Exploring the Dynamics of Risk and Quality in Solar Photovoltaic Systems

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Introduction

- Large-scale application of electroluminescence (EL) testing conducted at night on 85,000 PV modules.
- Integration of automated classification system for meticulous categorization of defects [1].
- Detailed temporal analysis from 2015 to 2023, supplemented by predictive modeling up to 2045.
- Escalating degradation rate and emphasizing the need for enhanced production technologies and maintenance protocols.

PV Installations Locations

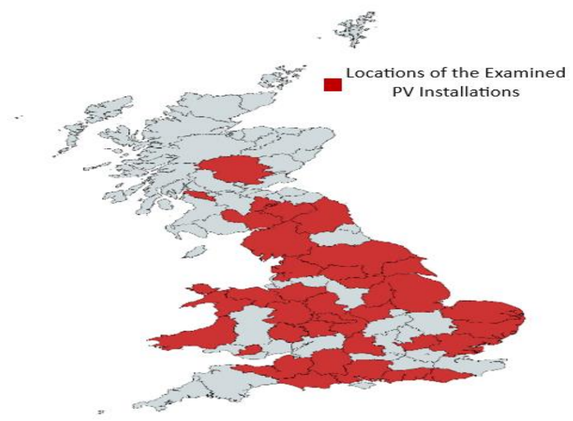

Figure 1. *Geographical distribution map showcasing the analysed PV installation sites across the UK region.*

Classification of PV Modules Defects

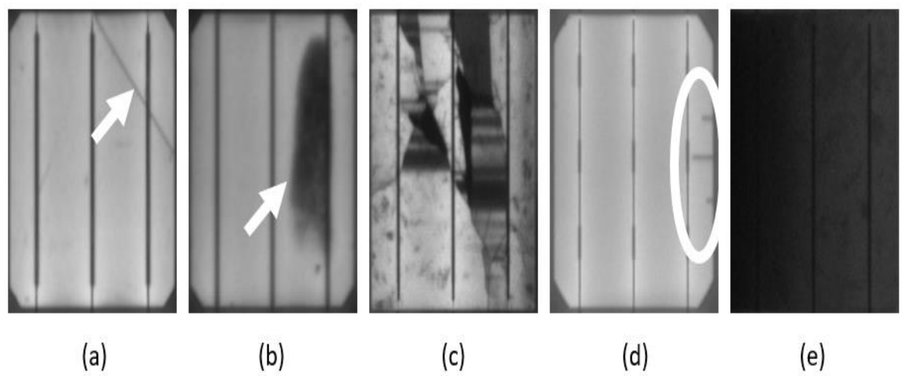

Figure 2. *PV defect types investigated in this work: (a) Line cracks; (b) Soldering anomalies; (c) Complex cracks; (d) Edge ribbon cracks; (e) PID [2].*

Automating the PV Defects Classification

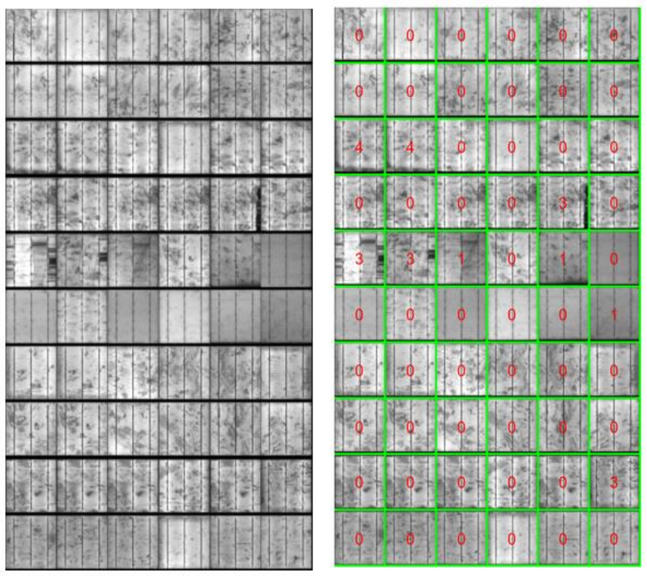

Figure 3. *EL image before and after automated crack processing, with 0 indicating a healthy cell and 1-5 representing specific crack types (line cracks, soldering anomalies, complex cracks, Edge ribbon cracks, and PID).*

