Stand-alone PV System for EE 452 Lab

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Project Statement

- Develop and expand the current EE-452 solar generation system to be more user friendly and educational for future students.

Why is this important?

- Renewable energy is an up and coming field that Power Engineers at Iowa State Univeristy need to be exposed too.

Our Solution

- Last Semester
  - Develop Working Simulink Model
  - Develop idea to bridge Motors and Solar Power via model trains and induction motors
- This Semester
  - Create a new workstation for solar equipment
  - Implement new labs and create the corresponding manuals
  - Continue the lab manuals created by previous teams and adapt them to our new lab setup
  - Develop plans for expanding the system in the future

Standards

- Workstation must be clean, safe and simple
- Lab exercises should have real world connections and be engaging
- IEEE standards should be followed in regard to sizing, installation and maintenance of lead acid batteries

Original Equipment

Solar Panel

Kyocera KD-185GX-LPU
Open circuit voltage : 29.5V
Short circuit current: 8.6A
Max power voltage : 23.4V
Max power current : 8.6A

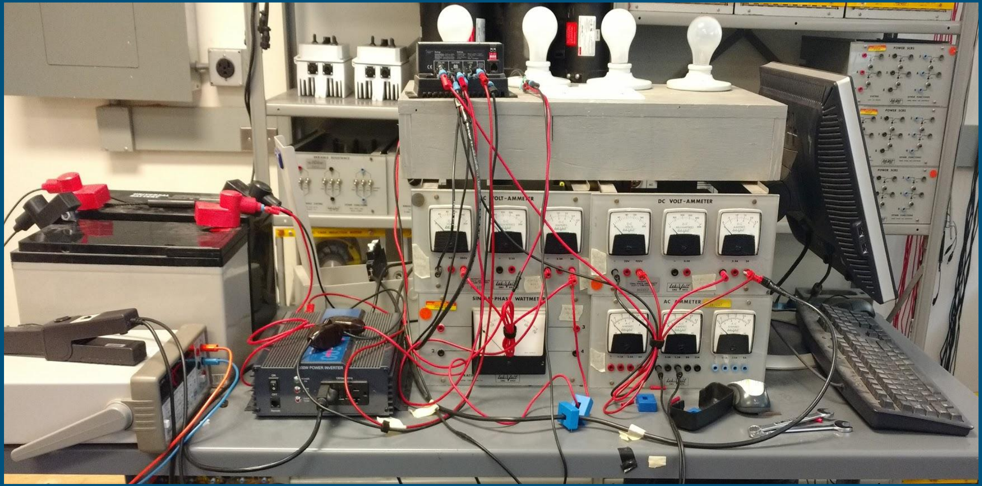
MPPT

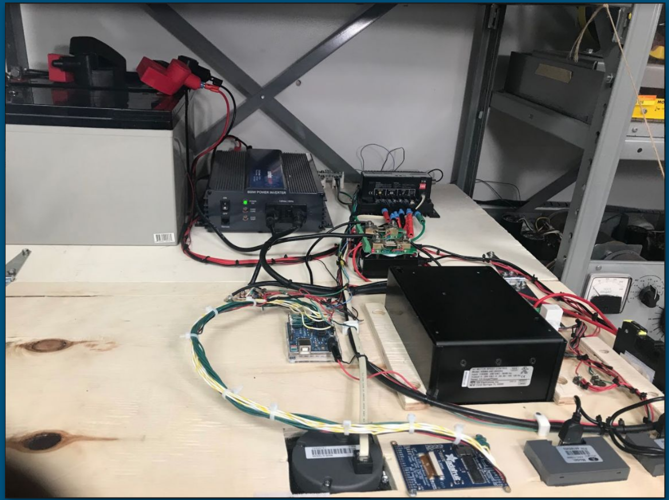
Original Equipment

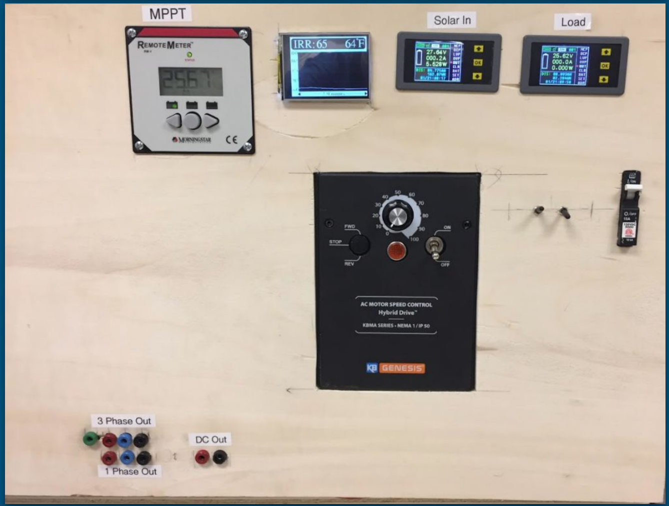
24 V DC to 120 VAC 600 W Inverter

Two 12 V Batteries

Current Workstation Vs New Workstation





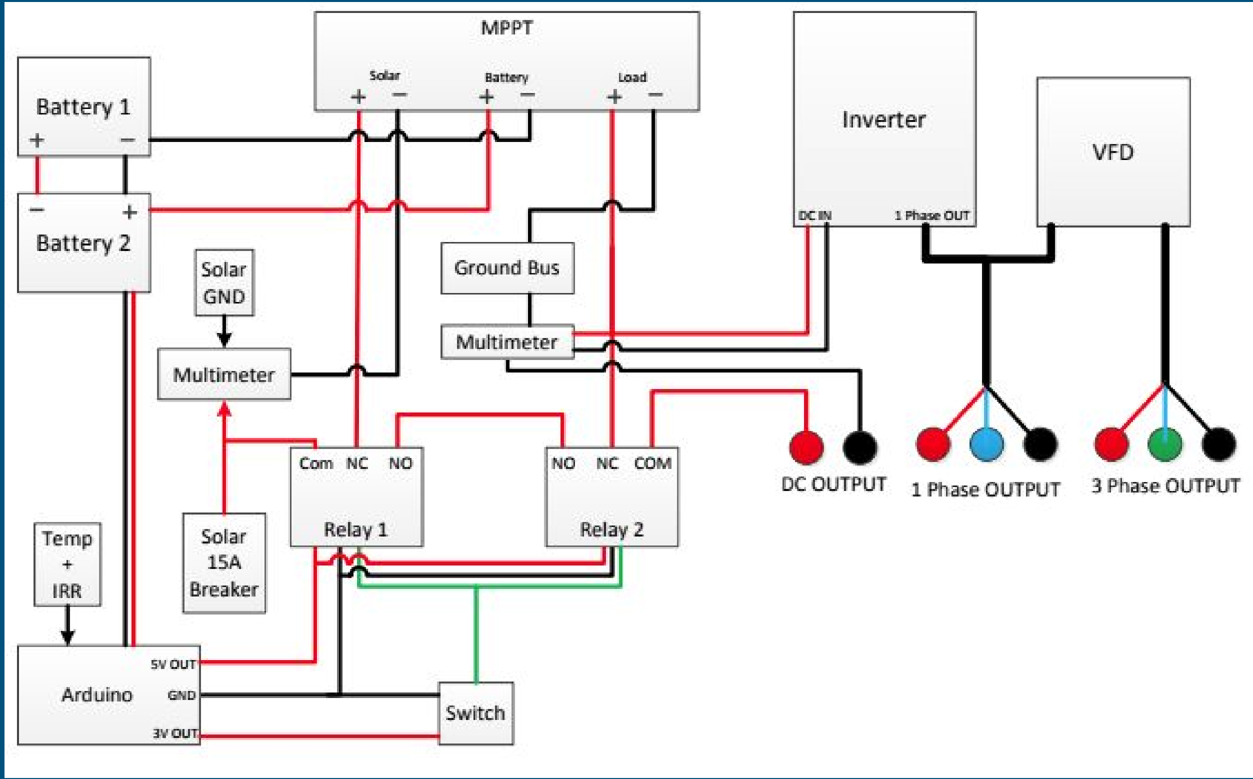


Current Workstation Vs New Workstation

Measurement Improvements

- New measurement capabilities and equipment Including:
  - A display measuring displays temperature and Irradiance using an Arduino
  - Multimeters that measure V, I, and P at the input of the solar panels and the load terminals
    - Can record data up to 24 hours
  - MPPT compatible display module that measures
    - Voltage and AH on the battery
    - Solar panel voltages
    - Voltage and AH on load

