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 exposed too.

Our Solution

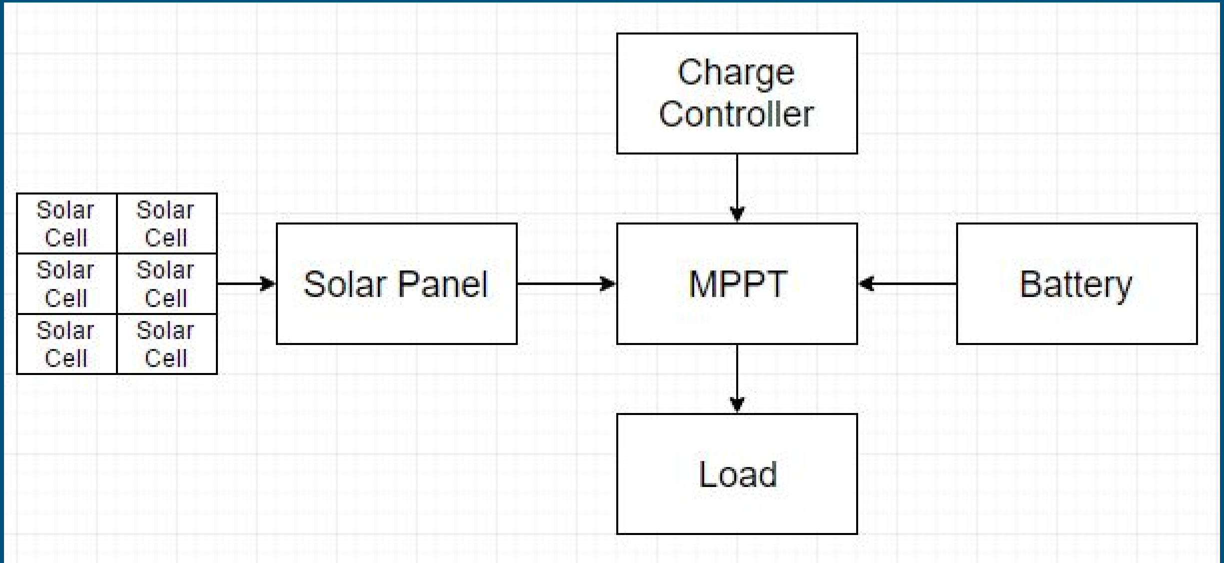
- This Semester
  - Develop Working Simulink Model
  - Bridge Motors and Solar Power via model trains

- Next Semester
  - Create a new workstation for solar equipment
  - Continue the lab manuals created by previous teams

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

The System



Charge Controller
Solar Cell
Solar Cell
Solar Cell
Solar Cell
Solar Cell
Solar Cell
Solar Panel
MPPT
Battery
Load

Understanding a Solar Cell

- Silicon p-n type junction
- Electrons jump to the holes in p-type(depletion zone)
- Electric field is formed from depletion zone
- Sunlight ejects electrons crossing depletion zone
  Creates electricity

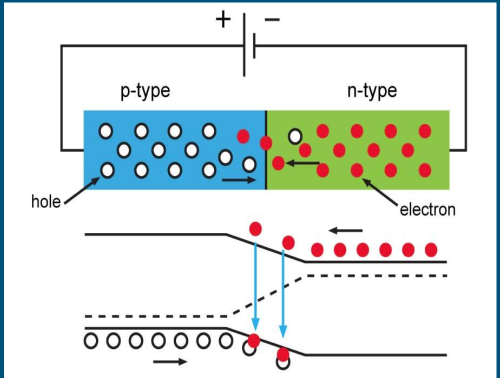
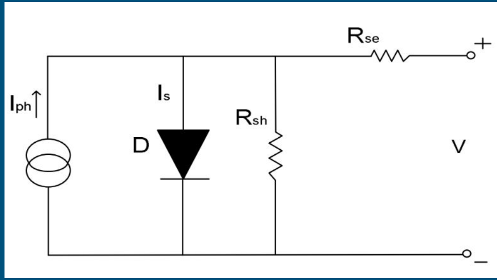


Image courtesy of bysolar.com



G.Bhucaneswari, R. Annamalai, “Development of a Solar Cell Model In Matlab For PV Based Generation System”

