# Photovoltaic transformerless string inverter 1500Vdc

# TECHNICAL SPECIFICATION

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During the whole life time of the equipment

# CONTENTS

# 1 MAIN FEATURES

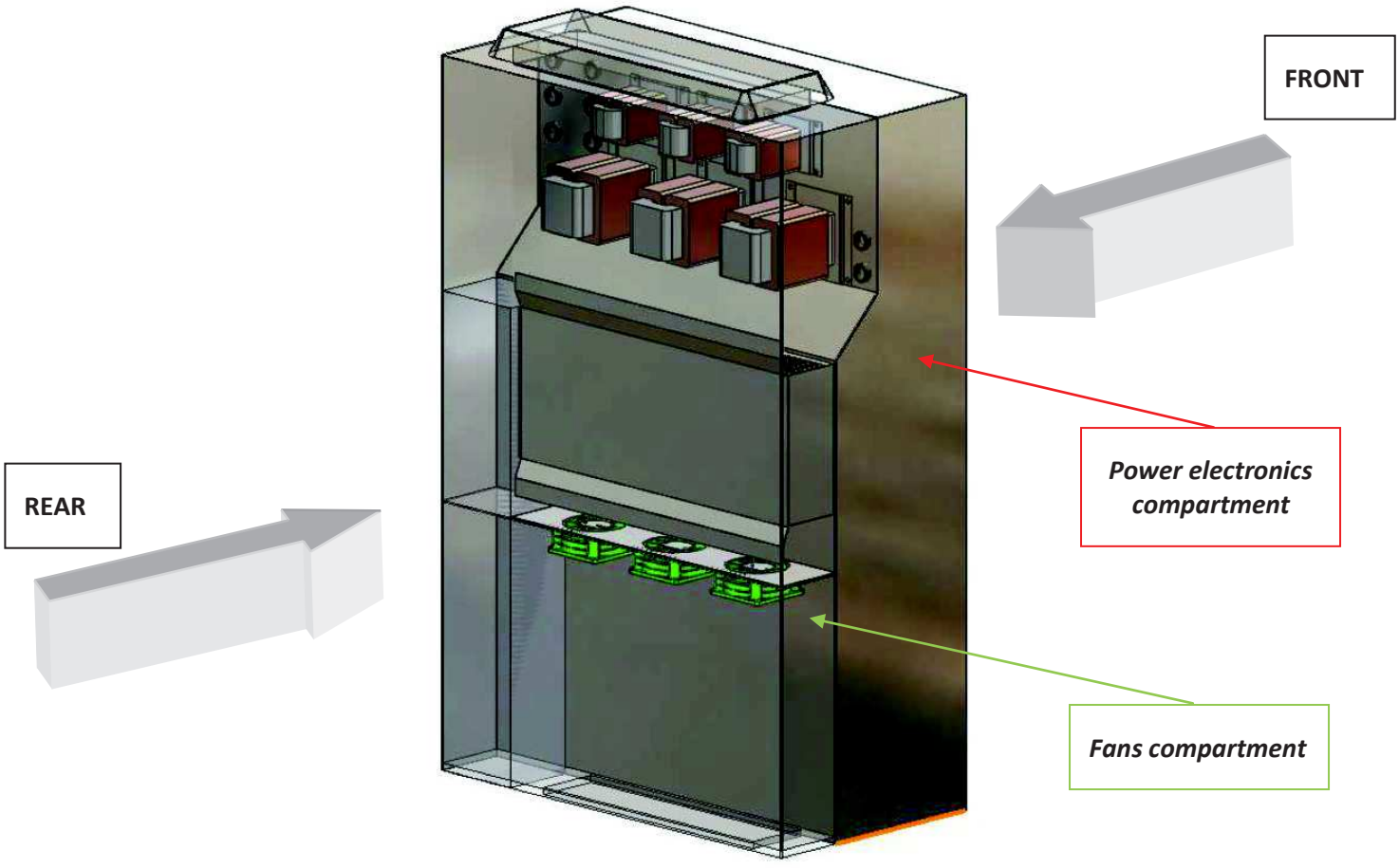
String Soleil inverter 1500Vdc is a grid-tied, three-phase photovoltaic inverter, best suited for Utility-scale PV farms, to be connected to a step-up, Low-to-Medium Voltage transformer.

It is available in one single form factor with a rated power of 110kVA, making it an equipment easy to install wall-mounted and quick to connect electrically, requiring a very few installation skill and a small set of tools for connection and mounting.

Thanks to its IP66 enclosure design (IP54 as far as fans compartment), it is best suited for outdoor operation and to work in most harsh environmental conditions of temperature (-25°C ... +50°C), dust, humidity and pollution (Degree 3).

The inverter enclosure is made of stainless steel with conformal coating for outdoor operation and from cross sectional point of view, it is divided into two different compartments:

- ***Power Electronic compartment,*** located in the frontal part of the equipment, containing the AC and DC terminals for connections, all the power electronics and control boards of the machine, accessible only by SIEL's authorized technical staff for maintenance and repairing.
- ***Fans compartment and ventilation duct,*** located in the rear part of the equipment, This section is accessible to SIEL's authorized and third party technical staff for maintenance and repairing.




