European Partnership on Metrology
Call 2024 –Digital Transformation, Green Deal, Normative and Research Potential

Selected Research Topic number: **SRT-v18**
Version: 1.0

Title: Metrology supporting large-scale deployment of efficient and resilient photovoltaic systems

Abstract

A step-change in deployment of solar power systems is needed to meet the European Green Deal objectives. Deployment is delayed, in part, due to risks traceable to metrological uncertainties. Accurate and reliable data on real-world performance and yield forecasts at the whole-system level underpin design optimisation and investment decisions. Submitted proposals should address systems-level challenges to optimise energy management and energy efficiency at the system level. It provides standards, best practice, calibration capabilities and research infrastructure at the European level to assure PV systems and technologies.

Keywords

Photovoltaics (PV), photovoltaic systems, solar energy, renewables, irradiance, digital twin models

Background to the Metrological Challenges

The EU Solar Energy Strategy states “solar energy has a significant potential to rapidly become a mainstream part of our power and heat systems and a main lever to achieve the European Green Deal objectives”. However very rapid scale up of investment and deployment are still required to meet climate targets and avoid catastrophic climate change. The strategy aims to deploy almost 600 GW of solar PV by 2030, requiring an investment of the order of one trillion € (including significant public funding and risk sharing through schemes such as REPowerEU). Average deployment rates must be 45 GW per year compared to 18 GW in 2020. Technological risks are a key barrier to investment, many of which can be traced directly to metrological uncertainties. The problem is worse for new high-efficiency solar technologies (bifacial, trackers, Tunnel Oxide Passivated Contact - TOPCon, heterojunction, etc.), where best practice, field experience and standards are less developed.

Europe leads the world in development of standards and metrology for Photovoltaics. Expertise has been demonstrated in previous top-rated EMRP and EMPIR projects such as Photoclass (ENG55), PV-Enerate (16ENG02) and Metro-PV (19ENG01), which have delivered critical international standards and metrology capability. However, these have focused on metrology at the PV cell and module level. The needs of stakeholders and the Green Deal require a project to support optimisation of energy management and efficiency at the system level.

Solar PV systems are optimised for their efficiency at converting solar irradiance into useable power. For predicting outputs or measuring performance, the most important variable is solar irradiance. Class A pyranometers achieve typical measurement uncertainties in the order of 3 % (95 % coverage) measuring short-wave irradiance from the sky. However, while pyranometers have flat spectral and angular responsivity, PV systems do not. Spectral and angular mismatches between pyranometers and PV systems amount to several % for sky irradiance, and as much as 25 % for ground-reflected light. There is increasing reliance on matched reference devices (reference cells) for plane-of-array measurements of the “usable solar resource”. While there is an international standard for classification of pyranometers (ISO 9060), there is no such specification for these matched reference devices, which leads to inconsistent measurement of system performance. Furthermore, unlike laboratory reference cells, commercial reference devices for systems typically produce digital outputs which prove a challenge for accurate independent calibration of their differential spectral, angular responsivity and linearity.

EURAMET MSU,
Email: part.msu@euramet.org
Metpart.eu

System performance indicators are widely used in the industry. They form the basis of contracts, inform decision making and determine financial risks. The simplest, Performance Ratio (PR) as defined in IEC 61724-1:2021, is based on the ratio between power output and irradiance input, but more sophisticated metrics or configurations introduce additional variables, complex models and even machine learning algorithms. Currently there is no consideration of measurement uncertainty propagation from sensors to performance metrics. While IEC 61724-1:2021 defines requirements for systems monitoring, quantified uncertainties are needed to study rational design of monitoring configurations for the best balance of cost versus accuracy.

Remote sensing irradiance data underpin yield forecasting and are increasingly used in performance indicators for smaller systems where maintenance of on-site sensors is not cost effective. Nevertheless, they rely on accurate ground-based measurements for validation and calibration. CEN/TC 312 states “The reliable use of solar energy in the form of thermal and electrical energy is one of the most important prerequisites for the transformation of the energy sector to a completely carbon neutral supply. This creates needs for digital data, especially real time radiation data from satellites as an alternative for on-site measured data”.

Performance degradation is a critical parameter for quantifying return on investment, Levelized Cost of Energy, and life-cycle analysis of a system. Today’s models use estimated performance loss rates (PLR), such as 0.5 % per year, based on laboratory studies and experience. These do not always account for changes in technology, differences between climates, and non-uniform degradation within a system. To understand how systems are actually degrading, data can be sourced from performance indicators at string, inverter and transformer level, which can be combined with periodic testing of individual modules. However, confidently discerning small trends in performance against a background of variable weather, data loss, system availability and maintenance is difficult. Furthermore, there is a trade-off between cost and accuracy of such studies. Currently there are no standard for PLR measurements, only proposed algorithms, and results are not comparable between different configurations and environments. A comprehensive experimental and modelling study is needed to define PLR unambiguously and harmonise best practice in measurement and reporting.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on the development of metrology capability in optimisation of the energy management and efficiency of PV systems.

The specific objectives are:

1. To develop a new draft specification for classification of matched reference irradiance sensors for PV systems (equivalent to ISO 9060 for pyranometers). To develop accompanying metrology capabilities for accurate characterisation and SI-traceable calibration of reference irradiance sensors with integrated electronics, including linearity, temperature dependence, spectral responsivity and angular responsivity measurements.
2. To develop and disseminate models for the propagation of measurement uncertainty in PV systems from sensors to various performance indicators, including performance ratio as defined in IEC 61724-1:2021, primary quantities (irradiance, output power), and auxiliary quantities. To use these to study rational optimisation of sensor selection and placement and issue good practice guidelines for accurate, cost-efficient monitoring of bifacial, single-axis tracker and commercial-rooftop systems.
3. To develop harmonised, validated methods and sampling strategies to quantify degradation rates in PV systems using combinations of system-level monitoring data with in-field module testing and characterisation, including indicative uncertainty budgets for common and proposed measurement scenarios.
4. To support the above objectives with reference PV systems comprising scientific grade instrumentation alongside common commercial instrumentation to provide high-accuracy open data with quantified measurement uncertainties. This requires development of validated digital twin models of the systems to provide accurate time-series data on system performance for facilitating the development of reduced-complexity system models and conducting studies on system and sensor optimisation.

5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (instrument manufacturers, accredited calibration and measurement laboratories), standards developing organisations (IEC TC82, IEA PVPS, PVQAT), and end users (e.g. PV system manufacturers).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented needs, in particular those supporting the European Green Deal. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP and EMPIR projects ENG55 Photoclass, 16ENG02 PV-Enerate and 19ENG010 Metro-PV, and how their proposal will build on those.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.8 M€ and has defined an upper limit of 3.5 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the ’end user’ community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your proposal’s results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the energy sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.