Inverter for photovoltaic applications

Photovoltaic transformerless
Central inverter

Tier 1: 530Vac output
550, 1100M, 2200M, 3300M, 4400M

Tier 2: 600Vac output
665, 1330M, 2600M, 4000M, 5330M

Tier 3: 640Vac output
708, 1415M, 2830M, 4245M, 5660M

Tier 4: 640Vac output
764, 1528M, 3056M, 4584M, 6112M

TECHNICAL SPECIFICATION

STORE THIS DOCUMENT IN A SAFE PLACE FOR REFERENCE
During the whole life time of the equipment

CONTENTS

1 SOLEIL DSPX TLH 1500VDC PRODUCT OVERVIEW

The Soleil DSPX TLH 3Ph, Utility-Scale PV inverter family, is added now with a 'state-of-the-art', brand new Inverter sub-family: the TLH 1500Vdc model. This new inverter is the ultimate solution for Utility Scale, large PV plants.

1500Vdc technology has recently begun to be considered by most of the EPCs and installers, the solution of choice for its high cost-saving rate in terms of connections of the inverters.

It allows scaling-up power rating of the installation, by keeping the current relatively small, on both the DC side and AC side of the inverters.

SIEL Soleil TLH 1500 is the answer to these highly challenging and rapidly changing demand.

Soleil TLH 1500 family is divided into three tiers, depending on the DC MPPT range and on AC output voltage of the inverter.

Each tier, is based on a different 'power core module', with a different baseline power:

- Tier 1: output voltage = 530Vac, 'power core': 550kVA rating.
- Tier 2: output voltage = 600Vac, power core': 665kVA rating.
- Tier 3: output voltage = 640Vac, power core': 708MVA rating.
- Tier 4: output voltage = 640Vac, power core': 764MVA rating.

Inverters with 'M' suffix, are composed by a 'twin power core' (Module '1' and 'Module '2') and they work according to 'Master & Multi-Slave' logic, as described in the following.

For instance, the 1.1MVA inverter is made by two 'power cores' of Tier 1, each of which delivering 550kVA, both controlled by a single DSP-based electronic card. It can be added in parallel with up to 3 more inverters of the same type, summing-up in a overall 4.4MVA system.

At the same time, the 1.33MVA inverter is made by two 'power cores' of Tier 2, each of which delivering 665kVA, both controlled by a single DSP-based electronic card,. It can be added in parallel with up to 3 more inverters of the same type, summing-up in a overall 5.33MVA system.

At the same time, the 1.415MVA inverter is made by two 'power cores' of Tier 3, each of which delivering 708kVA, both controlled by a single DSP-based electronic card,. It can be added in parallel with up to 3 more inverters of the same type, summing-up in a overall 5.66MVA system.

Lastly, the 1.528MVA inverter is made by two 'power cores' of Tier 4, each of which delivering 764kVA, both controlled by a single DSP-based electronic card,. It can be added in parallel with up to 3 more inverters of the same type, summing-up in a overall 6.112MVA system.

All the models of Soleil DSPX TLH 1500Vdc platform with 'M' suffix, benefit of the Master & Multi-Slave' approach, a brand new 'modular' and outstanding advanced technology, allowing to reach very large power ratings by increasing the weighted efficiency of the system.

Every single 'power core' composing the inverter, can be turned-on or disabled, depending on the actual amount of power available on the DC, achieving optimization of the efficiency at whichever power level.

In a multi-inverter system, the DC bus is common either among all the units composing the system, or at a two units granularity, i.e, for instance, a 5660M system, is composed in the two following possible ways:

- <u>Single transformer solution</u>: 4 inverters (8 power cores), each of 1415kVA.
    - AC connection: one MV-LV transformer, single secondary winding, common to all the 4 inverters.

  - DC connection: one DC bus common to all the 4 units, one DC sub-combiner cabinet.
  - Number of MPPT: 1 for the whole system.
  - Master & Slave 'granularity': 1 'power core' (708kVA) out of 8.

- Twin-transformer solution: 4 inverters (8 power cores), each of 1415kVA.
  - AC connection: two MV-LV transformers, each one rated half of the system (3000kVA).
    - Transformer 'A' connected to Inverters 1 and 2.
    - Transformer 'B' connected to Inverters 3 and 4.
  - DC connection: two DC buses, two DC sub-combiner cabinets:
    - 'A' common to Inverters 1 and 2.
    - 'B' common to Inverters 3 and 4.
  - Number of MPPTs: 2, one for system composed by Inverters 1 and 2, another one for system composed by Inverters 3 and 4.
  - Master & Slave granularity: 1 'power core' (708kVA) out of 4.

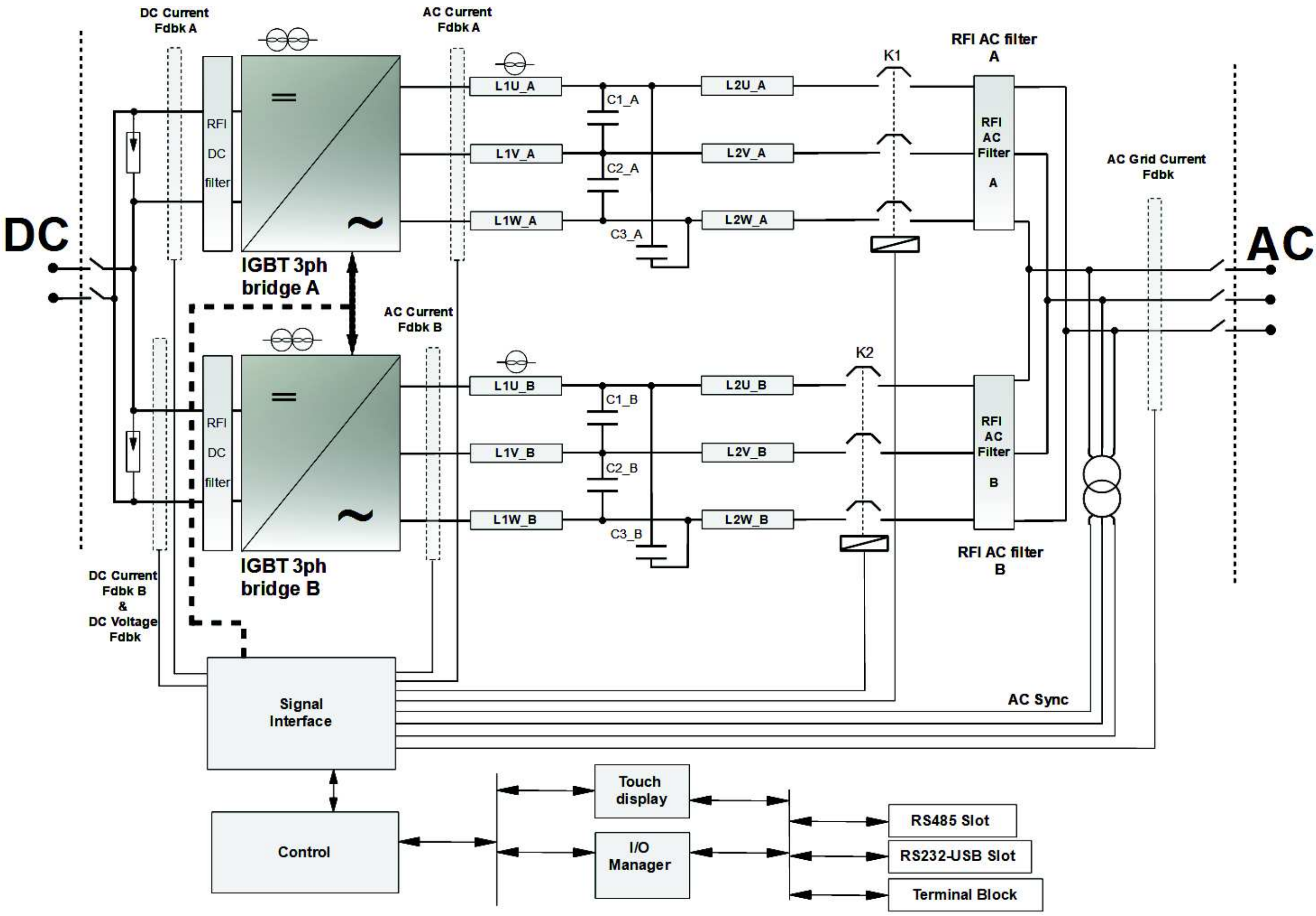
DC sub-combiner cabinets, are available for indoor operation.

1.1 Appearance of the inverters
(Tier 1 550, 1100M - Tier 2 665, 1330M - Tier 3 708, 1415M - Tier 4 764, 1528M)

1.2 Appearance of multi-inverter system (2 inverters)

2 INVERTER ARCHITECTURE AND FEATURES

Here below is a representation of the schematic block diagram of an 'M'-type inverter (2 power cores):



The inverter is composed by two power modules (550kW /665kW / 708kW/764kW each, depending on what 'tier' the inverter belongs to), both controlled in a Master & Slave logic by a Control board, receiving all the measures and the feedback signals from both modules and sending to relevant power bridges, the firing commands.

In a multi-inverter model, the architecture of each unit is the same as the one represented above. In this case, firing commands are generated by the Master Control (the Control board of one of the units present in the system, let's call it n. '1') and distributed throughout the whole system to all the other units. Similarly, all the units notify to the Master their own status and alarms through a CAN BUS line.

Therefore, in a multi-inverter system (e.g TLH DSPX 5330M), relevant control boards are connected according to a couple of daisy-chain links:

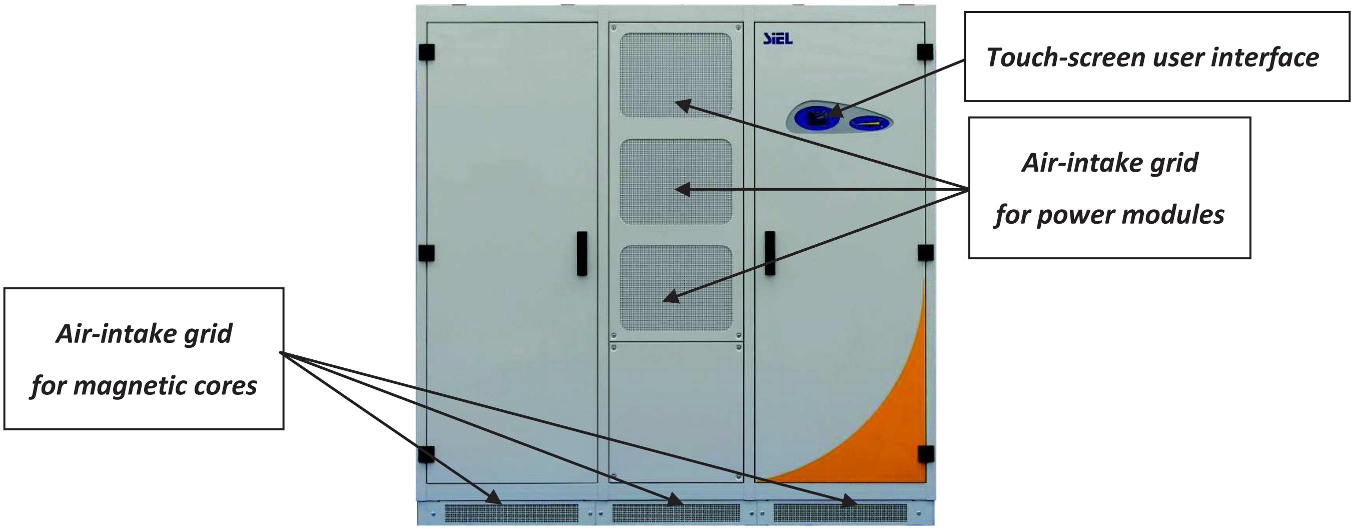
- Firing command connection: from inverter 'Master' to inverter 2, then from inverter 2 to inverter 3 and from inverter 3 to inverter 4.
- CAN bus connection: from inverter 'Master' to inverter 2, then from inverter 2 to inverter 3 and from inverter 3 to inverter 4.

Each 'M-type' inverter, has its own RS485 serial interface, i.e. every single inverter composing a multi-inverter system, is 'seen' by a remote monitoring system as a set of 'n' inverters, 'n' being the number of 'M-type' inverters connected.

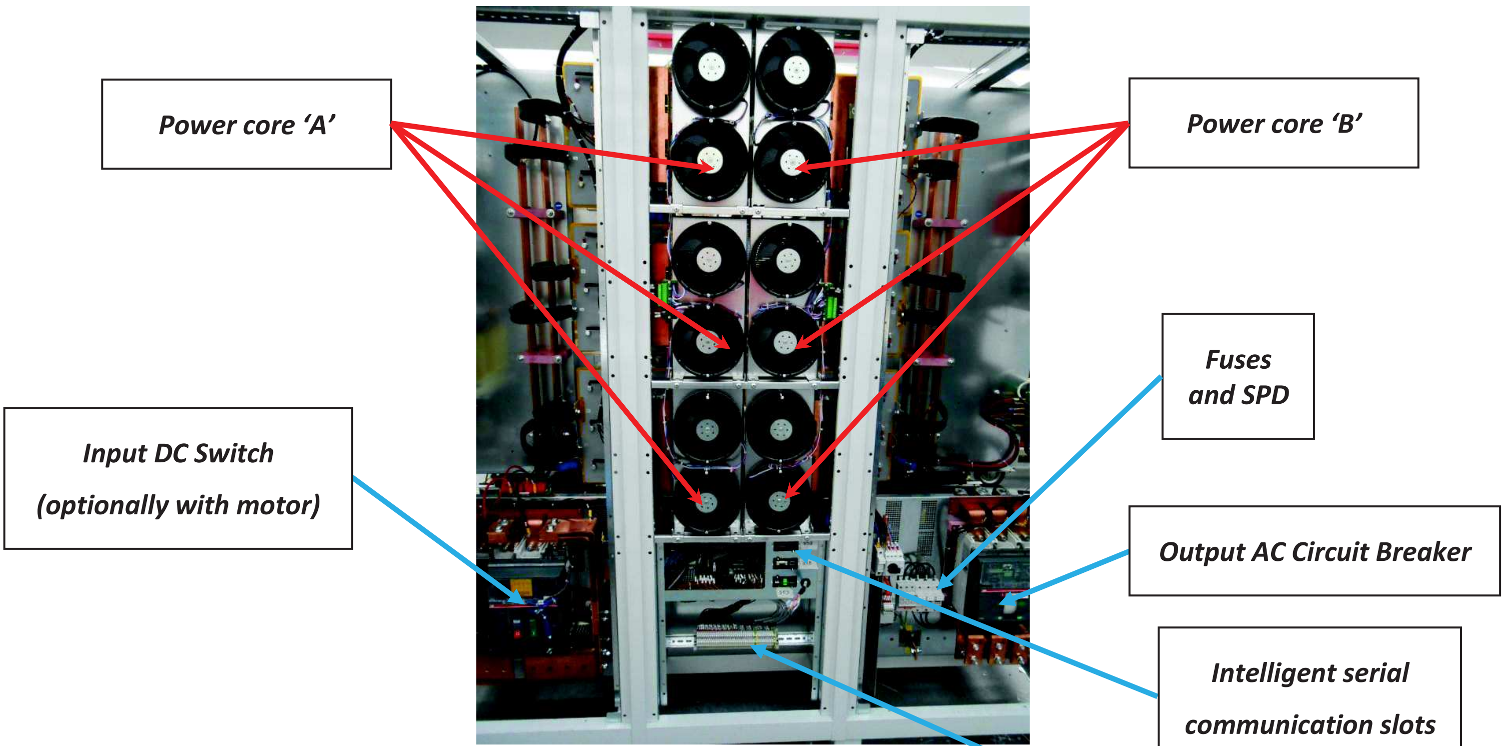
For example, in a Soleil DSPX TLH 5660M, there are n=4 inverters. Every inverter has its own Modbus address associated and the list of registers is the same for any of the 4 inverters connected together in the system.

