SOLAR ACADEMY - INTRODUCTION OF LARGE-SCALE PV PLANTS

UNSW SPREE PUBLIC RESEARCH SEMINAR

PHILIP KAO 4 JULY 2019

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SMA SOLAR TECHNOLOGY

Key Facts

- Headquartered in Niestetal, Germany since 1981
- 65 Gigawatt installed worldwide
- 3,200+ employees, around 2,000 in Germany
- 500 engineers in R&D
- Stock-listed since 2008

› World's most experienced inverter manufacturer – dedicated to SOLAR PV

SMA IN AUSTRALIA

SMA the experienced and reliable solutions partner

> Over 50 projects currently in AU

> 800+ Central inverters and 400+ Medium voltage power stations deployed

> Established application and Grid engineering teams to support/conduct initial project modeling and development applications

> Experience, direct engagement with Network regulator (AEMO) and DNSP's

> Field service team undertaking plant commissioning, R2 testing support and warranty service

> Local China sales and technical team to support and coordinate with China based EPC/Development customers

SMA Utility Power System

- Power Classes:
  2,200 kVA at 1000 Vdc
  2,475 kVA at 1500 Vdc
- Up to 150%
  over-dimensioning DC/AC
- Available as turnkey solution or
  package, with or without platform

DC connection area

- Easily accessible and clearly arranged
- Strict electrical isolation of + and - potential

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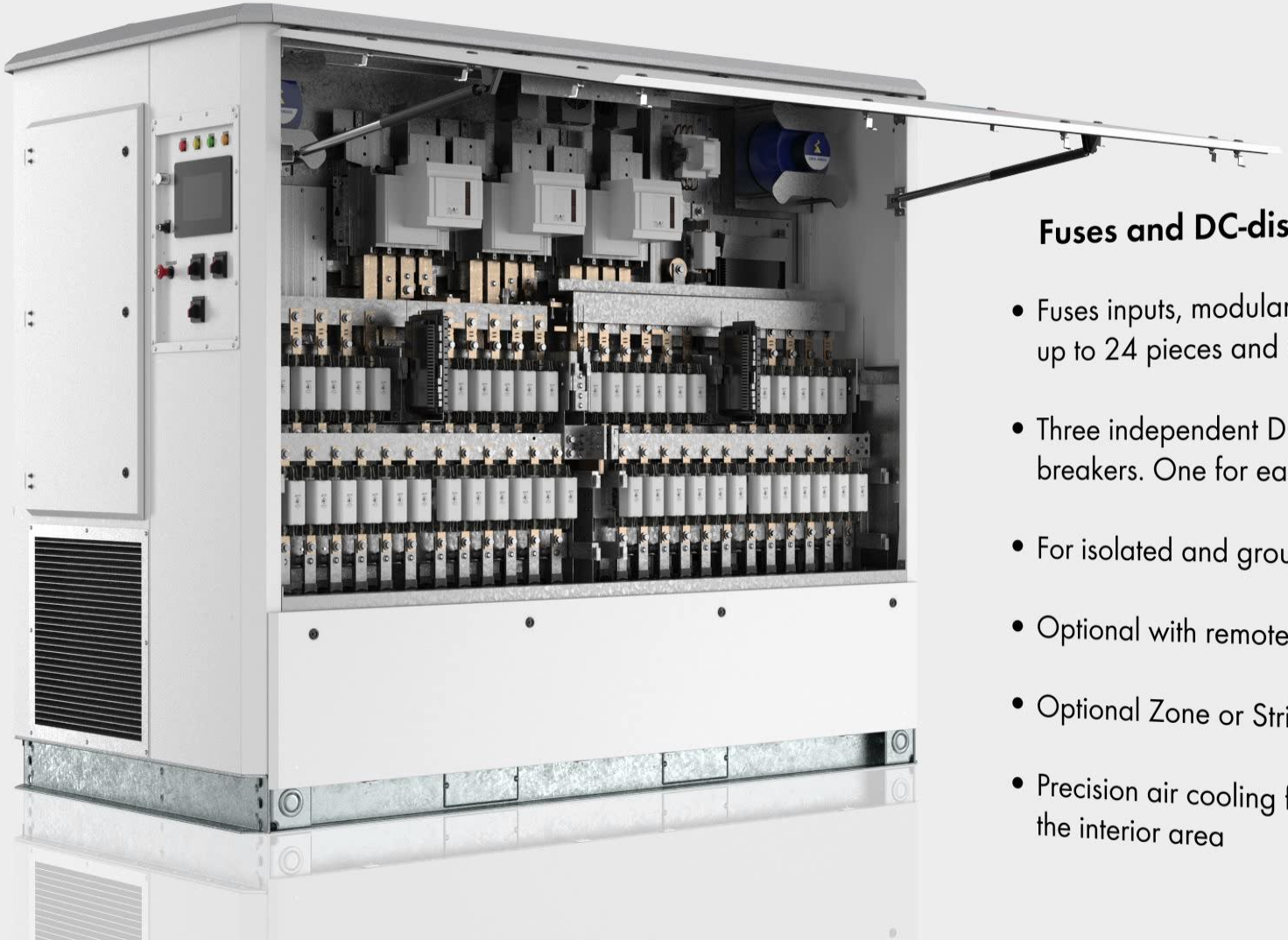
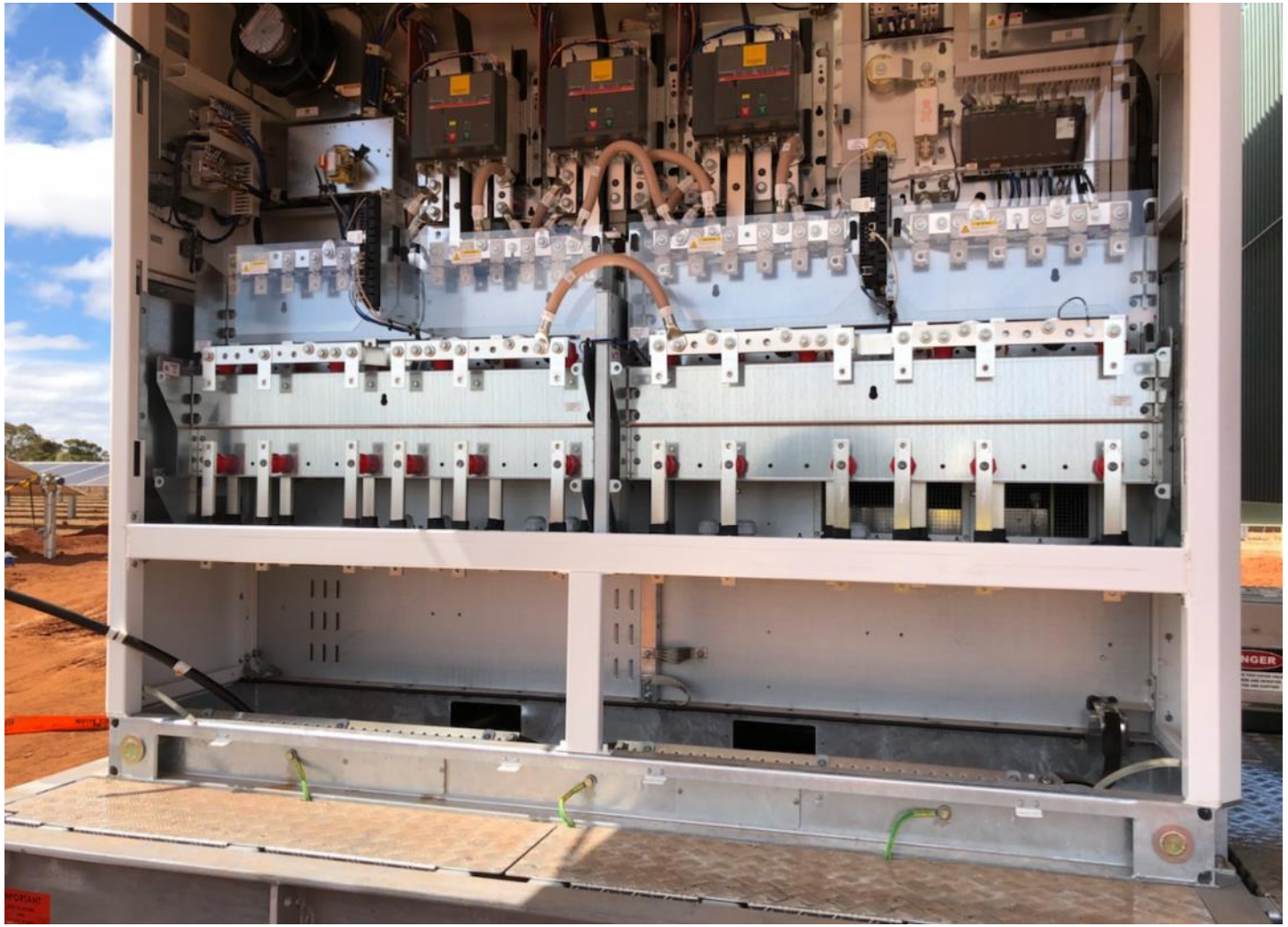


Fuses and DC-disconnects

- Fuses inputs, modularly extendable up to 24 pieces and 630A
- Three independent DC-circuit-breakers. One for each stack
- For isolated and grounded systems
- Optional with remote GFDI
- Optional Zone or String Monitoring
- Precision air cooling for the interior area

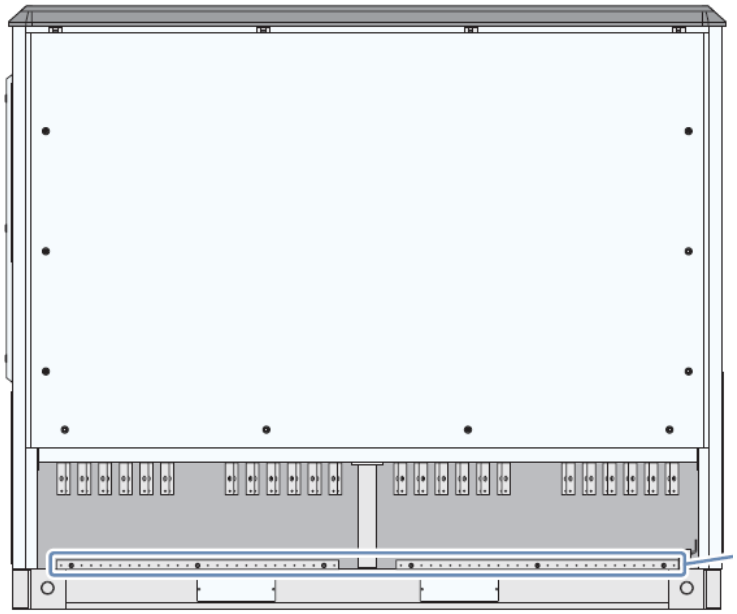
DC INPUTS

- 9/12/18/21/24/32* DC inputs
- Floating/Negative Grounding System
- DC:AC Ratio 2.5
- Zone Monitoring



DC INPUTS

> **Bottom cable entry**
> **Fast easy installation and O&M**



The cable entry area must be covered by appropriate means (such as a concrete base) so that foreign objects cannot enter the inverter.

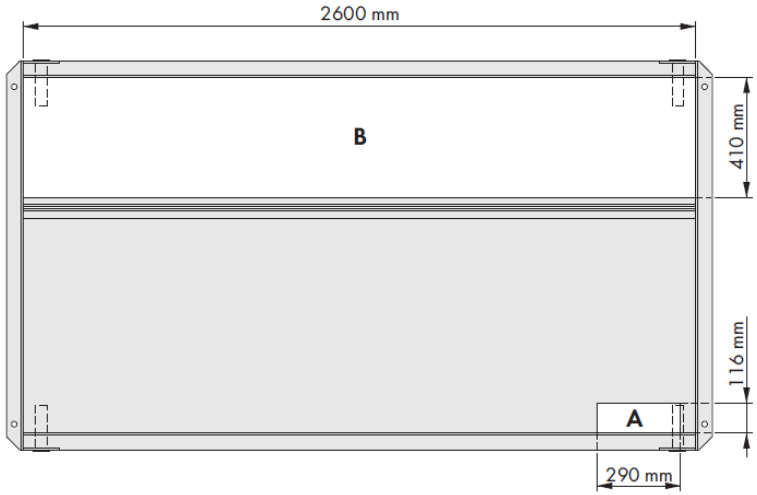
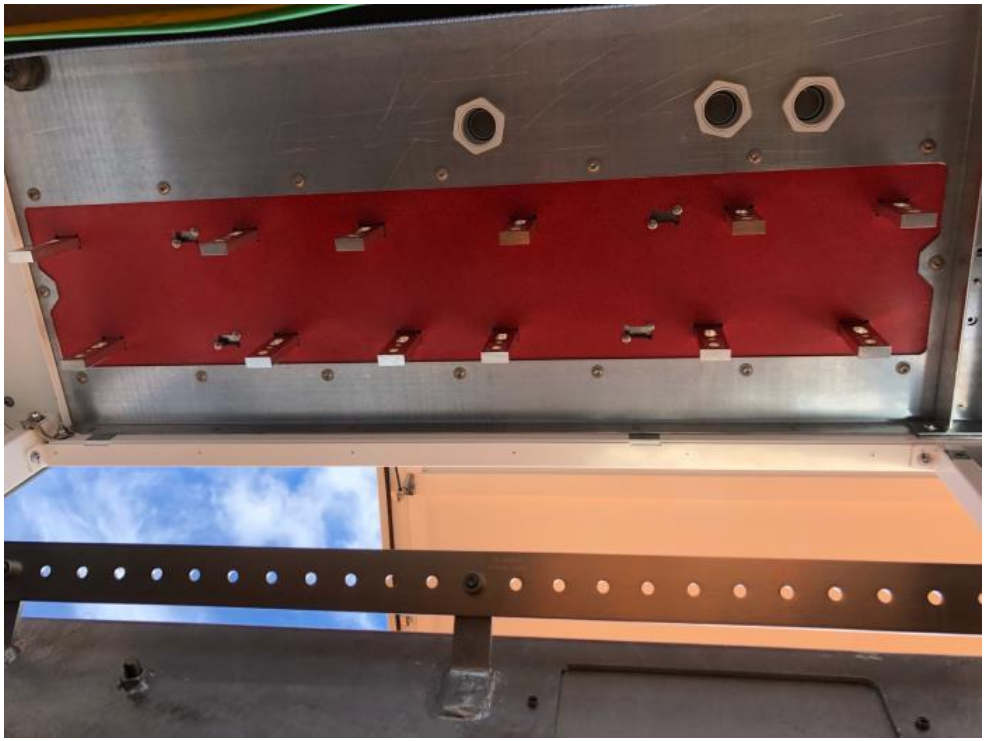


Figure 69: Cavity in the base area of the inverter

Position	Designation
A	Cable insertion area of the cables for communication, control, and monitoring
B	Cable insertion area of the DC cables and grounding cables

DC INPUTS

- Bottom cable entry
- Fast easy installation and O&M

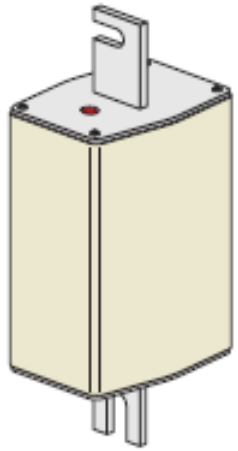


DC INPUTS

> Wide Range of DC fuses

The DC inputs are fused with LV/HRC fuses. Thermal stress and fluctuating loads result in a screening factor of 0.64. This screening factor must be taken into account in the DC cable design.

Fusing	Maximum DC short-circuit current I_{SC_STC} (Screening factor 0.64)
200 A	128.0 A
250 A	160.0 A
315 A	201.6 A
350 A	224.0 A
400 A	256.0 A
450 A	288.0 A
500 A	320.0 A



When selecting the fuse size, always consider the short-circuit current of the connected PV array at standard test conditions (I_{SC_STC}).

The reduction factors apply for a maximum irradiation of 1200 W/m² (hourly average value of the horizontal global radiation). In case the irradiation is higher, the reduction factor must be adapted linearly.

