USER MANUAL

SPPM-PV

Solar Panel Power Monitor for PV Plants

EN

V1.0

senseca

Contents

1 Introduction

The **SEMS SPPM-PV** is a monitoring system designed to measure the dirt accumulation (soiling) on photovoltaic (PV) solar panels. It is composed of the **SPPM-PV control unit** and the **MTD-4000** datalogger. The information provided by the SEMS SPPM-PV is essential for determining the optimal cleaning schedule for a solar plant's PV modules.

The SEMS SPPM-PV determines the level of soiling by processing samples directly taken from reference photovoltaic modules installed in the solar plant. This gives more representative accurate information on soiling accumulation that is correlated with the specific operating environment. This monitoring system is compatible with virtually any solar panel technology available on the market.

The **SEMS SPPM-PV** implements the processing algorithms recommended by **IEC 61724-1** standard to calculate soiling, based on the measurement of the short-circuit current and temperature of two reference panels.

The general operation of the SEMS SPPM-PV system involves keeping one of the panels clean at all times (**Clean Panel**). The other panel (**Soiled Panel**) will be cleaned only when the rest of the plant's panels are cleaned. This means that the soiling parameter will give information on the loss of energy caused by accumulated dirt or dust.

The SEMS SPPM-PV system provides nine data channels, offering monitoring capabilities to ensure optimal performance of the solar PV plant:

Channel	Unit	Description
Solar Elevation	º	(Optional) Angle of elevation of the Sun above the horizon.
Hour Angle	º	Angular deviation with respect to solar noon (15º/h).
Clean Panel Temperature	ºC	Clean panel temperature.
Soiled Panel Temperature	ºC	Soiled panel temperature.
I_{sc} Clean Panel	A	Clean panel short-circuit current.
I_{sc} Soiled Panel	A	Soiled panel short-circuit current.
SPPM-PV Status	Status	Binary code represented in bits with information on diagnosis and cleaning / pairing operations.
Daily Soiling	Ratio	Ratio of energy loss due to accumulation of soiling on the panel. One value is delivered per day.
Raw Soiling	Ratio	Ratio of energy loss due to accumulation of soiling on the panel, calculated each cycle of 30 seconds. A value of -32000 (Data not available) is returned when conditions are not met.

2 SEMS SPPM-PV system components

2.1 Elements on-site installed

The elements of SEMS SPPM-PV system and their respective functions are:

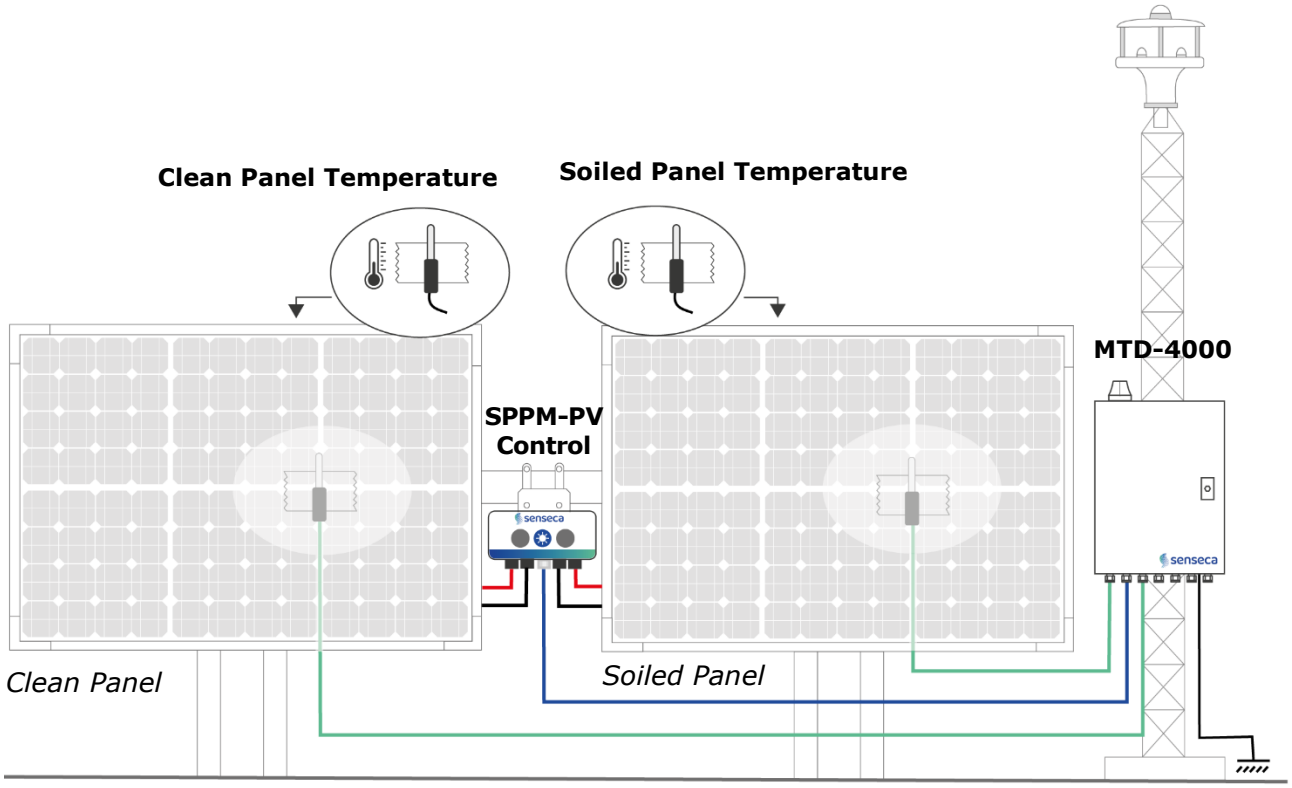


Fig. 2.1: SEMS SPPM-PV elements

- **Clean panel**
  The reference photovoltaic module, identical to the rest of the panels used in the photovoltaic plant, labelled as "CLEAN PANEL", which is cleaned periodically to keep it free of dust and dirt.