2.1 Physical Layout

Here below are the views of the single inverter, showing displacement of main components:

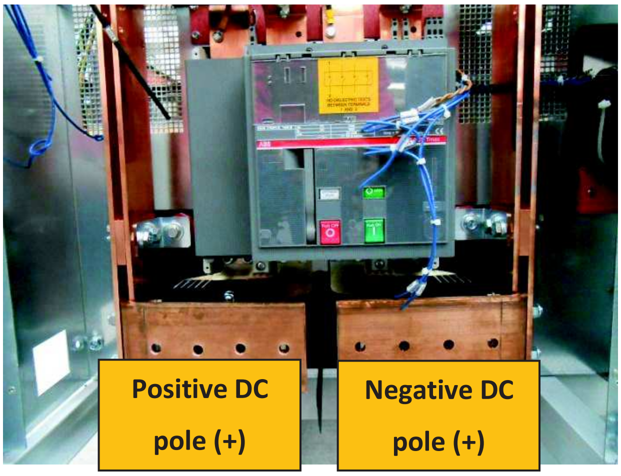


Front view of the inverter

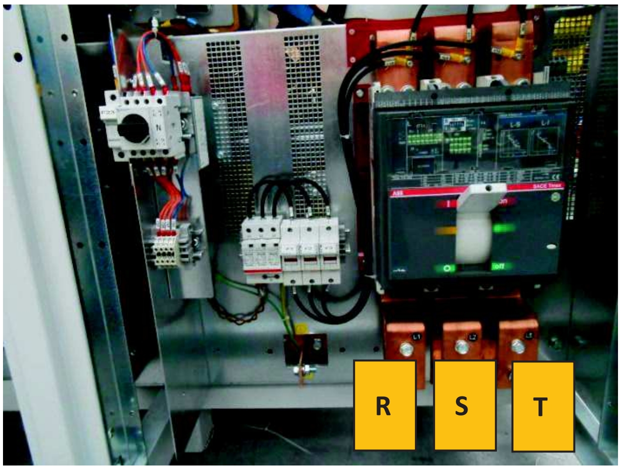


Internal view of the 'M-type' inverter (2 power cores)

Following part of this chapter is dedicated to clearly identify the spots of main interest for installation and maintenance of the unit (terminal blocks, control boards, fuses, etc.).



DC Input Terminal block for connection



AC output Terminal block for connection

Inverter	550	665	708	764	1100M	1330M	1415M	1528M
AC cables (number x section in mmq)								
Suggested	2 x 400	2 x 400	2 x 400	2 x 400	4 x 400	4 x 400	4 x 400	4 x 400
DC cables (number x section in mmq)								
Suggested	2 x 400	2 x 400	2 x 400	2 x 400	4 x 400	4 x 400	4 x 400	4 x 400
Protective conductor (PE) cables (number x section in mmq)								
Suggested	1 x 240	1 x 240	1 x 240	1 x 240	1 x 300	1 x 400	1 x 400	1 x 400

Remark: the sections suggested for both AC and DC cables, have been determined on the assumption that, at the maximum current of the inverter, the environmental temperature of the cable compartment is less than 50°C (keeping into account relevant derating coefficients, according to CEI UNEL 35024).

For multi-inverter systems, cables have the same sections reported in previous table.

Please notice that, previous sections are referred to **aluminum-made** cables, out of the shelf (type of power cables: ARG7OR, Uo/U=0.6kV/ 1kV; Um=1.2kV; Udc=1.5kVdc or 1.8kV).

Each cable must carry appropriate cable gland, according to its section.

Please contact manufacturer for information about other possible material-made cables.

2.2 Operation principles

When the inverter is energized, the control system checks for the presence of all the other units. Then its control performs a scan of power grid, voltage and frequency parameters. If all the parameters are within the correct range, the inverter checks for the voltage of the photovoltaic generator and when this is found above a certain threshold, power generation may start over.

The start sequences are similar no matter whether the system is one single inverter or a multi-inverter.

In order to start generation, the AC grid contactor(s) close and the inverter begins delivering power to the three-phase power grid.

At this point, the control system (the Master control in a multi-inverter 'M'-type system), starts varying the photovoltaic generator's operating point to track the maximum power point. This tracking takes place at intervals of about 2 seconds.

If the grid voltage and frequency values are within the range of acceptance established by the grid code in force, in conditions of low irradiation, the inverter enters into standby mode for 6 minutes. After this pause, if the photovoltaic generator and grid parameters are correct, the inverter restarts automatically resuming the conversion process.

Also for 'M-type' versions, each inverter has its own control board constantly checking for the correctness of the operating parameters and activating, if needed, proper protections, whenever some abnormal condition is detected.

The status of each inverter is then notified:

- to the Master Control through CAN BUS link,
- to the user through the touch screen signalling interface,
- to the remote monitoring system form its own RS485 serial interface.

The list of the statuses that an inverter can enter, after an event occurs, are reported here below:

- **Protection**: this is the maximum 'severity' level of action. One (or many) single inverter trips and stops, the others may keep running at a reduced power level.

  Information about the entity of the protection is notified to the Master through CAN BUS link.

  The Operator intervention is then needed to resume the operation or for calling the Service.
- **Alarm**: the control of one (or many) single inverter detects some anomaly potentially affecting the whole system and decides to stop itself 'temporarily', retrying to resume the operation after a short time. If the maximum number of the 'retry' is reached in a preset time interval, the inverter enters the 'Protection' state. One example of this condition is the 'Low solar radiation' event, in this case, the inverter , after the stop, resumes operation within 6 minutes.
- **Anomaly**: the control of one (or many) single inverter detects an abnormal self-relevant condition, but severity level of that condition is not such to arrest the inverter. The anomaly gets notified to the Master (through CAN BUS link) and communicated to the user through the display and the serial communication channel to the remote monitoring system.

2.2.1 Maximum power point tracking (MPPT)

In a multi-inverter system ('M-type), Maximum Power Point Tracking algorithm is executed from the Master. Therefore, a multi-inverter system, however, has only one MPPT, all the 'Slave Units' receiving the same firing commands from the Master.

This is not a limitation nonetheless, because multi-inverter systems are best suited for large, Utility-Scale PV plants, where the orientation of the whole PV field is quite likely the same for all the modules.

Existence of mobile trackers mounting structures, doesn't affect the behaviour of the MPPT algorithm of the inverter.

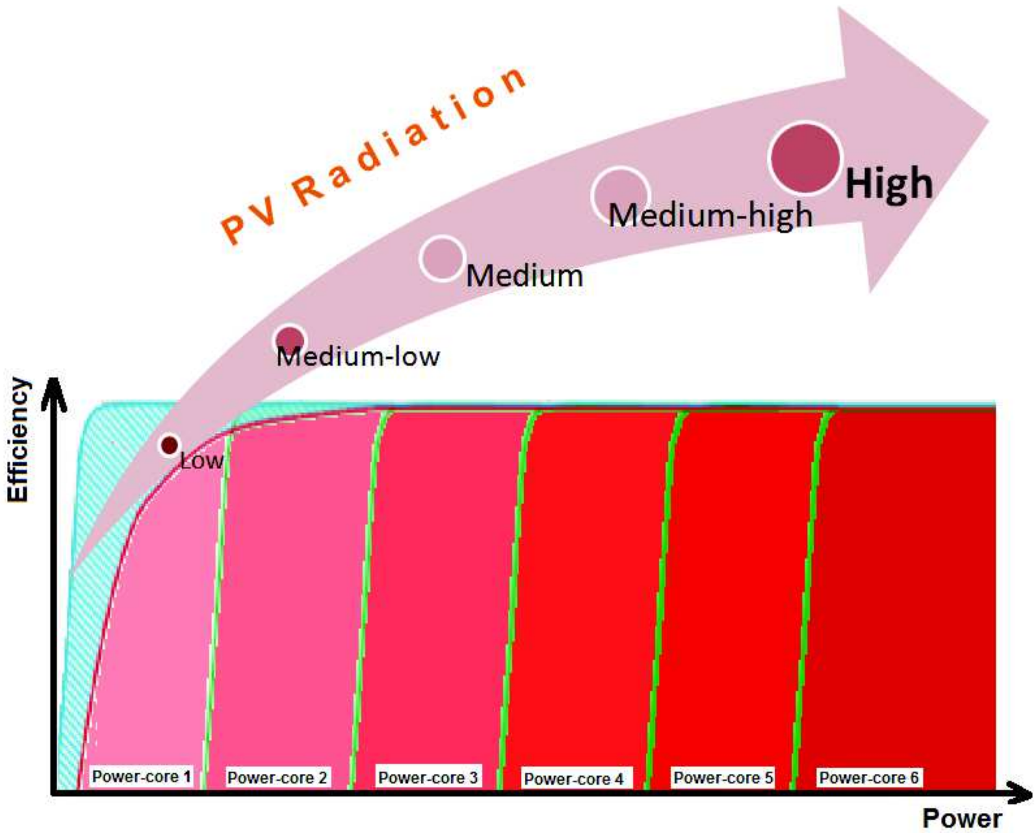
2.2.2 Master & Slave operation (for multi-inverter systems)

Master & Slave is a logic of operation available on inverters 'M' type only.

It consists in a control mode performed by the DSP control of the 'Master' inverter, that, upon the availability of DC power at the input, enables the proper number of power cores within the system, leaving disabled all the ones not needed.

This logic allows achieving higher efficiencies at low power levels, because, below a fraction of total power, which is a function of the number of 'M-type' inverters present in the system, it is more convenient to turn off one or more inverters, in order to get the operating ones work at their optimal power level from conversion efficiency standpoint.

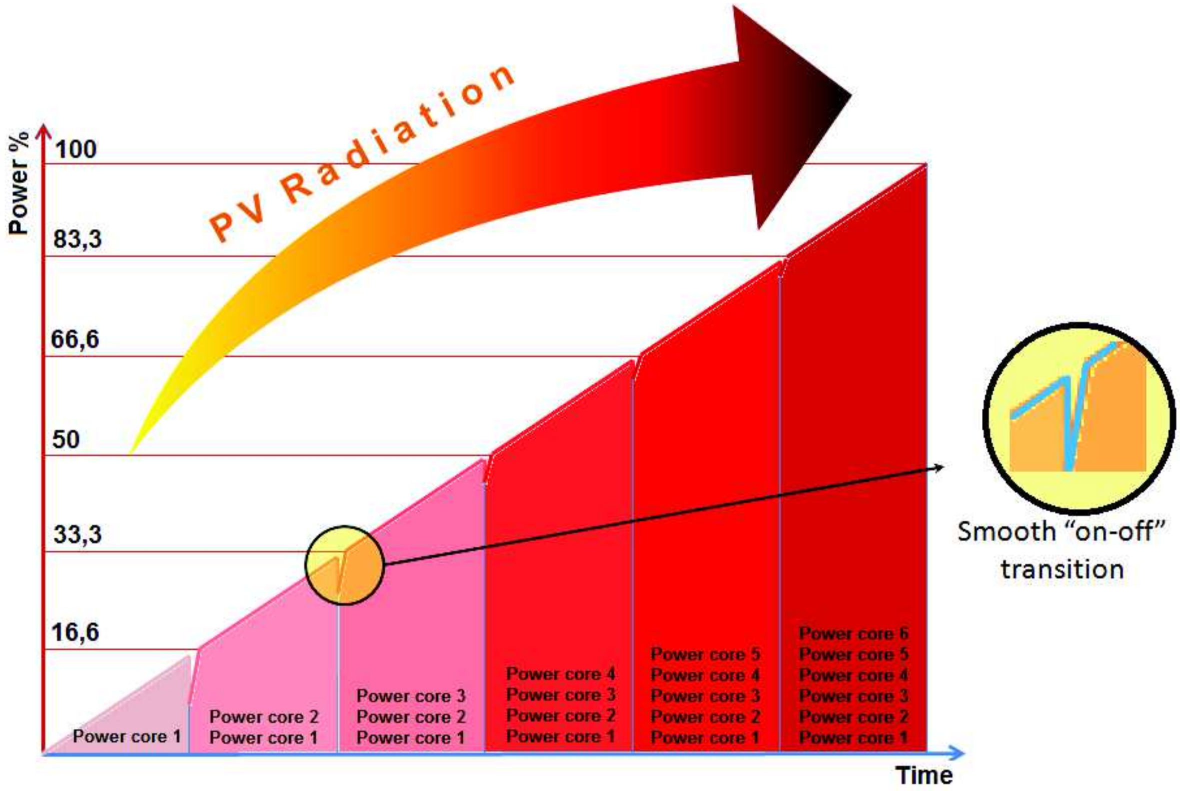
Here below a schematic representation of the trend of the efficiency in a DSPX TLH 4000M (3 inverters, 1330M each, totally 6 power cores).



The behavior is nonetheless dynamic, in the sense that, depending on the solar radiation actually present at each moment, only the 'optimal' number of power cores is active at the same time, by either turning back-on the cores previously disabled (radiation is increasing, therefore a greater number of cores are needed to keep the system overall efficiency at its optimum) or, conversely, turning-off the ones in excess (because radiation is decreasing, an excessive number of active cores would uselessly operate at a power level far from the optimum of the system).

In order to make the power transitions of the system as much smooth as possible during the 'on' and 'off' of the modules, some hysteresis is added across the 'on'-'off' thresholds of power, affecting the number of cores that need to be active at that particular instant. Furthermore, whenever a change in the number of active cores have to take place, smoothness of the change is secured by the control, which performs a soft power decrease (by acting on the MPPT working point at that instant) before turning-on (or off) one module and, subsequently, by ramping up the power to the actual available value.

