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

NSF CYBER-PHYSICAL SYSTEMS PRINCIPAL INVESTIGATORS' MEETING

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

SenSIP INDUSTRY CONSORTIUM

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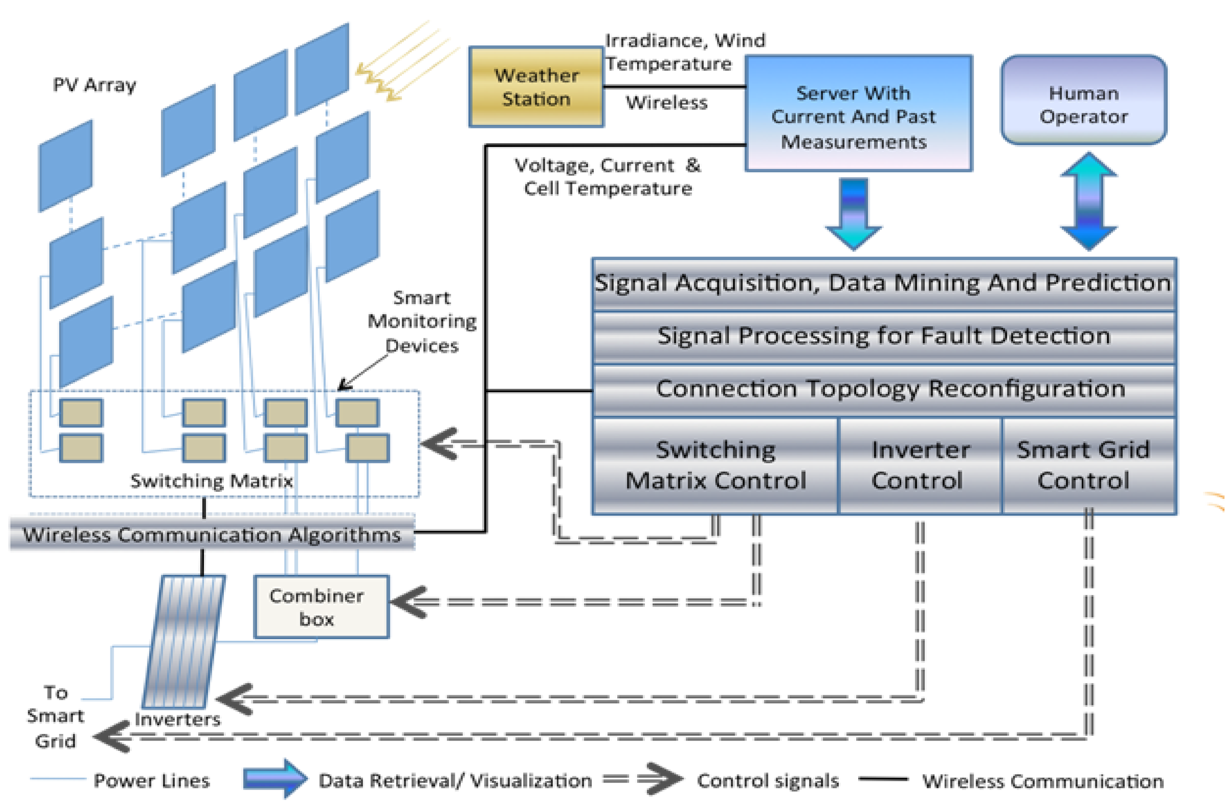
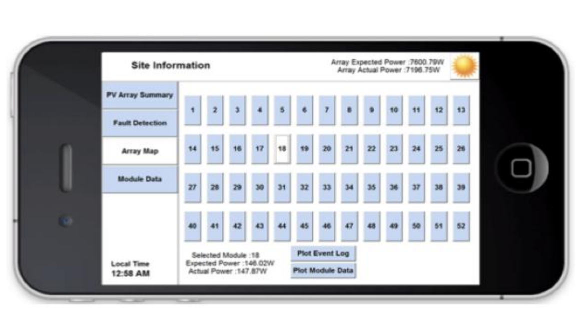
OVERVIEW