Front panel of the inverter is equipped with an LCD, 2 rows alphanumeric display, showing the main electrical parameters of operation of the unit (such as AC power, voltage and current and DC power, voltage and currents), as well as status and alarms of the inverter.

On the left hand side of the display, 3 led (Alarm, Ready, Communication OK) show the status of the inverter.

On the right hand side, 3 button (Enter/ON/OFF, UP and DOWN), allow to browse through the display functions.

Furthermore, a powerful I/O interface intelligent board is included managing all the connectivity-related functionalities of the unit:

- Two isolated serial interfaces (with Modbus RTU protocol), for both monitoring and control of the equipment.
- One USB ‘type B’ serial interface, for service and maintenance operation.
- Optional Power Line Communication device.

# 2 INVERTER OVERVIEW AND ARCHITECTURE

The inverter chassis is based on a pin fin aluminium heat-sink, located on the back of the unit. This part of the equipment, has a structural function and carries the whole weight load of the unit. Pins are disposed in such a way to achieve an optimal cooling with forced air circulation within the rear located ventilation duct. Fans are IP54 protected.

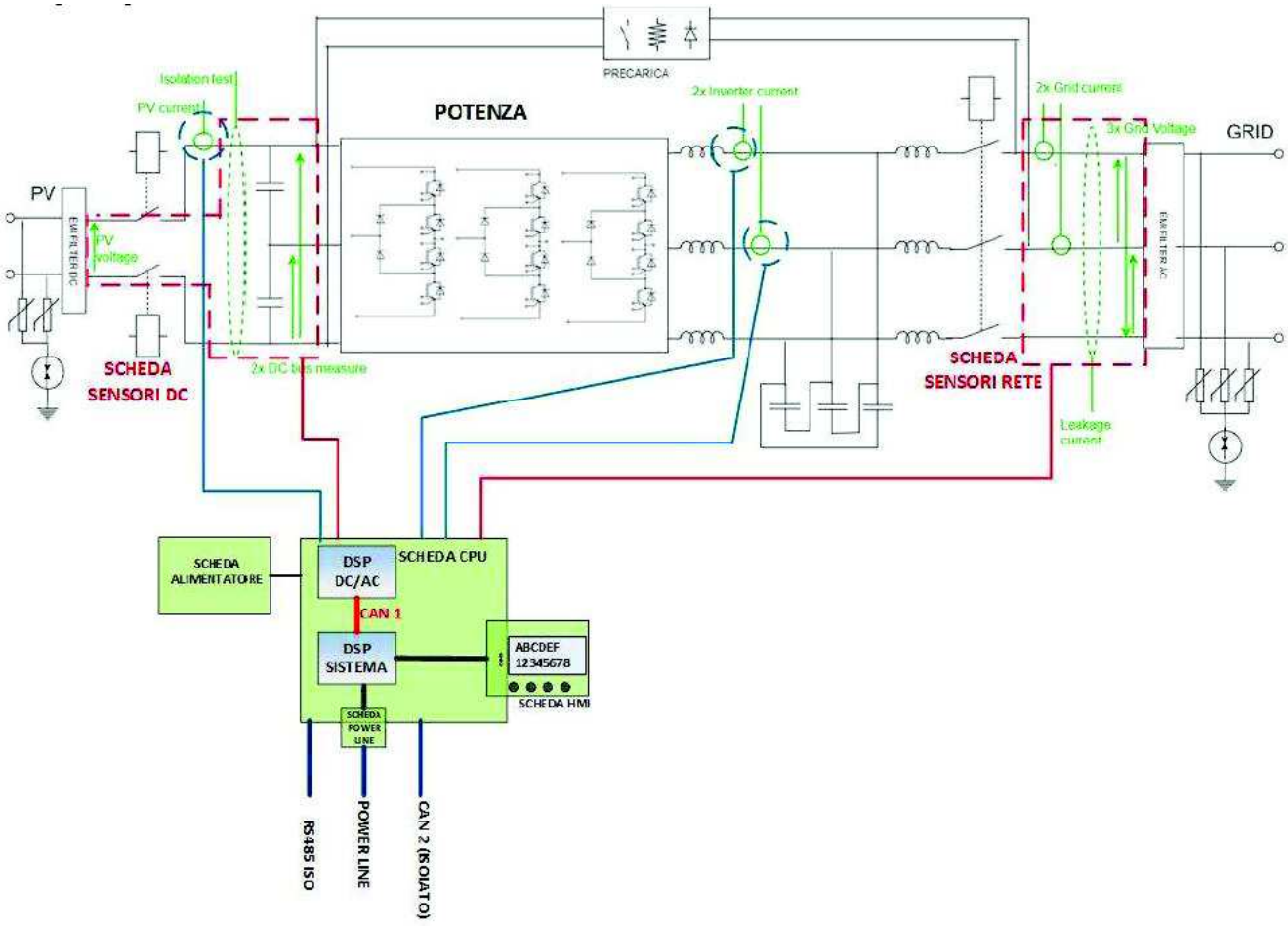
In order to properly allow the airflow for cooling, the unit has to be installed vertically, with its back aligned to the wall and secured to it through small-blocks (and nuts), fitting the eyelets located in the metal panel crossing the back of the inverter.

