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
DC connection area

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

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

<table>
<thead>
<tr>
<th>Position</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Cable insertion area of the cables for communication, control, and monitoring</td>
</tr>
<tr>
<td>B</td>
<td>Cable insertion area of the DC cables and grounding cables</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Fusing</th>
<th>Maximum DC short-circuit current $I_{SC,STC}$ (Screening factor 0.64)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 A</td>
<td>128.0 A</td>
</tr>
<tr>
<td>250 A</td>
<td>160.0 A</td>
</tr>
<tr>
<td>315 A</td>
<td>201.6 A</td>
</tr>
<tr>
<td>350 A</td>
<td>224.0 A</td>
</tr>
<tr>
<td>400 A</td>
<td>256.0 A</td>
</tr>
<tr>
<td>450 A</td>
<td>288.0 A</td>
</tr>
<tr>
<td>500 A</td>
<td>320.0 A</td>
</tr>
</tbody>
</table>

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 \( I_{sc} \)

- 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!**

6.75 MWp -> 225% DC/AC*

\[ 1.35 \text{MWp} \]  

SC 3000-EV

06.07.2019
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
World map with number of lightning strikes per year
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

RAYCAP STRIKESORB SPD’s

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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%
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
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
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
> **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 default)

• 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

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

SC30COM

Control Boards
INTEGRATED COMMUNICATION ENCLOSURE
LISTED COMS ENCLOSURE ALLOWS FOR CUSTOMIZED SOLUTIONS
- Inverter with both COM A and COM B
- Inverter with just COM A
- Multi-mode fibre
- Single-mode fibre
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
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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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- Modular adjustment for easy access and optimized service
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- Intelligent, rotating stack start-up
- Main fan for all three stacks and sine wave choke
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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Busbar connection

• Easy medium-voltage transformer connection via busbars

• Transformer temperature monitoring

• No earthwork for cabling required
**Busbar connection**

- Easy medium-voltage transformer connection via busbars
- Transformer temperature monitoring
- No earthwork for cabling required
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
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\(^\circ\) C
- No filter mats, 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 puts availability first to protect your yield.

**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
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

<table>
<thead>
<tr>
<th>Task</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacing the lithium-ion rechargeable battery.</td>
<td>10 years</td>
</tr>
<tr>
<td>Replacing the Industrial Compact Flash card.</td>
<td>10 years or after an error message</td>
</tr>
<tr>
<td>Replacing the interior fan</td>
<td>14 years</td>
</tr>
<tr>
<td>Replacing the inverter bridge fan.</td>
<td>14 years</td>
</tr>
<tr>
<td>Replacing the GFDI.</td>
<td>After 7,000 cycles or 100 short circuits</td>
</tr>
<tr>
<td>Replacing the Remote GFDI.</td>
<td>After 7,000 cycles</td>
</tr>
<tr>
<td>Replacing the three-phase short-circuiting device.</td>
<td>After a short circuit</td>
</tr>
</tbody>
</table>
AC COMPARTMENT
AC CIRCUIT BREAKER, CHOKE AND 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

- 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*

*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

Global Sales Call, November 2017, Carsten Wendt
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
**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

**SCM Benefits:** Protects stacks in case of a short circuit, no 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

06.07.2019

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
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.
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.

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 "Grid Feed", ensure that the external anti-islanding detection system generates the 24 V signal.

6.6.2 Connecting the Cable for External Fast-Stop Function

![Diagram of the terminal block for external fast stop function]

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

<table>
<thead>
<tr>
<th>Position</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Terminal block</td>
</tr>
</tbody>
</table>
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

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
Local Production for a booming market

WODONGA
- 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

- SWITCHGEAR KIOSK
- TRANSFORMER
- INVERTER
- SKID WITH OIL CONTAINMENT

TOTAL MASS 14000KG
Compact and robust design perfectly tailored for Australian conditions
An example of the MV solution for SC2500-EV
OIL CONTAINMENT

- MV CABLES
- INVERTER BUSHINGS
- PROTECTION CABLES
- EARTH BAR
HIGH QUALITY INVERTER TRANSFORMER 2500 KVA

LEVEL SWITCH

TEMPERATURE PROTECTION

TAP CHANGER

PRESSURE RELIEF VALVE

Comprehensive transformer protection – for maximum safety and reliability
MV SWITCHROOM

Top quality switchgear for maximum availability
LOW VOLTAGE CABINET

HARMONICS FILTER

LV PANEL

ETHERNET CONNECTION

30KVA AUXILIARY TRANSFORMER

CABLE ENTRY

AUX PROTECTION

> Configurable Low Voltage to suit your individual needs
40’ SKID DETAILS

- ARC FLASH EXHAUST
- PETRO PIPE
- MV CABLE
- OIL SPLASH PROTECTION
- SWITCHGEAR KIOSK LV SIDE
- BUSWAY 01
- BUSWAY 02
- INVERTER 01
- INVERTER 02
- 4 WINDING TRANSFORMER

› 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

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

- **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

- **Inverter 02**
  - Open from both sides for easy access

- **Inverter 01**
  - Open from both sides for easy access

- **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.

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*KNAF - biodegradable oil, fan forced cooling
ONAF - mineral oil, fan forced cooling
High Performance Turn-Key Solution – Minimum Space

Robust shipping container – IEC type approved station.

*KNAF - biodegradable oil, fan forced cooling
*ONAF - mineral oil, fan forced cooling
3.10.7 Fast-stop switch

With the "Safety equipment" order option, the MV Power Station is equipped with a 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
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)
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.