Training the Next Generation of PV Reliability Experts – Project SOLAR-TRAIN "Photovoltaic Life Time Forecast and Evaluation"

Ismail Kaaya[1,2], Enikö Bedö[1] and Karl-Anders Weiss[1]

[1] Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, (Germany)

[2] University of Malaga, Malaga (Spain)

Abstract

The quality assurance and life time prediction in the photovoltaic industry are yet in their infancy, requiring both underpinning science and trained personnel to reduce costs of energy. An unmet industrial requirement is an accelerated and operating environment specific, service life time and energy yield assessment. SOLAR-TRAIN qualifies early stage researchers (ESRs) in the field of PV durability as part of a highly innovative, multi-disciplinary project meeting industry requirements. The research objective is to develop novel and validated models for the service life time and energy yield prediction of PV modules and systems. To achieve this objective, different topics are being addressed; these include climatic degradation factors, analysis of degradation and failure modes of PV modules, evaluation of polymeric materials in PV modules and service lifetime prediction for PV modules and systems and related economic impact.

Keywords: Early stage researchers, PV degradation and failure modes, service lifetime and yield prediction

1. Introduction

The major goal of the project SOLAR-TRAIN "Photovoltaic Life Time Forecast and Evaluation" is to train 14 early stage researchers (ESRs) in the fields of PV durability and reliability assessment, life time and yield prediction by international and inter-sectoral research and exchange. It is funded by the EU Commission's Marie Sklodovska-Curie Actions (MSCA) programme. The collaboration between the MSCA fellows will develop new insights in all subtopics of PV reliability and durability such as (a) climatic degradation factors, (b) system analytics, (c) material (polymer) parameters, (d) service life & energy models, (e) linking production to performance and (f) performance enhancement by improved O&M.

The elements to this puzzle are researched in the frame of 14 PhD projects with individual areas of focus. Commercial and test samples are produced and tested in the distributed measurement campaign during this project, deployed in different operating environments. They are exposed to state-of-the-art and to-be-developed stress cycles to allow a validated link of degradation to stresses, production methods, materials and methods of deployment. Accelerated and lower cost test cycles for the assessment of innovative materials and module developments will be delivered.

The individual research projects will be merged with the aim to improve the state-of-the-art in-service life prediction of PV modules and systems to enhance the industry's economic security and predictability. In this way, SOLAR-TRAIN delivers on the targets of the Issue Paper No. 2 of the SET Plan to maintain and strengthen PV technology leadership in Europe.

The project is integrated both in terms of research as well as training. This inter-sectoral approach provides excellent theoretical and technical background as well as immersion in different business sectors and career mentoring, allowing ESRs to build up a sustainable professional network across Europe. To enable a most effective cross-sectoral training, the project's beneficiaries and partners represent the entire value chain, from materials developers / manufacturers through to operators and insurance companies.

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2. Innovative, educational and scientific approach

SOLAR-TRAIN's approach is twofold: ESRs are being trained in the framework of an extensive PhD program, covering all relevant aspects of PV durability and reliability testing and the specific aspects of their individual research tasks. They are being trained by 8 international leading institutions in this field (Fraunhofer ISE, Germany, Polymer Competence Center Leoben (PCCL), Austria, Loughborough University, UK, EURAC Research, Italy, University of Ljubljana, Slovenia, Centro Nacional de Energías Renovables (CENER), Spain, BayWa r.e. Operation Services, Italy and Electricité de France (EDF), France) and undergo international and inter-sectoral exchange during secondments at industrial partner organizations. Their academic training is enhanced by summer schools and workshops fostering interdisciplinary understanding, interaction and cooperation and by individually selected soft skill modules. Action centered learning and mentoring rounds off the education part of the projects with the aim to obtain a PhD.

2.1. Summer schools

In addition to the beginner's week, where ESRs were equipped with the fundamentals in photovoltaics, module design and reliability assessment, three summer schools were planned at different stages of the project. The summer schools were meant to address different topics such as; State-of-the-art in PV Module Technology, PV Module Lifetime & Reliability and Industrial Soft Skills & Entrepreneurship. These topics were given by experts within the field to deepen the understanding of cell technologies, PV module composition, components and materials, standardization and standardization and proceeds to the specifics of life time and reliability testing, performance monitoring and life time modelling. The final Summer School places these insights into the economic context, focusing on aspects of quality management, Intellectual Property Rights (IPR) management, ramp up processes, product development and project management in industry.