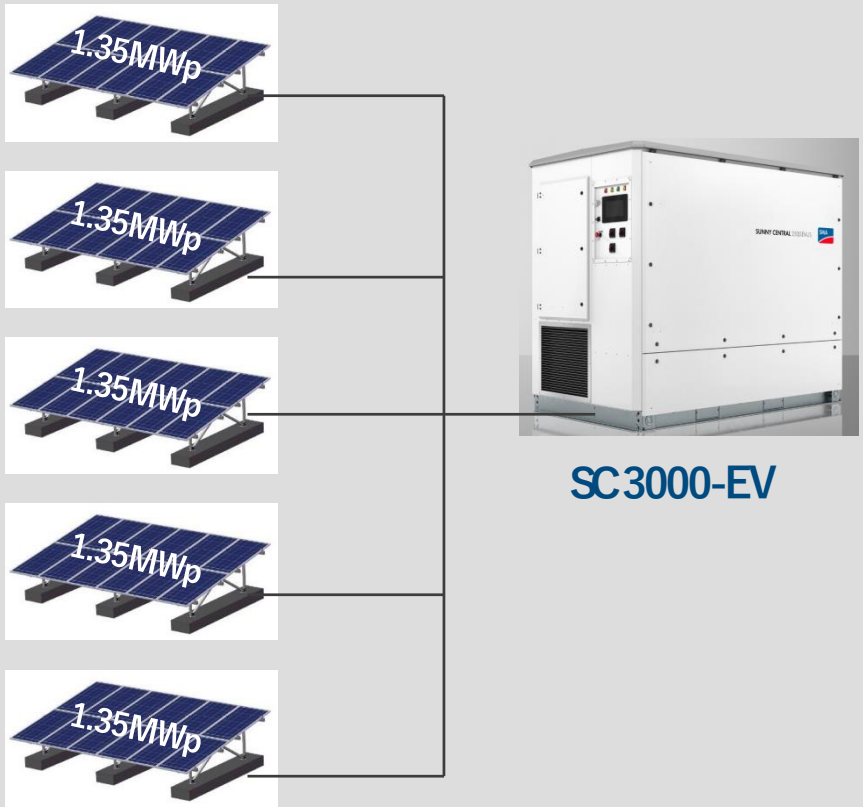
DC OVERLOADING

- **Max DC overloading** capacity depending on Short Circuit Current of the DC Load Break Switch, ONLY

DC Load Break Switch

Short circuit capability = 6400A Isc

- ✓ DC/AC Ratios **up to 225%** (SC 2500-EV)
- ✓ **No reduction in lifetime** -> thanks to SMA's Robust Stack Design



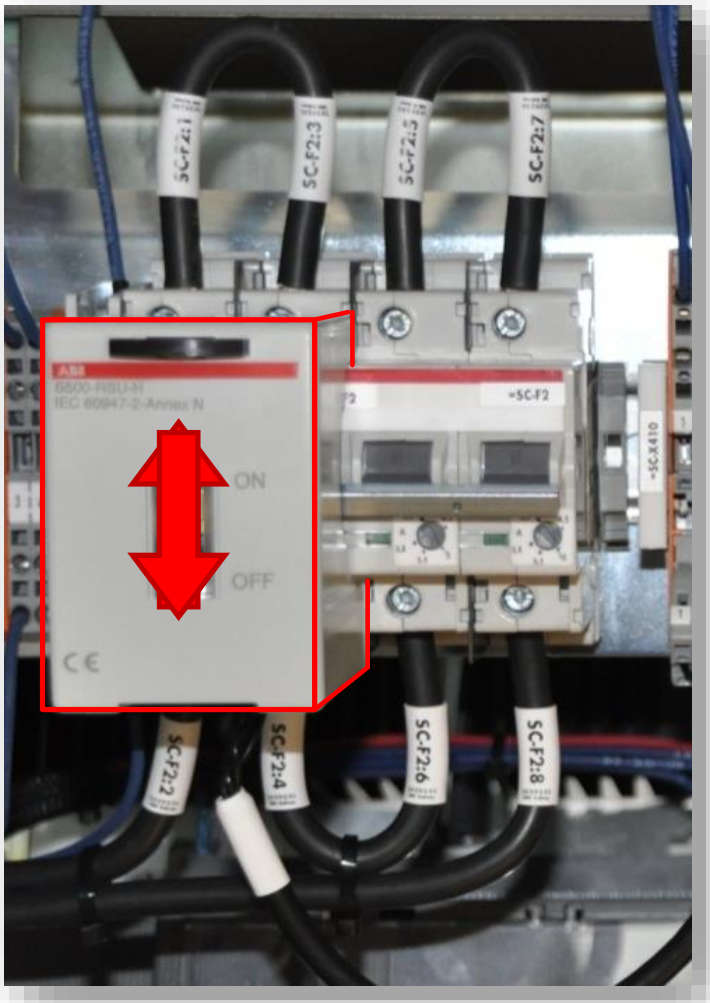
› USP: Extreme DC Overloading without any impact on the inverter lifetime!

1. *technically possible

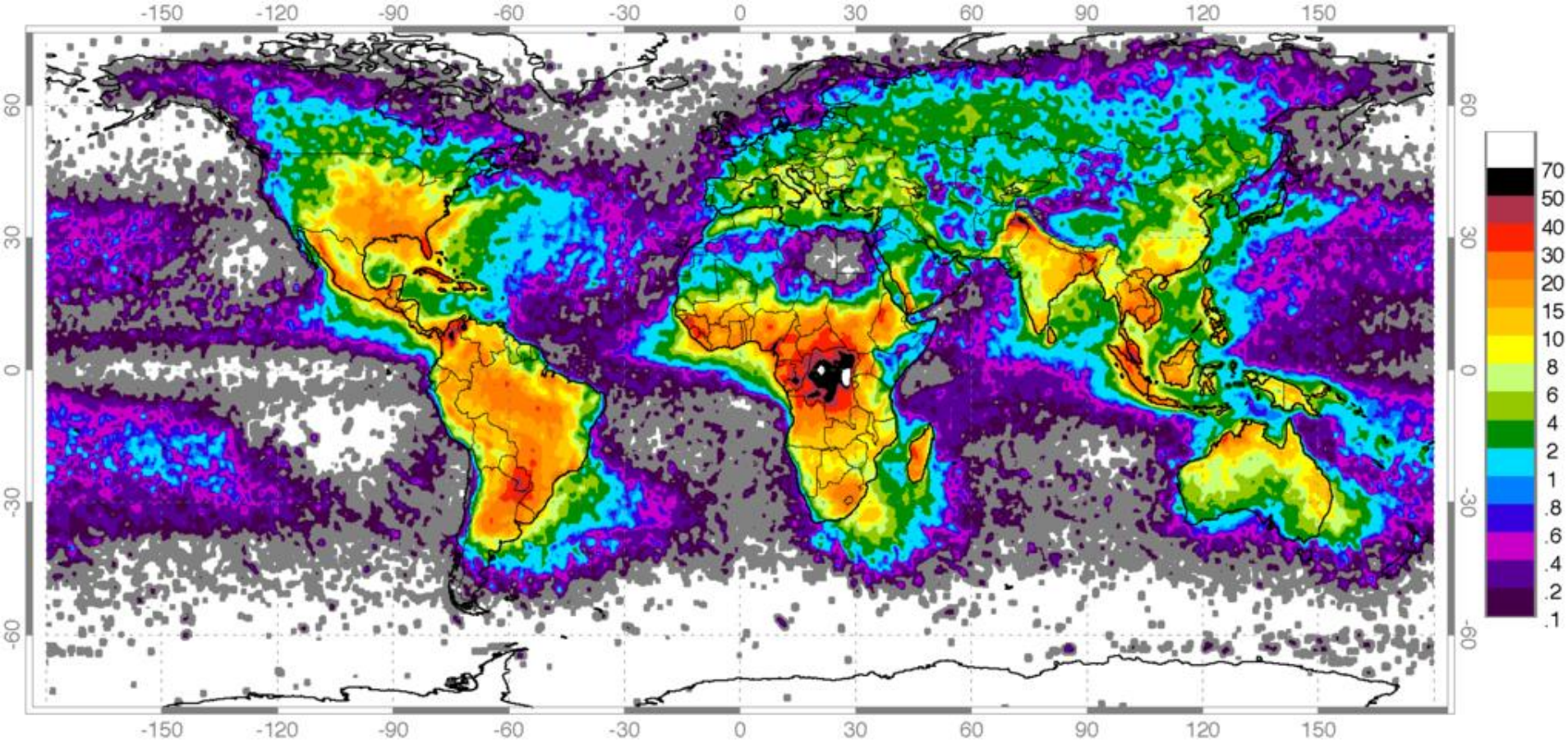
GROUNDING & DC CONNECTIONS
DETERMINES INVERTER GROUNDING CONFIGURATION

REMOTE Ground Fault Detection Interrupt (GFDI) & Insulation Monitoring Combined Option

- 5A Motor driven circuit breaker
- Introduces FUNCTIONAL GROUNDING of –ve pole of Solar module
- Programmable autonomous function



LIGHTNING PROTECTION

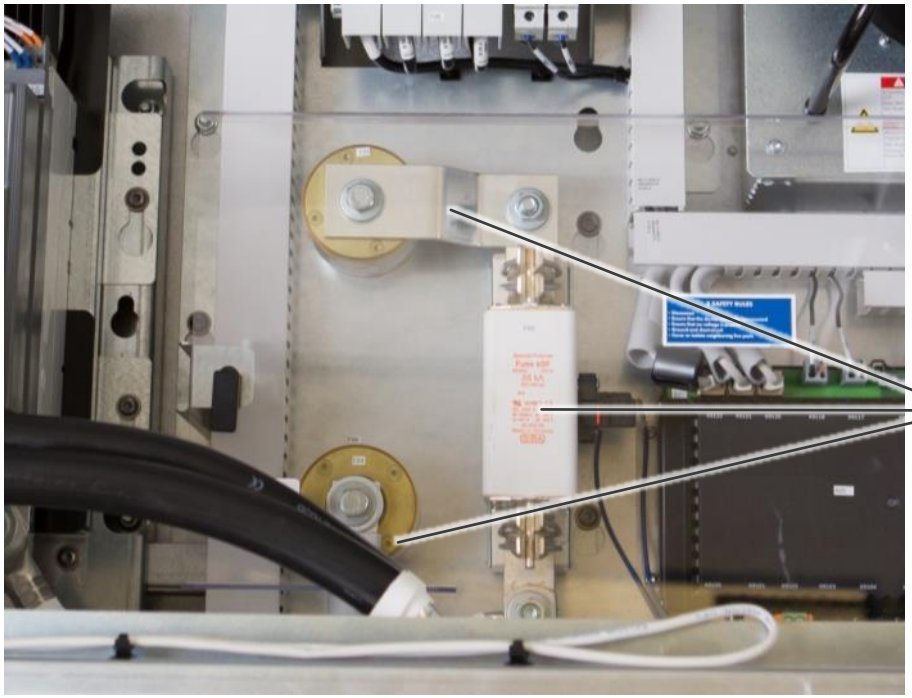


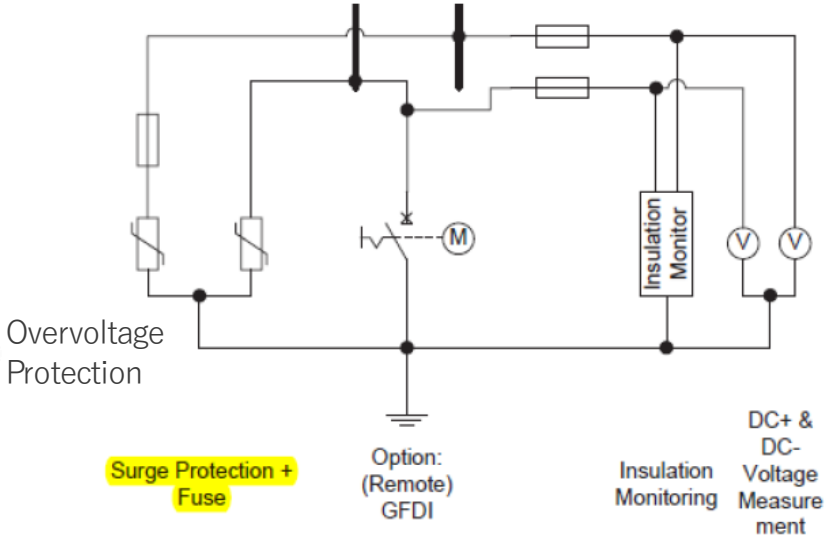
World map with number of lightning strikes per year

DC OVERVOLTAGE PROTECTION
DEFAULT LIGHTNING & SURGE PROTECTION

RAYCAP STRIKESORB SPD's

Strikesorb surge protection devices protect mission-critical applications from lightning surges and overvoltage events. Even in the most lightning prone environments, Strikesorb surge suppressor modules are capable of absorbing and dissipating the extreme energy of lightning strikes without degradation to the module.





AC OVERVOLTAGE PROTECTION
OPTIONAL LIGHTNING & SURGE PROTECTION

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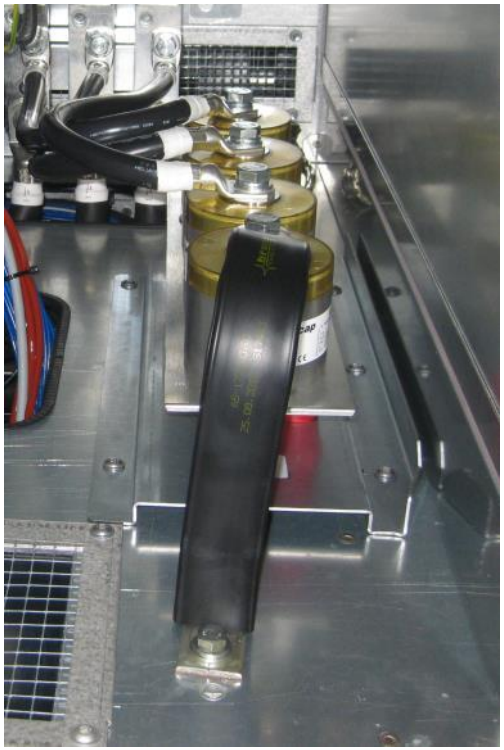
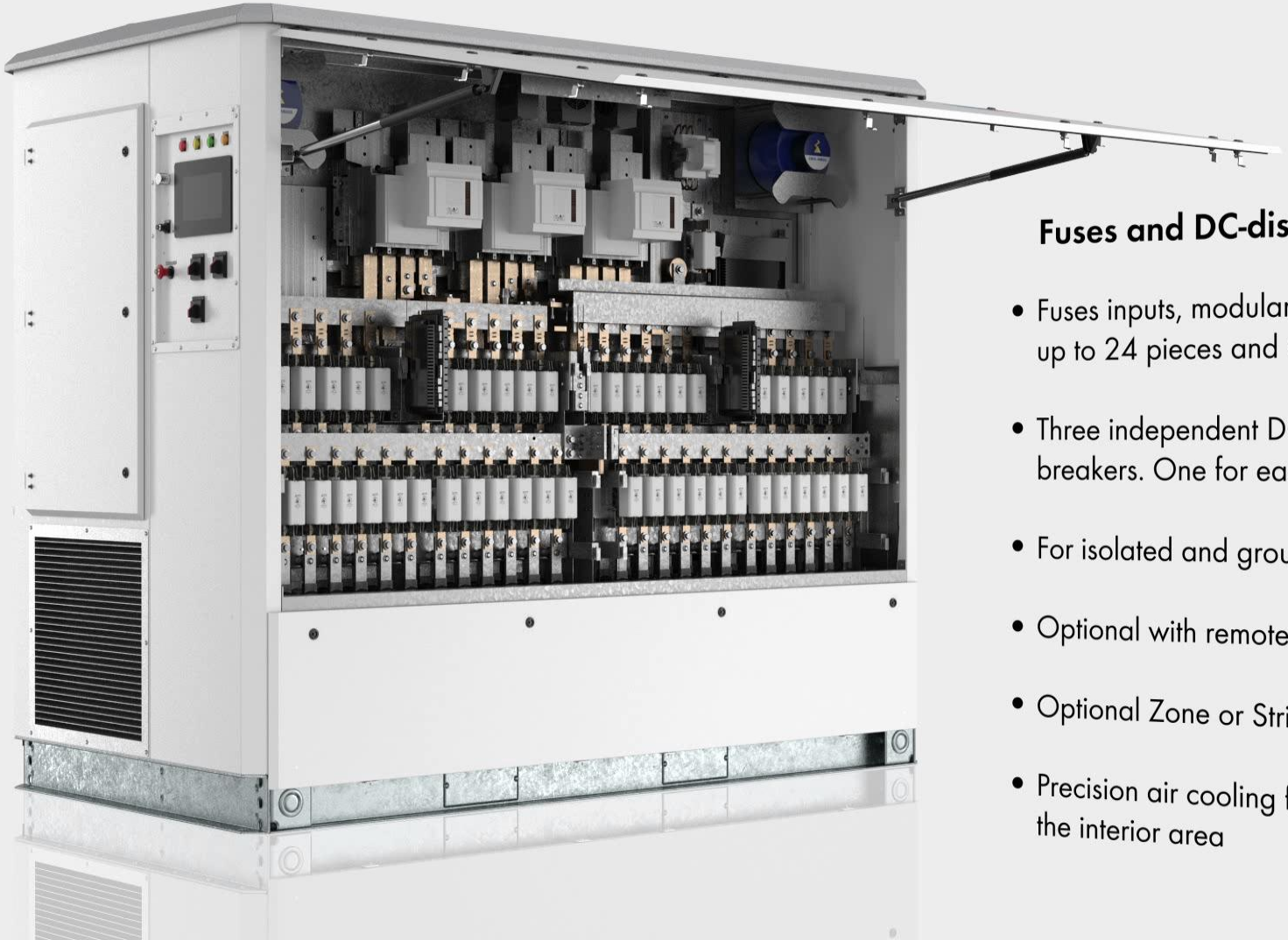


AC Overvoltage Protection

> No
> Yes

DC ENCLOSURE – HUMIDITY MANAGEMENT

- **Max. permissible value for relative humidity (condensing)**
  95% to 100% (2 month / year)
- **Max. permissible value for relative humidity (non-condensing)**
  0 % to 95%



