

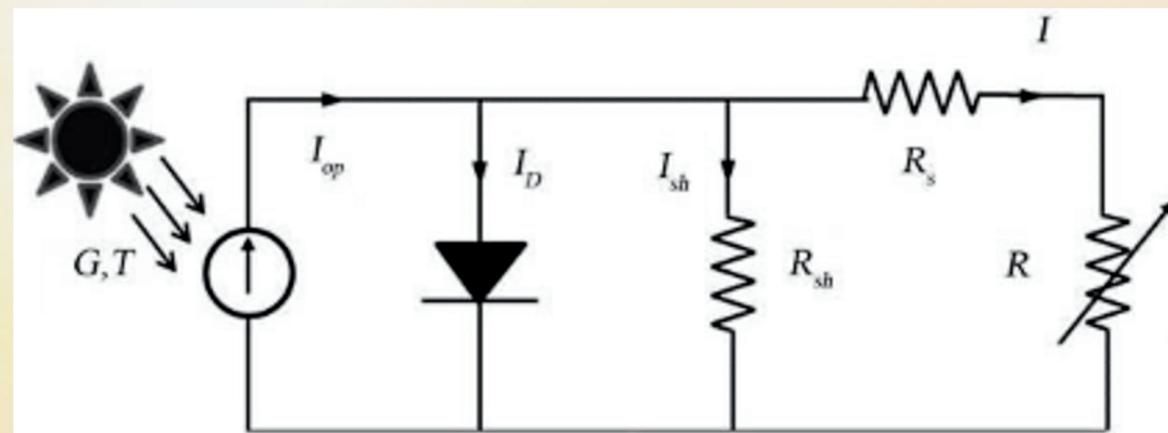
WPI

Intelligent System for Maximizing Photovoltaic Array Output Power Based on Varying Environmental Conditions

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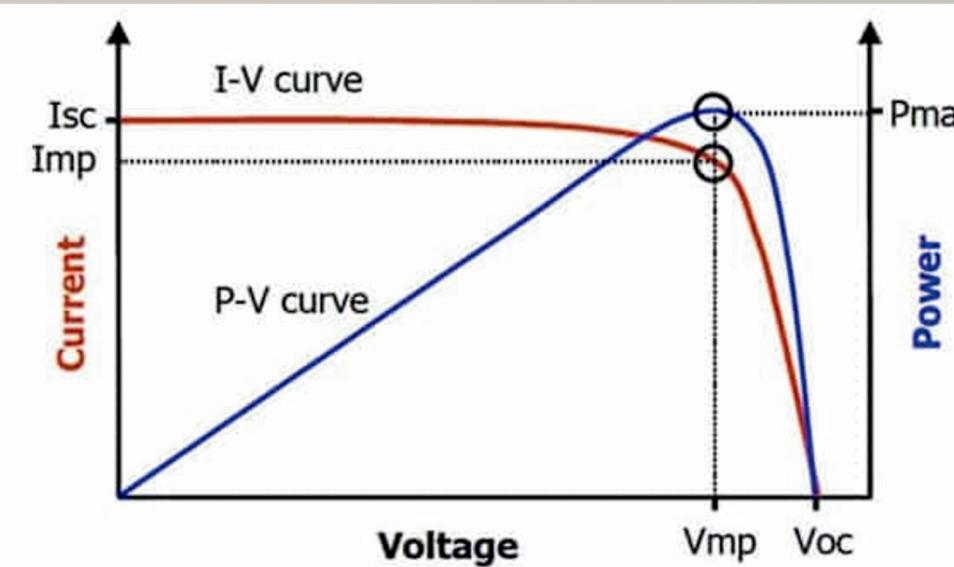
Problem

Solar panels generate varying power due to changes in sunlight, temperature, and load conditions. Without optimization, they may not operate at their highest efficiency, leading to energy losses.



What is MPPT?

Maximum Power Point Tracking (MPPT) is a technique used in solar energy systems to continuously adjust the operating point of a solar panel so that it always delivers its maximum possible power.



A custom device was developed in simulation and on hardware to run several MPPT algorithms and intelligently switch between them using environmental sensors. This system was also designed to charge a 12V lead acid car battery.

