TECHNICAL ANSWERS TO REAL WORLD PROBLEMS(TARP)

SOLAR NET-METERING PROJECT

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Objective: To create a system that can be efficiently used to power homes/offices using solar energy .

Components used:

1. PV Array: An interconnected system of PV modules that function as a single electricity-producing unit

2.Boost convertor: The buck boost converter is a DC to DC converter. The output voltage of the DC to DC converter is greater than the input voltage. The output voltage of the magnitude depends on the duty cycle.

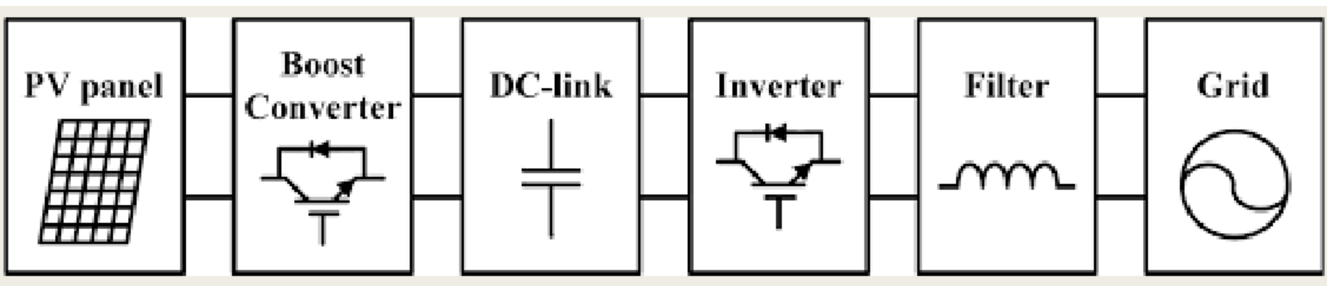
3.Microcontroller to adjust duty cycle of boost convertor

4.Single phase invertor: Used to convert DC input voltage to single phase sinusoidal alternating current. Made using mosfets.

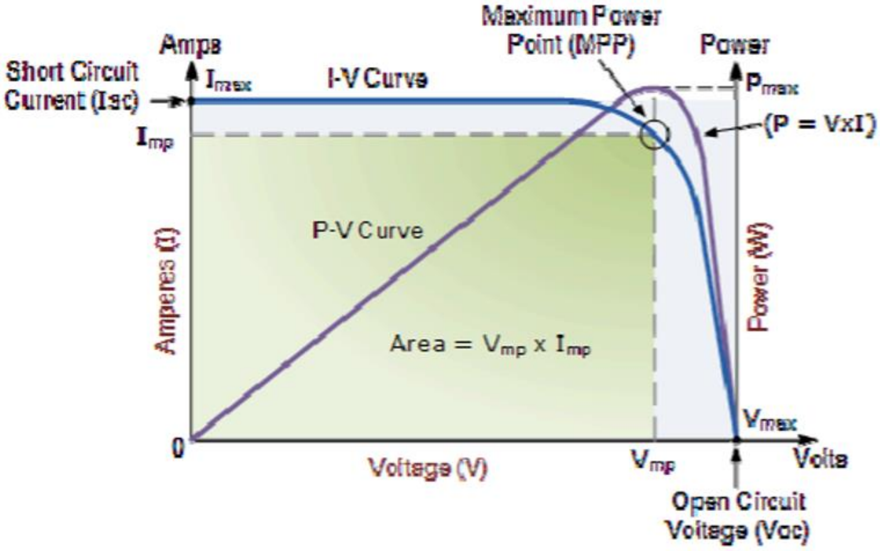
Overview of Net-metering:

Net metering (or net energy metering, NEM) is an electricity billing mechanism that allows consumers who generate some or all of their own electricity to use that electricity anytime, instead of when it is generated. This is particularly important with renewable energy sources like wind and solar, which are non-dispatchable (when not coupled to storage). Monthly net metering allows consumers to use solar power generated during the day at night, or wind from a windy day later in the month.

Circuit block diagram



Typical Characteristic curves of solar cell(I-V characteristics)



Maximum power point tracking Implementation:

Maximum power point tracking (MPPT) or sometimes just power point tracking (PPT)) is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions.

■ The MPPT charge controller ensures that the loads receive maximum current to be used by quickly charging the battery.

■ Maximum power point could be understood as an ideal voltage at which the maximum power is delivered to the loads, with minimum losses. This is also commonly referred to as peak power voltage.

■ The maximum power point (MPP) is the point on a current voltage (I-V) curve at which the solar PV device generates the largest power output i.e. where the product of current intensity (I) and voltage (V) is maximum on the I-V curve.

