this webinar is powered by
OTT HydroMet

pv magazine webinars

Field protection and reliability of solar radiation measurement instruments

11 October 2023

8:00 am – 9:00 am | PDT, Los Angeles
11:00 am – 12:00 pm | EDT, New York City
5:00 pm – 6:00 pm | CEST, Berlin, Madrid

Marija Maisch
Editor
pv magazine

Sajad Badalkhani
Manager, Technical Support and Services
OTT HydroMet

Marc Korevaar
Scientist
OTT HydroMet

Welcome!

Do you have any questions? ❓ 🙋

Send them in via the Q&A tab. 👉 We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 🎥

We'll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience. 👀 💡

Field Protection and Reliability of Solar Radiation Measurement Instruments

Sajad Badalkhani | Marc Korevaar | October 2023

Outline

- Advancements and challenges in protecting sensors in field applications
- The difference between active, passive, analog, and digital solar instruments
- The essence of field protection: Understanding its impact on data accuracy and instrument longevity
- Techniques for enhanced reliability: Installation, Effective wiring, Grounding, External Protection and Maintenance
- Case studies: Real-world examples

Advancements and challenges in protecting sensors in field applications

As sensors become more sensitive and industrial settings more challenging, system reliability is gaining more attention

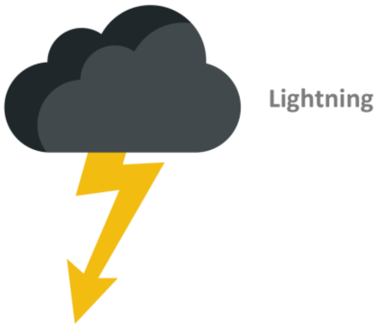
The advancement of technology necessitates an ever-growing deployment of sensors for data collection.

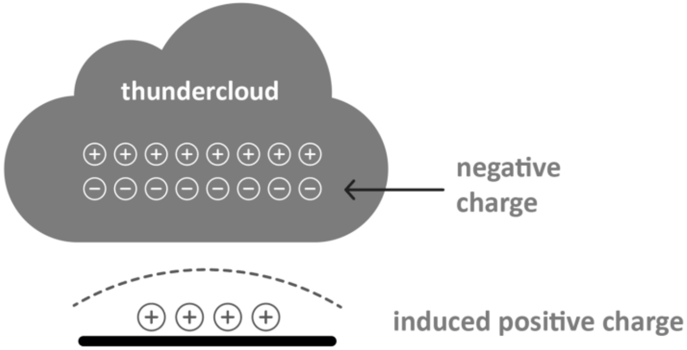
Leveraging communication protocols: Modbus, I2C, UART, and CAN.

A fundamental challenge: sensors face risks from both power and data transmission lines

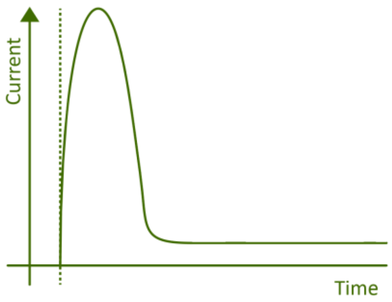
Systems Susceptible to risks

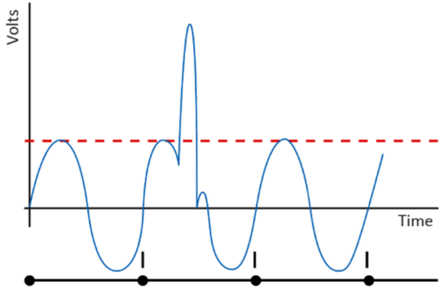
Outdoor usage, raising the likelihood of **lightning** and **electrostatic induction** due to cloud charges.

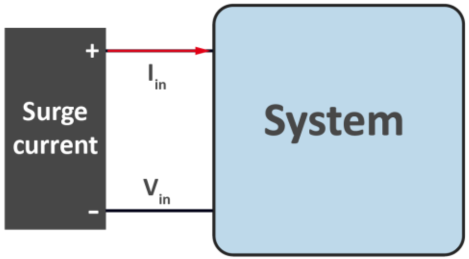


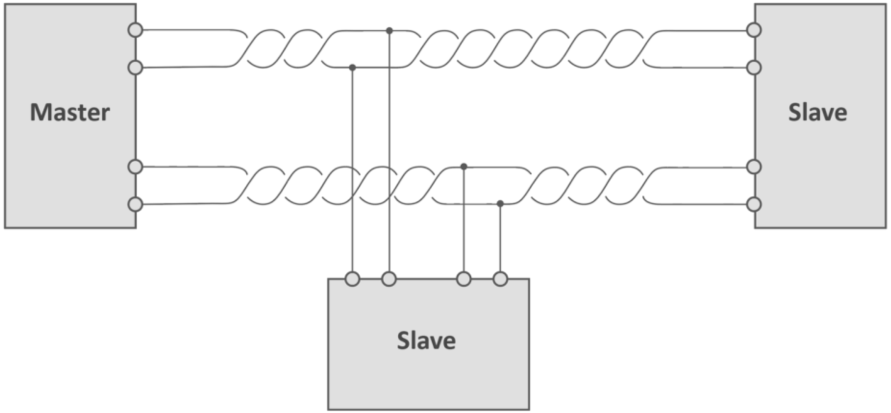


Inconsistency in power: High-current or high-voltage power inputs, increasing the vulnerability to surges.

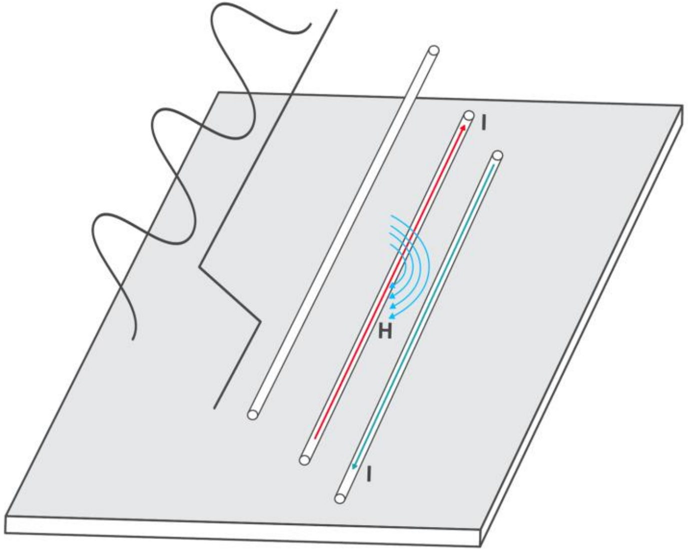






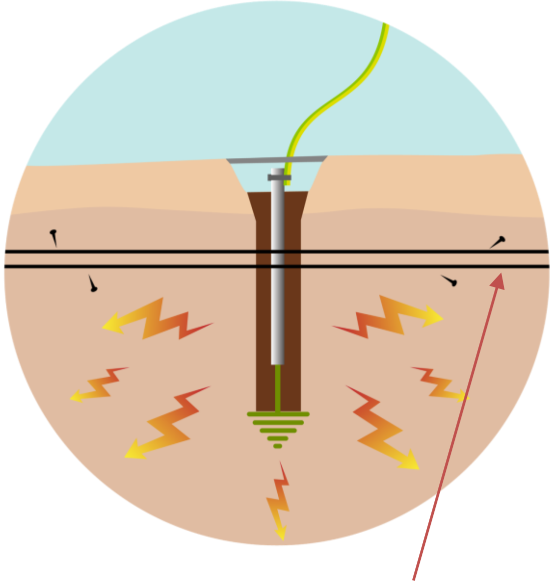


Presence of **communication lines** like **RS485** and Ethernet, which can be pathways for surges.



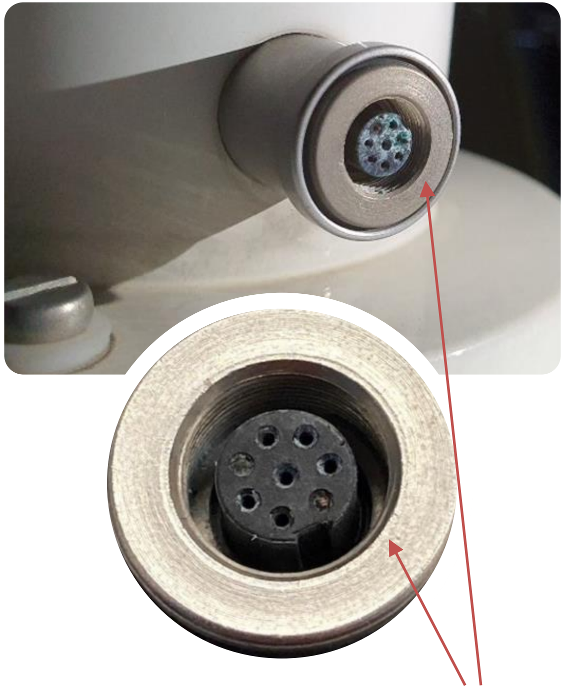
Lengthy cables and cabling running parallel with other systems, Routing communication lines near AC and DC power lines, making them more vulnerable to induced surges from nearby equipment.