Solar Panel

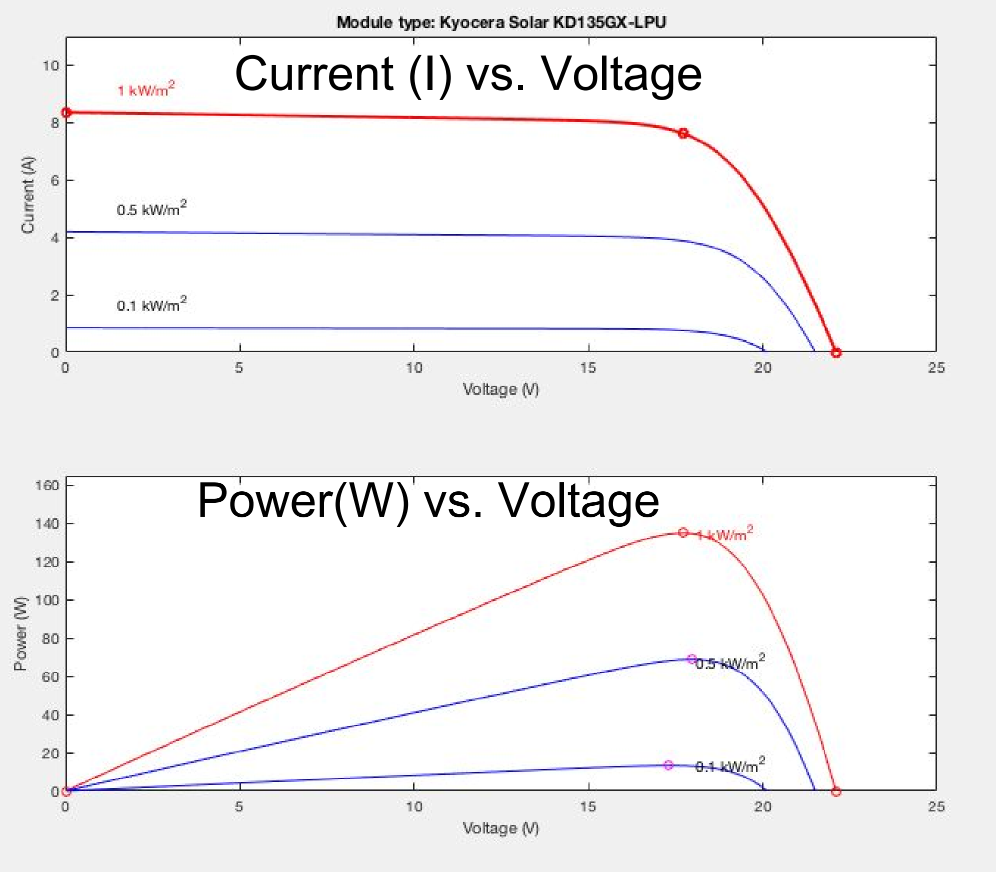
- Combination of solar cell in series or parallel (higher current/energy)
- Amplify & direct output current from the cells
- Output Power depends on Irradiance and Temperature
- Quiet, Low maintenance , Eco-Friendly

Solar Panel

- Profile curves are governed by equation:

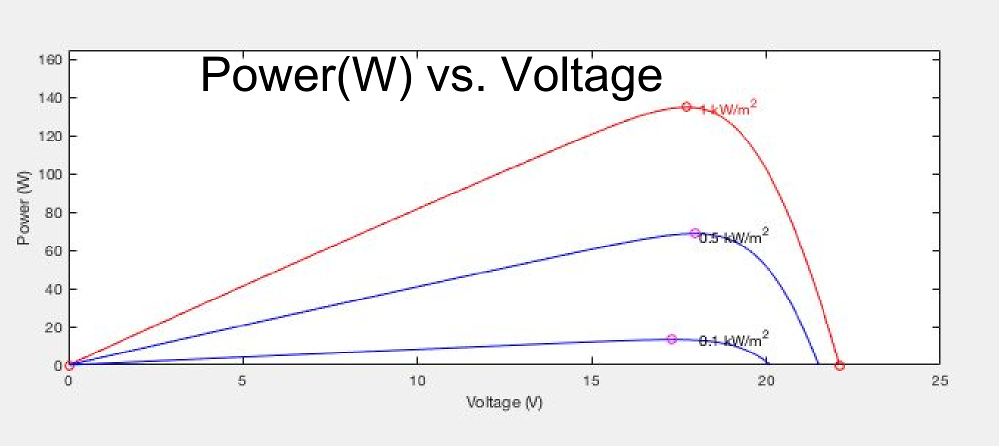
$$I_{tot} = I_l - I_0(e^{qV/kT}-1)$$

- Greatest efficiency is achieved when the current and voltage are balanced
- Relationship between I and V