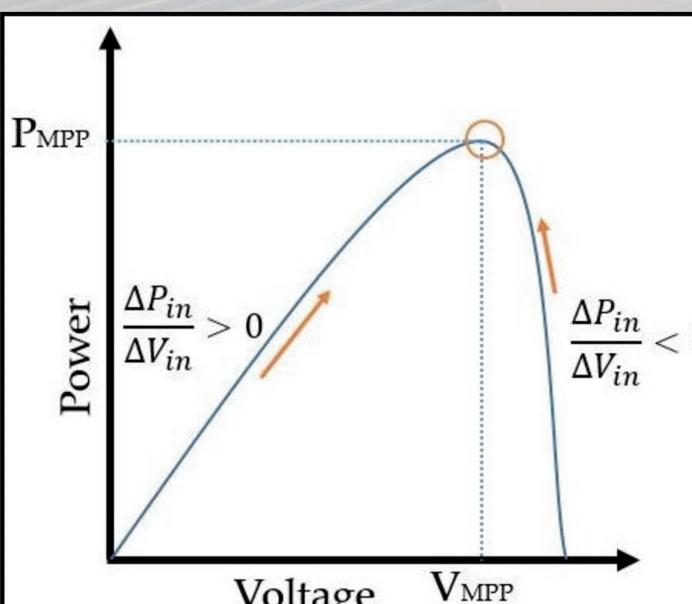
MPPT Algorithms

Trial and Error

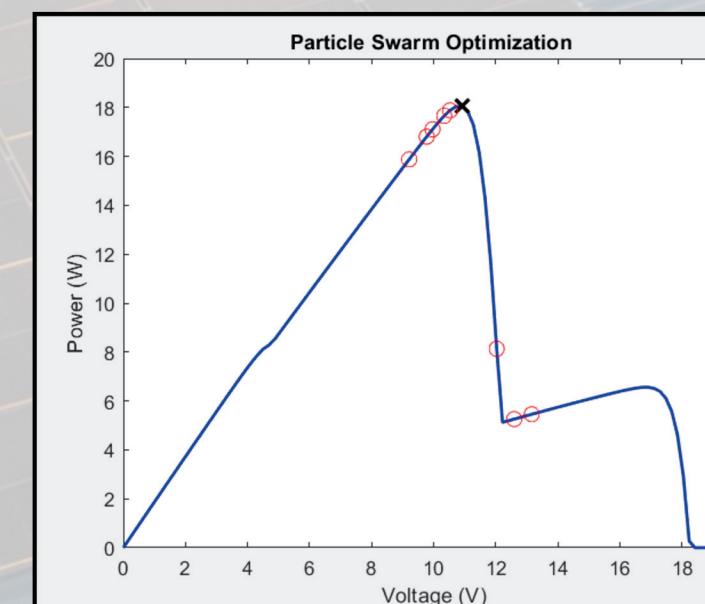
- Perturb & Observe (P&O)
 - Fixed Step Size
 - Variable Step Size
- Incremental Conductance (INC)
 - Fixed Step Size
 - Variable Step Size

Mathematical Calculation

- Particle Swarm Optimization (PSO)
- Temperature Parametric (TMP)



