Introduction to Photovoltaic Systems

Summary:

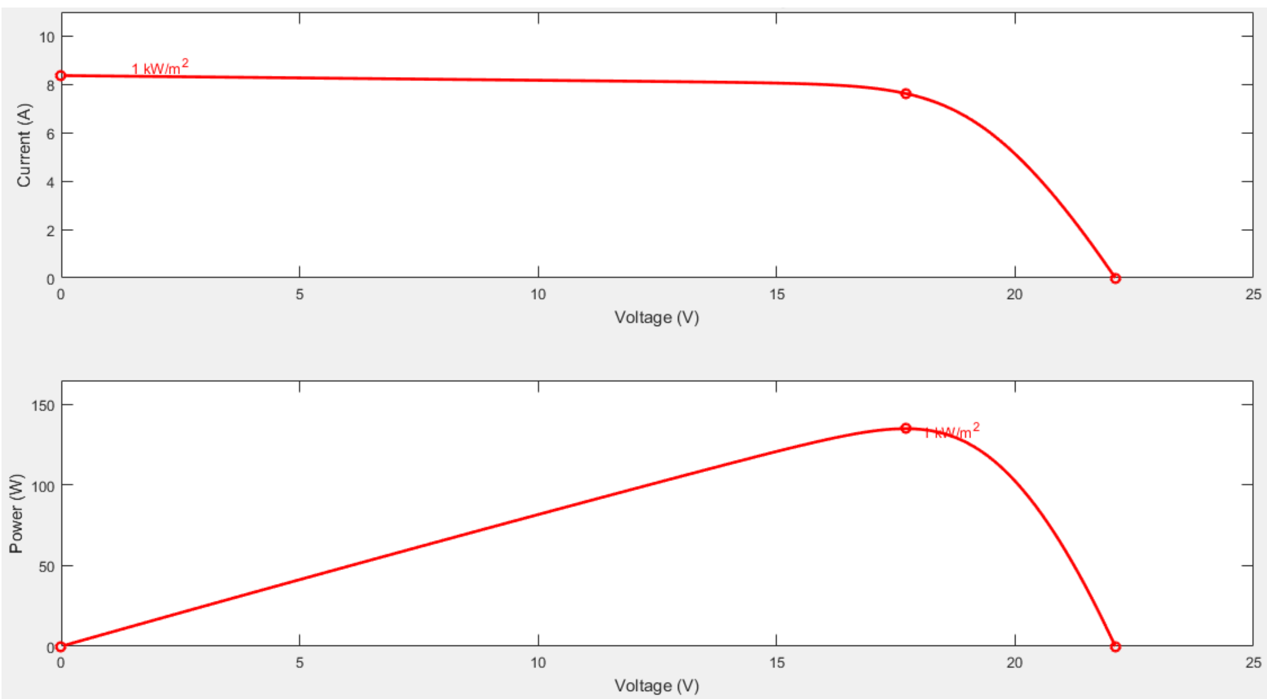
In this lab, PV behavior will be analysed. In addition the resulting I-V curves will be generated from simulation.

Learning Objectives:

