APPLICATION NOTE

System pro E Power configurations

for 800V AC combiners in photovoltaic plants

Discover ABB's comprehensive Switching and Protection solutions within the System pro E Power switchboard range, designed to protect and secure string inverters in photovoltaic plants. Learn how to perform design verification of switchboards for higher voltages, such as 800V AC.
Quickly configure Commercial and Industrial Photovoltaic (PV) AC Combiners using our pre-validated application bundles.

What is an AC Combiner?
An AC Combiner is a switchboard that connects several string inverters in parallel before connecting to the MV/LV transformer. It houses switching and protection devices, along with auxiliary and communication circuits.

Why do you need an AC Combiner?
Each feeder from the respective string inverter requires adequate galvanic switching and protection against overcurrents within a switchboard.

Main benefits

Smarter protection
Increase the power in your installation and reduce CAPEX by using the complete range of Low Voltage (LV) components rated up to 1000V AC. Achieve excellent performance across various temperature and humidity conditions.

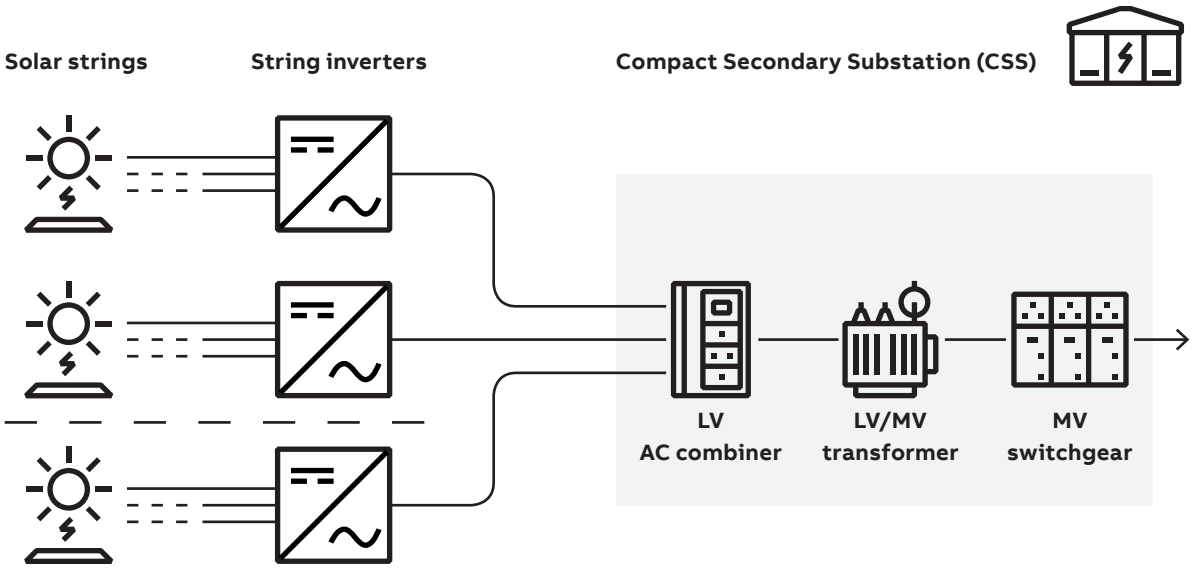
Speed up your projects
Rapid installation thanks to preconfigured bundles using a coordinated range of products with compact sizes.

Reliability
A trustworthy and comprehensive 800V AC switchboard solution, thanks to design verification according to IEC 61439, provided by our configurable and flexible System pro E Power top busbar system switchboard.

AC Combiners in String inverter architecture

Fundamentals, main components & functionalities

The power generated by solar strings and converted into AC by each string inverter is collected by the AC Combiner. The AC Combiner is a switchboard where several string inverters are placed in parallel by the relative feeder. Every feeder requires adequate switching and protection against overcurrents.



AC Combiner components

- Switchboard
- AC switching and protection devices
- Insulating monitoring device
- Surge protection device for direct lightning
- Grid feeding relay
- Auxiliary circuits

Optional components of AC Combiner

- Arc flash mitigation: Active, Passive or Preventive solutions
- Temperature monitoring relay.

Key trends

Solar power plants with String inverter architecture

Multi MPPT (maximum power point tracker) for string inverter architecture

The MPPT maximizes the energy yield of the connected solar string at any time during its operation. Solar inverters were originally designed to have a single MPPT capable of maximizing the output for one value of DC current. Having the solar array managed by several MPPTs, as in string inverters, helps to improve total energy production.

Advantages

- Higher plant flexibility and efficiency
- Elimination of PV string fuses on the DC input to the inverter
- DC combiner no longer required
- AC voltage distribution
- Simpler plant architecture with only 3 components: PV panels + solar inverters + MV/LV compact substations.

Solar plants are moving towards 800V on the AC side

Higher voltages, up to 800V AC, make the whole system more efficient, especially with string inverter architecture where the cables between the inverters and MV/LV transformer are usually very long.

Advantages

- Enhanced sustainability
- Reduced Balance of Systems costs (e.g. AC side cabling)
- Higher power enabled in the same enclosure (~30%) while maintaining the same current (fewer inverters per MW)
- 40-50 % savings on AC cables and components compared to 400V AC string inverters
- Typically used in large Commercial & Industrial facilities (P>500kW) where a dedicated MV/LV transformer is required by the design, regardless.

String Inverters with a higher power range and voltages up to 800V AC and 1500V DC

Thanks to string inverters with a higher power range, fewer inverters can be used in solar systems. String inverters are also scalable to support a range of power ratings and PV system sizes.

Typical features

- Voltages
- DC IN: 1500V DC
- AC OUT: 800V AC
- 100-330kW power range
- Output currents: 73-250A
- AC Protection nominal current: 160-250A
- AC main protection: Breaker, Fuses also used
- Certifications: IEC - CCC - UL

Meeting the Challenges of 800V AC Switchboards

Ensuring compliance and safety

System pro E power
Certificate of conformity

As solar plants are moving towards 800V AC voltage level on the AC side of string inverters, all components of AC combiners, not only devices but also switchboard itself, are needed to be developed and approved for 800V AC.

System pro E Power (SpEp) is currently fully certified with devices up to 415V AC rated service voltage as seen in below table, and only with construction and busbar system tested up to 1000V AC. In order to use devices at 800V AC the IEC 61439-2 standard becomes relevant using design verification approach on assembly or assembly system with alternative arrangement, where this performance is still to be confirmed.

Design verification is intended to verify compliance of the design of an assembly or assembly system with the requirements of the IEC 61439 standard series. When the assembly manufacturer** requires their own arrangements that are not included in the original manufacturer's* design, they are considered the original manufacturer for these and are responsible for verifying these alternative arrangements.

Here below you find main characteristics of SpEp as reported in the certificate of the conformity.

* Original manufacturer: organization that has carried out the original design and the associated verification of an assembly in accordance with the relevant assembly standard

** Assembly manufacturer: organization taking the responsibility for the completed assembly

Main characteristics of the series

Compliance with Standard		IEC 61439-1-2
Seismic withstand capability test		In accordance with Standard IEEE Std 693 and IEC 60068-2-57
Rated service voltage Ue		415 V
Rated insulation voltage Ui		up to 1000V AC - 1500V DC
Rated frequency		50-60Hz
Rated impulse withstand voltage Uimp		12kV
Rated current In		up to 6300A
Rated short-time withstand current Icw		up to 120kA
Rated peak short-circuit current Ipk		up to 264kA
IP protection class		IP30, IP31, IP40, IP41, IP65
IEC TR 61641 ed.03 Permissible current under arcing conditions		65 kA 0,3 s at 480 V, class A Up to 4000 A
Functional dimensions	**Height (mm)**	1800, 2000mm
	Width (mm)	300, 400, 600, 800, 1000, 1250mm
	Depth (mm)	200, 300, 500, 700, 900, 1250mm

Design Verification

Characteristics to be checked for 800V AC voltage designs

System pro E power Catalogue

In order to convert the SpEp design for 800V AC arrangements, the following items need to be verified first and this document focus only these ones.

- Clearances and Creepage distances
- Power frequency withstand voltage
- Impulse withstand voltage
- Short-circuit withstand strength

But the standard emphasizes that when any changes are made, all steps must be verified. Assembly manufacturers will be responsible for the design by making the necessary controls to verify the changes they make.
For more detailed and complete design verification requirements, Chapter 7 of SpEp TBBS catalogue can be checked.

Table D.1 in Annex D of IEC61439-1 provides a list of design verifications to be performed for various characteristics as below.

No.	Characteristic to be verified	Subclauses	Verification options available		
			Testing[a]	Comparison with a reference design	Assessment
Construction requirements					
1	Strength of material and parts:	10.2			
	Resistance to corrosion	10.2.2	YES	YES	NO
	Properties of insulating materials:	10.2.3			
	Thermal stability	10.2.3.1	YES	YES	NO
	Resistance to abnormal heat and fire due to internal electric effects	10.2.3.2	YES	YES	YES
	Resistance to ultra-violet (UV) radiation	10.2.4	YES	YES	YES
	Lifting	10.2.5	YES	YES	NO
	Mechanical impact (IK)	10.2.6	YES	YES	NO
	Marking	10.2.7	YES	YES	NO
	Mechanical operation	10.2.8	YES	YES	NO
2	Degree of protection of enclosures (IP)	10.3	YES	NO	YES
3	Clearances	10.4	YES	NO	NO
4	Creepage distances	10.4	YES	NO	NO
5	Protection against electric shock and integrity of protective circuits:	10.5			
	Effective continuity between the exposed conductive parts of a class I assembly and the protective circuit	10.5.2	YES	NO	NO
	Short-circuit withstand strength of the protective circuit	10.5.3	YES	YES	NO
6	Incorporation of switching devices and components	10.6	NO	NO	YES
7	Internal electrical circuits and connections	10.7	NO	NO	YES
8	Terminals for external conductors	10.8	NO	NO	YES
Performance requirements					
9	Dielectric properties:	10.9			
	Power-frequency withstand voltage	10.9.2	YES	NO	NO
	Impulse withstand voltage	10.9.3	YES	NO	YES
	Enclosures made of insulating material	10.9.4	YES	NO	NO
	External operation handles of insulating material	10.9.5	YES	NO	NO
	Conductors covered by insulating material to provide protection against electric shock	10.9.6	YES	NO	NO
10	Temperature-rise limits	10.10	YES	YES	YES
11	Short-circuit withstand strength	10.11	YES	YES	NO
12	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES

[a] Testing may be on representative sample if permitted in the appropriate test clause.

Design Verification

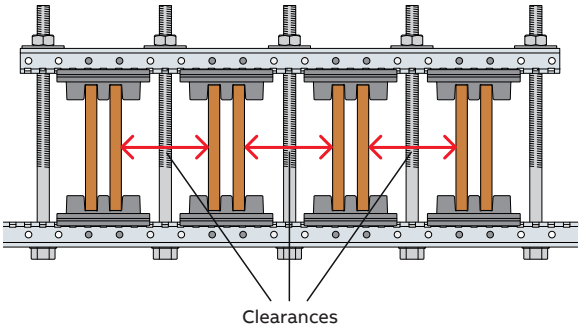
Characteristics to be checked for 800V AC voltage designs

Clearances and creepage distances
One of the main requirements which is highly effected by voltage is clearances and creepage distances.
They are intended to provide insulation coordination within the installation.

- When incorporating equipment into the assembly, the specified clearances and creepage distances shall be maintained during normal service conditions.
- For dimensioning clearances and creepage distances between separate circuits, the highest voltage ratings shall be used (rated impulse withstand voltage for clearances and rated insulation voltage for creepage distances).
- The clearances and creepage distances apply to line to line, line to neutral, and, except where a conductor is connected directly to earth, line to earth and neutral to earth.

The methods of determining clearances and creepage distances by measurement are indicated in examples in Annex F. Please check it for more detailed information.