Here below is an example of the real behavior of the M&S algorithm operating in a Soleil DSPX TLH 4000M (3 inverters, 1330M each, totally 6 power cores).



2.2.3 Inverter Master and inverter synchronization

The power-core which is given the token of 'Master', is established upon a 'wear-leveling' logic, i.e. a logic aiming to level the hours of operation among the power-cores composing the system. The instant at which a new power-core is given the token of 'Master', is synchronous with a start of the system after a complete stop (e.g. in the early hours of the day, when the irradiance is enough to restart the system after the night-time stop). If during the operation, the inverter 'Master' fails, it gets instantaneously excluded from the parallel, whereas another inverter among those in operation, becomes the new' Master' and the system keeps operating (at a reduced power level, due to the failure of one module).

Synchronization between the Master and the other inverters, is done through a dedicated multi-conductor shielded cable, highly immune to EMI.

The benefits of the synchronization are straightforward:

- Very accurate switching of power cores, therefore very low conducted and radiated emissions, despite outstanding power density of the system.
- No need of multiple secondary windings MV-LV transformers: regardless of the number of inverters the system is constituted by (e.g., up to 4 inverters – 8 power cores in the 4400M, 5330M, 5660M models), the system behaves as it was a 'single inverter', therefore galvanic insulation is not needed between different units.

- Despite the high number of power cores operating altogether, the multi-inverter system can be pole-grounded (on the DC side) and still be connected to a single-secondary winding MV-LV transformer, allowing significant saving of space for transformer hosting and cost.

2.3 Grid Code compatibility and grid-support functions.

Soleil DSPX TLH 1500Vdc series, supports many different country-specific grid code, such as (but not limited to):

- CEI 016 (Italy)
- Norma Técnica de Seguridad de calidad de Servicio (NTSCS-Chile 2014).
- PROCEDIMIENTO TÉCNICO DEL COMITÉ DE OPERACIÓN ECONÓMICA DEL SEIN PR-20 (Peru).
- 13. anexo_ix_requisitos_tecnicos_minimos_para_conexao_de_centrais_solar_fotovoltaica (Brasil).
- Reglas Generales de Interconexión al Sistema Electrico Nacional, Comision Reguladora de Energia (Codigo de Red, Mexico)
- South African Grid Code Requirements for Renewable Power Plants - Version 2.8.
- Namibian Grid Code *'NAMPOWER Technical Guidelines for Point of Common Coupling'.*
- Solar Energy Plants Grid Connection Code for Egypt (September 2015).
- PEA grid code (Thailand, 2015)

State of the art 'Grid support functions' are all implemented in the control of the unit, completely configurable by the User through the user interface, as far as:

- Voltage & Frequency thresholds (Min/Max) for disconnection.
- 'Voltage vs time' diagram for LVFRT and OVFRT functions. Particularly, all the points of the (V – t) diagram can be set by the user.
- Enable & Disable of Remote Power Management function (P and Q set-points).
- Enable & Disable of time-constant reactive power generation and relevant percentage value (both setpoint of Q or cosphi).
- Enable/Disable and behavioral operation of **Q @ night** function (optional). For instance, the user has the chance to set a 'continuous mode' of operation (the inverter does not turn off when the low radiation condition is reached, but it stays online generating the amount of reactive power Q as per relevant set-point).

  Conversely, if 'discontinuous' mode is set, the inverter turns-off as the 'low radiation' condition is reached, but can 'wake-up' upon receiving a specific command, restart (even at night, with no radiation present) and start generating the requested amount of reactive power Q as per relevant set-point.
- Enable & Disable of static generation of reactive power Q(V) function / Q(cosphi) functions.
- Parameter setting of static generation functions of reactive power (Voltage thresholds and Q thresholds).
- Enable & Disable of Active power limitation with frequency – P(f) and relevant parameters (such as percentage of droop, start threshold for droop, percentage of power reserve during under-frequency events and relevant threshold of activation).
- Set-up of different slopes for power ramps (% of power vs time, up & down directions).

For a closed-loop management and support of the grid, SIEL offers its self-developed Power Plant Controller, available as optional, as well as a complete professional SCADA system for complete monitoring and performance analysis of the complete PV installation.

Models for simulation of the whole TLH DSPX 1500Vdc series are available on request for different simulation platforms (DigSilent, PVSyst, PSSE).

3 REMOTE CONTROL & MONITORING

Two different platforms are available for remote Monitoring of the equipment:

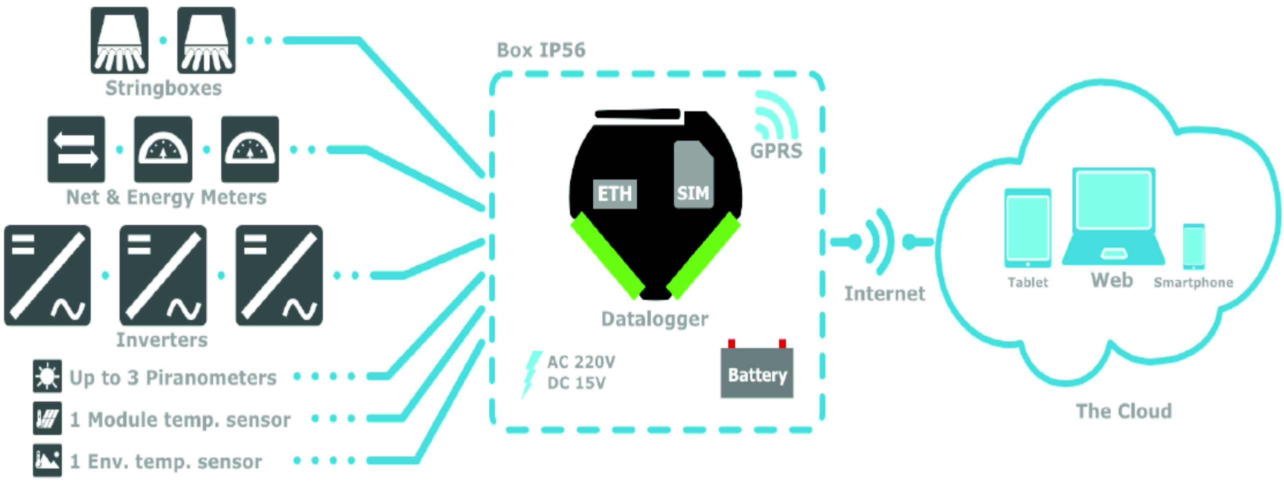
- Energy Monitor System, based on a datalogger, local to the installation and remote server-resident Monitoring SW.
- SCADA professional system, running on a dedicated server, usually installed in a dedicated room directly next to the installation, supporting main standard automation oriented protocols for monitoring and supervision from a remote, higher level SCADA system (e.g. grid operator or plant conductor control center's).

Either platform is better suited depending on the power scale of the PV installation and of the count of variables and parameters to monitor.

3.1 Energy Monitor

Here below is a schematic representation of the architecture of this platform.

It's composed by an industrial-standard datalogger, installed on field and acquiring many different devices such as inverters, energy meters, string junction boxes and meteo stations.



Thanks to its very versatile HW architecture, the datalogger supports different industry-standard serial links (RS232, RS485, CAN bus, USB & Ethernet) and communication protocols for device acquisition.

Network connection is done either through Ethernet (to a local LAN) or GPRS for direct access to the cloud.

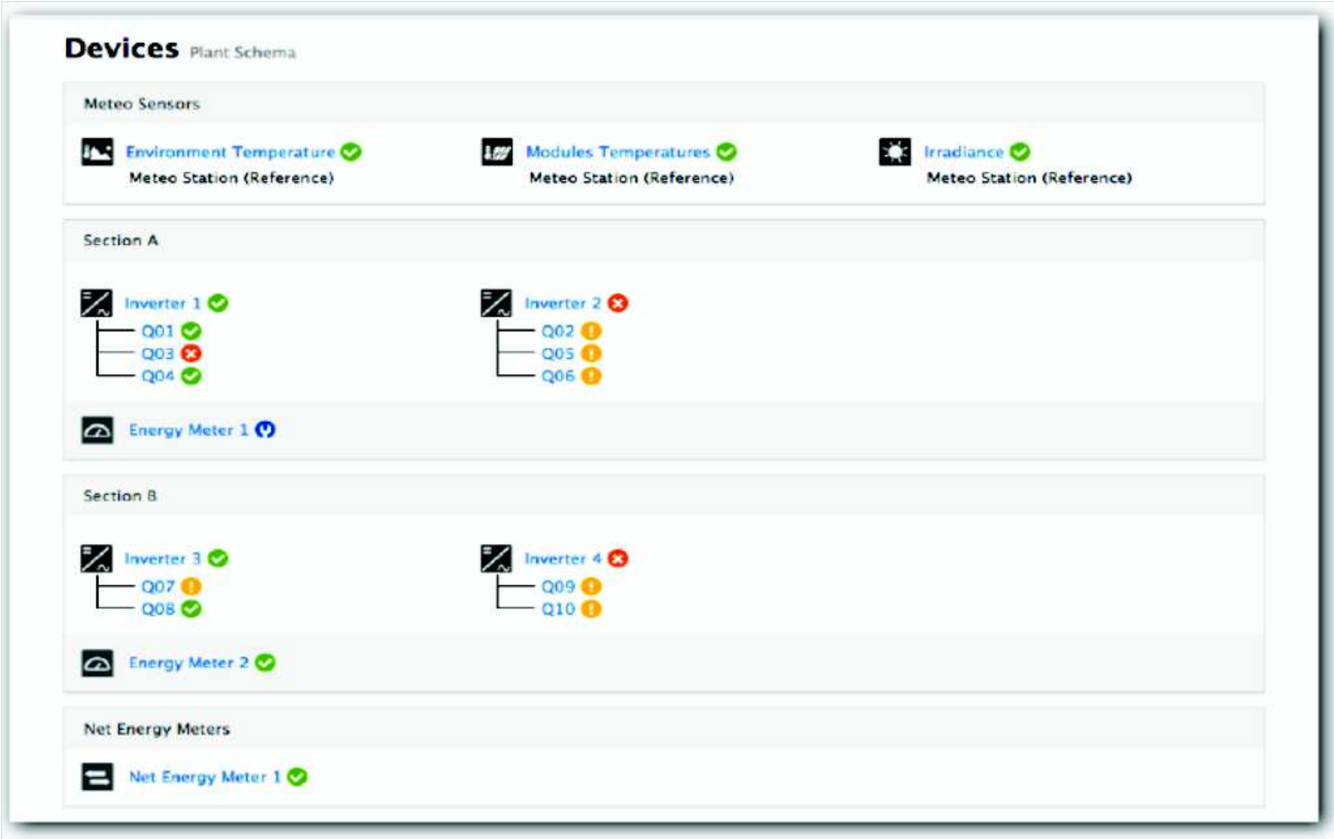
A web platform, 'in the cloud', receives and analyzes data in real time, making them available to the user for inspection, through a standard web page (standard browser).

Alerting through e-mail and SMS are user-friendly configurable.

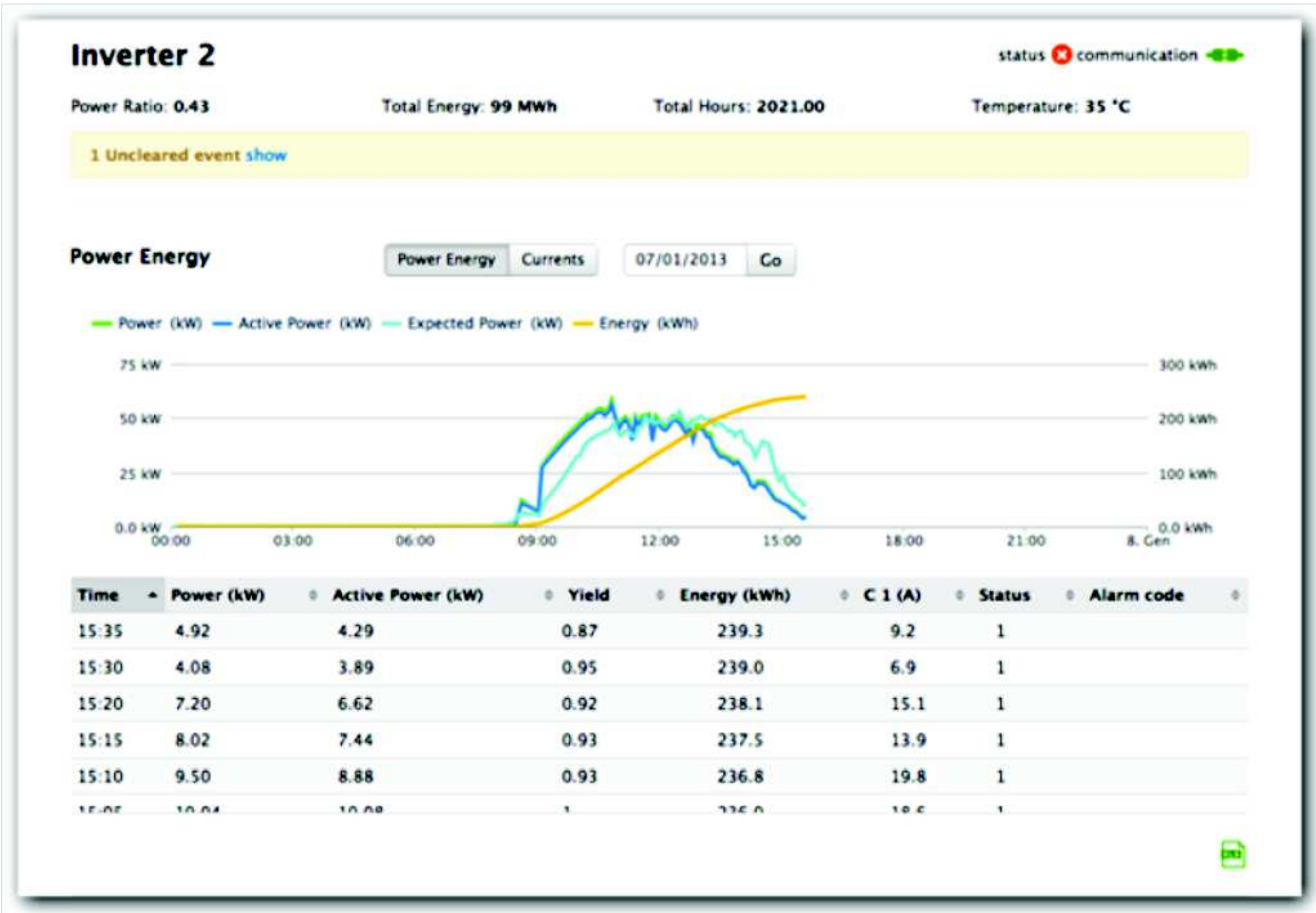
In the following page, some screenshots show how the PV plant is presented to the user:

- A main 'dashboard', through icons of the installed devices, provides a 'general overview' of the system.
- Each devices (depending on type), has its own inspection frame associated (e.g. the figure shows the one relevant to the inverter), where main data are presented along with notification (alarms, protections) and graphical trends.

