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UCZELNIA BADAWCZA
INICJATYWA DOSKONAŁOŚCI

QUALITY DIAGNOSTICS AND PREDICTION OF PV CELL ENERGY PRODUCTION USING AI METHODS

Project thema

Quality diagnostics and prediction of PV cell energy production using AI methods. The project is used to develop advanced diagnostic qualifications and predictive models for photovoltaic cells, enabling early detection of defects and forecasting of energy efficiency.

Project team members

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Project Assumptions

01 **Construction of the measurement platform**

02-06

02 **Communication with measurement devices**

02-03

03 **Preparation of the data acquisition application**

02-03

04 **Data acquisition**

03-04

05 **Development and implementation of diagnostic models**

03-04

06 **Model optimization and data presentation**

03-04

07 **Preparation of project documentation**

03-04

Achieved Goals

The project successfully met all initial objectives. A fully functional and automated test station was developed for measuring I-V characteristics of photovoltaic cells under precisely controlled environmental conditions. The system integrates the ESP32 microcontroller with a set of environmental sensors and includes custom firmware and a MATLAB-based user interface for real-time control, monitoring, and data logging. The measurement platform, featuring adjustable height and interchangeable light sources, allows accurate testing under various illumination scenarios. An automated I-V measurement procedure using the R&S NGU401 SMU and MATLAB was also implemented, ensuring high-resolution and repeatable data acquisition. The solution enables reliable evaluation of PV cell performance and lays the foundation for future development of AI-based diagnostic and predictive models for cell degradation analysis.

Applied implementation methods

As part of the project, a comprehensive preparation of the measurement setup has been planned, including the control of light sources and measurements of the current-voltage characteristics of PV cells. Experiments will be conducted using various damage models, such as surface matting, simulating cracks through scratches, or cyclic exposure of the cells to UV-C radiation, as well as shock resistance tests. To enable precise adjustment of the cell position relative to the light source, a stepper motor will be used. The environmental conditions inside the measurement chamber will be monitored using a set of sensors (including temperature, humidity, and light intensity), allowing for strict control of the experimental conditions. The data collected during the studies will be analyzed using artificial intelligence techniques for damage diagnostics and to develop algorithms for predicting cell quality based on the measurement results.

Achieved results

As part of the project, an advanced measurement station was designed and built, equipped with an automatic sample positioning system, light source control, and a set of precise environmental sensors. Thanks to the integration of an ESP32 microcontroller, modern transducers, and MATLAB software, it was possible to achieve accurate monitoring and full control over the course of experiments. The construction of the station enabled the collection of an extensive set of current-voltage (IV) characteristics of PV cells under various lighting conditions and multiple defect models (thermal, mechanical, and UV-induced). Based on these data, a diagnostic AI model was developed, capable of recognizing both the type and severity of cell defects. The project also allowed participants to develop skills in data analysis, AI modeling, working in an international team, and operating advanced measurement and programming technologies.

Final Conclusions

To summarize the implementation of the photovoltaic cell measurement station project, it is important to emphasize the key role played by international collaboration within the project team. The cultural, educational, and technical diversity of the team members proved to be a significant asset at every stage of the project - from the conceptual phase, through mechanical and electrical design, to system implementation and testing.

The team's broad range of knowledge and diverse problem-solving approaches enabled the development of an innovative, functional, and modular structure that meets high standards of measurement precision. Effective communication and task distribution within a multicultural environment allowed for smooth project management and efficient responses to unforeseen technical challenges.

This project clearly demonstrates that international cooperation in engineering not only enhances the quality of developed solutions but also fosters the growth of soft skills such as teamwork, adaptability, and interdisciplinary thinking. The experience gained through this collaborative effort represents substantial added value, both in academic contexts and future professional endeavors.