PV System Degradation: 2015-2023 Analysis

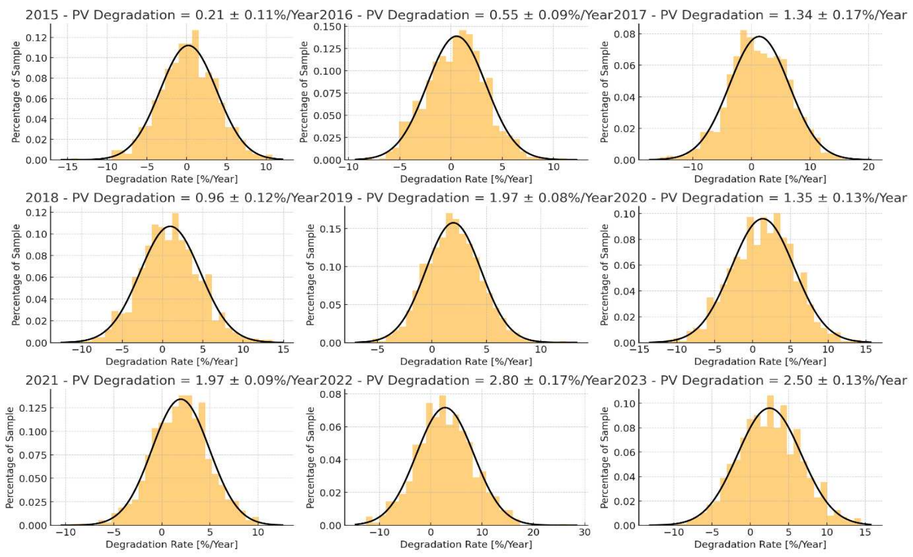

Figure 6. *Yearly distribution and trend analysis of all examined 167 PV systems degradation rates from 2015 to 2023, depicting mean annual degradation and variability through histograms with fitted normal distribution curves based on inverter data samples.*