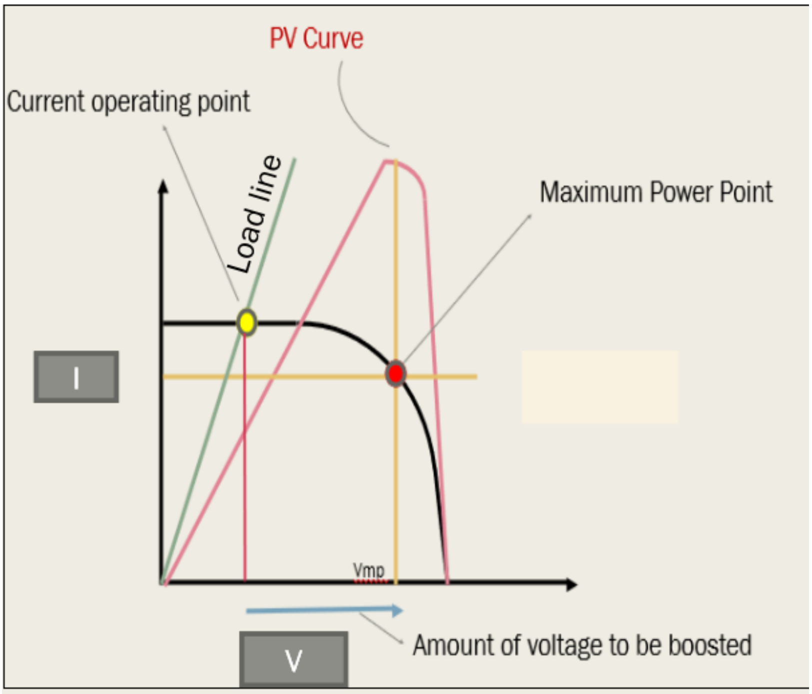
■ The MPP may change due to external factors such as temperature, light conditions and workmanship of the device.

■ In order to ensure maximum power output (Pmax) of a solar PV device in view of these external factors, maximum power output trackers (MPPT) may be operated to regulate the resistance of the device.

■ The output of Buck boost converter is controlled by the duty cycle of the switch in its circuit. This duty cycle is decided by the MPPT controller which takes into account the current, Voltage,Voc,Isc as inputs. The output voltage of convertor can be found out using formula:

$V_{out}=V_{in}/(1-d)$

Where d is duty cycle of switch in convertor.



When voltage needs to be boosted

Billing Mechanism: Net-Metering

■ The energy generated from Solar Rooftop System shall be adjusted against the consumption of energy from the DISCOM by an eligible developer/consumer every month. In case of groups/societies, the energy generated shall be prorated as per the installed capacity share indicated in the Agreement between the group/society and DISCOM. This computed energy share shall be adjusted against the consumption of energy for each consumer every month.

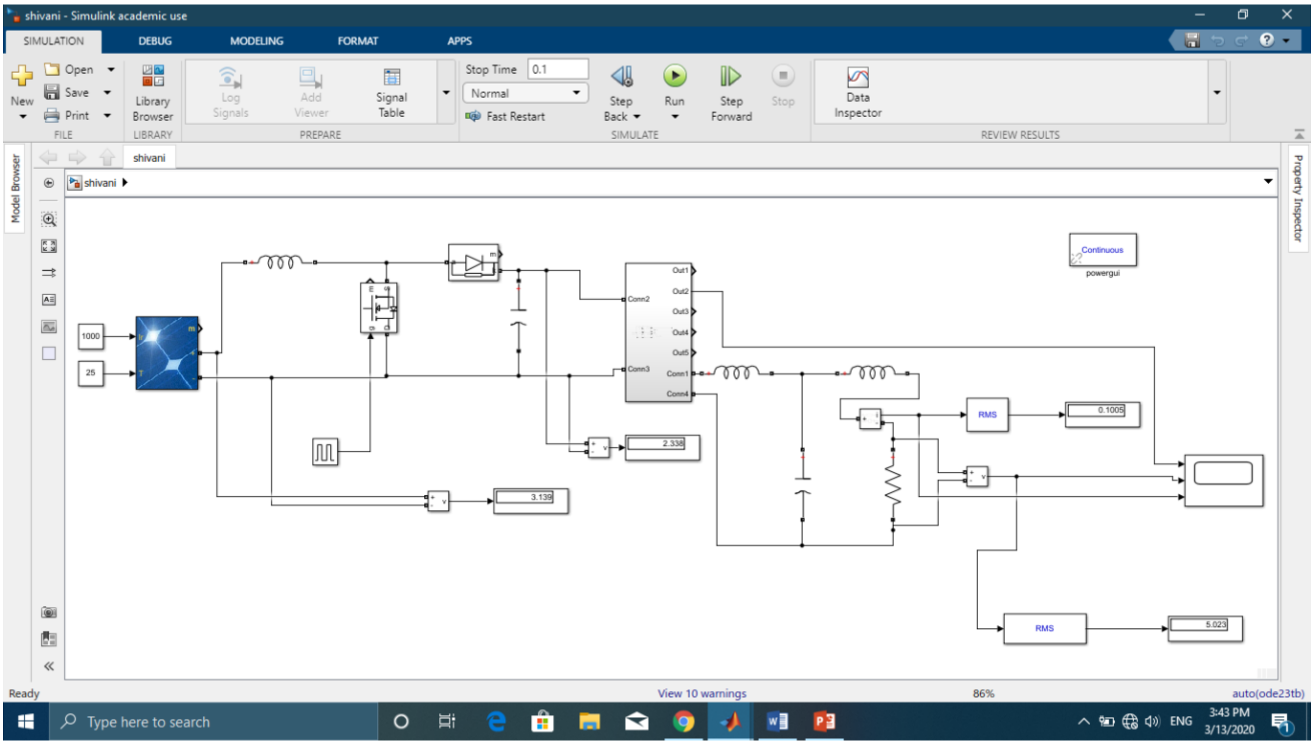
■ In case of excess generation (after energy adjustment) injected into DISCOM network in a billing month will be carried forward to the next month till every quarter end and settlement will take place on an Average Cost of Supply (ACOS) basis for net metering as determined by APERC from time to time .