- Understanding PV cells
- Reproduction of design

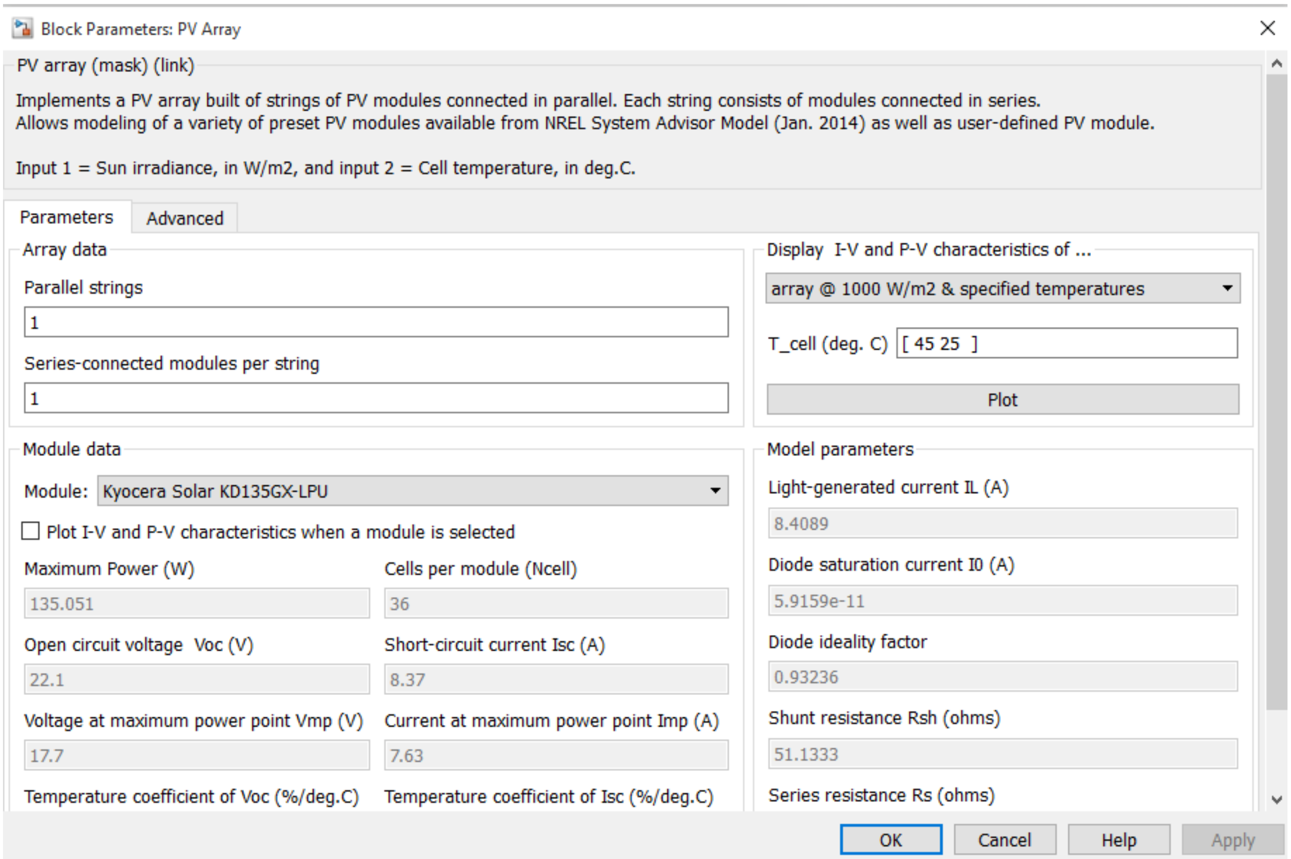
Prelab:

Observe the following I-V curve and P-V curve. These are the graphs of the Voltage, Current, and Power across a resistor. In what ways are these different from a curve using a normal voltage source? Report whether or not you believe the system is linear or non-linear?



Part 1: PV cell

For this lab we will be using a different library. In simulink most of the components that we will be usings are found Simscape>>SimPowerSystems>>Specialized Technology. In the solar area of this library find the block PV Cell. Open the block and get familiar with whats inside.

