

OPERATOR'S MANUAL



CR-PVS1 PV Soiling Loss Index RTU

Revision: 11/17



Copyright © 2017
Campbell Scientific, Inc.

Limited Warranty

“Products manufactured by CSI are warranted by CSI to be free from defects in materials and workmanship under normal use and service for twelve months from the date of shipment unless otherwise specified in the corresponding product manual. (Product manuals are available for review online at www.campbellsci.com.) Products not manufactured by CSI, but that are resold by CSI, are warranted only to the limits extended by the original manufacturer. Batteries, fine-wire thermocouples, desiccant, and other consumables have no warranty. CSI’s obligation under this warranty is limited to repairing or replacing (at CSI’s option) defective Products, which shall be the sole and exclusive remedy under this warranty. The Customer assumes all costs of removing, reinstalling, and shipping defective Products to CSI. CSI will return such Products by surface carrier prepaid within the continental United States of America. To all other locations, CSI will return such Products best way CIP (port of entry) per Incoterms ® 2010. This warranty shall not apply to any Products which have been subjected to modification, misuse, neglect, improper service, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied. The warranty for installation services performed by CSI such as programming to customer specifications, electrical connections to Products manufactured by CSI, and Product specific training, is part of CSI’s product warranty. **CSI EXPRESSLY DISCLAIMS AND EXCLUDES ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. CSI hereby disclaims, to the fullest extent allowed by applicable law, any and all warranties and conditions with respect to the Products, whether express, implied or statutory, other than those expressly provided herein.”**

Assistance

Products may not be returned without prior authorization. The following contact information is for US and international customers residing in countries served by Campbell Scientific, Inc. directly. Affiliate companies handle repairs for customers within their territories. Please visit www.campbellsci.com to determine which Campbell Scientific company serves your country.

To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 227-9000. Please write the issued RMA number clearly on the outside of the shipping container. Campbell Scientific's shipping address is:

CAMPBELL SCIENTIFIC, INC.

RMA# _____
815 West 1800 North
Logan, Utah 84321-1784

For all returns, the customer must fill out a "Statement of Product Cleanliness and Decontamination" form and comply with the requirements specified in it. The form is available from our website at www.campbellsci.com/repair. A completed form must be either emailed to repair@campbellsci.com or faxed to (435) 227-9106. Campbell Scientific is unable to process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com or by telephoning (435) 227-9000 (USA). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

Table of Contents

PDF viewers: These page numbers refer to the printed version of this document. Use the PDF reader bookmarks tab for links to specific sections.

1. Introduction	1
2. Precautions	1
3. Initial Inspection.....	1
4. Specifications.....	2
4.1 Back-of-Panel Temperature Measurements	2
4.2 Short-Circuit Current Measurements	3
4.3 Communications	3
4.4 System.....	3
4.5 Power Requirements	3
4.6 Compliance	3
4.7 Physical	4
5. Installation	4
6. Operation	4
6.1 Measurement.....	4
6.2 Soiling Loss Index Details	5
7. Maintenance	5
7.1 Offset Correction.....	5
 Appendices	
A. Glossary of Variable Names	A-1
B. Modbus Register Map.....	B-1

CR-PVS1 PV Soiling Loss Index RTU

1. Introduction

The CR-PVS1 PV Soiling Loss Index RTU provides solar energy professionals with the information needed to evaluate and manage the impact of soiling. Plant operators can use this information to determine when to clean the array, saving the cost of unnecessary cleanings as well as damage caused by frequent cleanings.

The CR-PVS1 is designed to be at the heart of an independent soiling measurement station or as an add-on peripheral to any new or existing meteorological station. It is delivered field ready and requires no programming. The CR-PVS1 will work with any photovoltaic (PV) panel up to 300 W. Smaller wattage panels can be used. Consult Campbell Scientific before purchasing if a panel less than 20 W is to be used. Two highly accurate and rugged back-of-panel sensors are included.

2. Precautions

READ AND UNDERSTAND the *Safety* section at the front of this manual.