FACILITY AT ASU

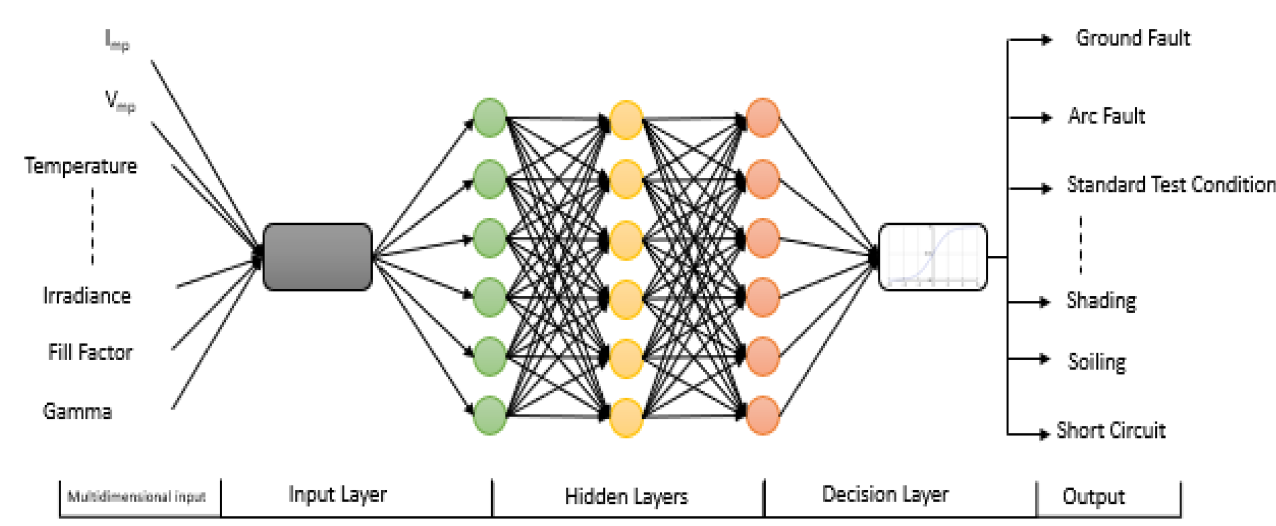
Solar Monitoring Facility at the ASU Research Park.

- PV array consists of 104 PV panels.
- Each panel has a smart monitoring device.
- SMDs equipped with sensors, actuators, RF and WiFi, sense current, voltage, irradiance and temp.



FAULT DETECTION USING NEURAL NETS

Fault Detection: 4 configurations (12S, 12P, 4S-3P, 3S-4P) to analyze 8 different faults.
PV data is used for training and testing.



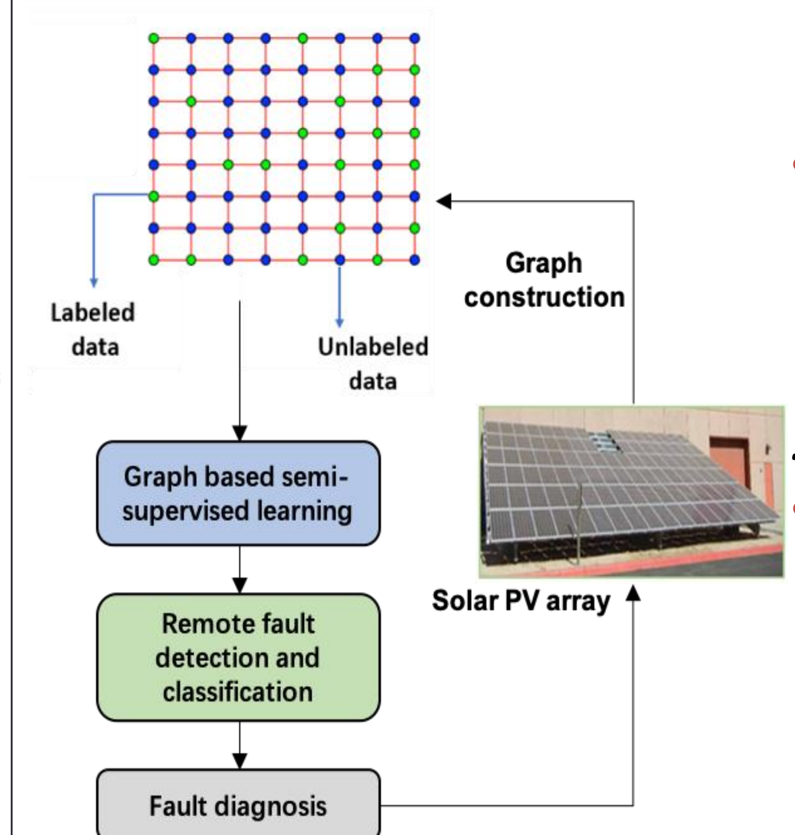
- Real dataset from PV Watts.
- Fully Connected and Dropout Neural Nets with different probabilities used.
- Concrete Dropout reduces overfitting.
- Monte Carlo simulation and K-fold cross validation performed.