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- Optional Zone or String Monitoring
- Precision air cooling for the interior area

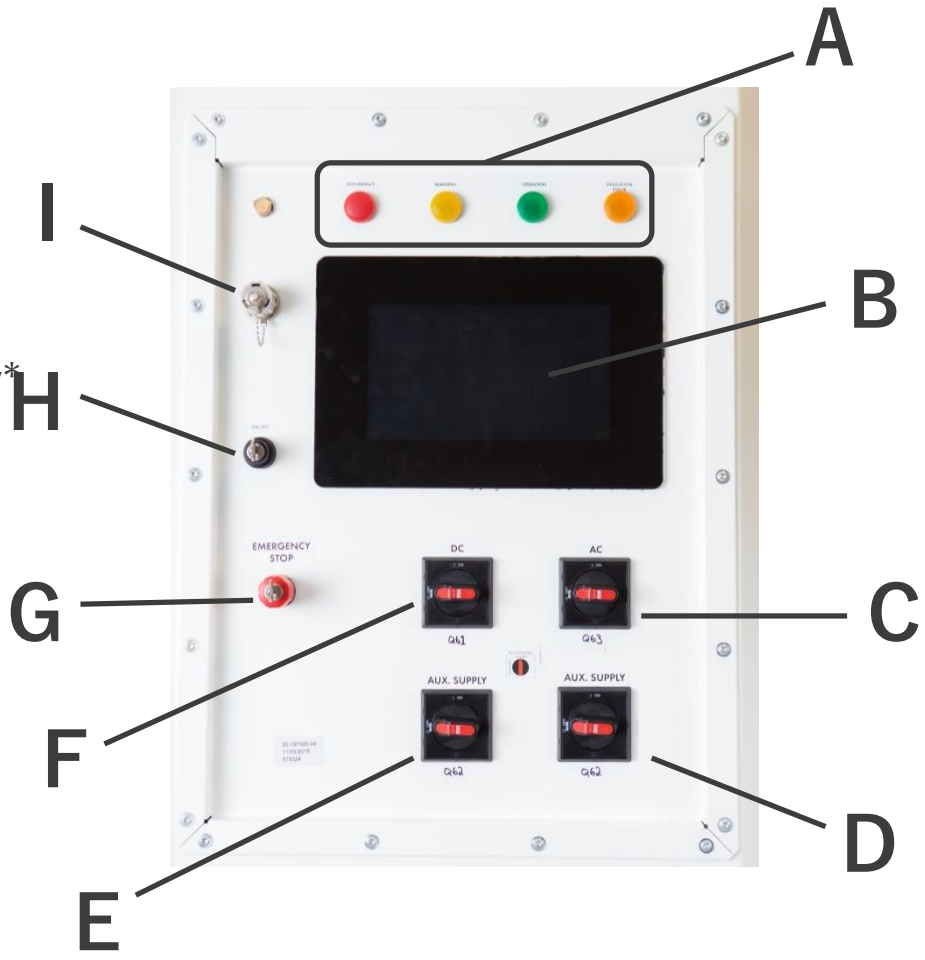
Control and customer equipment area

- Well-structured control-panel with touch screen
- Switch for safe inverter disconnection
- Area for customer equipment with integrated power supply for customer loads and trackers
- Optimized connection area
- Air outlet

EASE OF OPERATION (LOCALLY & REMOTELY)

> Updated HMI/display with remote LOTO Disconnects for all power sources

A. Operation LED indicators
B. Outdoor 10.4” color touch-display*
C. Load-break switch for main AC switchgear
D. Load-break switch for external power supply*
E. Load-break switch for internal power supply
F. Load-break switch for main DC switchgear
G. Emergency fast stop
H. Key switch for start/stop
I. Service interface via Ethernet port



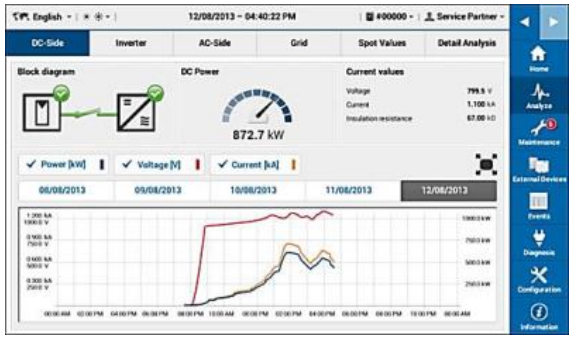
*OPTIONAL

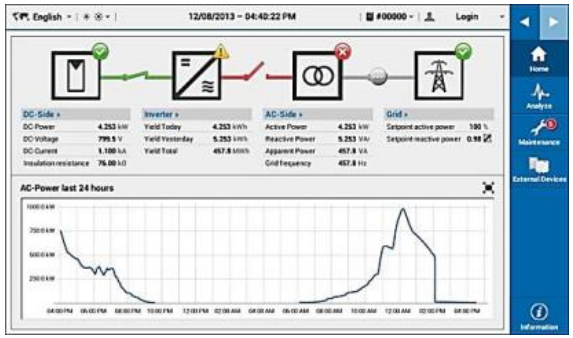
EASE OF OPERATION (LOCALLY & REMOTELY)

> Latest option covered display or without display

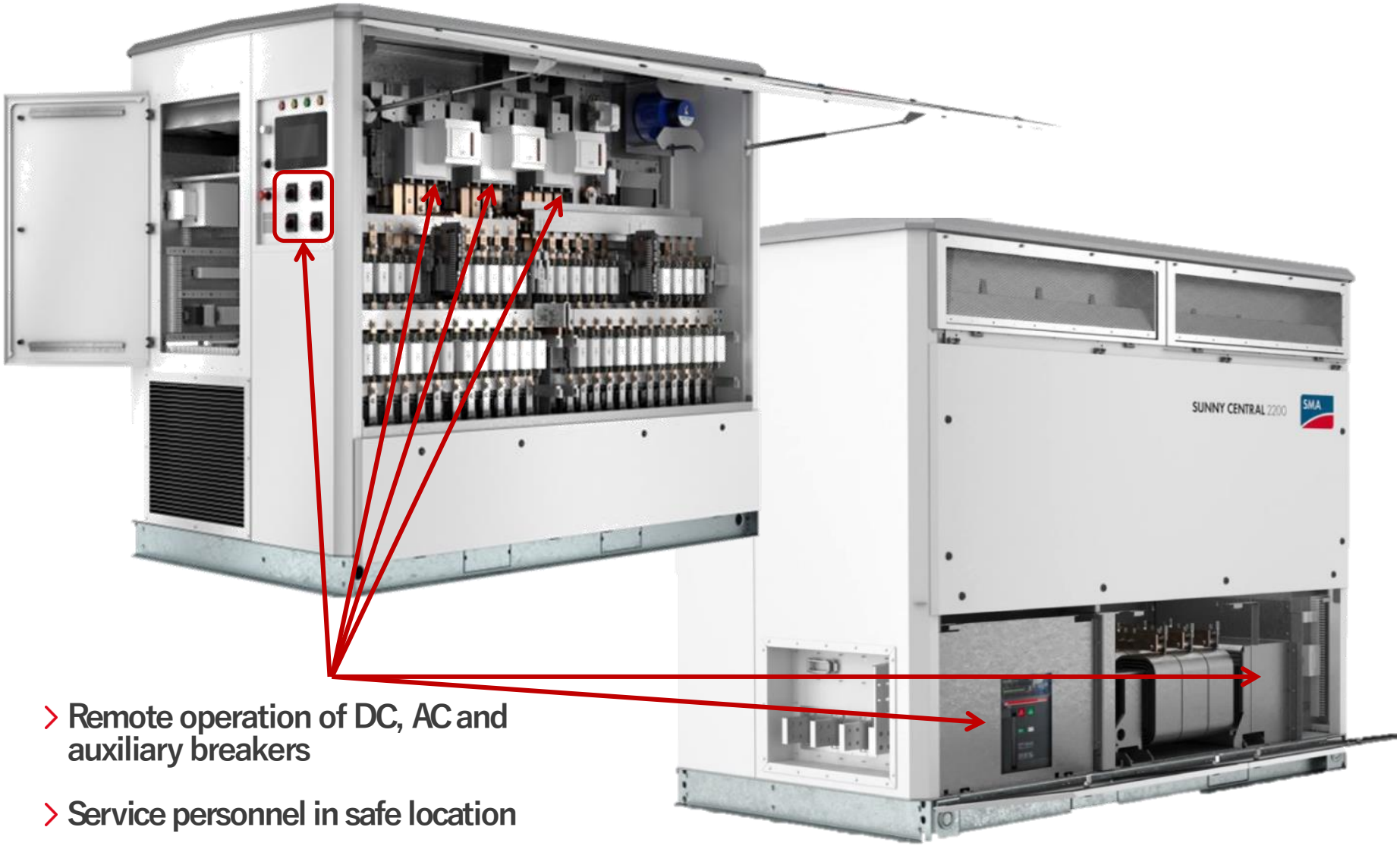
Display

> Display with cover
> No display





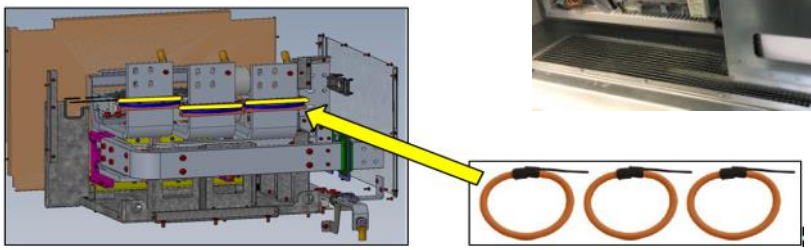
STAFF SAFETY BY DISTANCE



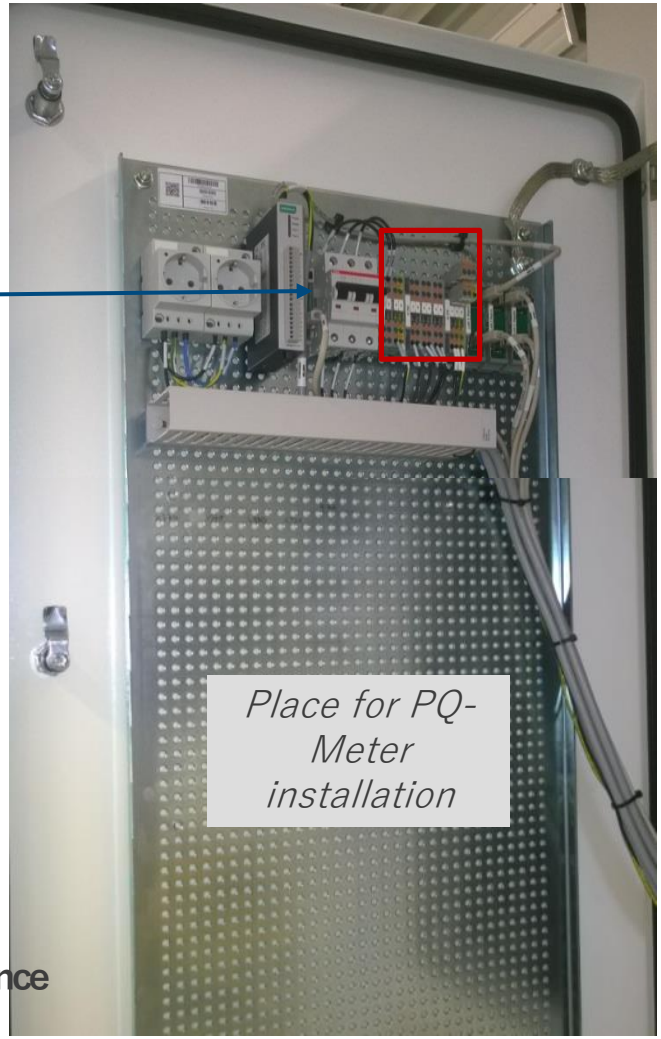
- Remote operation of DC, AC and auxiliary breakers
- Service personnel in safe location

PREPARATION FOR **PQ-METER** (OPTIONAL)

- Additional **AC current and voltage** measurement
- Suitable for meters with 400V & 5A inputs. E.g.:
  - Elspec G44xx
  - SEL-735
  - Janitza UMG 604E
  - Janitza UMG 604EP



- Rogowski coils for AC current measurement with **12% tolerance**
- Voltage transformer for AC voltage measurement with **2% tolerance**



- PQ-Meter itself must be provided and installed by customer, not in scope

PREPARATION FOR **PQ-METER** (OPTIONAL)

- Designed for **AEMO R2 testing (5.2.2)** or flexible customer communication device
  Integrated VT, CT and power supply to Elspec G4420 or G4430

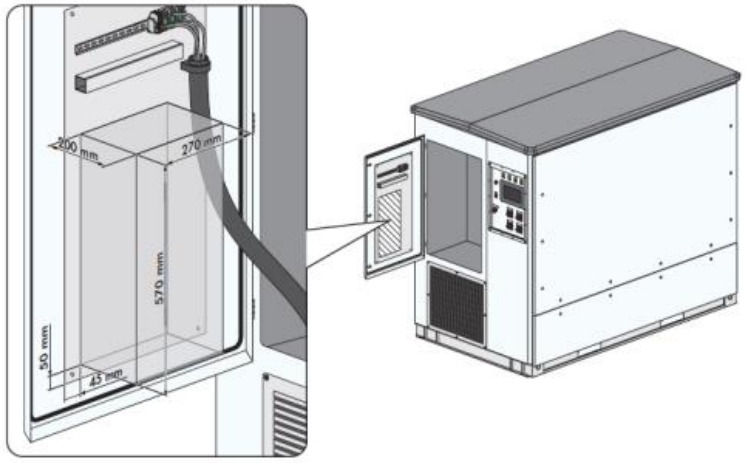
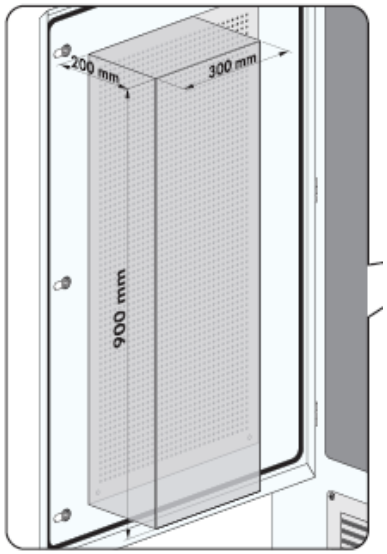


Figure 62: Area for the installation of the PQ-Meter in the customer installation location

- PQ-Meter itself must be provided and installed by customer, not in scope

INTEGRATED COMMUNICATION ENCLOSURE

- **Area for customer equipment**
  e.g. customer communication devices (900mm x 200mm x 300mm)
- **Without the metal plate**



REMOTE I/O (OPTIONAL)

4 types of **IO modules** (Moxa ioLogik) available

- **16 DI → Moxa E1210-T**

  16 digital inputs

- **8 AI → Moxa E1240-T**

  8 analog inputs (0-10 Vdc signals as defa

- **4 AI + 8 DI → Moxa E1242-T**

  4 analog inputs (0-10 Vdc default)