The System


MPPT
Solar
Battery
Load
Battery 1
Battery 2
Solar GND
Multimeter
Ground Bus
Multimeter
Inverter
DC IN
1 Phase OUT
VFD
Com NC NO
Relay 1
NO NC COM
Relay 2
DC OUTPUT
1 Phase OUTPUT
3 Phase OUTPUT
Temp + IRR
Solar 15A Breaker
Arduino
5V OUT
GND
3V OUT
Switch

Labs

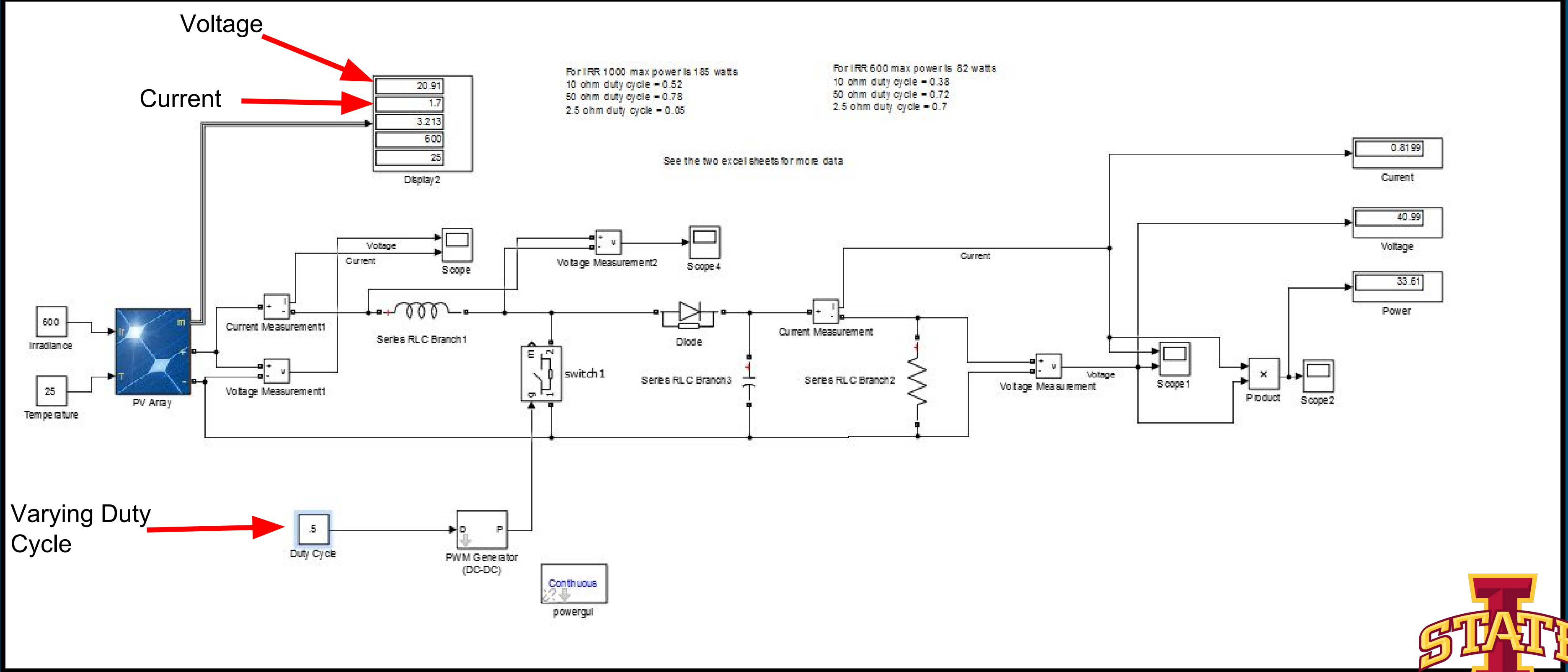
Developed four labs

These labs were made with intention of demonstrating different ways that solar power can be manipulated to power different loads.