MPP Power and Voltage Conditions for Trial and Error Algorithms



PSO Tracking Under Partial Shading Conditions

Constant Parameters

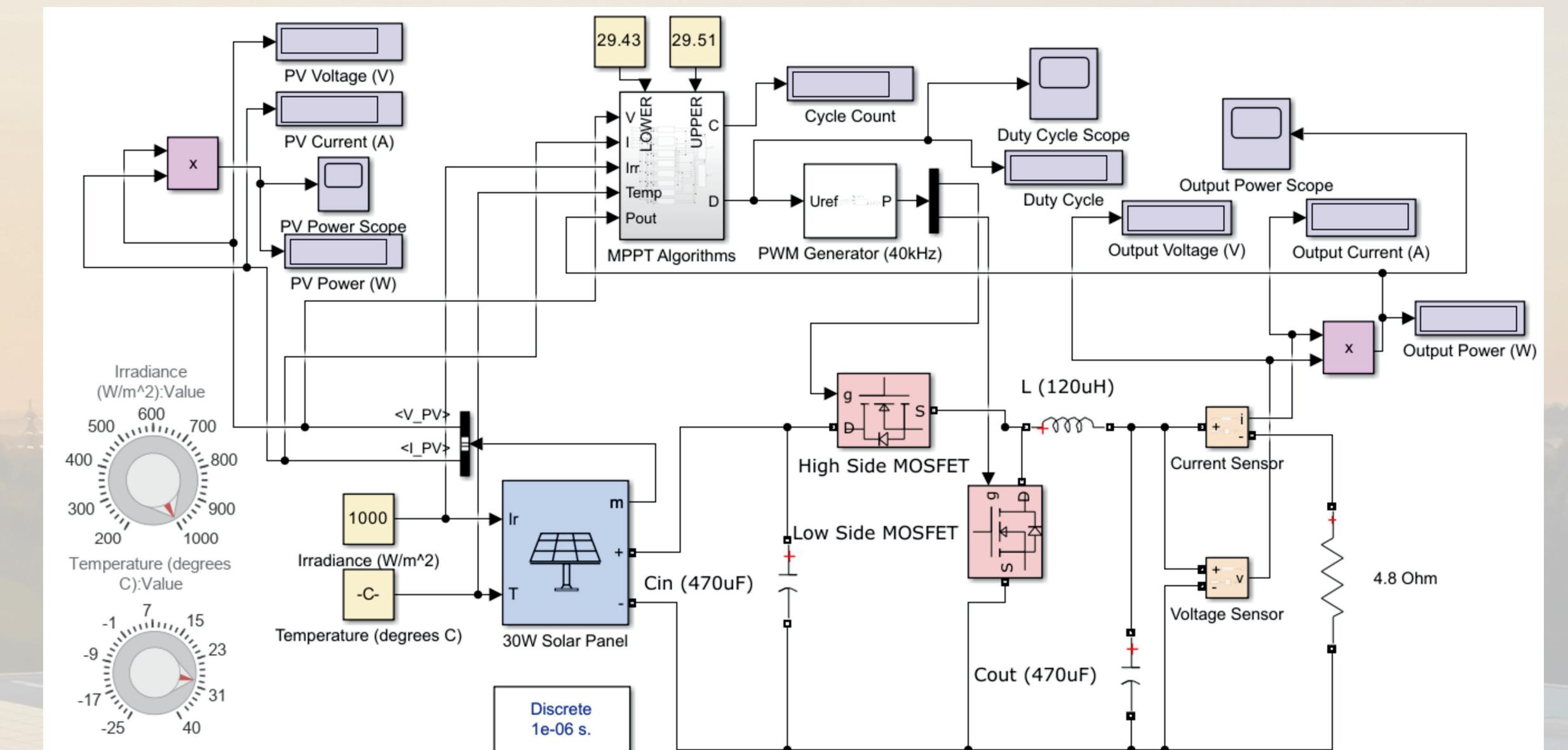
- Constant Voltage (CV)