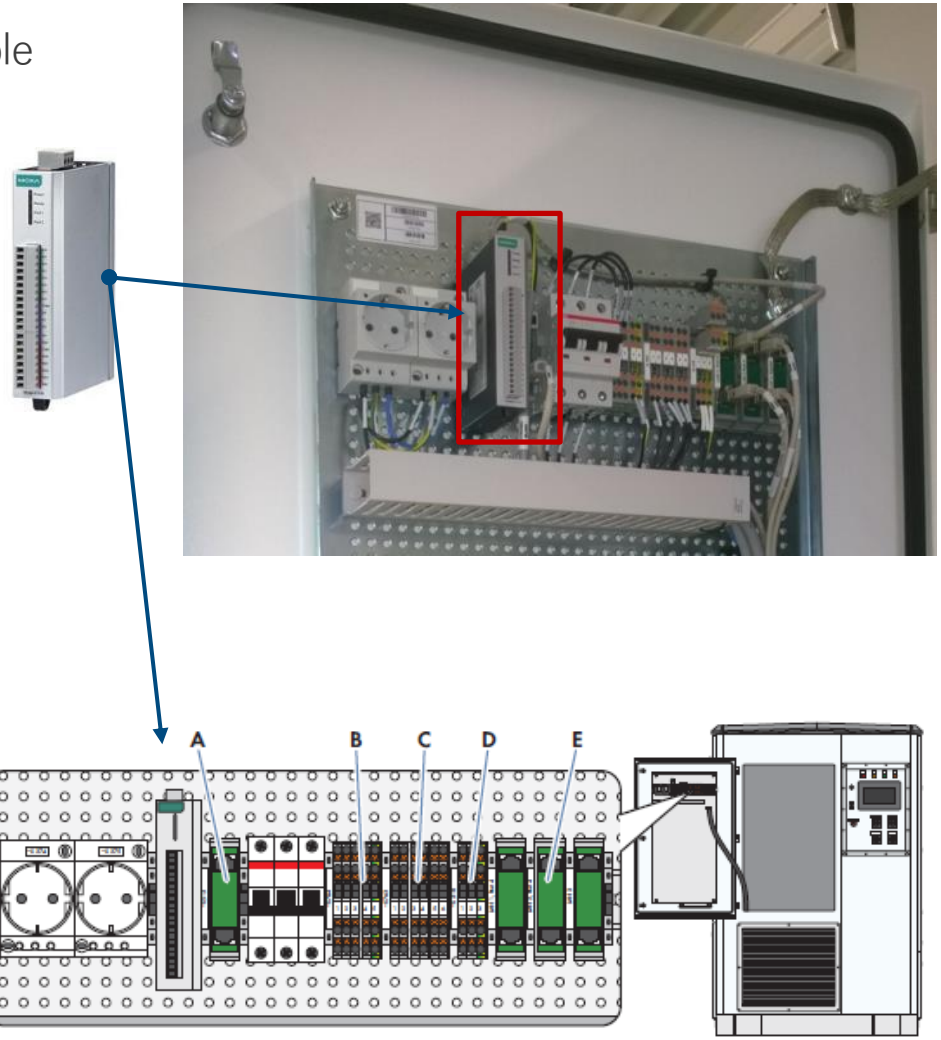
  4 digital inputs

  4 configurable digital in- or outputs

- **6 RTD → Moxa E1260-T**

  6 Temperature inputs for

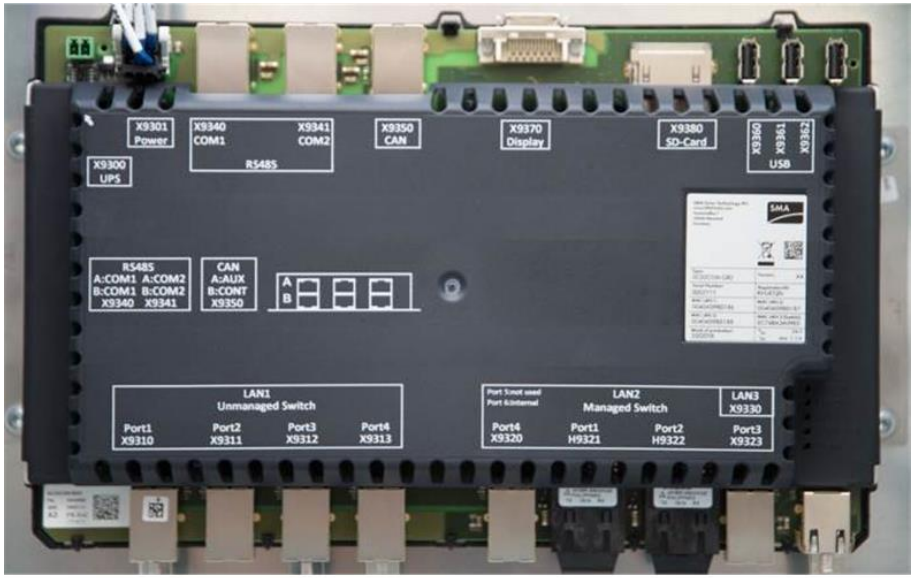
  PT50/PT100/PT200/PT500/PT1000)



INTEGRATED COMMUNICATION ENCLOSURE
LISTED COMS ENCLOSURE ALLOWS FOR CUSTOMIZED SOLUTIONS

Inside of the enclosure

- > Buffered Power Supply
- > Included additional 300W @ 230V Power Provision
- > Connections for MET/DAS Stations
- > Power for Transformer Alarm Contactors



Communication System A

0: Customer Communication

1: Managed Switch MMF

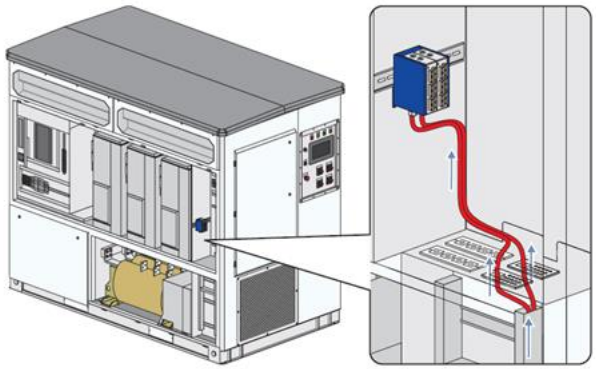
2: Managed Switch SMF

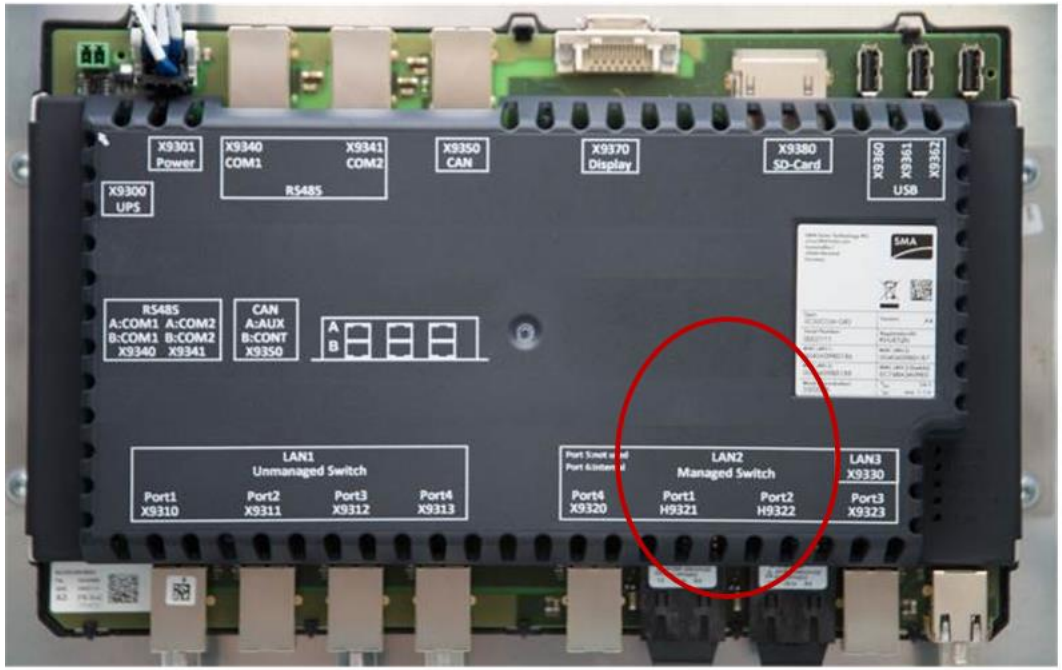
DC –UPS 24V Buffer
20A Nom Output - 8KJ Storage

SC30COM

Control Boards

INTEGRATED COMMUNICATION ENCLOSURE
LISTED COMS ENCLOSURE ALLOWS FOR CUSTOMIZED SOLUTIONS





Communication System A

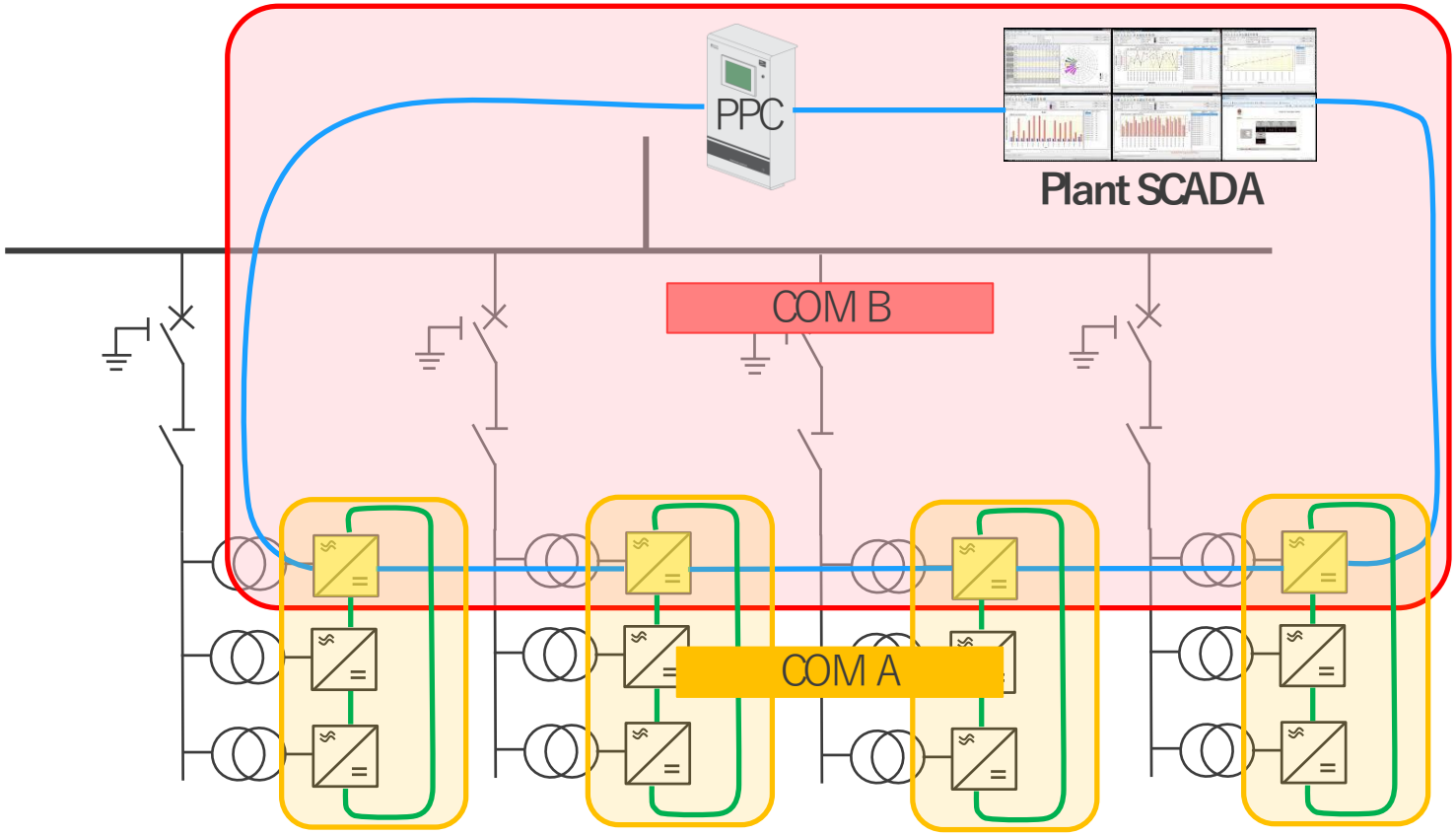
0: Customer Communication

1: Managed Switch MMF

2: Managed Switch SMF

splice box for the FO connections

COM A AND COM B



- Inverter with both COM A and COM B
- Inverter with just COM A
- Multi-mode fibre
- Single-mode fibre

Control and customer equipment area

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AC-area

- Robust proven inverter power stack B6-topology with efficiency above 98%
- 3 three-phase stacks, independent from each other
- Modular adjustment for easy access and optimized service
- Extended MPP-voltage range
- Intelligent, rotating stack start-up
- Main fan for all three stacks and sine wave choke

AC-area

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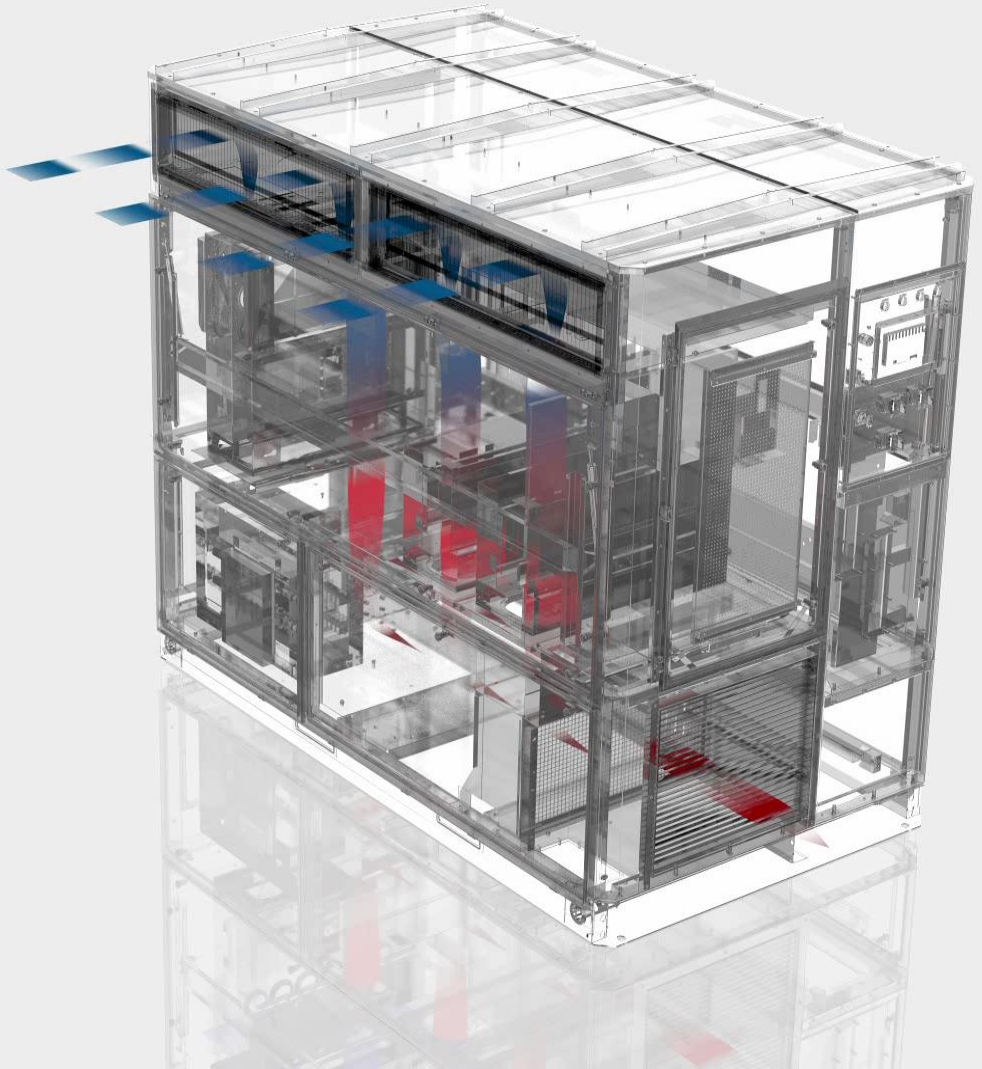
Proven air-cooling concept

- Proven, intelligent and robust cooling-concept OptiCool™, also for inverters in high power classes
- Efficient cooling of all heat generating parts
- Very low self-consumption
- Broad inverter temperature range from -40 to +60°C
- Suitable for any environment



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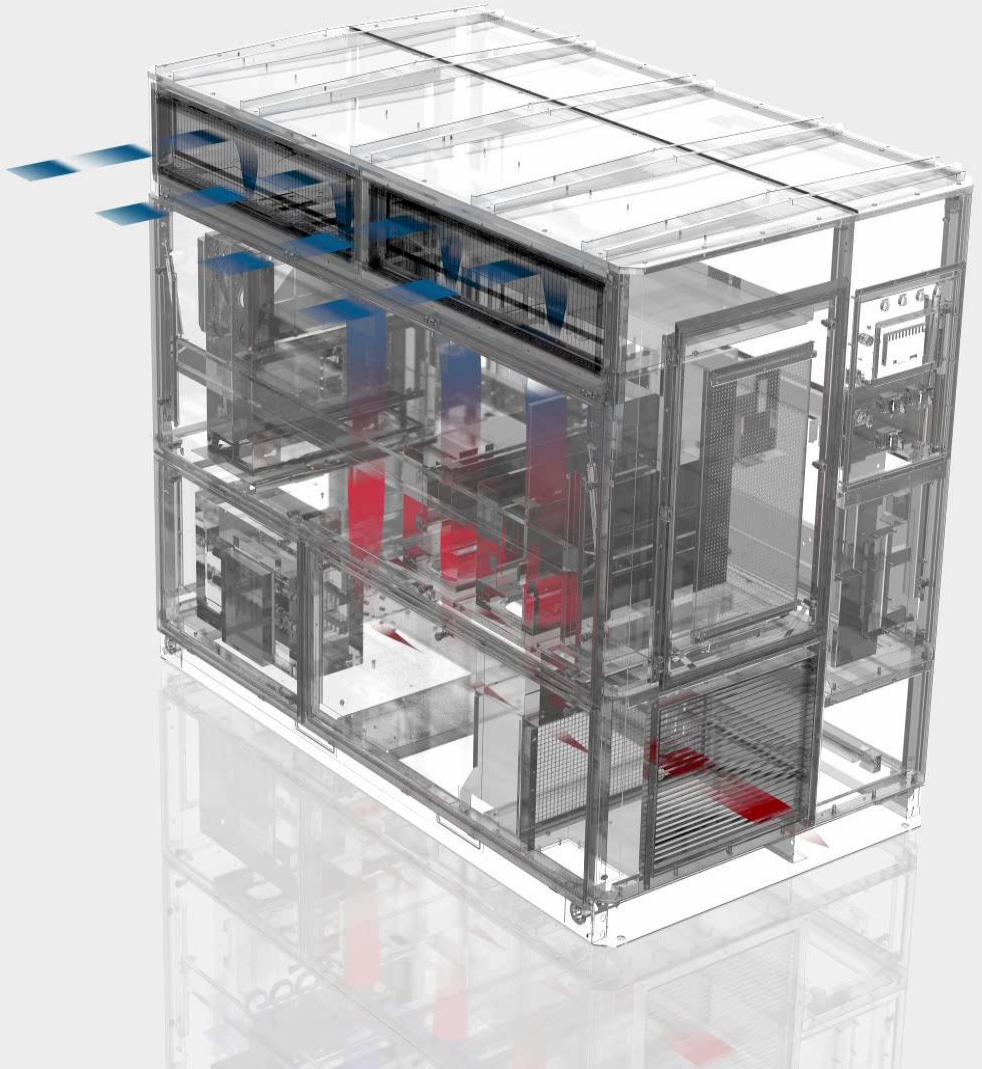