The enclosure, secured to the heat-sink, is made by sheet iron, with anti corrosion coating and painting (RAL 7035 for bright grey parts and RAL 1021 for yellow insertions).

The cable entrances/exits are all located on the bottom of the inverter and protected by plastic conformal cable bushings.

The machine is not equipped with manually operated disconnecting devices, which, indeed have to be installed into the parallel box in order to allow maintenance of the unit.

## 2.1 Inverter functional and physical architecture




From a functional point of view, the inverter can be divided into three sections:

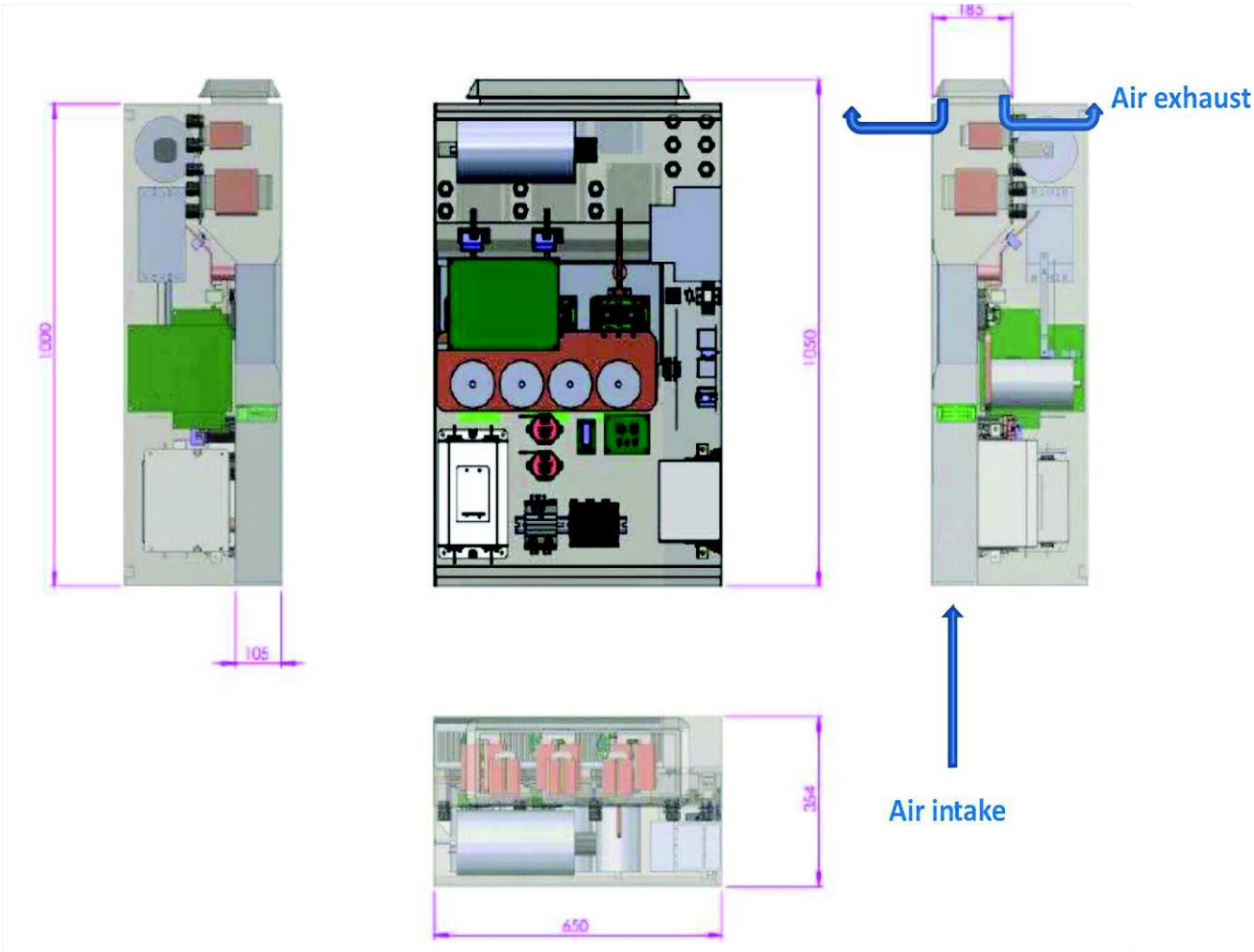
**Control section**: it is composed by the control PCB carrying DSP and microcontroller fro communication and management of the user display and by the system power supply board. These PCB are located on the uppermost layer of the HW composing the equipment, right behind the cover, immediately accessible by Service Personnel.