- **Soiled panel**
  The reference photovoltaic module, identical to the rest of the panels used in the photovoltaic plant, labelled "SOILED PANEL", which accumulates dirt at the same rate as the plant's other panels.

- **Temperature sensors (x2) for clean and soiled panels**
  PT100/PT1000 surface temperature probes, fixed to the back of the panel.

- **SPPM-PV control**
  Signal conditioning and operations control unit.

- **Data Acquisition System (DAS) model MTD-4000**
  Unit for acquisition, processing, storage and transmission of soiling data. Compatible with additional solar radiation and weather sensors.
  The model MTD-4000 collects the PV panels Isc, temperature and additional information about tasks performed at the field sensed by the Control Box. All of this information is used to calculate the soiling.

2.2 GEO-DataView software package

The data collected by the MTD-4000 is accessible from the different software applications included in GEO-DataView software package.

The GEO-DataView package is a set of applications, supplied in different modalities to cover different needs. Each modality includes a specific group of applications or services. The following table describes the available applications and their functions in the SEMS SPPM-PV system.

Application	Functions in SEMS SPPM-PV system
GEO-DataLink (Mobile App)	• Configuring the SPPM-PV system during start-up. • Local (Wi-Fi) and remote (3G/4G or Ethernet) use. • Downloading and viewing soiling data. • Storage of SPPM-PV data (CSV) using FTP
Teletrans (PC Software)	• Automation of remote downloading of SPPM-PV data. • Storing data in SQL database. • Automatic generation of CSV files with data.
Webtrans (Website)	• View soiling data on the Web.

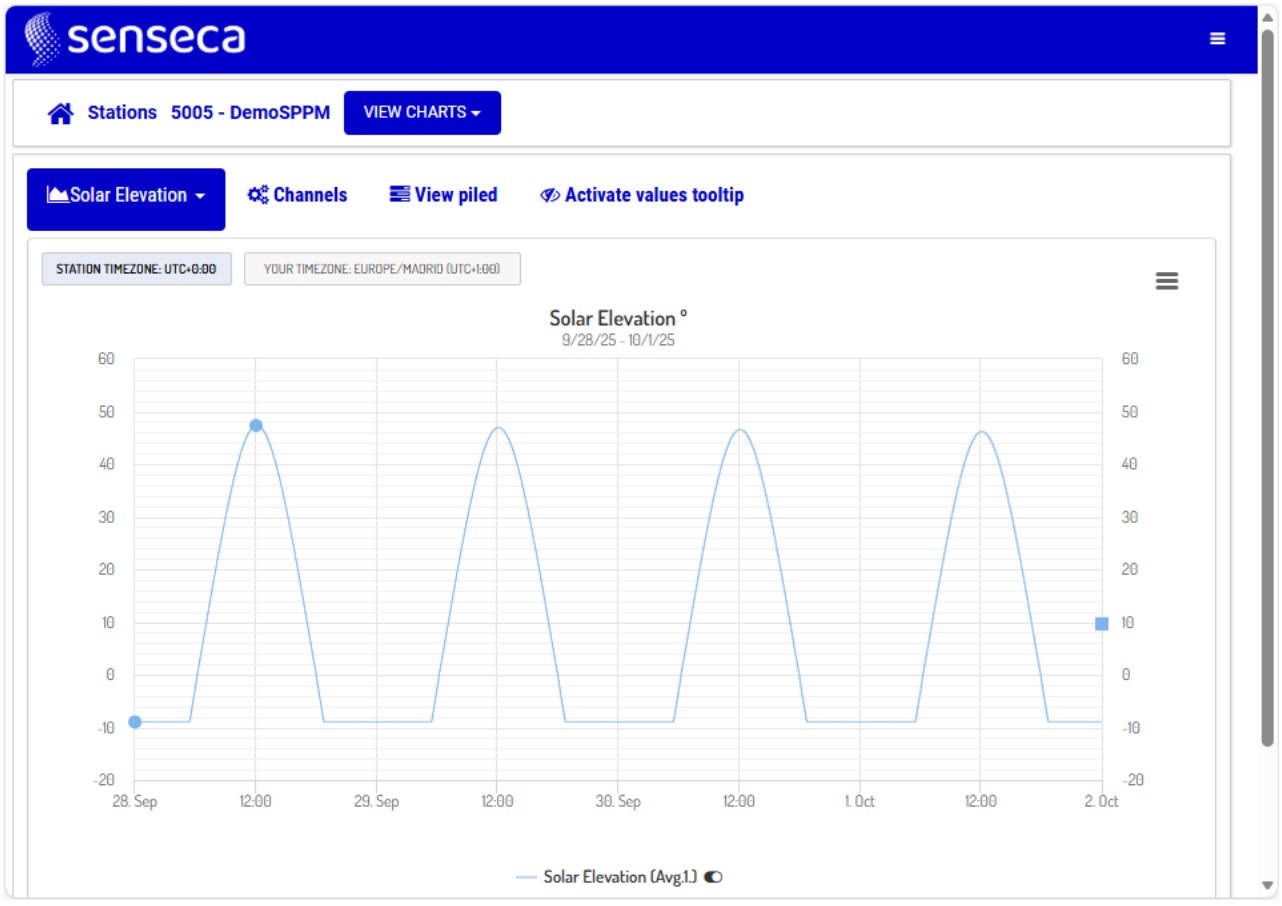


Fig. 2.2: SEMS SPPM-PV data on Web

3 Preliminary warnings and considerations

The development of photovoltaic technology is an area of research that is evolving continuously. The measurement of the soiling ratio is a new field under development. The SEMS SPPM-PV system was designed according to the recommendations in the latest standards to make it compatible with existing solar panel technologies.