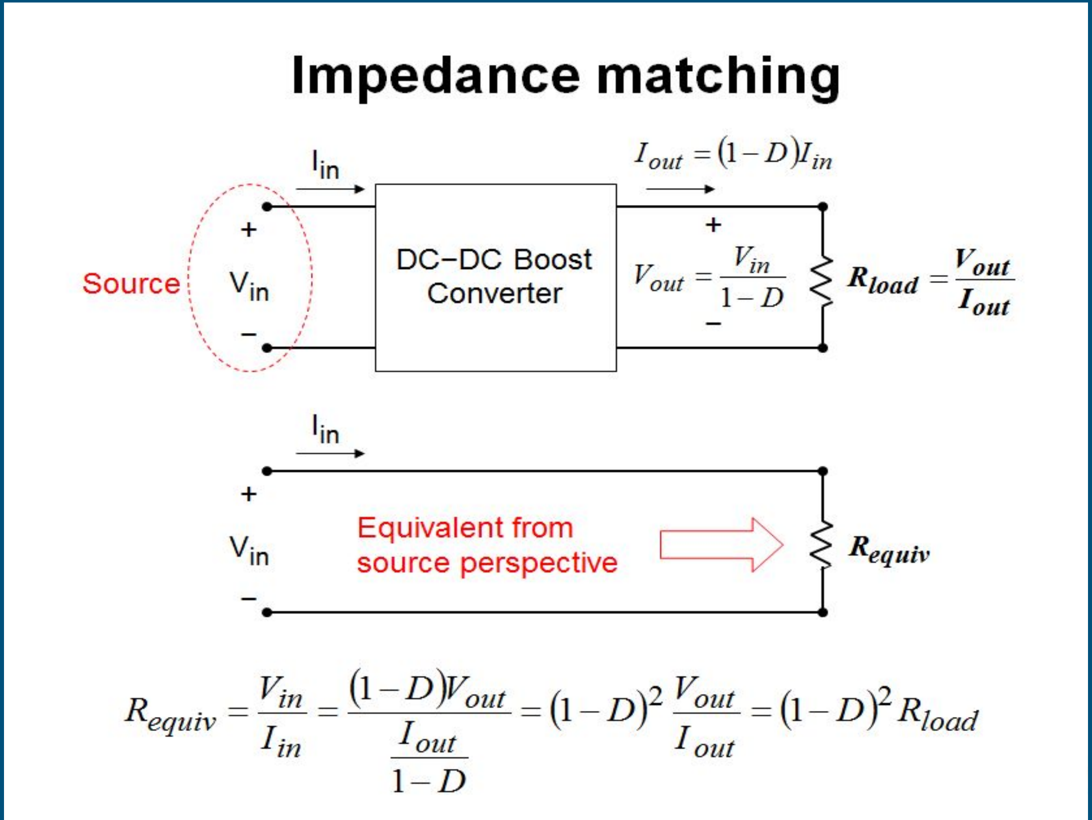
What is MPPT

- 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



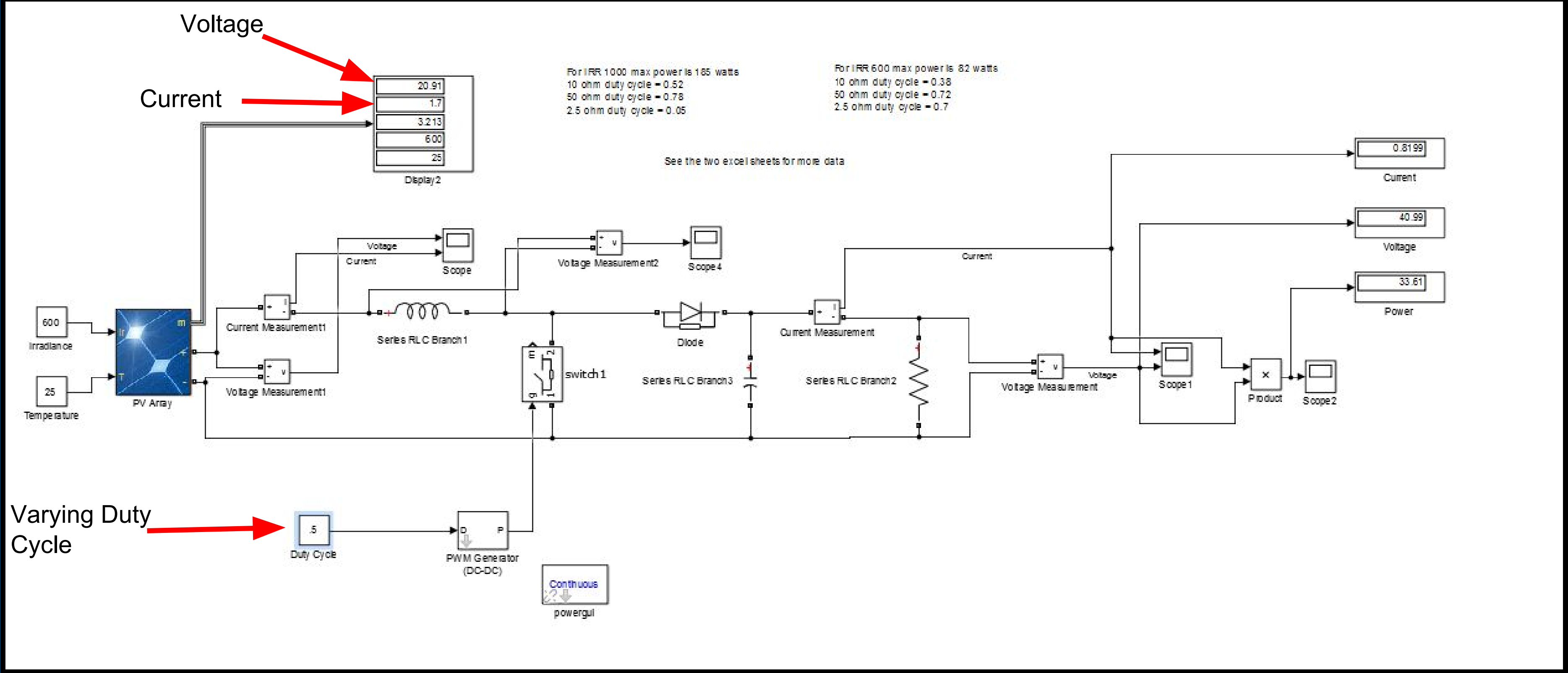
Use of DC-DC Converter Cont.