**Inverter and power section**: it is composed by the power semiconductors (3-level IGBT-based conversion bridge), DC filter, current and voltage sensors, input (DC) and output (AC) EMI filters, voltage surge protection devices and AC contactor.

All these HW components are easily accessible for quick repairing.

**Fans and ventilation duct:** this section is located in the rear part of the unit and contains the heatsink fins, the ventilation fans and the inductors and chokes constituting the output filter. These latter are resin-casted components IP54. Air intake grid, located in the rear bottom bottom part of the unit, are provided with anti-dust filters, easily extractable for cleaning.

## 2.2 Physical appearance and dimensions



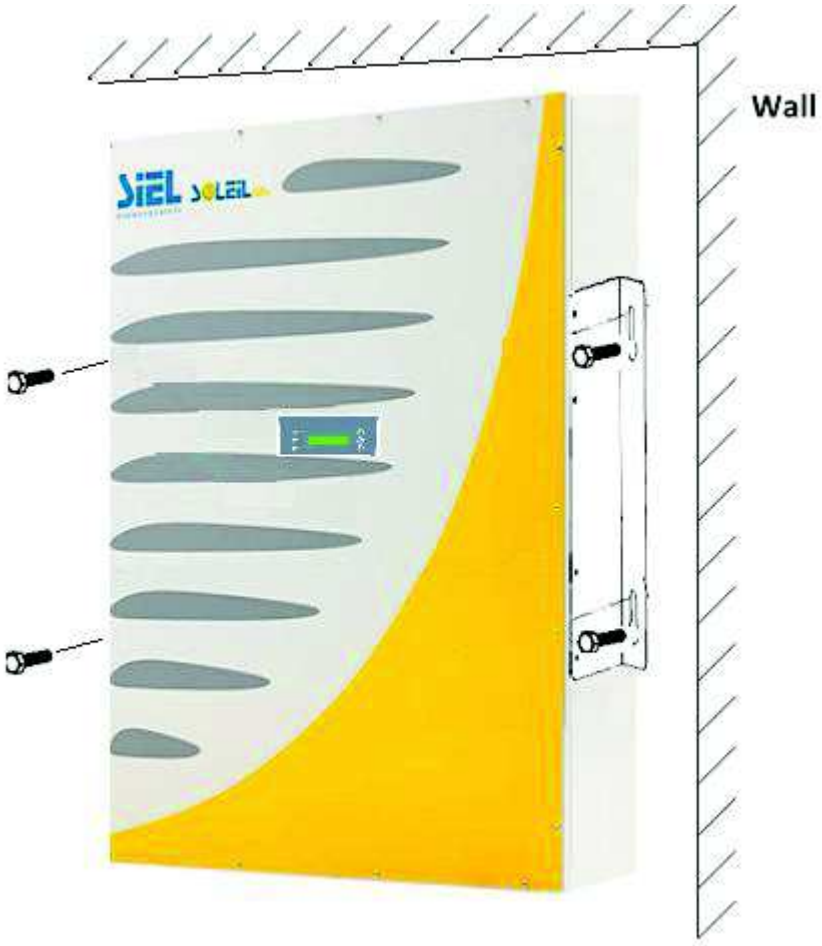
# 3 INSTALLATION OF THE PRODUCT

This Chapter provides a 'quick start' guide to get the inverter operating. As such, it must be taken as a synthetic summary of the sequence of operations required during the first start of the equipment.

Please conform to all the recommendations about issues on Safety, Environment, Electromagnetic Compatibility as described in the Installation Manual of the Inverter.

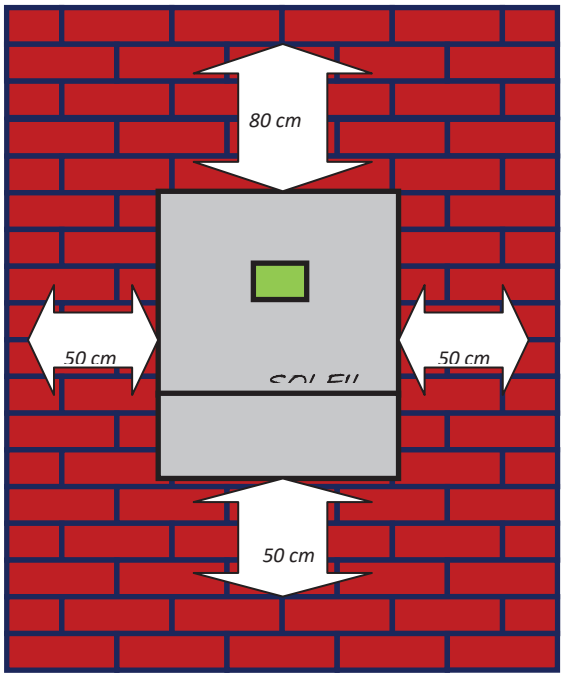
## 3.1 Wall mounting

Enclosed with the inverter delivery box, a metal bracket, some screws to fix it to the inverter chassis and 4 bolts for wall mounting, are provided, to hang the inverter across a wall. Please make sure that the wall can structurally stand a weight of approx 120kg before start mounting phase.