Hybrid

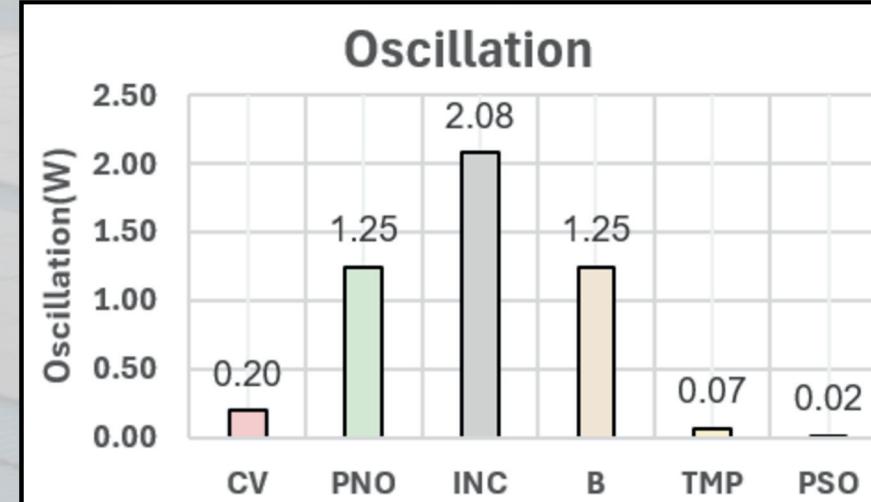
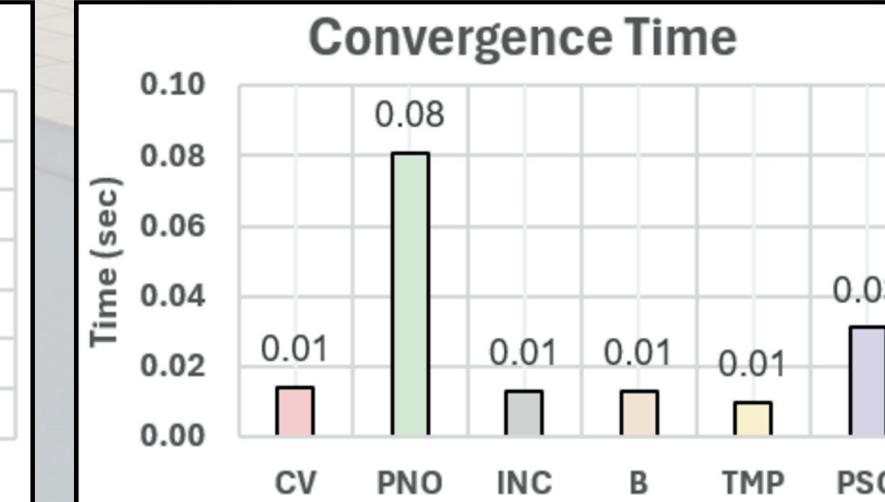
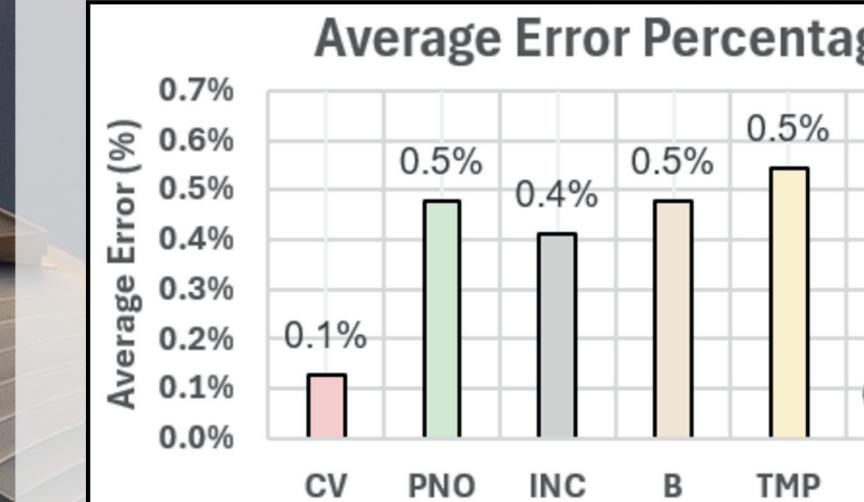
- Beta Method (B)

MATLAB Circuit

Developed a MATLAB model to simulate the solar panel at varying irradiance and temperature.