Proximity to grounding systems and **improper grounding**, causing potential raise that can lead to surge behavior.



Power and data lines not properly grounded

Systems with Environmental Threats: **Moisture** exposure, **corrosion**, Accumulation of **dust** and particulates, **extreme temperatures**



Corrosion and broken pins

Physical Concerns: Wear and tear, Improper **maintenance**, **mishandling**

The difference between active, passive, analog, and digital solar instruments

Active vs. Passive

- **Active Sensors:**
  Require an external excitation or power signal.
  Derive energy from external sources.

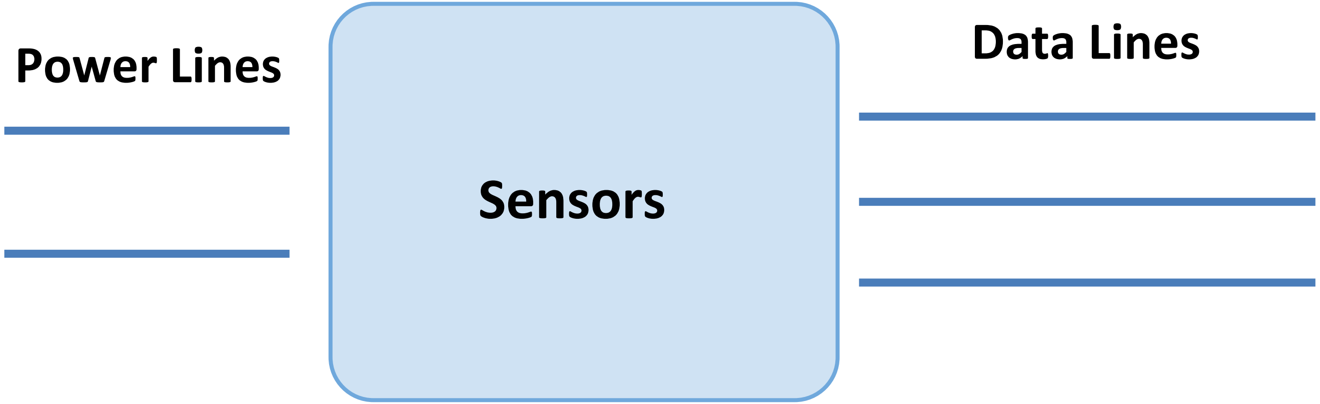
- **Passive Sensors:**
  Do not require any external power for their operation.
  Generate an output response directly based on the sensed quantity.

The difference between active, passive, analog, and digital solar instruments

Analog vs. Digital

- **Analog Sensors:**
  Produce a continuous output signal.
  Response varies with respect to the measured quantity.

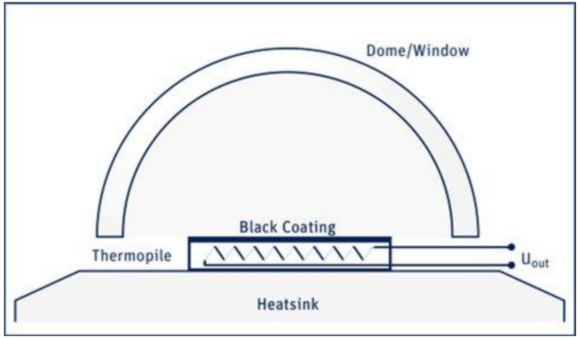
- **Digital Sensors:**
  Work with discrete or digital data.
  Data is digital in nature, ideal for conversion and transmission.

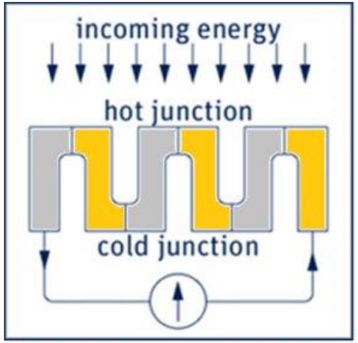

Power Lines
Sensors
Data Lines

TYPES OF SENSORS

Analog radiometers (CMP, CGR, CHP, UV meters, Net radiometers)

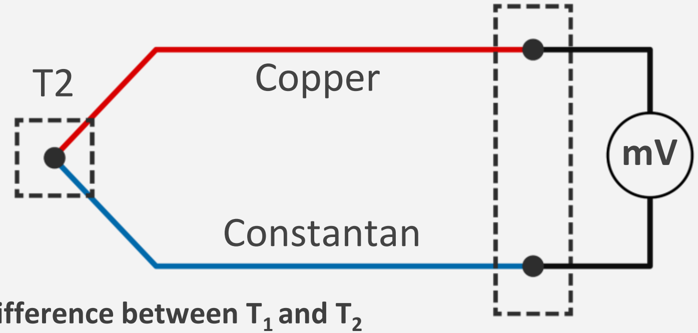
- Normally two wires – output 0-0.1V (mV range)
- 4 and 8 wires also possible (10K or PT100 temperature sensor)





The working principle of analog radiometers

Thermocouple



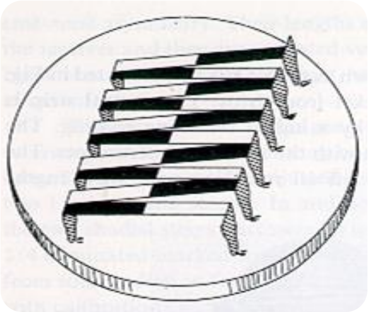
ΔT temperature difference between T_1 and T_2

Seebeck effect

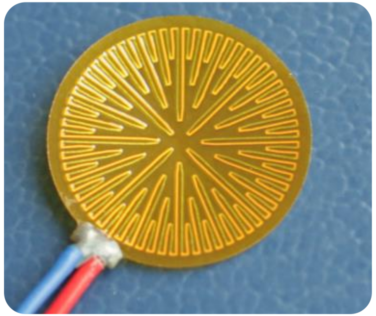
$$V_{seebeck} = \alpha \, . \, \Delta T$$

α = Seebeck coefficient

Radiation → Black absorber → Heat
→ temperature difference ΔT → output voltage



Moll thermopile



64 couple thermopile

Analog radiometers

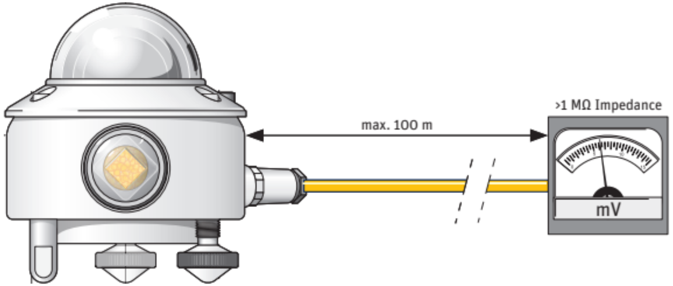
Pin layout (Instrument)

Pyranometer Connection		
Wire	Function	Connect with
1 Red	+	+ (Hi)
2 Blue	-	- (Lo)
Shield	Housing	⏚ Ground

Albedometer Connection		
3 Green	Lower	+ (Hi)
4 Yellow		- (Lo)

Thermistor		
3	Green	Thermistor
4	Yellow	

Pt-100			
4	Green	Combined	Pt-100
6	Brown		
3	Green	Combined	
5	Grey		



The Evolution of Solar Measurement: Analog to Smart Sensors

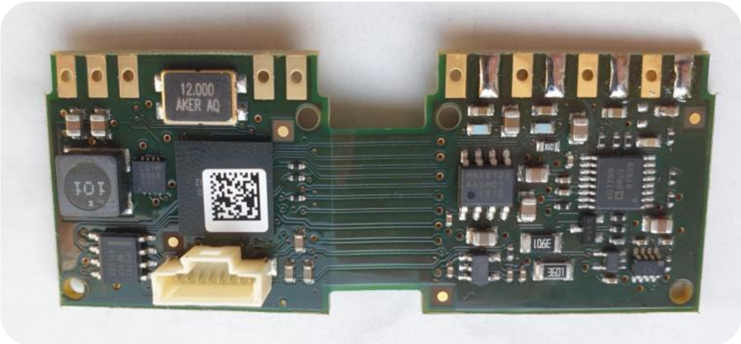
TYPES OF SENSORS

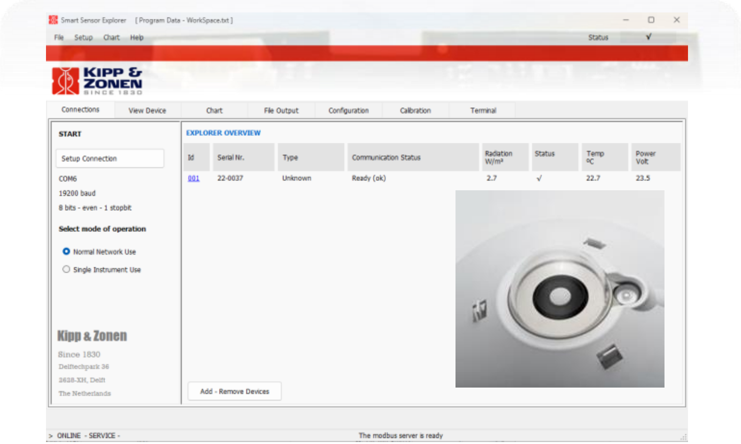
Smart (SMP3,6,10,11,21,22, SHP,SGR,SUV)

