38th Cycle

Automatic Detection of Defects in Photovoltaic Generators using Equivalent Circuits

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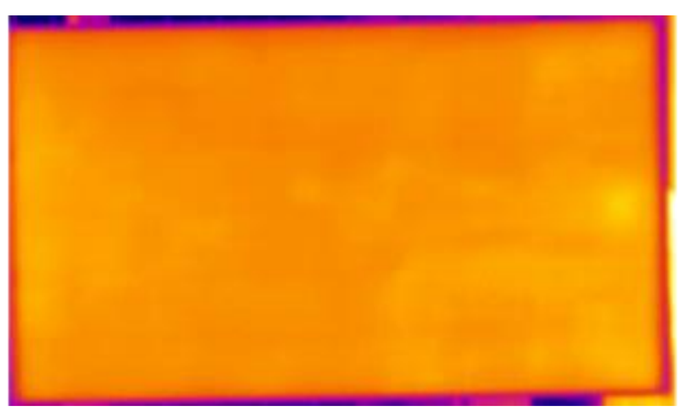
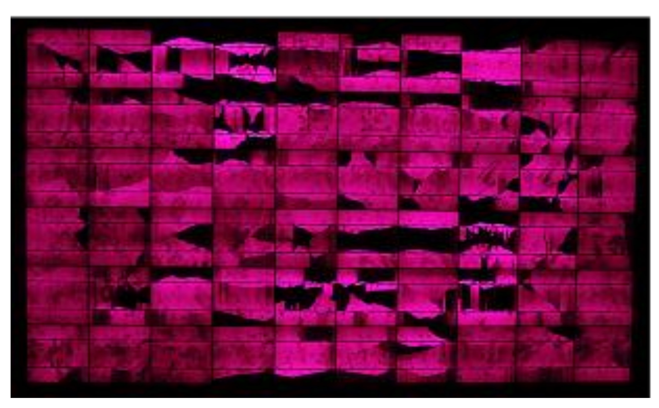
Research context and motivation

- In PV systems, traditional diagnostic processes follow these steps: initial notification of underperformance by a PV operator, locating faulty arrays using established diagnostic methods like ElectroLuminescence (EL) and Infrared Thermography (IRT), and ultimately replacing the defective arrays. However, it's important to note that these operations may entail downtime for healthy modules, at least until the defective ones are swapped out, which can impact overall system efficiency.
- The key goal is to maximize efficiency and quickly identify issues. Crucial to this are grid-connected inverters, which handle tasks like MPP tracking and DC/AC conversion. Despite PV modules' reliability, performance can decrease due to mismatch conditions, defects, or other problems. Diagnostic techniques are used when defects cause underperformance.
- The focus of the research is to find an effective way to implement innovative diagnosis capability on a commercial inverter.



