Lufft White Paper

Simultaneously keep an eye on 10 Solar System Performance Factors

The following paper explains why professional weather sensors play an important role in utility scale photovoltaic systems and gives valuable tips on how to choose the right weather sensor.

PV market trends

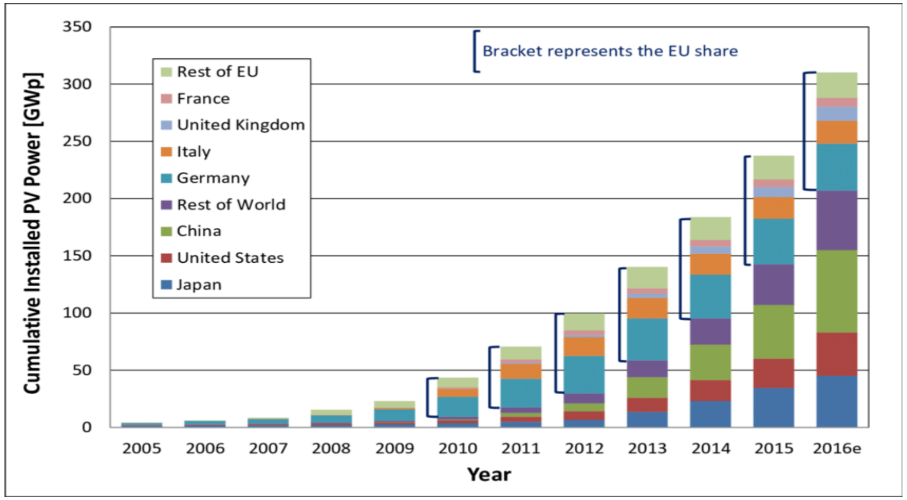


Fig. 1: Worldwide solar energy market growth[1]

By the end of 2015, all photovoltaic plants worldwide had a combined output of 227 GW. In 2016 approximately 75 GW were added. Researchers estimate that the average annual growth will reach 100 GW per year by 2020. In 2030, solar energy generation could break through the 10,000 GW level (see Fig. 1: Worldwide solar energy market growth).

Until recently, photovoltaics was considered to be the most expensive of renewable energies due to the high purchasing costs. However, the acquisition costs are currently falling drastically: within the last seven years they reduced by an impressive 75%. In the USA, for example, solar power prices are now realistically lower than 4.3 euro cents/kWh (5 US dollar cents/kWh). A plant in Chile generates energy for just 2.6 euro cents/kWh (3 US dollar cents/kWh). Already since 2014, solar plants have been able to compete with fossil power plants in many places.

Reasons for this are scale effects, technical development, sinking feed-in tariffs, increasing competitive pressure, e.g. from China, as well as funding programs within the framework of the energy revolution.

Solar energy is therefore fully in keeping with current trends because it is environmentally friendly and is now even affordable. No wonder

[1] PV Status Report 2016. Arnulf Jäger-Waldau, Nov 25, 2016. In: researchgate.net. Accessed on July 27, 2017.

PV plants today are shooting up everywhere.

How do PV plant investments payback quickly?

The fastest possible amortization and achievement of the break-even-point require the maximization of the annual yield, i.e. the annual amount of electricity generated. This requires top system performance. The available radiation energy varies according to the time of day and season: for example, it is up to 10 times higher in Germany in July than in December. In addition, weather conditions and other influencing factors play an important role (see Fig. 4). In Germany, the right equipment can achieve a maximum annual yield of 1000 kWh.

The following applies:

Minimize negative influences, maximize positive ones

On the one hand, this requires a suitable location, which, with the aid of measuring technology, is first evaluated for one year as part of the site assessment. On the other hand, even after the installation of the system, professional, continuous site monitoring by means of various units is required (see Fig. 2).