PV Snowfall Impact Analysis

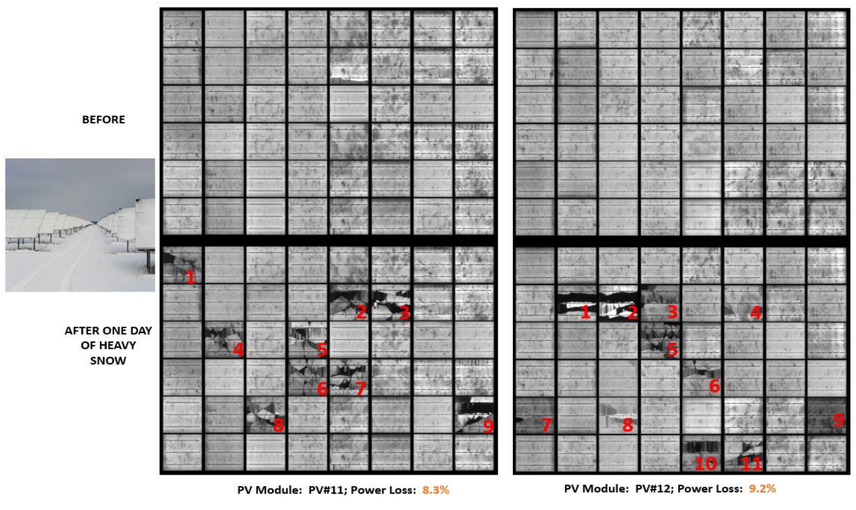

Figure 7. *Impact of heavy snow on PV efficiency and cracks propagation.*

Comparative Analysis of PV Defects

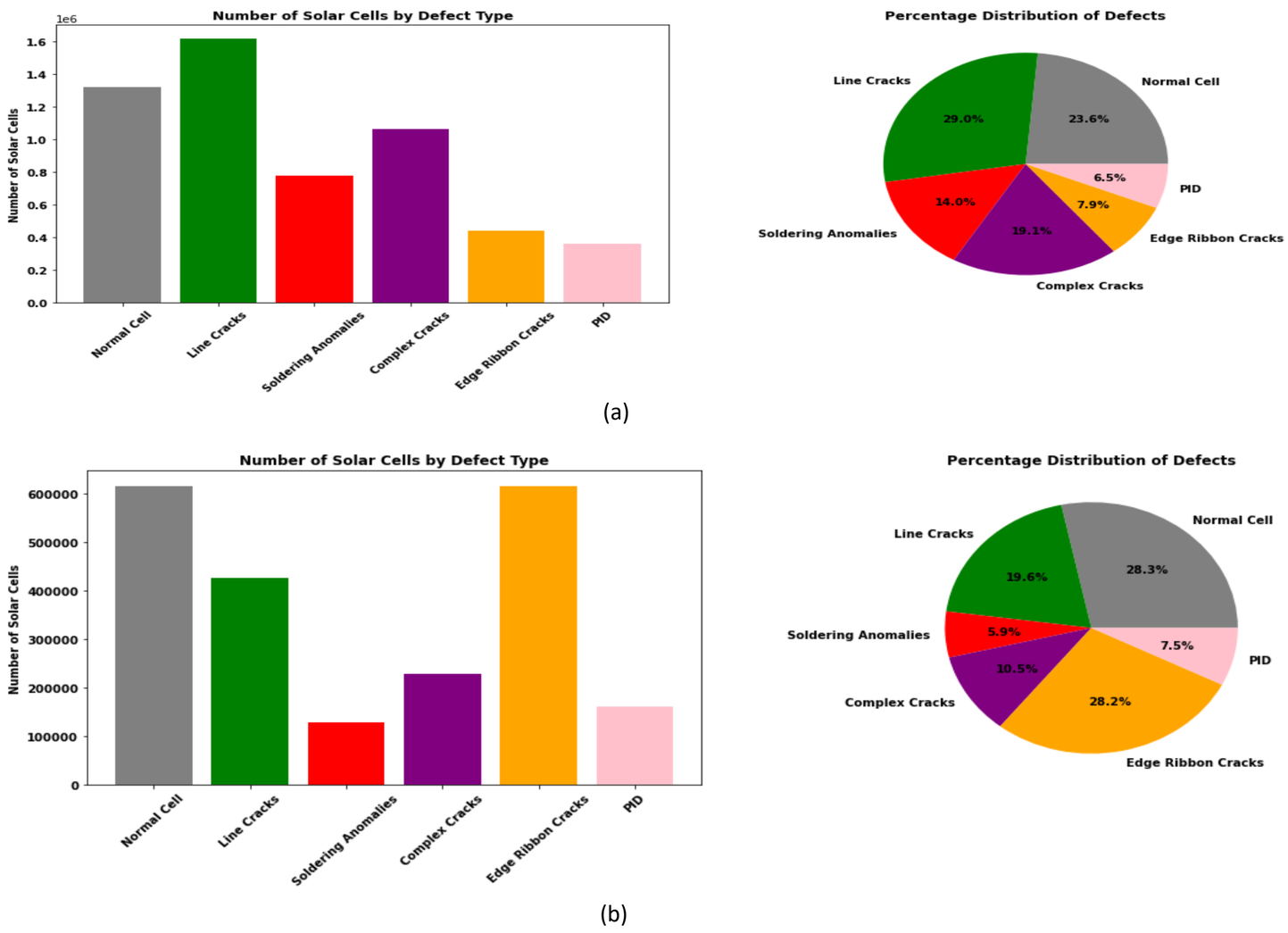

Figure 4. *Comparative analysis of PV modules defects: (a) Encompasses all PV installations, providing a comprehensive overview; (b) Isolates PV installations commissioned on or after 01/01/2022, offering insight into recent quality trends.*