The SPPM-PV control module can be connected to panels based on different technologies. Depending on the technology itself or the type of assembly used, different qualities in the measurements by the SEMS SPPM-PV can be obtained. The following graph shows the quality scale of the results obtained:

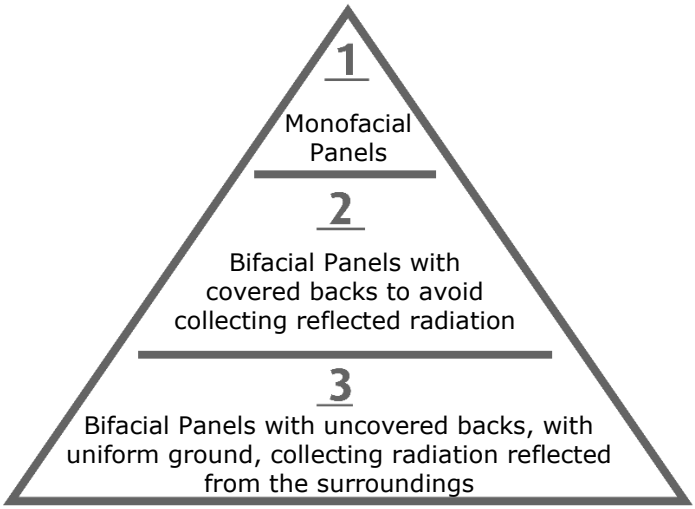


Fig. 3.1: Results quality for SEMS SPPM-PV

Attention!

Recommendations for installation in photovoltaic plants with bifacial solar panels.

If the SEMS SPPM-PV system is being installed in photovoltaic plants with bifacial panels, it is essential that the signal captured by the cells installed on the back of the clean and soiled panels be as uniform as possible. To do this, we recommend installing an opaque PVC or methacrylate sheet on the back of the panel, or covering the back of the panel using an opaque vinyl.

If the back surface of bifacial panels cannot be covered, ensure that both panels connected to the SPPM-PV control unit are installed on a uniform and regular surface, for example covered with gravel or other type of material that reflects light as uniformly as possible.

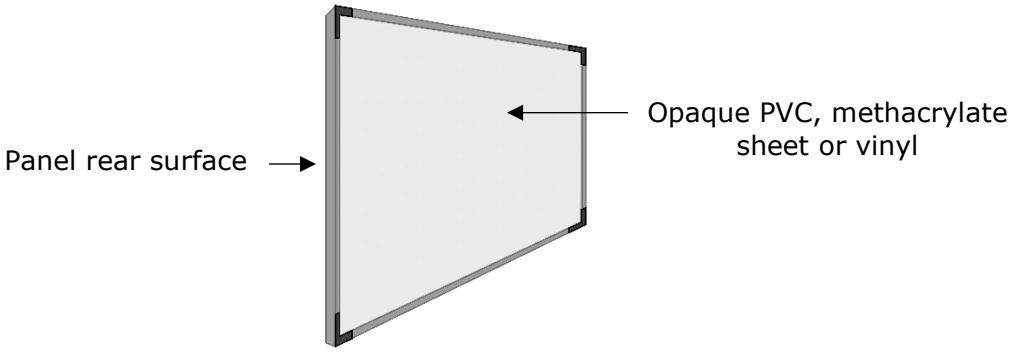


Fig. 3.2: Back of bifacial panel covered with vinyl

4 SPPM-PV installation procedure

4.1 Preliminary recommendations

Take the following factors into account in the final arrangement of elements in the installation:

- The clean panel must be installed next to the soiled panel and must be coplanar, with a deviation of less than 0.5º at any time of the day.
- The clean panel and soiled panel temperature sensors will be attached to the back surface of the panels. We recommend measuring the width and height of the panel and positioning the sensor on the back at one third of these distances. To minimize the shaded areas of the panel, use the current-conducting areas of the panel to attach the sensor itself and its cable.
- The SPPM-PV control unit should be installed less than 2 meters from the clean and soiled panels.
- The MTD-4000 datalogger can be located up to 30 meters away from the SPPM-PV control unit.
- The clean and soiled panels used as a reference in the SEMS SPPM-PV system must be installed on the same tracker structure as the rest of the panels in the plant.

4.2 Installing the SPPM-PV control unit

The SPPM-PV control unit installation kit is compatible with installation on panels, towers, masts or walls, as well as on the solar tracker's power transmission shaft (see image):