1. Fix any of the brackets to the inverter, through relevant screws (already positioned in the body of the unit).
2. Lift the inverter up to the desired point of mounting across the wall, which should have previously prepared by drilling in 4 points the wall and inserting the 4 relevant plugs
3. Secure the unit to the wall, by inserting the bolts in the correspondent eyelet of the bracket and tighten each of them.

4. Proper clearance must be ensured above the unit for air circulation, as shown in the following figure:




5. At the same time, appropriate clearance must be also left below the inverter, in order to respect a proper bending of cables entering the inverter for connection.

## 3.2 Wiring

Right after having the inverter secured to its mechanical support, the first check before the inverter can be operated, is to make sure that the AC disconnector (external, not included in the equipment) be open (otherwise it is necessary open it). The installation procedure of the inverter hereinafter described, assumes that Pv junction box feeding the inverter on the DC side has already been installed with the PV modules connected to it.

The sequence of operation to quickly start-up the inverter, after it has been unboxed, is summarized as follows:

a) Open the AC switch external to the unit.

b) Open the DC switch at the output of the PV junction box.

c) Make sure that no DC voltage is present (connectors in every junction box of the PV modules physically disconnected), by measuring it with a multi-meter.

d) Remove the cover panel of 'wiring section', located in the lowermost part of the inverter.

e) Plug any of the 'positive' cables from the PV string junction box into its own bushing.

f) Connect the cables to relevant terminal (+).

g) Repeat point 'd' for any of the 'negative' cables.

h) Connect the cable to relevant terminal (+).

i) Secure the cable gland on every DC cable bushings.

j) Put the cover panel of 'wiring section' back-on and secure it to the enclosure, by tightening the screws.

k) Close the AC/DC Switch ('ON' position).

### 3.2.1 Size of AC conductors for connections

The cross section of cables for the AC connection to the grid, has to be properly sized, in order to:

- minimize the Joule effect losses
- keep the series impedance of the cables as low as possible, in order to avoid voltage drops or phase displacement respect to the grid. This is mainly achieved by keeping the length of cables within certain constraints.
- Guarantee proper insulation among phases and toward ground.

Please remark that the cable has to be a 4-pole cable (3Ph + N).

Type of cable suggested is FG16R16 0,6/1k, 3x50 + 25.

### 3.2.2 AC line protection

In order to protect the AC line connecting the inverter with the grid and to operate safely on the inverter during maintenance, the installer has to provide either:

- an automatic circuit-breaker with differential protection (not part of the scope of supply), with following technical characteristics or
- Switch disconnector with fuse.

Please consider following table as reference for choice of the devices:

| **Protection device / operation disconnector** | | |
|---|---|---|
| **Type** | | |
| Type | **Automatic circuit breaker** | **Switch fuse** |
| Rated Voltage | 690V | 1000V |
| Rated Current | 160A | 160A |
| N. of poles | 3P+N | 3P+N |
| Magnetic curve type | B/C | aR |

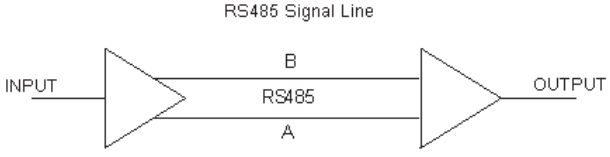
### 3.2.3 RS485 serial interface wiring

The inverter has two different RS485 isolated serial lines, featuring Modbus RTU protocol.

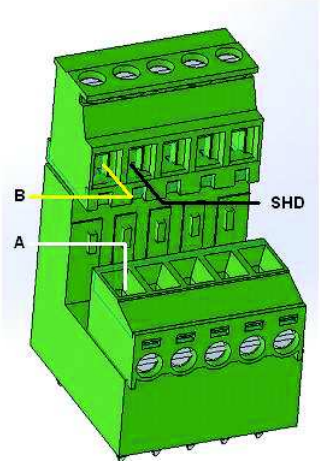
The connection between the RS485 (JP13 connector ) and the Master, requires a Shielded Twisted Pair (STP) cable (for ex. PLTC Belden 22AWG) , with characteristic impedance of 120 Ohm, which has to be routed into its bushing, located on the bottom of the unit, as shown in following picture:

**The cable gland ensures a true IP65 protection degree only if the cable is a 5-pole type, with an external diameter between 6 and 12mm.**

The mentioned type of cable, carries two conductors Data+ and Data- and it's protected against EMC coupling by an external metal shield tray.




The couple of wires (Data+ or line 'A' and DATA- or line 'B') of the RS485, have to be connected to the connector present on the intellingent communication board, as shown in following picture:




**The length of the RS485 serial cable has to be kept lower than 300m. Minimum recommended section is 0.32mm^2 per single conductor.**

For the connection of the single wires, it is highly recommended using terminals (e.g. PA6.6), previously crimped to the wire (see figure above on the right).