MAIN DASHBOARD OF THE PLANT



DEVICE-SPECIFIC INSPECTION PAGE



3.2 SCADA PLATFORM

A professional SCADA platform is available for mid-to-large scale PV plants (>10MW).

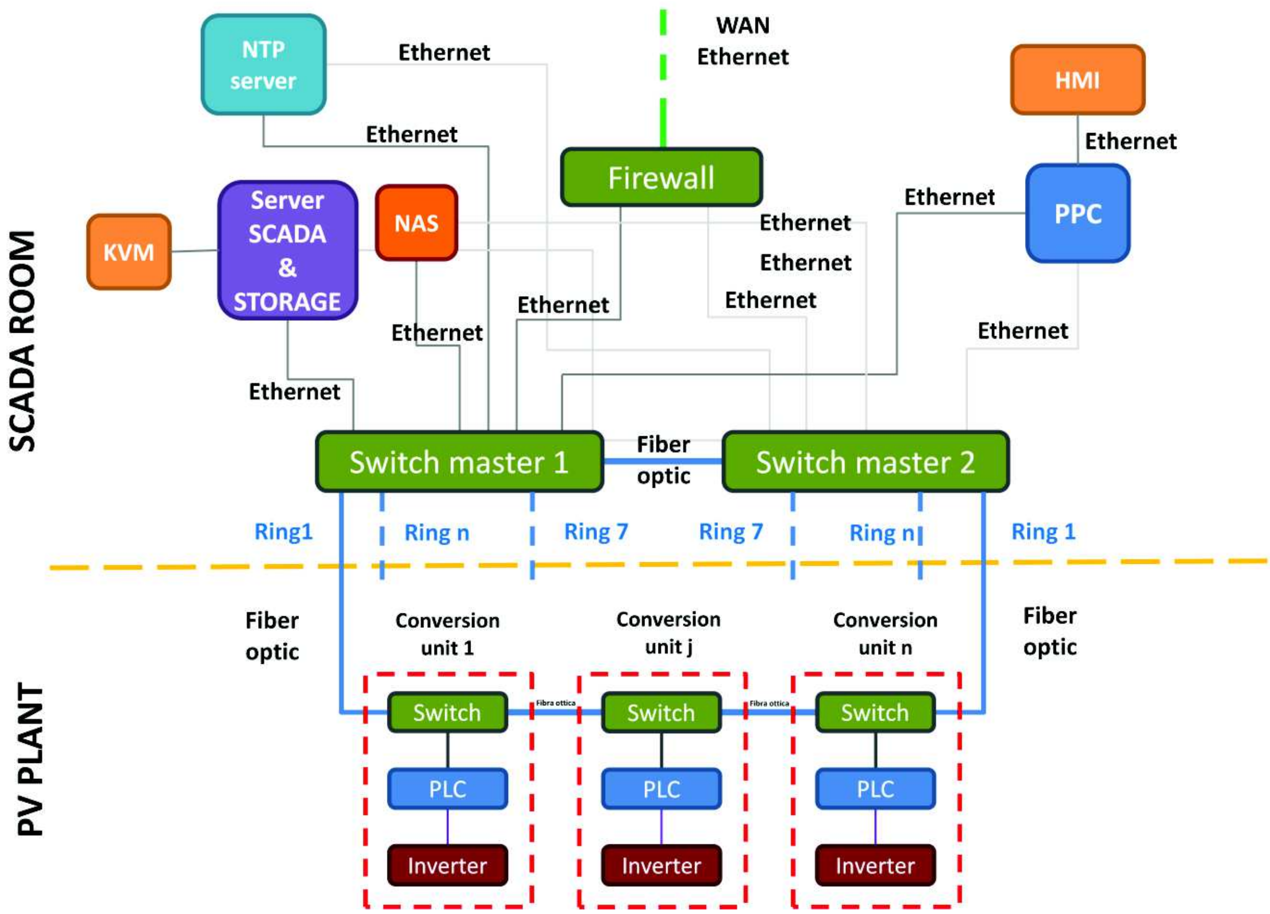
The architecture can be either redundant or non-redundant (depending on the customer's need).

Turn-key solutions are available as pre-determined configurations ('standard proposal') or can be totally 'tailor-made', upon customer's specification and demand.

The HW of the system has to be installed in a dedicated 'Scada Room' and it is composed at least by:

- N. 1 (or more, in case of redundancy) SCADA SERVER, running the SCADA application.
- N.1 NAS server.
- N.1 NTP server for synchronized time-stamp data-logging.
- N.1 (or more, in case of redundancy) optic switches for communication.
- N.1 HMI for local access of the user to the SCADA SW application.

A schematic view is represented here below:



As shown in the diagram, the access to the system from remote is Cyber-secured through Firewall and requires licensed authentication, according to different right of access ('regular' user, 'advanced' user or system administrator).

The PV plant, constituted by Conversion Units (usually hosted in marine-freight containers), string boxes, meteo-stations, is constantly monitored by the SCADA through fiber optic connection running throughout the whole field. The communication protocol relies on IEC 104 or IEEE 61850 industrial standards.

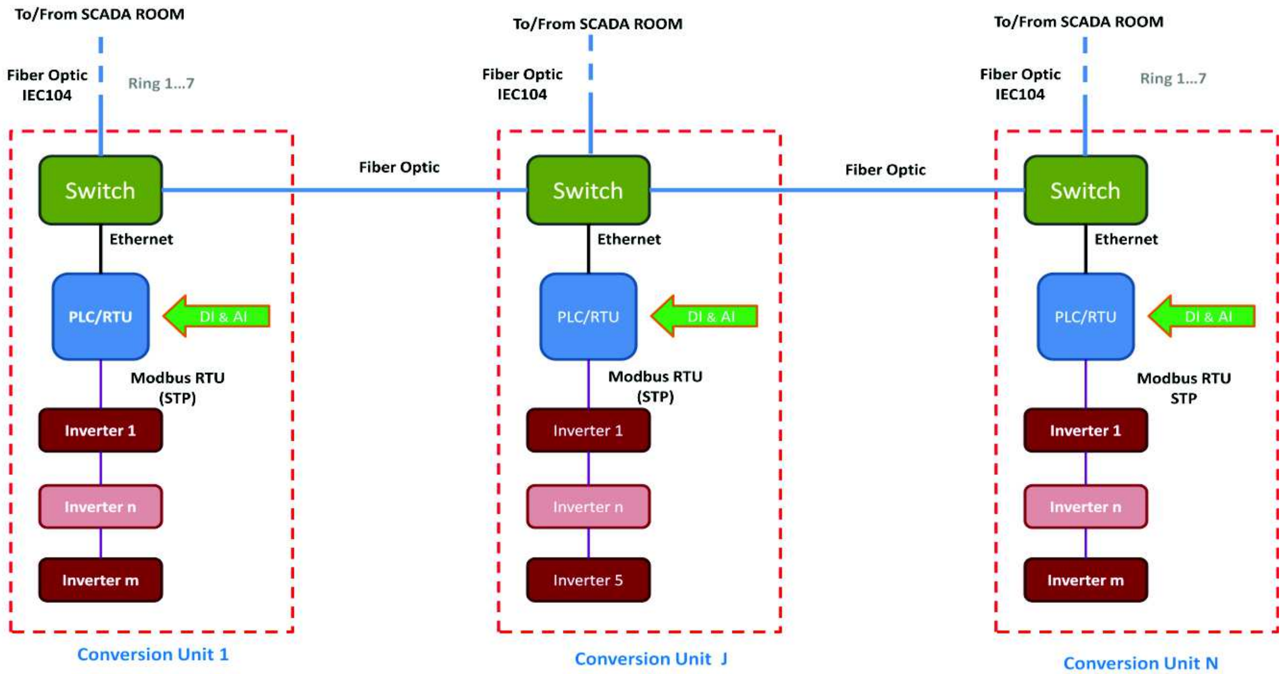
Following block diagram, shows a snapshot of the monitoring philosophy: each conversion units, connected to many others, forms a ‘communication ring’.

An RTU is present inside every Conversion Unit, gathering data from inverters therein present, relevant string-boxes, energy meters, meteo stations, digital I/Os from MV-LV transformer, MV and LV switchboards.

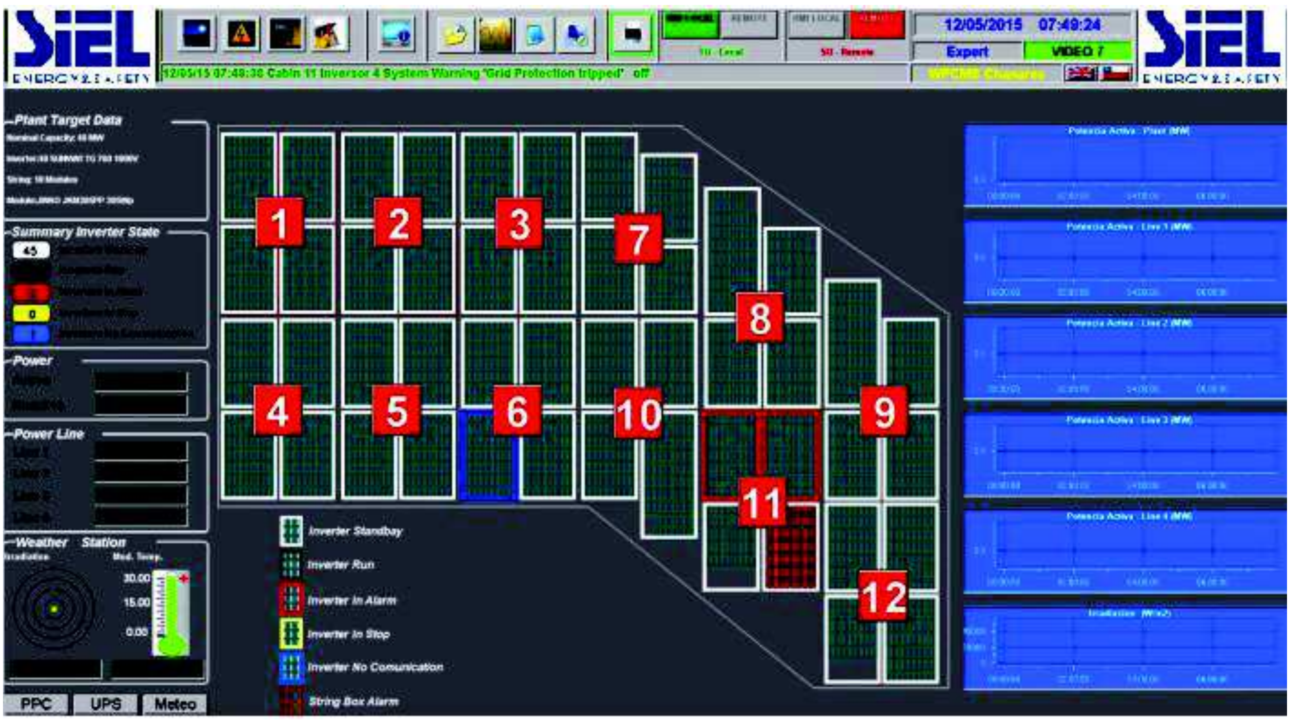
Connections inside the Conversion Units at a field-bus level, are routed through Shielded Twisted Pair according to RS485 standard and carry Modbus RTU packeted data.

Access from the SCADA to the field-bus present is granted by a Switch, local to every Conversion Unit.

All the information and data are sent to the SCADA server at a fast pre-determined sampling-rate.



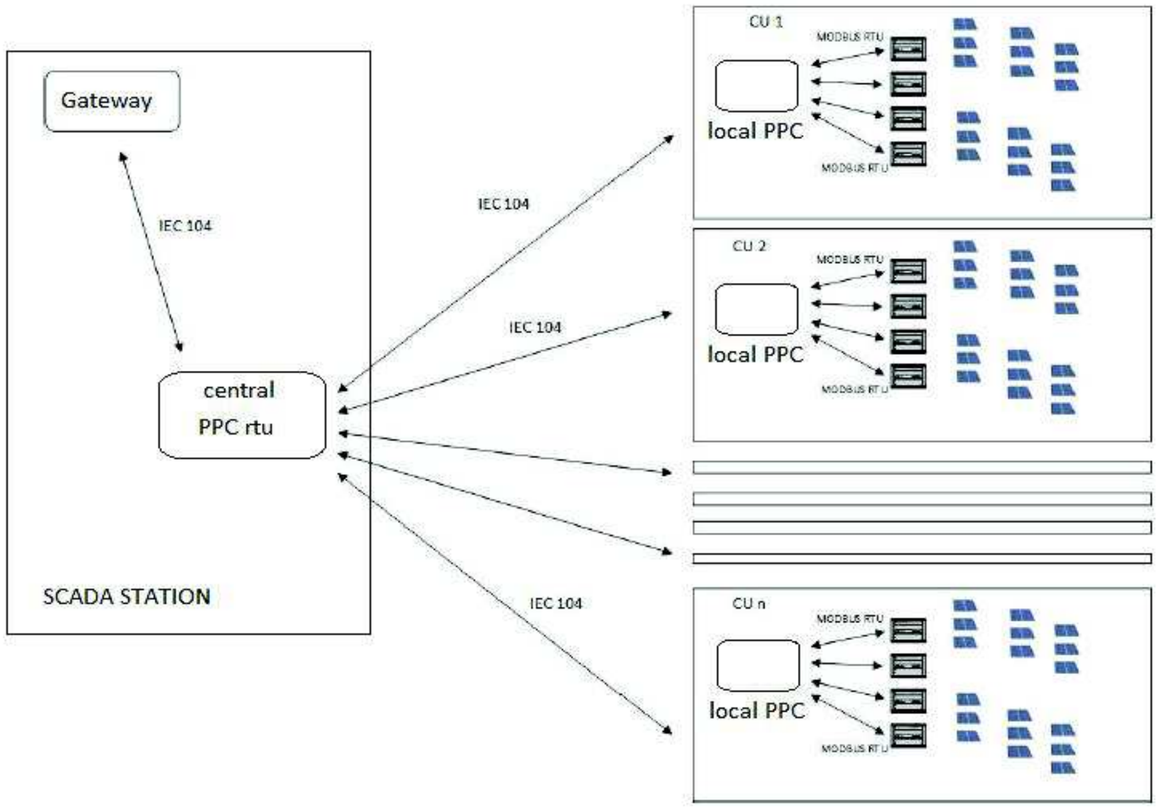
Here below a screenshot taken from an application monitoring on a 40MW PV plant:



3.3 Power Plant Controller

A 'Plant controller Master' is usually a CPU device (e.g. and Industrial PC), installed in the SCADA ROOM, working paired to all the 'local plant controllers', each of which is installed in every Conversion Unit.

