CPS: Synergy: Image Modeling and Machine Learning Algorithms for Utility-Scale Solar Panel Monitoring

A Cyber Physical System for Solar Array Fault Classification and Topology Optimization

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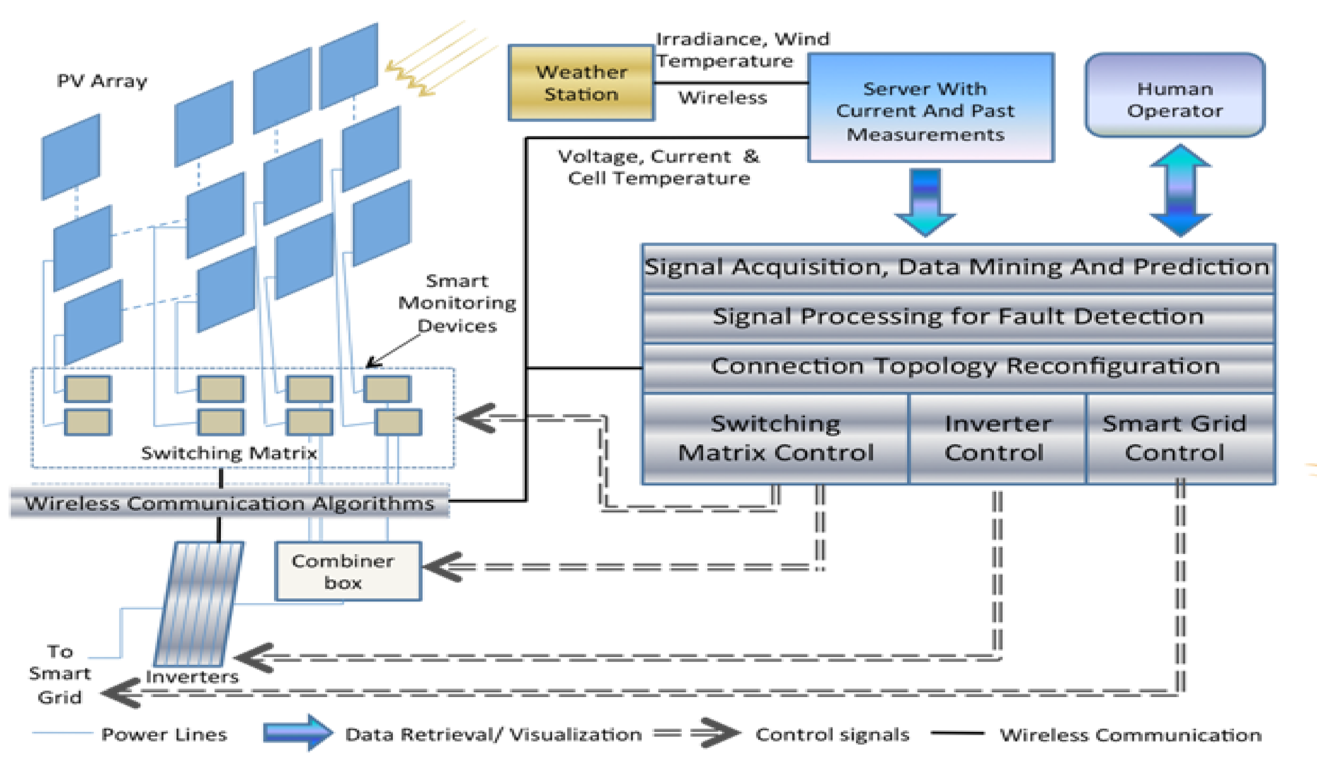
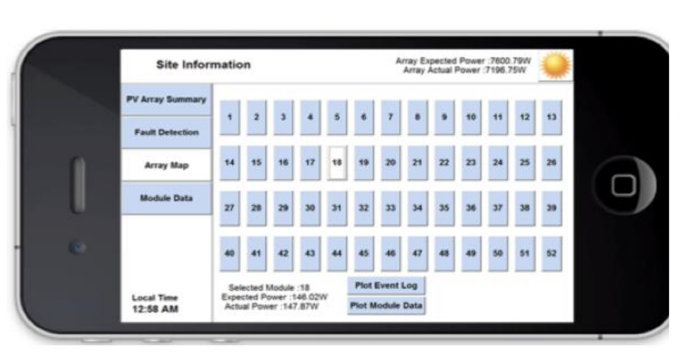
OVERVIEW OF PV MONITORING SYSTEM