Solid and secure

- Ventilated sine wave choke, located at the bottom for a low center of gravity
- AC-switch for a secure disconnect of the device
- Connection area for communication and power supply for additional external park equipment

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- AC-switch for a secure disconnect of the device
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Busbar connection

- Easy medium-voltage transformer connection via busbars
- Transformer temperature monitoring
- No earthwork for cabling required

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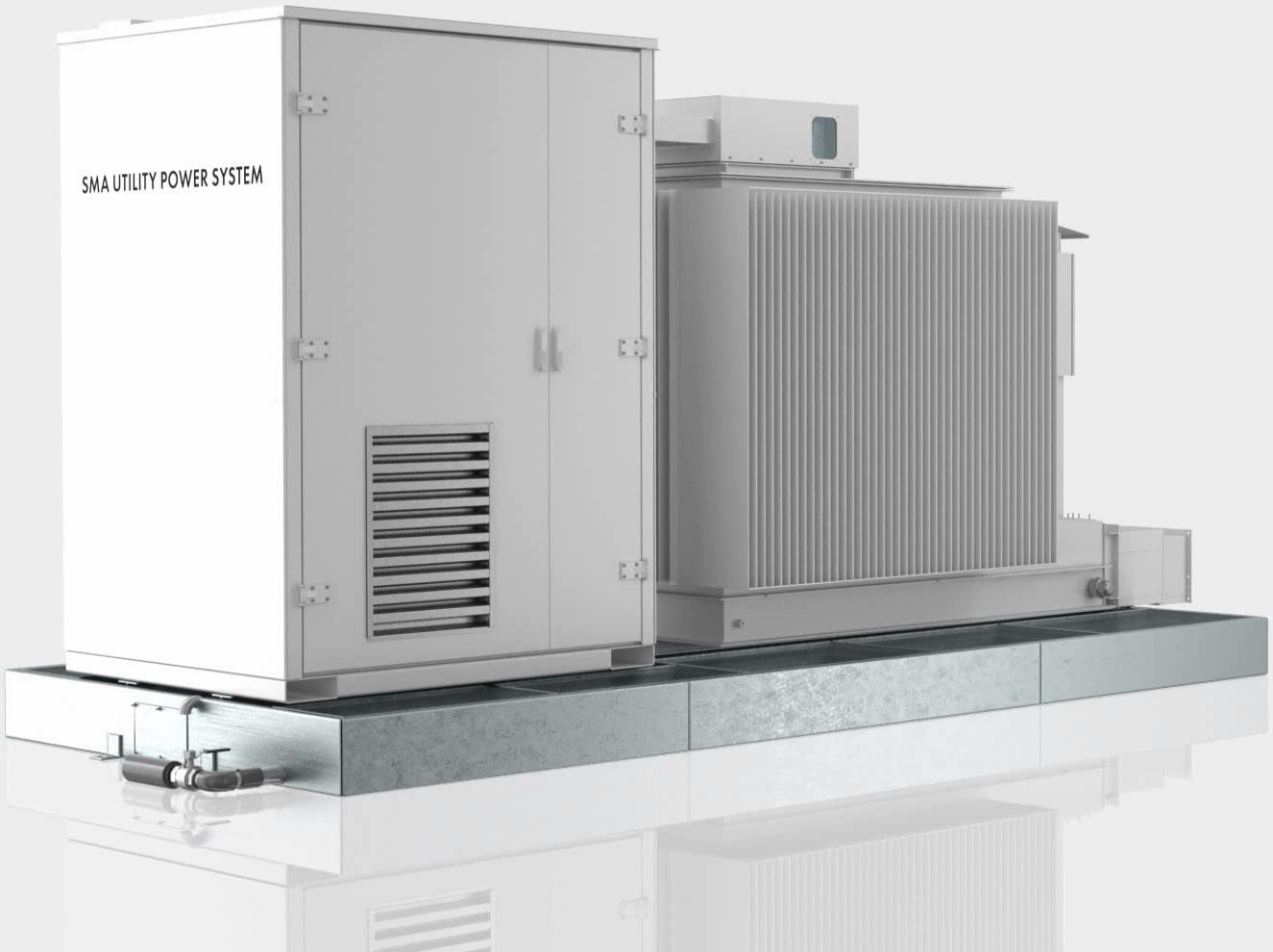


Medium-voltage block

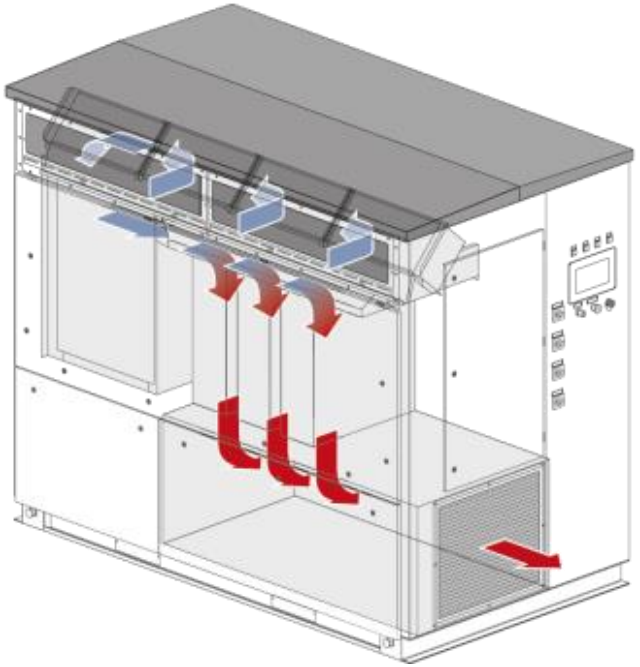
- Close busbar connection between inverter and transformer
- Durable galvanized steel platform
- Outdoor installation for optimized transformer cooling, no fan needed
- Available for all medium voltage levels from 6.6 to 35 kV
- Temperature ranges:
  Choose between -25 °C - +50 °C
  or -40 °C - +40 °C

COOLING SYSTEM DESIGN – SMA **OPTICOOL™**

The Cooling System is responsible for 2 of the top 10 failure sources of central inverters[1].
Intelligent cooling is one **key to highest availability**.

- Temperature range from -25 to +60° C
- No filter matts, air inlet 2 m above ground
- Self-cleaning high pressure system
- Air-to-air heat Exchanger (no water, lower Temperature)
- All power electronics are in IP 65 protected area (IEC 60529)
- Tested for operation in harsh environments

SMA's Proprietary OptiCool™ Air Cooling Concept



› **SMA puts availability first to protect your yield.**

1. Source: www.solarbankability.eu ("Technical risks in PV projects")

COOLING SYSTEM DESIGN – SMA **OPTICOOL™**

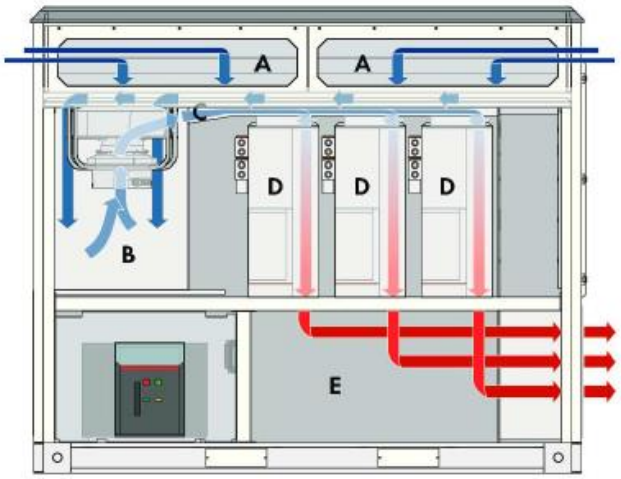
External air flow IP34

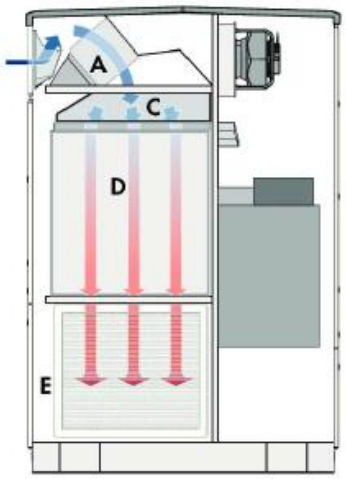
- Air is sucked in through the roof by stack fan
- Mechanical design of air intake grill does not allow particles > 2mm to enter
- Air flow slower than 6m/s so that water is not sucked in due to gravity
- Heat exchanger in roof cools hot air of internal air flow

Internal air flow IP65

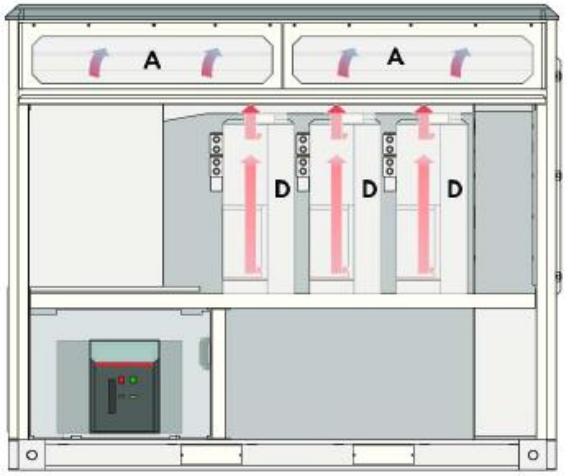
- Air is circulated in sealed area of the inverter by two fans on the DC side
- Power electronics are in protected area, only cooled by internal air flow
- All sealed components tests with 15 cm water column

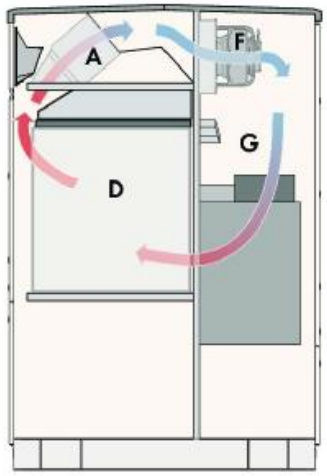
IP34





IP65

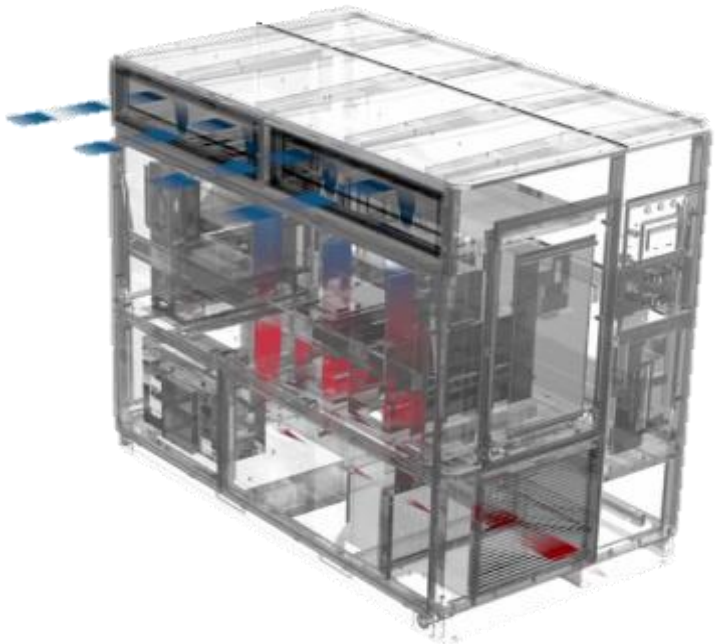




COOLING SYSTEM DESIGN – SMA **OPTICOOL™**
REDUCES SPACE, WEIGHT, SELF-CONSUMPTION AND O&M COSTS

Precision Air Cooling

> Simplicity: 1 Stack Fan and 2 Cabinet Fans
> Saves space, weight, time & cost
> Reduces self consumption
> Reduces O&M
  - No coolant change
  - No radiators
  - No pumps
  - No paper filters
> Increases Safety
  - No HazMat handling
  - No liquid near electricity

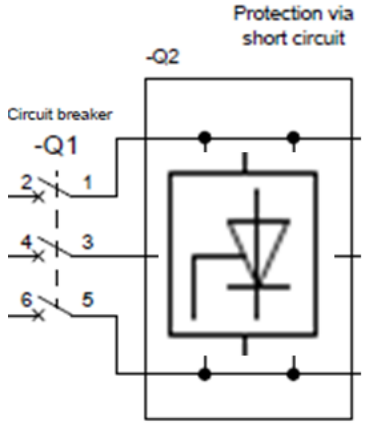


Task	Interval
Replacing the lithium-ion rechargeable battery.	10 years
Replacing the Industrial Compact Flash card.	10 years or after an error message
Replacing the interior fan	14 years
Replacing the inverter bridge fan.	14 years
Replacing the GFDI.	After 7,000 cycles or 100 short circuits
Replacing the Remote GFDI.	After 7,000 cycles
Replacing the three-phase short-circuiting device.	After a short circuit

AC COMPARTMENT

AC CIRCUIT BREAKER, CHOKE AND STACK PROTECTION

- Ventilated sine wave choke, located at the bottom **for a low center gravity**
- AC Circuit Breaker **with Arc Flash Protection**
- Short Circuit Module **for stack protection***



› **Key Advantage: Special Stack Protection via Short Circuit Module, protects the remaining stacks in case if one failed through a short circuit. Additional protection against Arc Flash**

*Detailed description, see appendix 2

WHY ARC FLASH PROTECTION?

Effect of arc flash in an inverter not protected properly:

- A severe failure in power electronic may lead to subsequent failures
- One broken IGBT may result in a burned cabinet

Failures must be contained

Subsequent failures have to be avoided

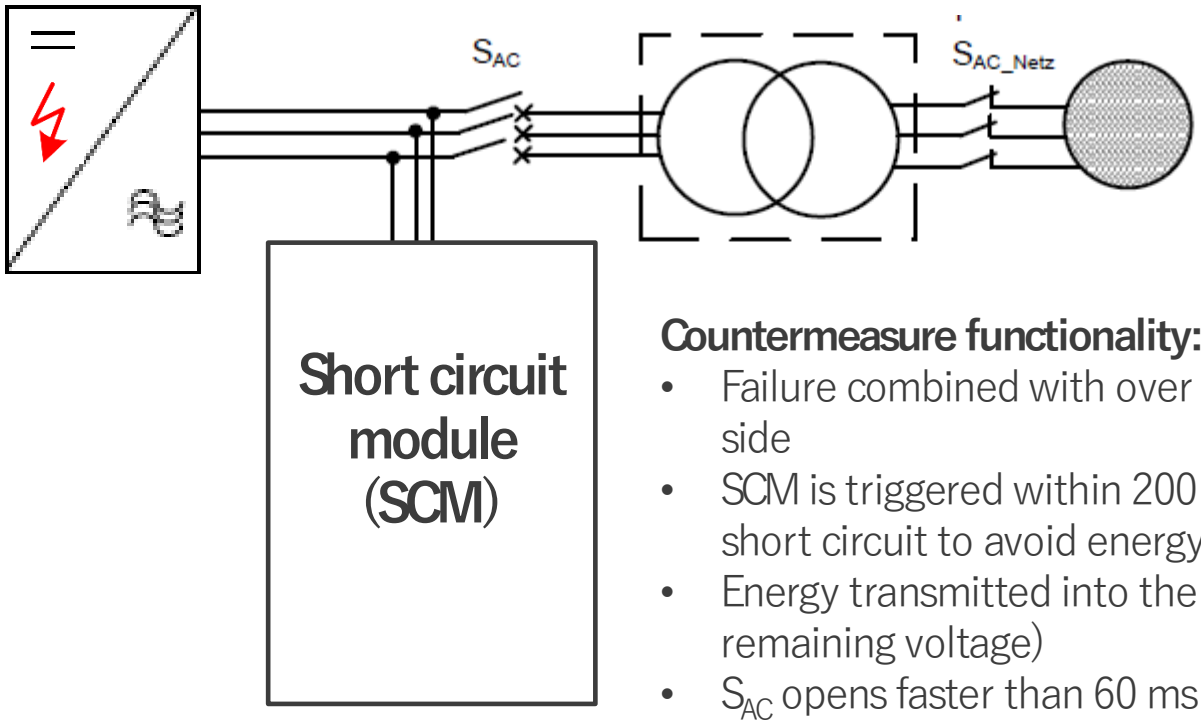
Staff has be protected

› Arc flash must be contained to protect entire device and service personnel

HOW DOES ARC FLASH PROTECTION WORKS?