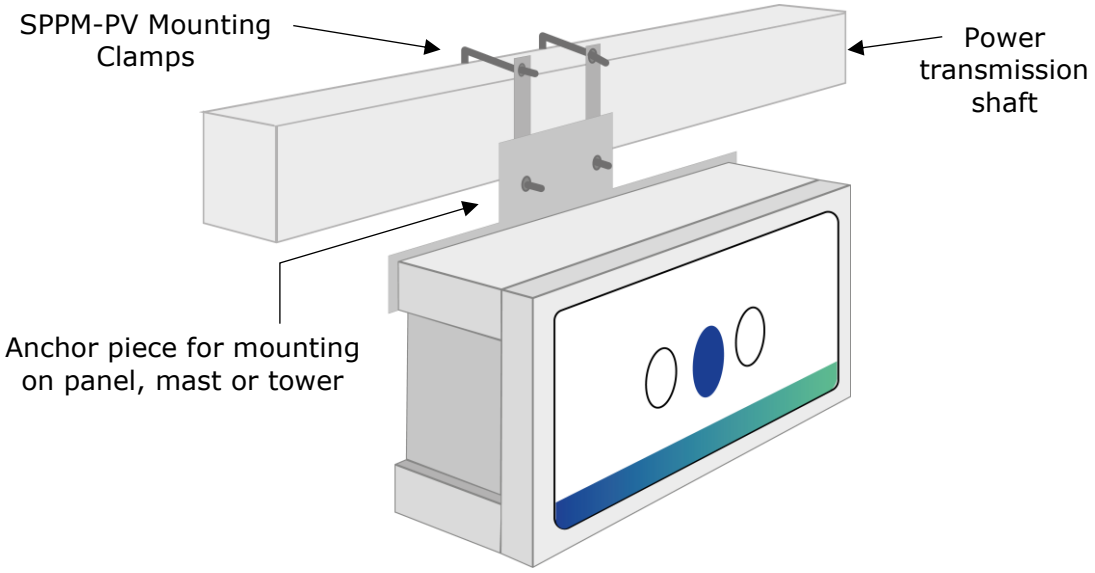


Fig. 4.1: SPPM-PV mounting kit

4.3 Connection diagram

The interconnection of the elements of the SEMS SPPM-PV system is shown in the following diagram. The connections of the MTD-4000 terminal blocks side are defined specifically for each project in a connections list provided with each delivery.

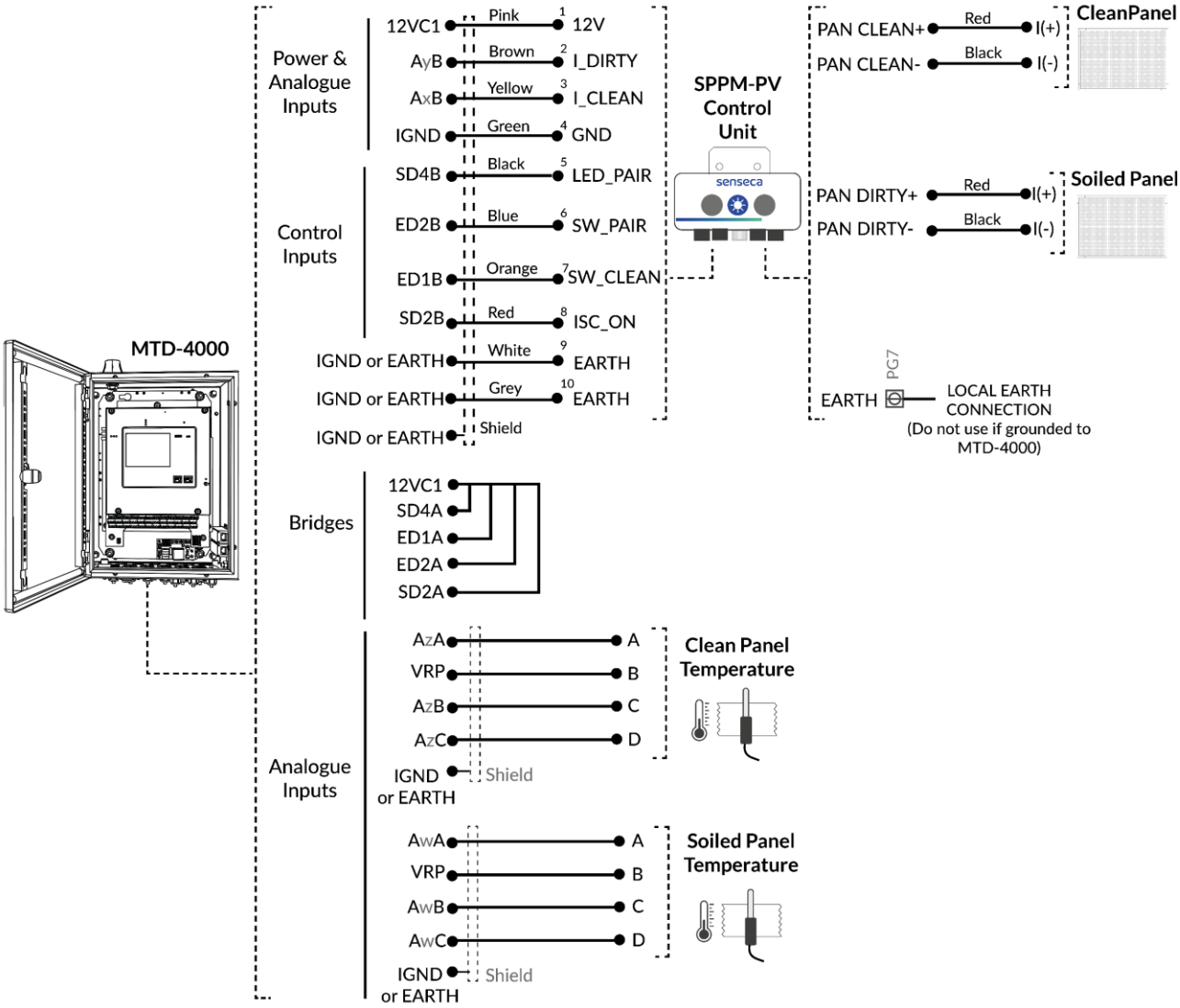


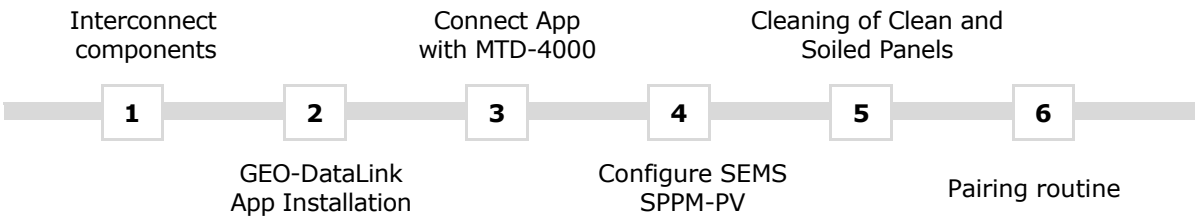
Fig. 4.2: SEMS SPPM-PV Connections

(1) The diagram above shows a typical connection diagram with analogue solar panel temperature sensors (PT100/PT1000). The SEMS SPPM-PV system is also compatible with smart temperature sensors (Modbus). If these are used, the specific list of connections will be included with the supply.