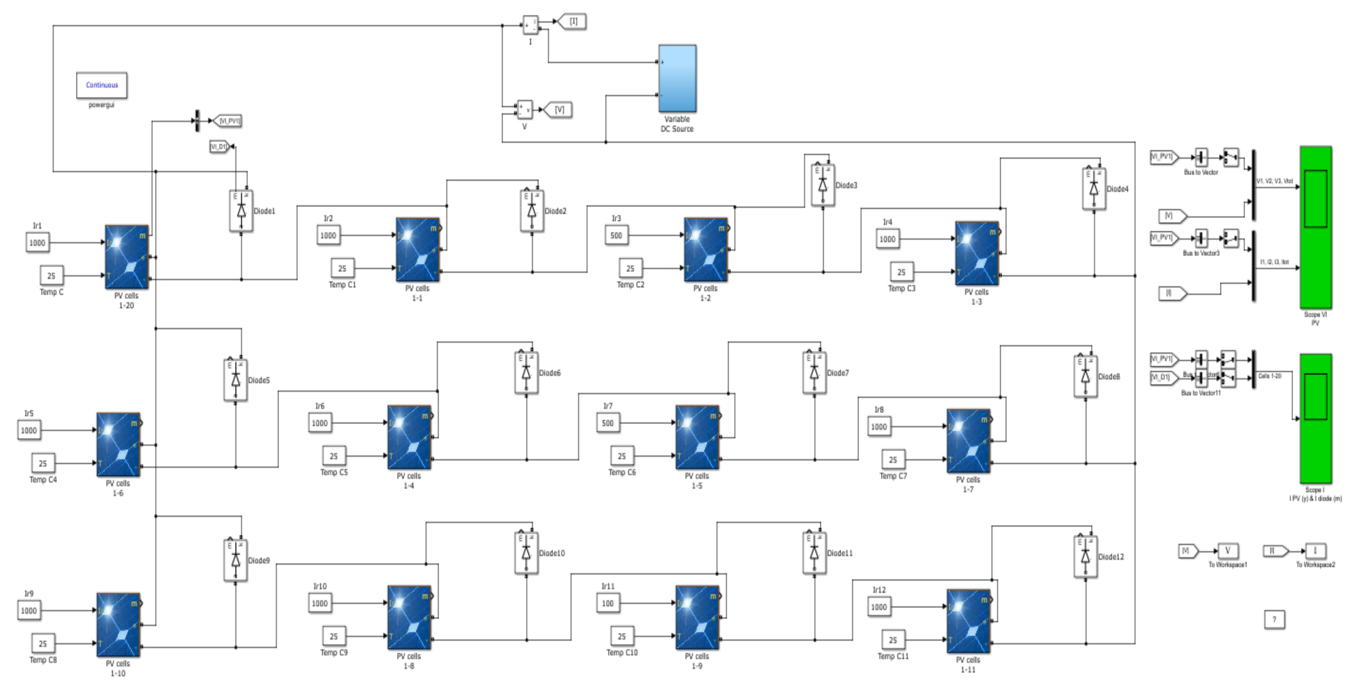


SOLAR ARRAY FACILITY AT ASU

- PV array consists of 104 PV panels.
- Each panel has a smart monitoring device.
- SMDs sense current, voltage, irradiance, temp. They have sensors, actuators, RF, Wi-Fi.



