Photovoltaic Array Simulation and Fault Prediction Via Multilayer Perceptron Models

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Outline

- Motivations
- Objective
- Background and Design Setup
- Java-DSP Models for Fault Detection
  - String Faults
  - Complex Cases
- Future Investigations and Conclusions

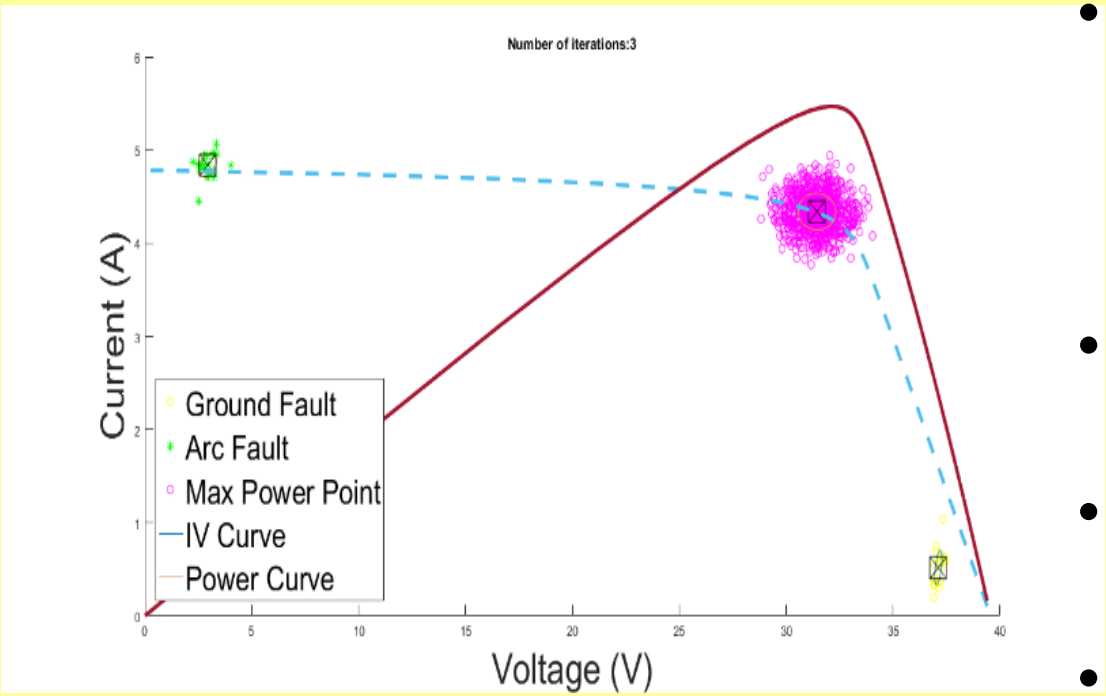
Objective

- Define unique characteristics of normal and faulty PV conditions
- Develop appropriate graphics to examine IV Curves, Maximum Power Point Tracking (MPPT), and Panel Faults
- Utilize Java-DSP and the nonlinear MLP classifier in order to simulation, categorize, and predict photovoltaic panel faults

Motivations

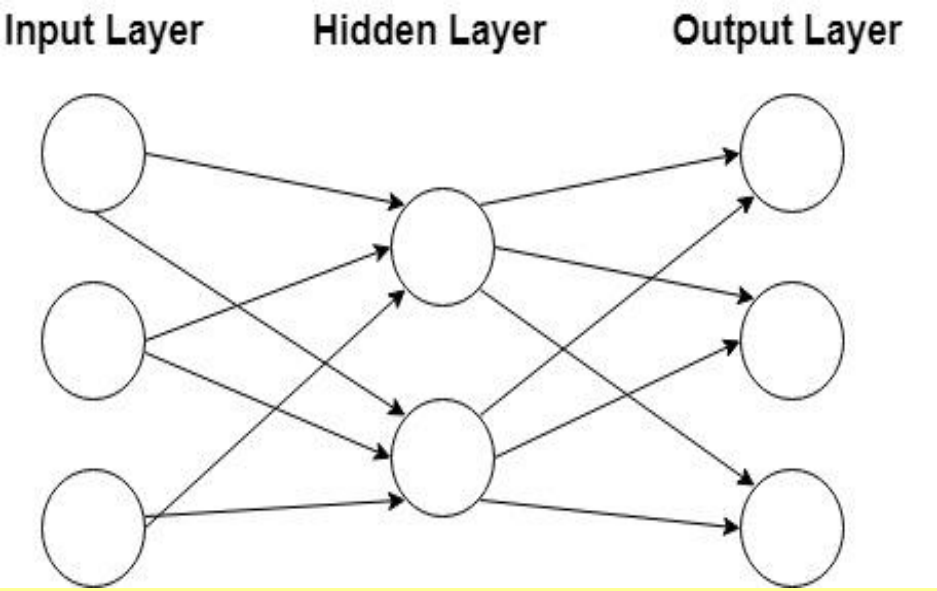
- Bakersfield, California Solar Plant Fire
- Caused by double-point Ground Fault
- Current GFP schemes are lacking