(2) The SPPM-PV control unit has a PG7 cable gland to connect the unit to the local ground. We recommend using this ground if the unit isn't grounded through the station.

(3) The SPPM-PV control unit has 4 MC4 panel connectors to connect directly to the cables running from the solar panels (I+_CleanP, I-CleanP, I+_SoiledP, I-SoiledP), with safe disconnection by pressing on tabs (see image). The SPPM-PV also comes with a set of air-side connectors for optionally crimping to the output cables of the panels if they don't have MC4 connectors.

5 SEMS SPPM-PV start-up procedure



Step 1: Interconnect components

Confirm that all of the elements of the SEMS SPPM-PV system are correctly installed and connected as indicated in these instructions. Turn on the MTD-4000 datalogger from the main switch located on the motherboard.

Step 2: GEO-DataLink App Installation

Download and install the Geo-DataLink (GDL) mobile app using the QR code or link below:

DOWNLOAD ON THE App Store

GET IT ON Google Play

Step 3: Connect App with MTD-4000

Switch the MTD-4000 station ON and add it into the GDL through the Wi-Fi interface. The app main screen includes a link to a video tutorial explaining how to make the connection with the different communication interfaces of the MTD-4000.

Step 4: Configure SEMS SPPM-PV

The internal algorithm of the SEMS SPPM-PV system needs to know the Sun's position at any given time, which is directly related to the date-time and geographical position. To do this, you need to configure the time zone and geographical coordinates in the MTD-4000 processing unit:

(4.1) Click the "SETUP" icon and find the "BASIC DATA" option.

(4.2) Enter the new values for "Latitude", "Longitude" and "Altitude".

(4.4) Set the site time zone (UTC Offset Hours) using the following equation:

Off= Round to nearest integer (LENGTH (º decimal) / 15º)

(4.5) Press the "SEND CONFIGURATION" button to finish.

Step 5: Cleaning of Clean and Soiled panels

Clean both panels. With bifacial panels with the back uncovered, be sure to clean both sides.

Step 6: Pairing routine

Pairing establishes the reference of clean and soiled panels to calculate soiling. This process is important to get good results in the measurement of the soiling ratio. For this reason, the SPPM-PV system sets a series of restrictions that are evaluated during the pairing process.

(6.1) Confirm that the required conditions for the pairing process described in the following section are fulfilled.

(6.2) Follow the steps described in the "PAIRING" section.

6 Operation description

The SEMS SPPM-PV system provides the soiling value as an indication of the energy loss caused by accumulated dirt on the plant"s panels by processing the data collected by one panel that is always kept clean (CLEAN PANEL) and another panel (SOILED PANEL) that will be cleaned only when the rest of the panels of the photovoltaic plant are cleaned.

6.1 Periodic routine for cleaning the clean panel

For the SEMS SPPM-PV system to provide real soiling data, it is important to ensure that the CLEAN PANEL is always clean by carrying out periodic cleaning routines. The frequency of these tasks depends on the conditions of the environment (rain, haze, etc.). Every time that a the "Clean Panel" is going to be cleaned, the steps below must be followed:

1. Clean only the reference panel labelled as "Clean Panel".

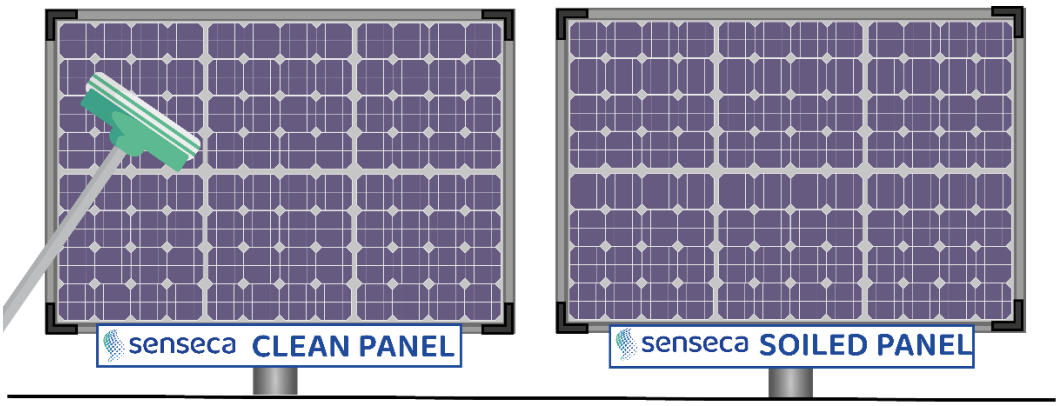


Fig. 6.1: Clean the panel labeled as "Clean Panel"

Attention!

Cleaning the clean panel at least once a week is recommended. Use water and a small concentration of detergent. Then dry. Perform a specific cleaning procedure for this panel (do not allow regular solar plant cleaning machines to clean this panel). Proper cleaning is important to obtain high-quality measurements.

2. Press the button labelled with "CLEAN".

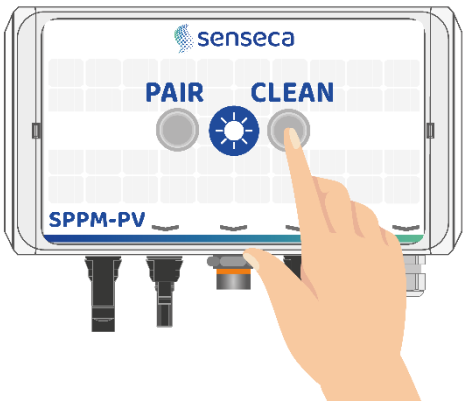


Fig. 6.2: Press "CLEAN" button

Attention!

