Review of Progress in Quantitative Nondestructive Evaluation (QNDE), online, July 28-30, 2021

Health Monitoring of Solar Arrays with Spread Spectrum Time Domain Reflectometry and Variational Autoencoders

Ayobami S. Edun, Cody LaFlamme,
Michael A. Scarpulla, Cynthia M. Furse, Joel B. Harley

Spread spectrum time domain reflectometry (SSTDR) has been used in several works to monitor, probe, and evaluate the state of aircrafts and photovoltaics (PV). SSTDR relies on sending a high frequency signal into the electrical system. This signal is reflected at every point of impedance mismatch. The reflected signal can then be analyzed. This technique has been used successfully to detect, locate, and characterize faults in PV systems. These faults include arc faults, ground faults, open circuit faults, and several others. In detecting these faults, baseline subtraction is often used. In this method, an SSTDR signal is sent to the system when we know there are no faults in the system. The reflected signal, known as the baseline, is then stored for future use. While the system is in operation, SSTDR can be used to probe the system at specified time intervals in a non-destructive way. Non-destructive in this sense means the SSTDR signal does not interfere with the underlying voltage or current signal flowing through the electrical system neither does it damage the system. In the monitoring phase, the reflected signal is then constantly subtracted from the baseline to inspect the possibility of a malfunctioning, fault, or anomalies in general.

One major challenge with this method is that baseline signals are highly affected by environmental conditions such as illuminance, rain, temperature, and other environmental changes. This implies that the baseline at the time of fault may have changed significantly from the stored baseline and this may influence the results. To address this issue, we introduced the use of a variational autoencoder for anomaly detection.

In this work, we combine the ability of spread spectrum time domain reflectometry (SSTDR) to probe an energized PV array intermittently with the representation ability of variational autoencoders to detect anomalous SSTDR signals. These anomalous signals are then further inspected to characterize them. The goal is to learn the distribution of non-faulty input signals, inspect the reconstruction error of test signals, flag anomalies, and then locate or characterize the anomalous data. A Wilma SSTDR box was connected to five (5) 36-cell solar panels with a leader cable of 64 m. SSTDR input signal was sent about 256 times in a second to constantly monitor or gather data from the array for inspection. We consider only disconnects in this work and our results show an overall accuracy of 95% for detecting anomalies and a location accuracy of 100%.

Acknowledgments

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number DE-EE0008169 and partially supported by the National Science Foundation under award number ECCS-1839704.