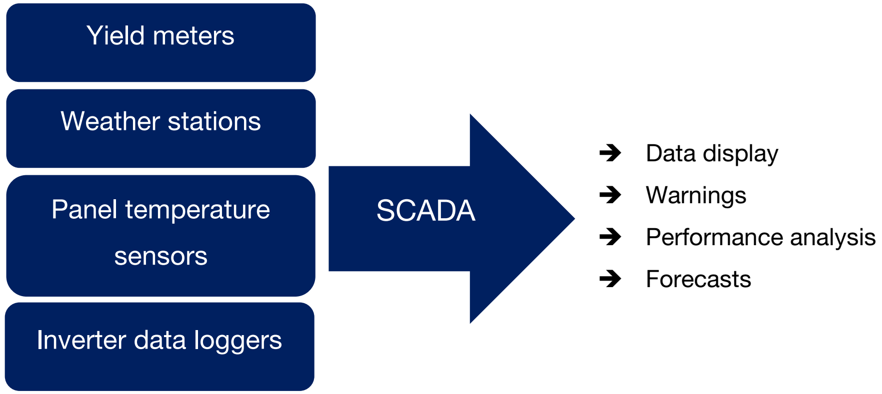


Fig. 2: Data collection and processing using a SCADA[2] system

For each utility-scale[3] plant, therefore, the professional weather monitoring system is a fixed component. It is sometimes prescribed by law and provides information about positive and negative influence factors. Thus, it gives important explanations for performance degradation and helps in performance optimization (e.g. by solar tracker). The performance of a solar system can be determined by the performance ratio formula. This is an annual value calculated as follows:

[2] Supervisory Control and Data Acquisition (SCADA): Monitoring and control of technical processes by means of a sophisticated computer system.

[3] A utility-scale solar system: plant with a size of around 10 MW, which supplies large energy suppliers.

$$\text{Performance Ratio} = \frac{\text{actual yield}}{\text{nominal yield}}$$

Nominal yield

Nominal yield
= energy applied to the module surface • nominal module efficiency

The module efficiency is the ratio between instantaneously generated, inflation-adjusted electrical power and irradiated light power. The higher it is, the smaller the area required for the installation. The nominal module efficiency, therefore, represents the reference value.

In Germany, an average performance ratio of 84% has been customary since 2010. Fig. 3 shows the development of the average performance ratio since the 1980s. It increases due to the constantly improved solar panel technology.

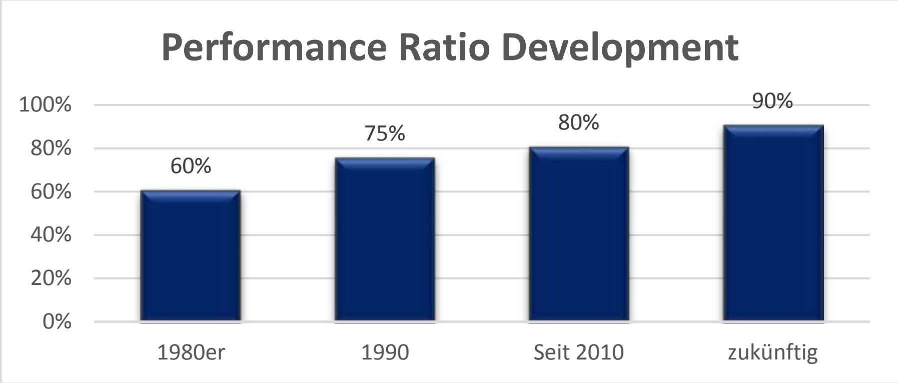


Fig. 3: Development of the Performance Ratio since 1980

If a PV system does not achieve these average values, one or more influencing factors have a negative effect (see Fig. 4) - provided all modules are intact.