The RTU hardware, connected to the 'Plant controller Master', provides feedback signals and measures for regulation.



Communication between the central controller (PPC RTU) and the Conversion Units, exploits the same link

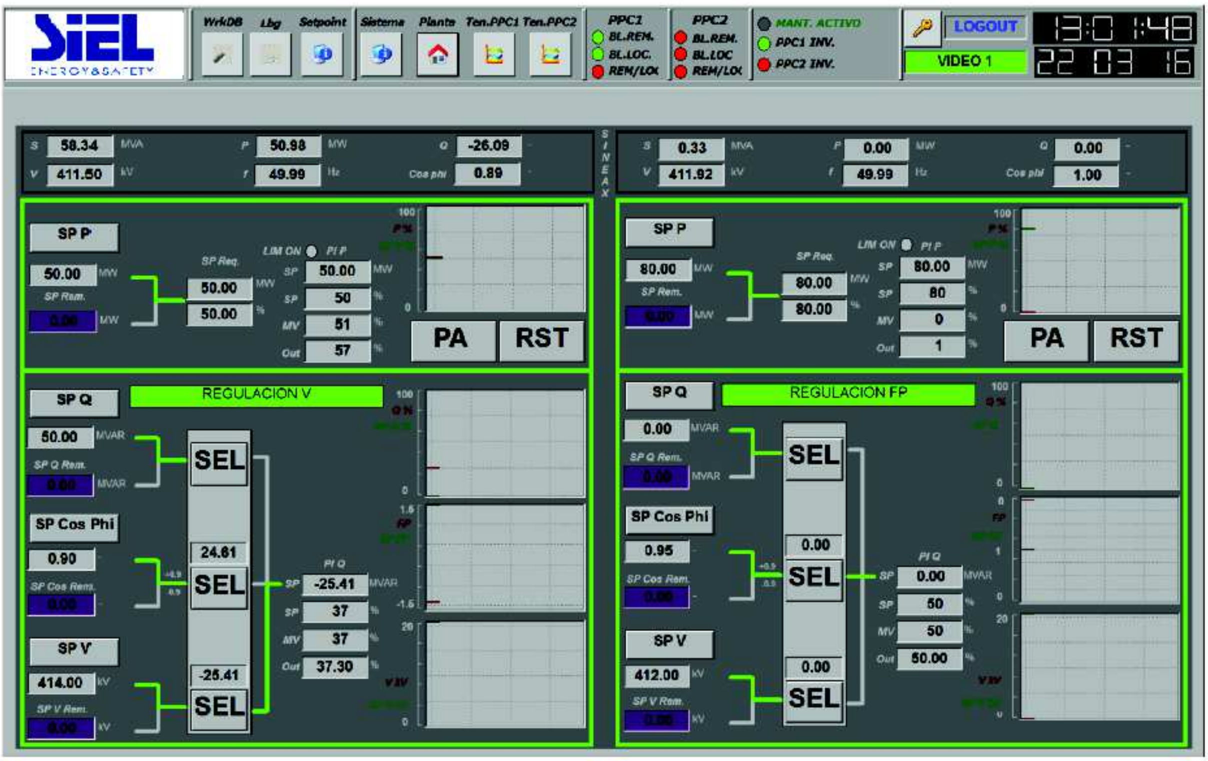
already present for SCADA (i.e. optic fiber network) and communicates through IEC104 protocol with RTU in conversion cabin (local PPC). The PPC local to the Conversion Units, manages communication with the inverters through dedicated field-bus based on STP and RS-485 standard, carrying Modbus RTU packeted data.

The plant controller can set the active and reactive power according to incoming input from the grid operator (TSO/DSO) or according the parameters noticed by the grid code.

The HW of the PPC is composed by a standard telecommunication-rack (19"), carrying:

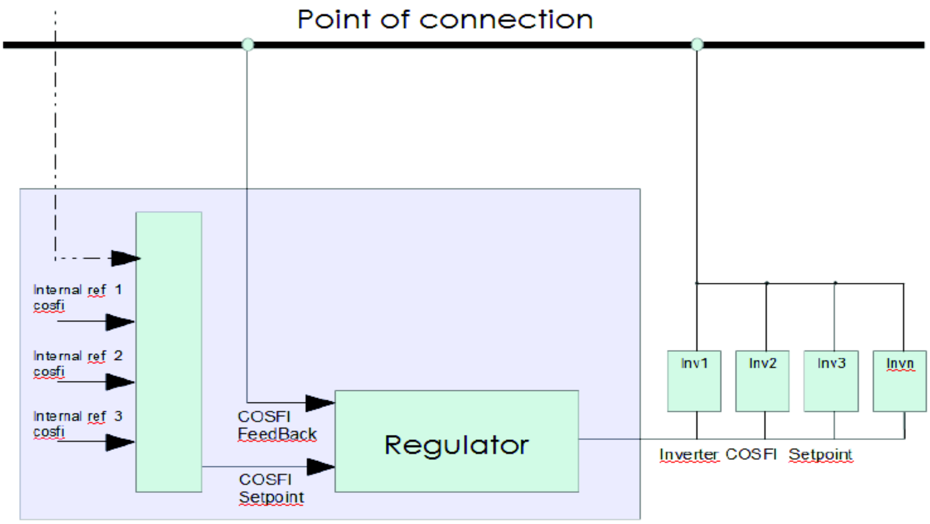
- a Panel PC, which is the 'heart' of the PPC, from which the operator can access all the functionalities and enter the setup mode for the regulation. The same operation (selection of the operating mode, change of parameters and so on), can also be performed remotely, by accessing at the proper IP address the PPC.
- One or more energy meters acquiring the measures of current and voltage (from dedicated current and voltage transformers) at the point of connection with the grid, where the regulation has to take effect.

The SW is composed by a visual application, based on intuitive windows for parameter entry and operating mode setup.



Previous screenshot shows the MAIN page of the control application of the PPC, carrying the four main capabilities of the PPC.

3.3.1 Example of PPC 'power factor' regulation function



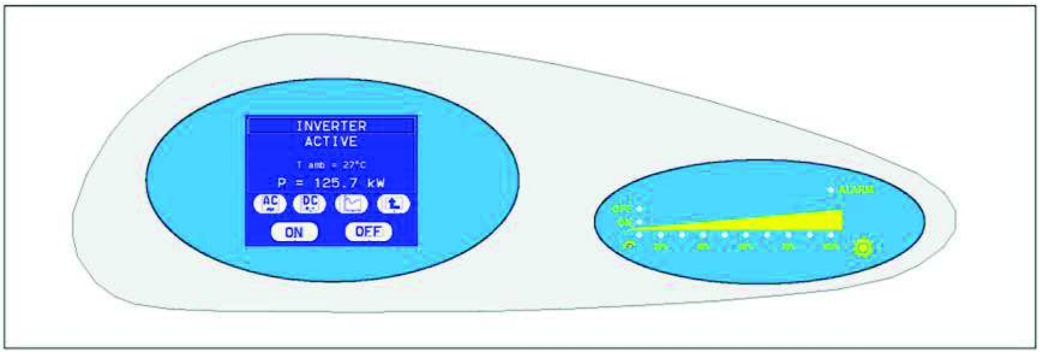
Previous schematic depicts the closed-loop mode regulation performed by the local PPC: in the example of the schematic, the power factor regulation is performed by the logic of the PPC local to any conversion unit, by either measuring voltages and currents at the point of delivery (or connection) or by receiving this measures from remote PPC. Out of the measures of V and I, the actual values of P (active power), Q (reactive power) and cosphi are calculated. This last value is then compared with the reference values (set-point) of cosphi and sent to a regulator.

The regulator's output will be the set-point of cosphi for each inverter in the plant, to have them generate the right amount of P and Q such to keep the actual value of cosphi at the Point of connection, constantly as close as possible to its reference set-point.

4 QUICK START GUIDE

The control panel is made up of a monochromatic “touch screen” display and a LED signalling panel showing the generated power.

The “touch screen” display acts both as viewer and as an interface to input or change the machine parameters.



The LED lights mean as follows:

- ALARM it lights up when the machine has stopped because an alarm/a protection has activated.
- OFF: it lights up when the machine is in the “disabled inverter status”.
- ON: It lights up when the inverter switches to the operating status energising the power grid (“inverter generating power” status).
- ON and OFF flashing alternatively: it happens during the first start up and in the “enabled inverter” status as well as after an error has been detected, immediately before closing the contactor and starting the generation process.
- LED power bar the amount of lit up LEDs is proportional to the instant power percentage delivered to the grid.

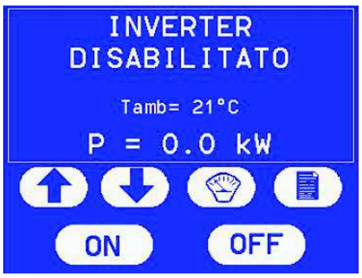
In a multi-inverter system, it is necessary to start every single inverter only the very first time.

To start the inverter:

- the input DC and output AC cables must be properly connected.
- the EPO contacts and EXTERNAL START INVERTER must be closed. As a default setting, both these contacts are short-circuited by the manufacturer.

  Closing the AC circuit breaker, voltage is fed to the control logic, the touch screen lights up showing a welcome screen and an acoustic “beep” is emitted.

Immediately after the welcome message, the main screen appears:



The top two lines show status messages and any alarm conditions in rotation. Immediately after the controller has been powered on under suitable grid and voltage conditions, the sequence of messages to appear is as follows:

- Inverter disabled
- Contactor open
- Mains voltage OK
- Mains frequency OK

By pushing the ON key on the "touch screen" and confirming by pressing the ENTER key as displayed in the following screenshot, the inverter will switch to "Enabled inverter" mode while the ON and OFF LEDs will flash alternately.

Under this condition, the following messages will appear on the display:

- Inverter enabled
- Contactor open
- Mains voltage OK
- Mains frequency OK

The inverter waits for the grid parameters (voltage and frequency) to come into the pre-established range for at least 5 minutes, after which the generation of grid power can begin.

At this point the ON LED stays lit. The messages shown on the display are as follows:

- 'Inverter generating'
- "Contactor closed"
- "Mains voltage OK"
- "Mains frequency" OK

The default inverter operating mode is AUTOMATIC, i.e. with maximum power point tracking enabled.

During standard operation, if the photovoltaic field voltage drops below the minimum or the available power from the power grid is below a given threshold (1,5% of the rated input power), the inverter switches to "Inverter enabled" mode and starts a 6-minute countdown.

The sequence of the messages displayed is as follows:

- "Inverter enabled"
- "Contactor open"
- "Mains voltage OK"
- "Mains frequency" OK
- "Insufficient radiation"

When the countdown is over, if the mains and cell voltage conditions are correct, the inverter starts up again, closes the contactor and resumes the power generation to grid.

If the electrical grid is not suitable (voltage or frequency outside specification), the inverter remains in “inverter enabled” status, the ON and OFF LEDs flash alternatively and the sequence of messages displayed is as follows:

- “Inverter enabled”
- “Contactor open”
- “Mains frequency outside specification” or “Mains voltage outside specification”

When correct conditions of the power grid are restored, the inverter starts up again, closes the contactor and resumes the power generation to grid.

To disable the inverter, all that is needed is to press OFF without having to confirm the command with other buttons. Confirmation of switching off the inverter is given by the yellow OFF LED that stays lit.

Users should take note of the fact that under such conditions, the inverter does NOT generate electricity and this condition should only be employed for maintenance work.

5 BASIC INSTALLATION HINTS

This Chapter contains a brief summary of the criteria for a correct installation of a multi-inverter system, in order to get it into operation in the quickest and most reliable way.

5.1 Positioning of the inverters and ventilation

The positioning of the inverter has to take into account the type of installation:

- **Dedicated concrete-made technical room** : the inverter can be positioned either on a floating floor or on a concrete soil (in this case, power cables have to be routed to the inverter's power connection through underground dedicated conduits). In both cases, a dedicated mounting kit provided by SIEL has to be used to secure the inverter to the hosting surface.
- **Containerized Metal Conversion Unit**: the best practice to position the inverter, is placing it on a metal frame of crossbeams, covering the perimeter of the inverter itself.

  A dedicated mounting kit provided by SIEL has to be used to secure the inverter to the metal frame.

Regardless of the type of installation, the inverter has to lie on a horizontal surface, able to carry at least 1000kg/m^2.

If the system is a multi-inverter system, all the inverters have to be placed one beside the other, all front-sided, as per following figure (example: DSPX TLH 5660M):

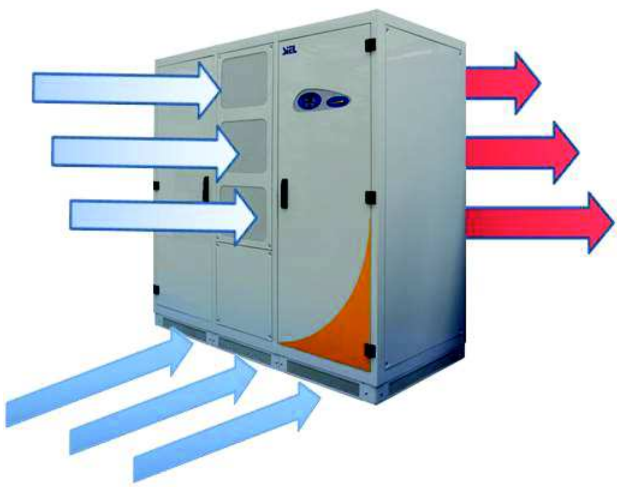
(!) DSPX TLH 1500Vdc inverters, cannot be installed in a back-to-back fashion

Fresh air intake is from the front , hot air exhaust from the rear of the unit.

Proper clearance (1m from the front, 1m from the rear side) must be left respect to walls and possible obstacles, in order to ensure proper ventilation to the inverter.