-They emphasize power use and efficiency

1. Simulink Lab
2. Light Bulb Lab
3. DC Train Lab
4. Induction Motor Lab

Simulink Lab



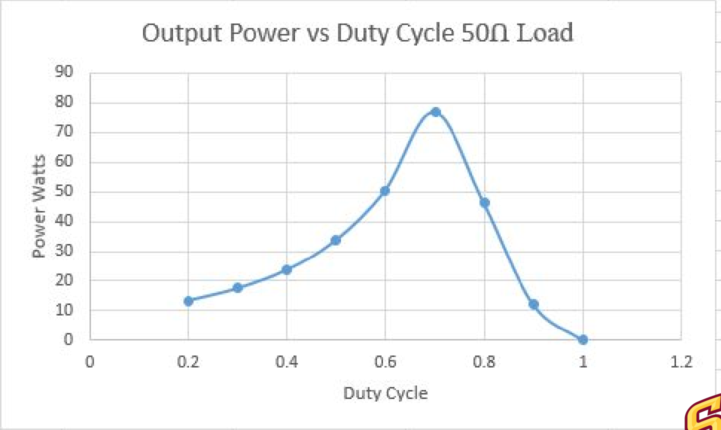
Simulation Comparison and Calculation

- Excel Spreadsheets are created, students only need to fill in empty data

- Experiments include varying;
  - Irradiance
  - Temperature
  - Load
  - MPPT Duty Cycle

Each experiment gives insight on how the system behaves

IRR = 1000 & Temp = 25C				
Duty Cycle	Panel Current (A)	Panel Voltage (V)	R equivalent (Ohms)	Output Power
0.2	0.59	26.69	44.88	13.44
0.3	0.77	30.39	39.31	17.54
0.4	1.06	35.21	33.09	23.73
0.5	1.56	41.74	26.72	33.61
0.6	2.47	50.93	20.64	50.36
0.7	4.18	62.73	15.01	76.74
0.8	4.88	48.82	10.00	46.12
0.9	4.98	25.47	5.12	12.17
1	5.03	0.01	0.00	0

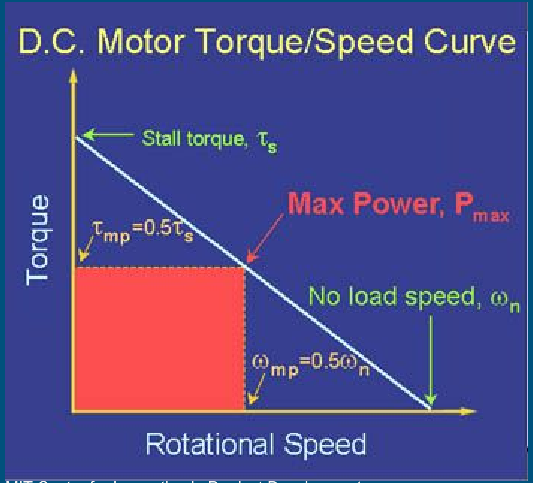


Light Bulb Lab

- Demonstrates single phase loads
- Students will incrementally turn on lights and measure
  - Loss of the system via inverter
  - Power used from solar
  - Power used from battery
- Learn what happens when the inverter isn’t supplied enough power