Danger:

- Failure energy delivered from AC side is very large ⇒ failure may cause severe destruction



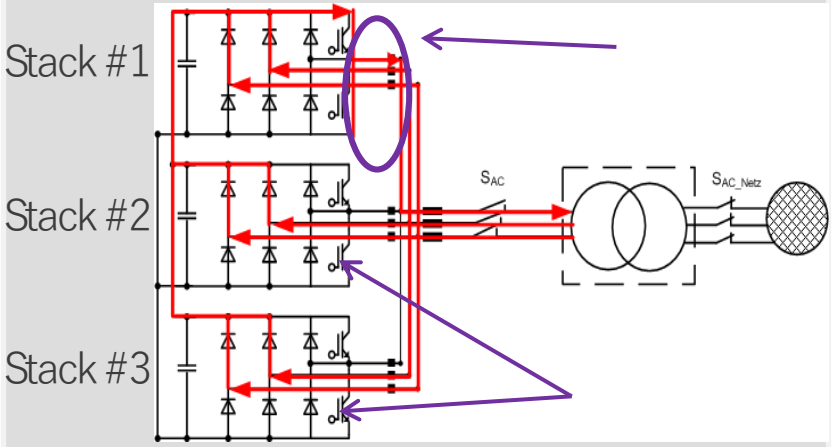
Countermeasure functionality:

- Failure combined with over current flow from AC-side
- SCM is triggered within 200 - 400 µs and performs a short circuit to avoid energy flow into the stack
- Energy transmitted into the failure is low (no remaining voltage)
- S_{AC} opens faster than 60 ms and interrupts the failure
- Failed stack and inexpensive SCM have to be replaced
- Energy intake from DC side will be interrupted by DC switching components

› **Energy intake due to slow AC circuit breakers is too high for components**

STACK PROTECTION VIA SHORT CIRCUIT MODULE (SCM)

Scenario without SCM

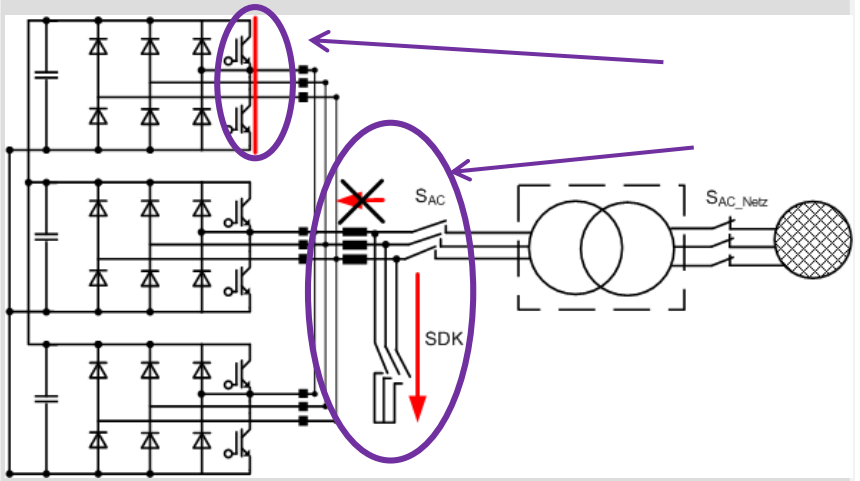


(1) Short Circuit Failure occur on Stack #1

(2) Reverse current from the AC side destroys the
Stack Diodes since AC Circuit Breaker is not fast enough to switch beforehand

(3) All three stacks needs to be replaced & Risk of Arc Flash

Scenario with SCM



(1) Short Circuit Failure occur on Stack #1

(2) A Rogowski Coil measures the high current and
triggers the Thyristors which are causing a short
circuit

(3) The Short Circuit is forcing to trip
the AC Circuit Breaker immediately and protects
Stack #2& #3*

› **SCM Benefits: Protects stacks in case of a short circuit, no Risk of Arc Flash**

1. Only the cost-effective Thyristors needs to be replaced

REMOTE AC BREAKER DISCONNECT

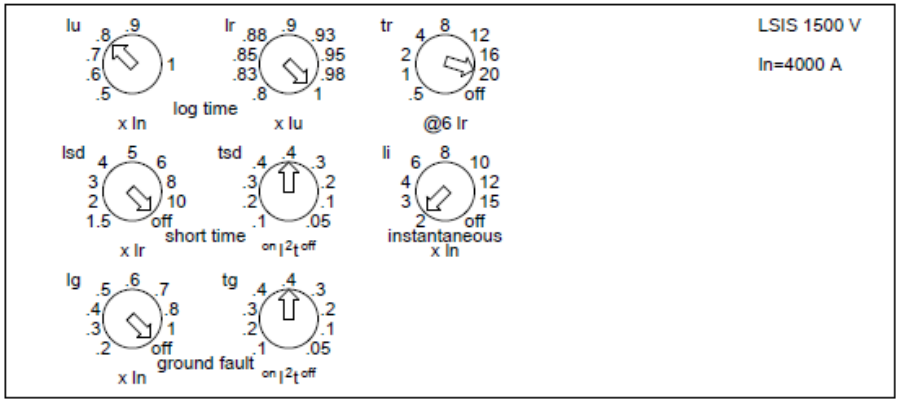
Trip the breaker from the HMI

LSIS customized version for SMA

>4000A Circuit Breaker

>Remote Operable (HMI)

>With Lock Out, Tag Out



REMOTE FAST STOP FOR "BACK-UP PROTECTION"

CUSTOMER GUIDELINE - High Voltage Connected Embedded Generation
CitiPower Pty Powercor Australia LTD

6.15. Protection Requirements

The customer protection design shall be based on detecting all faults within the customer's distribution system and operating the customers CB's to isolate the fault without impacting the CitiPower/Powercor system. It is the customer's responsibility to determine all further performance requirements for the generator protection, given that the functionality will depend on the type of machine and its method of electrical coupling.

The protection design should include primary protection and back-up protection. Back-up protection can be via duplicated unit protection schemes with local CB failure schemes or via non-unit protection schemes. The back-up protection must also cover all sections of primary plant and must provide protection for both relay failure and CB failure.

Abstract from Citipower/Powercor Customer Guildline – High Voltage Distribution Connection Embedded Generation

REMOTE FAST STOP FOR “BACK-UP PROTECTION”

3.2.2.2 Fast-Stop Key Switch -S2

When the key switch is actuated, the inverter disconnects from the utility grid in under 100 ms by opening the DC switch-disconnector and the AC disconnection unit.

The supply voltage and the optional additional auxiliary power supply remain connected so that the inverter can continue to be accessed.

Actuation of the fast-stop key switch -S2

The fast-stop key switch **-S2** should only be tripped in case of imminent danger. Tripping occurs without previous rapid discharge of the link-circuit capacitors. If the inverter is to be switched off and properly shut down via an external signal, the external start/stop function **-X433** should be used.

13.2.2.6 External Islanding Detection

If the overall system is equipped with an external anti-islanding detection system with transfer trip, the formation of stand-alone grids can be detected at the plant level. If a stand-alone grid has formed, a signal is transmitted to the fast stop input of the inverter. A suitable cable must be connected at the fast stop input at terminal **-X440:1,3** of the inverter during installation.

During normal operation conditions, a 24 V signal is transmitted to the fast stop input of the inverter. If a stand-alone grid has formed, the signal switches to 0 V and the inverter switches to "Error" and is disconnected from the utility grid.

In order to switch back the inverter to the operating state "GridFeed", ensure that the external anti-islanding detection system generates the 24 V signal.

6.6.2 Connecting the Cable for External Fast-Stop Function

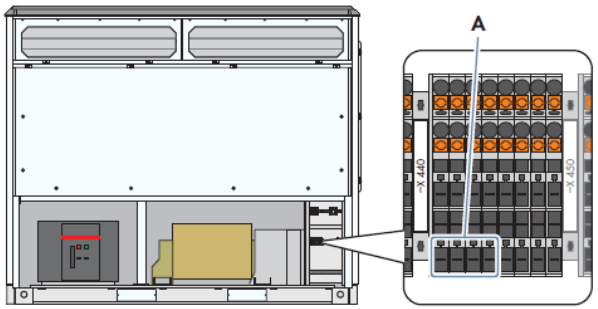


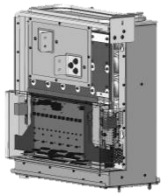
Figure 47: Position of the terminal block for external fast stop function

Position	Designation
A	Terminal block

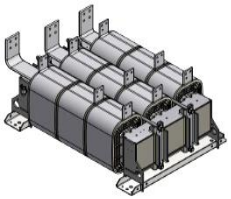
SMA FUTURE CONCEPT

POWER STACK

- NEW GENERATION OF IGBTS
- OPTIMIZED HEATSINK
- OPTIMIZED PCBS



SINEFILTER



- HIGHER CURRENT

- HIGHER VOLTAGE

CABINET

= OPTIMIZED AIR DUCT

CONTROL

- KODIAK 1.0 FIRMWARE EXTENSION

› More Power with only small changes. Reduction of specific costs.

MEDIUM VOLTAGE POWER STATION - INTEGRATED SOLUTION

› Source: Gannawarra Solar Farm, AREANA

MV POWER STATION – MVPS-S-AU SERIES

WILSON TRANSFORMER COMPANY

THE TRANSFORMER PEOPLE

Key Facts

- Fully Australian owned family business
- Founded in 1933
- Located in Glen Waverley and Wodonga (VIC)
- 16 kVA to 500 MVA / 400 kV Transformers
- Production of compact substations and skids
- Hundreds of thousands of transformers sold

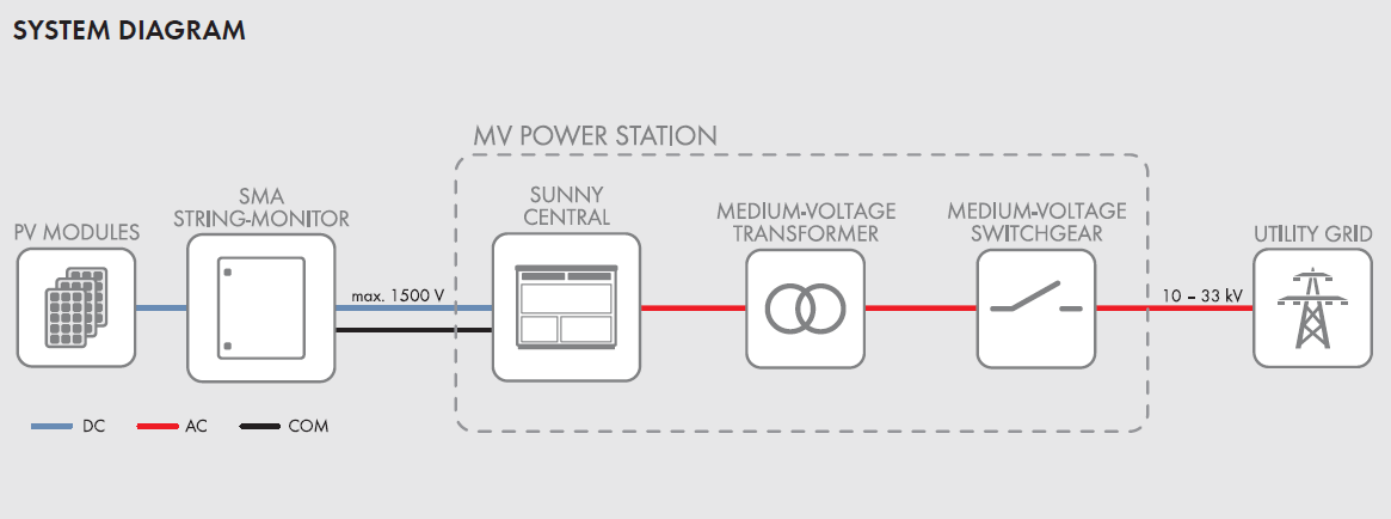
› WILSON TRANSFORMER COMPANY – the market leader in transformer solutions

1. Source: www.wtc.com.au

WILSON TRANSFORMER COMPANY

› Local Production for a booming market

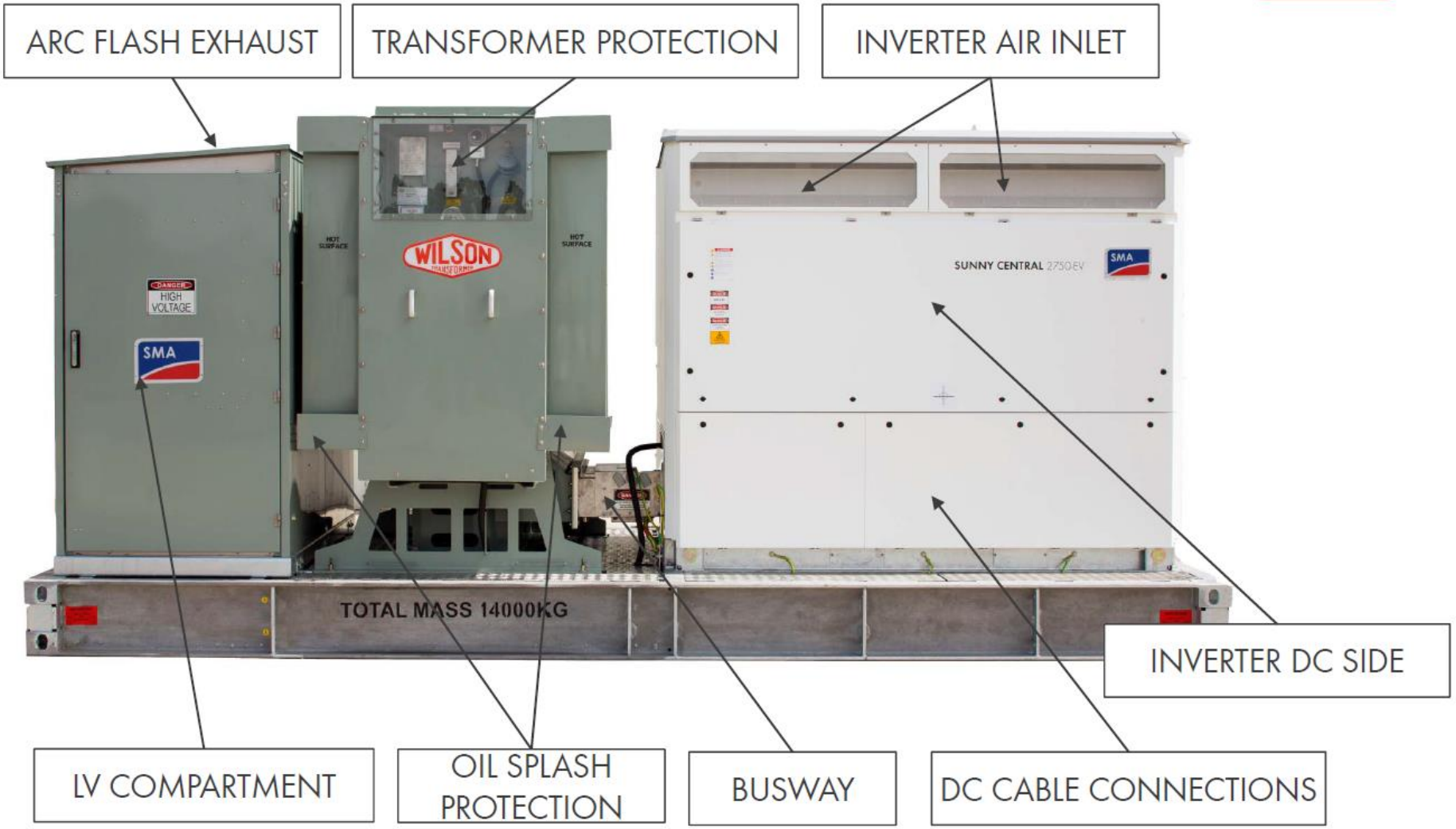
MEDIUM VOLTAGE POWER STATION - INTEGRATED SOLUTION



- Turnkey solution
- Short time to markets in new markets
- For extreme environments
- Numerous options
- Cooling concept MV transformer
- Reduced transformer losses
- Type tested incl. IAC
- 5 years warranty
- Easy transportation
- High power density