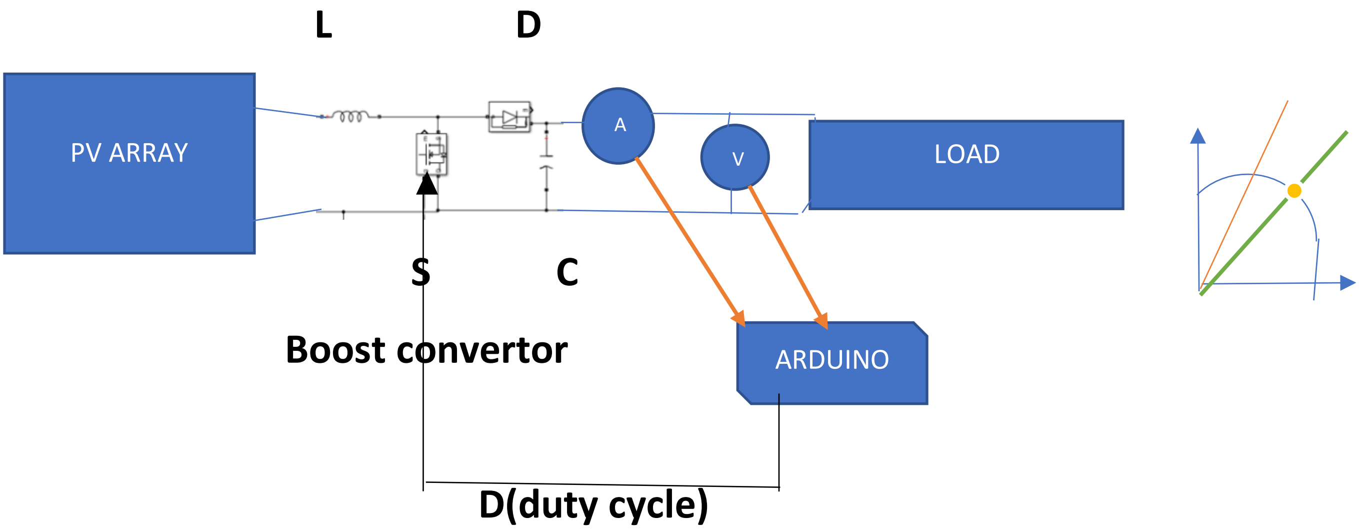
Net power consumed=Power from grid + power from solar panel

Power from grid = Net power consumed - Power from Solar panel

Total cost = cost per unit* units of net active power consumed

Basic Circuit Diagram and Explanation:



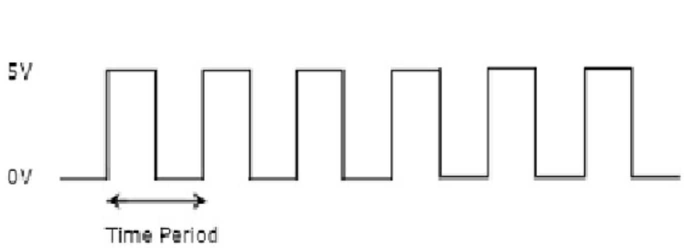


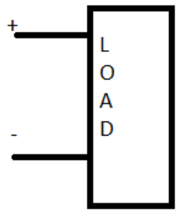
At a particular irradiance and temperature level ,I-V characteristics of a PV array are known and Imp and Vmp viz current and voltage corresponding to maximum power point are known. House load changes with time. This causes the load line to change and operation point changes. For extracting maximum power from solar panel, we want out circuit operating point to be same as maximum power point. This can be achieved by changing the duty cycle of boost convertor suitably ,so that effective resistance seen by the PV panel is same as Vmp/Imp. The output load resistance is continuously changing ,so corresponding to it,duty cycle is changed. The current RL(load resistance) is measured using current and voltage sensors.Using RL and Rmax(Vmp/Imp), duty cycle is calculated by microcontroller and pulses are given to mosfet in boost convertor.

Sine wave PWM Inverter.

PWM: pulse width modulation.

Let’s take an 5v , 50% duty cycle signal.



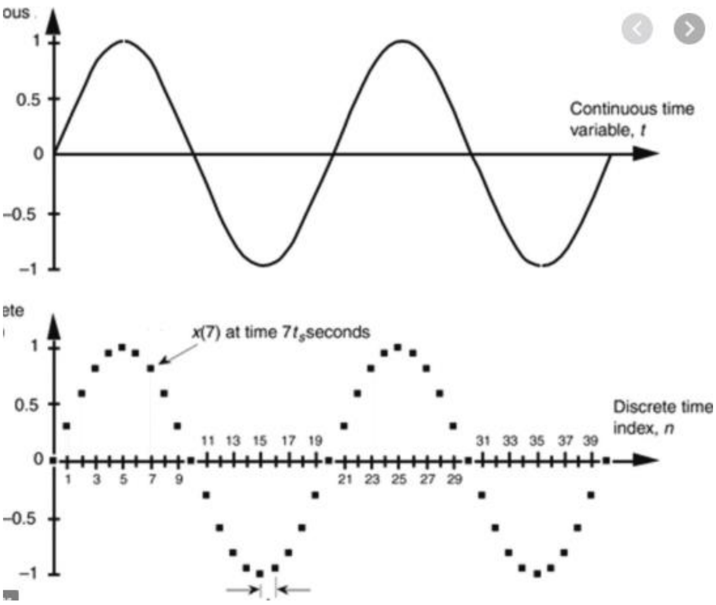


Vout = 0.5 x Vin
= 0.5 x 5
= 2.5v

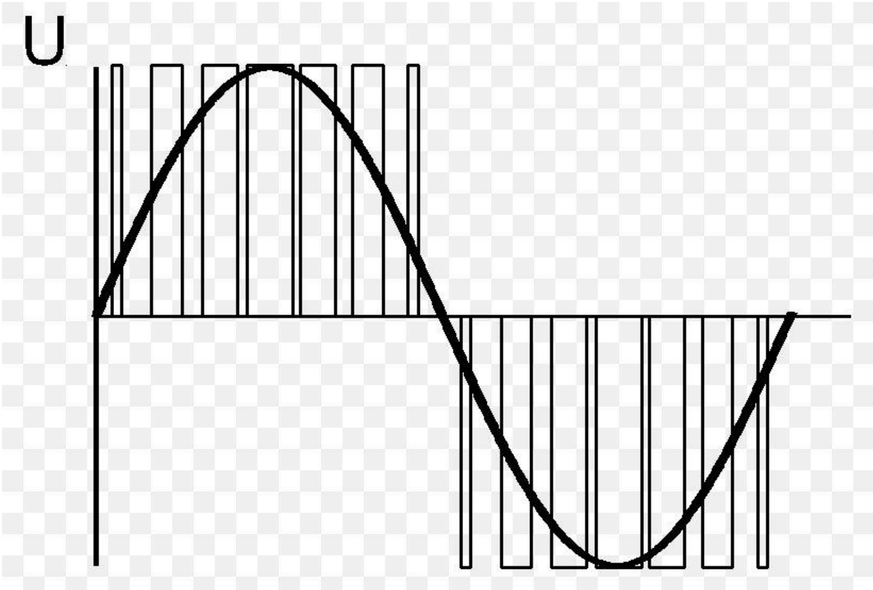
Load experience only 2.5v

The concept of pwm is used when there is a requirement of variable voltage.