FAULT DETECTION - RESULTS

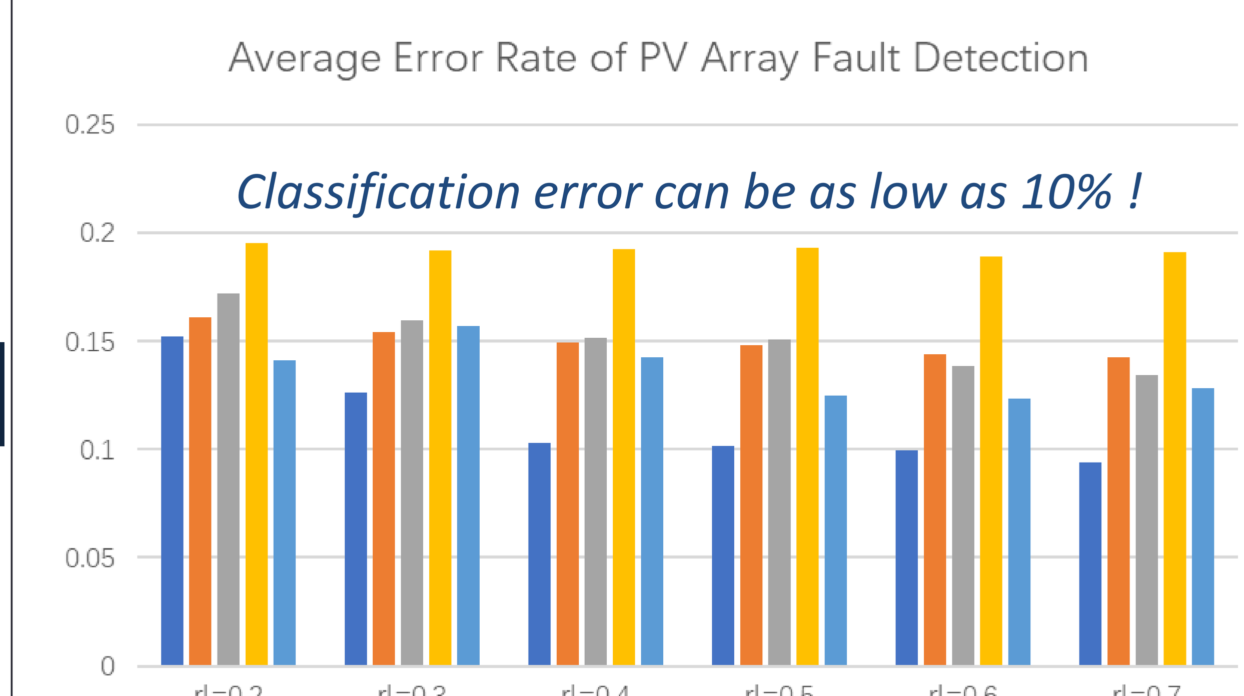
Architecture	Train Accuracy(%)	Test Accuracy(%)	Test Accuracy Change	RPN weighted Accuracy
Fully Connected	91.62	89.34	Baseline	85.20
Concrete Dropout	91.45	89.87	+0.5%	85.25
Dropout p=0.1	89.71	89.34	0%	84.53
Dropout p=0.2	89.29	89.13	-0.21%	84.53
Dropout p=0.3	88.92	88.77	-0.57%	84.56
Dropout p=0.4	87.38	88.77	-2.14%	82.39
Dropout p=0.5	85.51	85.42	-3.92%	79.55
RFC	100	86.32	-3.02%	87.57
KNN	87.15	85.76	-3.58%	73.82
SVM	83.51	83.29	-6.05%	79.30

Comparison of various classifiers – PV fault classification

FAULT DETECTION USING GRAPH SIGNAL PROCESSING



- PV fault detection via a *graph-based semi-supervised classifier*
- Lower computational cost over supervised ML algorithms