Clearences
Clearance is the shortest distance in air between two conductive parts.
The clearances shall be sufficient to enable the declared rated impulse withstand voltage (Uimp) of a circuit to be achieved.



Clearances shall be verified by measurement, or verification of measurements on design drawings, employing the measurement methods stated in Annex F.

The clearances shall be at least 1.5 times of the values specified in Table 1 of IEC 61439-1 below. This factor applied is to avoid impulse withstand voltage tests for design verification. It is a safety factor that takes into consideration manufacturing tolerances.

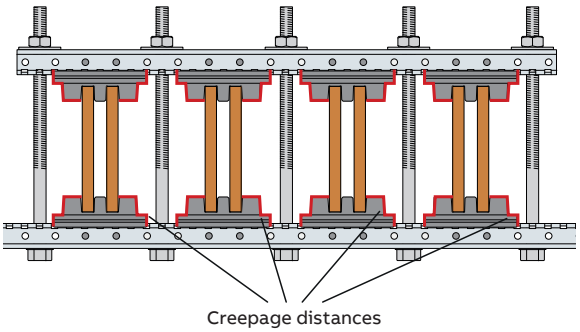
Table 1 of IEC 61439-1 – Minimum clearances in air

Rated impulse withstand voltage, U_{imp} (kV)	Minimum clearance[a] (mm)
≤ 2,5	1,5
4,0	3,0
6,0	5,5
8,0	8,0
12,0	14,0

[a]Based on inhomogeneous field conditions and pollution degree 3.

Creepage distances
Creepage distance is the shortest distance along the surface of a solid insulating material between two conductive parts.
The original manufacturer shall select a nominal insulation voltage (Ui) for the circuits of the assembly for which the creepage distance(s) are to be determined.

- The rated insulation voltage (Ui=1000V AC) shall not be less than the rated operational voltage (Ue=800V AC).
- The creepage distances shall not, in any case, be less than the associated minimum clearances.



Design Verification

Characteristics to be checked for 800V AC voltage designs

As a rule, this procedure shall take into account the type of insulating material and the relevant comparative tracking index CTI (in Volt) expressing the maximum withstand voltage which can be withstood without discharges.
The more valuable the product (glass, ceramic material), the higher is this index (600 and over) and the lower the relevant material group.

The above can be summarized in the following Table 2, which shows the minimum creepage distances in mm for each component housed in the assembly, as a function of the rated insulation voltage Ui, of the pollution degree and of the material group.

Table 2 of IEC 61439-1 - Minimum creepage distances

Rated insulation voltage U_i	Minimum creepage distances mm							
	Pollution degree							
	1	2			3			
	Material group[c]	Material group[c]			Material group[c]			
V[b]	All material groups	I	II	IIIa and IIIb	I	II	IIIa	IIIb
32	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
40	1.5	1.5	1.5	1.5	1.5	1.6	1.8	1.8
50	1.5	1.5	1.5	1.5	1.5	1.7	1.9	1.9
63	1.5	1.5	1.5	1.5	1.6	1.8	2	2
80	1.5	1.5	1.5	1.5	1.7	1.9	2.1	2.1
100	1.5	1.5	1.5	1.5	1.8	2	2.2	2.2
125	1.5	1.5	1.5	1.5	1.9	2.1	2.4	2.4
160	1.5	1.5	1.5	1.6	2	2.2	2.5	2.5
200	1.5	1.5	1.5	2	2.5	2.8	3.2	3.2
250	1.5	1.5	1.8	2.5	3.2	3.6	4	4
320	1.5	1.6	2.2	3.2	4	4.5	5	5
400	1.5	2	2.8	4	5	5.6	6.3	6.3
500	1.5	2.5	3.6	5	6.3	7.1	8.0	8.0
630	1.8	3.2	4.5	6.3	8	9	10	10
800	2.4	4	5.6	8	10	11	12.5	a
1000	3.2	5	7.1	10	12.5	14	16	
1250	4.2	6.3	9	12.5	16	18	20	
1600	5.6	8	11	16	20	22	25	

NOTE 1
- Pollution degree 1: No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
- Pollution degree 2: Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.
- Pollution degree 3: Conductive pollution occurs, or dry, non-conductive pollution occurs which is expected to become conductive due to condensation.

NOTE 2 The CTI values in footnote c refer to the values obtained in accordance with IEC 60112:2003 and IEC 60112:2003/AMD1:2009, test solution A, for the insulating material used.

NOTE 3 Values taken from IEC 60664-1:2007, but maintaining value of 1,5 mm.

a) Insulation of material group IIIb is not recommended for use in pollution degree 3 above 630 V.

b) As an exception, for rated insulation voltages of 127 V, 208 V, 415 V, 440 V, 660 V/690 V and 830 V, creepage distances corresponding to the lower values 125 V, 200 V, 400 V, 630 V, and 800 V may be used.

c) Material groups are classified as follows, according to the range of values of the comparative tracking index (CTI) (see 3.6.16):

- Material group I 600 ≤ CTI
- Material group II 400 ≤ CTI < 600
- Material group IIIa 175 ≤ CTI < 400
- Material group IIIb 100 ≤ CTI < 175

Design Verification

Characteristics to be checked for 800V AC voltage designs

Power-frequency withstand voltage (Ui)
The circuits of the assembly shall be capable of withstanding the appropriate power-frequency withstand voltages given in Table 8 and Table 9 (Clause 10.9.2). The test voltage at the moment of application shall not exceed 50% of the full test value. It shall then be increased progressively to this full value and maintained for 60 seconds (Clause 10.9.2.3).
The overcurrent relay shall not operate and there shall be no disruptive discharge during the tests.

Table 8 of IEC 61439-1 – Power-frequency withstand voltage for main circuits

Rated insulation voltage, U_i (line to line AC or DC) V	Dielectric test voltage AC RMS V	Dielectric test voltage DC V
$U_i \leq 60$	1000	1 415
$60 < U_i \leq 300$	1500	2 120
$300 < U_i \leq 690$	1890	2 670
$690 < U_i \leq 800$	2000	2 830
$800 < U_i \leq 1000$	2200	3 110
$1\,000 < U_i \leq 1\,500$ [a]	2700	3 820

[a] for DC only

Table 9 of IEC 61439-1 – Power-frequency withstand voltage for auxiliary circuits

Rated insulation voltage, U_i (line to line) V	Dielectric test voltage AC RMS V	Dielectric test voltage DC V
$U_i \leq 12$	250	355
$12 < U_i \leq 60$	500	710
$60 < U_i$	See Table 8	See Table 8

Impulse withstand voltage (Uimp)
The capability of the assembly to withstand stresses caused by peaks and transient non-linear overvoltage due to atmospheric causes (lightning) depends all on the dielectric strength of the air between the two live parts carrying the impulse.

Formerly such performance was defined only by experimental testing; according to the new IEC 61439-1 also verification by assessment is possible as an alternative to and with the same validity of testing.

As already mentioned under clearances title, the clearances shall be verified by measurement or verification of measurements on design drawings, employing the measurement methods stated in Annex F. The clearances shall be at least 1.5 times of the values specified in Table 1 of IEC 61439-1. This safety factor, that takes into consideration manufacturing tolerances, is to avoid impulse withstand voltage tests. For verification by test method, Chapter 7 of SpEp TBBS catalogue can be checked.

It shall be verified by assessing the device manufacturer's data that all incorporated devices are suitable for the specified rated impulse withstand voltage (Uimp). It is evident that to guarantee a determined Uimp value for the whole assembly, in addition to the test or verification which confirms this characteristic, also all incorporated devices shall have an equal or higher Uimp value.

Short-circuit withstand strength
For this characteristic, assembly manufacturers are required to assess the potential risks that may arise from small design differences under current conditions and within the specific environment.

However, both the standard and ABB strongly recommend repeating the test if a comparative analysis does not meet the desired conditions and poses potential risks.
For complete requirements, please refer to the IEC 61439-1 standard or Chapter 7 of SpEp TBBS catalogue.

IMPORTANT NOTE
All the above points should be considered as suggestions only, to enable an assembly manufacturer to use enclosures at voltages higher than 415V AC. It is important to note that, at present, all our SpEp systems certificates and system test reports fully cover voltages up to 415V AC and up to 1000V only for busbar system and construction. The assembly manufacturer must verify all assembly or assembly system with alternative arrangement in compliance with IEC61439 1-2, and if necessary, take actions to eliminate residual risks, as we currently cannot provide reports of our 800V AC devices tested in the cubicles of our SpEp enclosures.

Applications

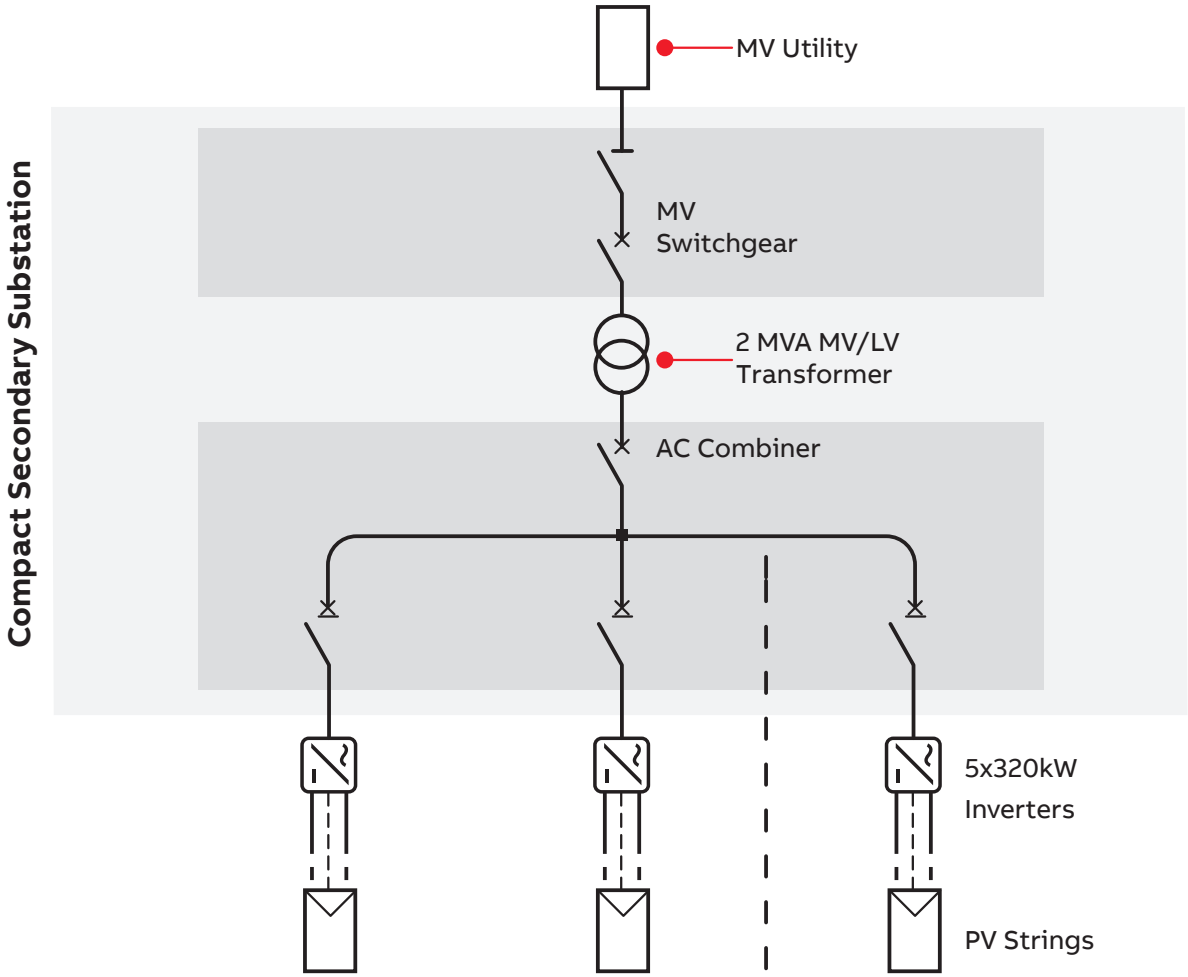
In addition to the theoretical explanations provided above, you can find a comprehensive example that has been verified by ABB together with device and design requirements.