DANGER: Fire, explosion, and severe-burn hazard. Misuse or improper installation of the internal lithium battery can cause severe injury. Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent lithium batteries properly.

WARNING:

- Protect from overvoltage.
- Protect from water.
- Protect from ESD (electrostatic discharge).

IMPORTANT: Maintain a level of calibration appropriate to the application. Campbell Scientific recommends factory recalibration of the CR-PVS1 every three years.

3. Initial Inspection

The CR-PVS1 ships with the following:

- 2 x back-of-panel temperature sensors: 110PV-L15-PT Surface-Mount Thermistors
- Heat-Resistant Kapton Tape with Silicone Adhesive, 5 yds (pn 27015), for securing temperature sensors
- UV-Resistant 8 in. Cable Ties (pn 7364) used to secure the temperature sensor cables
- Flat-Bladed Screwdriver (pn 1113) for connecting wires to terminals
- 4 x Grommets (pn 32364) and 4 x Screws (pn 505) for mounting the CR-PVS1 to a Campbell Scientific enclosure backplate

- USB 2.0 Cable Type A Male to Micro B Male (pn 27555) for computer communications
- CR300 Certificate of Calibration
- 8 GB USB flash drive with *Device Configuration Utility* software
- CR-PVS1 Quick Deploy Guide (also available at www.campbellsci.com/cr-pvs1)

Upon receipt of the CR-PVS1, inspect the packaging and contents for damage. File damage claims with the shipping company.

Immediately check package contents. Thoroughly check all packaging material for product that may be concealed. Check model numbers, part numbers, and product descriptions against the shipping documents. Model or part numbers are found on each product. On cabled items, the number is often found at the end of the cable that connects to the measurement device. The Campbell Scientific number may differ from the part or model number printed on the sensor by the sensor vendor. Ensure that you received the expected cable lengths. Contact Campbell Scientific immediately about discrepancies.

4. Specifications

All CR-PVS1 RTUs are tested and guaranteed to meet electrical specifications in a standard -40 to 70 °C non-condensing environment. Factory recalibration is recommended every three years.

Soiling Loss Index:	can detect $\approx 1\%$
PV Panels:	up to 300 W crystalline or thin-film
Maximum Voltage:	50 V
Maximum Current:	20 A
Measurement Accuracy:	$\approx 2 \mu\text{V}$

4.1 Back-of-Panel Temperature Measurements

Measurement Range: -40 to 135 °C

Temperature Uncertainty:

Temperature	Tolerance
-40 to 70 °C	± 0.2 °C
71 to 105 °C	± 0.5 °C
106 to 135 °C	± 1 °C

Steinhart-Hart Linearization

Equation Error: 0.0024 °C maximum (at -40 °C)

4.2 Short-Circuit Current Measurements

Current Shunt

Maximum Operating Temperature:	80 °C
Shunt Accuracy:	±0.25%

4.3 Communications

Modbus RTU

Format:	RS-232, 19200 baud, 8 data bits, no parity, 1 stop bit
Supported Functions:	03
Modbus Address:	11
Data Type:	32-bit Float, CDAB
USB:	USB micro-B device only, 2.0 full-speed 12 Mbps, for computer connection.
RS-232:	Female RS-232, 9-pin interface

4.4 System

Clock Accuracy:	±1 min per month
Clock Resolution:	1 ms
Program Execution Rate:	30 seconds

4.5 Power Requirements

Charger Input (CHG):	16 to 32 Vdc, current limited at 0.9 A. Power converter or solar panel input.
External Batteries (BAT):	12 Vdc, lead-acid 7 Ah battery, typical
Internal Lithium Battery:	3 V coin cell CR2016 (Energizer) for battery-backed clock. 6-year life with no external power source.
Typical Power Requirements	
Sleep:	1.5 mA
Active 1 Hz scan with analog measurements:	5 mA
USB Power (USB):	For programming and limited functionality

4.6 Compliance

View the EU declaration of conformity at www.campbellsci.com/cr-pvs1.