Background – MPPT Curve



- MPP Curve Model for both P-V (Power-Voltage) and IV curves [1].
- MPP Tracking via Fault Detection
- Ground Fault: High Voltage, Low Current
- Arc Fault: Low Voltage, High Current

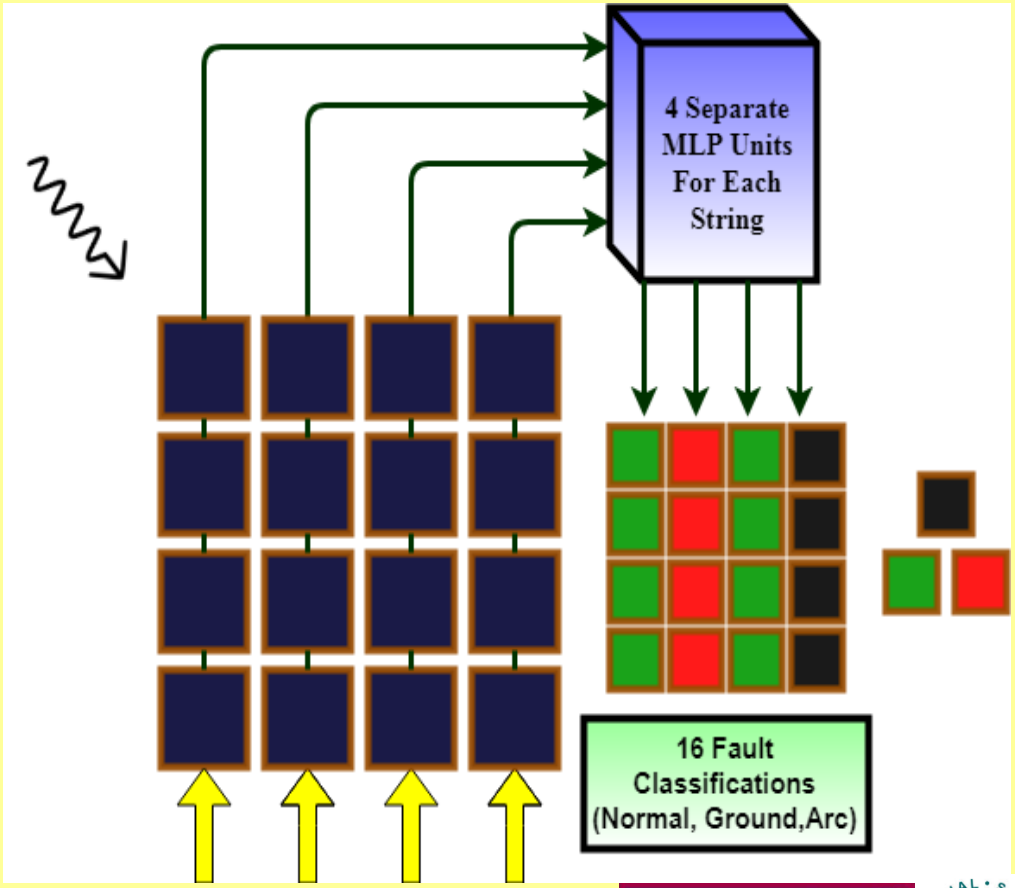