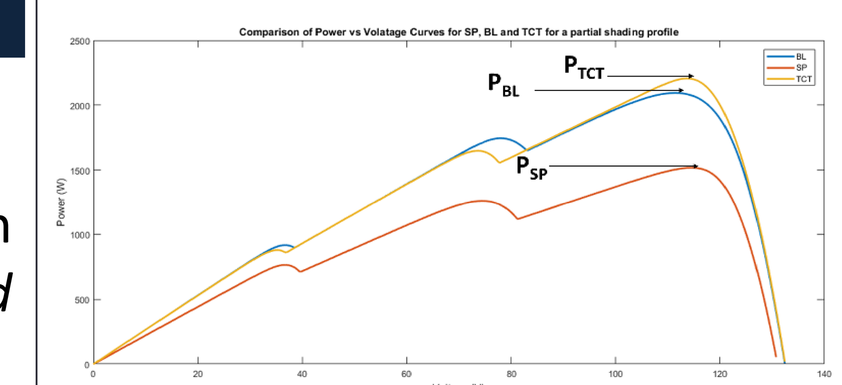


TOPOLOGY SELECTION – USING NEURAL NETWORKS

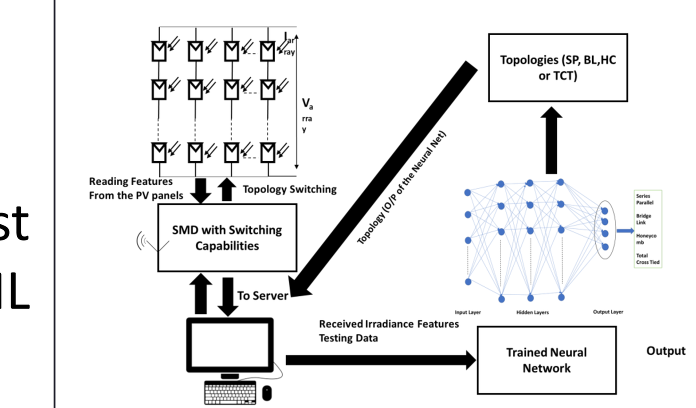
Topologies such as *series parallel (SP)* and *total cross tied (TCT)* produce different max. power points under shading - *Need to choose the optimal configuration*

Approach: Use neural networks to learn partial shading profiles under the effect of resistance loading losses and map to the best topology.

TOPOLOGY SELECTION- RESULTS



Using simulations under resistor loading losses, we find efficiency improvements as much as 16% with partial shading.



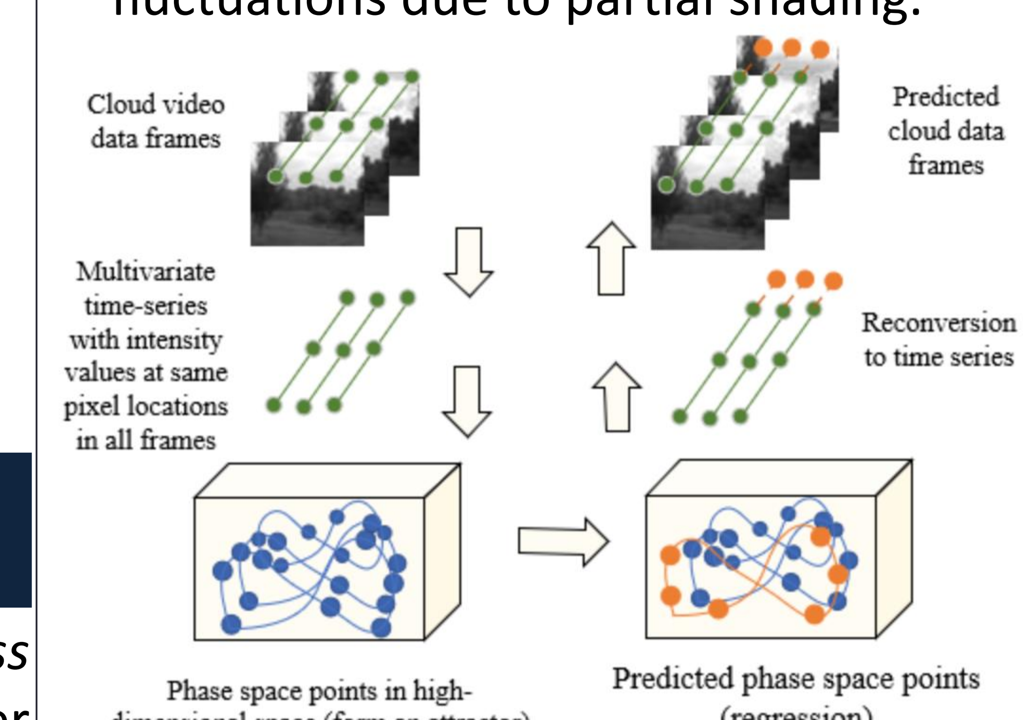
Predicted

Actual	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

Predicted

SHADING PREDICTION VIA KERNEL REGRESSION

- Use *kernel regression on* cloud video data to predict cloud movement to manage power fluctuations due to partial shading.



80% reduction in prediction time with minimal loss in visual quality.

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

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Sensor Signal and Information Processing Center
https://sensip.engineering.asu.edu/cps-solar-project/

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