During the summer schools, ESRs also get a chance to present their individual work and progress. Each presentation is followed by a peer discussion of the presented research and joint planning of next steps. The hands-on projects and laboratory tours during the summer schools helps ESRs to have a broad knowledge beyond there individual research topics.

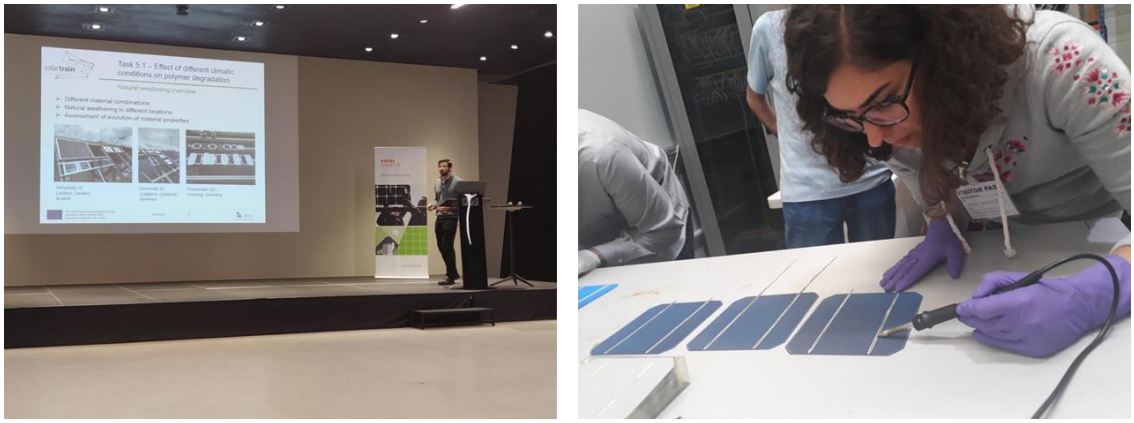

Fig. 1 Left: ESR presenting his work progress during the last summer school at PCCL in Austria and right: ESRs having a hands-on experience on cells soldering during the first summer school at University of Loughborough, UK.

The summer schools also provide a unique platform for a face-to-face interaction of SOLAR-TRAIN's ESRs. These personal contacts are essential for the successful cooperation. To ensure a successful social integration, the schedule includes time slots for social events and activities.

Fig. 2 Left: ESRs enjoying the sunset at the sea, during the second summer school at University of Ljubljana in Slovenia and right: ESRs learning activity on agile and classical project management methods during the last summer school at PCCL in Austria.

3.2. Online seminars

To ensure a continuous exchange between ESRs in the periods between the Summer Schools there are monthly online seminars. Each month half of the ESRs report on their progress. For each meeting a chair of the ESRs is defined who organizes the meeting, takes minutes of discussions, collects presentations and archives them in the project database. Typically, presentations are followed by questions/discussions and then a round of formative feedback on how to improve the presentation. The seminars are essential to track progress and also for the cohort feeling as the ESRs 'meet' regularly. The rotating chair and the minute taking teach essential skills for future scientific careers.

3.3. Action Centred Learning

Action Centered Learning evolves in annual training events, so-called 'Challenge Calls' or competitive group projects. The supervisors of the hosting institutions specify small research tasks, contributing towards the deliverables of the WPs which require interactions of ESRs. The ESRs are split into three teams. The team selects a team-leader as well as other team roles as required. The team has to write a project application as it would do for an external client, i.e. including business plan and deliverables. The teams are required to complete the tasks within their budgets, both in terms of time as well as financial and deliver the promised deliverables. The projects are then submitted, and a 'winner' is chosen based on scientific quality, cost effectiveness and timely delivery. The aim of these actions is to train the ESRs in skills such as team work, project planning, team leadership and time management.

3.4. Scientific approach and current state of the project

Work is progressing in all the different addressed sub-topics and work packages of the project according to the schematic diagram (see Fig.1). Starting in summer 2017, commercial and test samples are produced and tested in distributed measurement campaigns and deployed in different operating environments. They are exposed to state-of-the-art and to-be-developed stress cycles to allow a validated link of degradation to stresses, production methods, materials and methods of deployment. In collaboration with different PV systems owners, different PV systems performance data are also under comprehensive assessment with the aim to evaluate the performance loss and degradation rates and to understand the performance reducing effects.