# 4 ‘QUICK START’

After the inverter has been properly wired to both DC source and AC grid, if DC voltage provided by PV modules is more than 200V, the display of the inverter gets ‘ON’ and starts showing firstly the ‘welcome’ message and, after a few seconds, the status of the inverter:

Please notice that the unit is now in ‘Stand-by’ mode, i.e. waiting for the ‘ON’ command to start generation. The ‘Stand-by/Alarm’ red led is on:


Therefore, the sequence of operations to start the unit, is like follows:

a) Connect the equipment with a PC running the PC tool application, through USB service port.

b) Set-up the country specific grid code, from the application and confirm. Wait for the green led on the application to turn on, meaning that the command has been correctly sent to the inverter.

c) If no alarm is present, (no red led is ‘on’), by keeping the Enter/ON/OFF button pressed for 2 seconds, the inverter moves to status ‘Ready’ (green led on, as in the figure below), where it performs the synchronization to the grid and starts generating power after some time (depending on the grid code selected). Now the inverter is in the ‘On Grid’ status.



d) If the inverter stops generation, the red led is turned on, the green led is off and the display shows the present alarm:


e) Stop of the unit could happen for following two reasons:

   a. ***Some failures/protections trip occurs***: in this case the red led turns-on and the user has to browse through the pages of the display, from the Main 'Energy' page, in order to retrieve information about the alarm/protection occurred. Please refer to Chapter 4 of this document to get insight of the alarm list and relevant root causes. If some alarms requires repairing, please contact SIEL's Service Department.

      *OR*

   b. ***The input power from the PV field is not enough to keep the unit in generation***. In this case, no red led in 'on', the inverter enters the 'Ready' status, waiting for 2 minutes before retry generation. This sequence repeats until either the power is enough to maintain the inverter in the 'On Grid' status, or the inverters gives up, because the input voltage gets lower than 200V.

# 5 DESCRIPTION OF THE EQUIPMENT

## 5.1 User interface (Keyboard and Display)

The user interface is constituted by an LCD display (2 rows, 16 characters per row), 3 leds and a 3 buttons soft touch keyboard.


First row of the display always show the status of the unit (if there are more than one message to be displayed, they are queued and rotating in and out at a rate of three seconds each), whilst second row shows-up different measures than can be selected by using the arrows

-  **ON/OFF - ENT** button ():
  - If pressed for more than 2 secs: it turns ON or OFF the inverter.
  - If pressed for less than 2 secs: it selects a function from the menu (where selection available).
-  **'Arrow Up'** and  **'Arrow Down'** buttons: used to browse through measures in the lowermost row of the display.

## 5.2 Alarm Word

The status and alarm word, is a 5 hexadecimal ciphers information, where the encoded status of each bit ( 0 or 1), represents the presence (1) or absence of the alarm.

In order to figure out which are the active bit (set to '1') in a hexadecimal cipher, please follow this procedure:

| b19 | b18 | **b17** | **b16** | **b15** | **b14** | **b13** | **b12** | **b11** | **b10** | **b9** | **b8** | **b7** | **b6** | **b5** | **b4** | **b3** | **b2** | **b1** | **b0** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **H4** | | | | **H3** | | | | **H2** | | | | **H1** | | | | **H0** | | | |

The hexadecimal encoding of every of the 5 hex ciphers, is like follows (for ex. of cipher H0):

| **Hex value H0** | **b3** | **b2** | **b1** | **b0** |
|---|---|---|---|---|
| **0** | 0 | 0 | 0 | 0 |
| **1** | 0 | 0 | 0 | 1 |
| **2** | 0 | 0 | 1 | 0 |
| **3** | 0 | 0 | 1 | 1 |

| | | | | |
|---|---|---|---|---|
| **4** | 0 | 1 | 0 | 0 |
| **5** | 0 | 1 | 0 | 1 |
| **6** | 0 | 1 | 1 | 0 |
| **7** | 0 | 1 | 1 | 1 |
| **8** | 1 | 0 | 0 | 0 |
| **9** | 1 | 0 | 0 | 1 |
| **A** | 1 | 0 | 1 | 0 |
| **B** | 1 | 0 | 1 | 1 |
| **C** | 1 | 1 | 0 | 0 |
| **D** | 1 | 1 | 0 | 1 |
| **E** | 1 | 1 | 1 | 0 |
| **F** | 1 | 1 | 1 | 1 |

The same encoding schema goes for ciphers H1,H2,H3 and H4.

Only the two bit b16 and b17 are meaningful for hex cipher H4.

Every bit of the alarm word, carries a binary information ('active'=1, 'not active'=0) about each alarm, according to herein reported table.