Background – MLP Model



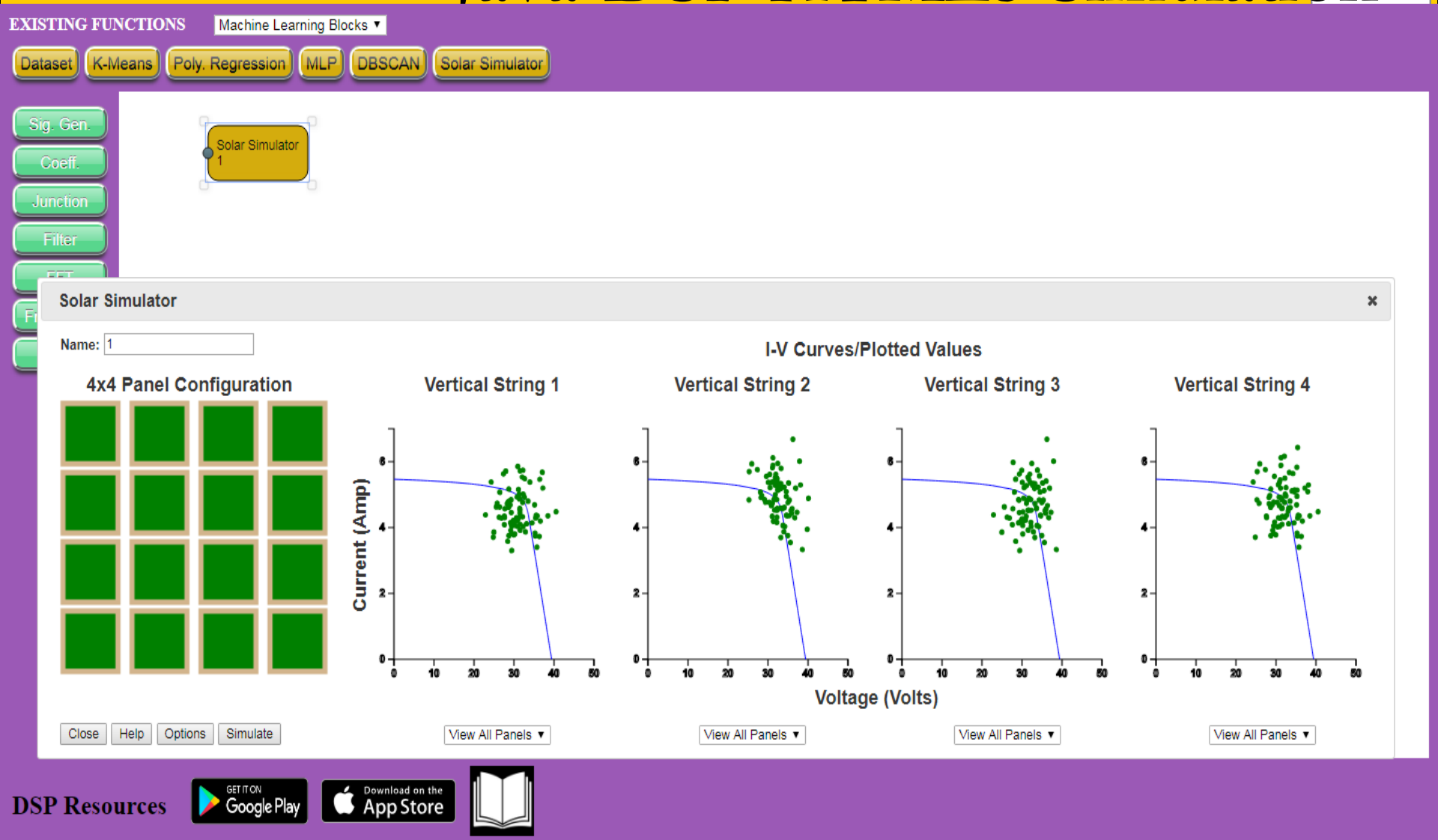
- Simplified MLP model (3 Input, 2 Hidden, 3 Output)
- Weighted sum of input determines output
- Nonlinear classification means higher granularity of states