- Normally 8 wires
- 2 wires for DC power input
- 2 wires for the analog output which can be 0-1.5V and 4-20 mA
- 3 wires for Modbus
- 1 wire for shield (which is intended to connect the sensor housing to earth)

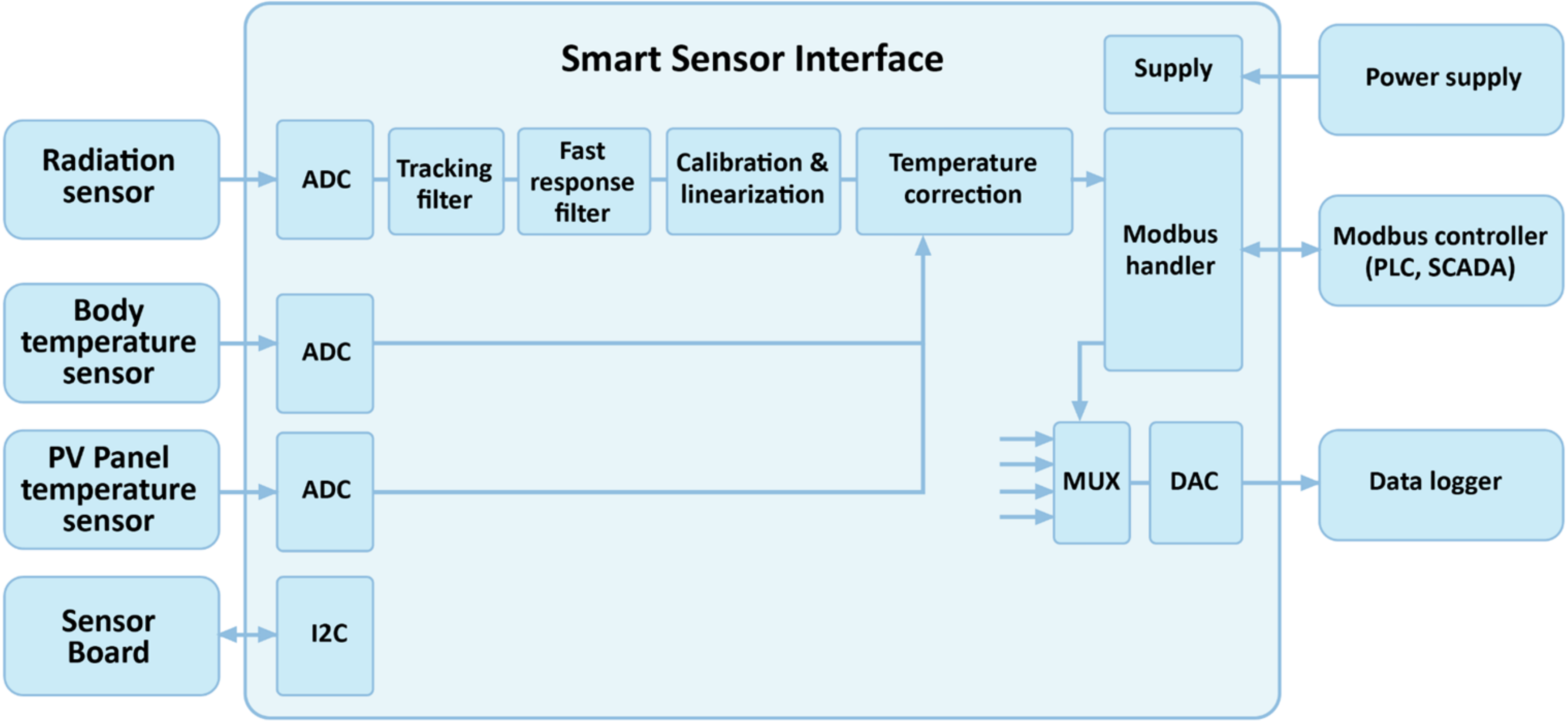
Smart SMP12

- The same wiring configuration for smart series – Voltage and current range DC input is different, no analog output

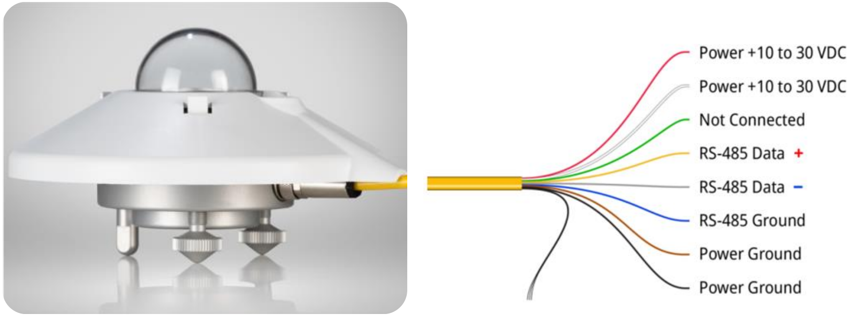




Smart Radiometers



Pin layout

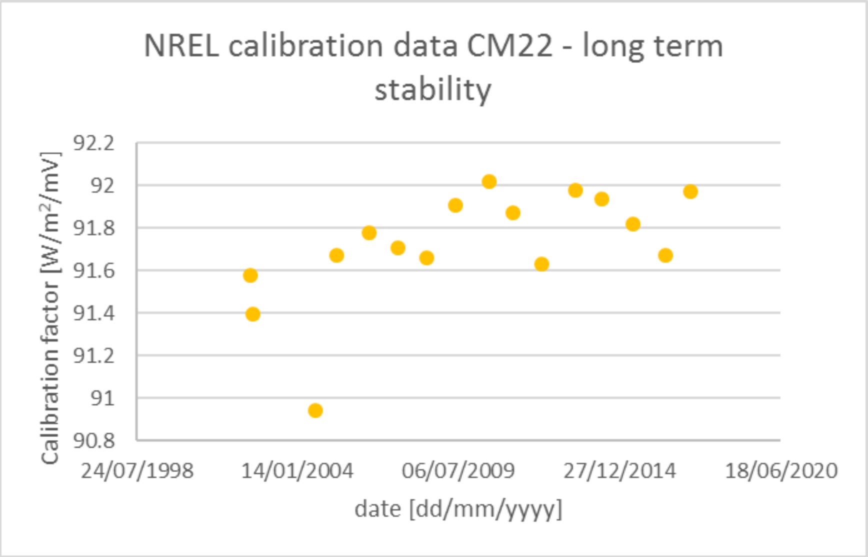


Radiometer Connection

	Wire	Function	Connect with
3	Green	Analogue out	V+/4-20 mA(+)
6	Brown	Analogue ground	V-/4-20 mA(-)
4	Yellow	Modbus® RS-485	B/B'/+
5	Grey	Modbus® RS-485	A/A'/-
7	White	Power 5 to 30 VDC (12V recommended)	
8	Black	Power ground	
1	Red	None	Not connected
2	Blue	Modbus® common / Ground	
	Shield	Housing	⏚ Ground*

*Connect to ground if radiometer not grounded

Pyranometer stability – rationale for protecting quality equipment



- 15 year outdoor use with good maintenance shows good stability
- Drift over 15 years of ±0.65%
- A quality instrument is worthwhile to protect

NREL Golden

The essence of field protection: Understanding its impact on data accuracy and instrument longevity

- **Impact on Data Accuracy and Continuity:** Ensuring optimal conditions for sensors guarantees consistent and precise data collection over time.

- **Cost Efficiency:** Protecting instruments minimizes damage risks, resulting in substantial savings on repairs or replacements.

- **Instrument Longevity:** Proper field protection prolongs the operational lifespan of our solar instruments, allowing for extended usage.

- **Optimal Performance:** With adequate protection, solar instruments maintain peak efficiency and deliver accurate results throughout their service life.

Techniques for enhanced reliability: Installation

- **Guidelines:**
  Always read to the manual before installation.

- **Environmental Protections:**
  Ensure the instruments are safeguarded against local environmental threats such as **extreme temperatures**, **moisture**, **dust**, etc

- **Cabling:**
  Use original cables provided by the manufacturer, which are Shielded, UV-resistant and have optimal impedance for accurate measurements.