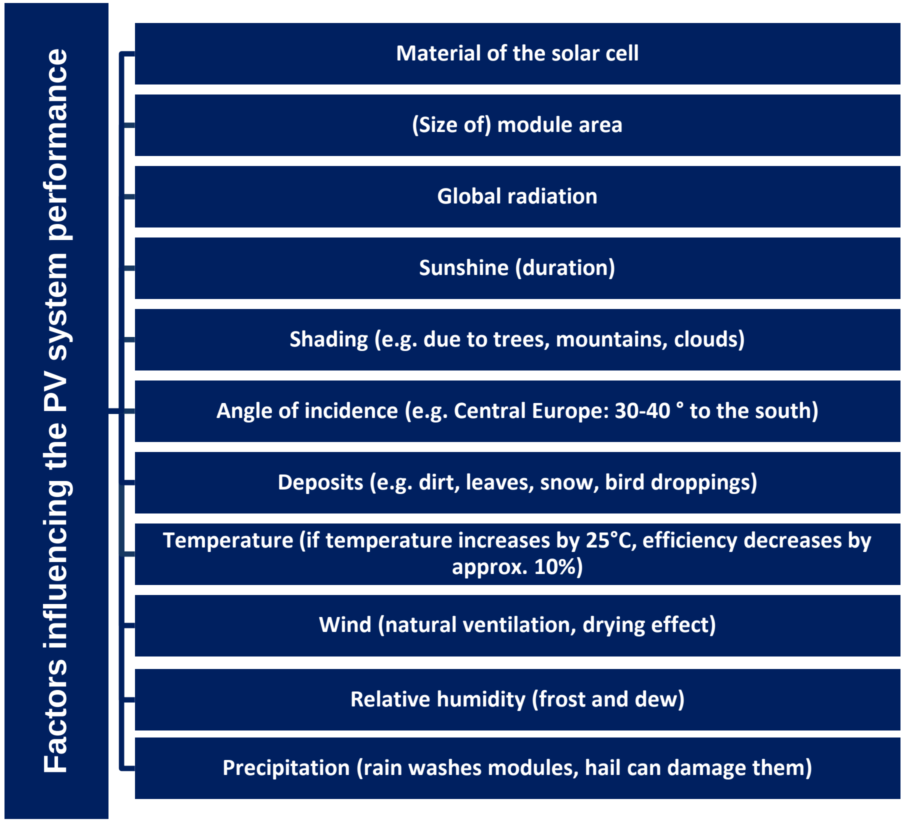


Fig. 4: Factors influencing the PV system performance (efficiency)

There is the possibility that different materials are deposited on the solar modules (see Fig. 5). In such cases cleaning is mostly required.

Fig. 5: Types of deposits on solar panels

However, liquid precipitation (rain) can provide relief. For the most efficient planning and coordination of cleaning operations, precipitation sensors are recommended.

The life expectancy of modern solar collectors is 35 years. In the best case, solar monitoring systems should not only supply all relevant, measurable data, but also be able to keep up with the life cycle of a PV system.

Professional weather sensors

Professional weather sensors form the heart of large solar plants. They support their operation, maintenance and performance optimization.

Lufft was the first sensor manufacturer to combine several weather sensors in one housing, creating an all-in-one sensor family.

“The family of professional, multiparameter weather sensors from Lufft is, so far, the largest weather sensor family on the market”, confirms Udo Kronmüller, sales manager at Lufft. It includes 21 models for many different purposes. “Our weather sensor family ranges from the WS300, which purely measures temperature, humidity and air pressure, to the WS800, which even detects lightning” adds Udo Kronmüller. All are of similar construction and have the same measurement principles, protocols and channels. This means that if one of them works, they all work. Combining several sensors in one housing saves installation and maintenance expense.

Before the times of modular all-in-one weather sensors, installers had to install each sensor individually. This meant dealing with many different cables, signal outputs and components and therefore was associated with a huge effort - both during setup and in operation.

Smart, highly integrated, low maintenance sensor combinations, which require only one cable and one interface, cover everything that is important in weather monitoring, saving effort, time and - in the end - money.

The WS600, in particular, is a popular version. It measures precipitation intensity as well as quantity, wind speed and direction, air pressure, relative humidity and ambient temperature.

Leave nothing to chance: keep all influencing factors in view

Measurement of global radiation using different pyranometer types

The Lufft WS models are available with three different pyranometer types (see Fig. 6):

Silicon pyranometer from Lufft:
WS302, WS502, WS504 (tiltable), WS700 & WS800

CMP3 Second Class pyranometer from Kipp&Zonen:
WS301, WS303 (tiltable) WS501 & WS503 (tiltable)

CMP10 Secondary Standard pyranometer from Kipp&Zonen

WS310, WS510 & WS3100

Fig. 6: WS family with pyranometer

The Lufft silicon pyranometer, which is based on a photo diode, is suitable for smaller budgets or PV roof systems. It reacts faster but has a somewhat lower accuracy than thermopile variants. The latter is currently the most advanced technology on the market.