The column 'Cause of the event', provides a simplified explanation of the root cause of failure.

| Bit | Meaning | Alarm/Status | Cause of the event | Actions for clearing |
|---|---|---|---|---|
| b0 | Power limitation for overtemperature | Alarm | Fault or improper installation condition | Failure fixing |
| b1 | Desaturation of IGBT inverter | Alarm | Fault occurred to inverter module | Failure fixing |
| b2 | Inverter overcurrent | Alarm | Fault occurred to inverter module | Failure fixing |
| b3 | Main Frequency out of range | Alarm | Triggered by an abnormal event of the grid | Grid back to normal condition |
| b4 | Mains Voltage out of range | Alarm | Abnormal grid conditions | Grid back to normal condition |
| b5 | Internal over | Alarm | Abnormal grid | Grid back to |

| | temperature | | conditions | normal condition |
|---|---|---|---|---|
| b6 | CANBUS 2 communication fault | Alarm | Fault occurred to isolated CANbus | Failure fixing |
| b7 | Inverter 'Disconnected' | STATUS (val. '1') | 'ON/OFF' button pressed by user while in 'On grid' status, or any 'alarm' triggered | - |
| b8 | Insufficient irradiation | Alarm | Input power not enough for generation | - |
| b9 | EEPROM communication fault | Alarm | Fault | Failure fixing |
| b10 | Manual Mode | Alarm | 'Manual' mode selected by user | 'Auto' mode restored back by user |
| b11 | Loss of insulation DC | Alarm | Fault | Failure fixing |
| b12 | CANBUS 1 communication fault | Alarm | Fault occurred to internal system CANbus | Failure fixing |
| b13 | Emergency power-off | Alarm | EPO contact open | EPO contact closed and inverter reset |
| b14 | Inverter 'Ready' | STATUS (val. '1') | 'ON/OFF' pressed by user, inverter checking for proper grid condition before starting generation | - |
| b15 | Presence of operator | Alarm | Any action done on user keyboard | - |
| b16 | Inverter 'On grid' | STATUS (val. '1') | Some time elapsed after inverter entered 'Ready' status with grid OK | - |

| | | | | |
|---|---|---|---|---|
| b17 | External Protection Trip (dig. Input 0): val | Alarm | Dig. Input 0 shortened to 0V. | Feed Dig. Input 0 with 10V |
| b18 | Don’t care | - | - | - |
| b19 | Don’t care | - | - | - |

# 6 TECHNICAL CHARACTERISTICS

| SOLEIL String TLH 1500 | 110 string |
|---|---|
| **DC input side– Recommended power of the modules** | |
| Rated [kWp] | 111,6 |
| Maximum [kWp] | 140 |
| **DC input side– Electrical specifications** | |
| Operating voltage range [V][7] | 950 - 1450 |
| MPPT voltage [V][7] | 950 - 1400 |
| Max voltage (no operation) @-10°C [V] | 1500 |
| Rated DC voltage (max efficiency) | 1100 |
| Min voltage @+70°C [7] [V] | 950 |
| Max input DC current [A] | 112 |
| Modules max. Isc [A] | 140 |
| N. MPPT | 1 |
| **AC output side** | |
| Rated Apparent Power Sn [kW][1] | 110 |
| Max Apparent Power Smax [kVA][1] | 110 |
| Max Active Power Pmax [kW][1] | 110 |
| Nominal voltage [V] (line-to-line) | 640 |
| Connection | 3ph+PE |
| Rated current [A][2] | 100 |
| Maximum current Imax [A][3] | 110 |
| Min Smax operating voltage [V][4] | 90% Vn (576) |
| Minimum operating voltage [V][4] | 85% Vn (544) |
| Maximum operating voltage [V][4] | 115% Vn (736) |
| Nominal frequency [Hz] | 50 or 60 |
| Frequency interval [Hz][5] | Adjustable (47,5 - 51,5) or (55.5 to 62.5) |
| Max. efficiency[%][6] | **99** |
| Euro efficiency [%][6] | **98,6** |
| Static MPPT Efficiency [%] | **99,8** |
| Dynamic MPPT Efficiency [%] | **98,78** |
| THD I @Pnom [%] | **<3** |
| Power factor[1] | 0.9 … 1.0 leading-lagging |
| Max current unbalance | 1% |
| Short circuit current contribution [A] | 165 |
| **Other data** | |
| Ventilation system | Forced Air |
| Dissipated power without load [W] | 20 |
| Control | DSP |

| | |
|---|---|
| Output wave form | Pure Sine wave |
| Operating temperature (full power)[°C] | -25°C / + 51°C |
| Max Operating temperature [C°] | +60°C (linear derating for T>51°C) |
| Storage temperature range [°C] | -25°C / + 70°C |
| Operating humidity range | 5% / 95% |
| Maximum altitude with no power derating [m] | 3000 (s.l.m) |
| Absolute maximum altitude for operation [m] | 4000 (s.l.m) |
| Environment category | OUTDOOR IP66 (IP54 for fans compartment) |
| Pollution Degree | PD3 |
| **Protections** | |
| Anti-islanding protection | Y |
| LVFRT/HVFRT | Y |
| DC reverse connection protection | Y |
| AC short circuit protection | Y |
| DC switch | Y |
| DC contactor (or motorized disconnector) | Upon request of Q@night |
| AC switch | N |
| DC fuse | N |
| Overvoltage DC | Type 2 |
| Overvoltage AC | Type 2 |
| **Mechanical characteristics** | |
| dBA | 65 |
| Overall (WxDxH) [mm] | 650/354/1050 |
| Weight [kg] | 80 |
| DC PV string junction box | N (external) |
| **Normatives and Grid Codes** | |
| Safety IEC 62109-1, 62109-2 | Full certification (CB scheme) |
| Anti-islanding IEC 62116 | Full certification (CB scheme) |
| IEC 61000-6-4 (Emissions) | Full certification (CB scheme) |
| IEC 61000-6-2 (Immunity) | Full certification (CB scheme) |
| IEC 55030 (Efficiency) | Test report 3rd party lab |
| CEI016 | Full Certification |
| Other Grid codes | Available on request |
| **Connectivity** | |
| Serial Interface with cable / Protocol (*) | RS485 / Modbus RTU |
| Serial interface for service | (USB type 'B') – SIEL Protocol |
| Power line Communication | As plug-in, using PRIME / G3 standard |