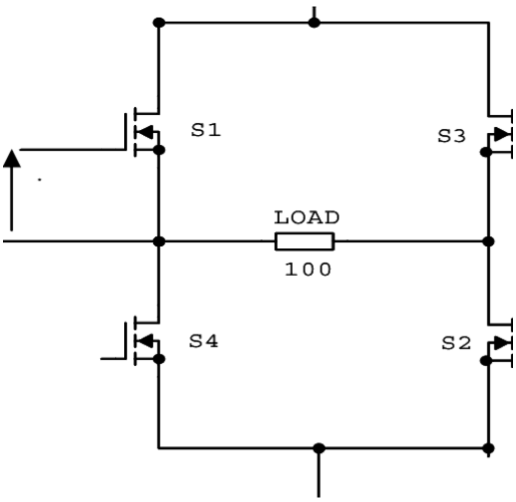
Let’s take the sinusoidal voltage source. As the time changes the voltage is also varying.



The idea here is to use the concept of pwm and duty cycle. **As the time changes the duty cycle is varied to get the required voltage.**



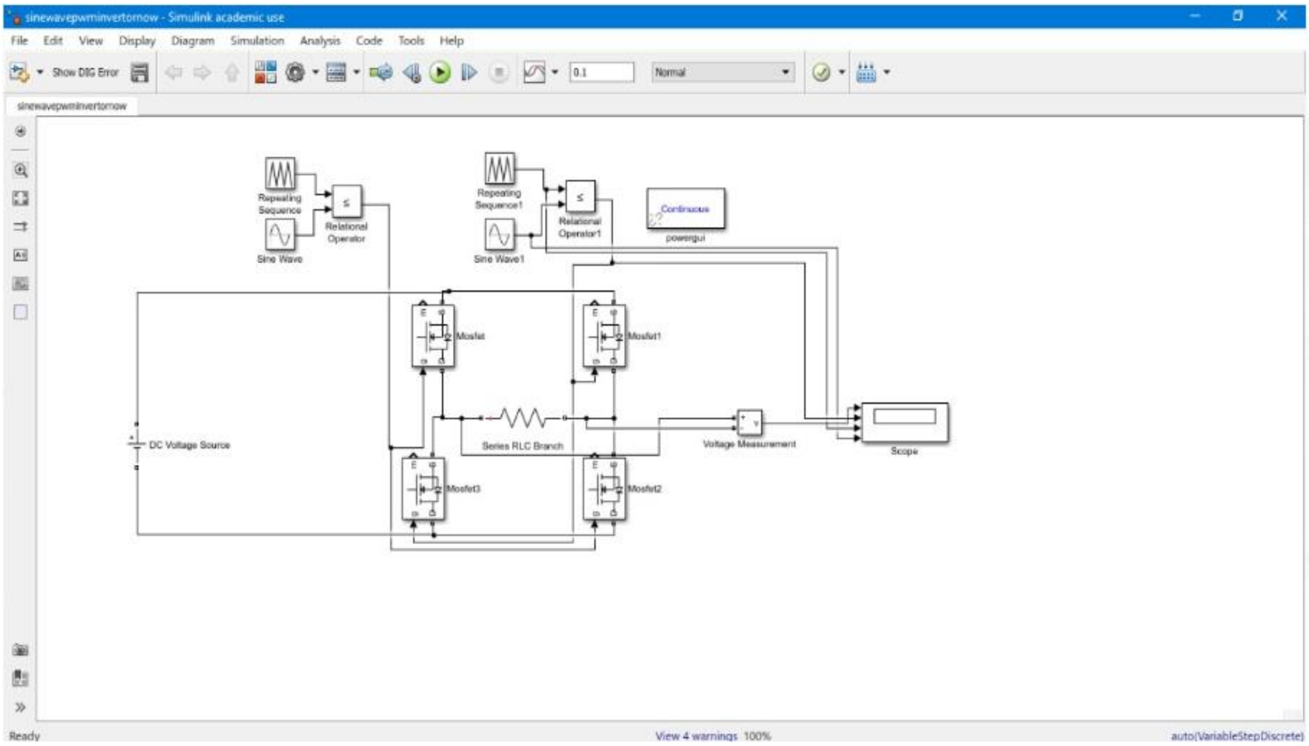
To get the sinusoidal AC from the solar panel DC output. Single phase inverter circuit was used.