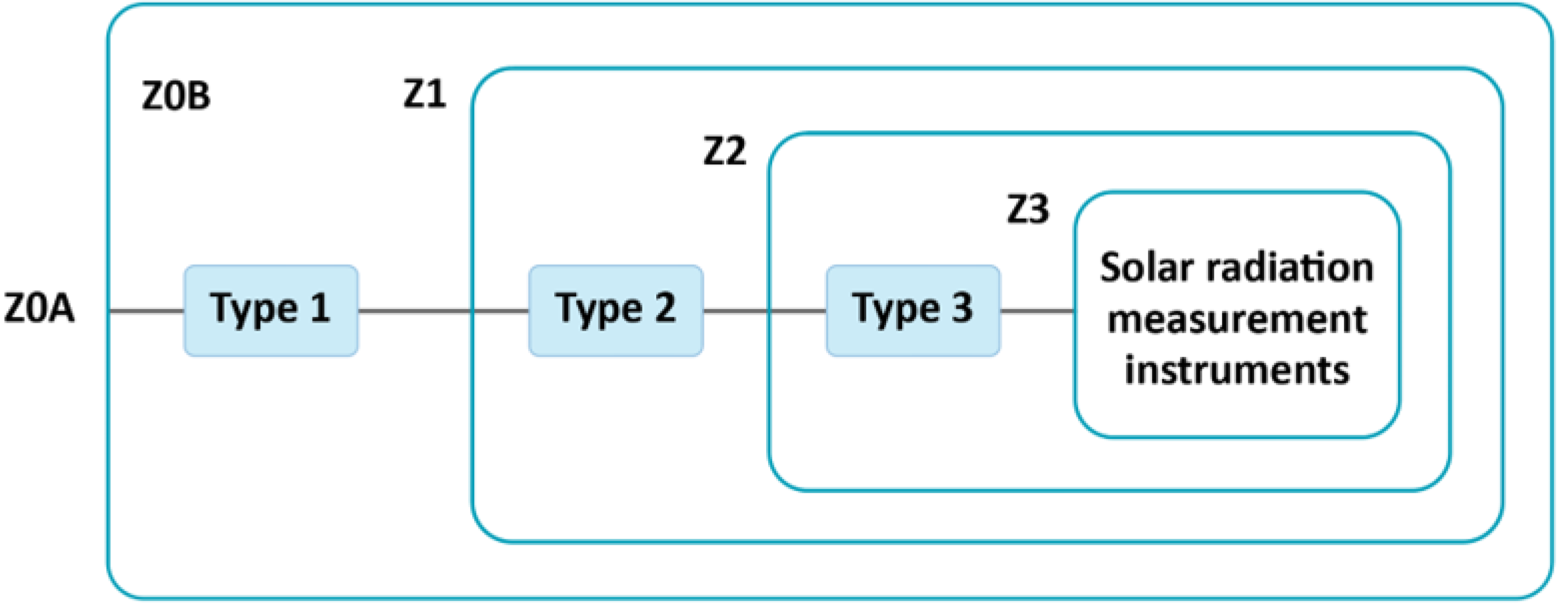
Techniques for enhanced reliability: Installation

- **Mounting Precautions:**
  Refrain from directly attaching pyranometers or their brackets to PV panels or array mounting frames. This helps in avoiding potential electrical safety and grounding complications.

- **Cable Ducts:**
  Utilize grounded metal cable ducts for wiring.
  Ensure these ducts are away from high-power or noise-emitting cables to minimize electromagnetic interference.

Techniques for enhanced reliability: Effective wiring, Grounding

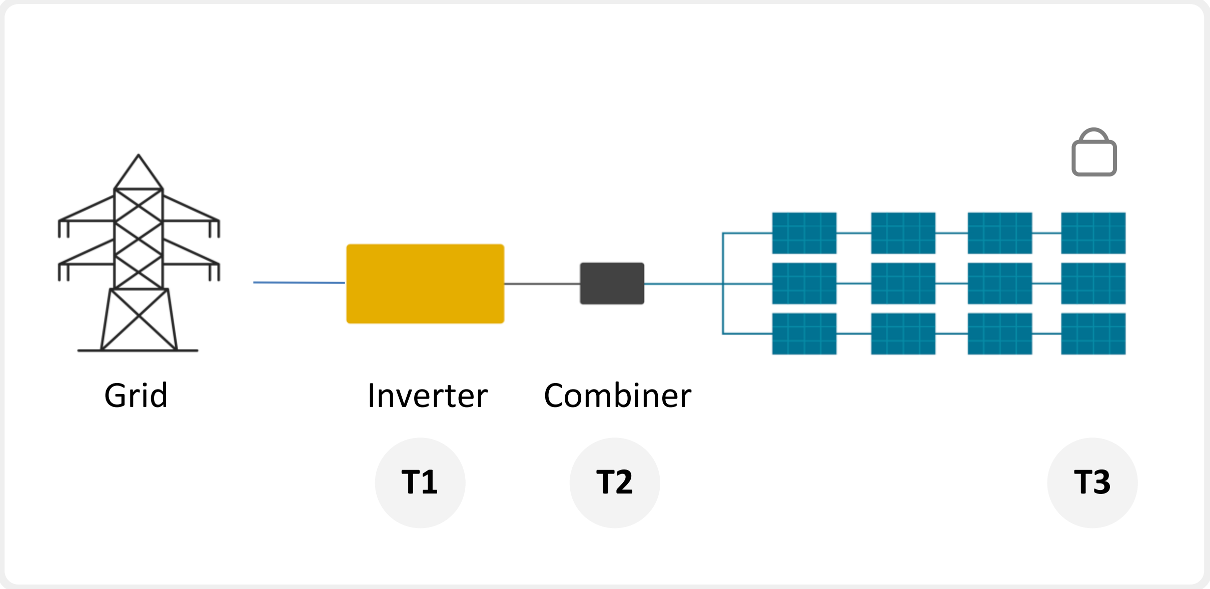
Multi-level protection concept



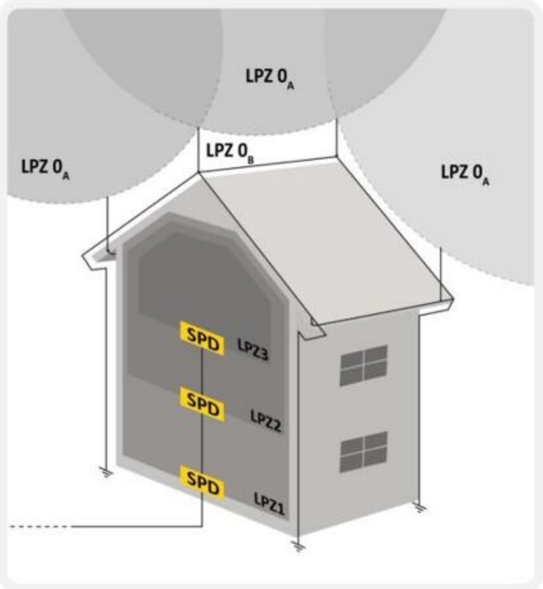
Techniques for enhanced reliability: Effective wiring, Grounding