Simulation Setup

- 4 Vertical PV Strings in Series Configuration
- Current flow – bottom to top
- Input Gaussian time-series I-V curve data into model
- Each string fed into MLP classification unit
- Output of 16 PV classifications



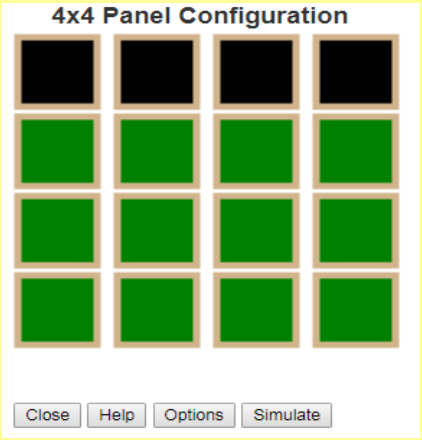
Java-DSP HTML5 Simulation

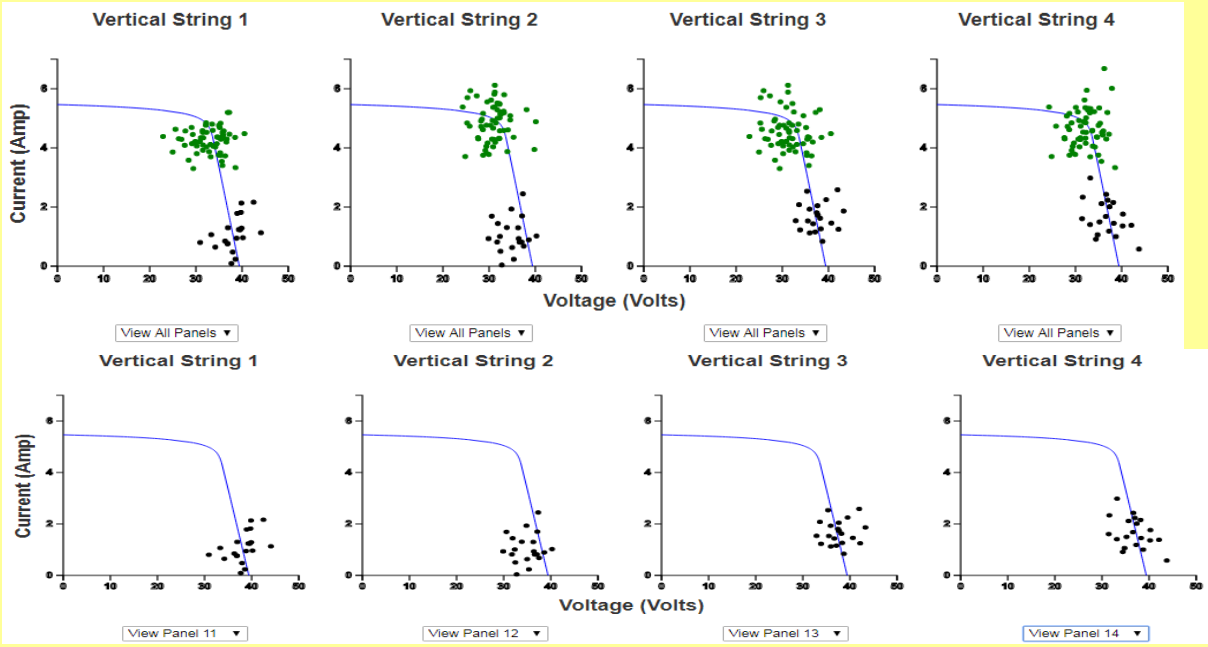


JAVA Digital Signal Processing (J-DSP) Editor

Case 1: Symmetric Ground Faults

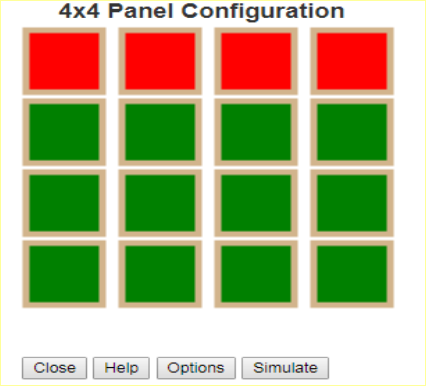
- Current flow – bottom to top
- Panel configuration in row m, column n
- Panels $p_{11}, p_{12}, p_{13}, p_{14}$ have ground faults (labelled by black panels)

