Title: Metrology for emerging PV applications

Abstract

The world market volume for PV was about €100 billion in 2018 and it is predicted to grow by 575 GW of new capacity by 2023 according to the International Energy Agency. Therefore, the PV industry is continuing to grow rapidly and there is increasing interest in emerging concepts and applications that could transform the economics of PV. Perovskite-based cells have emerged as one efficient and low-cost option, which European organisations are seeking to rapidly scale-up and commercialise in applications such as PV integrated into buildings and vehicles and indoor energy-harvesting. However, if this is to be realised, the PV industry will require validated standards, performance measurements and quality infrastructure. These urgently need to be developed to accelerate commercialisation and the acquisition of market share by world-leading European organisations.

Keywords

Photovoltaic, energy-harvesting, energy rating, IEC 60904, IEC 61853, multijunction PV, perovskite, shade-tolerant PV, solar devices, standard test conditions

Background to the Metrological Challenges

The second renewable energy directive 2018/2001 specifies that by 2030, 32 % of energy consumption should come from renewable sources in order to reduce greenhouse gas emissions and the dependence on imported energy. A significant increase in photovoltaic energy generation will contribute to this goal. Photovoltaic energy generation is silent, can be decentralised and will continue to reduce costs at a faster rate than any other renewable energy technology. Thus, the demand for photovoltaic installations will continue to rise.

If new types of PV devices, such as multijunction PV devices or those constructed from perovskite, are to be adopted investors need to have confidence in the energy yield predictions that are based on measurements according to IEC 60904 and IEC 61853. However, some materials produce unique effects such as hysteresis and metastability, and the choice of reference device can also affect the reproducibility of the measurements. In addition, different methods are being used to address these problems. IEC TC82 has proposed a harmonised technical specification on this topic, but it requires end-user input. Therefore, the methods proposed in the technical specification need to be validated and the uncertainty needs to be reduced.

The energy rating standards IEC 61853-1 for the determination of a temperature-irradiance matrix, and IEC 61853-2 for the spectral responsivity, require measurements to be made according to IEC 60904-1 and IEC 60904-8. However, at present these standards do not provide a model of the evaluation, or information on how to determine the measurement uncertainty budget. Therefore, the uncertainty sources, related to the output power of PV modules, need to be determined. In addition, models need to be developed to quantify the uncertainty sources that are associated with the measurement of the IV-curve in accordance with IEC 60904-1 and the spectral irradiance and spectral response of PV devices in accordance with IEC 60904-8.

The next phase of PV growth is expected to be associated with existing building stock in the urban environment. Shade-tolerant PV modules will need to be designed as energy loss through shading is anticipated to make a significant contribution to the uncertainty in energy yield estimation. In addition, PV module standards will need to be upgraded to include an evaluation of energy yield or even instantaneous power loss. Therefore, a quality metric needs to be defined for the behaviour of PV modules in shady locations in order to quantify the benefits of shade-tolerant module designs.

PV-based energy-harvesting devices, which can perform in low-light (indoor) conditions, are needed to power Internet of Things applications. However, most photovoltaic test and measurement laboratories do not have sources and calibrated references that operate with spectra that differ greatly from natural sunlight, thus precluding accurate traceable measurement. In addition, there are no international standards defining standard test conditions for such applications, consequently manufacturers currently use their own in-house measurements. A draft standard for indoor PV (working title: IEC 62607-7-2) has been proposed, but it requires validation and input from European manufacturers and end-users. Therefore, to support the development of this standard, a classification needs to be prepared by developing and validating traceable methods for evaluating the performance of these devices in low-light (indoor) conditions and their sensitivity to influencing factors such as the pulse-width modulation of modern efficient light sources.

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 JRP shall focus on the traceable measurement and characterisation of emerging PV applications.

The specific objectives are

1. To validate the suitability and reduce the uncertainty, associated with measuring the nominal power of PV devices, within the calibration chain according to IEC 60904. This should include multijunction PV devices and devices constructed from perovskite materials.
2. To determine the uncertainty sources related to the output power of PV modules. This should include development of models to quantify the uncertainty sources that are associated with measurement of the IV-curve in accordance with IEC 60904-1 and spectral irradiance and spectral response of PV devices in accordance with IEC 60904-8.
3. To define a quality metric for the behaviour of PV modules in shady locations such as urban areas in order to quantify the benefits of shade-tolerant module designs.
4. To prepare a classification of PV-based energy-harvesting devices for Internet of Things (IoT) applications, by developing and validating traceable methods for evaluating their performance in low-light (indoor) conditions and their sensitivity to influencing factors e.g. the pulse-width modulation of modern efficient light sources.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers), standards developing organisations (IEC, especially IEC TC113) and end users (e.g. photovoltaics industry). Use the results from objective 2 for appendices of the IEC 60904 standard.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. 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 project ENG55 PhotoClass and the EMPIR project 16ENG02 PV-Enerate and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.0 M€, and has defined an upper limit of 2.3 M€ for this project.

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

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 JRP 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,
- Transfer knowledge to the renewable 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 EMPIR 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.

Time-scale

The project should be of up to 3 years duration.