Multi-level protection concept

PV plant

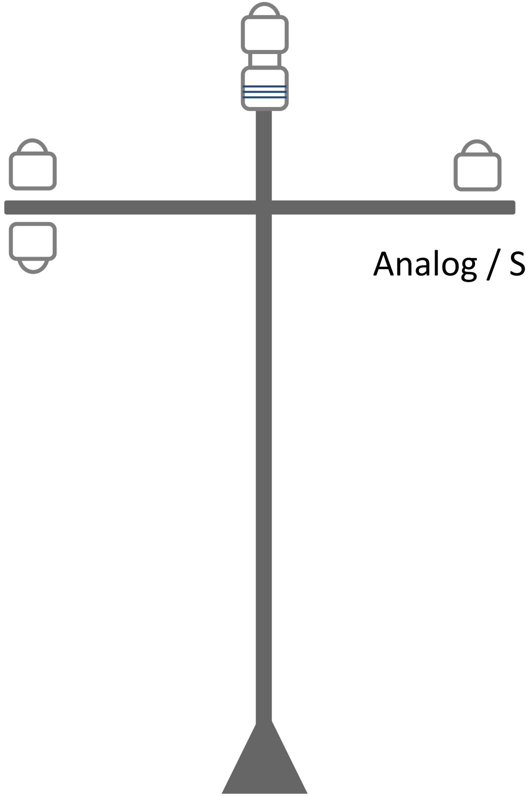


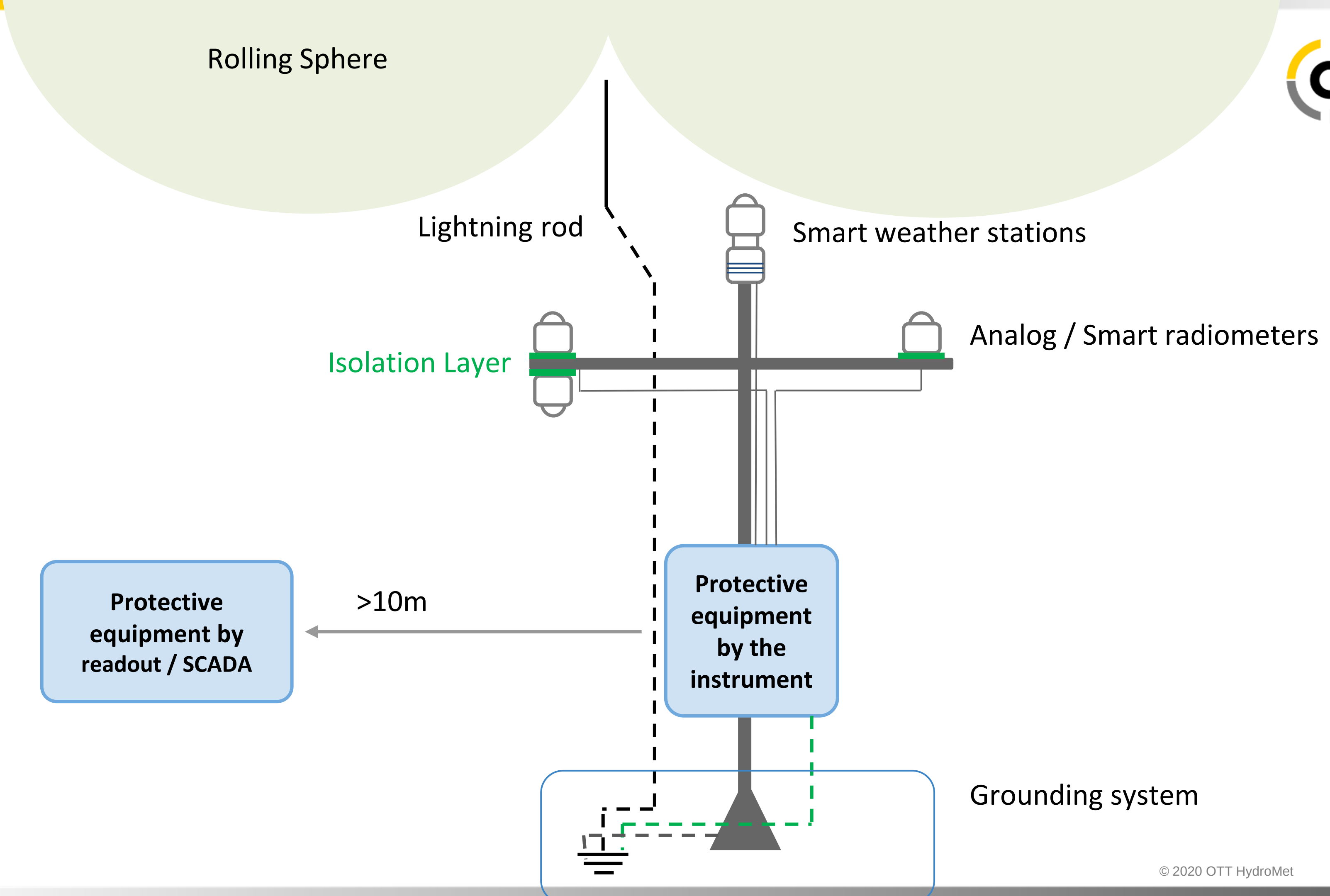
Residential setup



Techniques for enhanced reliability:
Effective wiring, Grounding

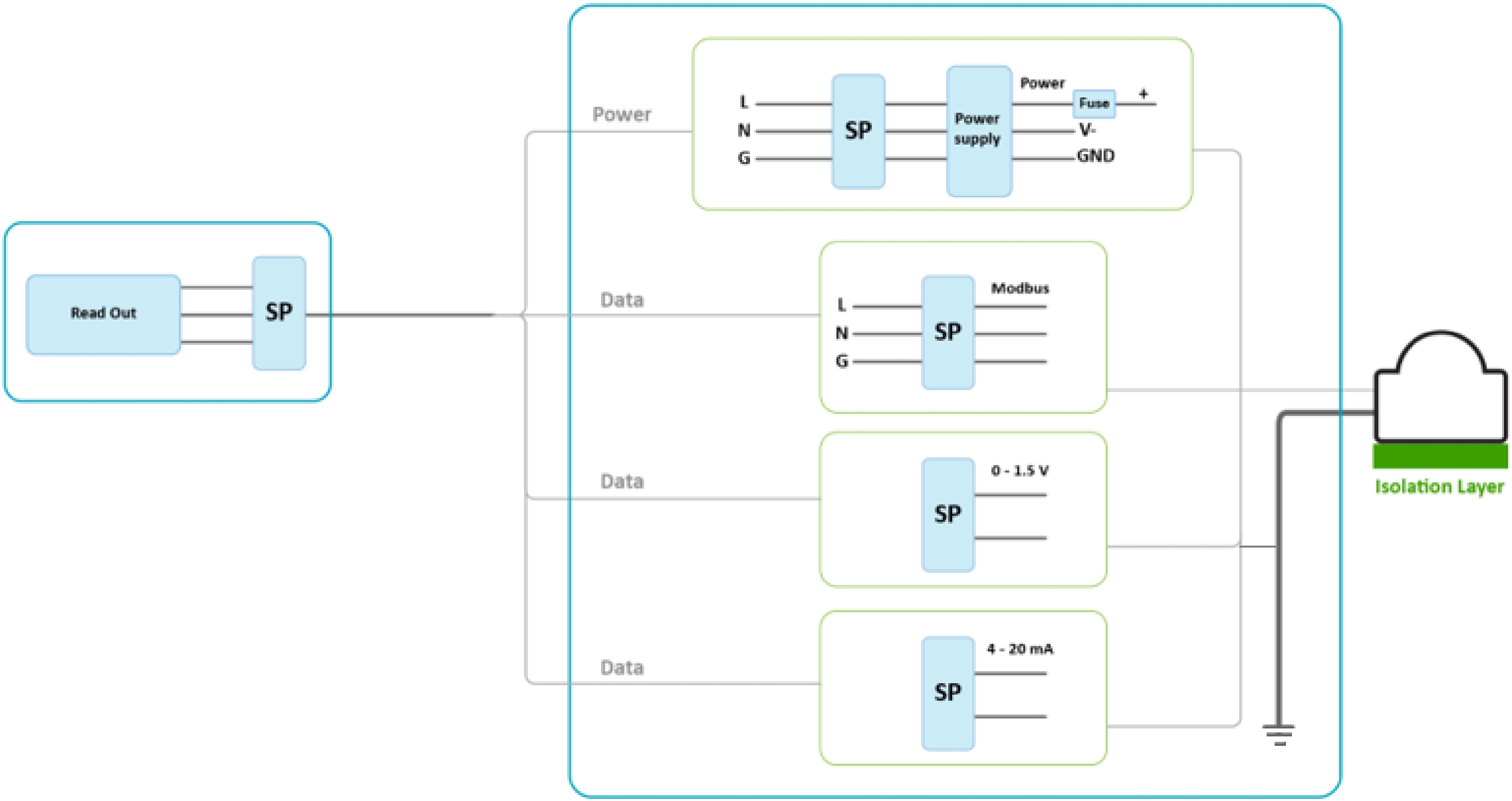
Scenario 1
Small footprint – Compact installations




Rolling Sphere
Lightning rod
Smart weather stations
Isolation Layer
Analog / Smart radiometers
Protective equipment by readout / SCADA
>10m
Protective equipment by the instrument
Grounding system