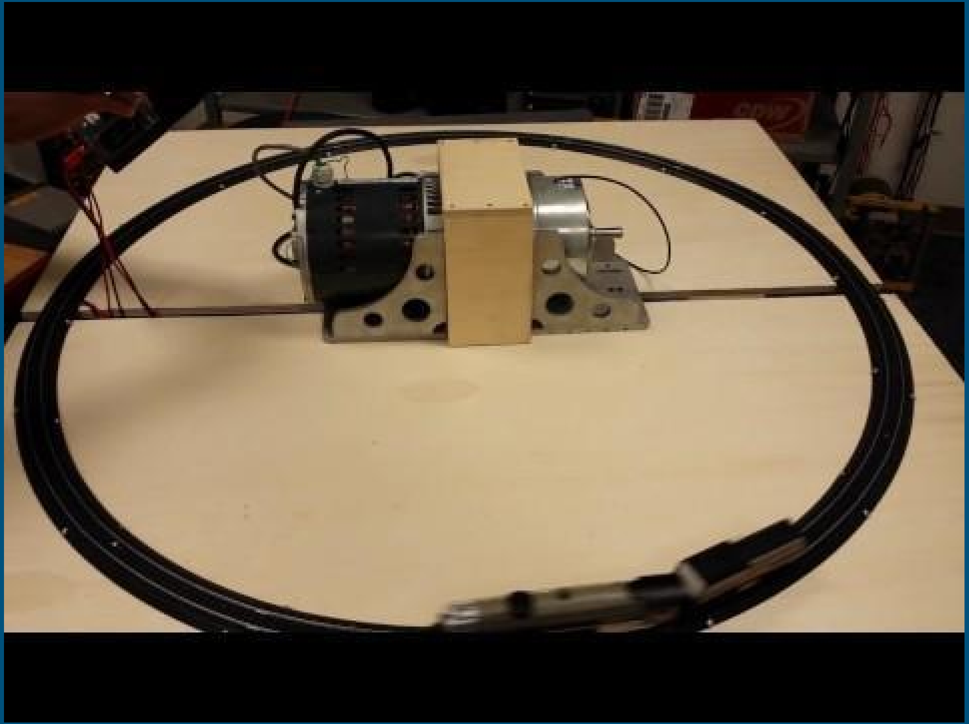
Solar Train Lab

- Students will learn and see the effects of MPPT
- DC motors propel the train around the track
- Main topic in EE 452
- Find max power on Torque - Rotational Speed plot
- Calculate battery capacity needed to power trains at night
- Examine different charge controllers to understand how the system receives power in day/night



MIT Center for Innovation in Product Development

DC Train Demonstration



Induction Motor Lab

-Demonstrates solar can be converted to run a three phase load using a single phase AC inverter and a KBMA Drive converts 60 Hz Single Phase AC to Variable Frequency Three Phase AC

-In the lab students will calculate/Measure

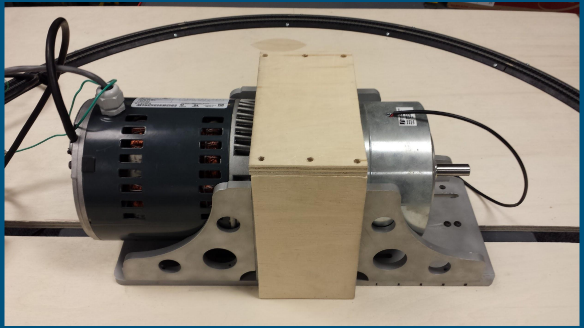
-Power into the Solar Panel

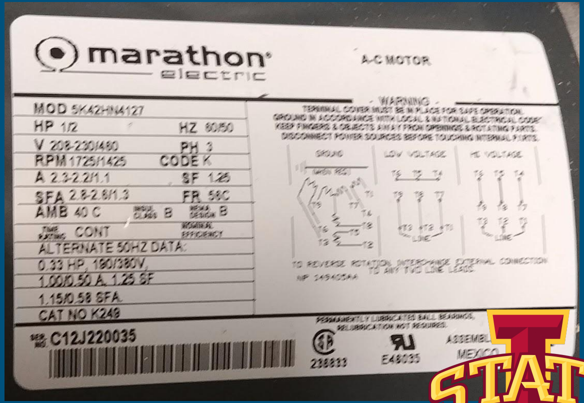
-Speed of the motor

-Power drawn by the motor

-Power loss between single phase DC to AC inverter, KBMA drive, and the motor

-Efficiency of the system





Induction Motor Demonstration

Expansion Plans

- Upgrade Morningstar MPPT module from 15 A to 45 A module
- Upgrade Solar Panels to two 295 Watt Solar Panels
  - Improves from 5.87$ to 2.87$ per Watt
  - Increases capacity from 300 Watts to 600 Watts
  - This would max out the current DC to AC inverter
  - Batteries would remain the same
  - The new measurement equipment would be compatible

Summary

The old EE 452 solar panel system has been improved by:

- Implementing a cleaner more compact design.
- Adding new measurement tools.
- Developing and implementing new and old labs such as:
  - The simulink lab
  - The lightbulb lab
  - The DC train lab
  - The induction motor lab
- This new and improved setup will improve students understanding of Solar Power.

Questions?