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



From Kwasinski, University of Texas

Simulation Circuit

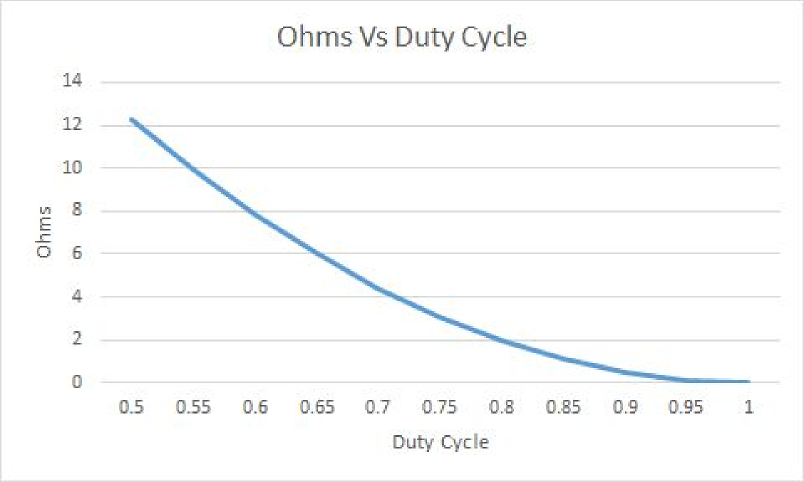


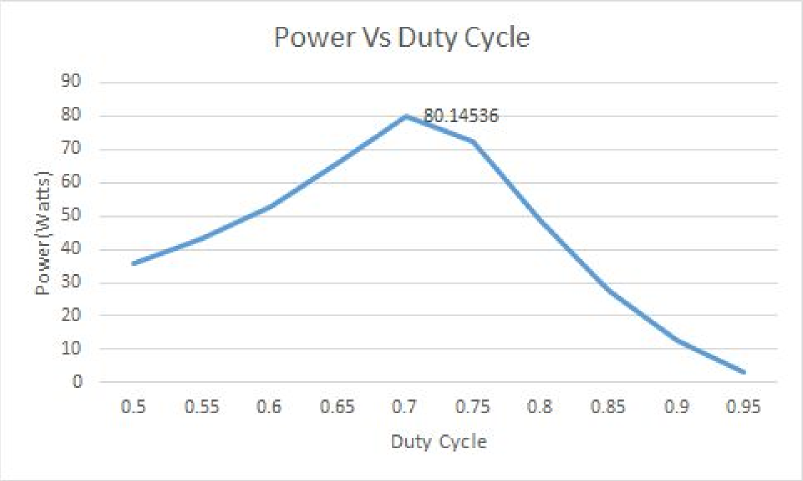
Simulation Comparison and Calculation

Parameters		
Load	50	ohms
Inductor	6*10^-6	Henry's
Capacitor	324*10^-6	Farads
Frequency	16000	Hz
Irradiance	600	W/m^2
Temperature	25	C
Duration of Simulation	0.7	S

Measurements							
Duty Cycle	V (Volts)	I (Amps)	Measured V/I(Ohms)	Calculated(Ohms)	%error	V*I	
0.5	20.9	1.7	12.29411765	12.5	1.6%	35.53	Watts
0.55	20.71	2.082	9.947166186	10.125	1.8%	43.11822	Watts
0.6	20.3	2.597	7.81671159	8	2.3%	52.7191	Watts
0.65	19.91	3.308	6.018742443	6.125	1.7%	65.86228	Watts
0.7	18.84	4.254	4.42877292	4.5	1.6%	80.14536	Watts
0.75	14.98	4.849	3.089296762	3.125	1.1%	72.63802	Watts
0.8	9.79	4.917	1.991051454	2	0.4%	48.13743	Watts
0.85	5.62	4.966	1.13169553	1.125	0.6%	27.90892	Watts
0.9	2.55	5.001	0.50989802	0.5	2.0%	12.75255	Watts
0.95	0.667	5.023	0.13278917	0.125	6.2%	3.350341	Watts
1	0.005031	5.031	0.001	0	N/A	0.025310961	Watts
				Req = (1-D)^2*Rload			

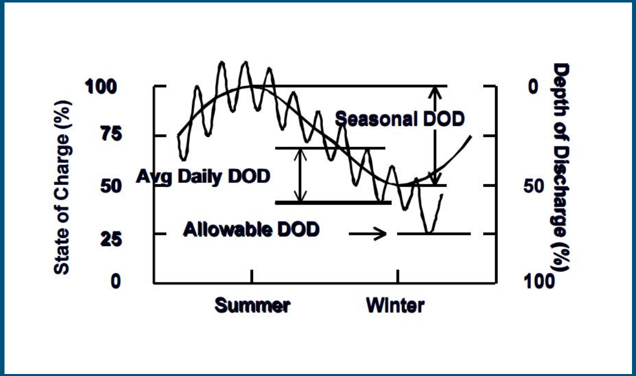
Max Power Point		
	3.8766234	Ohms
	82.42	Watts
Calculated Duty Cycle	0.7215535	
Measurments		
Volts	17.75	
Amps	4.647	
V/I	3.8196686	Ohms
Power	82.48425	Watts





Battery

- Allows continuous operation
- Sized by amount of Ah required by the system
- Depth of Discharge determines charging cycle
- Charge-Discharge affects lifespan (efficiency less than 80%)



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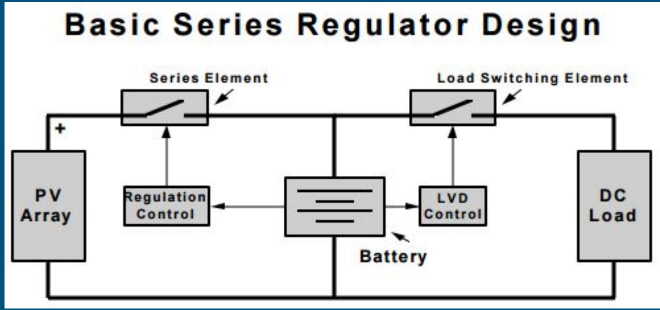
Charge Controller

- Elongates lifespan of the battery
- Series or shunt controller
- Regulates amount of current flowing in/out of battery
- Controls source seen by load



