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Detection of Potential Induced Degradation in c-Si PV Panels Using Electrical Impedance Spectroscopy

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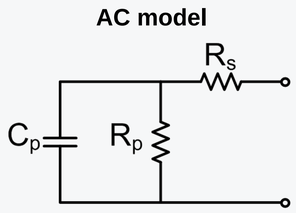
Abstract This work, for the first time, investigates an Impedance Spectroscopy (IS) based method for detecting potential-induced degradation (PID) in crystalline silicon photovoltaic (c-Si PV) panels. The method has been experimentally tested on a set of panels that were confirmed to be affected by PID by using traditional current-voltage (I-V) characterization methods, as well as electroluminescence (EL) imaging. The results confirm the effectiveness of the new approach to detect PID in PV panels.

AC model of the PV panels



- The equivalent circuit model of PV panel used for the parameter fitting. In this case the emphasis is on the parallel components C_p and R_p.

$$Z = R_s + \frac{R_p}{1 + j\omega C_p R_p} \quad (1)$$

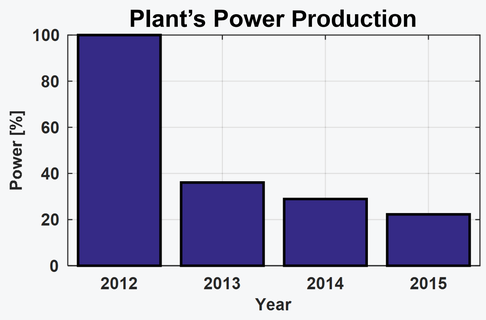
- To determine the parameters of the equivalent circuit equation (1) is decomposed in real (2) and imaginary (3) parts. The two corresponding models are fitted to the IS measurements.

$$\mathrm{Re}(Z) = R_s + \frac{R_p}{1 + \omega^2 C_p^2 R_p^2} \quad (2)$$

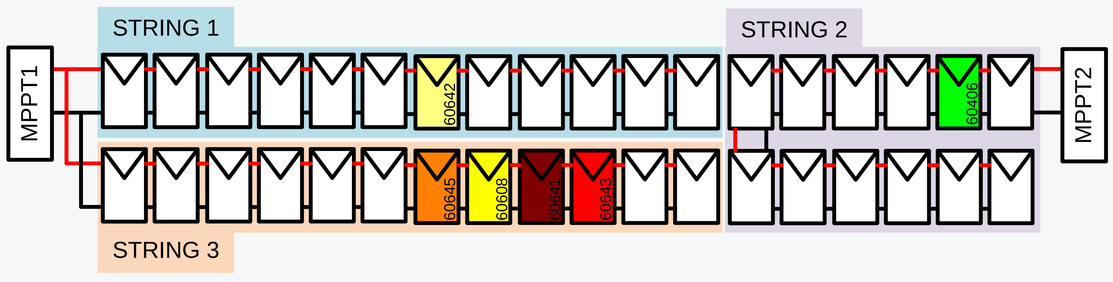
$$\mathrm{Im}(Z) = -\frac{\omega C_p R_p^2}{1 + \omega^2 C_p^2 R_p^2} \quad (3)$$

Case study

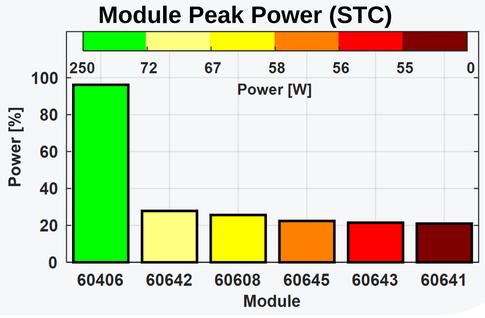
- A residential PV plant was inspected for faults, since the plant experienced a dramatic loss in power generation. The figure to the right present the evolution of the plant.