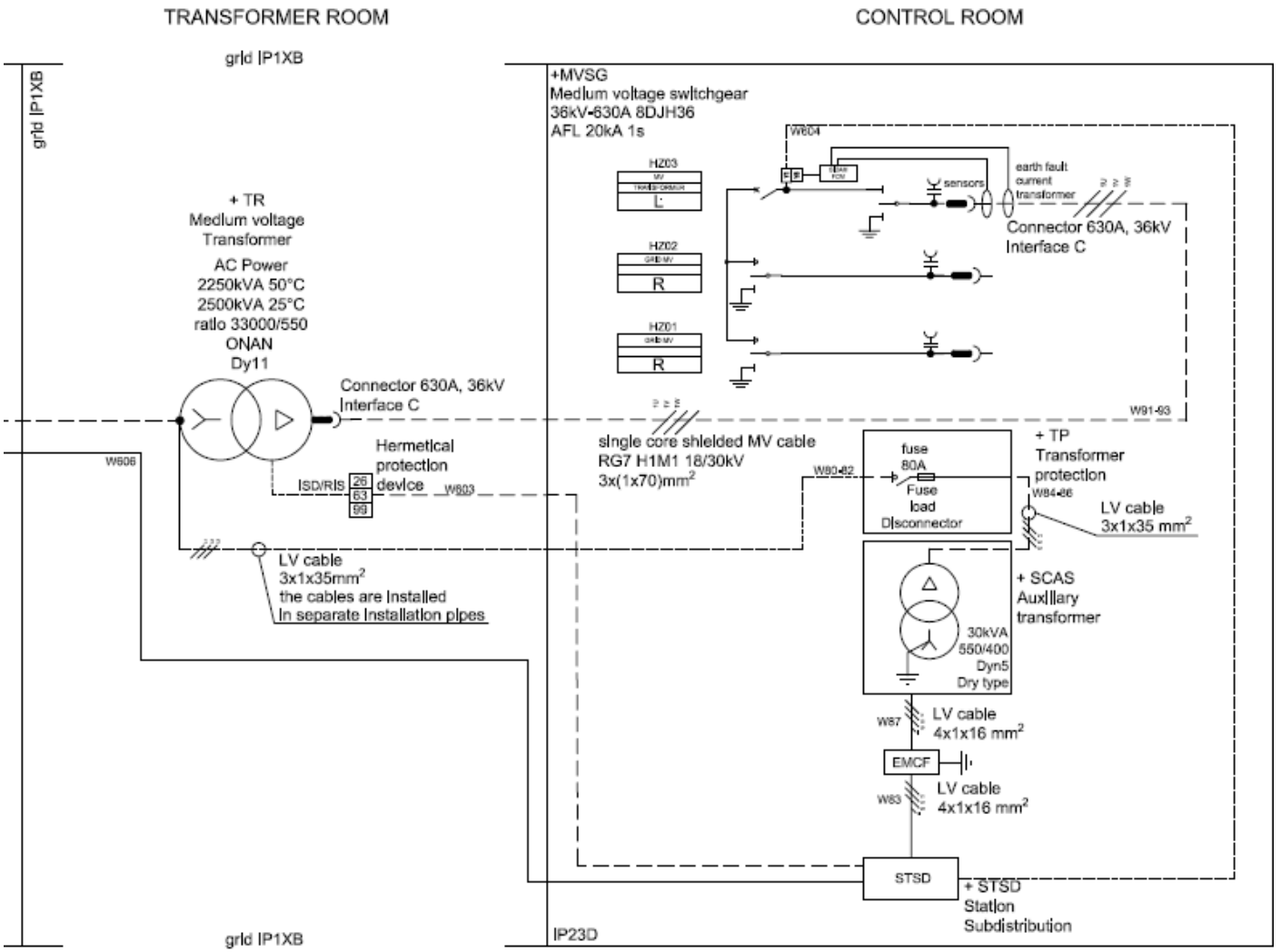
20‘ SKID – MVPS2500/2750/3000-S-AU

20‘ SKID DETAILS



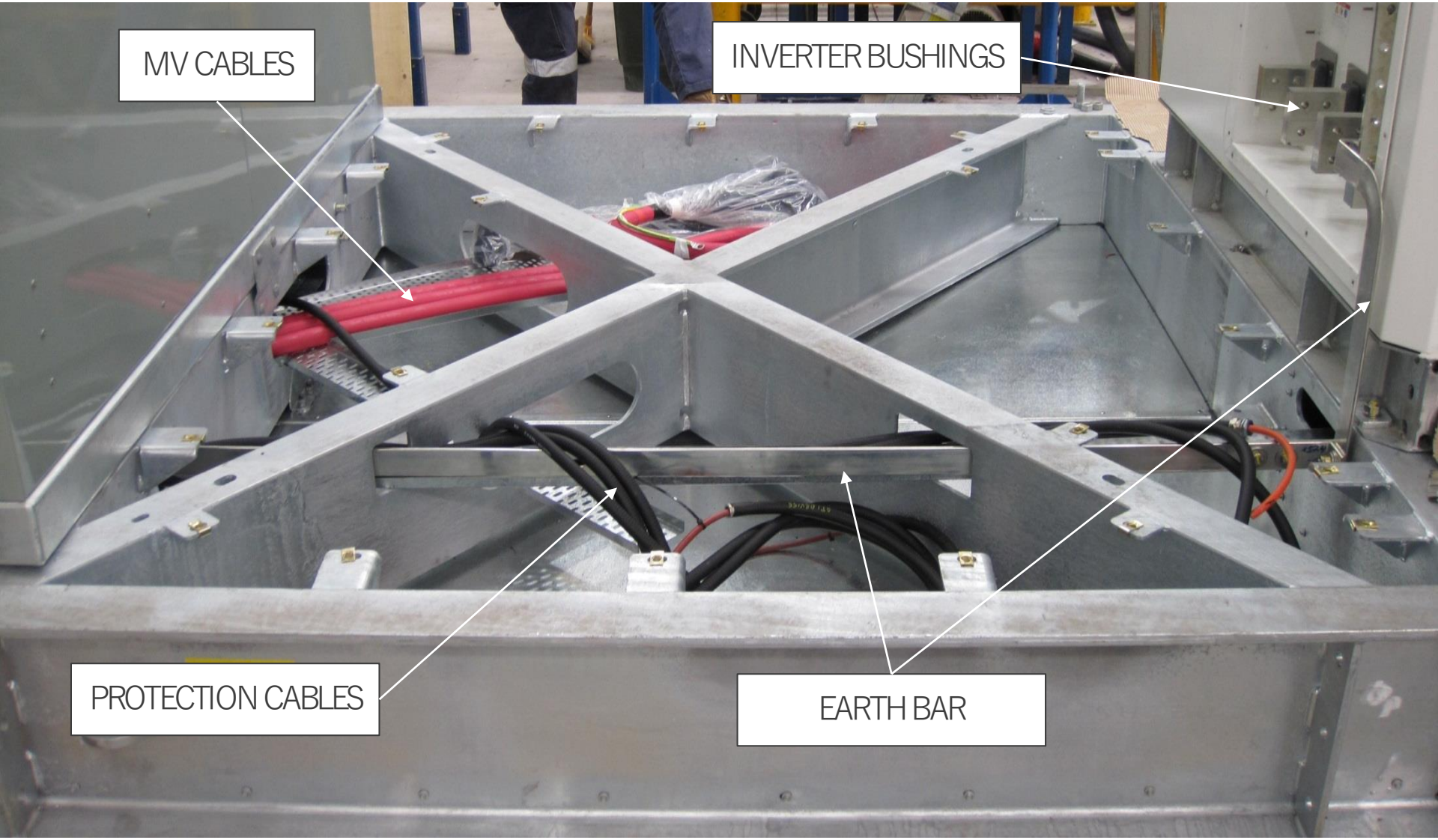
> Compact and robust design perfectly tailored for Australian conditions

MEDIUM VOLTAGE POWER STATION - INTEGRATED SOLUTION



› An example of the MV solution for SC2500-EV

OIL CONTAINMENT



HIGH QUALITY INVERTER TRANSFORMER 2500 KVA

LEVEL SWITCH

TEMPERATURE PROTECTION

TAP CHANGER

PRESSURE RELIEF VALVE

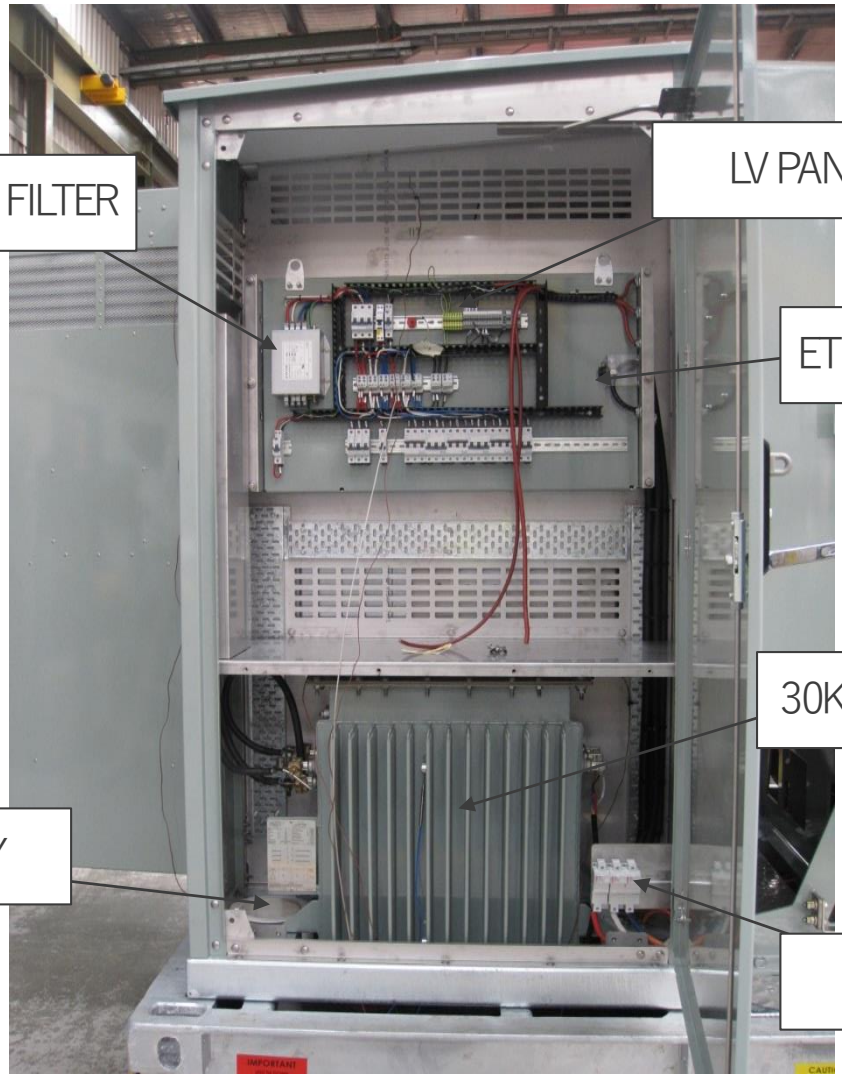
> Comprehensive transformer protection – for maximum safety and reliability

1. For Testing Purposes only

MV SWITCHROOM

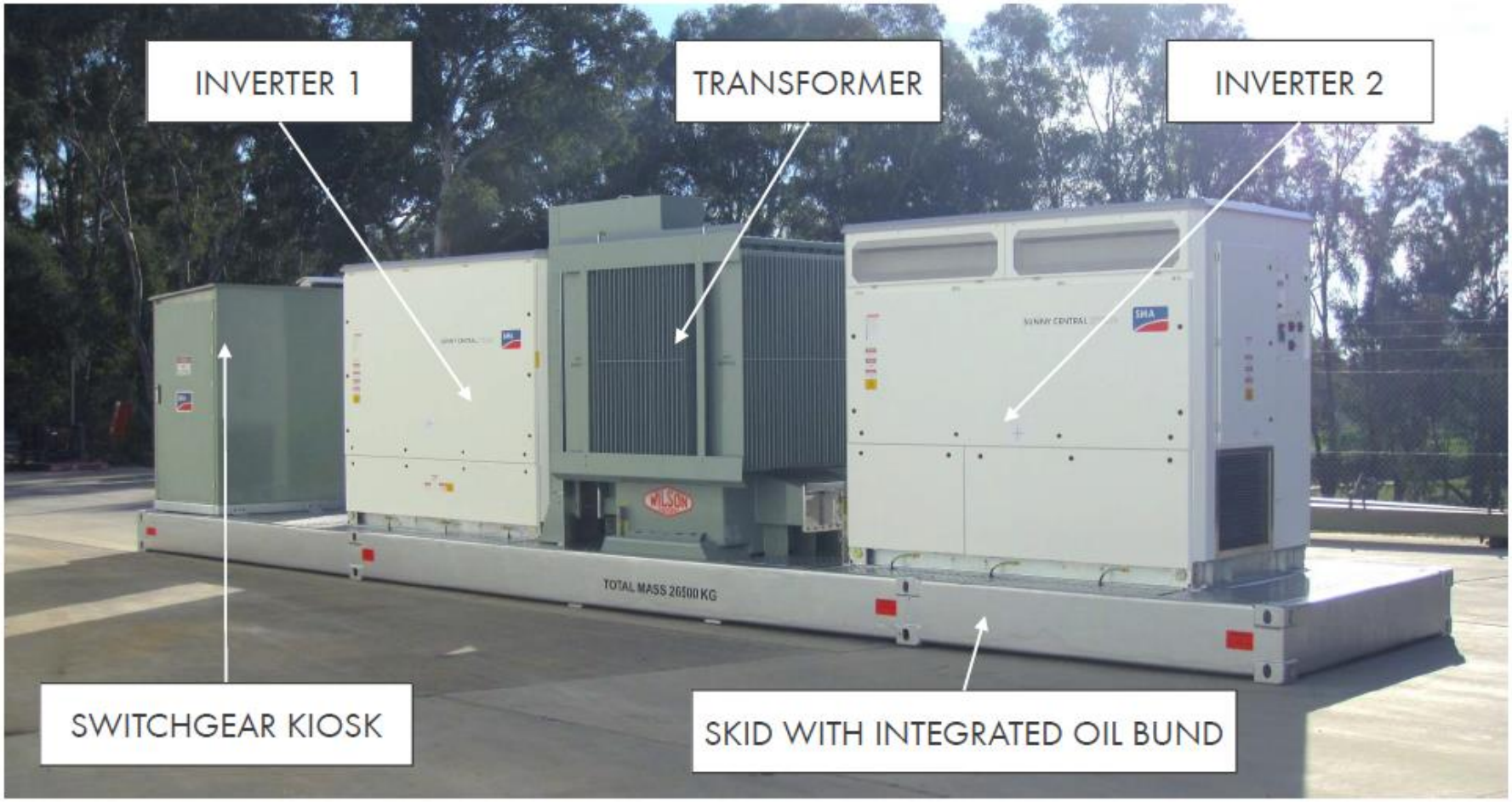
› Top quality switchgear for maximum availability

LOW VOLTAGE CABINET



› Configurable Low Voltage to suit your individual needs

40' SKID – MVPS5000/5500/6000-S-AU



40’ SKID DETAILS

ARC FLASH EXHAUST

PETRO PIPE

MV CABLE

OIL SPLASH PROTECTION

SWITCHGEAR KIOSK LV SIDE

BUSWAY 01

BUSWAY 02

INVERTER 01

4 WINDING TRANSFORMER

INVERTER 02

> **Easy access from all sides**

The new dimension up to 6MVA

MVPS 4400SC / 4950SC / 5000SC-EV / 5500SC-EV / 6000SC-EV

Maximum performance
at minimum costs

Completing the Range for Large Scale PV

500 2000 2500 6000

Max. AC Power (kW)

MVPS 500SC – 2000SC

- Turnkey system solution with Sunny Central CP XT inverters in 20‘shipping container
- 500 kVA – 2000 kVA

MVPS 2200SC – 3000SC-EV

- Turnkey system solution with one Sunny Central 2200/2500-EV/2750-EV/3000-EV inverters in 20‘shipping container
- 2200 kVA – 3000 kVA

MVPS 4400SC – 6000SC-EV

- Turnkey system solution with two Sunny Central 2200/2500-EV/2750-EV/3000-EV inverters in 40‘shipping container
- 4400 kVA – 6000 kVA

> Providing a complete product platform for all central inverter solutions.