Application - 1,6 MW Photovoltaic plant

Overview

Discover our Switching and Protection solutions for easy 800V AC Combiner configuration considering a 1,6MW photovoltaic plant with 5 x 320kW string inverters in parallel.

1 Combiner, 5 x 320kW string inverters



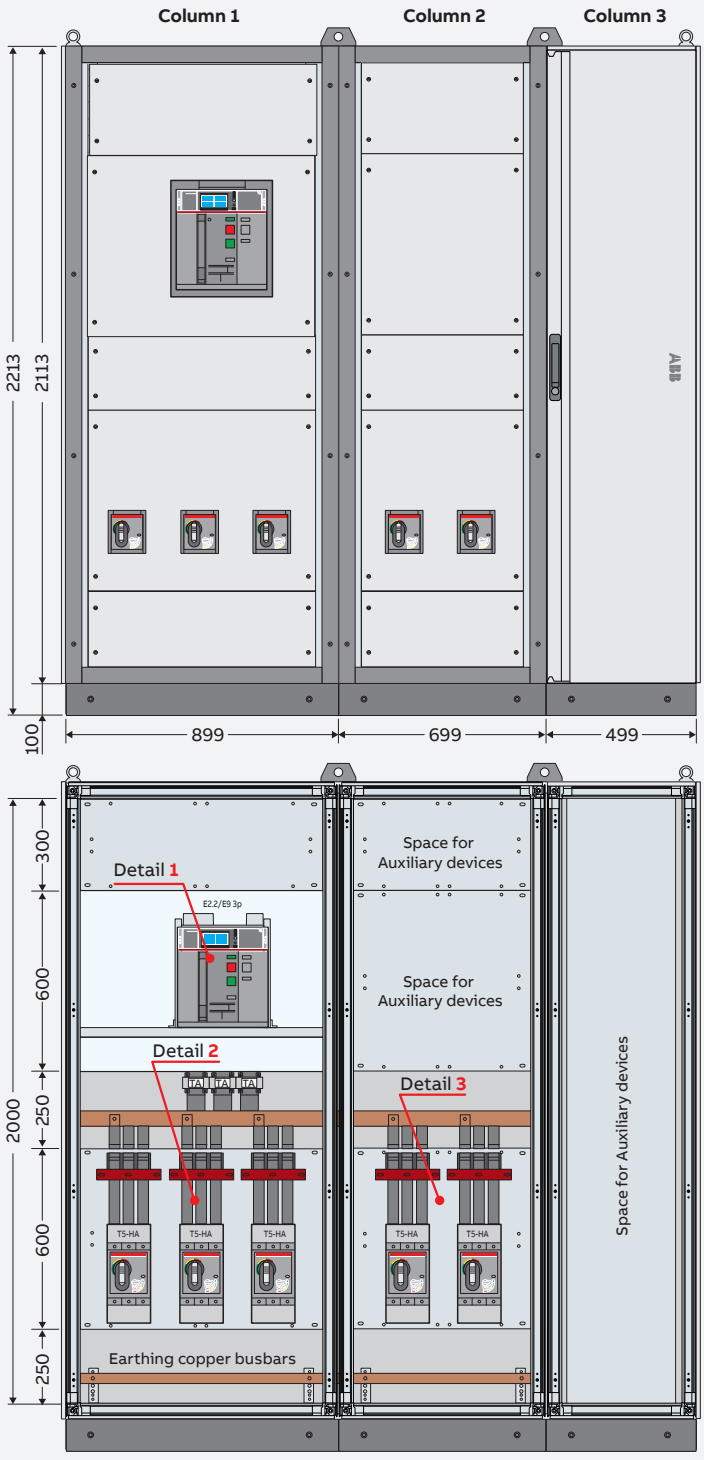
Input data	IEC
System rated power [MW]	1,6
MV/LV transformer rated power (Y/D) [MVA]	2,0
Transformer impedance voltage (%) Uk	6%
Rated MVAC voltage [kV]	20
Rated LVAC voltage [V]	800
Rated LVAC bus current [A]	1283
Inverter rated LVAC active power [kW]	320
Inverter max. output current [A]	254
N. inverter per AC combiner	5
Cosfi	0,9
Short circuit current LVAC bus [kA]	25
Short circuit current LVAC feeders [kA]	27
Suitability for IT network	Yes

Application - 1,6 MW Photovoltaic plant

Key Characteristics of the configuration

This is the application for an AC combiner panel of 1,6MW photovoltaic plant. There are 5 circuit breakers for protection of inverters which are mounted vertically. Cables coming from the inverters enter to switchboard from the bottom. Additionally, there is one main circuit breaker.

The conductor connecting to the upper terminal of this circuit breaker goes to the transformer from the top of the switchboard. The vertical mounting of the circuit breakers eases the connection of the large aluminum cables.



Application - 1,6 MW Photovoltaic plant

Key Characteristics of the configuration

Key characteristics of the configuration

Switchboard	
Type of installation	Indoor, front access
Rated service voltage Ue [V AC]	800
Rated current In [A]	up to 2500
IP protection class	IP30
RAL	7035 orange peel
Form of segregation	
Inverter protection circuit breaker section	2a/2b
Main circuit breaker section	2a/3a (mandatory)
Auxiliary circuit section	2b
Functional dimensions	
Height [mm]	2000
Width [mm]	1800 (1x800; 1x600; 1x400)
Depth [mm]	700
External dimensions	
Height [mm]	2213
Width [mm]	2097 (1x;899; 1x699; 1x499)
Depth [mm]	817

Note: When a busduct connection is required, the distances specified in subclauses 10.4, 10.9, and 10.11 of Table D.1 need to be checked with ABB.

Switching and protection devices	
Inverter protection circuit breaker	Tmax T5V-HA 400
Rated service voltage [V AC]	800
Rated current In [A]	320 (derating 263A @70°C)
Rated breaking capacity, Icu [kA]	32
Pole	3 poles
Version	Fixed
Terminal	F Front terminal*
Trip unit	Thermomagnetic adjustable, TMA
Accessory - mandatory	Rotary handle operating mechanism, RHD**
Main circuit breaker	E2.2H/E9 2000
Rated service voltage [V AC]	900
Rated current In [A]	2000
Rated breaking capacity, Icu [kA]	65
Pole	3 poles
Version	Fixed
Terminal	HR/VR rear adjustable terminals***
Trip unit	Electronic, Ekip Dip LSI

* The busbar connection of the inverter protection circuit breaker should be done with isolated flexible bars, so the terminals need to be chosen as F front terminals. However, as an option, the inverter connection of those circuit breakers could be chosen as Fc-CuAl or FcCU.

** RHD type rotary handle is mandatory to use for this configuration to create needed distance in the cubicle.

*** Emax 2/E circuit breakers should have rear adjustable terminals, HR/VR. The adjustable terminals are supplied as standard and in the HR – HR configuration.

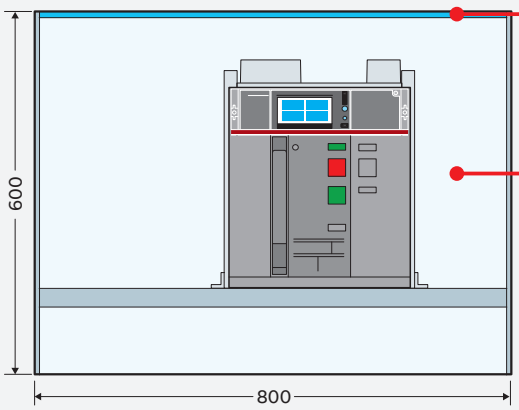
Application - 1,6 MW Photovoltaic plant
Switchboard Design Requirements

These are the design criterias which has been evaluated according to IEC 61439-2 and switching devices' requirements.

To execute this configuration of AC Combiner, it is vital to implement this steps.

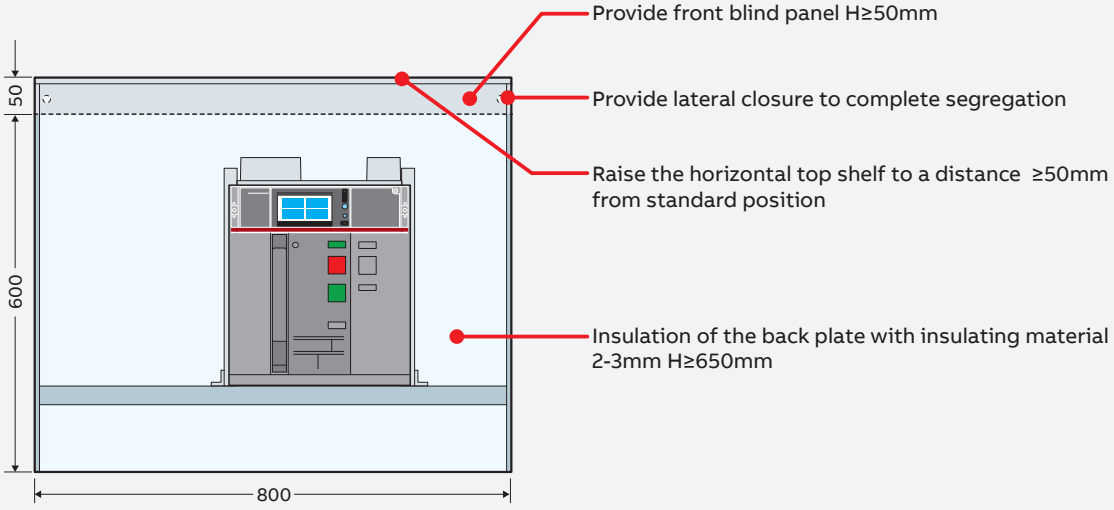
Detail 1 - solution A

- Emax E2.2/E9 3p fixed circuit breaker in the structure L=800mm
- Standard base kit for circuit breaker - code PVDE2441
- Segregation F 2a-3a consists of 2 horizontal shelves, 1 back plate and 2 side shelves - code PSVF6082



Detail 1 - solution B

- Emax E2.2/E9 3p fixed circuit breaker in the structure L=800mm
- Base kit for standard circuit breaker - code PVDE2441
- Segregation F 2a-3a consists of 2 horizontal shelves, 1 back plate and 2 side shelves - code PSVF6082

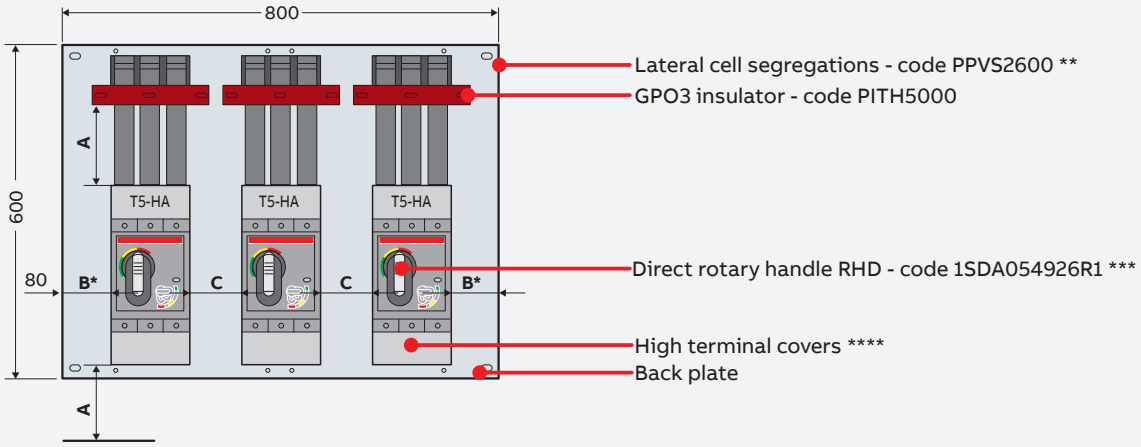


Application - 1,6 MW Photovoltaic plant

Switchboard Design Requirements

Detail 2

- No.3 Tmax T5-HA 3p fixed circuit breakers in the structure L=800mm (also valid for T4-HA circuit breakers)
- Front blind panel H=600 x L=800mm - code PPFB6080 (to be drilled)
- Back plate H=600 x L=800mm - code PPMB6080 (to be drilled)