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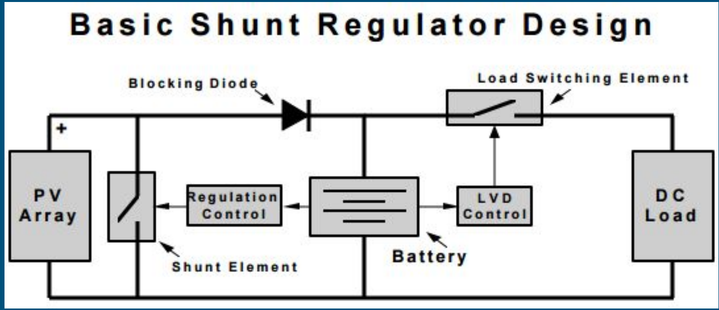

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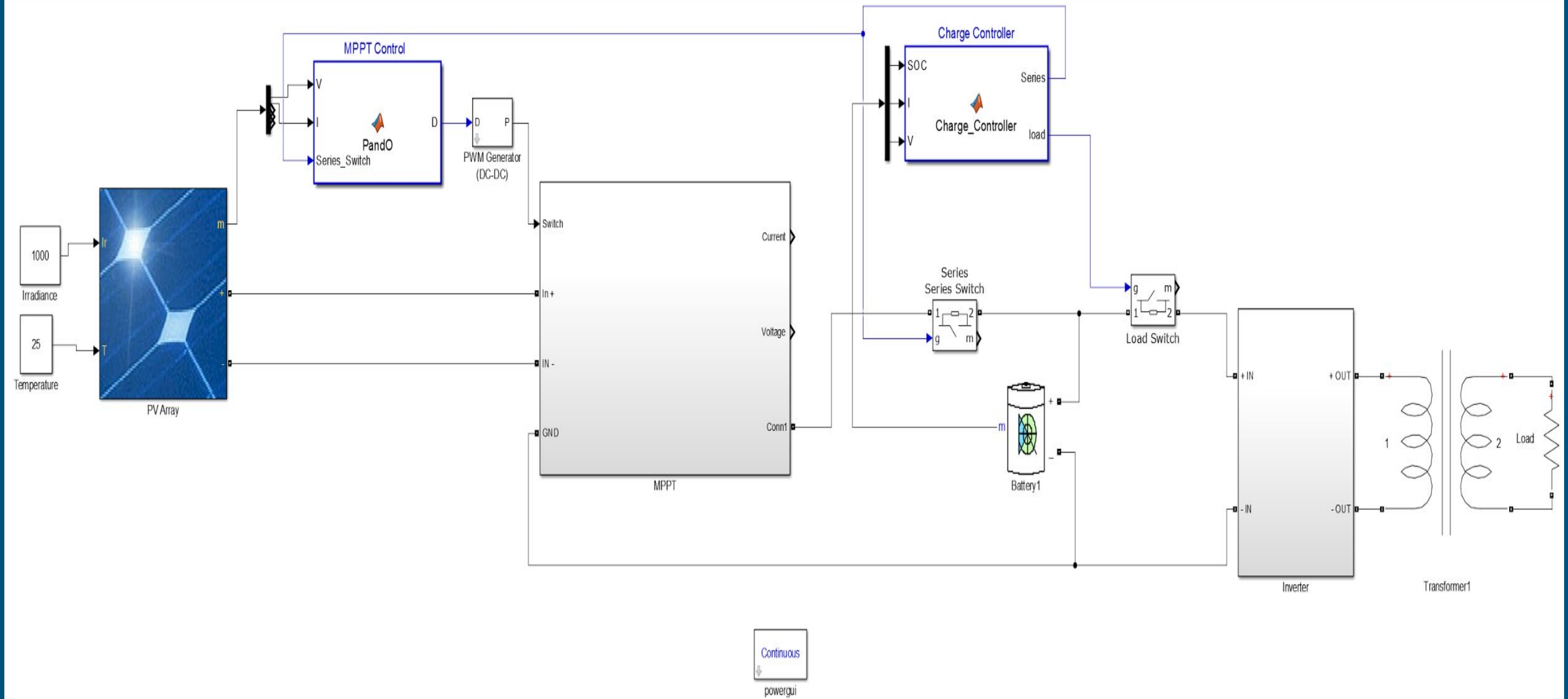
Need For Simulink Model