Press (forcefully) and hold the button for at least one second. If it is pressed correctly, the status of the PAIR button LED changes for one second (flashing).

Each time the cleaning routine is done, a record will appear in the "SPPM-PV Status" parameter.

If the SPPM-PV detects that the CLEAN PANEL hasn't been cleaned in the last 7 days (configurable value), an alarm will be generated through the "SPPM-PV status" parameter (see "DATA ANALYSIS").

6.2 Pairing or re-pairing

The pairing routine sets an initial relationship between the signal measured by the clean panel and the signal measured by the soiled panel. This routine is not necessary for the system to start calculating the soiling but it is highly recommended as it allows more accurate data to be obtained.

Attention!

Re-pairing is recommended at least once a year.

Pairing operation conditions

The SEMS SPPM-PV system will only carry out the pairing operation successfully if the following criteria are met:

(a) It is during the minutes of the day when the Sun is in the most favorable position (Solar Noon ± 30 min).

(b) The effective radiation calculated from the data collected by the clean panel exceeds a predefined threshold (400 W/m2 by default).

(c) The signal received by the clean and soiled panels does not differ by more than 20%. Larger differences indicate a failure in the operation of the panels.

(d) The temperatures of the clean and soiled panels do not differ by more than 2ºC. Larger differences indicate a failure in the operation of the panels or temperature sensors.

(e) The signal received by the soiled panel does not exceed the signal received by the clean panel by more than 10%. Larger differences indicate a cleanliness problem.

These criteria are stated by the MTD-4000 to obtain the best SNR conditions for the measurements carried out by the system.

Routine pairing operations:

In order to perform the MDFS pairing, these steps must be sequentially followed:

1. Ensure both panels "Clean Panel" and "Soiled Panel" are in the best possible cleaning conditions.

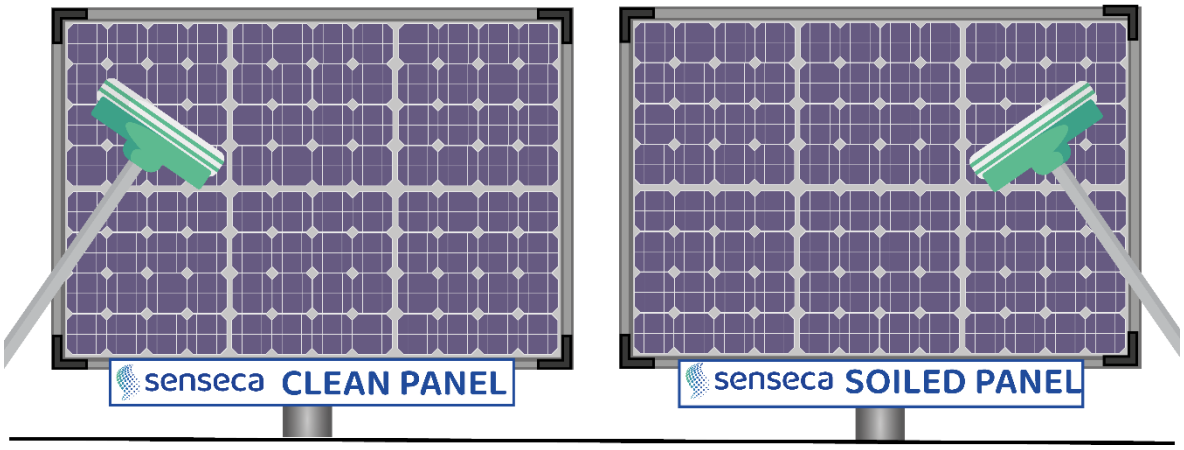


Fig. 6.3: Clean both panels connected to SPPM-PV control

2. Then, press the "PAIR" button to start the pairing process.

Fig. 6.4: Press "PAIR" button

Attention!

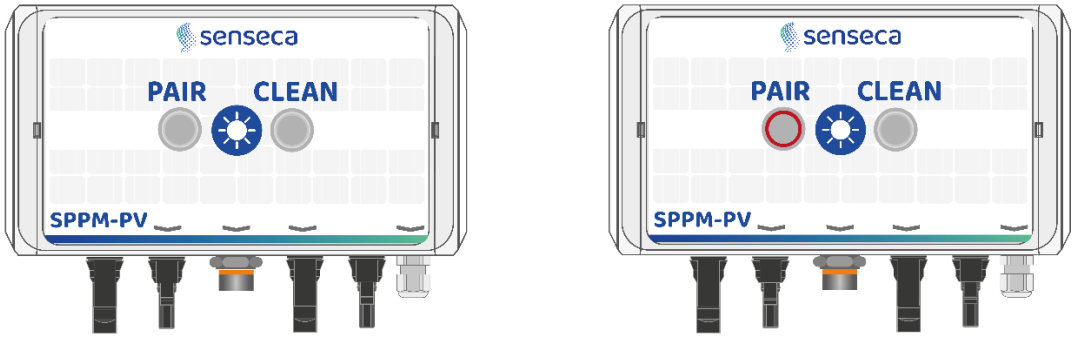
Press (forcefully) and hold the button for at least one second.

3. The system will be performing the automatic pairing during two minutes. During this time the LED around the PAIR button will be blinking.

4. After this time, the system will show the pairing results through the LED and also by means of the info provided by the "SPPM Status" channel at the MTD-4000 logger.

   The parameter "SPPM-PV status" records both the pairing attempt and its result (see the "DATA ANALYSIS" section).