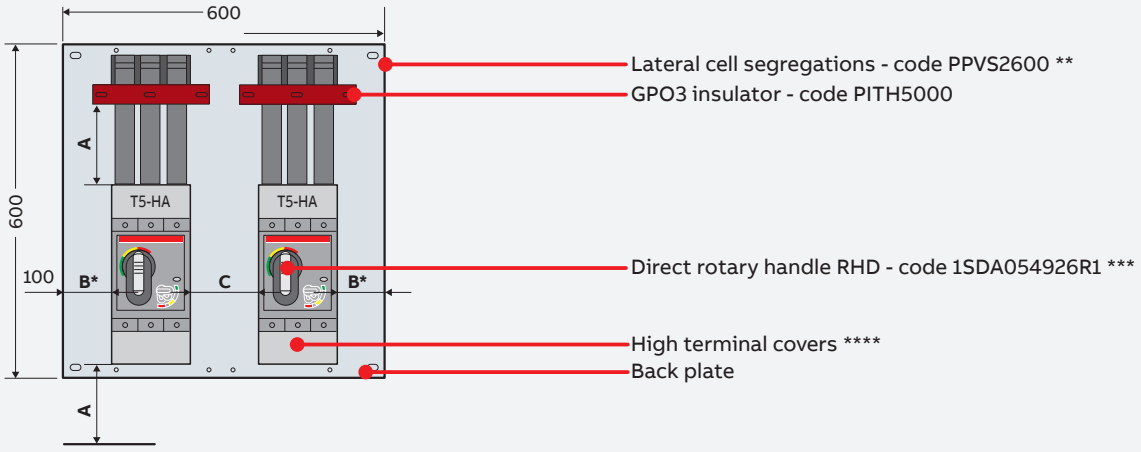
Minimum distances of circuit breakers to be maintained with respect to metal parts

A (mm)	**B*** (mm)	**C** (mm)
150	50	100

* Mandatory is to use of available lateral space to increase distance "B".
** Reduction in area volume by interposing vertical segregation between circuit breakers is not allowed.
*** Mandatory to use.
**** Mandatory to use. It is supplied as standard by T4-HA and T5-HA circuit breakers.

Detail 3

- No.2 Tmax T5-HA 3p fixed circuit breakers in the structure L=600mm (also valid for T4-HA circuit breakers)
- Front blind panel H=600 x L=600mm - code PPFB6060 (to be drilled)
- Back plate H=600 x L=600mm - code PPMB6060 (to be drilled)



Minimum distances of circuit breakers to be maintained with respect to metal parts

A (mm)	**B*** (mm)	**C** (mm)
150	50	100

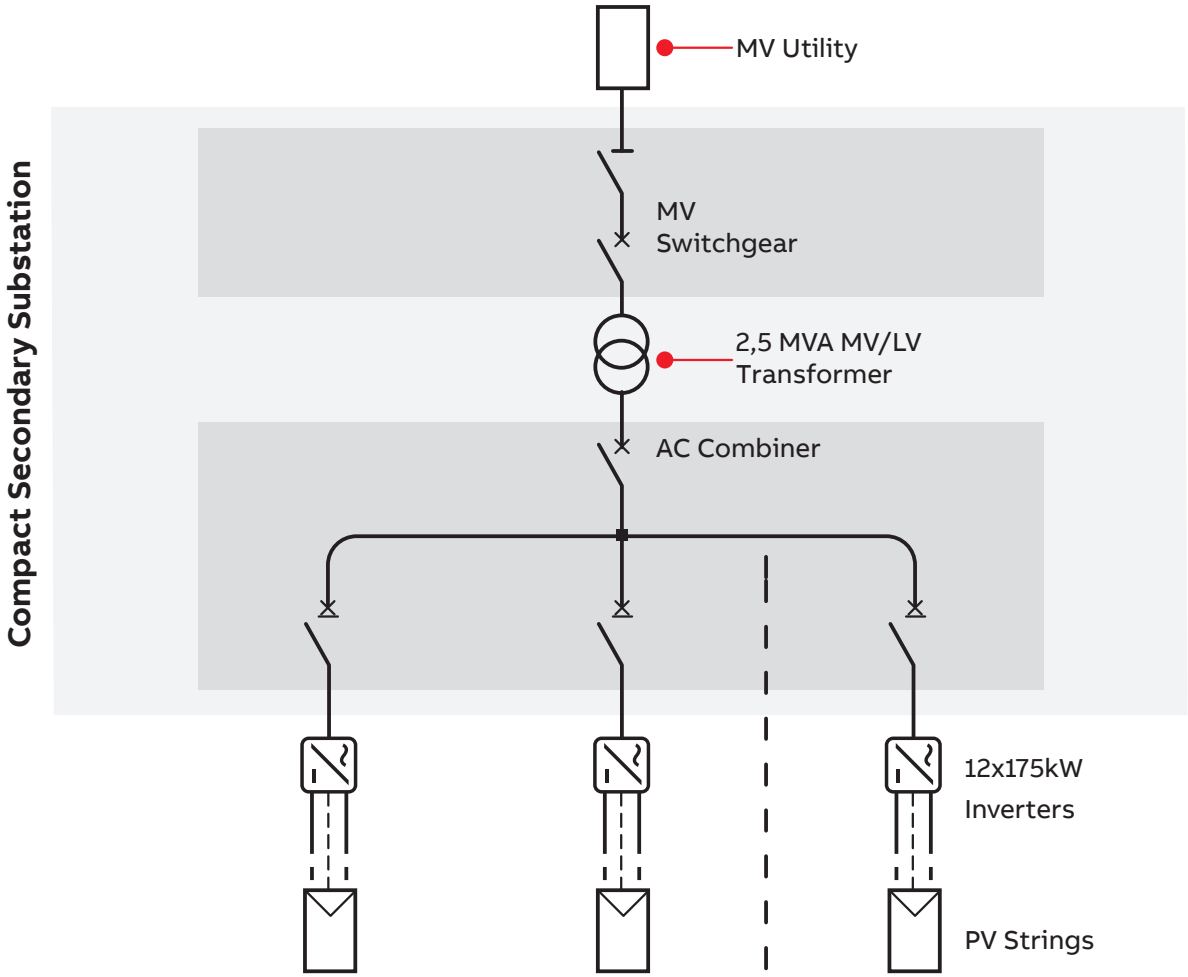
* Mandatory is to use of available lateral space to increase distance "B".
** Reduction in area volume by interposing vertical segregation between circuit breakers is not allowed.
*** Mandatory to use.
**** Mandatory to use. It is supplied as standard by T4-HA and T5-HA circuit breakers.

Application - 2,1 MW Photovoltaic plant

Overview

Discover our Switching and Protection solutions for easy 800V AC Combiner configuration considering a 2,1MW photovoltaic plant with 12x175kW string inverters in parallel.

1 Combiner, 12 x 175kW string inverters

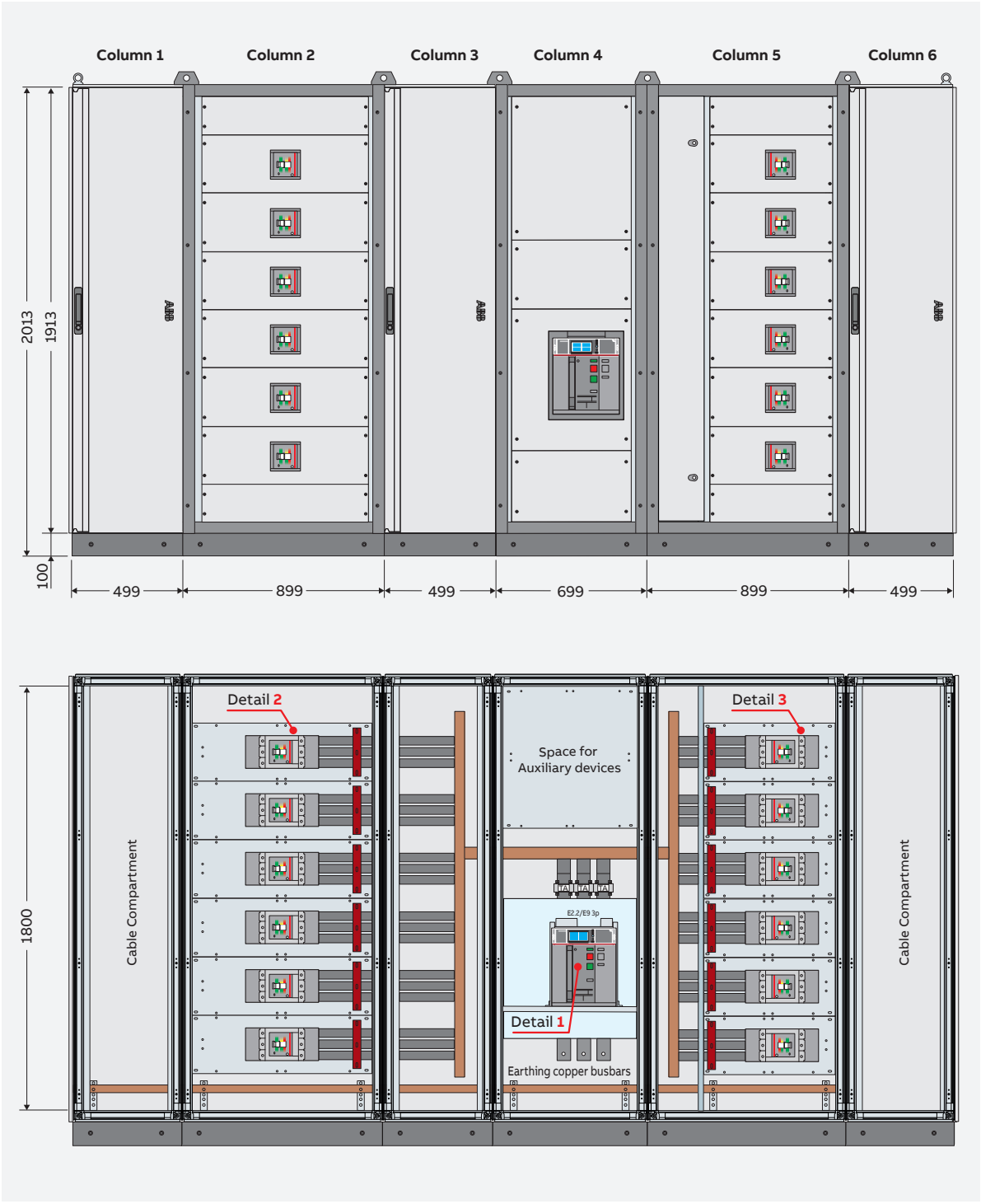


Input data	IEC
System rated power [MW]	2,1
MV/LV transformer rated power (Y/D) [MVA]	2,5
Transformer impedance voltage (%) Uk	8%
Rated MVAC voltage [kV]	20
Rated LVAC voltage [V]	800
Rated LVAC bus current [A]	1684
Inverter rated LVAC active power [kW]	175
Inverter max. output current [A]	135
N. inverter per AC combiner	12
Cosfi	0,9
Short circuit current LVAC bus [kA]	24
Short circuit current LVAC feeders [kA]	26
Suitability for IT network	Yes

Application - 2,1 MW Photovoltaic plant

Key Characteristics of the configuration

This is the application for an AC combiner panel of 2,1MW photovoltaic plant. There are 12 circuit breakers for protection of inverters which are mounted horizontally.
Cables coming from inverters enters to switchboard from bottom into cable column. It would be more appropriate to choose smaller sized inverters to keep the current carrying capacity lower, making the cable bending work easier. Additionally, there is one main circuit breaker.
The cable connecting to lower terminal of this circuit breaker goes to the transformer from the bottom of the switchboard.