Shock and Vibration:	ASTM D4169-09
Protection:	IP30

4.7 Physical

Width:	20.3 cm (8 in); 21.6 cm (8.5 in) with mounts
Height:	6.3 cm (2.5 in)
Depth:	14 cm (5.5 in)

5. Installation

For installation and configuration, follow the steps shown in the included Quick Deploy Guide. *Device Configuration Utility* software is required. This can be installed from the USB sent with the CR-PVS1. It is also available for download at www.campbellsci.com/devconfig.

NOTE Download the Quick Deploy Guide at www.campbellsci.com/cr-pvs1.

DANGER **To prevent injury, completely cover the PV panels to limit output and current and voltage during installation. Do not short PV panel + and – leads.**

The CR-PVS1 has a Modbus RTU output. For the complete Modbus Register Map, see Appendix B, *Modbus Register Map* (p. B-1).

6. Operation

6.1 Measurement

To estimate soiling loss index (SLI), the CR-PVS1 system compares the outputs and temperatures of two identical PV panels mounted side by side: one clean, and the other soiled naturally.

Current measurements and back-of-panel temperature measurements are made every 30 seconds. To make the current measurements, both panels are short-circuited for 5 seconds using a solid-state relay. Short-circuit current is measured with a precision current-sensing shunt. To help minimize PV panel degradation, the panel is maintained in an open-circuit hold state between measurements.

From short-circuit current and back-of-panel temperature, the effective irradiance of each panel is calculated in accordance with IEC 60904, and the SLI is calculated according to equation 6-2.

A daily average SLI is calculated, available for SCADA (supervisory control and data acquisition), and stored in onboard memory. For immediate feedback, a real-time index and quality factor are available. Raw measured data are stored and available for analysis or independent post-processing. Available values are shown in Appendix A, *Glossary of Variable Names* (p. A-1).

In accordance with IEC 60904, the CR-PVS1 calculates the daily soiling loss index during the hour before and the hour after solar noon and only includes the values showing effective irradiance greater than 500 W/m² to minimize the

effects from the zenith angle of the sun, PV panel current dependence on irradiance level, and air mass density. The CR-PVS1 also filters out data that is classified as unstable (IEC 60904), such as data during cloud cover. A variable, *Stable_Data_Count*, increments when all criteria are met.

6.2 Soiling Loss Index Details

In terms of quantities that can be measured directly from a PV panel, Soiling Loss Index (SLI) is defined as the loss in the irradiance reaching the solar cells of a PV panel. If all other factors are the same, then this loss is primarily due to the loss in transmission properties of the glass as a result of soiling.

The irradiance is calculated from short-circuit current as

$$G_{\text{eff}} = I_{\text{SC}} \frac{[1 - \alpha(T - T_0)]}{I_{\text{SC,STC}}} \quad 6-1$$

Where G_{eff} : effective irradiance reaching the solar cells

I_{SC} : measured short-circuit current of the panel

$I_{\text{SC,STC}}$: short-circuit current at standard test conditions (STC)

T : back-of-panel temperature

T_0 : back-of-panel temperature at STC, typically 25 °C

α : temperature coefficient of short-circuit current

The SLI uses the effective irradiances of a clean reference panel and a dirty test panel. It is defined as

$$\text{SLI} = \left(1 - \frac{G_{\text{eff,Ref}}}{G_{\text{eff,Test}}} \right) \cdot 100\% \quad 6-2$$

Where $G_{\text{eff,Ref}}$ is the effective irradiance calculated from the clean reference panel, and $G_{\text{eff,Test}}$ is the effective irradiance calculated from the test panel.

7. Maintenance

For more accurate soiling-rate estimations, clean the reference (clean) panel as often as the pyranometer, a minimum of once per week. Clean with distilled water and a lint-free cloth.

7.1 Offset Correction

PV panels often differ in power output under identical conditions, even when they are from the same batch of the same model. This offset in power output can be determined upon installation and updated after each cleaning. The procedure determines the offset, and then implements a correction factor into the measurement sequence to remove any effects that may be caused by the offset.