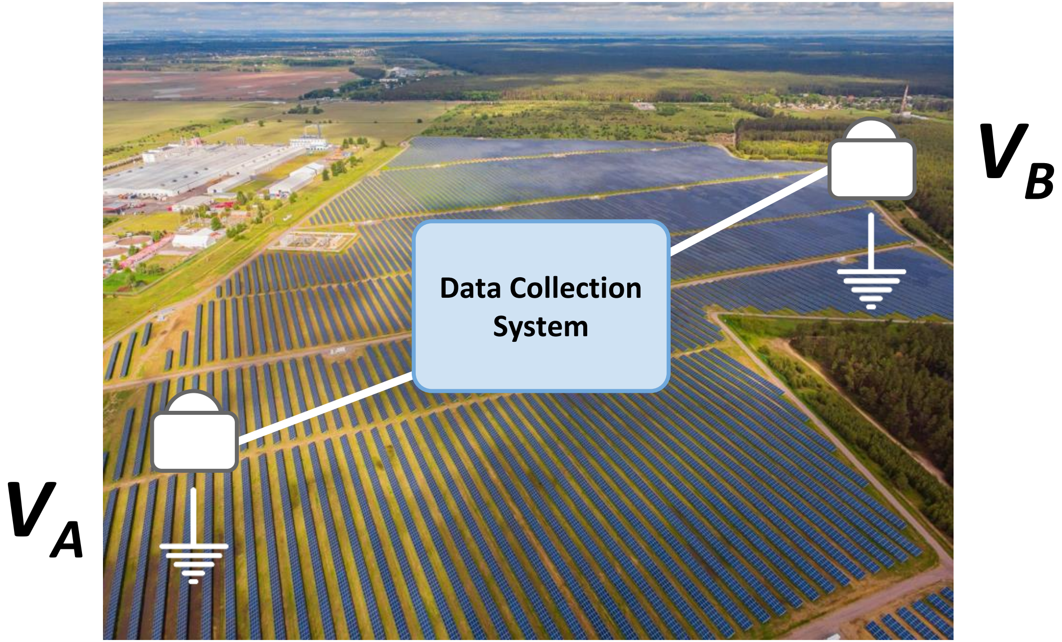
Protective equipment by readout / SCADA

Protective equipment by the instrument



Techniques for enhanced reliability: Effective wiring, Grounding

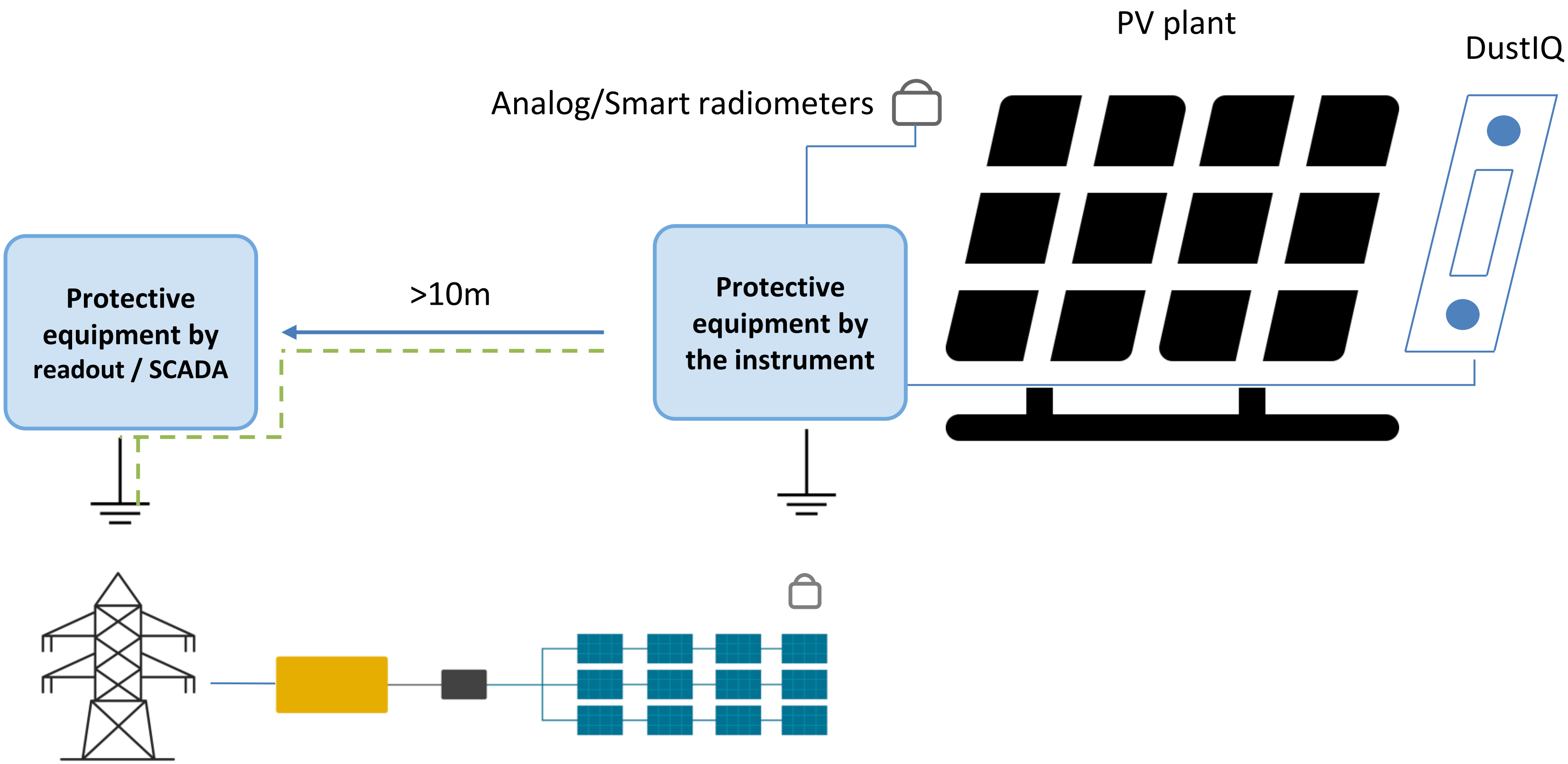
Scenario 2: Larger footprint:



$V_A \neq V_B$

Different ground potentials due to differences in soil composition, moisture levels, or other environmental factors

Scenario 2: Larger footprint: A solar plant



Desired working parameters : Power Supply

	Voltage limit	Current limit
Analog radiometers (CMP, CGR, CHP, UV meters, Net radiometers)	—	—
Smart (SMP3, 6, 10, 11, 21, 22, SHP, SGR, SUV)	5-30V DC	Max. 250 mA Nominal: 200mA peak and 100mA sustained
Smart SMP12	8-30V DC	Max. 1000 mA Nominal: 400mA sustained

Desired working parameters : Modbus

	Voltage limit	Current limit
Analog radiometers (CMP, CGR, CHP, UV meters, Net radiometers)	—	—
Smart (SMP3, 6, 10, 11, 21, 22, SHP, SGR, SUV)	All with three wires Modbus communication	
Smart SMP12		

Desired working parameters : Analog Output

	Output type	Output range
Analog radiometers (CMP, CGR, CHP, UV meters, Net radiometers)	Voltage	0-0.1 V Normally in uV range – resistance of the protective equipment must be low
Smart (SMP3, 6, 10, 11, 21, 22, SHP, SGR, SUV)	Voltage, current	0-1 V 4-20mA
Smart SMP12	-	-

Power Supply

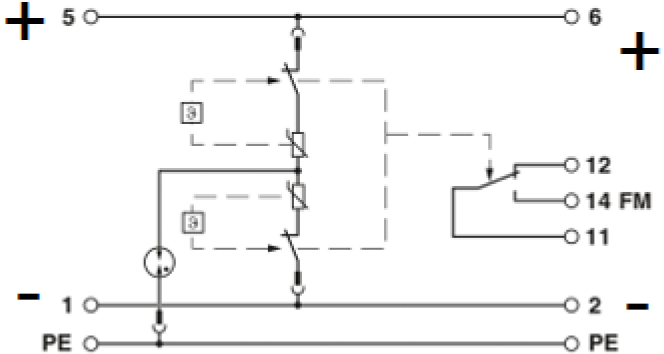
- **Surge Protection:** Be equipped with guards against voltage spikes.
- **Inrush Limitation:** Protect from sudden current surges during startup.
- **Electrical Isolation:** Contain isolating components to safeguard connected devices from power supply faults.
- **Stable Output:** Ensure consistent DC output.
- **Efficient Power Use:** Have optimal energy utilization.

Note: The primary side of the power supply should be protected with a circuit breaker or fuse

QUINT4-PS/1AC/24DC/10 - Power supply unit

Surge Arrestors: Instrument side

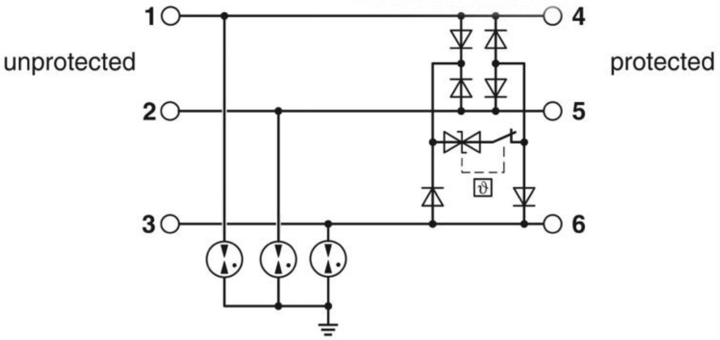
- **T3 Classification:** For immediate protection from quick, low-energy surges.
- **Response:** Swift reaction to surges, safeguarding electronics.
- **Protection:** Handles peak expected surges in its environment.
- **Indicators:** visual aids for device status or faults.
- **Compliance:** Complies with essential local and global electrical standards.



PLT-SEC-T3-24-FM-PT - Type 3 surge protection device

Voltage outputs 0-1.5V

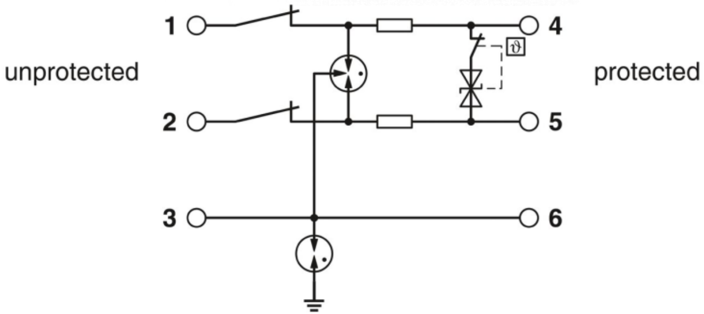
- **T3 Classification:** For immediate protection from quick, low-energy surges.
- **Response:** Swift reaction to surges, safeguarding electronics.
- **Protection:** Handles peak expected surges in its environment.
- **Impedance**: Low impedance to reduce voltage drop
- **Indicators:** Visual aids for device status or faults.
- **Compliance:** Complies with essential local and global electrical standards.



TTC-6P-3-24DC-PT-I - Surge protection device

Ampere output 4-20mA

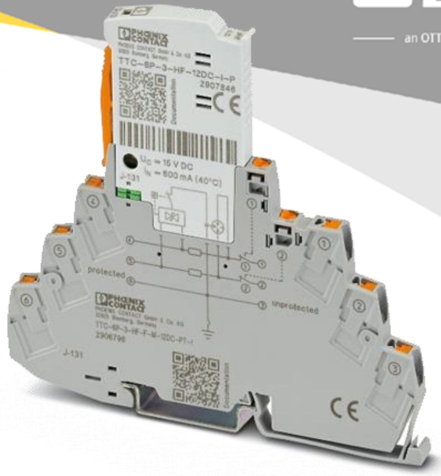
- **T3 Classification:** For immediate protection from quick, low-energy surges.
- **Response:** Swift reaction to surges, safeguarding electronics.
- **Protection:** Handles peak expected surges in its environment.
- **Impedance**: Low impedance to reduce voltage drop
- **Indicators:** Visual aids for device status or faults.
- **Compliance:** Complies with essential local and global electrical standards.