- Provides an in depth understanding of the equipment we will be working with

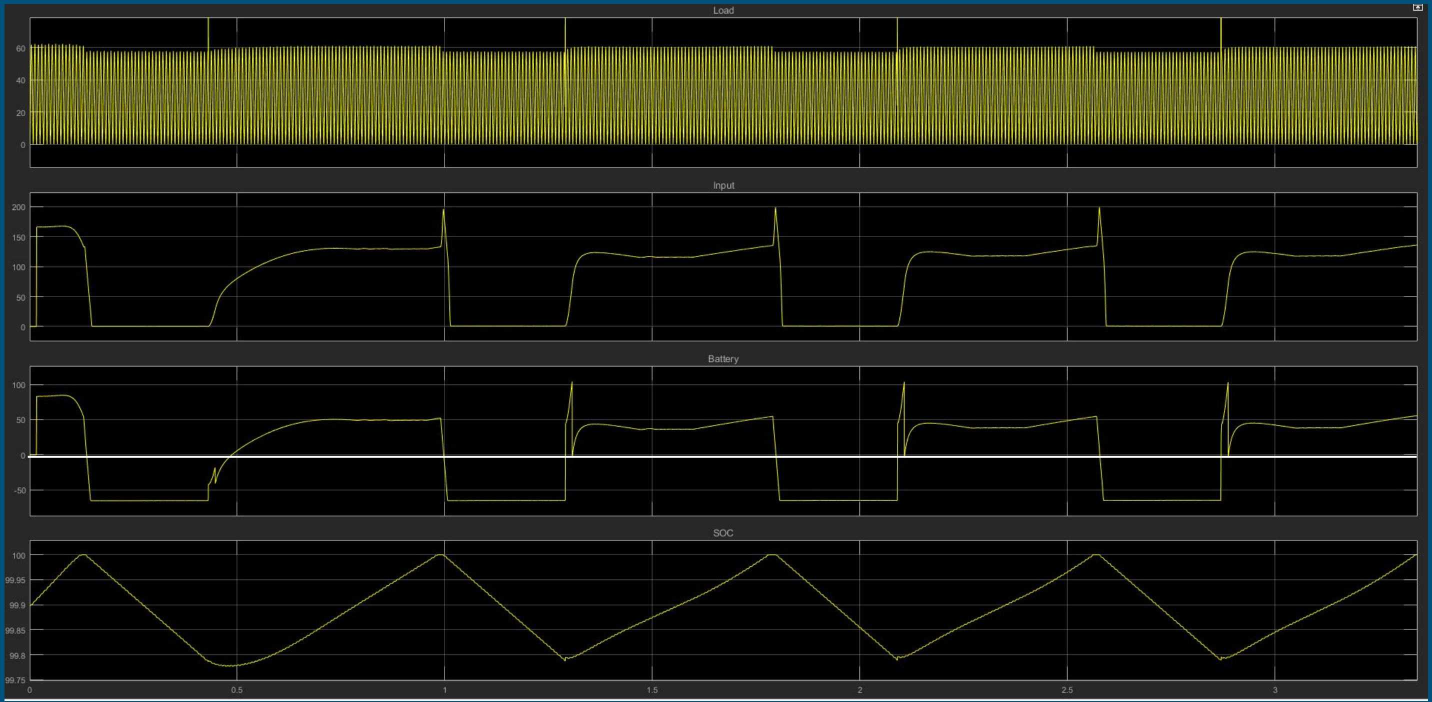
- Each part of the system can be built and simulated using Simulink

- This can be used by students in lab, as well as by us to, help us understand different applications

Simulink Model



Model Data



Load

From Boost Converter

Charging Batt.

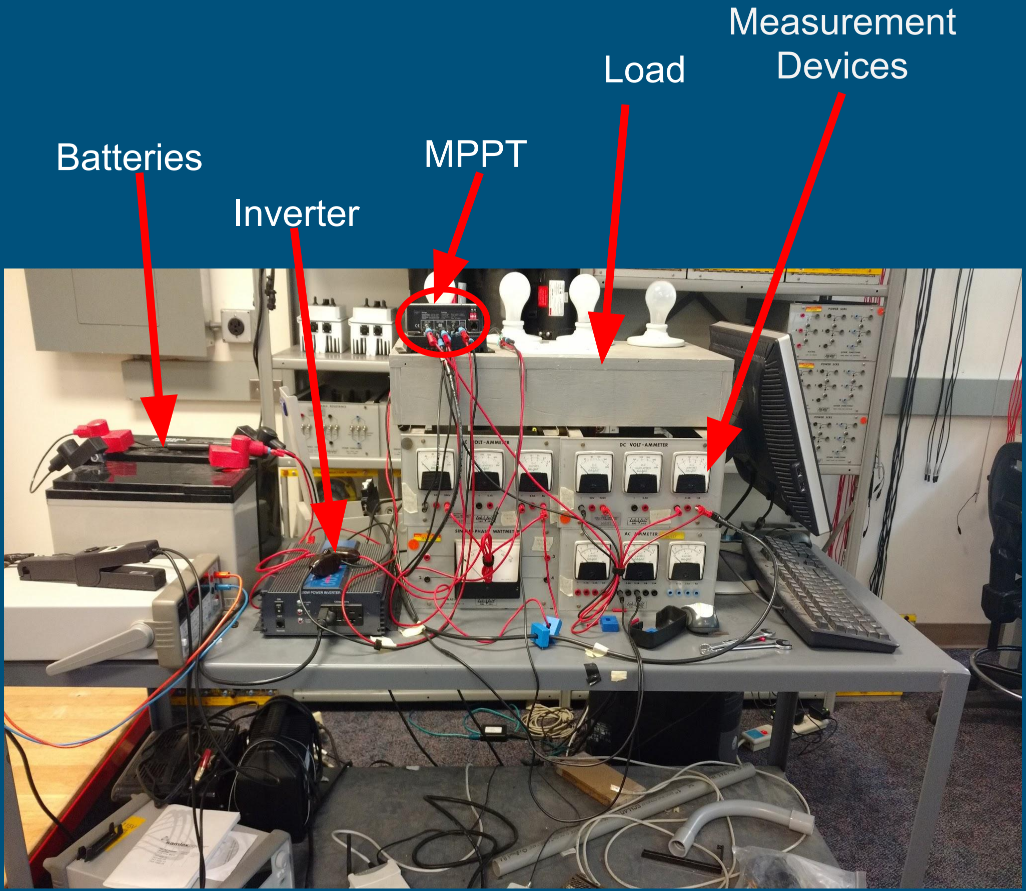
Discharging Batt.

Battery Charge %

100 ohm load, 60hz

Current Workstation

- Messy and unorganized
- Safety hazards
- Create a slimmer smarter package.
    - New Ammeters, voltmeters and wiring setup.