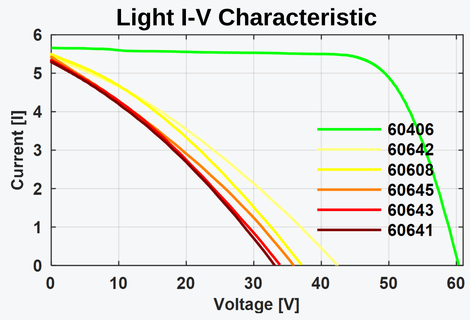
Plant Setup and Modules Positioning

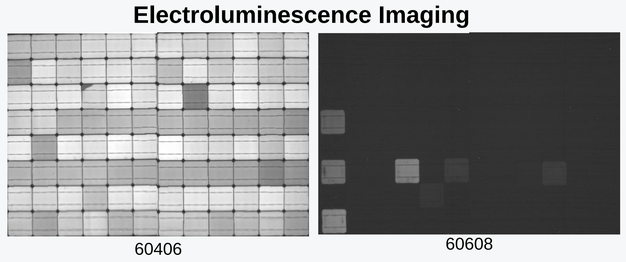


- The best and five worst performing modules were identified in the field using the Z100 PV tester and were selected for laboratory tests.

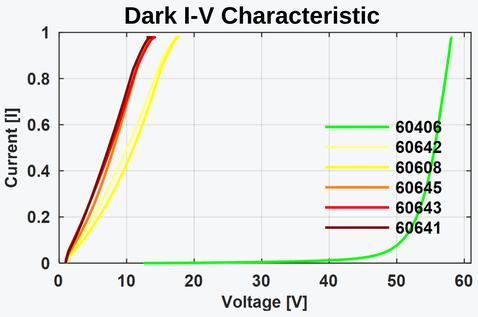


Lab tests for PID

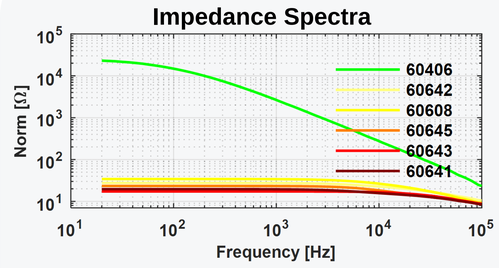


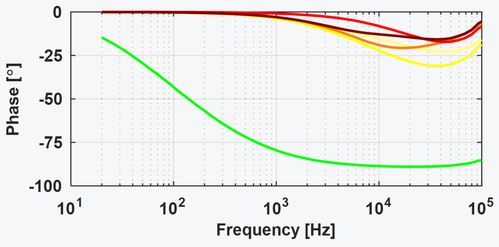


- Light and dark I-V characteristics of the PV modules correlated with the EL images point out the degradation to be PID. The shunt resistance had dropped considerably.



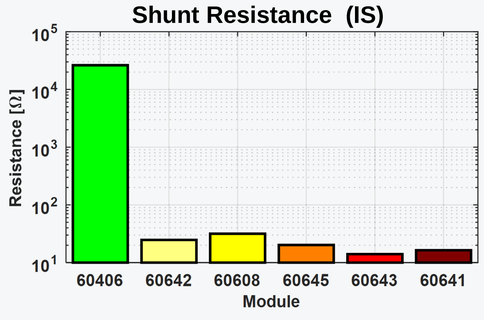
IS measurements

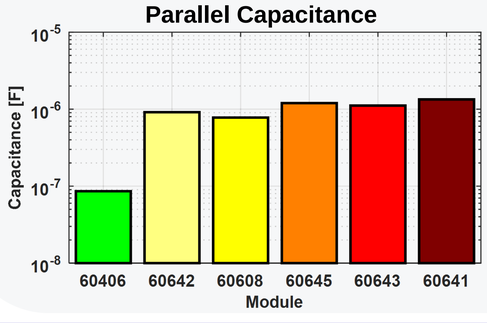




- Impedance spectra of the six PV modules, measured in dark condition in a frequency range from 20Hz to 100 kHz. The difference is evident between the best performing module (60406) and the others.

- Shunt resistance values determined from the IS measurements illustrate the same picture as the other characterizations. The PID modules have an R_p much lower than the typical value for c-Si PV panels, which is around few kΩ.





- The parallel capacitance shows one order of magnitude increase in value for the degraded modules in comparison to the well performing module. The change is significant and supports the hypothesis that the AC parameters can be used to observe changes in the PV panel state.

Conclusion – In this work a case study of c-Si PV panels that experienced PID in the field has been investigated. It has been shown that PID can affect the capacitance of PV panels, and simple IS methods can be used to detect the change in their parallel capacitance. In the study case a significant increase in capacitance has been detected in the presence of extensive PID. The results confirm the potential of IS as a diagnostic method for PV modules also in the field, however further controlled degradation tests are needed to better assess the dependency of the parallel capacitance on PID in the early stages of degradation. It should be noted that other types of faults may have a similar effect on the parallel capacitance, therefore further research is needed for assessing the value of this parameter in presence of various faults.