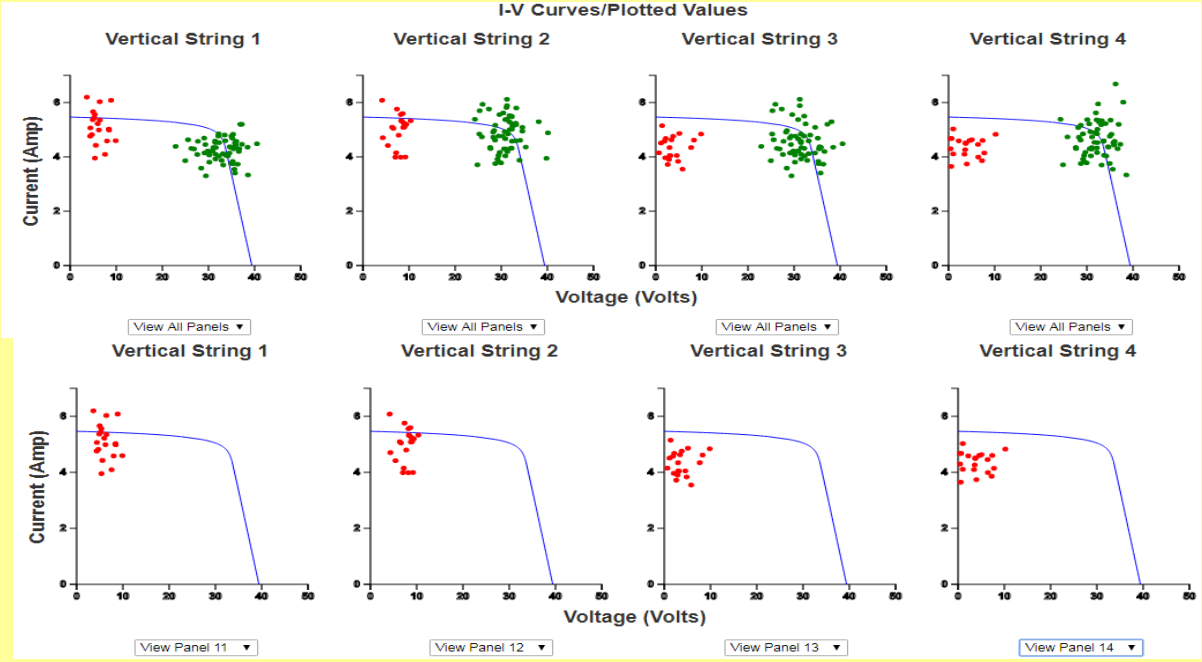




Case 2: Symmetric Arc Faults

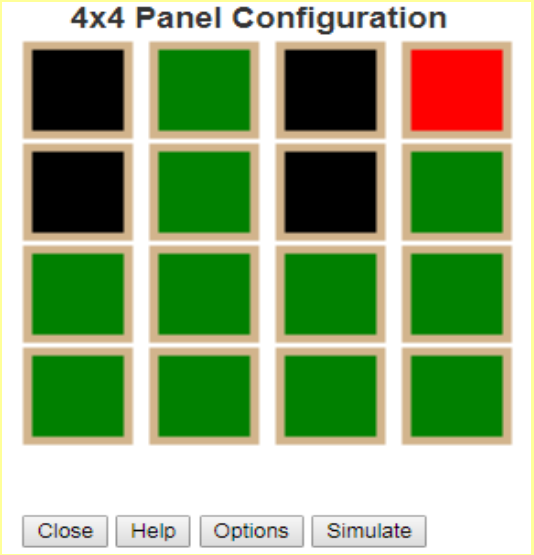
- Current flow – bottom to top
- Panel configuration in row m, column n
- Panels $p_{11}, p_{12}, p_{13}, p_{14}$ have arc faults (labeled by red panels)
- Graphics showing all panel statistics, and arc-faulted panel statistics