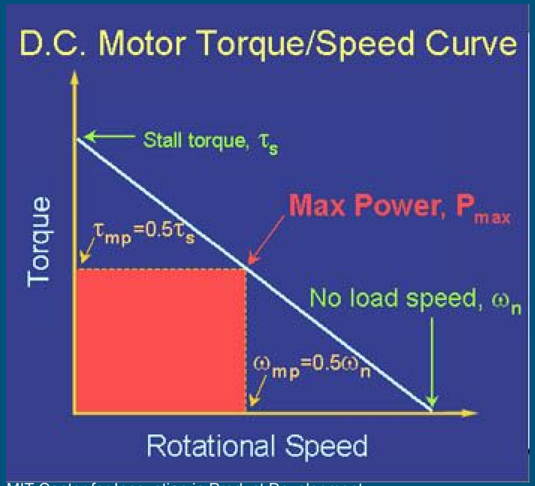


Project Goals Next Semester

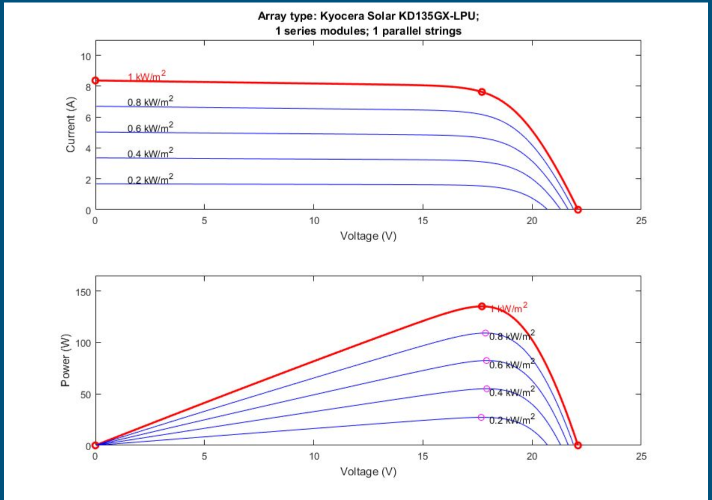
- Improve current workstation layout
- Build upon previous groups lab manuals / generate new
- Create a new lab with model trains

Solar Train

- Students will learn and see the effects of MPPT
- DC motors propel the train around the track
- Main topic in EE452
- 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



Courtesy of Simulink PV Model

Summary

- Discussed our project statement and standards
- Went over how our system works and showed our current model
- Showed results pertaining to our models
- Discussed next semester's goals and objectives

Questions?

References

- *Anca D. Hensen, Poul Sorensen, Lars H. Hansen, Henrik Binner, “Models for a Stand-Alone PV System”, Riso National laboratory, Roskilde, pp. 1-78, 2000.*
- *G.Bhucaneswari, R. Annamalai, “Development of a Solar Cell Model In Matlab For PV Based Generation System”, India Conference (INDICON), 2011 Annual IEEE, pp. 1-5, 2011.*
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- *Mishra, Bibek, and Bibhu Prasanna Kar. "Matlab Based Modeling of Photovoltaic Array Characteristic." Thesis. National Institute of Technology, Rourkela, 2012.*
- *O.E.M Youssef, N.M.B Abdel-Rahim, A. Shaltout, “Performance of Stand-alone Hybrid Wind-Photovoltaic System with Battery Storage”, 14th international Middle East Power Systems Conference (MEPCON’10), Cairo University, pp 1-7, 2010.*
- *Ting-Chung Yu, Yu-Cheng Lin, “A Study on Maximum Power Point Tracking Algorithms for Photovoltaic Systems”, Lunghwa University of Science and Technology, pp. 1-10, 2010.*
- *Tyson DenHerder, “Design and Simulation of Photovoltaic Super System Using Simulink” California Polytechnic State University, San Luis Obipo, 2006.*
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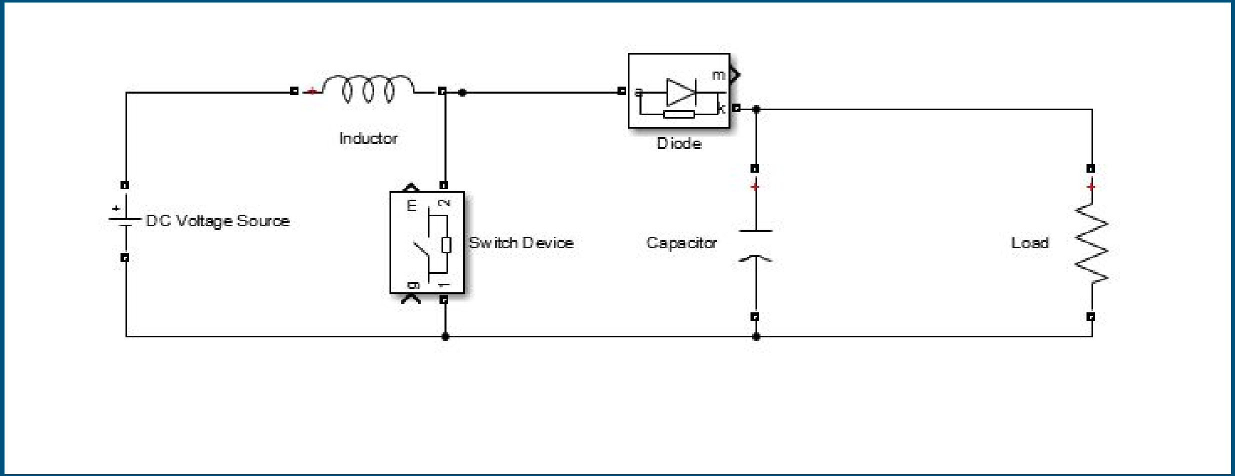
Boost Converter Circuit