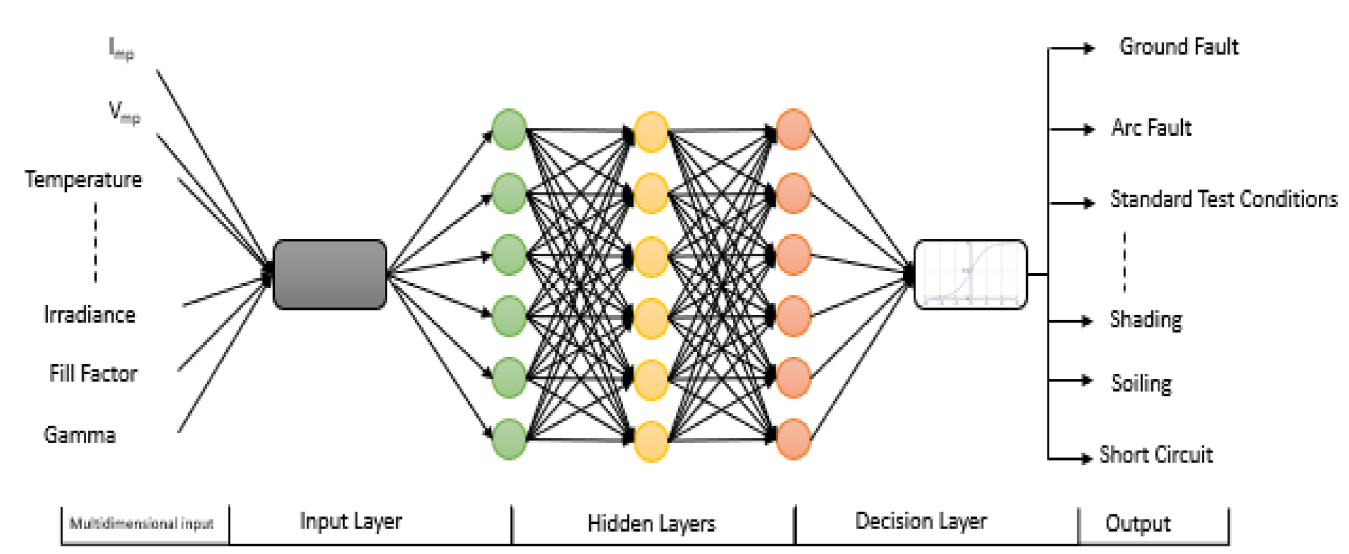
SOLAR ARRAY SIMULINK MODEL



Simulation model used for Data generation.

FAULT DETECTION USING NEURAL NETS

- **Fault Detection**: 4 configurations (12S-1P, 6S-2P, 4S-3P, 3S-4P) to analyze 8 different faults.
- **Topology Optimization**: Performance with partial shading. SP, TCT, BL, HC structures.
- **PV data** is used for training and testing.



- Real dataset from PV Watts.
- Fully Connected and Dropout Neural Nets with different probabilities used.
- Concrete Dropout reduces overfitting.
- Monte Carlo simulation and K-fold cross validation performed.

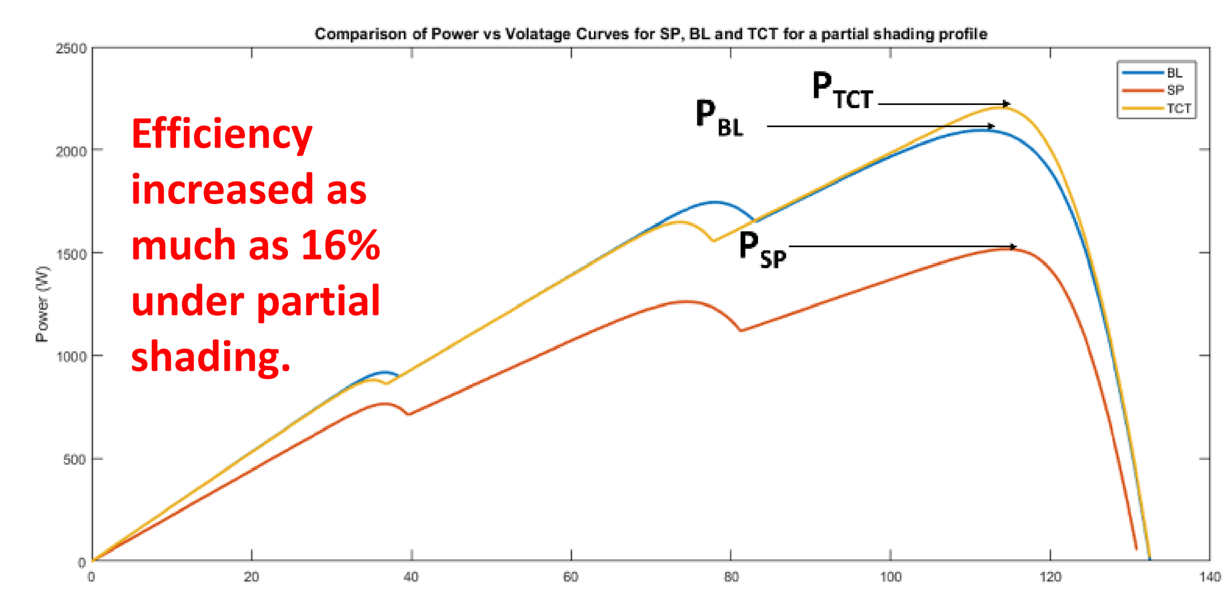
PV FAULT DETECTION RESULTS

Architecture	Train Accuracy (%)	Test Accuracy (%)	Test Accuracy Change
Fully Connected	91.62	89.34	Baseline
Concrete Dropout	91.45	89.87	0.5%
Dropout with p=0.1	89.71	89.34	0%
Dropout with p=0.2	89.29	89.13	-0.21%
Dropout with p=0.3	88.92	88.77	-0.57%
Dropout with p=0.4	87.38	88.77	-2.14%
Dropout with p=0.5	85.51	85.42	-3.92%
Random Forrest Classifier	100	86.32	-3.02%
KNN Classifier	87.15	85.76	-3.58%
SVM Classifier	83.51	83.29	-6.05%

Concrete and Uniform dropout (p=0.1) reduces overfitting and achieves good classification accuracy.