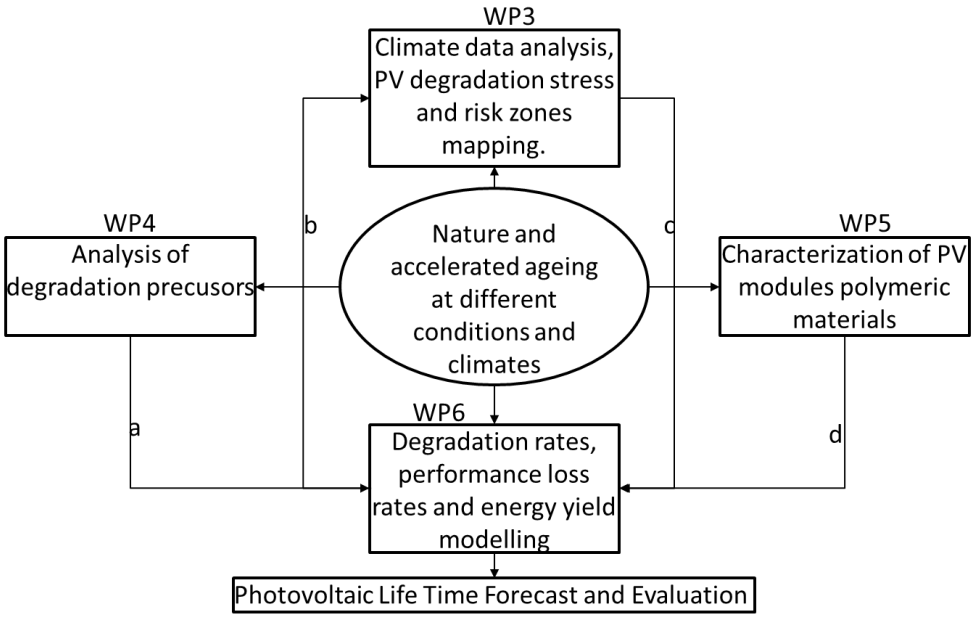

Fig. 3 Schematic diagram showing the different work packages and their connections.

The work packages are designed in such a way that they complete each other, for example starting from WP4, different degradation precursors are being investigated and the findings of this WP package are used in WP6 to select the relevant degradation precursors for service lifetime prediction (SLP). The degradation models developed in WP6 require climatic data inputs; since uncertainties relating to climatic data can highly affect the accuracy of the models, it's a prerequisite to have high quality data, hence the results on climatic data analysis from WP3 are required to improve the prediction accuracy. Moreover, identifying the most influencing climatic factors for degradation, which is part of WP3 is necessary inputs for WP6. Using the calibrated models from WP6 from high data quality, the degradation rates can then be extended to a global scale to make a degradation risk map in WP3. Analysing how polymers age carried out in WP5, is crucial to have a physical understanding and correlation of the degradation rates evaluated in WP6. At the end the whole chain is completed for lifetime forecast and evaluation.

Itis not in the scope of this paper to describe the scientific content of the project, therefore, only a general overview of the current working status is described, more scientific contributions can be accessed freely on the official homepage www.solar-train.eu

For example, new climate classification is being developed by integrating Köppen-Geiger classification and irradiation map with the aim of creating climate classes suitable for degradation evaluation. Encapsulant degradation analyses of several samples are being carried out in order to evaluate the encapsulant discoloration and optical properties. New non-destructive characterization techniques are under investigation on both mini and full PV modules.

To add on different approaches are being employed in degradation modelling, e.g. by using analytical approaches, it is now possible to calculate, degradation rates as well as the performance loss of PV modules provided reliable climatic data as inputs of the desired location. Different statistical methods for calculating the performance loss of PV modules and systems were tested and applied and the best performing methods with low uncertainties were identified.

Currently, we are working on the estimation of performance losses of operating PV systems where no meteo-data and very limited metadata are available. Algorithms to estimate the tilt and azimuth of a system from its power time-series are developed and the calculation of the Performance Ratio is performed by using irradiance data from sources such as PVGIS. Different methods to improve irradiance data quality are under investigation with the aim to increase the accuracy of proposed predictive models.

3. Conclusion

The project is integrated both in terms of research as well as training. This inter-sectoral approach provides excellent theoretical and technical background as well as immersion in different business sectors and career mentoring, allowing ESRs to build up a sustainable professional network across Europe. To enable a most effective cross-sectoral training, the project's partners represent the entire value chain, from materials developers/ manufacturers through to operators and insurance companies. Highlights of results of the research and trainings, and more information about the project can be derived from the official homepage www.solar-train.eu

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