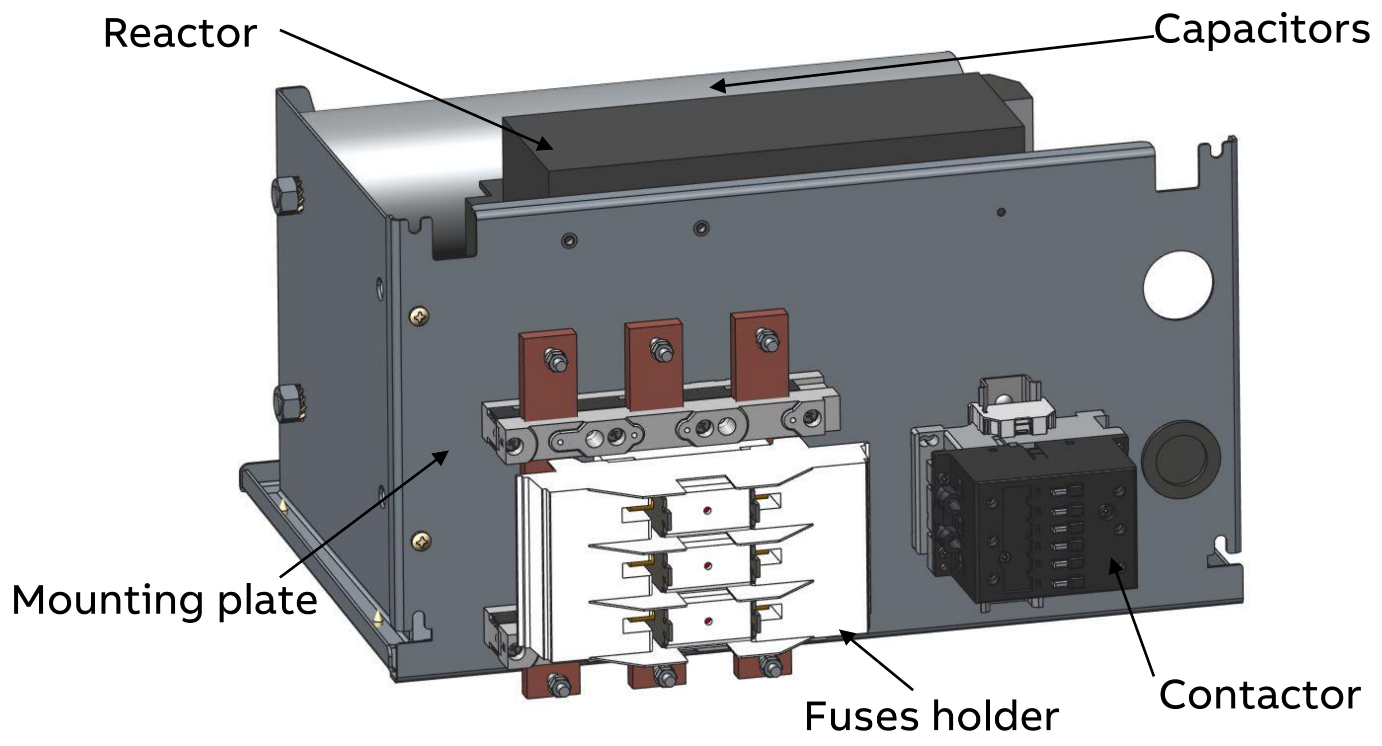
Example of 100 KVAR capacitor shelf



Power Quality – Harmonic basics

Reactor protected capacitor

Example of 50 KVAR capacitor step module with reactor



Contactors for Capacitors Switching

AC-6b utilization category according to IEC 60947-4-1

UA…RA Contactors

- The insertion of damping resistors protects the contactor and the capacitor from the highest inrush currents.
- Used with standard capacitors

UA Contactors (without damping resistors)

- UA Contactors (without damping resistors) can be used in conjunction with detuned reactors