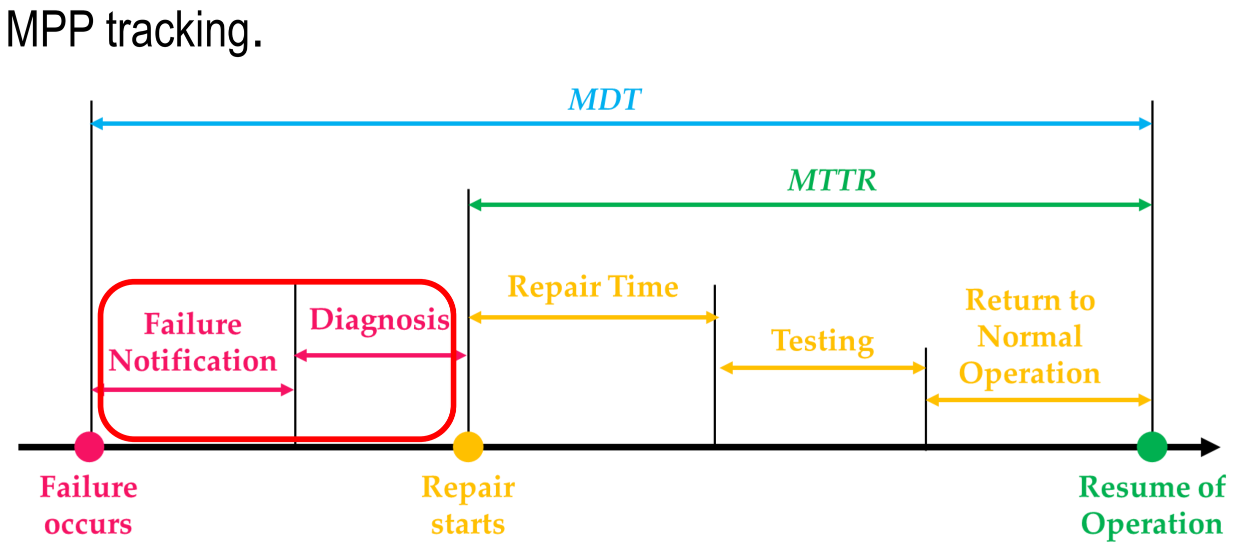
InfraRed Thermography



ElectroLuminescence

Addressed research questions/problems

- **Optimizing Efficiency in PV Systems**: The primary concern is how to consistently maximize the efficiency of PhotoVoltaic (PV) generators under diverse weather conditions. This includes the challenge of ensuring optimal performance when faced with varying environmental factors.
- **Rapid Problem Identification**: Another key issue is the swift identification of problems or sources of loss in PV systems. The proposal seeks to find a solution to quickly detect any issues that may arise, such as mismatch conditions, manufacturing defects, or other factors that can lead to underperformance.
- **Enhancing PV Module Reliability**: PV modules are generally reliable, but there is a need to address factors that can cause them to underperform. This includes exploring the impact of mismatch conditions, manufacturing defects, and other potential issues that may affect the reliability of PV modules.
- **Enhancing the efficiency of diagnostic processes** in PV systems and developing an innovative diagnostic system. It aims to assess conventional fault diagnosis methods like EL and IRT, and their impact on healthy module downtime. The project also centres on creating a diagnostic system, both hardware and software, to reduce energy losses and costs associated with PV array faults. This system aims for real-time fault detection, portability, high performance, and the ability to emulate an inverter for MPP tracking.