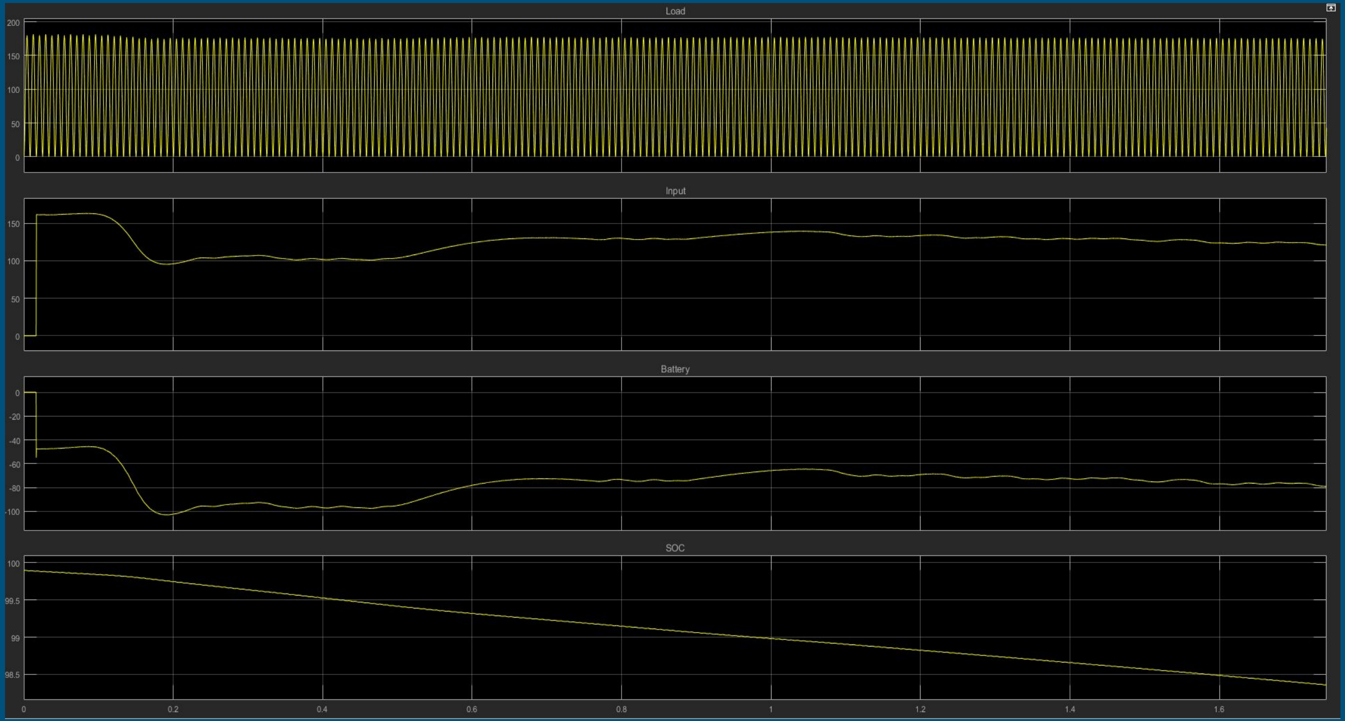


MPPT Code & Charge Controller Code (Extra)

```
persistent Vold Pold Dold;

dataType = 'double';

if isempty(Vold)
    Vold=0;
    Pold=0;
    Dold=Dinit;
end
%if the series switch is open, the duty cycle should stay were it is.
if Series_Switch == 0
    D = Dold;
    return
end

P= V*I;
dV= V - Vold;
dP= P - Pold;

if dP ~= 0
    if dP < 0
        if dV < 0
            D = Dold - deltaD;
        else
            D = Dold + deltaD;
        end
    else
        if dV < 0
            D = Dold + deltaD;
        else
            D = Dold - deltaD;
        end
    end
else D=Dold;
end

if D >= Dmax || D<= Dmin
    D=Dold;
end

Dold=D;
Vold=V;
Pold=P;
```

```
function [Series, load] = Charge_Controller(SOC, I , V)

persistent flag

if isempty(flag)
    flag = 0;
end
Series = 1;
load = 1;
%Not fully charged, keep charging
if SOC < 100 && flag == 0
    Series = 1;
    flag = 0;
%Reached full charge, stop charging
elseif SOC >= 100
    Series = 0;
    flag = 1;
    load = 1;
%voltage still okay, keep discharging
elseif 100 < SOC > 99.8 && flag == 1
    Series = 0;
    load = 1;
%Voltage is low enough to charge again
elseif SOC < 99.8 && flag == 1
    Series = 0;
    load = 1;
    flag = 0;
%Voltage is to low, disconnent load and charge
elseif SOC <=60
       load = 0;
       Series = 1;
       flag = 2;
%Voltage needs to build up before discharging again
elseif (80 < SOC < 60) && Flag == 2
        load = 0;
        Series = 1;
%We have charged enough, start discharging
elseif SOC > 80 && flag == 2
        load = 1;
        Series = 1;
        flag = 0;
end
```

Model Data



Load

From Boost Converter

Battery

Battery Charge %

30 ohm AC load