Following table shows the required minimum air flow:

Model	Air flow (m^3/h)
550, 665, 708, 764	5500
1100M, 1330M, 1415M, 1528M	11000
2200M, 2660M, 2830M, 3056M	22000
3300M, 4000M, 4245M, 4584M	33000
4400M, 5330M, 5660M, 6112M	44000

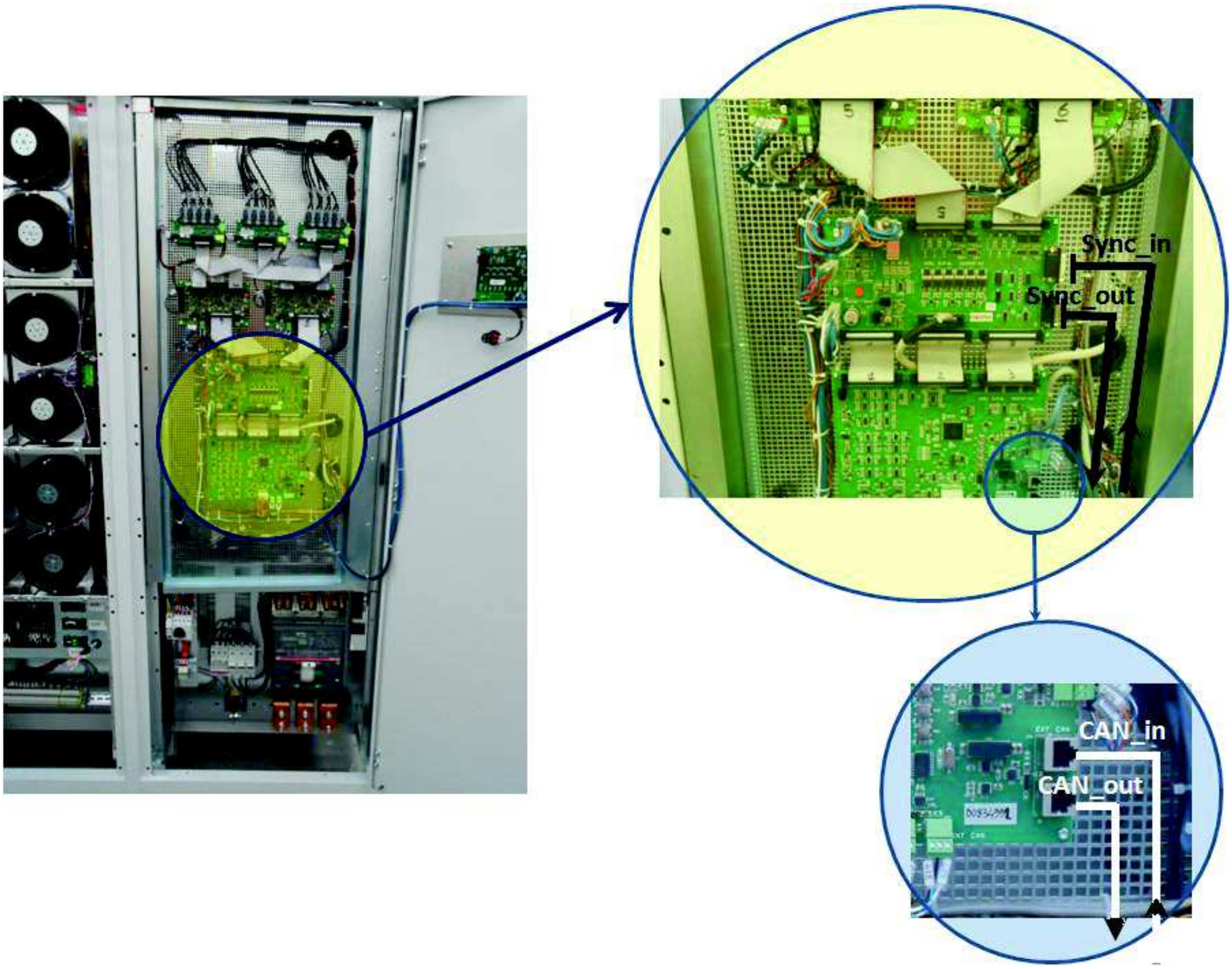


5.2 Synchronization cable and CAN-bus (multi-inverter systems)

In multi-inverter models (2200M, 2660M, 2830M, 3300M, 4000M, 4245M, 4400M, 5330M, 5660M), every inverter is connected in a daisy-chain fashion with the next one and the previous one (except the Master and the last inverter of the system) as far as:

- Synchronization channel: the synchronized firing commands are received by one unit on the 'Interface Board' and retransmitted forward, by using a twisted multi-conductor, shielded cable , terminated with a multi-pole DIN connector (link '**Sync_in**' & '**Sync_out'** in the figure below).
- CAN-bus channel: the CAN link carrying the status information of every unit, is received by one unit on the 'DSP control board' and retransmitted forward, by using a twisted multi-conductor shielded cable for high frequency, terminated with a CAT5 – RJ45-like connector ('CAN-in' & 'CAN-out' in the figure below).

As anticipated, these two communication links are functional to the Master & Slave operation of the system.

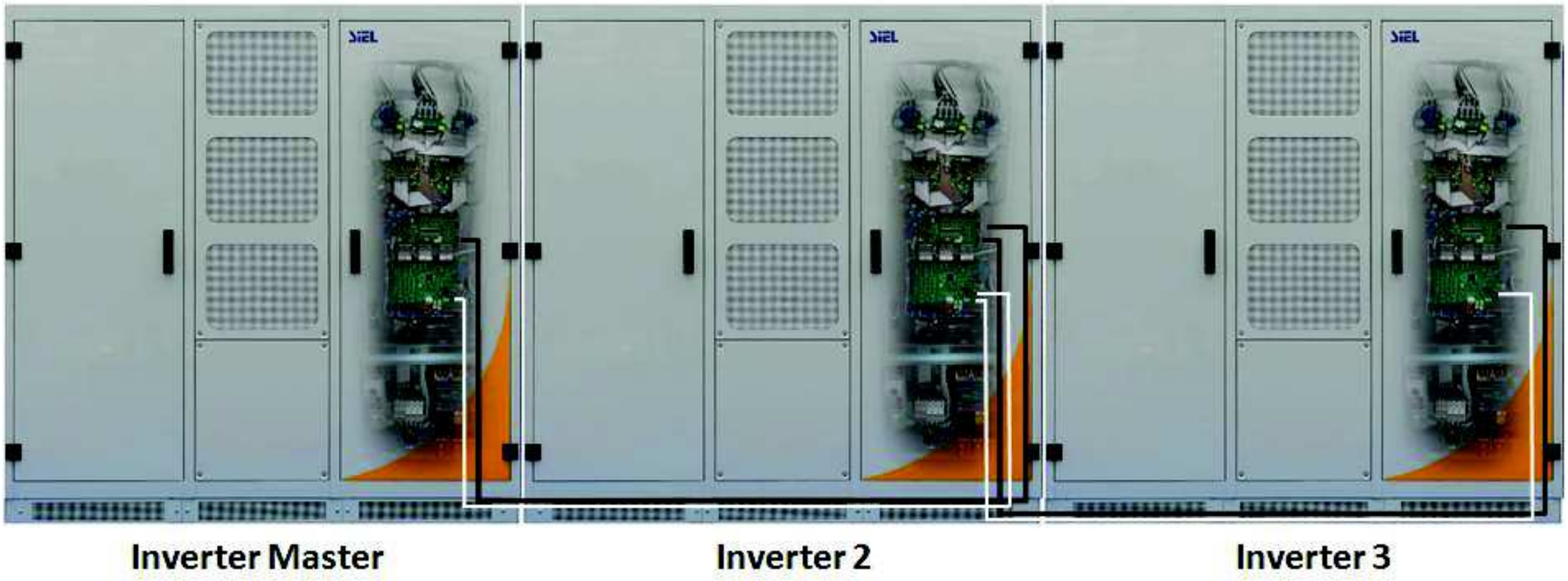


In a multi-inverter system, the overall length of these two connection has to be kept as low as possible and, however, less than 20m, for signal integrity and timing constraints.

This is the main reason why, as recommended in previous paragraph, it is essential to keep the inverters aligned to each other on the front side.

Next figure shows the path of both 'Sync' and 'CAN' connections among units.

SINCHRONIZATION AND CAN BUS CONNECTION EXAMPLE (DSPX TLH 4000)



- Synchronization connections: black lines
- CAN bus connections: white lines

6 TECHNICAL DATA TABLES

6.1 Tier 1: 530Vac output voltage core

SOLEIL DSPX TLH 1500	550	1100M (*)	2200M (*)	3300M (*)	4400M (*)
DC input side– Recommended power of the modules					
Rated [kWp]	559	1116	2227	3336	4447
Maximum [kWp]	699	1395	2784	4170	5559
Number of power cores	1	2	4	6	8
DC input side– Electrical specifications					
Operating voltage range [V] [7]	800 - 1450				
MPPT voltage [V] [7]	800 - 1400				
Max voltage (no operation) @-10°C [V]	1500				
Rated DC voltage (max efficiency)	1100				
Min voltage @+70°C [7] [V]	800				
Max input DC current [A]	699	1395	2784	4170	5559
Modules max. Isc [A]	874	1744	3480	5213	6949
N. DC inputs (per pole)	4	4	4	4	4
N. MPPT	1	1	1	1	1
AC output side					
Rated apparent power Sn [kVA]	550	1100	2200	3300	4400
Max Apparent Power Smax [kW] [1]	594	1188	2376	3564	4752
Max Active Power Pmax [kVA] [1]	594	1188	2376	3564	4752
Nominal voltage [V] (line-to-line)	530				
Connection	3ph				
Rated current In [A] [2]	600	1199	2397	3595	4794
Maximum current Imax [A] [3]	719	1438	2876	4314	5752
Min Smax operating voltage [V] [4]	90% Vn				
Minimum operating voltage [V] [4]	85% Vn				
Maximum operating voltage [V] [4]	115% Vn				
Nominal frequency [Hz]	50 or 60				
Frequency range [Hz] [5]	Adjustable (47,5 - 51,5) or (55.5 to 62.5)				
Max. efficiency[%] [6]	**99,45 (**)**	**99,45 (**)**	**99,45 (**)**	**99,45 (**)**	**99,45 (**)**
Euro efficiency [%] [6]	**99,21 (**)**	**99,21 (**)**	**99,24 (**)**	**99,24 (**)**	**99,22 (**)**
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 umbalancement	1%				
Short circuit current contribution [A]	1079	2157	4314	6471	8628
Other data					
Ventilation system	Forced Air				

Dissipated power without load [W]	80	80	80	80	80
Control	DSP				
Output wave form	Pure Sine wave				
Operating temperature range [°C][7]	-20°C / + 51°C				
Max Operating temperature [C°]	+60				
Storage temperature range [°C]	-25°C / + 70°C				
Operating humidity range	5% / 95%				
Maximum altitude with no power derating at max ambient temp (+51°C)	2000 (s.l.m)				
Power derating with altitude	1% every 100m above 2000m				
Environment category	INDOOR				
Pollution Degree	PD3				
Overvoltage class (input DC)	Class II				
Overvoltage class (output AC)	Class II				
Mechanical characteristics					
Class of protection	IP20				
dBA	65	69	69	69	69
Footprint size for basement (LxD) [mm]	2000/1000	2000/1000	4000/1000	6000/1000	8000/1000
Overall (LxDxH) [mm]	2000/1000/2000	2000/1000/2000	4000/1000/2000	6000/1000/2000	8000/1000/2000
Weight [kg]	1600	1800	3600	5400	7200

(*): operating with **Master & Multi-Slave logic**

(**): Third Party lab measured values. Test report available upon request. Values measured according to IEC EN 50530. Measures taken at DC input voltage level of 800V.

6.2 Tier 2: 600Vac output voltage core

SOLEIL DSPX TLH 1500	665	1330M (*)	2660M (*)	4000M (*)	5330M (*)
DC input side– Recommended power of the modules					
Rated [kWp]	676	1349	2693	4033	5377
Maximum [kWp]	845	1686	3366	5041	6721
Number of power cores	1	2	4	6	8
DC input side– Electrical specifications					
Operating voltage range [V][7]	900 - 1450				
MPPT voltage [V][7]	900 - 1400				
Max voltage (no operation) @-10°C [V]	1500				
Rated DC voltage (max efficiency)	1150				
Min voltage @+70°C [7] [V]	900				
Max input DC current [A]	751	1498	2991	4480	5974
Modules max. Isc [A]	939	1873	3740	5602	7469
N. DC inputs (per pole)	4	4	4	4	4
N. MPPT	1	1	1	1	1
AC output side					
Rated apparent power Sn [kVA]	665	1330	2660	3990	5320
Max Apparent Power Smax [kW] [1]	699	1397	2793	4190	5586
Max Active Power Pmax [kVA] [1]	699	1397	2793	4190	5586
Nominal voltage [V] (line-to-line)	600				
Connection	3ph				
Rated current In [A] [2]	640	1280	2564	3839	5127
Maximum current Imax [A] [3]	748	1496	2991	4487	5982
Min Smax operating voltage [V][4]	90% Vn				
Minimum operating voltage [V][4]	85% Vn				
Maximum operating voltage [V][4]	115% Vn				
Nominal frequency [Hz]	50 or 60				
Frequency range [Hz] [5]	Adjustable (47,5 - 51,5) or (55.5 to 62.5)				
Max. efficiency[%] [6]	**99,52 (**)**	**99,52 (**)**	**99,52 (**)**	**99,52 (**)**	**99,52 (**)**
Euro efficiency [%] [6]	**99,38 (**)**	**99,31 (**)**	**99,33 (**)**	**99,34 (**)**	**99,32 (**)**
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 umbalancement	1%				
Short circuit current contribution [A]	1122	2244	4486,5	6730,5	8973
Other data					
Ventilation system	Forced Air				
Dissipated power without load [W]	80	80	80	80	80

Control	DSP				
Output wave form	Pure Sine wave				
Operating temperature range [°C][7]	-20°C / + 51°C				
Max Operating temperature [C°]	+60				
Storage temperature range [°C]	-25°C / + 70°C				
Operating humidity range	5% / 95%				
Maximum altitude with no power derating at max ambient temp (+51°C)	2000 (s.l.m)				
Power derating with altitude	1% every 100m above 2000m				
Environment category	INDOOR				
Pollution Degree	PD3				
Overvoltage class (input DC)	Class II				
Overvoltage class (output AC)	Class II				
Mechanical characteristics					
Class of protection	IP20				
dBA	65	69	69	69	69
Footprint size for basement (LxD) [mm]	2000/1000	2000/1000	4000/1000	6000/1000	8000/1000
Overall (LxDxH) [mm]	2000/1000/2000	2000/1000/2000	4000/1000/2000	6000/1000/2000	8000/1000/2000
Weight [kg]	1600	1800	3600	5400	7200

(*): operating with **Master & Multi-Slave logic**

(**): Third Party lab measured values. Test report available upon request. Values measured according to IEC EN 50530. Measures taken at DC input voltage level of 900V.