Fig. 7: CMP10 pyranometer from Kipp&Zonen

The pyranometer of the WS303, WS304, WS503 and WS504 models is provided with a hinge to make it tiltable. This makes it possible to optimally adapt to the solar modules or to attach them under the solar cells, in order to simulate the module position as precisely as possible.

The CMP10 (see Fig. 7) Secondary Standard Radiation Sensor with the highest accuracy is mainly used in multimegawatt systems.

Ambient temperature

The power of PV modules decreases with increasing temperature (see Fig. 4). Therefore, high-precision temperature sensors are essential in PV systems. The following properties must be taken into account to ensure the highest possible accuracy:

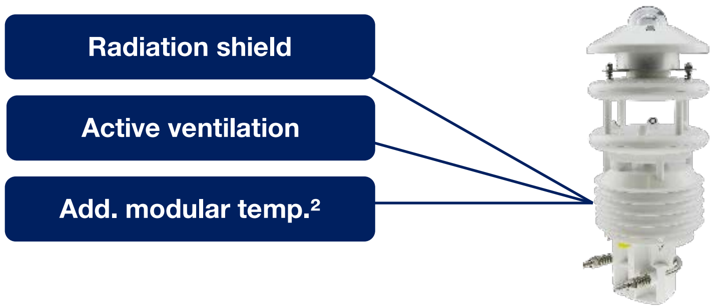


Fig. 8: Temperature sensor using the WS510 as an example

[1] *Active ventilation protects against direct sunlight and rainfall, which can lead to deviations of several °C or °F. All Lufft-WS are actively ventilated by aerating the temperature probe inside.*

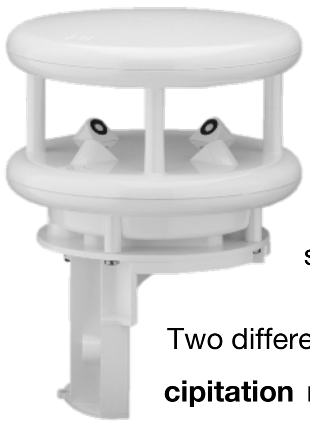
² A modular, self-adhesive temperature probe located about 10 m away from the weather sensor, which is connected by means of an external sensor input, provides comparative measurements.

Sensors with these characteristics have accuracies of ±0.2 °C.

Nice-to-have: wind and precipitation sensors

Wind direction and speed measurements make sense when it comes to the prevention of possible storm damage. For example, they enable the control of solar trackers: they can be aligned to the wind direction in order to give the wind the smallest possible attack surface. For systems without solar tracker, they provide evidence of possible storm damage.

Fig. 9: Ultrasonic wind sensor



Special maintenance-free ultrasonic sensors without moving parts are suitable for **wind measurements** (see Fig. 9). These are standard in many Lufft compact weather sensors (WS500 - WS800).

Two different measuring principles can be used for **precipitation measurements**: Tipping spoon with bucket or Doppler radar. This results in differences regarding the measurement accuracy and the measured objects: While a tipping spoon only detects whether precipitation falls, the radar sensor can distinguish between intensity, quantity and type (rain, snow, sleet and hail). These measurements provide information on the natural module cleaning function of rain. In addition, they inform of the threat of snow accumulation or hail damage (also see Fig. 5).

Fig. 10: WS601 with tipping bucket

Fig. 11: WS600 with radar-Sensor

MODBUS RTU

The Modbus RTU protocol (Remote Terminal Unit) is an open standard communication protocol, which most of the common data loggers make use of. Thus, for the simple integration of sensors into the PV network, it is important that the installed weather sensors and pyranometers also communicate in the MODBUS. Fig. 12 shows a possible sensor network based on MODBUS.