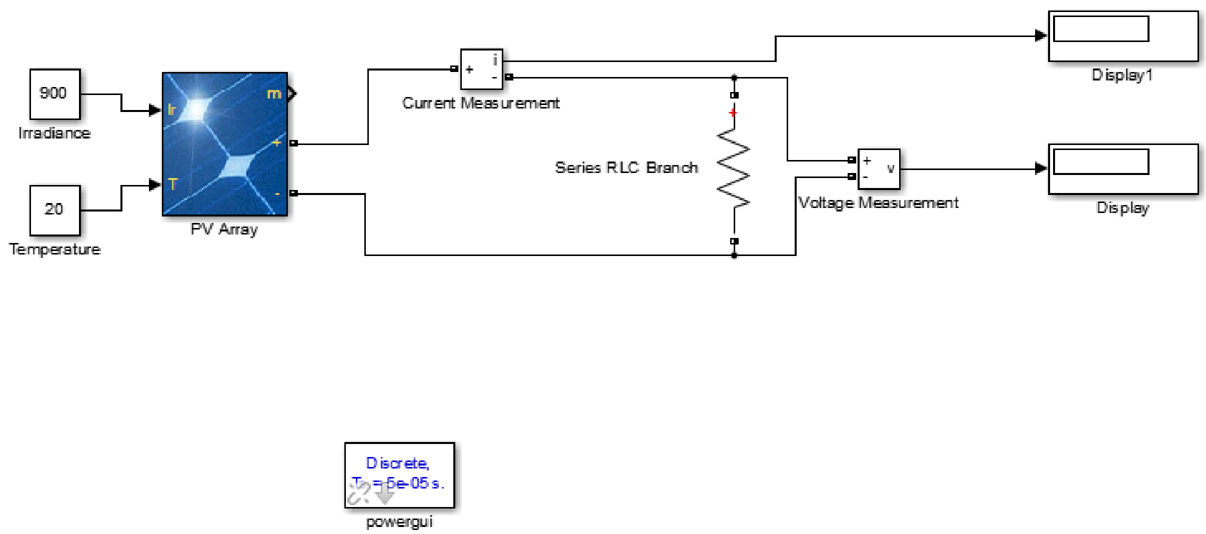


In order to match the results of everyone else, change the number of parallel strings and series connected models to 1. This is because we are only going to simulate one solar panel, but if we wanted to go back we can easily simulate larger systems. In addition please change the module to the Kyocera Solar KD135GX-LPU, which are the solar panels that we will use at a later time. Make sure to click apply and compare your characteristics.

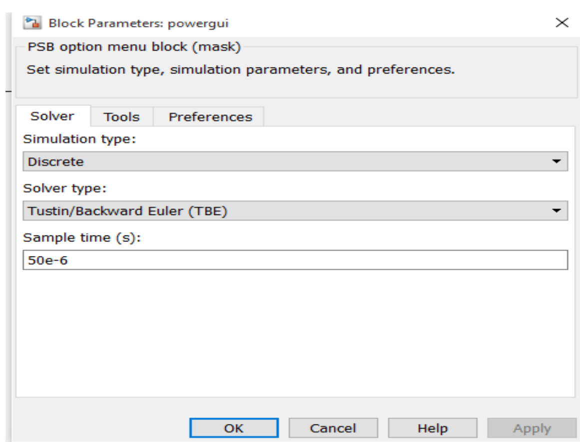
Once everything matches the picture above, plot the array characteristics using several different parameters, we will use this for reference.

Simulation:

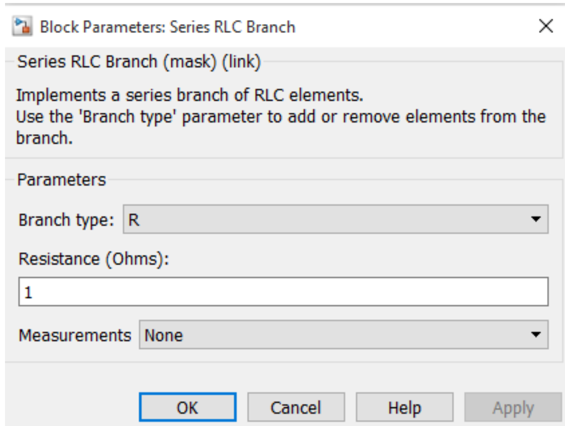
Use the components in the Specialized Technology library to recreate the system below



Assuming the PV array is still in the correct format, we will now apply the correct settings to the rest of the system. First make sure that the Irradiance value is 900 and the temperature is 20(Celsius). First we need to change the power gui to discrete, as shown below. This allows us to run fast simulations at different step sizes.