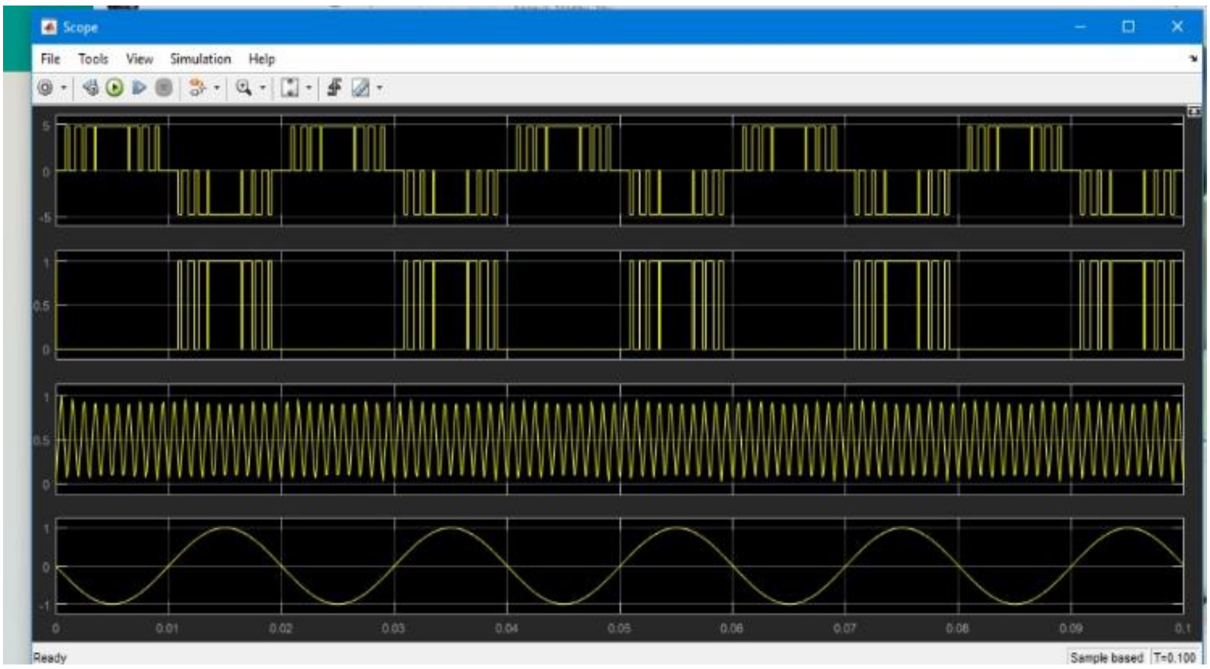
S1 and s2 are switched on and off together , S3 and s4 are switched on and off together .

When S1,S2 are switched on the out voltage is +ve. When S3,S4 are switched on the out voltage is -ve.

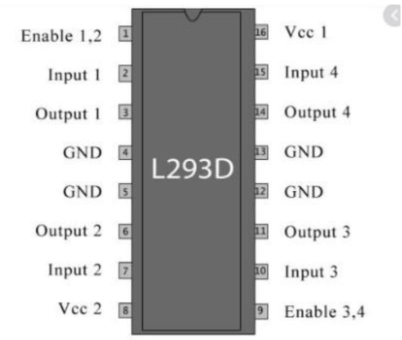
MATLAB MODEL:

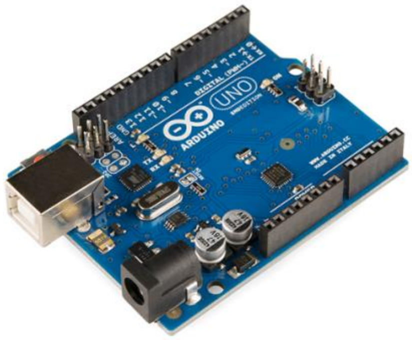


OUTPUT:



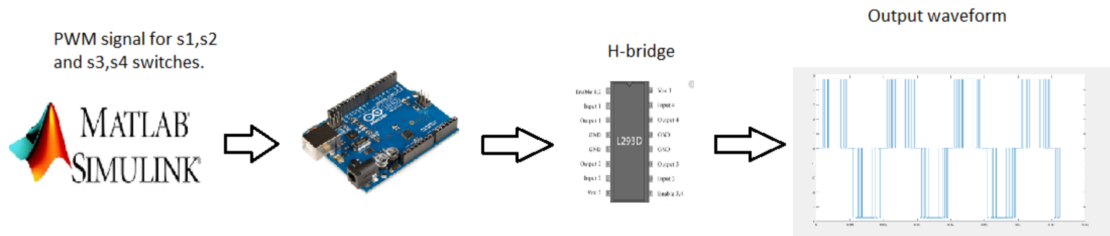
Hardware implementation of pwm inverter concept.