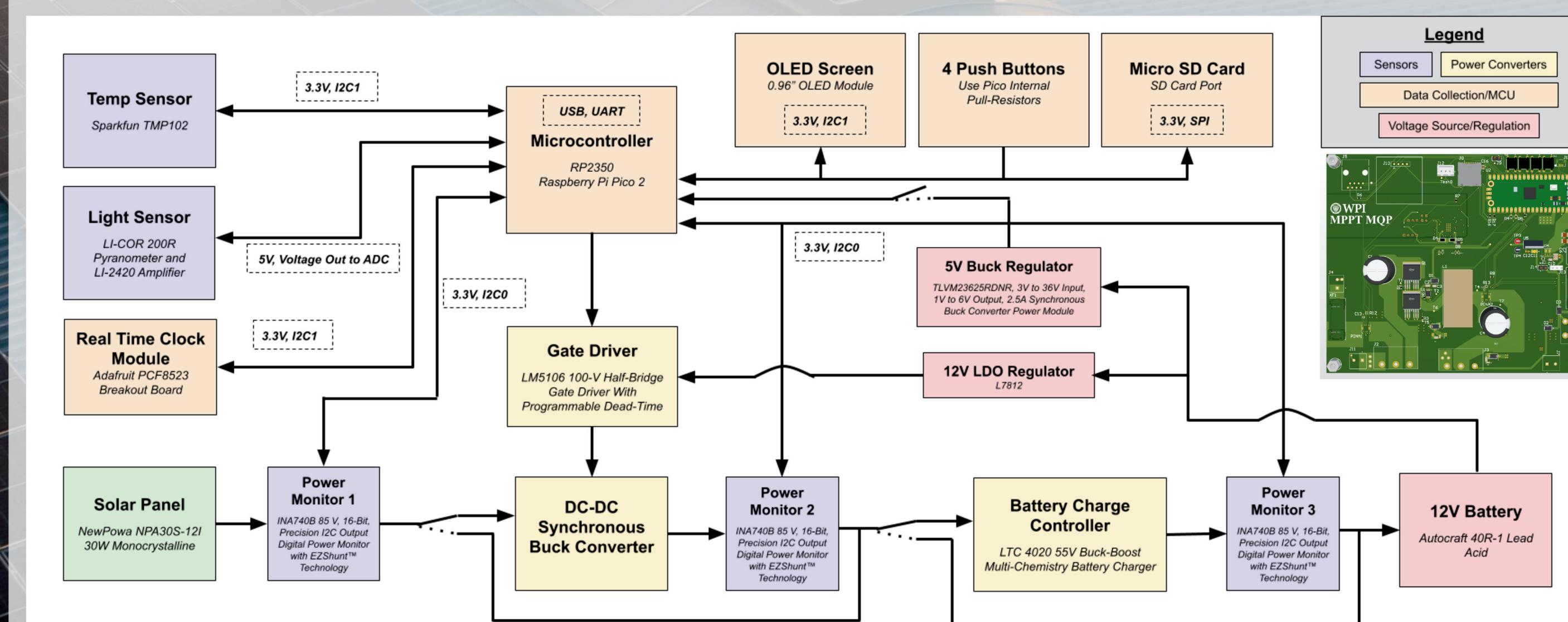
MATLAB Results



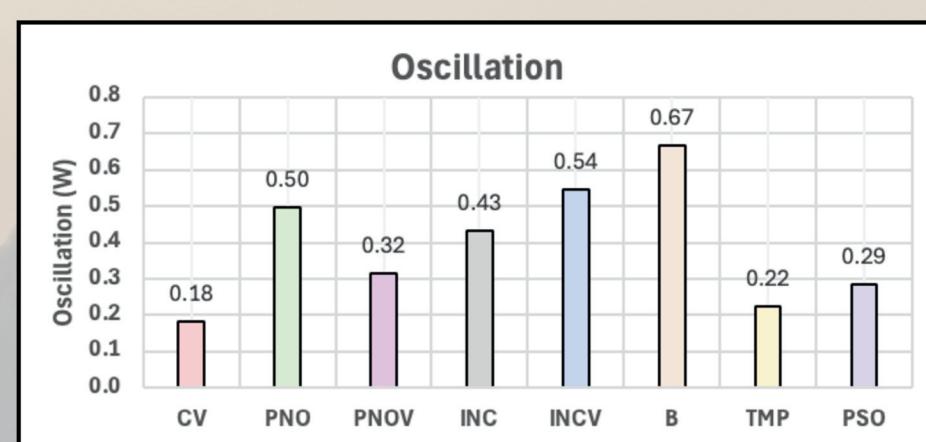
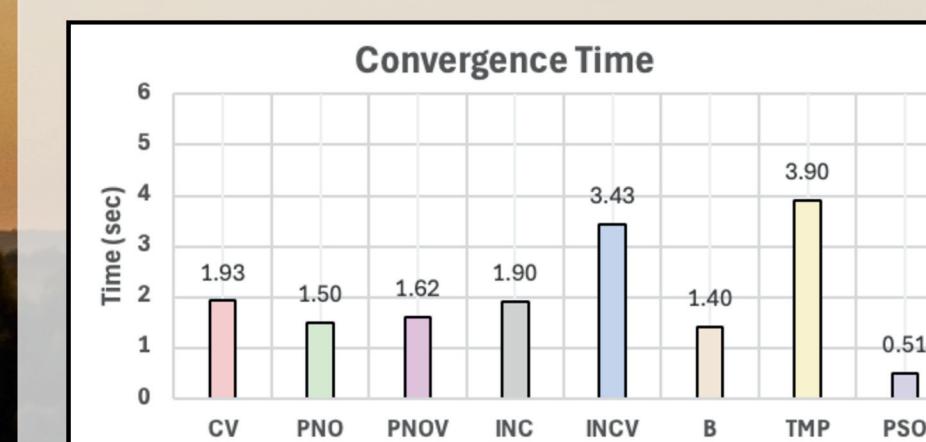
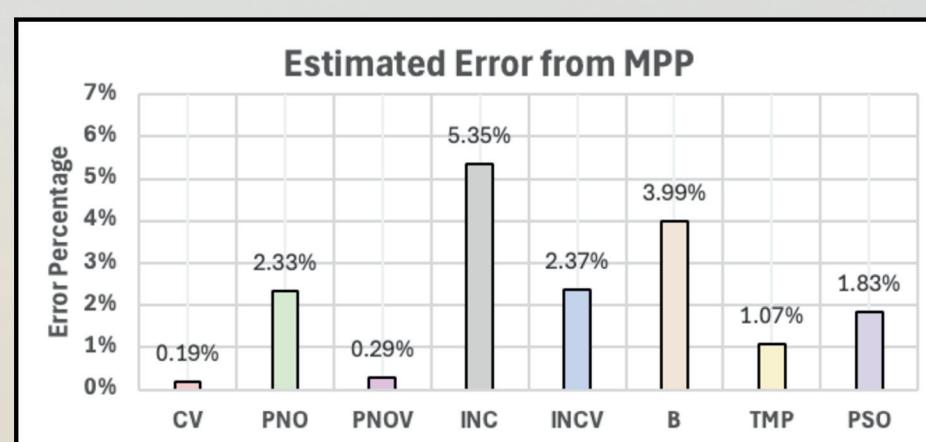
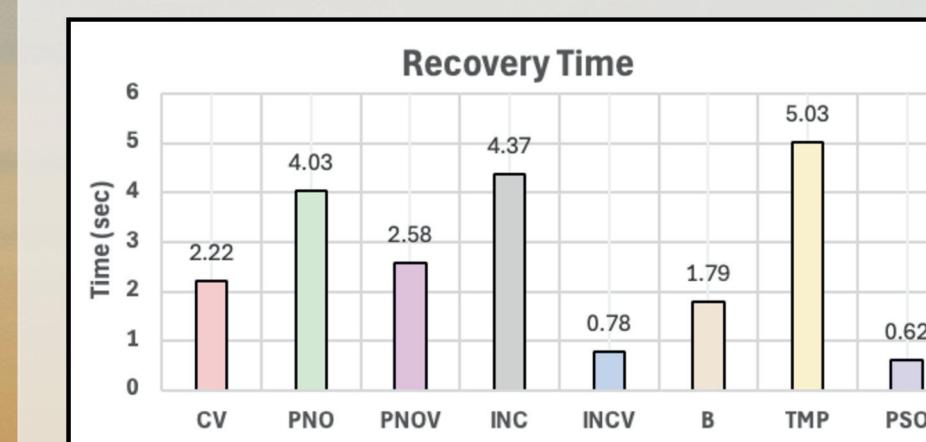
The MATLAB algorithms were tested under a total of 34 different conditions varying in irradiance and temperature. These results greatly influenced which algorithm was chosen for each condition in the algorithm of algorithms. There was less error in the simulations compared to the hardware due to lack of real world factors. The graphs above are the tested algorithms at standard test conditions.

Hardware Design

Designed our own PCB to integrate the DC-DC converter and sensing circuits to execute MPPT efficiently.