6.3 Tier 3: 640Vac output voltage core

SOLEIL DSPX TLH 1500	708	1415M (*)	2830M (*)	4245M (*)	5660M (*)
DC input side– Recommended power of the modules					
Rated [kWp]	718	1435	2865	4291	5721
Maximum [kWp]	899	1794	3582	5364	7152
Number of power cores	1	2	4	6	8
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)	1170				
Min voltage @+70°C [7] [V]	950				
Max input DC current [A]	757	1511	3016	4517	6023
Modules max. Isc [A]	947	1889	3770	5647	7529
N. DC inputs (per pole)	4	4	4	4	4
N. MPPT	1	1	1	1	1
AC output side					
Rated apparent power Sn [kVA]	707,5	1415	2830	4245	5660
Max Apparent Power Smax [kW] [1]	721,65	1443,3	2886,6	4329,9	5773,2
Max Active Power Pmax [kVA] [1]	721,65	1443,3	2886,6	4329,9	5773,2
Nominal voltage [V] (line-to-line)	640				
Connection	3ph				
Rated current In [A] [2]	639	1277	2553	3830	5106
Maximum current Imax [A] [3]	724	1447	2894	4341	5787
Min Smax operating voltage [V][4]	90% Vn				
Minimum operating voltage [V][4]	85% Vn				
Maximum operating voltage [V][4]	115% Vn				
Nominal frequency [Hz]	50 or 60				
Frequency range [Hz] [5]	Adjustable (47,5 - 51,5) or (55.5 to 62.5)				
Max. efficiency[%] [6]	**99,55 (**)**	**99,55 (**)**	**99,55 (**)**	**99,55 (**)**	**99,55 (**)**
Euro efficiency [%] [6]	**99,29 (**)**	**99,33 (**)**	**99,36 (**)**	**99,36 (**)**	**99,35 (**)**
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 umbalancement	1%				
Short circuit current contribution [A]	1086	2170,5	4341	6511,5	8680,5
Other data					
Ventilation system	Forced Air				
Dissipated power without load [W]	80	80	80	80	80

Control	DSP				
Output wave form	Pure Sine wave				
Operating temperature range [°C][7]	-20°C / + 51°C				
Max Operating temperature [C°]	+60				
Storage temperature range [°C]	-25°C / + 70°C				
Operating humidity range	5% / 95%				
Maximum altitude with no power derating at max ambient temp (+51°C)	2000 (s.l.m)				
Power derating with altitude	1% every 100m above 2000m				
Environment category	INDOOR				
Pollution Degree	PD3				
Overvoltage class (input DC)	Class II				
Overvoltage class (output AC)	Class II				
Mechanical characteristics					
Class of protection	IP20				
dBA	65	69	69	69	69
Footprint size for basement (LxD) [mm]	2000/1000	2000/1000	4000/1000	6000/1000	8000/1000
Overall (LxDxH) [mm]	2000/1000/2000	2000/1000/2000	4000/1000/2000	6000/1000/2000	8000/1000/2000
Weight [kg]	1600	1800	3600	5400	7200

(*): operating with **Master & Multi-Slave logic**

(**): Third Party lab measured values. Test report available upon request. Values measured according to IEC EN 50530. Measures taken at DC input voltage level of 955V.

6.4 Tier 4: 640Vac output voltage core

SOLEIL DSPX TLH 1500	764	1528M (*)	3056M (*)	4584M (*)	6112M (*)
DC input side– Recommended power of the modules					
Rated [kWp]	813	1622	3239	4851	6468
Maximum [kWp]	1017	2028	4049	6064	8085
Number of power cores	1	2	4	6	8
DC input side– Electrical specifications					
Operating voltage range [V][7]	1020 - 1480				
MPPT voltage [V][7]	1020 - 1450				
Max voltage (no operation) @-10°C [V]	1500				
Rated DC voltage (max efficiency)	1020				
Min voltage @+70°C [7] [V]	1020				
Max input DC current [A]	798	1591	3176	4756	6342
Modules max. Isc [A]	998	1989	3970	5946	7927
N. DC inputs (per pole)	4	4	4	4	4
N. MPPT	1	1	1	1	1
AC output side					
Rated apparent power Sn [kVA]	764	1528	3056	4584	6112
Max Apparent Power Smax [kW] [1]	800	1600	3200	4800	6400
Max Active Power Pmax [kVA] [1]	800	1600	3200	4800	6400
Nominal voltage [V] (line-to-line)	640				
Connection	3ph				
Rated current In [A] [2]	690	1379	2757	4136	5514
Maximum current Imax [A] [3]	722	1444	2887	4331	5774
Min Smax operating voltage [V][4]	100% Vn				
Minimum operating voltage [V][4]	85% Vn				
Maximum operating voltage [V][4]	115% Vn				
Nominal frequency [Hz]	50 or 60				
Frequency range [Hz] [5]	Adjustable (47,5 - 51,5) or (55.5 to 62.5)				
Max. efficiency[%] [6]	**99,67 (**)**	**99,67 (**)**	**99,67 (**)**	**99,67 (**)**	**99,67 (**)**
Euro efficiency [%] [6]	**98,84 (**)**	**99,39 (**)**	**99,53 (**)**	**99,56 (**)**	**99,61 (**)**
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 umbalancement	1%				
Short circuit current contribution [A]	1083	2166	4330	6496	8661
Other data					
Ventilation system	Forced Air				
Dissipated power without load [W]	80	80	80	80	80

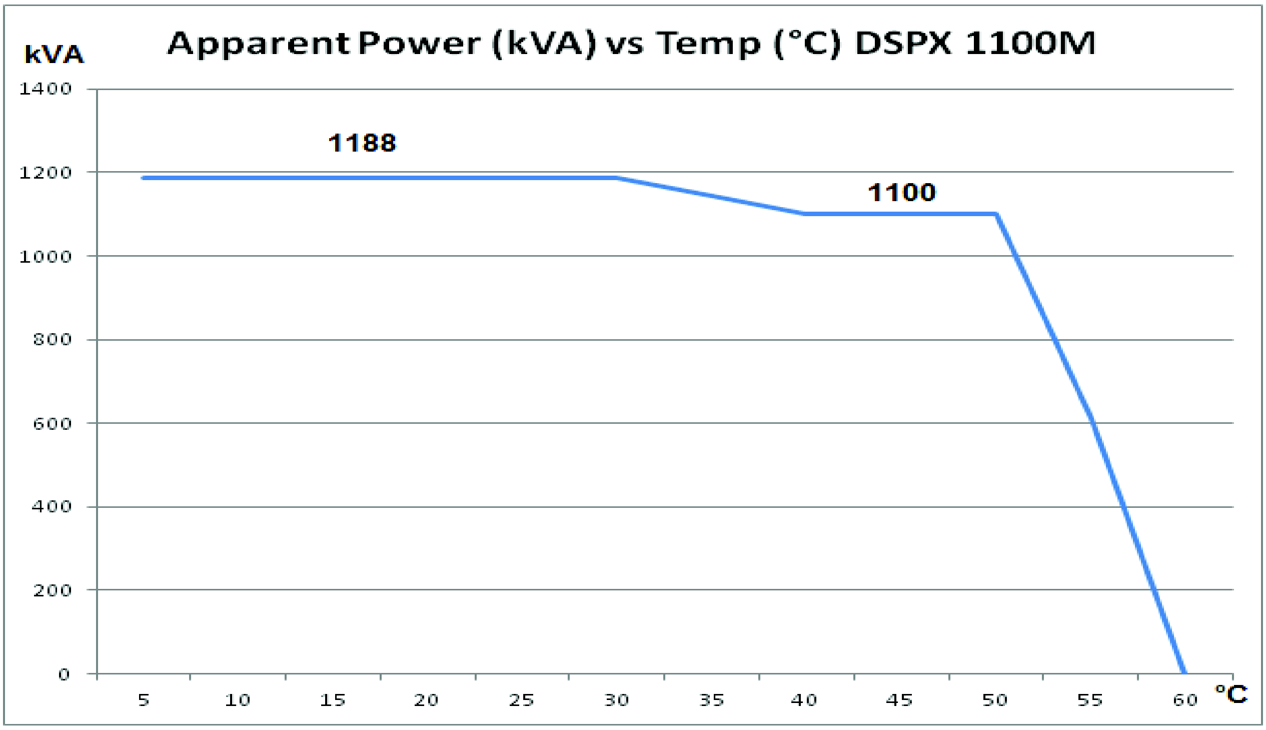
Control	DSP				
Output wave form	Pure Sine wave				
Operating temperature range [°C][7]	-20°C / + 51°C				
Max Operating temperature [C°]	+60				
Storage temperature range [°C]	-25°C / + 70°C				
Operating humidity range	5% / 95%				
Maximum altitude with no power derating at max ambient temp (+51°C)	2000 (s.l.m)				
Power derating with altitude	1% every 100m above 2000m				
Environment category	INDOOR				
Pollution Degree	PD3				
Overvoltage class (input DC)	Class II				
Overvoltage class (output AC)	Class II				
Mechanical characteristics					
Class of protection	IP20				
dBA	65	69	69	69	69
Footprint size for basement (LxD) [mm]	2000/1000	2000/1000	4000/1000	6000/1000	8000/1000
Overall (LxDxH) [mm]	2000/1000/2000	2000/1000/2000	4000/1000/2000	6000/1000/2000	8000/1000/2000
Weight [kg]	1600	1800	3600	5400	7200

(*): operating with **Master & Multi-Slave logic**

(**): Third Party lab measured values. Test report available upon request. Values measured according to IEC EN 50530. Measures taken at DC input voltage level of 1030V.

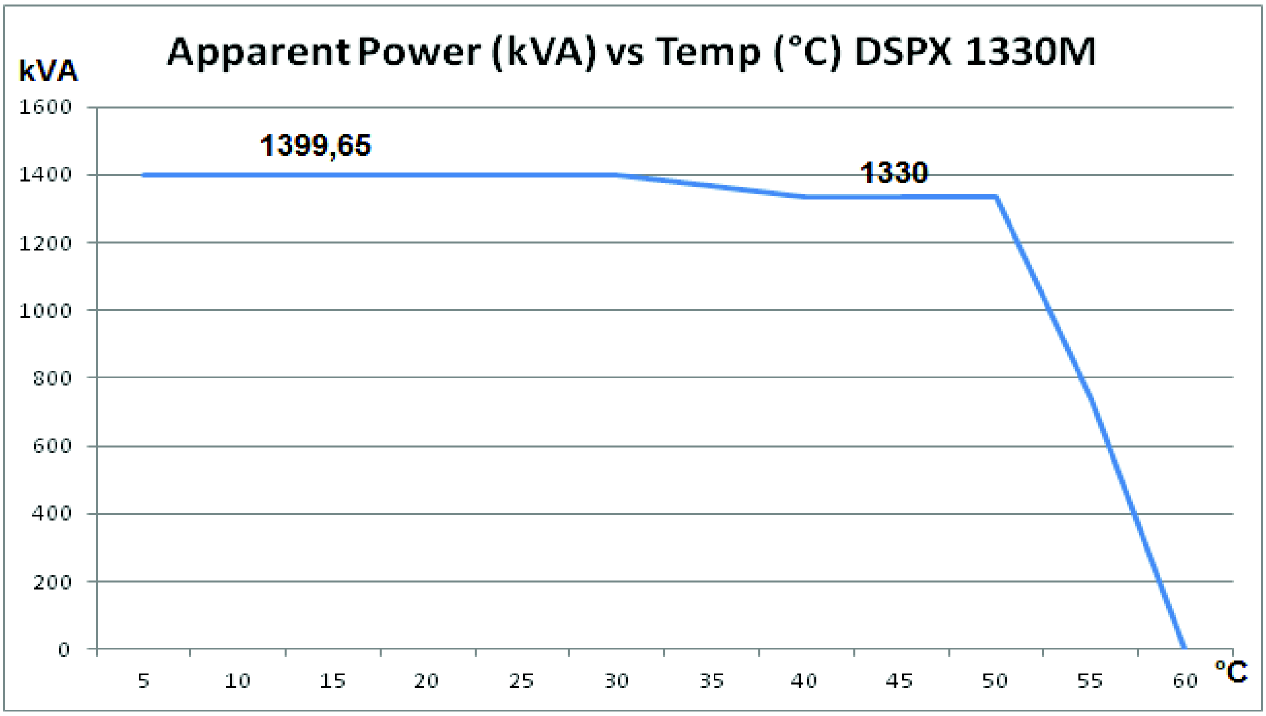
6.5 Apparent power vs Temperature graphs

Soleil DSPX "Tier 1" 1100M



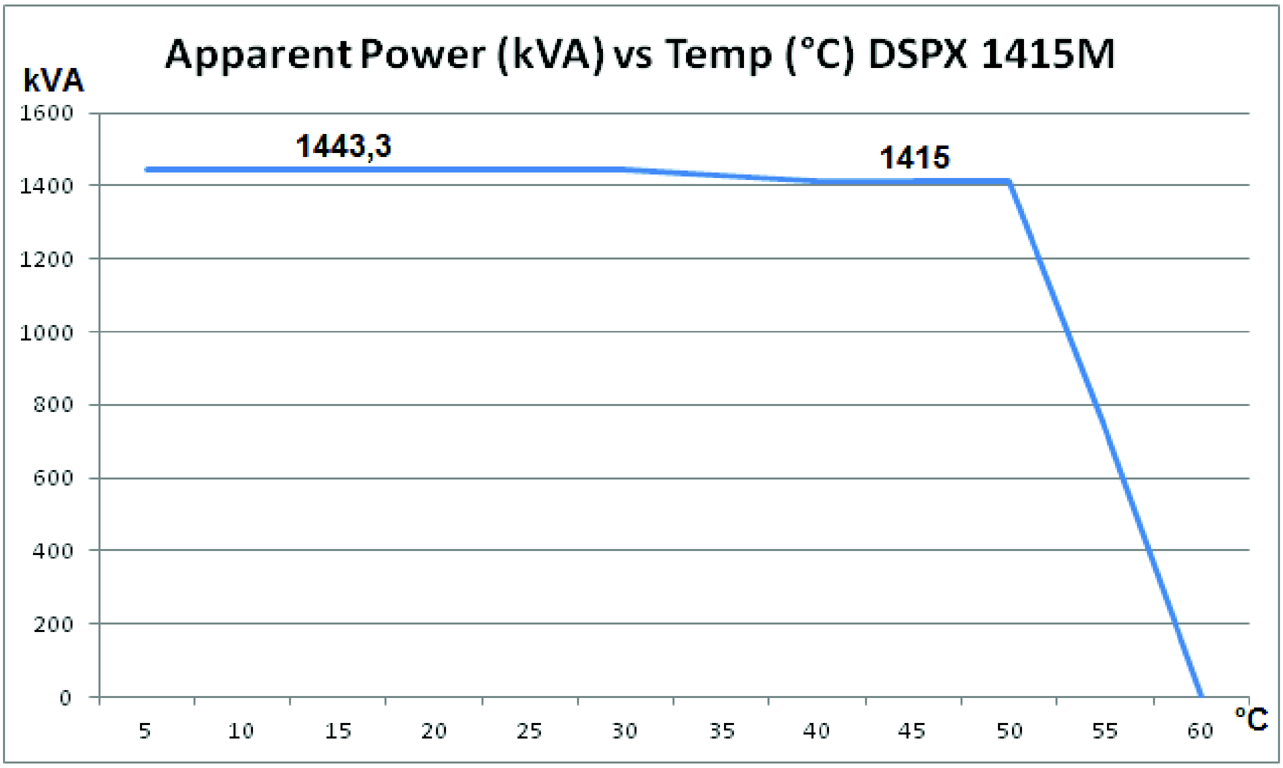
Please notice that, for power models which are multiple of this model, values scale-up accordingly (e.g. for 2200M, Smax is 1188x2 = 2376kVA).