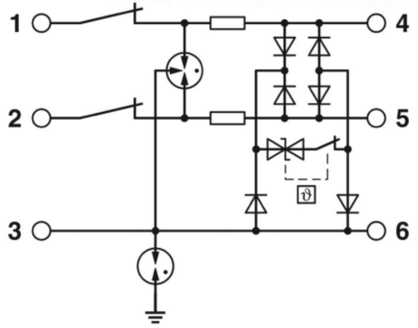


TTC-6P-2X1-F-M-24DC-PT-I - Surge protection device

Modbus

- **High Frequency Application:** Reliable protection without disrupting the high speed data signals
- **Telecommunications Interface**: Does Not require a supply voltage
- **Indirect Grounding**: To avoid disruptions from ground potential differences
- **Response:** Swift reaction to surges, safeguarding electronics.
- **Protection:** Safeguards three signal wires simultaneously against harmful voltage spikes.
- **Indicators:** Visual aids for device status or faults.
- **Compliance:** Complies with essential local and global electrical standards.

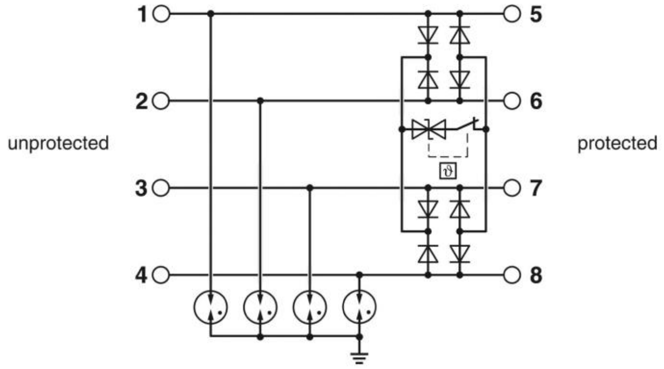




TTC-6P-3-HF-F-M-12DC-PT-I - Surge protection device

PT 100

- **4 Wire configuration:** Reliable protection without disrupting the high speed data signals
- **Impedance**: Low impedance to reduce voltage drop
- **Indirect Grounding**: To avoid disruptions from ground potential differences
- **Response:** Swift reaction to surges, safeguarding electronics.
- **Indicators:** Visual aids for device status or faults.
- **Compliance:** Complies with essential local and global electrical standards.



TTC-6P-4-24DC-PT-I - Surge protection device

KIPP & ZONEN
an OTT HydroMet brand

SMP12

*New thermopile and diffuser to allow solid state dome heating, to always have accurate measurements.

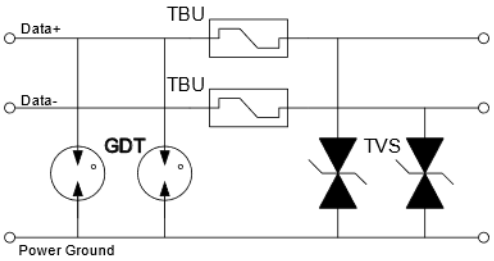
OTT HydroMet

*Patent pending on heating technology and optical flatness

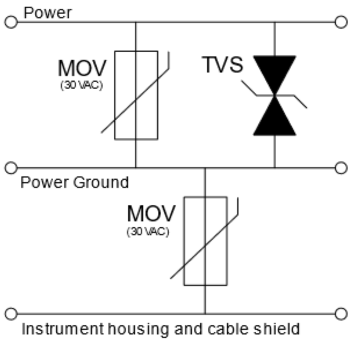
SMP12 – Surge Protection

- The best surge protection possible given space available
- Surge protection increased from "Generic - Industrial" to the highest "Measurement, Control & Laboratory use"
- A 3-stage protection on the data lines and 2-stage on the power lines

RS-485 with 3-stage data line protection: GDT (100 Ampere 4kV, gas discharge tube), Protectors) and TVS (400 Watt, transient voltage suppression diode)



Power input with 2-stage protection: TVS (1500 Watt diode), and MOV (200 Ampere Metal Oxide Varistor)



Techniques for enhanced reliability: Maintenance

There are 3 maintenance recommendations available (BSRN, IEC61724 and TR9901:2021). Below is a selection of these

Daily Maintenance (BSRN)

- **Clean optical windows and domes** using a soft lint-free cloth and inspect for marks or damage. If there are any deposits present use deionised water or an alcohol that will leave no residue to clean. Ideally cleaning should be **before sunrise,** to maximise measurement time.
- Where **frost or ice** cannot be removed by wiping, **warm the dome** gently (e.g. by using a hair-dryer). Never scrape ice off a dome or window.

Techniques for enhanced reliability: Maintenance

Daily Maintenance (BSRN)

- Check for **condensation within** the outer domes of pyranometers.
- Check the condition of the (black or white) **absorber** (TR9901:2021)
- Check that the instruments are **leveled and aligned**.
- **Check cables for damage.**
- Check ventilation unit **fans** are operating.
- Check that the **data acquisition system** is operating correctly.

Techniques for enhanced reliability: Maintenance

Weekly Maintenance **(BSRN)**

- Check the **desiccant** in each instrument and replace it if necessary, usually the desiccant will last several months. When replacing the desiccant check the O-ring seal for damage and replace it if necessary.

Monthly Maintenance **(TR9901:2021)**

- Visual and electrical **check** of the data acquisition system (TR9901:2021) (BSRN is more detailed here and weekly)
- **Check clock** of data acquisition system (TR9901:2021)

Techniques for enhanced reliability: Maintenance (IEC 61724)

Weekly Maintenance (Class A systems)

- **Check soiling on domes** and clean weekly (may be less frequently when conditions allow)
- Check that the instruments are **aligned**.
- **Check** for faults
- **Maintenance according to manufacturer requirements.**
- Check the **desiccant** in each instrument and replace it if necessary.

Techniques for enhanced reliability: Maintenance

Six-monthly Maintenance (BSRN)

- Replace any items showing signs of deterioration (e.g. cables).
- **Check ventilation unit filters** and clean or replace as necessary (more frequent inspection may be necessary in dusty environments. (more often in TR9901:2021)
- Check **seals of weatherproof enclosures**, and apply grease if necessary.
- Regularly inspect and upkeep the **grounding system** to ensure optimal performance.

Techniques for enhanced reliability: Maintenance

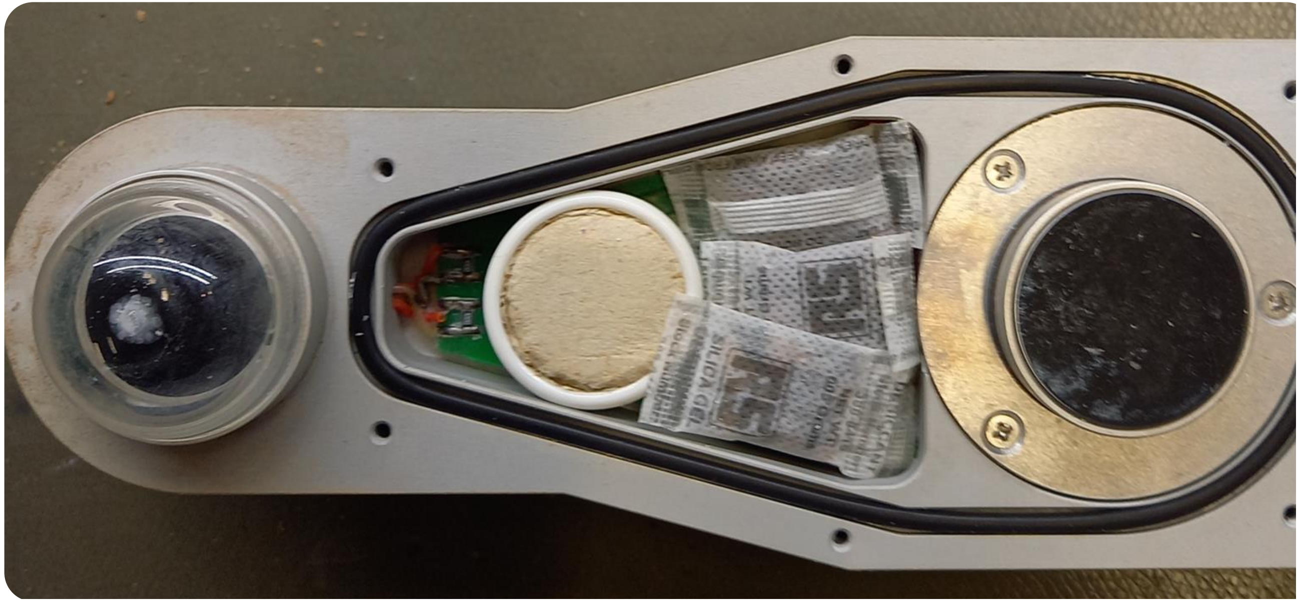
Annual Maintenance

- Loosen, lubricate and retighten all **fixings, connectors**, etc. (BSRN)
- **TR9901: Calibration** of the pyranometer and data acquisition system are typically calibrated at a **2 year interval**. (IEC61724 identical for pyranometers at Class A)
- When disconnecting a radiometer for longer (for recalibration), cover or store the wire connector (to prevent corrosion).