In addition we need to make sure the RLC branch is purely resistive. In the settings we can change the value of the resistor and the components in the branch. Note: make sure to use the branch and not the load for correct simulation.



Once everything is correct proceed to take measurements with different values of resistors. This is because the PV system acts like a current source and we need to induce different characteristics across our resistor. Using the table below fill out and take measurements on each case.

Resistor (ohms)	100	20	10	6	5	4	3	2.5	2	1	.01
Voltage (volts)											
Current (amps)											
Power (watts)											

Plot the values that you simulated for a Power vs Voltage and Voltage vs Current in Excel or MATLAB and compare this to the graph in the beginning of the lab. The values will not be the same but does this system react the way that we expect? If we reduce the difference in some of our resistor steps would we receive a better graph?

Next given that we have completed the last part, we can test our system to see how everything reacts to different values of Irradiance and time. Repeat the previous table as shown below for an Irradiance of 500 and temperature of 20. Then compare this new graph to the one that you made in the last part.

Resistor (ohms)	100	20	10	6	5	4	3.5	3	2	1	.01
Voltage (volts)											
Current (amps)											
Power (watts)											

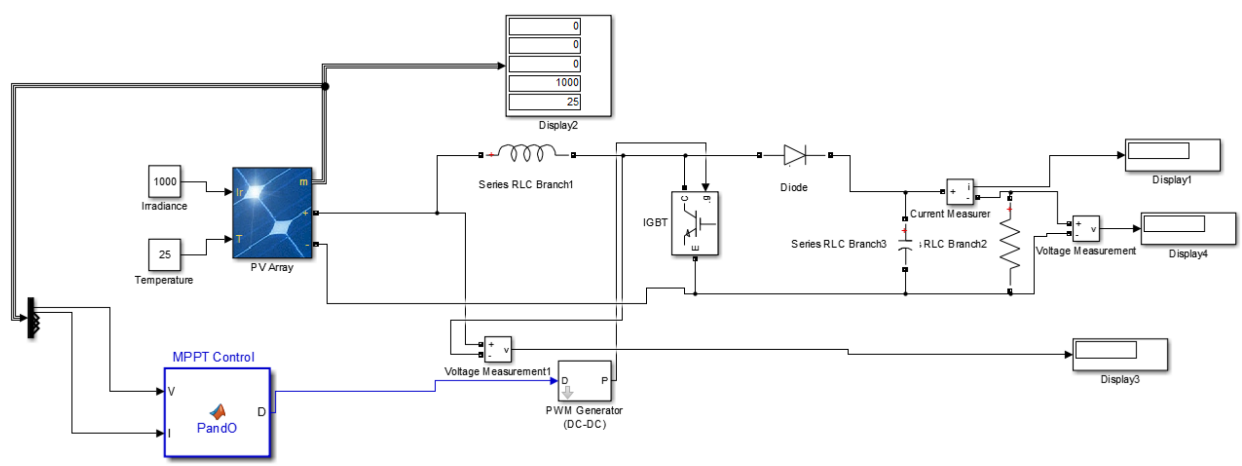
Then redo the graph again for a temperature value of 15 degree and an Irradiance of 900, report the graphs for comparison.

Resistor (ohms)	100	20	6	5	4	3	2.5	2	1	.5	.01
Voltage (volts)											
Current (amps)											
Power (watts)											

System with MPPT (Design Problem)

As we have found in the graphs before, we can only get the maximum output from the solar panels at a specific resistive value. Because it would be impractical to go through at every irradiance and temperature value to come up with the perfect point, we will go ahead and create a system that can do this for us. As we have learned in the class there are many ways to simulate a load being exerted on a system, for this system we will use a boost converter much like the one that we have created before.