Soleil DSPX "Tier 2" 1330M



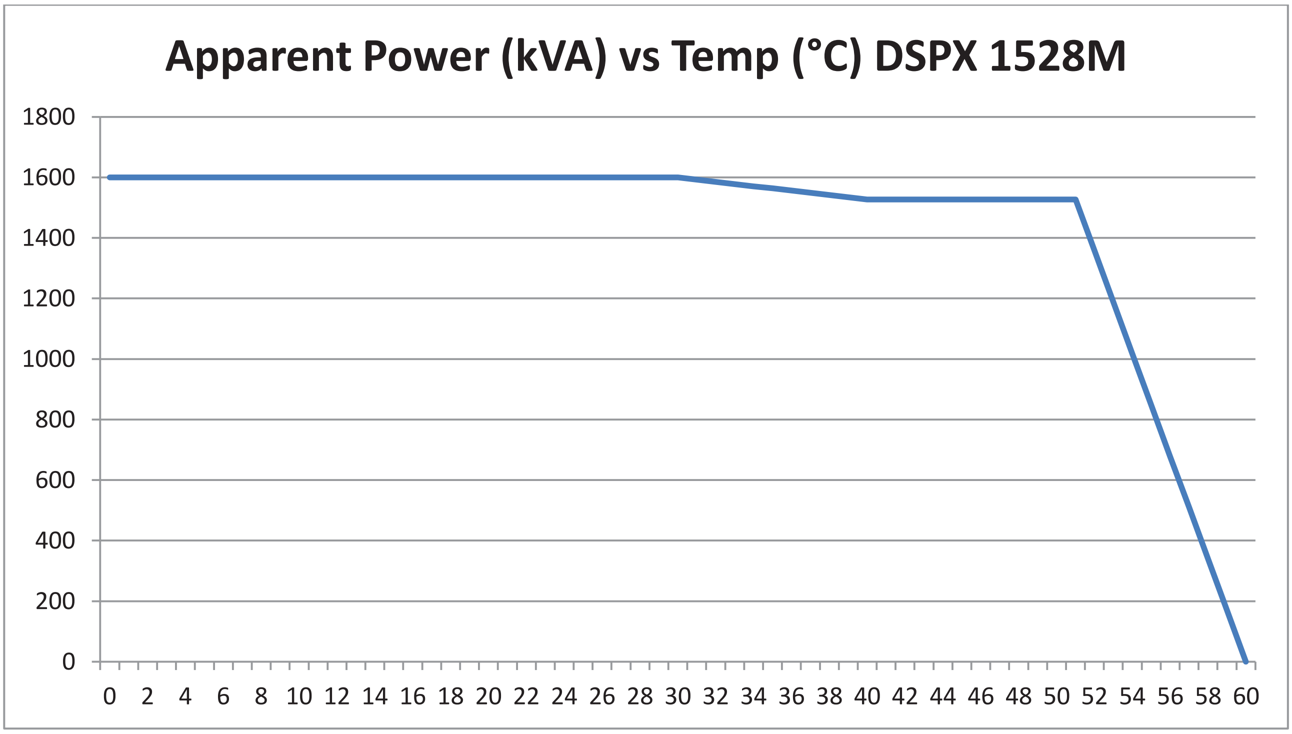
Please notice that, for power models which are multiple of this model, values scale-up accordingly (e.g. for 2660M, Smax is 1399,65x2 = 2799,3kVA).

Soleil DSPX "Tier 3" 1415M



Please notice that, for power models which are multiple of this model, values scale-up accordingly (e.g. for 2830M, Smax is 1443,3x2 = 2886,6kVA).

Soleil DSPX "Tier 4" 1528M



Please notice that, for power models which are multiple of this model, values scale-up accordingly (e.g. for 3056M, Smax is 1600x2 = 3200kVA).

6.6 DEPENDENCE OF THE APPARENT POWER ON THE AMBIENT TEMPERATURE AND THE GRID VOLTAGE

The P-Q capability of the inverter is correlated not only to the temperature, but also to the instantaneous rms value of the grid voltage, according to the following law:

6.6.1 Inverters belonging to 'Tier 1', Tier 2', 'Tier 3'

Referring, as an example, to the model 1415M:

- If the rms value of the AC voltage is at its rated value (V=Vn=640V), the capability of the inverter (maximum value of its apparent power) follows trends illustrated in figure 1 and 2, depending only on the ambient instantaneous values.

- If the rms value of the AC voltage is greater than the rated value (V>Vn), the maximum apparent power of the inverter increases linearly with the rms value of the AC voltage.
  This increase, nevertheless, has a correlation with the temperature, according to the GREEN line in FIGURE 3:

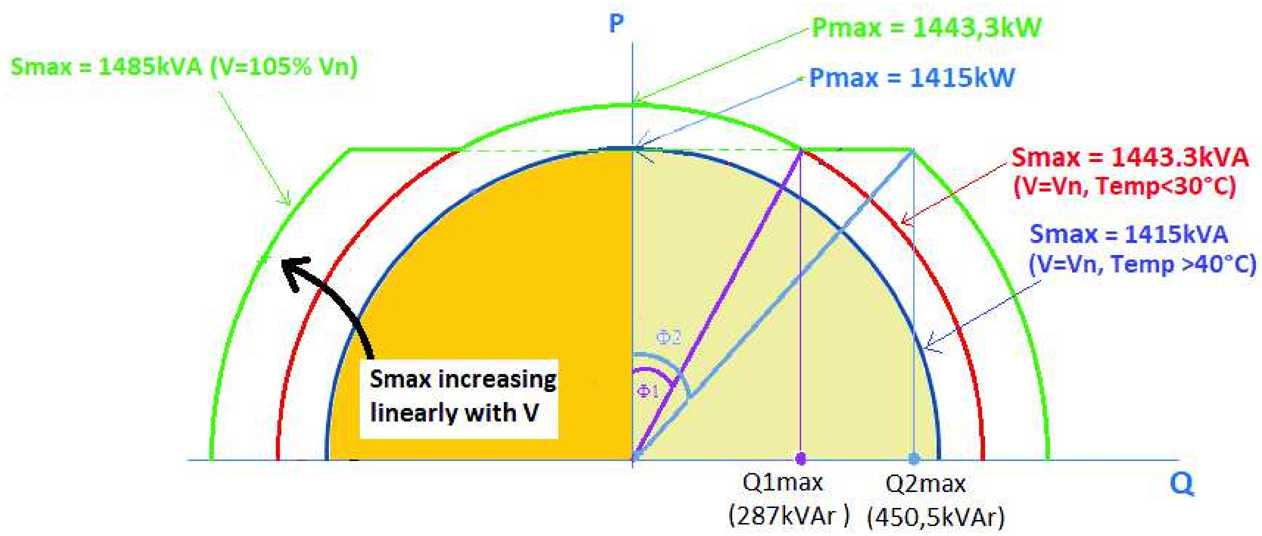


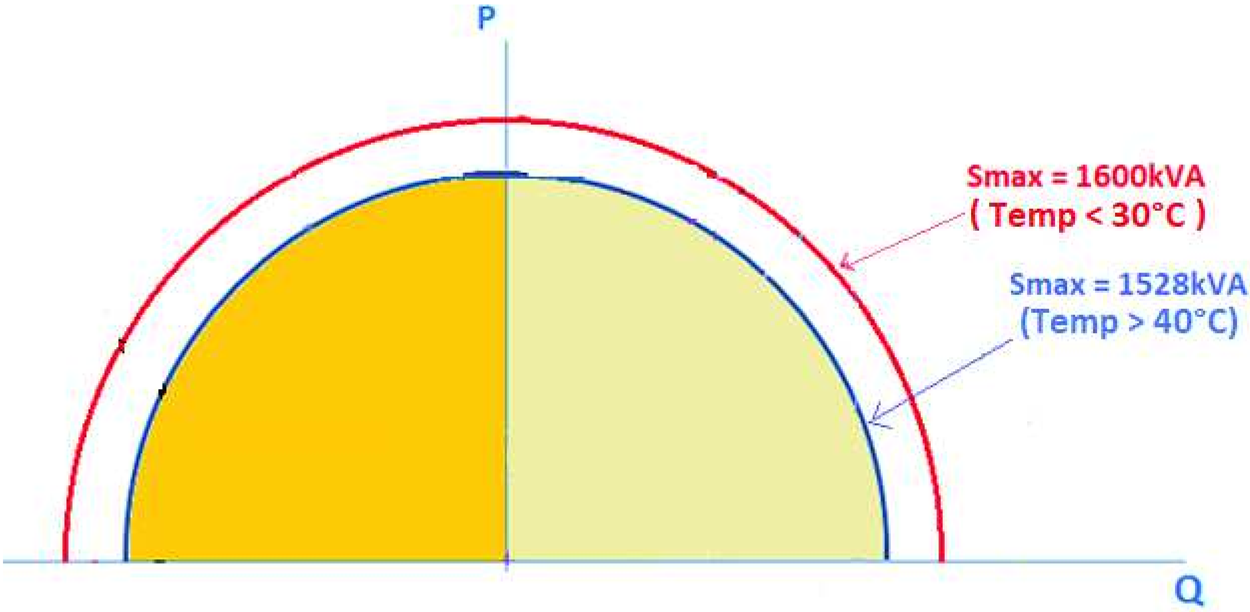
FIGURE 3

In previous figure the power factor corresponding to angles Φ1 and Φ2 are respectively:

- Cos Φ1 = 1415/1443 = 0,98 Q1max = 1443 x sin Φ1 = 287kVAr
- Cos Φ2 = 1415/1485 = 0,9528 Q2max = 1485 x sin Φ2 = 450,5kVar

6.6.2 Inverters belonging to 'Tier 4'

Referring, as an example, to model 1528M, the apparent power is only dependent on the ambient temperature according to following diagram:



- If the grid voltage is greater than Vn, the maximum apparent power stays unchanged, depending only on the temperature (e.g: Temp>40°C and V = 1.05Vn, → Smax = 1528kVA).
- If the grid voltage is lower than Vn, the maximum apparent power decreases accordingly (e.g.: Temp <30°C and V = 0.9Vn → Smax = 1600 x 0.9 = 1440kVA).

6.7 Notes

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

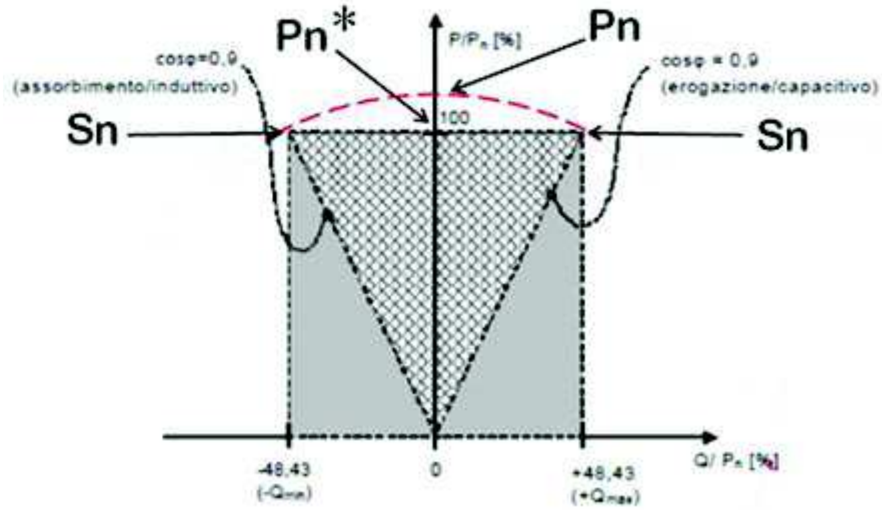
- **Sn:** rated value of the **apparent power**. This value is defined as the power value that can be continuously generated when the ambient temperature exceeds 40°C, up to 51°C.
    - **For inverters belonging to Tier 1, Tier 2, Tier 3,** this value is guaranteed when the voltage of operation is between 0.9Vn and the rated voltage Vn.
    - **For inverters belonging to Tier 4,** this value is guaranteed only at V=Vn. In the operating voltage between 0,9Vn and Vn, the power is decreased linearly with the voltage.
- **Smax:**
    - **For inverters belonging to Tier 1, Tier 2, Tier 3,** Smax is the 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 6.5.
    - **For inverters belonging to Tier 4,** Smax is the maximum value of the **apparent power** that can be generated at the operating voltage Vn, from the minimum operating temperature up to 40°C, according to graphical trends "Apparent Power vs Temperature" reported in paragraph 6.5.
- **Pmax:**
    - **For inverters belonging to Tier 1, Tier 2, Tier 3,** Pmax is the 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 6.5.

  - **For inverters belonging to Tier 4,** Pmax is the maximum value of the **active power** (at power factor = 1) that can be generated at the operating voltage Vn, from the minimum operating temperature up to 40°C, according to graphical trends “Apparent Power vs Temperature” reported in paragraph 6.5.

Other power definitions (see figure below):

- **Pn (Rated value of active power)**:
  - **For inverters belonging to Tier 1, Tier 2, Tier 3**, 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.
  - **For inverters belonging to Tier 4,** 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 Vn.
- **Pn* (Rated value of active power at p.f. = 0,9Pn)**:
  - **For inverters belonging to Tier 1, Tier 2, Tier 3,** 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.
  - **For inverters belonging to Tier 4,** 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 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**:
   - **For inverters belonging to Tier 1, Tier 2, Tier 3** Imax is the maximum value of current, corresponding to the maximum value of apparent power, when the grid voltage is 0.9Vn (-10%).
   - **For inverters belonging to Tier 4** Imax is the maximum value of current, corresponding to the maximum value of apparent power.

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 voltages of:
    - 800V for Tier 1 models
    - 900V for Tier 2 models
    - 955V for Tier 3 models
    - 1030V for Tier 4 models