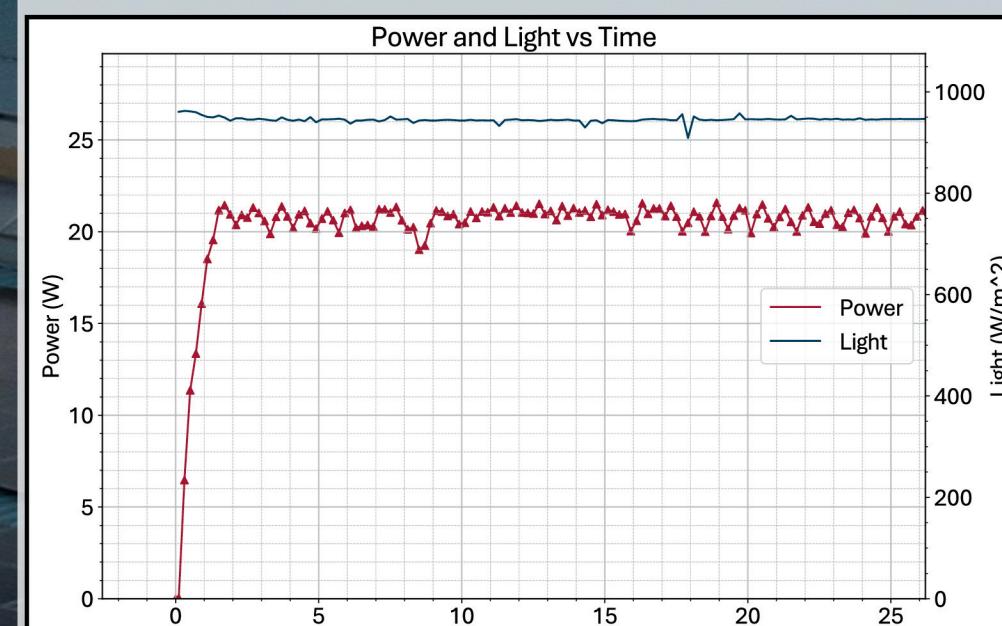


Hardware Results

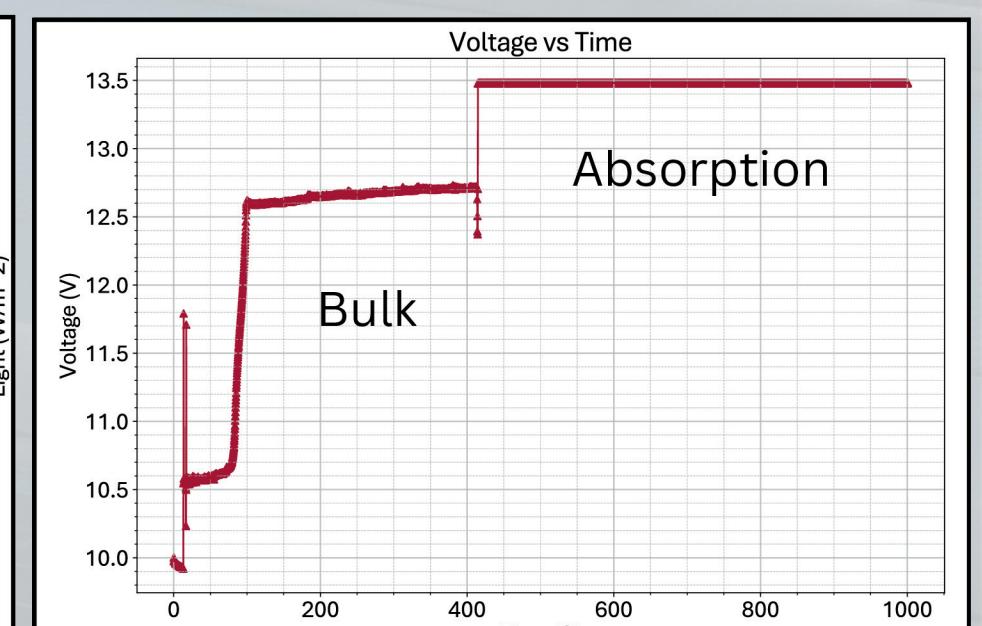


- Final hardware tests were conducted outdoors under full irradiance.
- A sweep of the DC-DC converter duty cycle was performed to find the estimated MPP at current conditions.
- The charge controller was able to achieve bulk and absorption charging stages.