References

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- *Tyson DenHerder, "Design and Simulation of Photovoltaic Super System Using Simulink" California Polytechnic State University, San Luis Obipo, 2006.*
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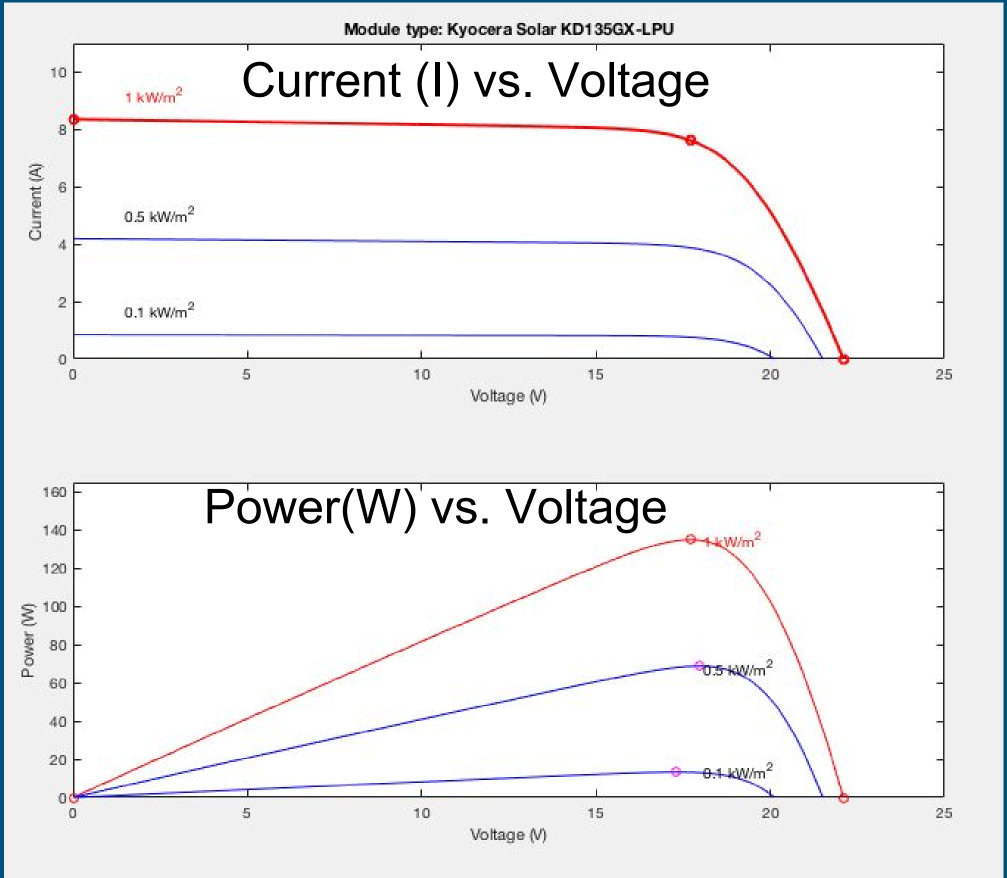
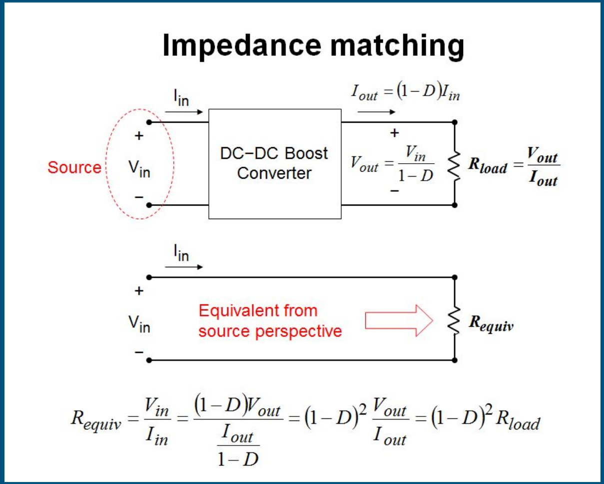
What is MPPT

- Balance of parameters for maximum solar panel performance
- Four methods:
  - Perturb & Observe
  - Incremental Conductance
  - Current Sweep
  - Constant Voltage
- Responds with varying conditions
- P&O is the simplest to understand



Use of DC-DC Converter

- Buck/Boost converter
- Stabilize varying current received from solar panels
- Uses impedance matching to achieve max power



From Kwasinski, University of Texas