Power Quality – Harmonic basics

Reactor protected capacitor

Causes of Harmonics

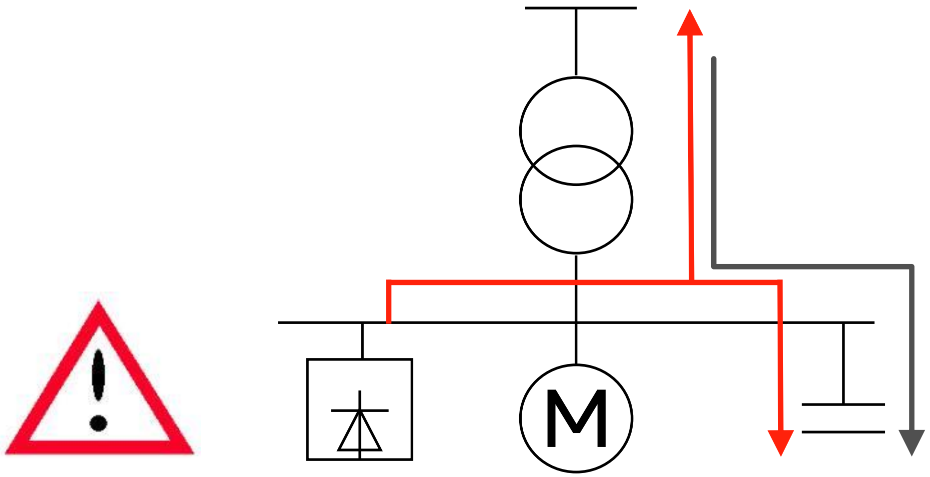
Consequences

Power Factor & Resonance

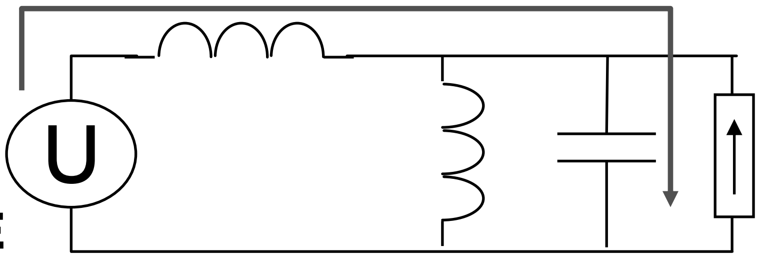
- Resonance can cause amplification of harmonics in an electrical network leading to equipment failure.
- Resonance is impossible to avoid
- Capacitors & reactors will always create resonance for some frequency(ies)

- **Solution:**
  - Add a reactor in series with each capacitor and this detuning reactor must be selected carefully

- **Note:**
  - Detuned reactors protects the power factor its self **ONLY** and **doesn't** eliminate or mitigate the harmonics on the network



$$Z(\omega) = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$



RESONANCE

Power Quality – Harmonic basics

Suitable Reactor Factor

Typical reactor values

- Choose the tuning order (resonance frequency) **BELOW** the first significant harmonic order
- Check also not to disturb the remote control frequency.
- ABB mainly uses detuned reactors of:

  – 7% reactor : n_0 = 3.78
  tuning on 3.78*50Hz = 189 Hz
  for systems with 5th harmonic

  – 14% reactor : n_0 = 2.67
  tuning on 2.67*50Hz = 134 Hz
  for systems with 3rd harmonic

Reactor percentage :

$$p(\%) = \left(fn / fo \right)^2 * 100$$

$$n_0 = \sqrt{\frac{1}{P}} = (f_0/f_n)$$

Resonance frequency

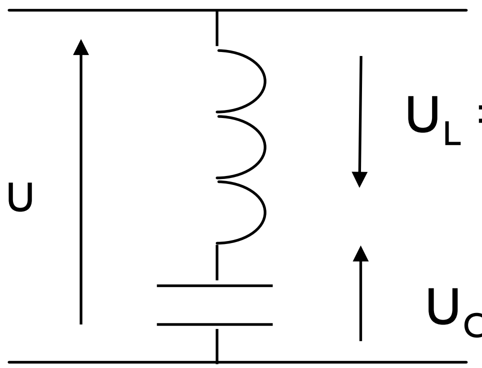
$$f_0 = \frac{f_N}{\sqrt{p}}$$

Power Quality – Harmonic basics

Reactor protected capacitor

Example of voltage increase on the capacitor:

- $U = 400$ V
- Capacitor in series with 7% reactor, p=0.07



$U_L = p/(1-p).U$

$U_C = U/(1-p)$

- $U_C = 400/(1-0.07) = 430$ V

→ Choose capacitor having min.430V nom. Voltage

- $U_L = 0.07/(1-0.07)*400 = 30$ V

The new KVAR at the new voltage must be calculated

If Q=300 KVAR at 400V
At new operating voltage 430, new Q must be calculated

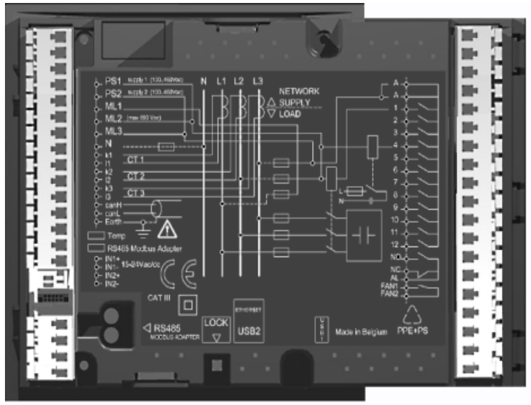
$Q1/Q2 \propto (V1/V2)^2$
New KVAR $Q2 = Q1 \times (V2/V1)^2$
$Q2 = 300x\,(430/400)^2 = 346 \approx 350$ KVAR