Application - 2,1 MW Photovoltaic plant

Key Characteristics of the configuration

Key characteristics of the configuration

Switchboard	
Type of installation	Indoor, front access
Rated service voltage Ue [V AC]	800
Rated current In [A]	up to 2500
IP protection class	IP30
RAL	7035 orange peel
Form of segregation	
Inverter protection circuit breaker section	2a/2b
Main circuit breaker section	2a/3a (mandatory)
Auxiliary circuit section	2b
Functional dimensions	
Height [mm]	1800
Width [mm]	3400 (1x400;1x800; 1x400; 1x600; 1x800; 1x400)
Depth [mm]	700
External dimensions	
Height [mm]	2013
Width [mm]	3994 (1x499;1x899; 1x499; 1x699; 1x899; 1x499)
Depth [mm]	817

Note: When a busduct connection is required, the distances specified in subclauses 10.4, 10.9, and 10.11 of Table D.1 need to be checked with ABB.

Switching and protection devices	
Inverter protection circuit breaker	Tmax T5V-HA 400
Rated service voltage [V AC]	800
Rated current In [A]	320 (derating 263A @70°C)
Rated breaking capacity, Icu [kA]	32
Pole	3 poles
Version	Fixed
Terminal	F Front terminal*
Trip unit	Thermomagnetic adjustable, TMA
Main circuit breaker	E2.2H/E9 2000
Rated service voltage [V AC]	900
Rated current In [A]	2000
Rated breaking capacity, Icu [kA]	65
Pole	3 poles
Version	Fixed
Terminal	HR/VR rear adjustable terminals**
Trip unit	Electronic, Ekip Dip LSI

* The busbar connection of the inverter protection circuit breaker should be done with isolated flexible bars, so the terminals need to be chosen as F front terminals. However, as an option, the inverter connection of those circuit breakers could be chosen as Fc-CuAl or FcCU.

** Emax 2/E circuit breakers should have rear adjustable terminals, HR/VR. The adjustable terminals are supplied as standard and in the HR – HR configuration.

Application - 2,1 MW Photovoltaic plant

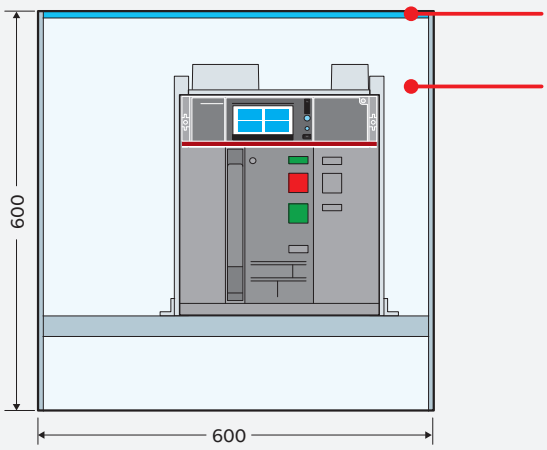
Switchboard Design Requirements

These are the design criterias which has been evaluated according to IEC 61439-2 and switching devices' requirements.

To execute this configuration of AC Combiner, it is vital to implement this steps.

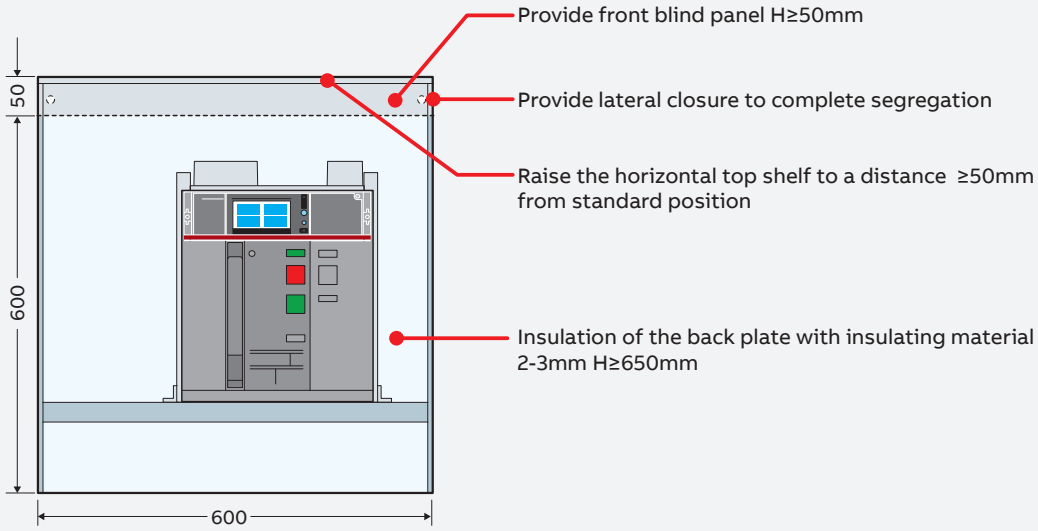
Detail 1 - solution A

- Emax E2.2/E9 3p fixed circuit breaker in the structure L=600mm
- Standard base kit for circuit breaker - code PVCE2441
- Segregation F 2a-3a consists of No.2 horizontal shelves, No.1 back plate and No.2 side shelves - code PSVF6062



Detail 1 - solution B

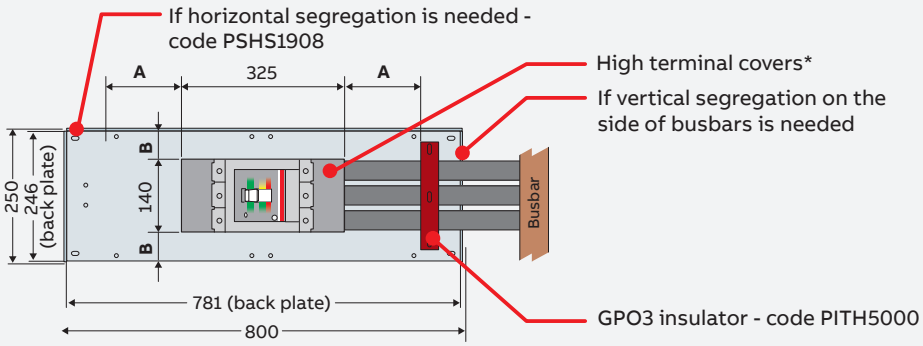
- Emax E2.2/E9 3p fixed circuit breaker in the structure L=600mm
- Standard base kit for circuit breaker - code PVCE2441
- Segregation F 2a-3a consists of No.2 horizontal shelves, No.1 back plate and No.2 side shelves - code PSVF6062



Application - 2,1 MW Photovoltaic plant
Switchboard Design Requirements

Detail 2

- Tmax T5-HA 3p fixed circuit breaker in the structure L=800mm (also valid for T4-HA circuit breakers)
- Front blind panel H=250 x L=800mm - code PPFB2580 (to be drilled)
- Back plate H=250 x L=800mm - code PPMB2580 (to be drilled)



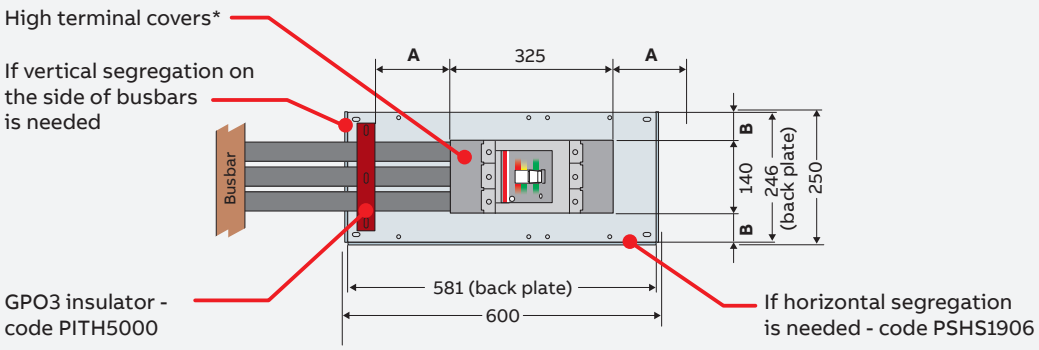
Minimum distances of circuit breakers to be maintained with respect to metal parts

A (mm)	**B** (mm)
150	50

Note: It is possible to use the T5 horizontal kit PHDT5406 without using horizontal segregation code PSHS1908 since this combination do not respect the minumum distances of the circuit breaker.
*Mandatory to use. It is supplied as standard by T4-HA and T5-HA circuit breakers.

Detail 3

- Tmax T5-HA 3p fixed circuit breaker in the structure L=600mm (also valid for T4-HA circuit breakers)
- Front blind panel H=250 x L=600mm - code PPFB2560 (to be drilled)
- Back plate H=250 x L=600mm - code PPMB2560 (to be drilled)



Minimum distances of circuit breakers to be maintained with respect to metal parts

A (mm)	**B** (mm)
150	50

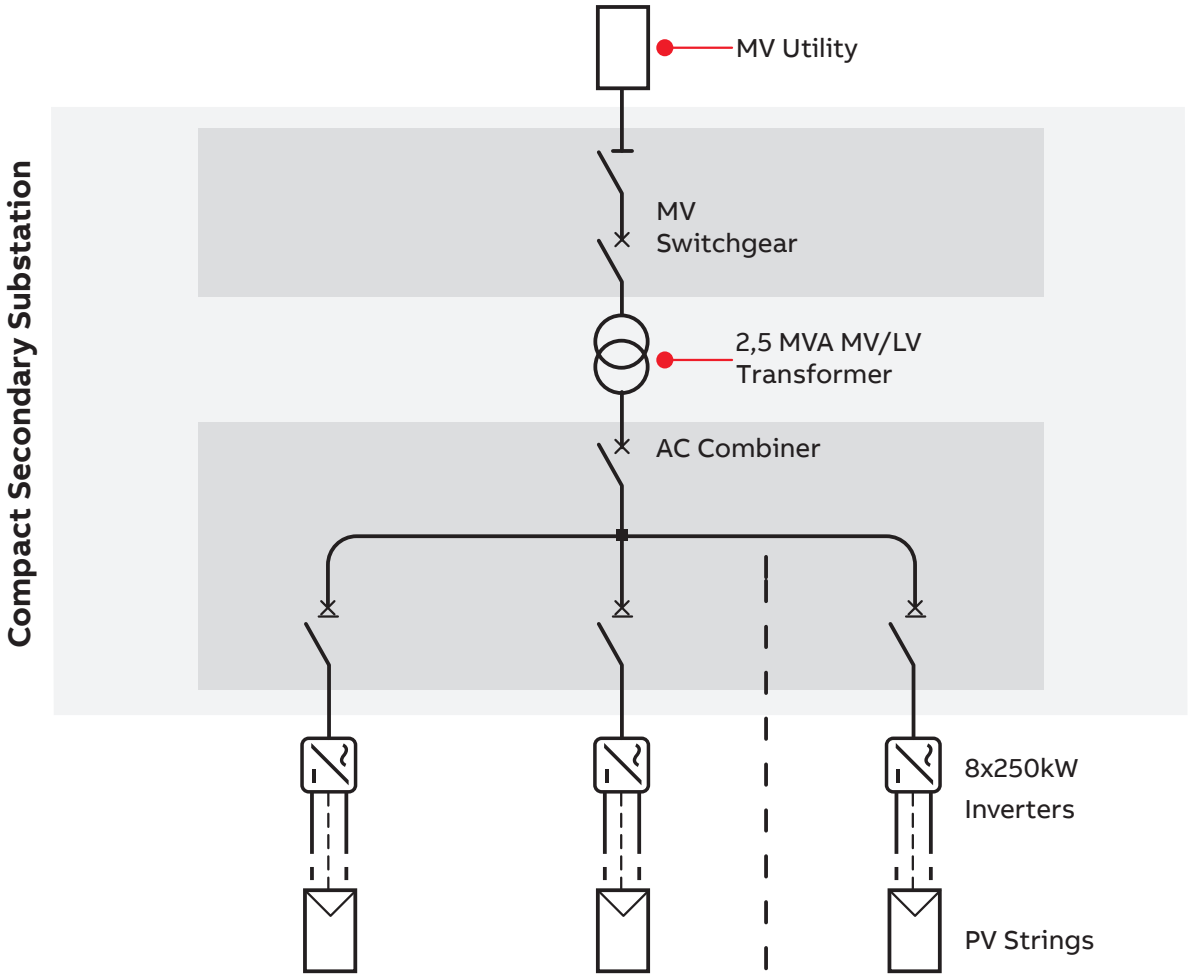
*Mandatory to use. It is supplied as standard by T4-HA and T5-HA circuit breakers.