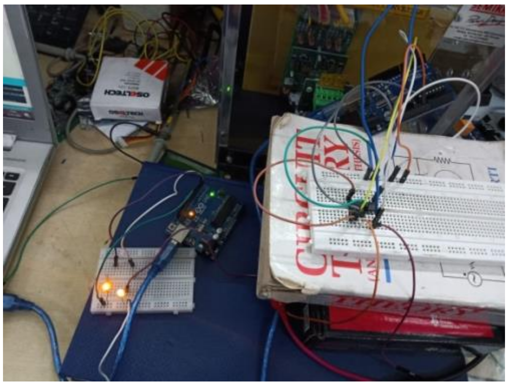


L293D Ic is a motor driver. Which has H-bridge circuit inside.

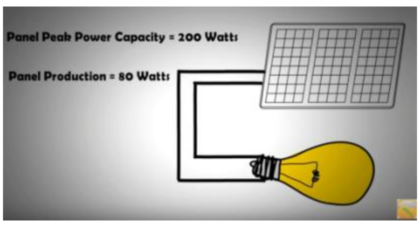
Block diagram:



Pictures of the experiment performed in the Solar research lab, VIT.



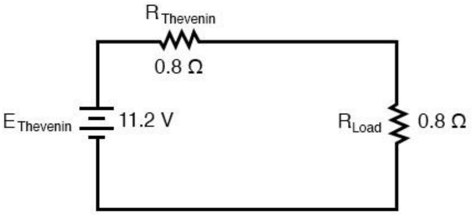
Experiment on extracting maximum power from the solar panel.



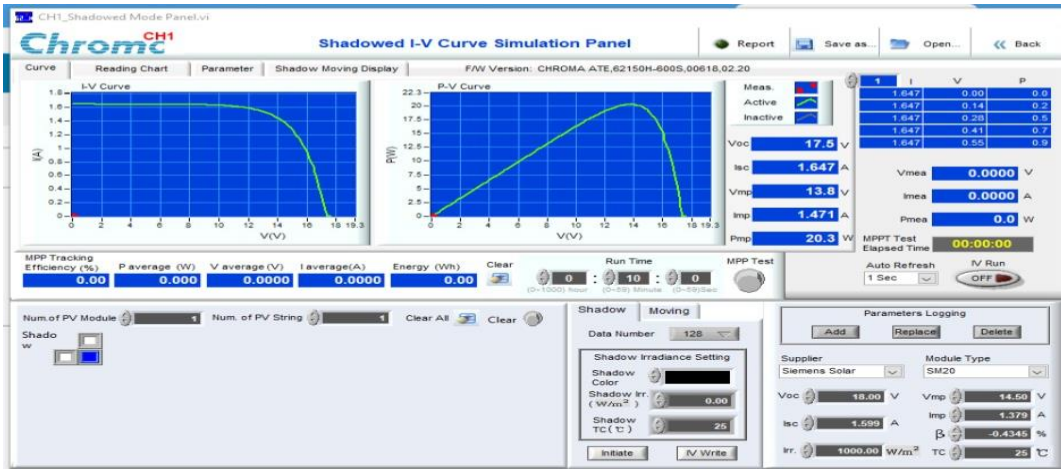
In this case the solar power is underutilized.

According to **Maximum power tansfer theorem**.

Load resistance = Source internal impedance.



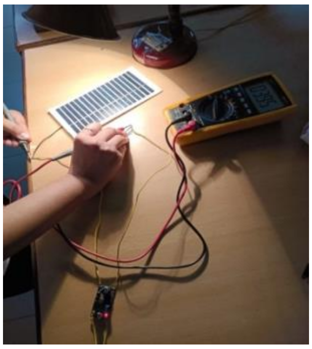
Solar emulator is used to set the desired irradiance, temperature for a solar panel.



Solar panel with maximum power of 20.299watt was selected in the emulator.
Vmp = 13.8v Imp = 1.471A
R(LOAD) = Vmp/Imp
RL = 9.38Ohms.

A rheostat was connected to the terminal of the solar emulator and adjusted the resistance to 9.38ohms. The output power was = 20.3watt.
So, we were able to get the maximum power out of solarpanel.

Experiment with the boost converter and of DASOL BPL Solar Panel (Pmax=1.3W,Vmp=7.5V) to get the maximum power.

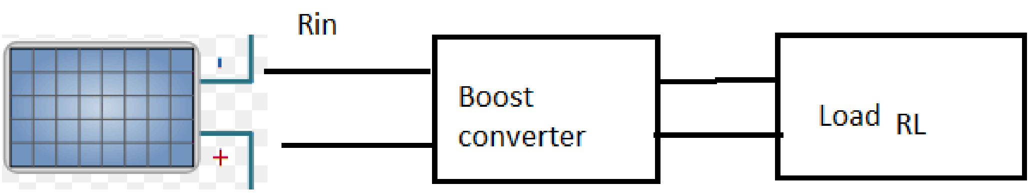
 

Irradiance was given by sodium vapor lamp.