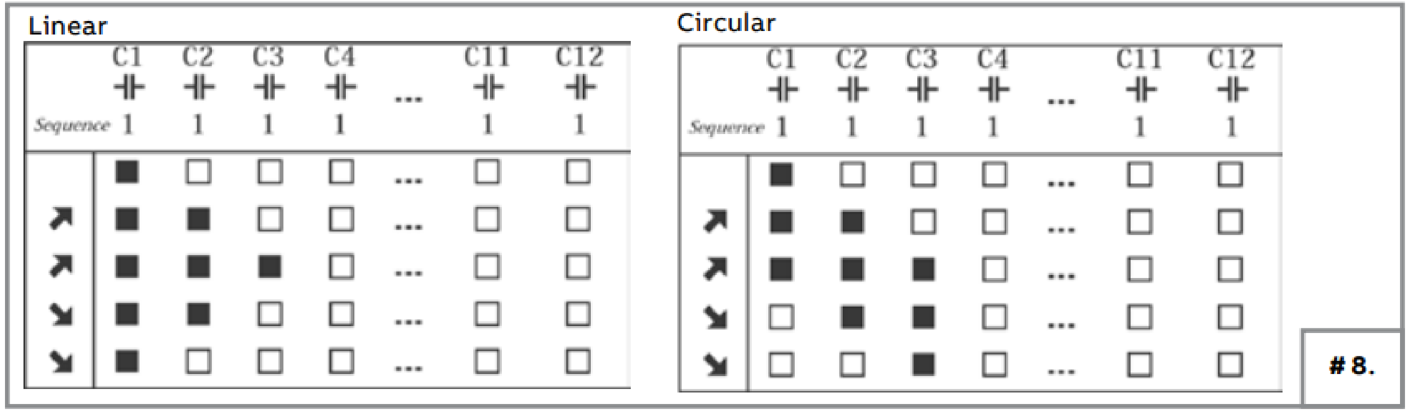
Capacitor Bank

Precise control and monitoring of system power quality

Mode of switching

The modes of switching for all the programmable
switching sequences are normal or integral, progressive or direct, linear or **circular**





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Harmonics Case Study

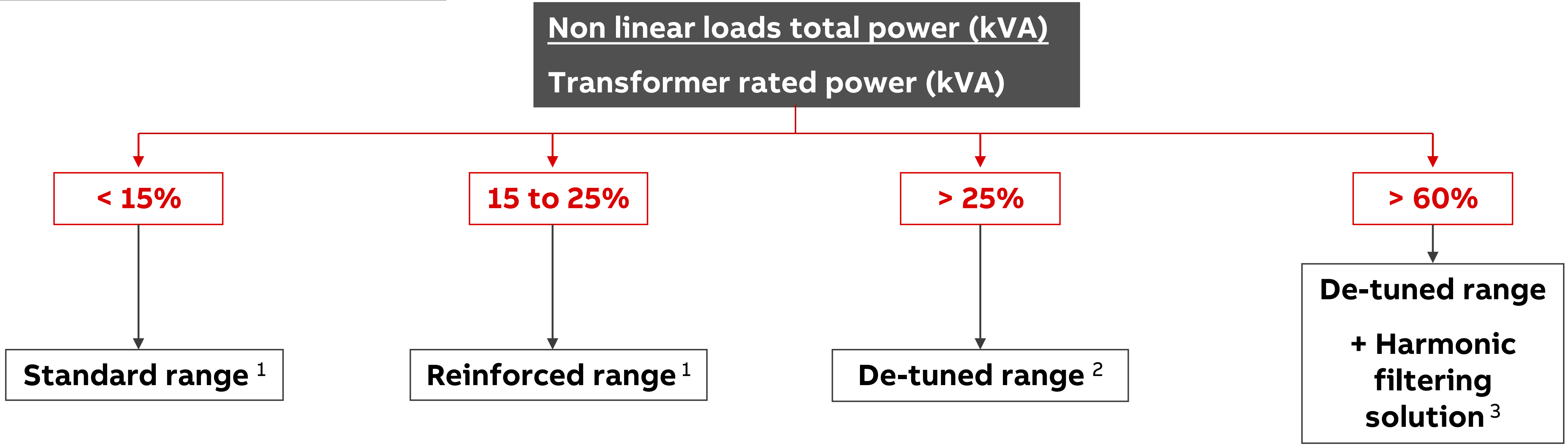
Technical & Commercial

Quick selection guide

APCQ series

“Quick” selection guide

$$Q_{comp} = P \times (tg\varphi_1 - tg\varphi_2)$$



[1] Providing there is no resonance
[2] Reactor value must not interfere with existing telecommunication frequency.
[3] Requires harmonic analysis. Please contact ABB’s specialist.

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