   If the SPPM-PV detects that re-pairing hasn't been done in the last year (configurable value), an alarm is generated through the "SPPM-PV Status" parameter. However, it will continue to apply the corrections extracted from the last pairing even though the recommended validity time has been exceeded.



Successful **Failed**

5. Fig. 6.5: Pairing result at SPPM Status LED

The PAIR button LED provides the following information:

LED Status	Description
Steady ON	Pending pairing (pairing has never been done or there was an error with the last pairing).
Steady OFF	Pairing correct. System measuring soiling.
Blinking	Pairing in progress.
Inst. Flashing	Pressing of the cleaning button detected.

Attention!

Senseca ships each SPPM-PV system configured for the specific characteristics of each project (type of solar panel, etc.) and the requirements of each client. Both the thresholds defined for the pairing process and the number of days stipulated to generate alarms due to lack of cleaning or lack of calibration can be reconfigured easily. The reconfiguration process is outside the scope of this guide. For more information about this procedure contact Senseca technical team.

7 SPPM-PV: Data analysis

7.1 SPPM-PV status

This channel provides information on the overall status of the SPPM-PV system encoded in bits. The resulting values of the active bits are stored in a Real type variable accessible from Modbus.

Use the following online spreadsheet to interpret the code based to the information in the table.

LINK TO "SPPM-PV STATUS"

Bit (Dec.)	Description
Bit 0 (1)	Pressing of the pairing button ("PAIR") detected.
Bit 1 (2)	Pressing the cleaning button ("CLEAN") detected.
Bit 2 (4)	Cleaning not detected in the last 7 (default) days.
Bit 3 (8)	Pairing error.
Bit 4 (16)	Outside solar position window (noon ±30 min. default).
Bit 5 (32)	Insufficient estimated solar radiation (400 W/m2 by default).
Bit 6 (64)	Panel signals differ by more than 20% (by default).
Bit 7 (128)	Too few valid samples during pairing.
Bit 8 (256)	Inconsistency: Signal from clean p. lower than soiled p. (> 10%).
Bit 9 (512)	Pending pairing / pairing validity time exceeded

7.2 Soiling ratio

The SEMS SPPM-PV system gives an average daily soiling value. We advise against obtaining soiling rate results by using instantaneous readings of soling rate data, as it could lead to non-accurate results. This average value only considers samples collected under conditions with sufficient irradiance and in a time range close to solar noon.

The system lets you program alarms via e-mail to alert the plant manager when the dirt on the panels reaches a certain level. Contact the Senseca technical team for more information about the configuration procedure.

Attention!

The SPPM-PV generates a "Not Available" (-32000) value of soiling if:

- Pairing has not been done.
- Irradiance conditions are insufficient.
- The current instant is outside of the time window during which angular effects are minimized (solar noon ± 30 minutes).

If you get a value not available in soiling, consult the "SPPM-PV Status" parameter to determine the exact cause.