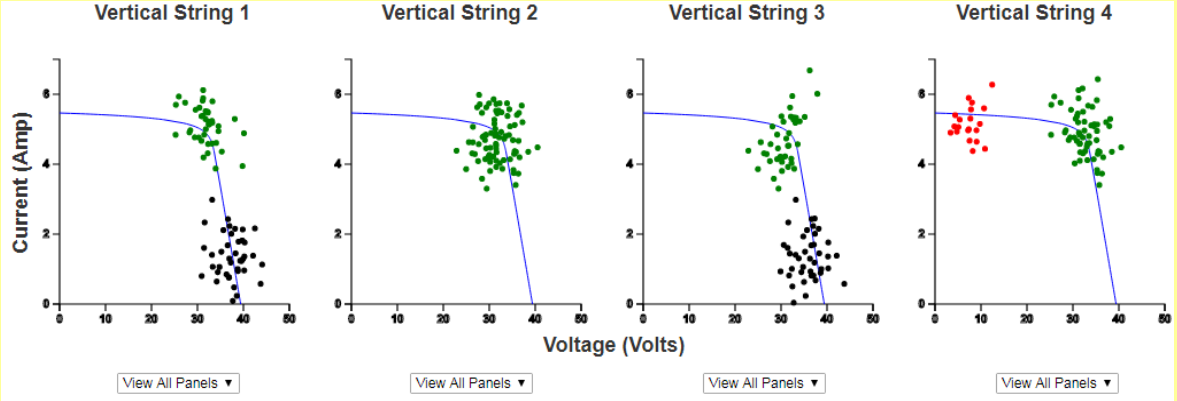




Case 3: Complex Faults

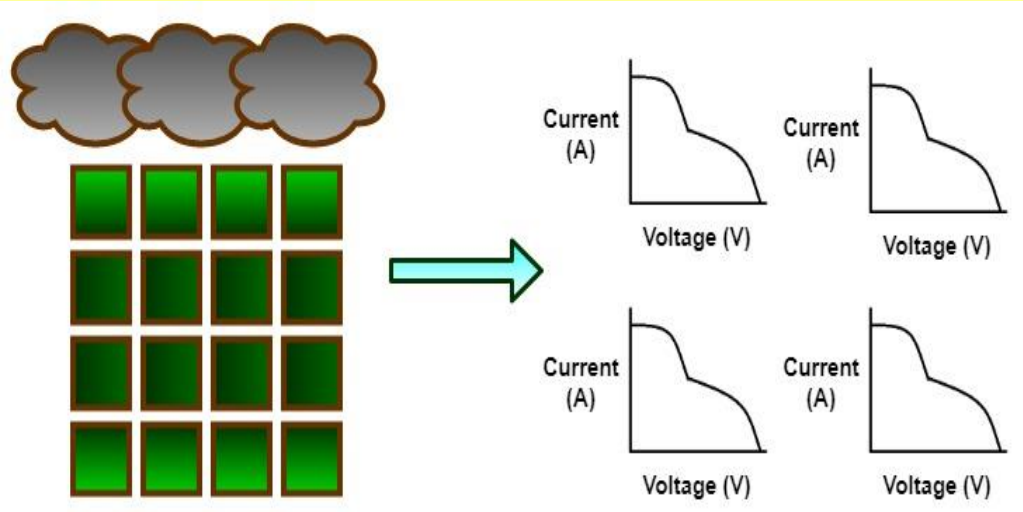
- Complex example – Multiple fault patterns across strings
- MLP can nonlinearly classify and detect ground fault, arc fault, and normal operation around the I-V curve
- Multi-point, diverse fault conditions characterized





Future Investigation: Partial Shading

- Partial shading in panels create I-V hotspots
- I-V characteristics not as obvious, requires finer tuning
- Nonlinearity of MLP allows for higher granularity of states



Cited Sources

- G. Muniraju, S. Rao, S. Katoch, A. Spanias, P. Turaga, C. Tepedelenlioglu, M. Banavar, D. Srinivasan, "A Cyber-Physical Photovoltaic Array Monitoring and Control System", International Journal of Monitoring and Surveillance Technologies Research, vol., issue 3, May, 2018 [1].