Application - 2 MW Photovoltaic plant

Overview

Discover our Switching and Protection solutions for easy 800V AC Combiner configuration considering a 2 MW photovoltaic plant with 8x250kW string inverters in parallel.

1 Combiner, 8 x 250kW string inverters



Input data	IEC
System rated power [MW]	2,0
MV/LV transformer rated power (Y/D) [MVA]	2,5
Transformer impedance voltage (%) Uk	8%
Rated MVAC voltage [kV]	20
Rated LVAC voltage [V]	800
Rated LVAC bus current [A]	1604
Inverter rated LVAC active power [kW]	250
Inverter max. output current [A]	199
N.inverter per AC combiner	8
Cosfi	0,9
Short circuit current LVAC bus [kA]	24
Short circuit current LVAC feeders [kA]	26
Suitability for IT network	Yes

Application - 2 MW Photovoltaic plant

Key Characteristics of the configuration

This is the application for an AC combiner panel of 2 MW photovoltaic plant. There are 8 circuit breakers for protection of inverters which are mounted vertically.
Cables coming from the inverters enter to switchboard from the bottom.

Additionally, there is one main circuit breaker.
The conductor connecting to the upper terminal of this circuit breaker goes to the transformer from the top of the switchboard.
The vertical mounting of the circuit breakers ease the connection of the large aluminum cables.

Application - 2 MW Photovoltaic plant

Key Characteristics of the configuration

Key characteristics of the configuration

Switchboard	
Type of installation	Indoor, front access
Rated service voltage Ue [V AC]	800
Rated current In [A]	up to 2500
IP protection class	IP30
RAL	7035 orange peel
Form of segregation	
Inverter protection circuit breaker section	2a/2b
Main circuit breaker section	2a/3a (mandatory)
Auxiliary circuit section	2b
Functional dimensions	
Height [mm]	1800
Width [mm]	3000 (3x800; 1x600)
Depth [mm]	700
External dimensions	
Height [mm]	2013
Width [mm]	3396 (3x899; 1x699)
Depth [mm]	817

Note: When a busduct connection is required, the distances specified in subclauses 10.4, 10.9, and 10.11 of Table D.1 need to be checked with ABB.

Switching and protection devices	
Inverter protection circuit breaker	Tmax T5X-HA 400
Rated service voltage [V AC]	800
Rated current In [A]	320 (derating 310A @70°C)
Rated breaking capacity, Icu [kA]	35
Pole	3 poles
Version	Fixed
Terminal	F Front terminal*
Trip unit	Electronic, PR222DS-LSIG
Accessory - mandatory	Rotary handle operating mechanism, RHD**
Main circuit breaker	E2.2H/E9 2000
Rated service voltage [V AC]	900
Rated current In [A]	2000
Rated breaking capacity, Icu [kA]	65
Pole	3 poles
Version	Fixed
Terminal	HR/VR rear adjustable terminals***
Trip unit	Electronic, Ekip Touch LSI

* The busbar connection of the inverter protection circuit breaker should be done with isolated flexible bars, so the terminals need to be chosen as F front terminals. However, as an option, the inverter connection of those circuit breakers could be chosen as Fc-CuAl or FcCU.

** RHD type rotary handle is mandatory to use for this configuration to create needed distance in the cubicle.

*** Emax 2/E circuit breakers should have rear adjustable terminals, HR/VR. The adjustable terminals are supplied as standard and in the HR – HR configuration.

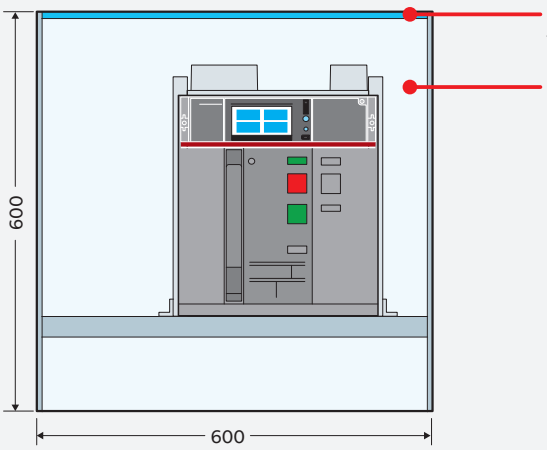
Application - 2 MW Photovoltaic plant
Switchboard Design Requirements

These are the design criterias which has been evaluated according to IEC 61439-2 and switching devices' requirements.

To execute this configuration of AC Combiner, it is vital to implement this steps.

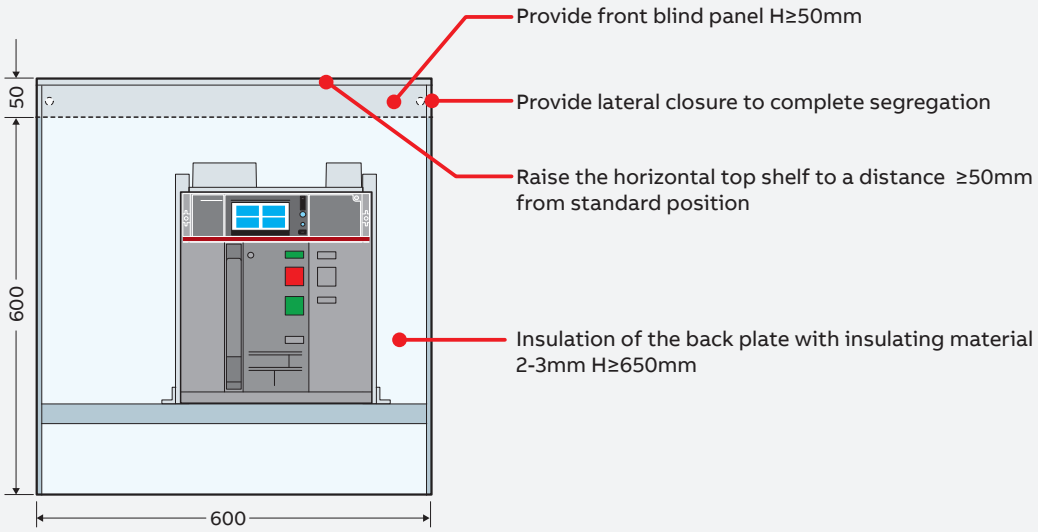
Detail 1 - solution A

- Emax E2.2/E9 3p fixed circuit breaker in the structure L=600mm
- Standard base kit for circuit breaker - code PVCE2441
- Segregation F 2a-3a consists of No.2 horizontal shelves, No.1 back plate and No.2 side shelves - code PSVF6062



Detail 1 - solution B

- Emax E2.2/E9 3p fixed circuit breaker in the structure L=600mm
- Standard base kit for circuit breaker - code PVCE2441
- Segregation F 2a-3a consists of No.2 horizontal shelves, No.1 back plate and No.2 side shelves - code PSVF6062

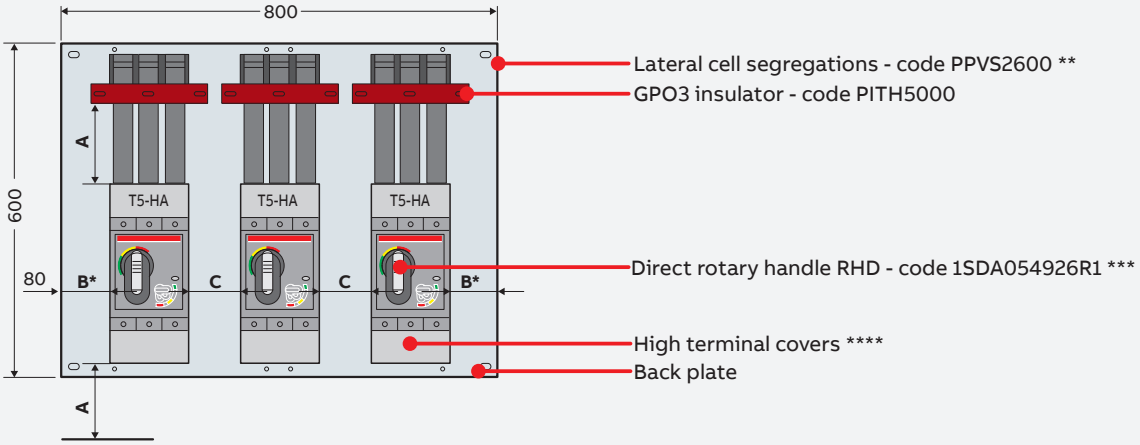


Application - 2 MW Photovoltaic plant

Switchboard Design Requirements

Detail 2

- No.3 Tmax T5-HA 3p fixed circuit breakers in the structure L=800mm (also valid for T4-HA circuit breakers)
- Front blind panel H=600 x L=800mm - code PPFB6080 (to be drilled)
- Back plate H=600 x L=800mm - code PPMB6080 (to be drilled)



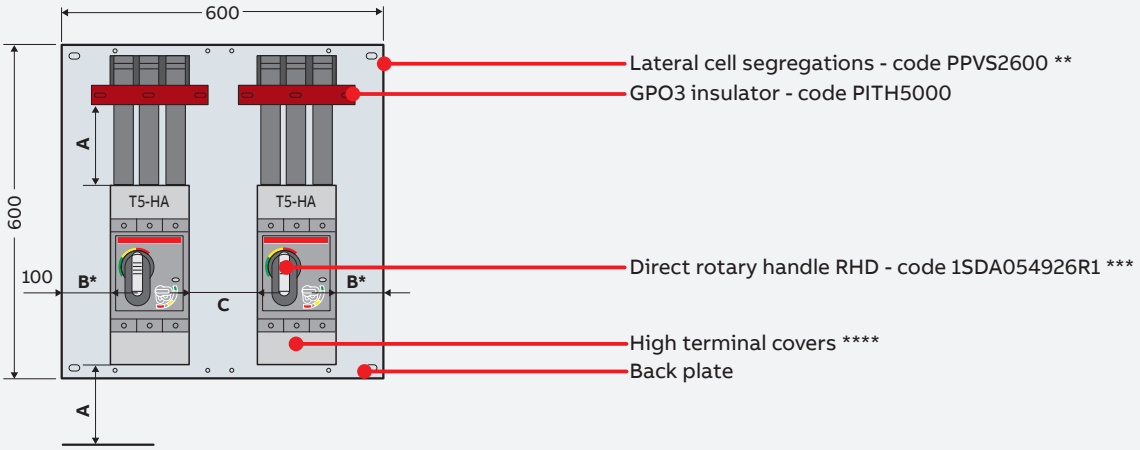
Minimum distances of circuit breakers to be maintained with respect to metal parts

A (mm)	**B*** (mm)	**C** (mm)
150	50	100

* Mandatory is to use of available lateral space to increase distance "B".
** Reduction in area volume by interposing vertical segregation between circuit breakers is not allowed.
*** Mandatory to use.
**** Mandatory to use. It is supplied as standard by T4-HA and T5-HA circuit breakers.