Case studies: Real-world examples

Lightning

Humidity

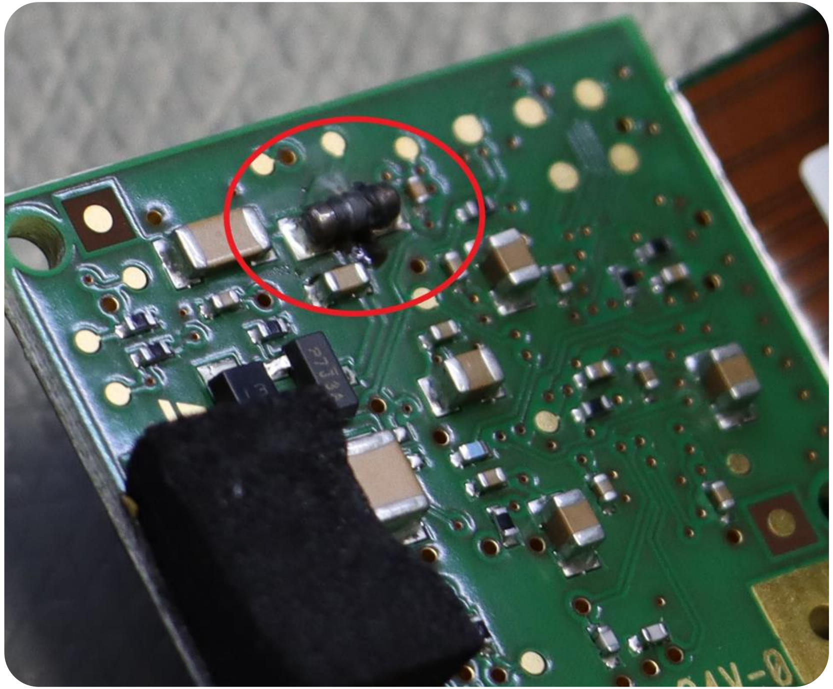


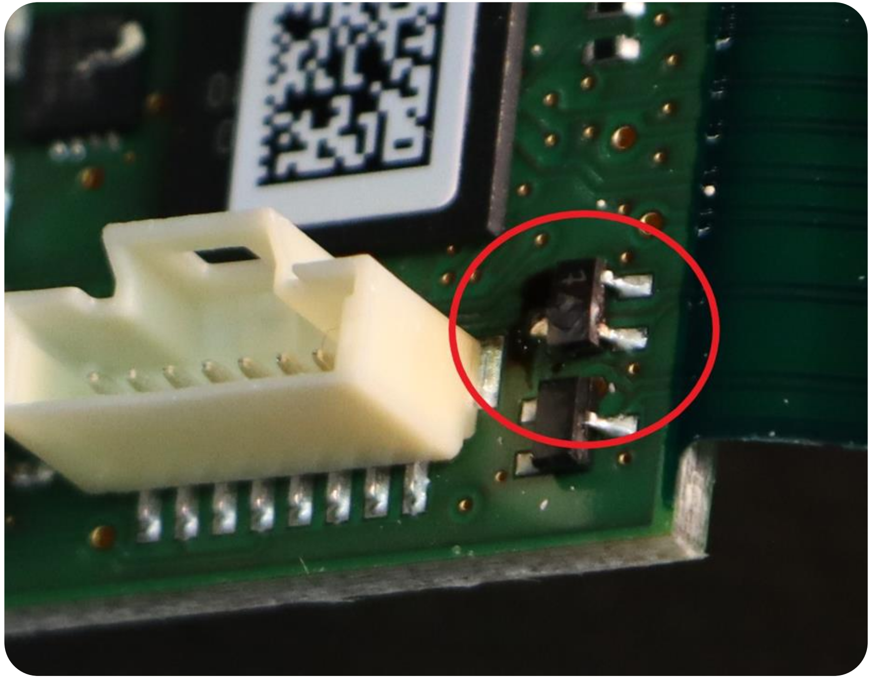
Case studies: Real-world examples

Corrosion

Damaged dome

Damaged PCBs

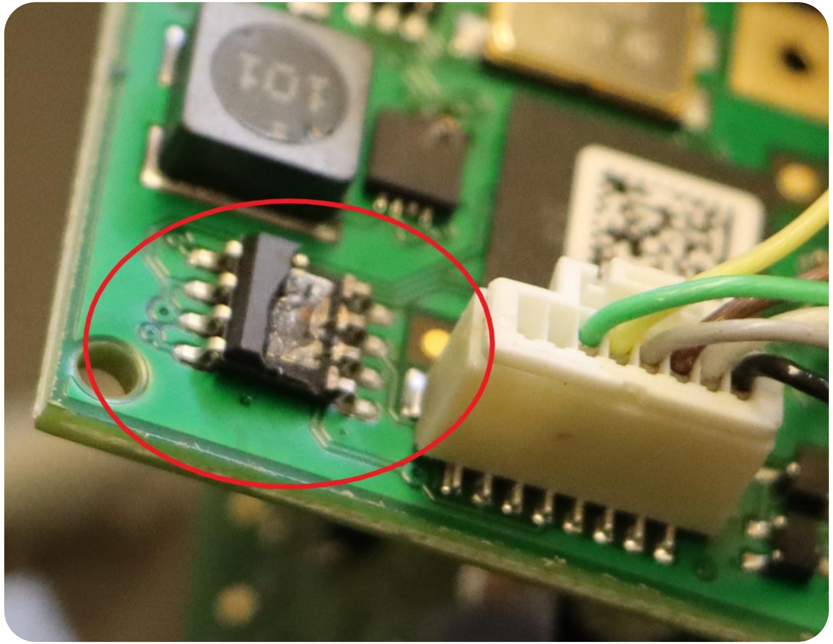


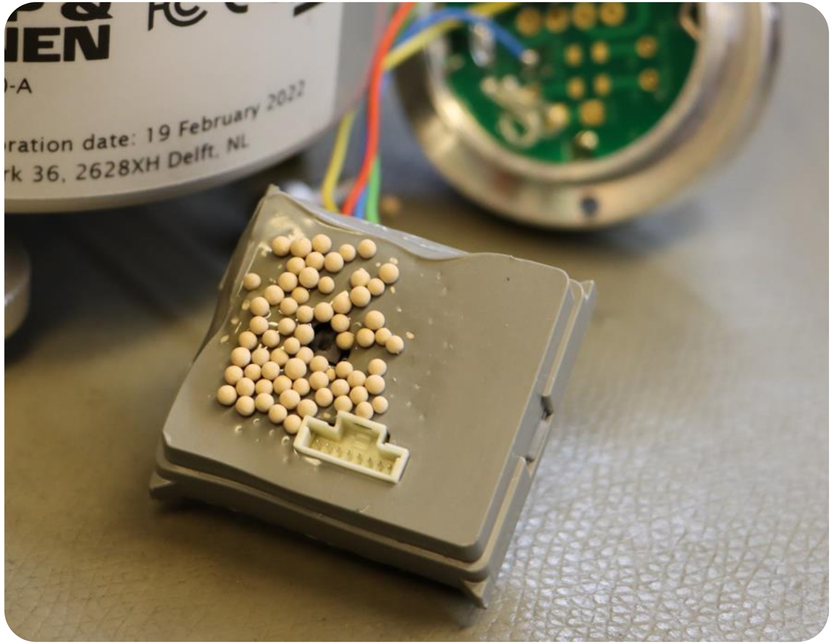


Case studies: Real-world examples

OTT HydroMet

Damaged PCBs





Thank you!

this webinar is powered by

OTT HydroMet

pv magazine webinars

Field protection and reliability of solar radiation measurement instruments

Q&A

11 October 2023

8:00 am – 9:00 am | PDT, Los Angeles
11:00 am – 12:00 pm | EDT, New York City
5:00 pm – 6:00 pm | CEST, Berlin, Madrid

Marija Maisch
Editor
pv magazine

Sajad Badalkhani
Manager, Technical Support and Services
OTT HydroMet

Marc Korevaar
Scientist
OTT HydroMet

pv magazine webinars

The latest news | print & online

10% off your subscription with ***Webinars10***

Most-read online!

European warehouses now storing more than 80 GW of unsold solar panels

by Emiliano Bellini

High resolution satellite imagery for residential PV system detection

by Lior Kahana

pv magazine webinars

Coming up next...

Tuesday, 17 October 2023
2:00 pm - 3:00 pm BST, London
3:00 pm – 4:00 pm CEST, Berlin

New mounting systems for solar facades

Thursday, 19 October 2023
2:00 pm - 3:00 pm CEST, Berlin
3:00 pm – 4:00 pm AST, Riyadh

Securing successful solar project financing via sustainability standards

Many more to come!

In the next weeks, we will continuously add further webinars with innovative partners and the latest topics.

Check out our pv magazine Webinar program at:

www.pv-magazine.com/webinars

Registration, downloads & recordings are also be found there.

this webinar is powered by

OTT HydroMet

pv magazine webinars

Marija Maisch

Editor

pv magazine

Thank you for joining today!