MVPS 5000SC-EV – The New Dimension in Cost Efficiency

20%

Reduced watt specific price*

35%

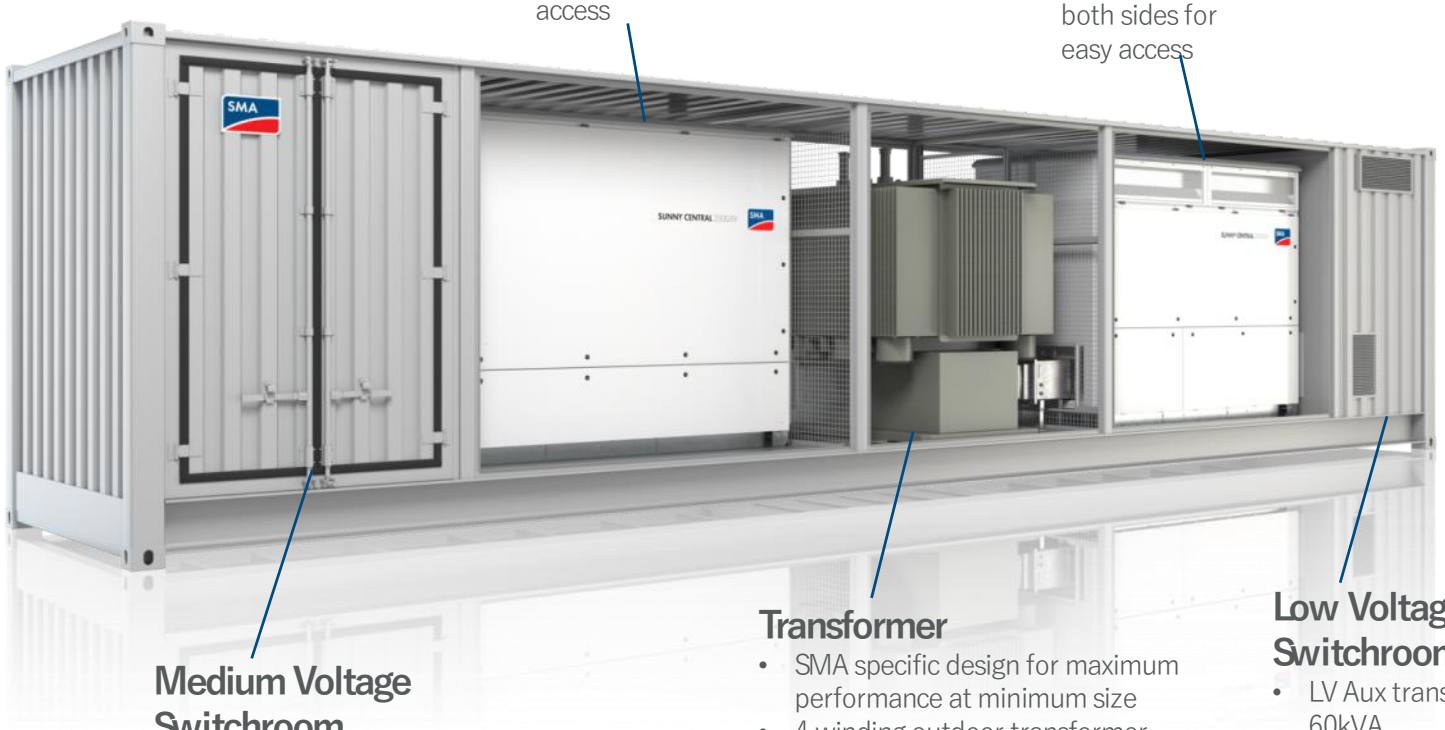
Lower transportation costs*

10%

Reduced installation costs*

*Maximum possible savings compared to MVPS2500SC-EV.

High Performance Turn-Key Solution – Minimum Space



Inverter 02
Open from both sides for easy access

Inverter 01
Open from both sides for easy access

Medium Voltage Switchroom
- Walk in switchroom
- Inverter 1 – Comms + MMI
- MV switchgear
- Fire detection

Transformer
- SMA specific design for maximum performance at minimum size
- 4 winding outdoor transformer
- ONAF or KNAF*
- LV bushings at bottom of transformer tank

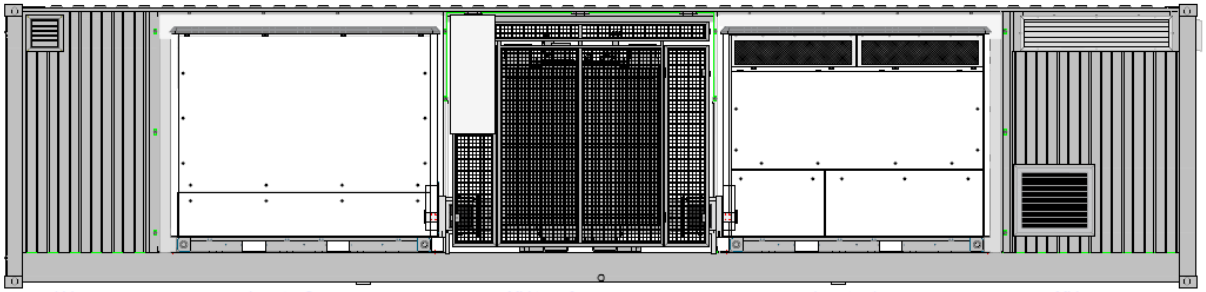
Low Voltage Switchroom
- LV Aux transformer upto 60kVA
- Inverter 01 – Comms + MMI
- Fire detection
- Space for customization (SCADA DAS, Array Tracker Controller…)

› Robust shipping container – IEC type approved station.

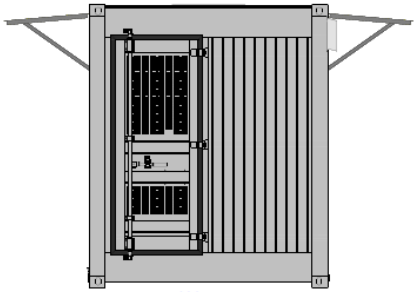
*KNAF - biodegradable oil, fan forced cooling
ONAF - mineral oil, fan forced cooling

High Performance Turn-Key Solution – Minimum Space

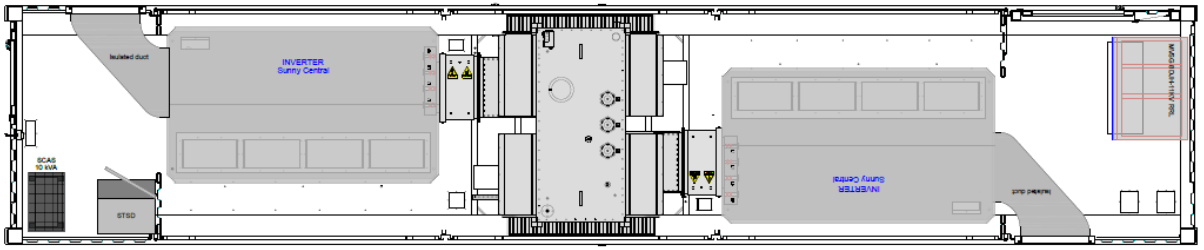
Left side view



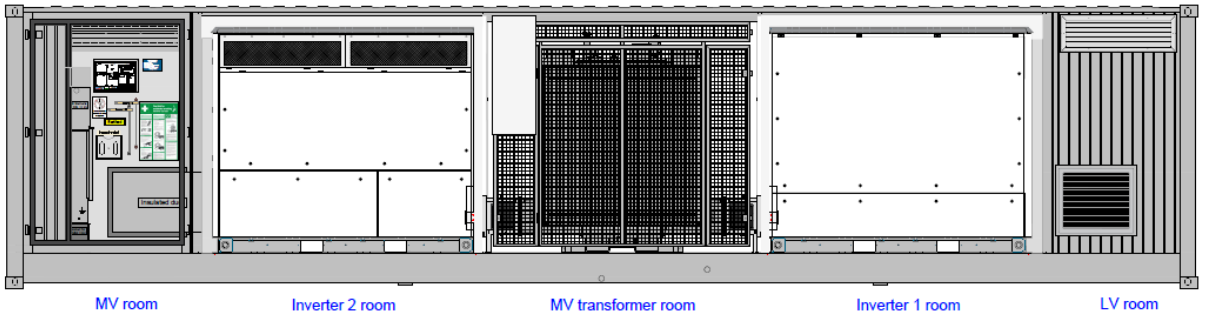
Front side view



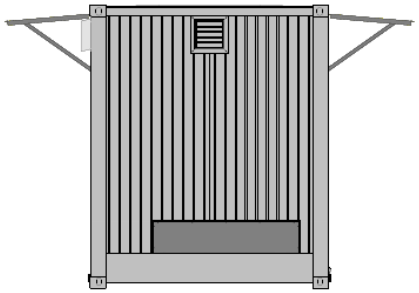
Top view - without the roof



Right side view - with MV room door open



Rear side view



› **Robust shipping container – IEC type approved station.**

*KNAF - biodegradable oil, fan forced cooling
ONAF - mineral oil, fan forced cooling

SAFETY EQUIPMENT

3.10.7 Fast-stop switch

With the "Safety equipment" order option, the MV Power Station is equipped with a fast-stop switch.

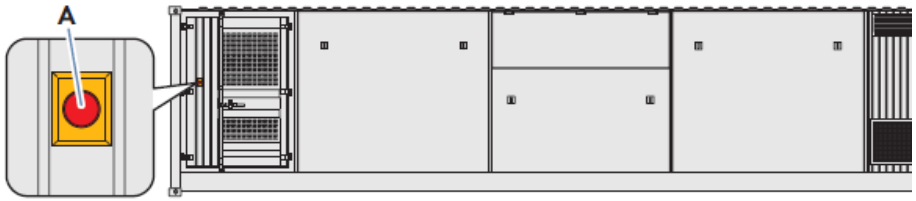


Figure 15: Position of the fast-stop switch

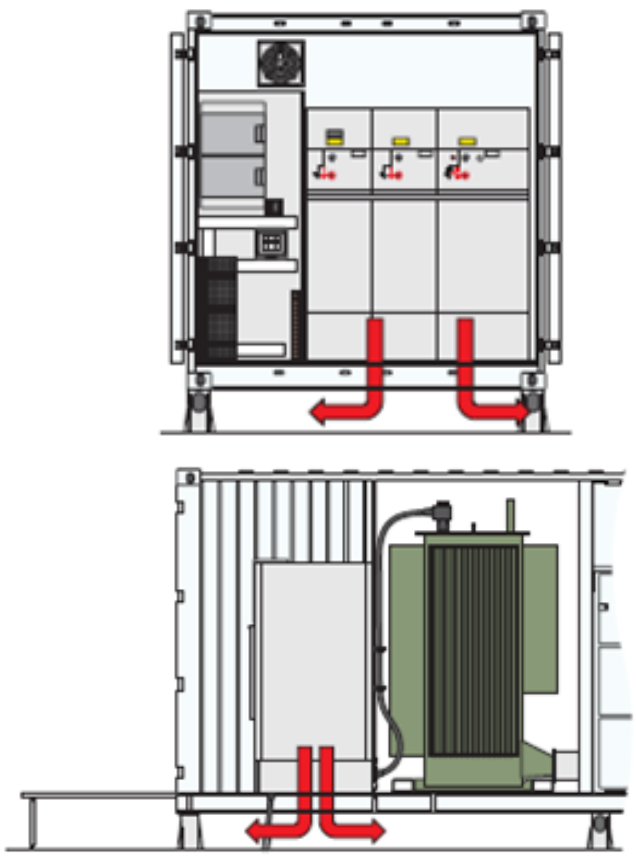
Position	Designation
A	Fast-stop switch
B	Medium-voltage compartment

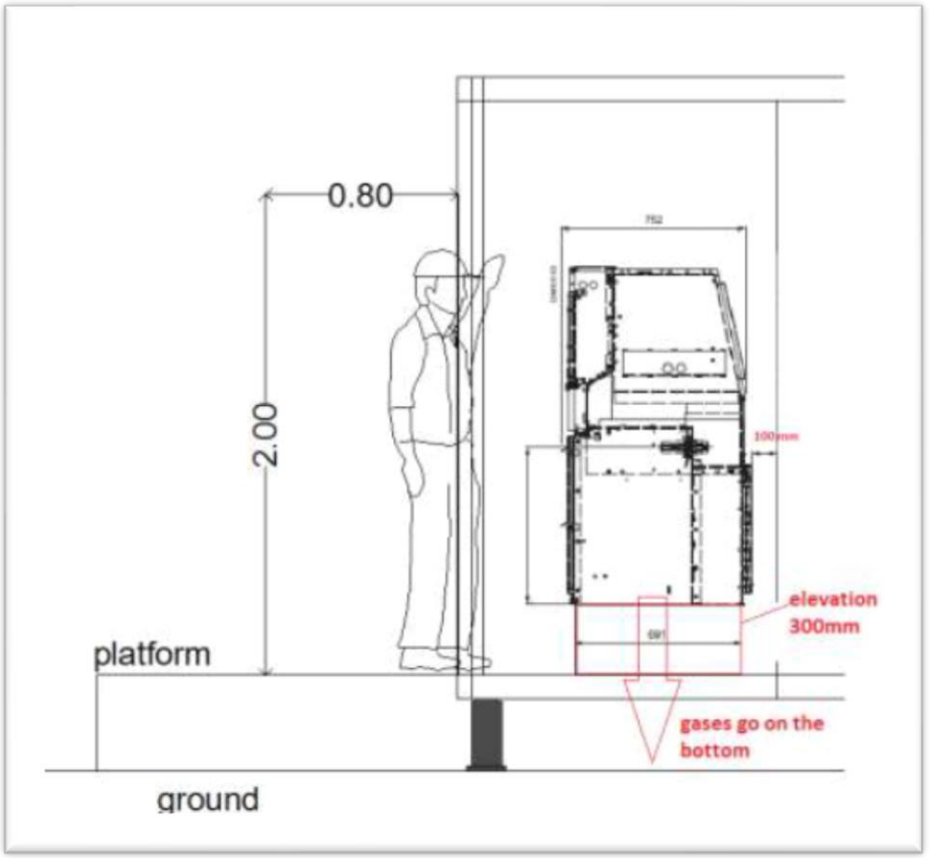
Fire Heat Detector

Optional safety devices

MV SWITCHGEAR

- **Safety first** according to the standards IEC 62271-202, IEC 60076 and IEC 60271-200
- **Internal arc classification** in the switch room IAC A 20 kA 1 s





Internal arc pressure at the MV Power Station

MV SWITCHGEAR

Before

> Example video of the consequences of an Internal Arc Flash without appropriate protection

> The burning indicators show the severe damage caused by this arc flash

> After a first unsuccessful test, the design was improved

After

> Example video of the Internal Arc Flash Test after design improvement

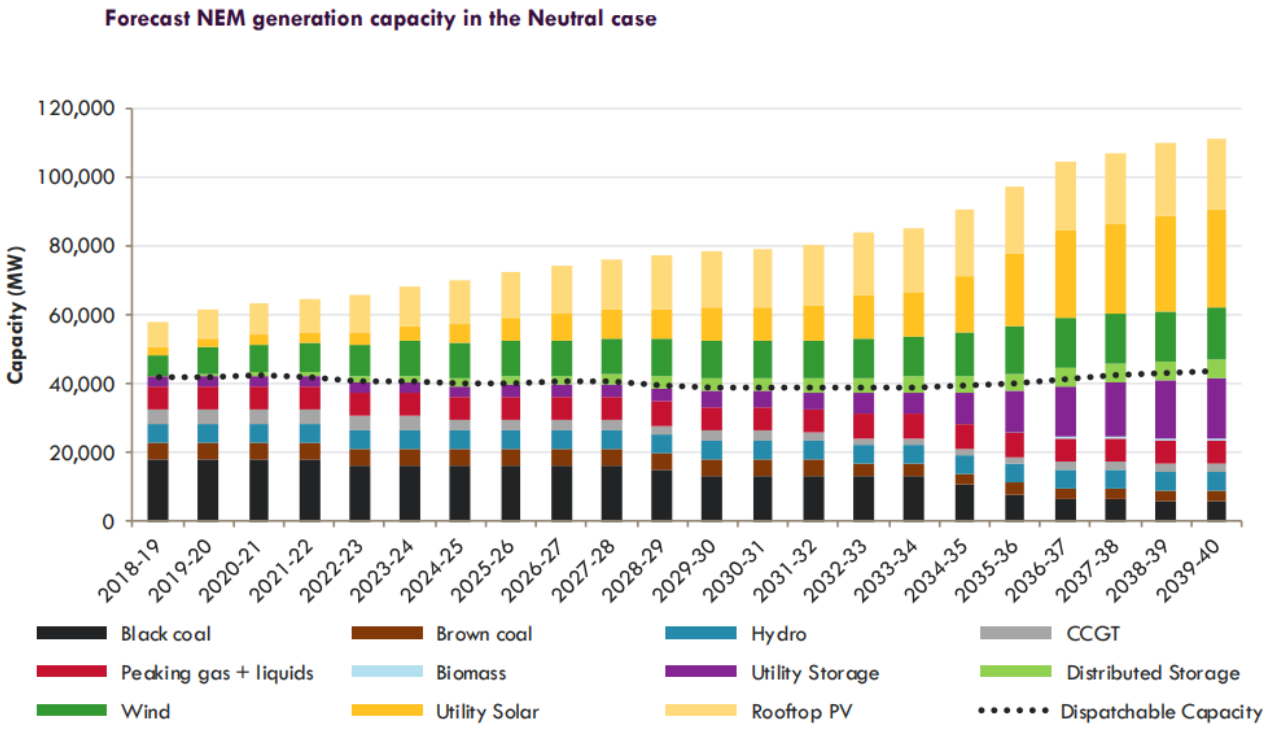
> As none of the indicators burns, operation of switchgear is considered safe!

> If not designed for Arc Flash, an operator may not survive operating the switchgear!

> Whilst the likelihood for this risk may be very low, the consequences are fatal and as such this risk would not pass a HAZOP analysis (Hazard and Operability Study)

AUSTRALIA UTILITY MARKET OVERVIEW

- Conservative estimates of generation sources to 2040 highlight the shift to renewables
- Utility Solar and storage based solutions will form a significant percentage of the energy mix
- Overall it is projected that Solar and storage will represent in excess of 40% of the total energy mix



ENERGY
THAT
CHANGES

SOCIAL MEDIA
www.SMA.de/Newsroom