Detail 3

- No.2 Tmax T5-HA 3p fixed circuit breakers in the structure L=600mm (also valid for T4-HA circuit breakers)
- Front blind panel H=600 x L=600mm - code PPFB6060 (to be drilled)
- Back plate H=600 x L=600mm - code PPMB6060 (to be drilled)



Minimum distances of circuit breakers to be maintained with respect to metal parts

A (mm)	**B*** (mm)	**C** (mm)
150	50	100

* Mandatory is to use of available lateral space to increase distance "B".
** Reduction in area volume by interposing vertical segregation between circuit breakers is not allowed.
*** Mandatory to use.
**** Mandatory to use. It is supplied as standard by T4-HA and T5-HA circuit breakers.

Annex - Product Requirements

Instructions to be followed for Emax 2/E Air Circuit Breakers over 690V AC

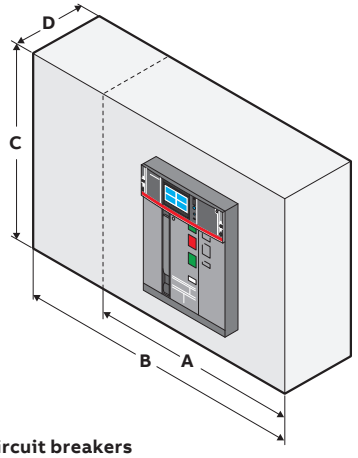
Kit protections for fixed type Emax2/E

SACE Emax 2/E

Drawings Selector

Insulation distance

Insulation distance of the circuit breakers in an installation cubicle should be as follows:



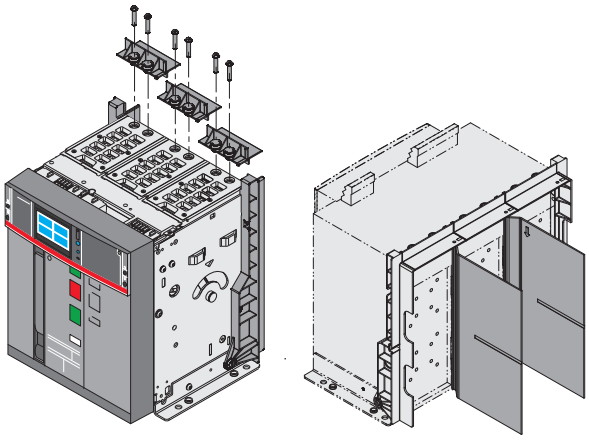
Fixed circuit breakers

[mm]	A 3p	B 4p	C	D
E1.2	250	322	382.5	130
E2.2	400	490	500	221
E4.2	500	600	500*	221
E6.2	900	1000	500	221

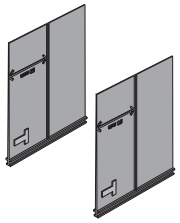
(*) For /E1.2 Fixed, 500mm with insulated roof panel; 600mm otherwise.

Separator / Phase Barriers

The rear part of the circuit breaker has been designed with specific slots in which insulating walls are placed to facilitate segregation between polarities. Phase separators are mandatory with all Emax 2/E circuit breakers. For the fixed version, they are provided as standard with an additional protection kit to be installed on field (see document 1SDH001000R0746, Kit protections for fixed type Emax2/E).



For spare parts, you can order using the codes below



Separators - PB [1]

Size	Type	Code
PB Separators		
E1.2	H=100mm 4pz E1.2 F 3P	1SDA073877R1
E1.2	H=100mm 6pz E1.2 F 4P	1SDA073878R1
E1.2	H=200mm 4pz E1.2 F 3P	1SDA073879R1
E1.2	H=200mm 6pz E1.2 F 4P	1SDA073880R1
E2.2...E6.2	2 pz E2.2..E6.2 F 3P	1SDA076166R1
E2.2...E6.2	3 pz E2.2..E6.2 F 4P	1SDA076167R1

[1] Only as loose part

Overall dimensions

The Emax 2/E range is based on standard Emax 2 frames, sharing the same overall dimensions, with specific connection setup and insulation parts. Visit our Drawings Selector to find and download the 2D and 3D files for Emax 2 breakers and connections.

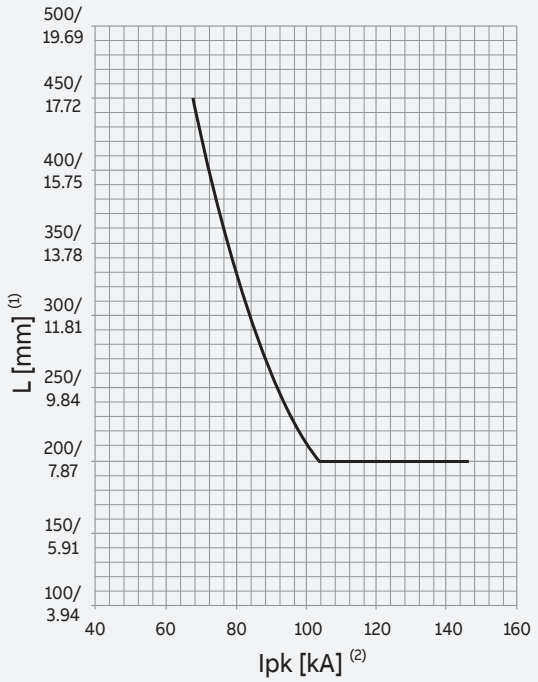
Annex - Product Requirements

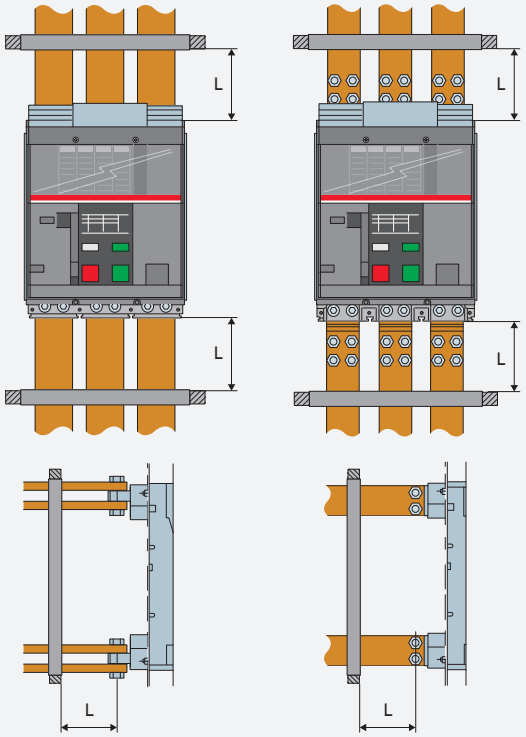
Instructions to be followed for Emax 2/E Air Circuit Breakers over 690V AC

Positioning anchor plates

The diagram below indicates the distance for positioning the first anchor plate according to the circuit breaker type and the peak current

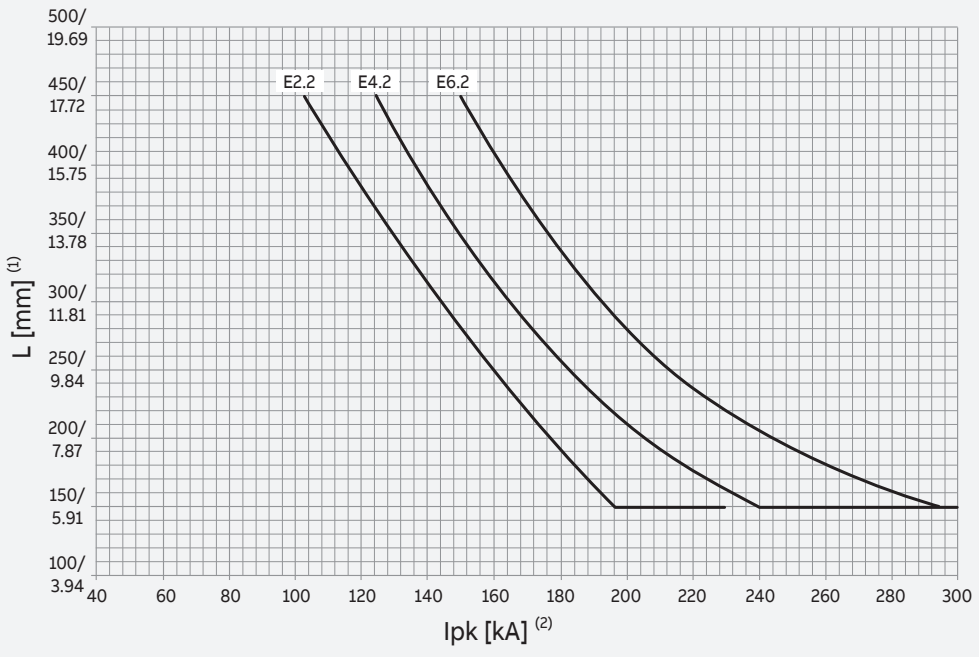
Emax2 E1.2- Installation, operation and maintenance instructions for the installer and the user

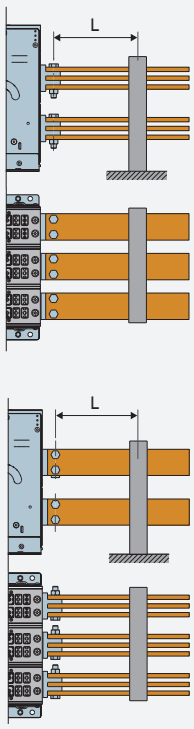




(1) distance of the first anchor plate from the circuit-breaker terminals
(2) peak current

Emax2 E2.2-E4.2- E6.2 Installation, operation and maintenance instructions for the installer and the user





(1) distance of the first anchor plate from the circuit-breaker terminals
(2) peak current

Annex - Product Requirements

Instructions to be followed for Emax 2/E Air Circuit Breakers over 690V AC

Emax 2 - Instructions for using Ekip Touch protection trip units and Accessories.

Measurement for rated voltages over 690V AC
The Measurement Enabler module is supplied with Ekip Touch trip units by default and is installed to the right of the trip unit.

This module enables the trip unit to internally measure phase and neutral voltages, as well as power and energy. Depending on the functionality desired, a software package may need to be purchased separately through ABB Ability™ Marketplace.

The voltage outlets for the measurement are installed on the lower terminals by default.
For rated voltages higher than 690V, the voltage connection is need to be moved outside the circuit-breaker by enabling to use external isolation voltage transformers which are mandatory and connected to the terminal box.

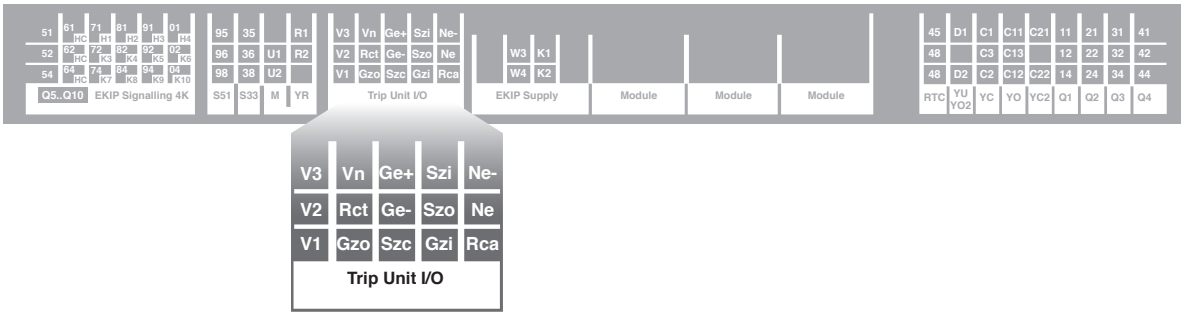
The installation of external voltage transformers does not guarantee Class 1 accuracy.