Thermal IR vs. EL Imaging and Power-Voltage Analysis

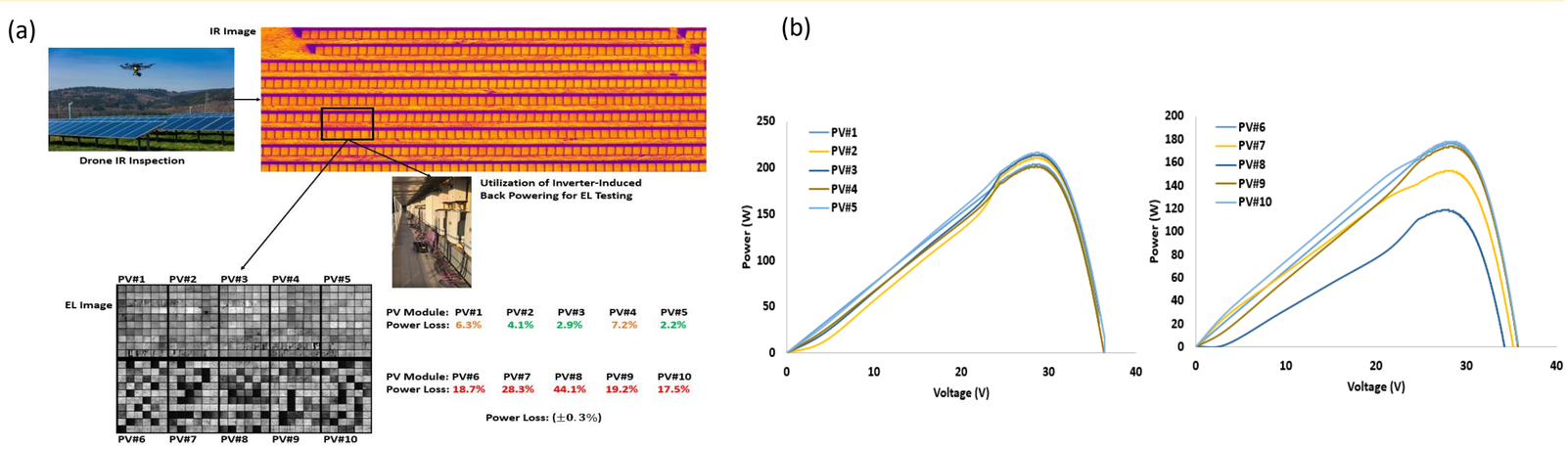

Figure 5. *Influence of PV defects on the electrical output of PV modules: (a) Comparative analysis employing thermal IR versus EL imaging techniques across a sample set of 10 distinct PV modules; (b) Power-voltage characteristics of the examined modules, with measurements conducted under specific test conditions of solar irradiance at 812 W/m² and an ambient temperature of 20.6°C, providing insight into the performance deviations attributable to the detected defects.*

Acknowledgment

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References

1. Hassan, S.; Dhimish, M. Dual Spin Max Pooling Convolutional Neural Network for Solar Cell Crack Detection. *Scientific Reports 2023 13:1* **2023**, *13*, 1–16, doi:10.1038/s41598-023-38177-8.
2. Hassan, S.; Dhimish, M. Enhancing Solar Photovoltaic Modules Quality Assurance through Convolutional Neural Network-Aided Automated Defect Detection. *Renew Energy* **2023**, *219*, 119389, doi:10.1016/J.RENENE.2023.119389..