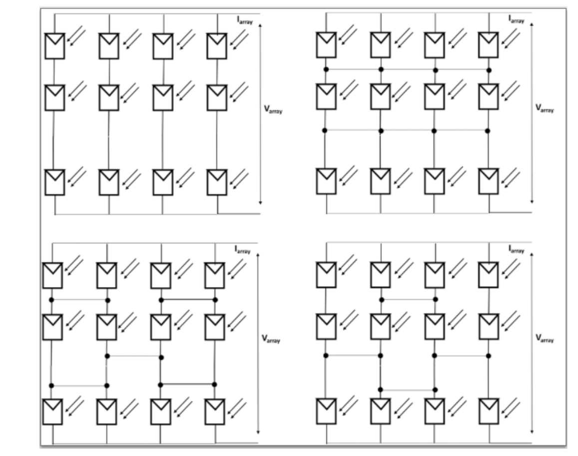
PV TOPOLOGY OPTIMIZATION

Need for Topology reconfiguration: Depending upon partial shading, array topologies such as series parallel (SP), Bridge Link (BL) or HoneyComb (HC) and total cross tied (TCT) produce different maximum power points

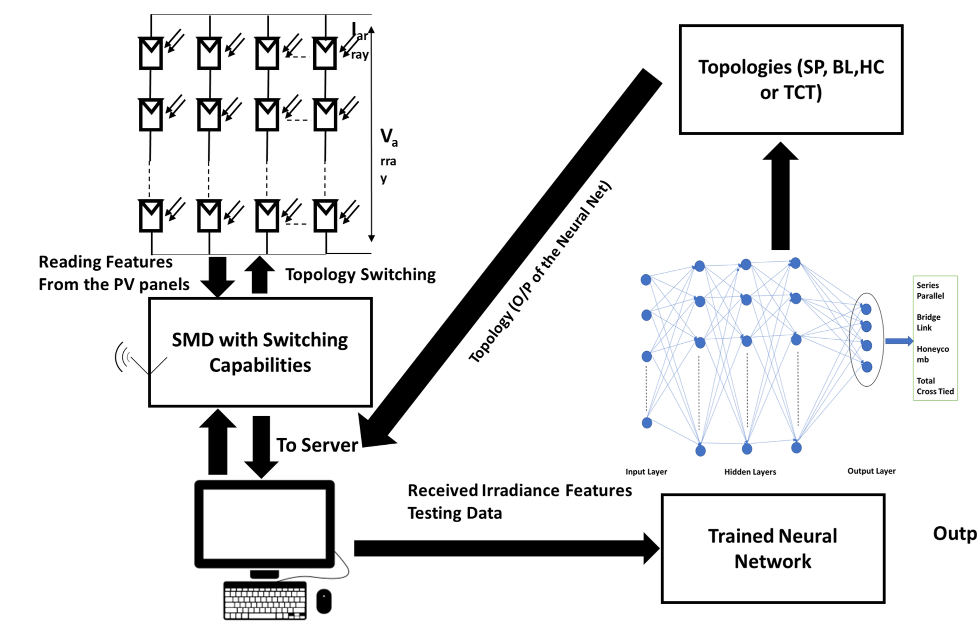


Comparison of maximum power points for different topologies under a partial shading condition.

TOPOLOGY SELECTION STRATEGY



Topologies considered (clockwise) **Series-Parallel (SP), Total Cross Tied (TCT), Honeycomb (HC) and Bridge Link (BL)**



- **Solution:** Use neural nets to learn partial shading profiles and map to the best topology.
- Accuracy ~ 93 %

Actual \ Predicted	Series Parallel	Bridge Link	Honey Comb	Total Cross Tied
Series Parallel	74	2	7	16
Bridge Link	5	55	3	31
Honey Comb	3	3	232	29
Total Cross Tied	22	12	34	1520

REFERENCES

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[5] **Provisional Patents:** Topology: US 62/808,677 / Fault Detection: US 62/843,821

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