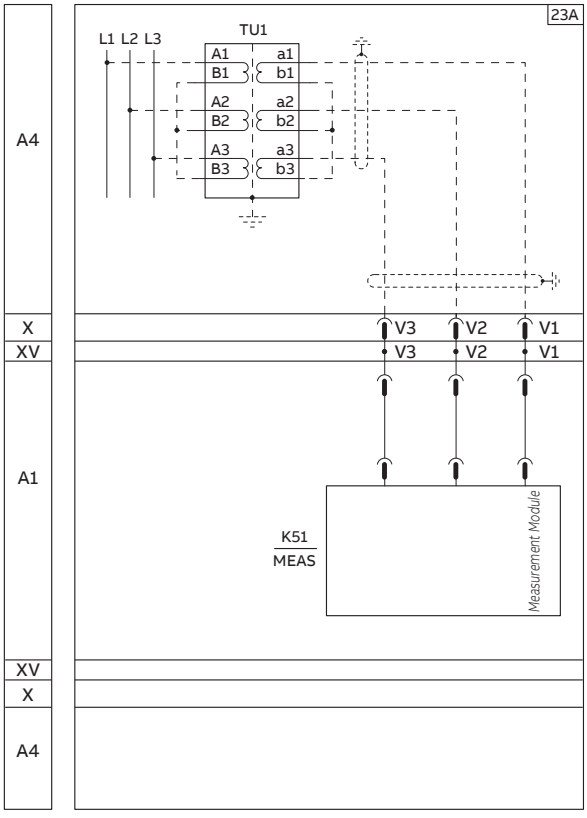
External voltage outlets has to be ordered with below order code as mounted to the circuit breaker.

External voltage outlets

Size	Type	Code
E1.2..E6.2	External installed voltage outlets	1SDA074217R1

External insulation voltage transformers must be installed and connected to the terminal box according below scheme.





The isolation voltage transformer must conform to standard IEC 60255-27 and possess the following electrical characteristics:

- Accuracy class: ≤ 0,2
- Performance: ≥ 10 VA
- Overload: 20 % permanent
- Insulations: 4 kV between inputs and outputs, 4 kV between shield and outputs, 4 kV between shield and inputs
- Frequency: Fn +-10%
- Primary voltage: 100 to 1200 V (nominal, to be configured via menu)
- Secondary voltage: 100 to 230 V (nominal, to be configured via menu)

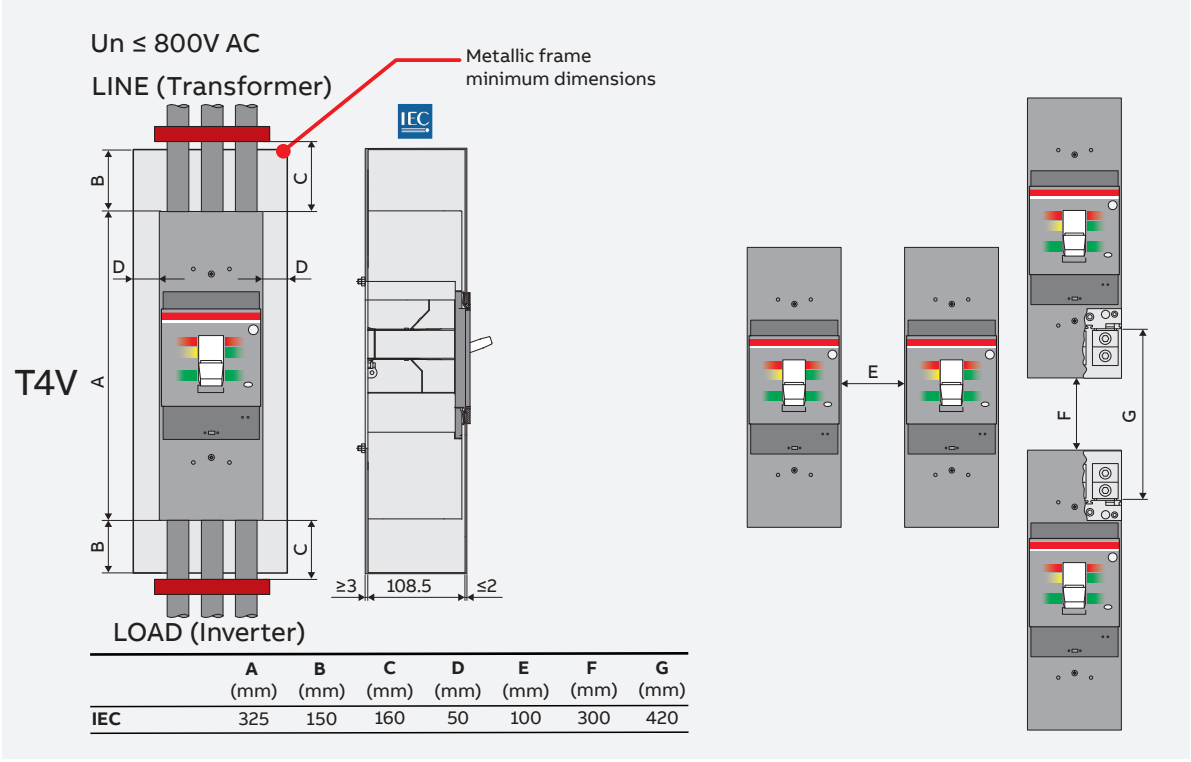
For more information and trip unit configuration details, please check instructions for using Ekip Touch protection units.

Annex - Product Requirements

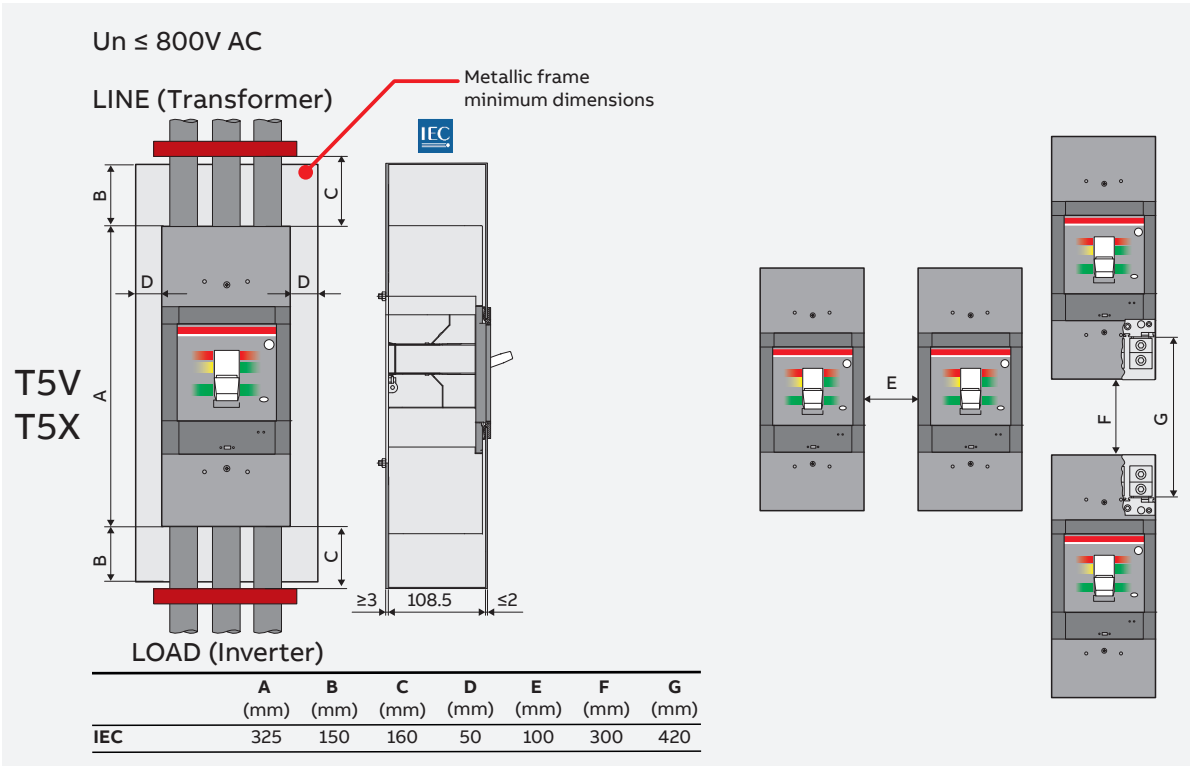
Instructions to be followed for SACE Tmax T-HA Moulded Case Circuit Breakers over 690V AC

Insulation distance

Insulation distance of the circuit breakers in an installation cubicle and the minumum center distance between two circuit-breaker side by side should be as follows. When side by side breakers are different in size, the larger reference clearance should be considered.



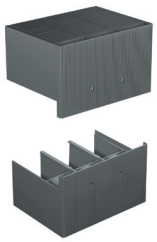
	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)
IEC	325	150	160	50	100	300	420



	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)
IEC	325	150	160	50	100	300	420

Annex - Product Requirements

Instructions to be followed for SACE Tmax T-HA Moulded Case Circuit Breakers over 690V AC



Terminal Covers and Separator / Phase Barriers

High Terminal Covers are mandatory for top and bottom and already included in the circuit-breakers ordering codes. For spare parts, you can order using the codes below.

High insulating terminal covers - HTC

Type	3 poles	4 poles
HTC T4	1SDA054958R1	1SDA054959R1
HTC T5	1SDA054960R1	1SDA054961R1

Overall dimensions

For overall dimensions you can check the instructions.

Power Connection

The basic version circuit-breaker is supplied with front terminals (F). Front terminals which allow connection of cables or busbars working directly from the front of the circuit breaker.
Terminals are available for direct connection of bare copper or aluminium cables which is indicated as below.

T4V-HA Instructions for installation

T5V-HA and T5X-HA Instructions for installation

Wire options Tmax T4-HA and T5-HA

Ambient temp.		40°C
Cable type	Copper	Aluminum
In (A)		required wires (number x section)
T4		
80	1 x 25mm²	1 x 35mm²*
100	1 x 35mm²	1 x 50mm²*
125	1 x 50mm²	1 x 70mm²*
160	1 x 70mm²	1 x 120mm²*
200	1 x 95mm²	1 x 150mm²*
250	1 x 150mm²	1 x 185mm²*
T5		
320	1 x 185mm²	2 x 120mm²*
400	1 x 240mm²	2 x 150mm²*
500	2 x 150mm²*	2 x 240mm²*
630	2 x 185mm²*	Lug not available

*with FcCuAL

Terminals for Tmax T-HA

Size	Type	3 pcs (1/2 kit for 3p)	4 pcs (1/2 kit for 4p)
T4	FcCuAL 1x350kcmil	1SDA054988R1	1SDA054989R1
	FcCu 1x185mm²	1SDA054980R1	1SDA054981R1
	FcCuAl 1x185mm²	1SDA054988R1	1SDA054989R1
T5	FcCuAL 1x500kcmil	1SDA055020R1	1SDA055021R1
	FcCu T5 1x240mm²	1SDA055016R1	1SDA055017R1
	FcCuAl T5 1x240mm²	1SDA055020R1	1SDA055021R1
	FcCuAl T5 2x240mm²	1SDA055032R1	1SDA055033R1

For further details about installation, please see the related instructions provided with the circuit-breaker.

Product offering

SACE Emax 2/E Air circuit breakers

WEB PAGE

CATALOG

SACE Tmax for special applications

WEB PAGE

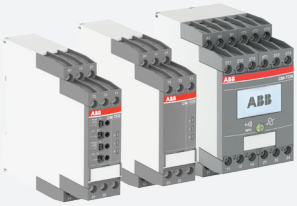
CATALOG

System pro E power main distribution switchboards

WEB PAGE

CATALOG

Temperature monitoring relays:



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