Recreate the Simulink block that is shown below.



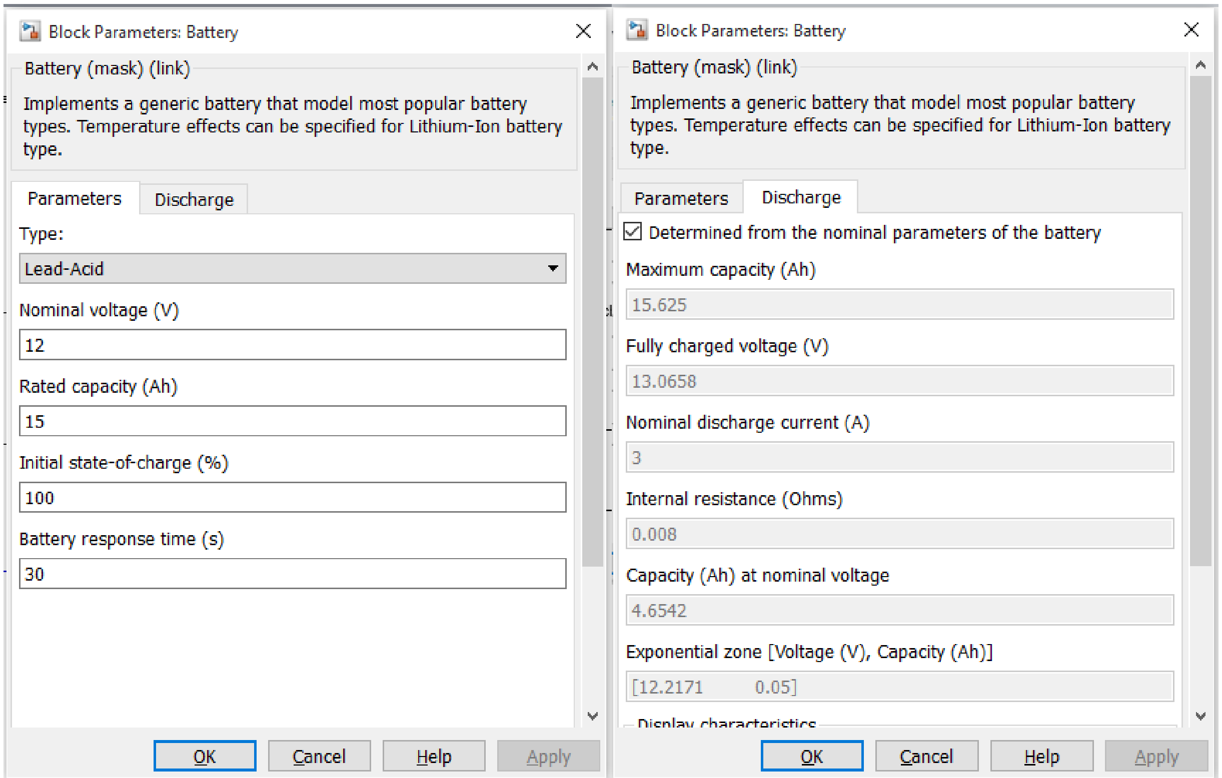
We have provided the block for the MPPT Control, this will help us run the system at the maximum transfer rate of power. As you can see this MPPT block is attached to a PWM generator that runs a boost converter. In order to receive a .1V ripple in the output what size of capacitor should we use? For the output resistor use a 10ohm resistor and a .1H inductor. Determine the value of the PWM switching frequency also.

In order to observe the behavior of the system running at the MPPT, we must now observe how the system behaves under different load resistances. Unlike before the system should not change the output of the solar panel but instead the output across the load. Run the system using the following resistors and report the values below, attach the resulting graphs. Would it be safe to run the system with these values in a physical system?