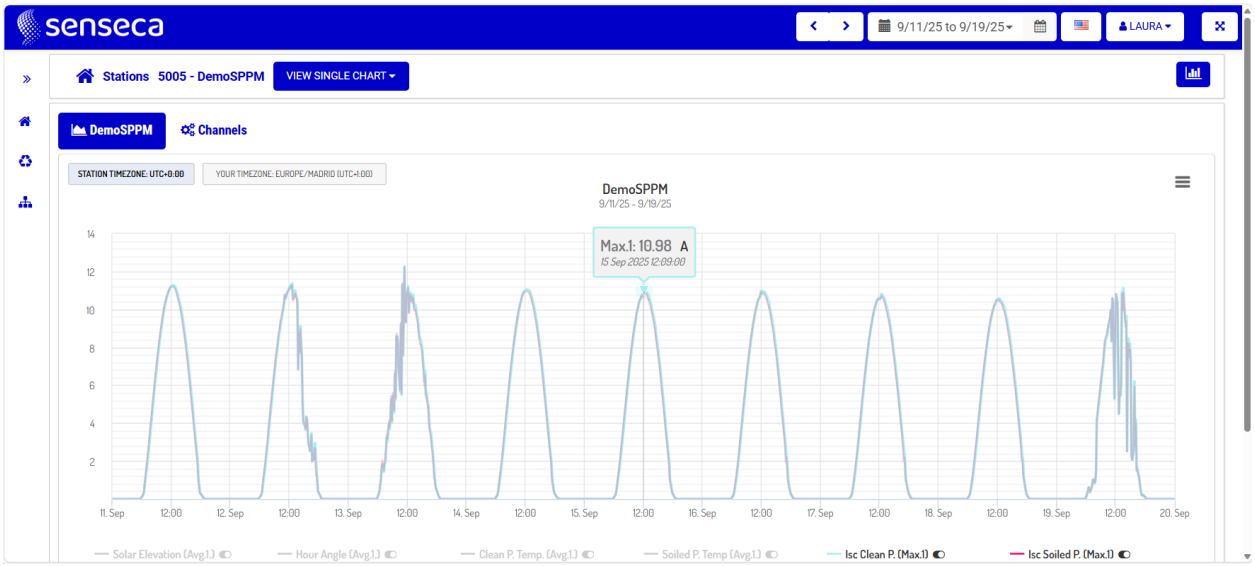


Fig. 7.1: Example of clean and soiled panels Isc

Fig. 7.2: Example of soiling ratio evolution

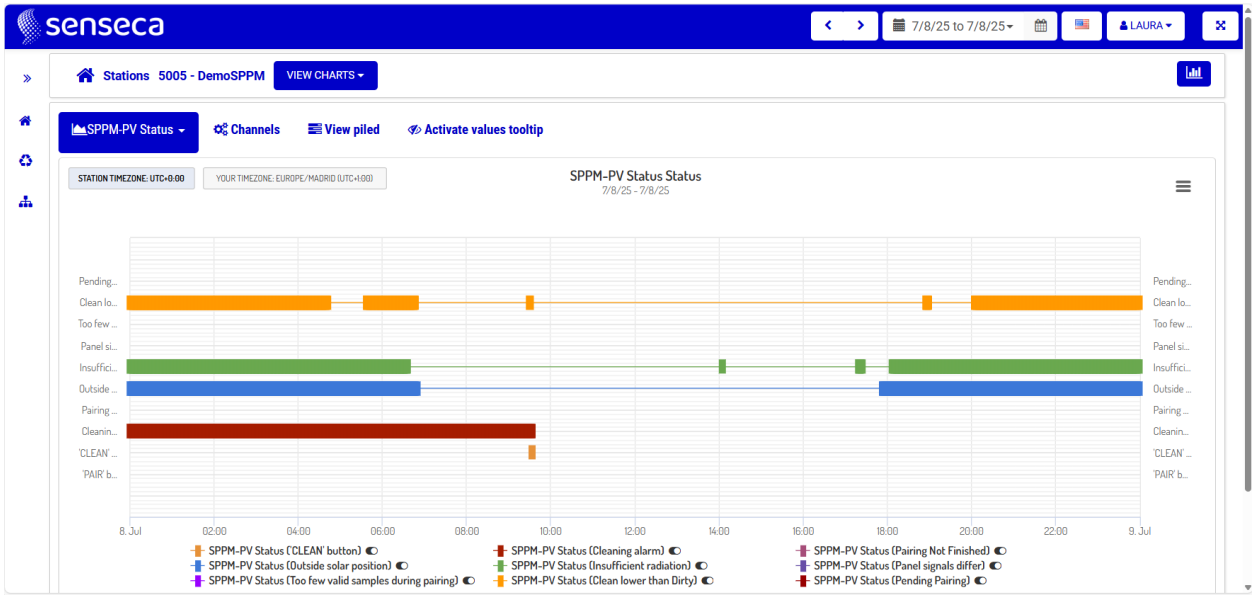


Fig. 7.3: Example of SPPM-PV Status

8 SPPM-PV technical specifications

SPPM-PV control unit. Housing	
Material	Polycarbonate, UV resistant
Characteristics	Fire retardant and self-extinguishing Suitable for outdoor use (f1 approval according to UL 746C)
Cover	Hinge closure
Installation	Installation kit for mounting on panels, towers, masts or walls
Protection	IP66, NEMA4/4X
Dimensions	231 x 125 x 90 mm (L × W × D)
Connection to solar panels	MC4 Panel Connector (Optional) Kit of 4 additional air-side MC4 connectors
Connection to MTD-4000	SAMTEC APC & ACR series connector, 10 pins

SPPM-PV control unit. Measurement of panel current Isc	
Power supply	7.2 to 35 VDC (from MTD-4000 datalogger)
Operating temperature	-40 to +85ºC
Precision Isc	0.1% F.S.
Insulation	1.5KV AC
Surge and ESD Protection	1W SERIES Resistor + 600W TVS Diode 10/1000 µs for signal lines 8/20us varistor (Class 2)
Range Isc	0 to 20 A
Short-circuit activation	Programmable cycle (maintains an electrical state that does not degrade the panel)
Duality	Double panel
Measurement Isc	According to IEC 61724-1
Output Isc	2 x 4-20 mA
Load resistance	Max.(Ω) ≤ (Vsupply - 7.2) / 0.023
Soiling (IEC 71724-1)	0 to 1

SEMS SPPM-PV system. Compatibilities	
Panel technologies	Monofacial / Bifacial. Mono-crystalline split cell, thin film, etc.
Panel arrangement	Panel arrays on fixed structure / Panel arrays on tracker
Panel temperature	PT100 / PT1000 with resistance output/ 4-20mA / Modbus

NOTES

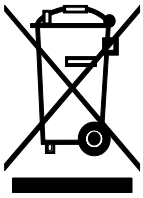
WARRANTY

The manufacturer is required to respond to the "factory warranty" only in those cases provided by Legislative Decree 6 September 2005 - n. 206. Each instrument is sold after rigorous inspections; if any manufacturing defect is found, it is necessary to contact the distributor where the instrument was purchased from. During the warranty period (24 months from the date of invoice) any manufacturing defects found will be repaired free of charge. Misuse, wear, neglect, lack or inefficient maintenance as well as theft and damage during transport are excluded. Warranty does not apply if changes, tampering or unauthorized repairs are made on the product. Solutions, probes, electrodes and microphones are not guaranteed as the improper use, even for a few minutes, may cause irreparable damages.
The manufacturer repairs the products that show defects of construction in accordance with the terms and conditions of warranty included in the manual of the product. For any dispute, the competent court is the Court of Padua. The Italian law and the "Convention on Contracts for the International Sales of Goods" apply.

TECHNICAL INFORMATION

The quality level of our instruments is the result of the continuous product development. This may lead to differences between the information reported in the manual and the instrument you have purchased.
We reserve the right to change technical specifications and dimensions to fit the product requirements without prior notice.

DISPOSAL INFORMATION



Electrical and electronic equipment marked with specific symbol in compliance with 2012/19/EU Directive must be disposed of separately from household waste. European users can hand them over to the dealer or to the manufacturer when purchasing a new electrical and electronic equipment, or to a WEEE collection point designated by local authorities. Illegal disposal is punished by law.

Disposing of electrical and electronic equipment separately from normal waste helps to preserve natural resources and allows materials to be recycled in an environmentally friendly way without risks to human health.

CE RoHS

senseca.com

Senseca Spain S.A.U.
C. Electrónica, 51
28923 Alcorcón, Madrid
SPAIN
info.madrid@senseca.com

senseca