PNO Power Output Over Time

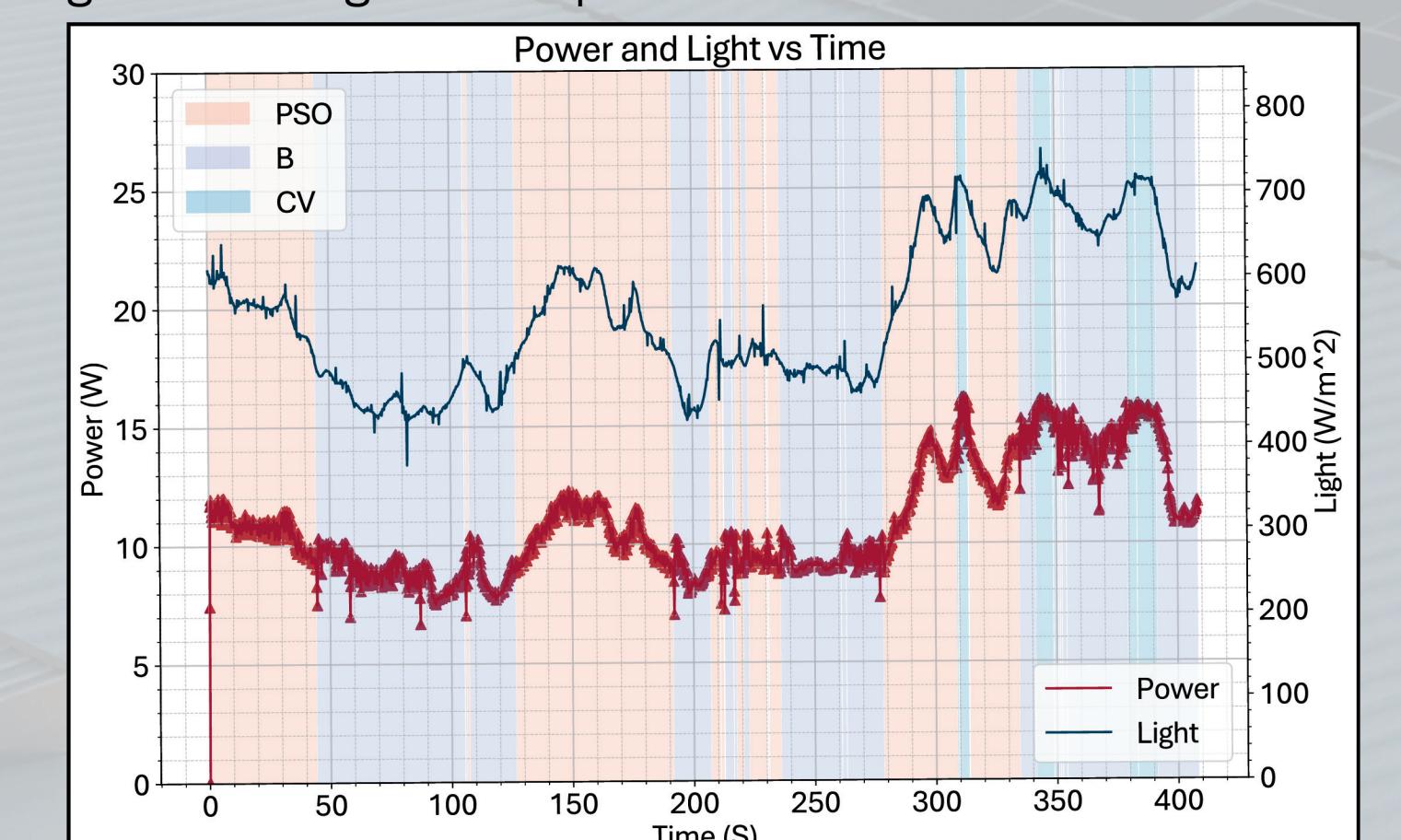


12V Lead Acid Battery Voltage over Time



Algorithm of Algorithms

MATLAB simulation data was used to determine which algorithm has the least oscillation and highest power output at each weather condition. The Algorithm of Algorithms automatically switches to the ideal algorithm for given temperature and irradiance values.



References & Acknowledgements

- PV Equivalent Circuit: https://www.researchgate.net/figure/Equivalent-circuit-of-solar-panel_fig2_32499209
- MPP Curve: https://www.researchgate.net/figure/Maximum-Power-Point-MPP-curve-9_fig3_33842507
- Trial and Error Curve: https://www.researchgate.net/figure/Principle-of-the-hill-climbing-algorithms-for-MPPT_fig3_356464235

We would like to thank Gregory Noetscher for all his guidance and support throughout the project. We would also like to thank the following individuals for their contributions: William Appleyard, James O'Rourke, Matthew Ford