Resistor (ohms)	1500	1000	500	200	100	50	20	10	6
Voltage (volts)									
Current (amps)									
Power (watts)									
PV Power									

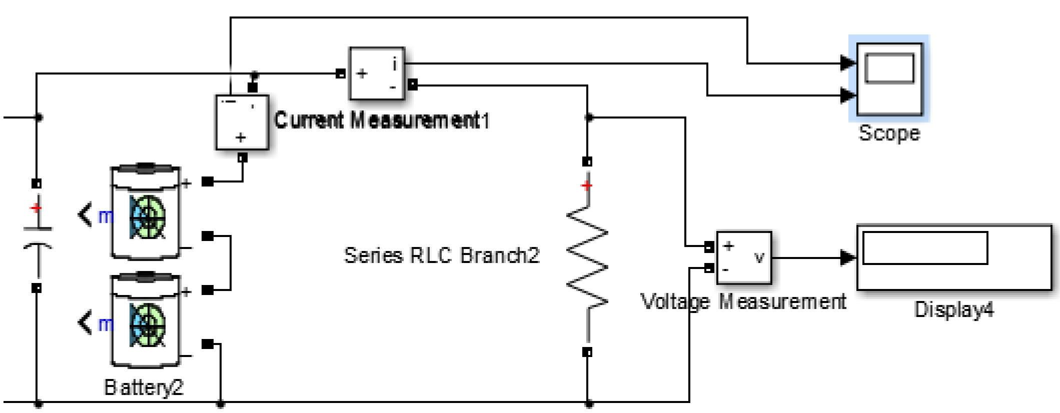
System with battery attached

Next we will attach a battery to the system, this is put in for system stability and to provide when our solar panels are not providing. In the Power Systems Library>Specialized Technology>Electronic Drives>Extra sources select the battery and insert it in the previous system.



Make sure that the settings match the ones in the previous pictures. By clicking the Deteremined from nominal parameters box we can have Matlab help us with simulating a normal battery. Once everything looks the same press apply and we will continue.

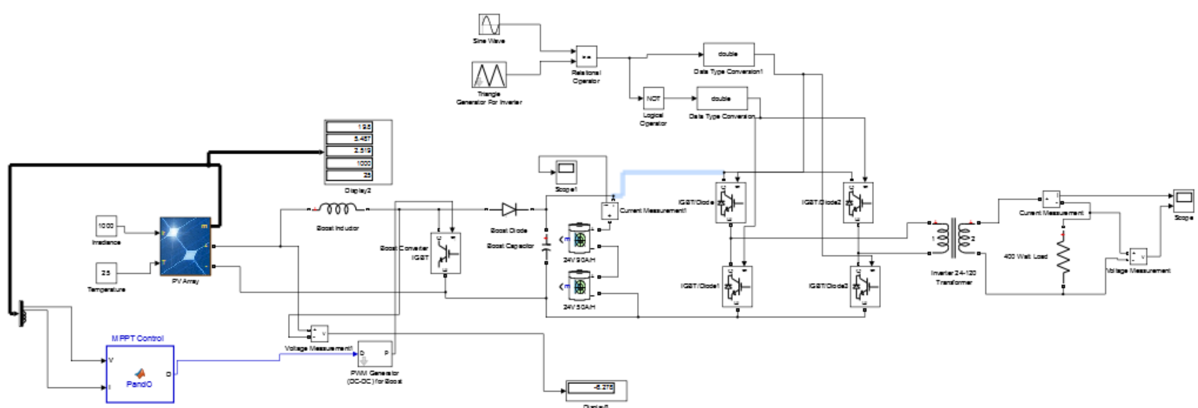
Because we are running the system with a boost converter we will need to keep the value of the output higher than that of the input. To do this we will insert two batteries in parallel to maintain a constant voltage of 24V. Although the value of the batteries can change a little, it should not go below the max value of the solar panels.