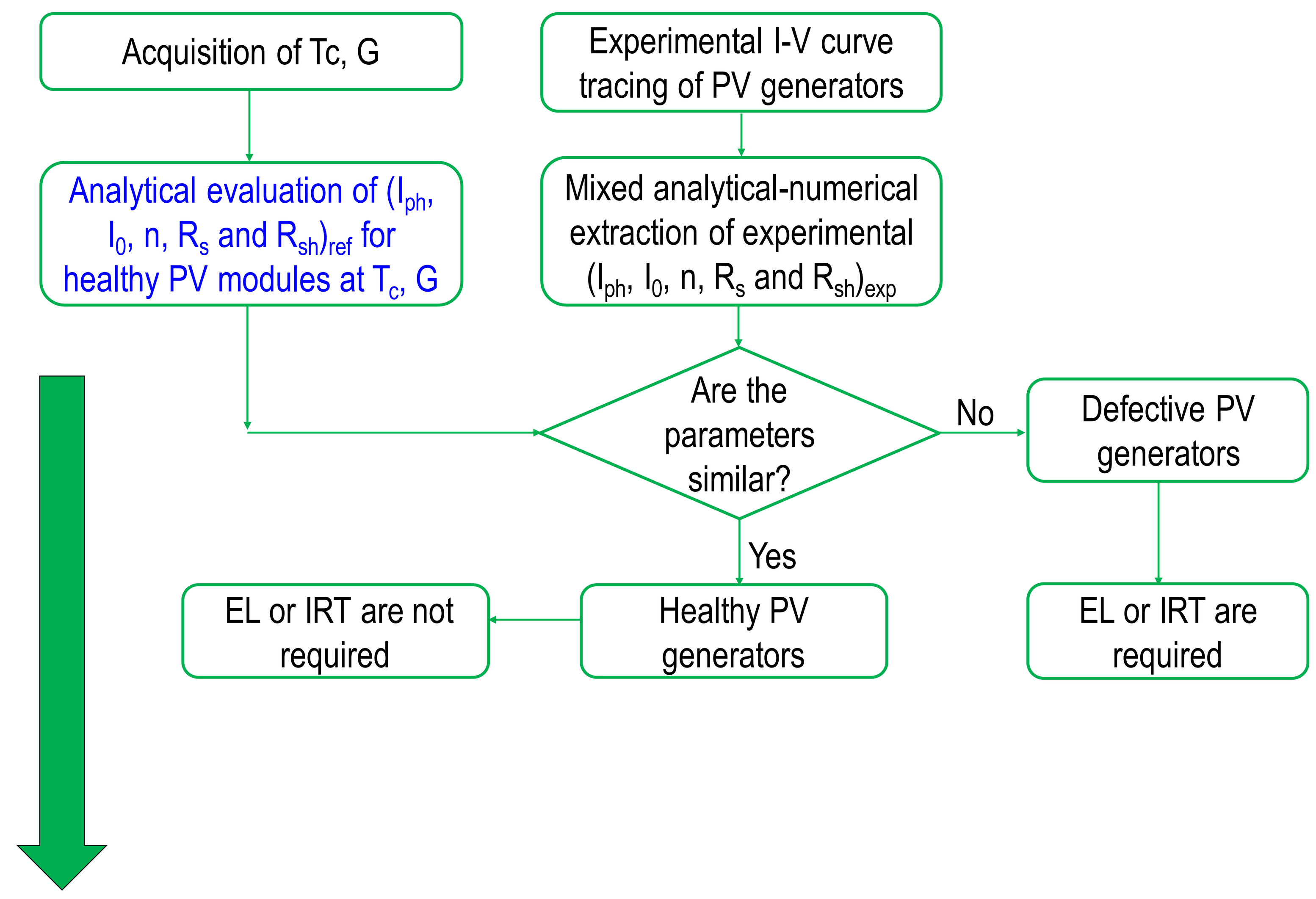
Novel contributions

- **Development of a method** to detect defects in photovoltaic (PV) generators without the need of sensors, and in real time, by analysing the electrical signals of the PV modules.
- **Improvement of the accuracy and reliability of the PV equivalent circuit model**, which represents the electrical behaviour of the PV cell under different operating conditions.
- **Design of a high-performance data acquisition system** that will continuously measure the environmental signals and the electrical signals of the PV modules with low uncertainty and extract the parameters of the PV equivalent circuit model using a suitable algorithm.
- **Selection of an optimisation algorithm** for parameter extraction of the PV equivalent circuit model, considering different factors such as computational complexity, robustness, and sensitivity to noise and measurement errors.

Adopted methodologies

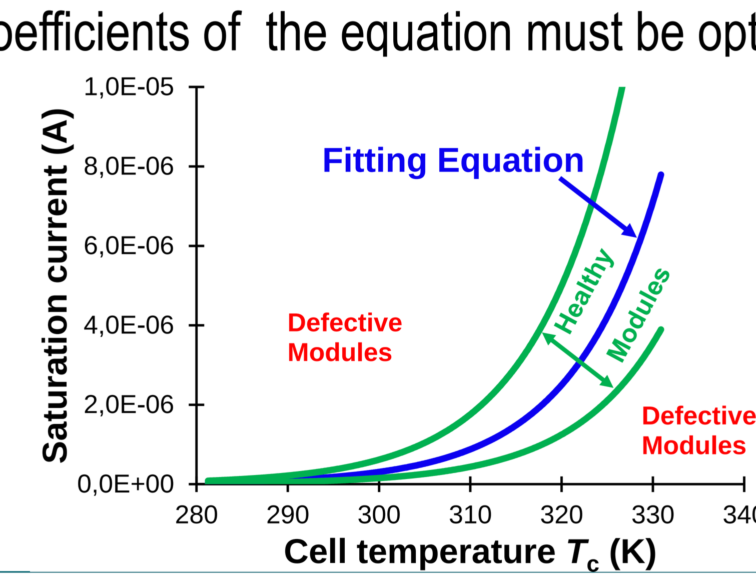
Automatic detection of defects in PV generators

DC/AC converters acquire the I-V curve of PV generators, extract in real time the 5 parameters of the equivalent circuit from the experimental data and evaluate the state of health of the generators by comparing the current parameters (from experiments) with reference values for healthy PV modules.



Identification of semi-empirical equations for a m-Si PV module under test

- I-V curves are measured in several (G, Tc) with an automatic calibrated data acquisition System
- The five parameters of the equivalent circuit are from the measurements
- A nonlinear regression on experimental parameters permits to identify the semi-empirical equations for the dependence with G, Tc.
- The optimal set of coefficients of the equation must be optimized for the specific PV generator.



Future work

- Starting the experimental campaign that will acquire that data to validate the circuit model
- Application of the procedure to a sample of PV generators for three technologies (conventional m-Si, high efficiency m-Si and p-Si)
- Determination of the range of parameters for healthy and defective PV modules → a priori identification of the type of defect and integration of the procedure in the inverter software
- Creation of a database that will contain the range of extracted parameters for each kind of PV technology
- Building a real-time fault detection device that, based on the forementioned database, will work autonomously.

Publications

- Submitted works: 1 journals, 1 conferences

- F. Spertino, A. Ciocia, P. Di Leo, G. Malgaroli, S. Schubert, A. Amato; "Design and Operation of a Laboratory for All-Electric Energy Communities: the Case Study of PVZEN Microgrid"; RTUCON conference, 2023, accepted
- A. Ciocia, S. Gulkowski, G. Malgaroli, J. Díez, S. Schubert, F. Spertino; "An Innovative Technique for Energy Assessment of Photovoltaic Modules with Different Technologies by Equivalent Circuit's Parameters"; IEEE Transaction on energy conversion, 2023, review in progress.