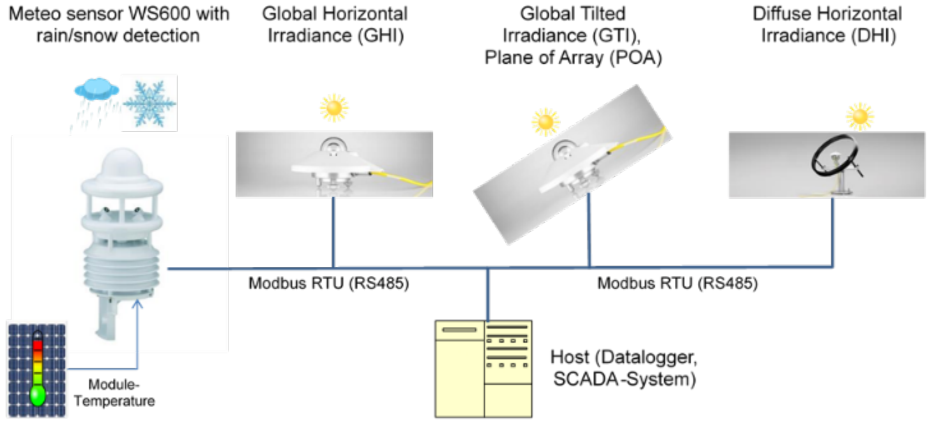


Fig. 12: Possible Modbus communications set-up of a solar network[4]

WS800 – flagship of the Lufft WS family

The WS800 All-in-One weather sensor combines eight parameters in one housing (see Fig. 13) making it the most versatile WS variant.

It was launched in July 2015 and is distinguished from the WS700 by an innovative lightning detection module. This reliably differentiates electromagnetic waves of lightning caused by storms from other light effects. Particularly in the case of damage, such information is useful, e.g. for insurance purposes.

[4] WS600, module temperature, several pyranometers (horizontal, diffuse horizontal, and plane of array) communicating with host data loggers and finally with SCADA system via MODBUS RTU (RS485 connector).

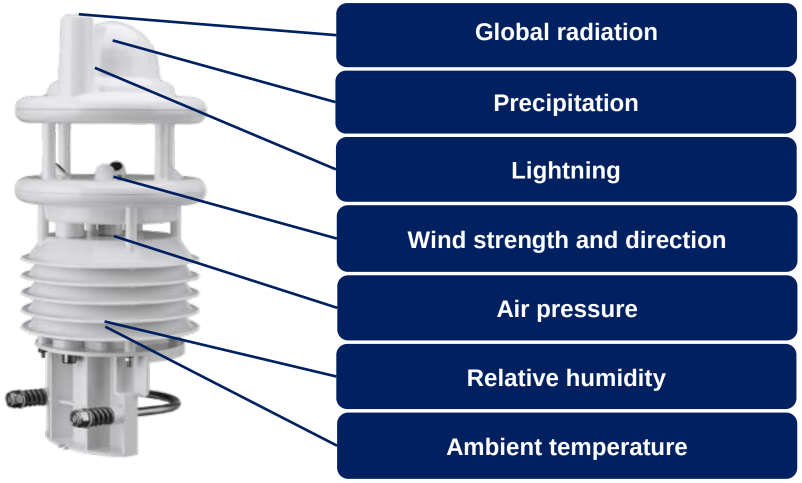


Fig. 13: WS800 - Lufft WS flagship

Conclusion

Professional modularly built weather sensors, which cover several parameters at once, are an easy way to keep an eye on all the influencing factors which affect the performance of solar systems.
The less attack surface the sensor offers in the form of cables and mechanical and moving parts, the higher is its stability and durability. The MTBF in the field for Lufft compact weather sensor is on average 10 years. Compared to this, mechanical sensors generally need to be replaced after 24 months (see Fig. 14). Thus, modern solar cells and digital weather sensors are the perfect match.

Digital compact weather sensors	Mechanical Weather Sensors
Cover many parameters at once	Cover only one parameter per sensor (e.g. wind direction & speed)
No moving parts	Movable parts with great wear
Maintenance-free	Maintenance required (e.g. ball bearing lubrication)
IP66 – IP68	IP55
Very low response threshold (e.g. wind speed measurement from 0.1 m/s)	Response thresholds higher due to friction (e.g. wind speed measurement from 0.3 m/s)
High acquisition costs, no/low maintenance costs	Low acquisition costs, high maintenance/replacement costs
MTBF Ø 10 years	MTBF Ø 2 years

Fig. 14: Mechanical vs. digital sensors

G. Lufft Mess- und Regeltechnik GmbH

Gutenbergstr. 20

70736 Fellbach

Germany

E-mail: info@lufft.de

Tel: +49 711 51822 0

Fax: +49 711 51822 41

Further information can be found on the Lufft website at www.Lufft.com

Or contact us at www.lufft.com/contact/