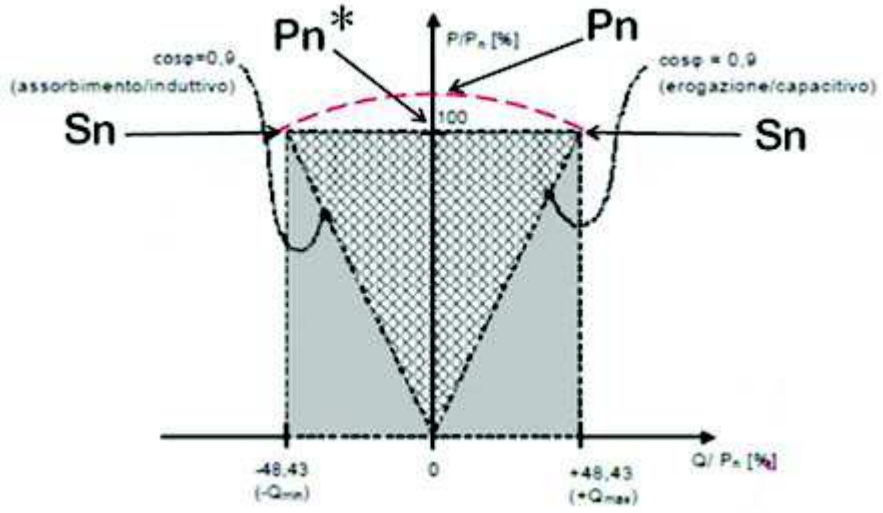
**Notes:** please refer to Annex 1 for details

# Annex 1

1. Power definitions (from table of technical characteristics):

   - **Sn:** rated value of the **apparent power**. This value is defined as the power value that can be continuously generated when the ambient temperature exceeds 40°C, up to 51°C and the voltage of operation is between 0.9Vn and the rated voltage Vn.
   - **Smax:** maximum value of the **apparent power** that can be generated throughout the whole operating temperature range and the voltage of operation is between 0.9Vn and the rated voltage Vn. This value is available from the minimum operating temperature up to 40°C, according to graphical trends "Apparent Power vs Temperature" reported in paragraph 1.1.
   - **Pmax:** maximum value of the **active power** (at power factor = 1) that can be generated throughout the whole operating temperature range and the voltage of operation is between 0.9Vn and the rated voltage Vn. This value is available from the minimum operating temperature up to 40°C, according to graphical trends "Apparent Power vs Temperature" reported in paragraph 1.1.

   **Other power definitions (see figure below):**
   - **Pn (Rated value of active power)**: This value is defined as the power value that can be continuously generated at power factor 1, when the ambient temperature exceeds 40°C, up to 51°C and the voltage of operation is between 0.9Vn and the rated voltage Vn.
   - **Pn* (Rated value of active power at p.f. = 0,9Pn)**: This value is defined as the power value that can be continuously generated at power factor 0.9 (lead/lag), when the ambient temperature exceeds 40°C, up to 51°C and the voltage of operation is between 0.9Vn and the rated voltage Vn.




2. **In:** rated value of current, corresponding to the rated value of apparent power Sn, when the voltage is at its rated value Vn.
3. **Imax**: maximum value of current, corresponding to the maximum value of apparent power, when the grid voltage is 0.9Vn (-10%).

4. Voltage definitions
   - **Min Smax operating voltage**: minimum voltage at which the Smax generation of the maximum power is possible.

- **Min operating voltage**: from 90%Vn to 85%Vn the inverter operates within the limitation of the current; for voltages less than 85%Vn, the inverter can remain connected to the grid without generating power (LVFRT function enabled, see graphic) or disconnect itself.
- **Max operating voltage**: for voltage values above 115%Vn, the inverter disconnects from the grid.

5. **Frequency range**: Configurable according to the type of connection.

6. **Max Euro Efficiency**: Efficiency measured at the DC voltage of 1100V.

7. **Operating temperature range**: Range of temperature within which the equipment can deliver the rated apparent power **Sn** with grid voltage at its rated value **Vn**.