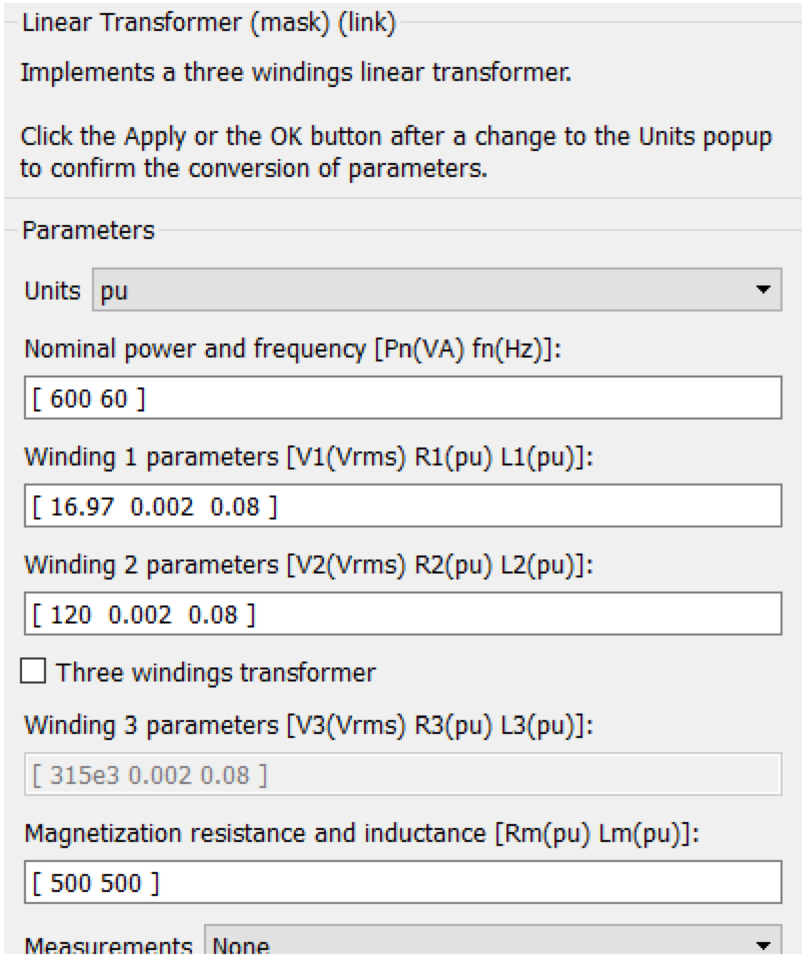
Insert the batteries with a current measurement to the right of the capacitor, as shown above. After the batteries are ready, we will now need to change the value of the resistor. Since we are maintaining a constant value of the output voltage we will now have a large change in current. We will monitor this current so that we can observe where in the system it is going. Change the value of the resistor to 2.4Ohms to observe a constant current of around 10A. Observe the behavior of the current across the battery, is the voltage going up or down? Repeat this with a resistor of the value 10Ohms, and observe the voltage. Report the previous graphs and voltage values.

System with Inverter

The last part of this lab is to attach the DC to AC components to our system. For this we will need to attach a 60Hz chopper with a transformer attached. This will allow us to take our DC voltage and convert it into a sine wave and then boost that sine wave up to a 120Volt AC value. The first thing to do is to recreate the 60Hz chopper as we have done in a previous lab. We will use the linear transformer block and the igbt/diode blocks from the power systems library.



Create the system as shown above with a 60Hz sine wave, and the triangle wave should be running at a good frequency no lower than 10^4Hz. For the transformer we must specify what voltage we will be stepping up from in order to properly get a 120V RMS output. Open up the block parameters box for the transformer and make sure everything matches the picture below.



Once everything is set up we need to run this system using different output resistances. Run the system to simulate from one to four 100watt light bulbs (144ohms) in parallel. Report the graphs of the system to show where the power flow in the system is happening. How much power can this system handle?

Conclusion

Write a short paragraph about what you learned in this lab and interesting points. If there was any major problems report them in this part.