NOTE

Carefully clean both panels before initiating this process. Cleaning should be completed before 11 a.m.

1. Connect to the CR-PVS1 using *Device Configuration Utility*. In the **Device Type** list, select **CR300 Series**. Follow the steps shown in the right panel of the window.
2. Once connected, select the **Data Monitor** tab. Click **Public** in the table list.
3. Double-click on the value in the **Update_Offset** field. Enter **1** and press **Enter**.

Deployment	Logger Control	Data Monitor	File Control	Send OS	Settings Editor	Terminal
Constants		GeffRef		1,027.288		
DailyAvg		Offset_Geff		1.024962		
DataTableInfo		Stable_Data_Count		24		
Offset		_____Initiate_Offset_Correction				
Public		Update_Offset		0		
RawMeasurementData		_____UserEntered_Data				
Status		UTC_Offset_UserEntered		-6		
		Latitude_UserEntered		40		
		Longitude_UserEntered		-112		
		AlphaTest_UserEntered		0.005		
		AlphaRef_UserEntered		0.005		
		IscTeststc_UserEntered		8.6		
		IscRefstc_UserEntered		8.6		

4. Results will be available with the next measurements.

Appendix A. Glossary of Variable Names

Variable Name	Description
<i>RTU_Internal_Temp</i>	Panel temperature of CR-PVS1, °C
<i>RTU_Voltage</i>	Battery voltage of CR-PVS1, Vdc
<i>Soiling_Loss_Index_Corrected</i>	Soiling loss index with offset correction applied, %
<i>Soiling_Loss_Index_Raw</i>	Soiling loss index without offset correction applied, %
<i>Live_Index_Corrected</i>	Real-time index of reference to test panel with offset correction applied, %
<i>Live_Index_Raw</i>	Real-time index of reference to test panel without offset correction applied, %
<i>Stable_Data_Check</i>	Variable indicating if environmental conditions are stable, True (-1)/False (0)
<i>Time_Status</i>	Variable indicating if the time of day is appropriate for performing soiling loss index calculations
<i>Geff_Status</i>	Variable indicating if the measured effective irradiance is appropriate for performing soiling loss index calculations
<i>Isc_Status</i>	Variable indicating if the measured short-circuit current is appropriate for performing soiling loss index calculations
<i>Temp_Status</i>	Variable indicating if the measured back-of-module temperature is appropriate for performing soiling loss index calculations
<i>IscTest</i>	Short-circuit current of test panel, Amps
<i>IscRef</i>	Short-circuit current of reference panel, Amps
<i>TempTest</i>	Back-of-module temperature of test panel, °C
<i>TempRef</i>	Back-of-module temperature of reference panel, °C
<i>GeffTest</i>	Effective irradiance of test panel, W/m ²
<i>GeffRef</i>	Effective irradiance of reference panel, W/m ²
<i>Offset_Geff</i>	Measured offset between reference and test panels, %
<i>Stable_Data_Count</i>	Incrementally counts when conditions are appropriate for performing soiling loss index
<i>Update_Offset</i>	Boolean variable that user triggers when the offset correction is to be performed
<i>UTC_Offset_UserEntered</i>	User-entered UTC offset of site location, hours
<i>Latitude_UserEntered</i>	User-entered latitude of site location
<i>Longitude_UserEntered</i>	User-entered longitude of site location
<i>AlphaTest_UserEntered</i>	User-entered temperature coefficient of the test panel
<i>AlphaRef_UserEntered</i>	User-entered temperature coefficient of the reference panel
<i>IscTeststc_UserEntered</i>	User-entered short-circuit current coefficient of the test panel
<i>IscRefstc_UserEntered</i>	User-entered short-circuit current coefficient of the reference panel
<i>LocalSolarNoon</i>	Solar noon of site location, as determined by user-entered site location data

Appendix B. Modbus Register Map

Com Port: RS-232

Baud Rate: 19200

Serial Format: 8N1

Address: 11

Data Type: 32-bit Float

Data Order: CDAB

Parameter	Description	Register Start	Register End	Range Low	Range High	Units
Heartbeat	Incremental counter equal to RTU seconds clock	40001	40002	0	59	Seconds
Soiling Loss Index Corrected	SLI with offset correction	40003	40004	-20	20	%
Soiling Loss Index Raw	SLI without offset correction	40005	40006	-20	20	%
Live Index Corrected	Real-time index with offset correction	40007	40008	-7999	7999	%
Live Index Raw	Real-time index without offset correction	40009	40010	-7999	7999	%
Isc Test	Short-circuit current of test panel	40011	40012	0	20	Amps
Isc Ref	Short-circuit current of reference panel	40013	40014	0	20	Amps
Temp Test	Back-of-module temperature of test panel	40015	40016	-40	135	°C
Temp Ref	Back-of-module temperature of reference panel	40017	40018	-40	135	°C
Geff Test	Effective irradiance of test panel	40019	40020	0	2000	W/m ²
Geff Ref	Effective irradiance of reference panel	40021	40022	0	2000	W/m ²
Stable Data Check	Real-time indicator of environmental condition stability	40023	40024	-1	0	True/False
RTU Voltage	Input voltage of CR-PVS1	40025	40026	9	32	Vdc
RTU Internal Temp	Internal temperature of CR-PVS1	40027	40028	-40	70	°C

Campbell Scientific Companies

Campbell Scientific, Inc.

815 West 1800 North
Logan, Utah 84321
UNITED STATES

www.campbellsci.com • info@campbellsci.com

Campbell Scientific Canada Corp.

14532 – 131 Avenue NW
Edmonton AB T5L 4X4
CANADA

www.campbellsci.ca • dataloggers@campbellsci.ca

Campbell Scientific Africa Pty. Ltd.

PO Box 2450
Somerset West 7129
SOUTH AFRICA

www.campbellsci.co.za • cleroux@csafrica.co.za

Campbell Scientific Centro Caribe S.A.

300 N Cementerio, Edificio Breller
Santo Domingo, Heredia 40305
COSTA RICA

www.campbellsci.cc • info@campbellsci.cc

Campbell Scientific Southeast Asia Co., Ltd.

877/22 Nirvana@Work, Rama 9 Road
Suan Luang Subdistrict, Suan Luang District
Bangkok 10250
THAILAND

www.campbellsci.asia • info@campbellsci.asia

Campbell Scientific Ltd.

Campbell Park
80 Hathern Road
Shepshed, Loughborough LE12 9GX
UNITED KINGDOM

www.campbellsci.co.uk • sales@campbellsci.co.uk

Campbell Scientific Australia Pty. Ltd.

PO Box 8108
Garbutt Post Shop QLD 4814
AUSTRALIA

www.campbellsci.com.au • info@campbellsci.com.au

Campbell Scientific Ltd.

3 Avenue de la Division Leclerc
92160 ANTONY
FRANCE

www.campbellsci.fr • info@campbellsci.fr

Campbell Scientific (Beijing) Co., Ltd.

8B16, Floor 8 Tower B, Hanwei Plaza
7 Guanghua Road
Chaoyang, Beijing 100004
P.R. CHINA

www.campbellsci.com • info@campbellsci.com.cn

Campbell Scientific Ltd.

Fahrenheitstraße 13
28359 Bremen
GERMANY

www.campbellsci.de • info@campbellsci.de

Campbell Scientific do Brasil Ltda.

Rua Apinagés, nbr. 2018 – Perdizes
CEP: 01258-00 – São Paulo – SP
BRASIL

www.campbellsci.com.br • vendas@campbellsci.com.br

Campbell Scientific Spain, S. L.

Avda. Pompeu Fabra 7-9, local 1
08024 Barcelona
SPAIN

www.campbellsci.es • info@campbellsci.es

Please visit www.campbellsci.com to obtain contact information for your local US or international representative.