Duty cycle was varied using a potentiometer to achieve maximum power point on PV-curve.

Because the Irradiance was unkown , maximum power corresponding to the sodium vapour lamp irradiance was also unkown. But as we were changing the dutycycle the power output of the solar was changing. It was measured using multimeter.

In the real world scenario the load will be varying , the load line will not cut the pv curve at maximum power point. We need to vary the boost converter duty cycle in order get achieve the maximum power.



Rin is the resistor that solar panel experiences.

$Vo = Vs/(1-D)$

Considering boost converter is 100% efficient.

Pin(Solar output) = Pout(Boost converter output)

$Vo^2/ R_L = Vs^2/Rin$

$(1/(1-D))^2 = R_L/Rin$

$D = 1 – \mathrm{sqrt}(Rin/R_L)$

We know the value of Rin, Rin should always be equal to Vmp/Imp to achieve the maximum power . As the load varies Rin also changes but by changing the Duty cycle we can keep Rin constant.

Why LCL filter?

The output of solar PV array is of DC nature, so it can't be integrated directly to the grid. As, the grid utility requires constant AC voltage and constant frequency to synchronize with rest of the system.

Therefore, Converter has been employed across the PV array for the conversion of DC into AC.

But due to the switching action of the conversion, harmonic distortion has been observed in the system.

Issues we face with Total Harmonic Distortion(THD):

- It distorts the output waveform of voltage and current
- Increased losses
- Thereby, reducing the quality of the output power
- Also, reduces life of the equipment

In order to deal with such issues, either the level of the inverter can be increased or any filter can be used after the inverter.

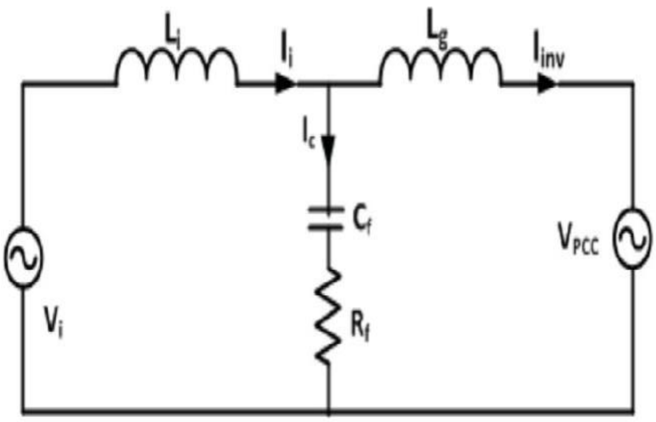
Simple type of filter can be used .i.e., series inductor but:

- their harmonic attenuation is not very pronounced.
- High voltage drop is produced resulting in the bulkiness of the inductor.

We have used LCL filter to serve the purpose because of the following reasons:

- Higher attenuation along with cost savings
- Overall weight and size reduction of the components
- Good performance can be obtained using small values of inductors and capacitors

LCL Filter Modeling



Model of LCL filter

L_i=Inverter side inductor

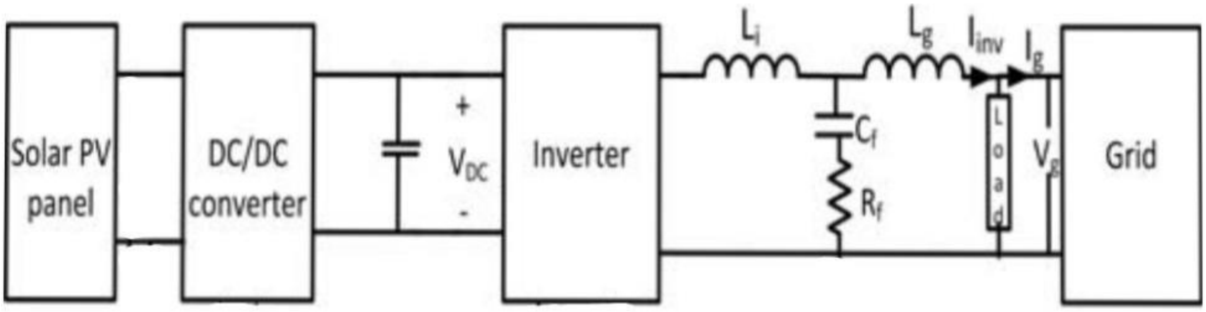
L_g=Grid side inductor

C_f=filtering capacitor

R_f=damping resistor(to avoid resonance)

V_i=voltage across inverter

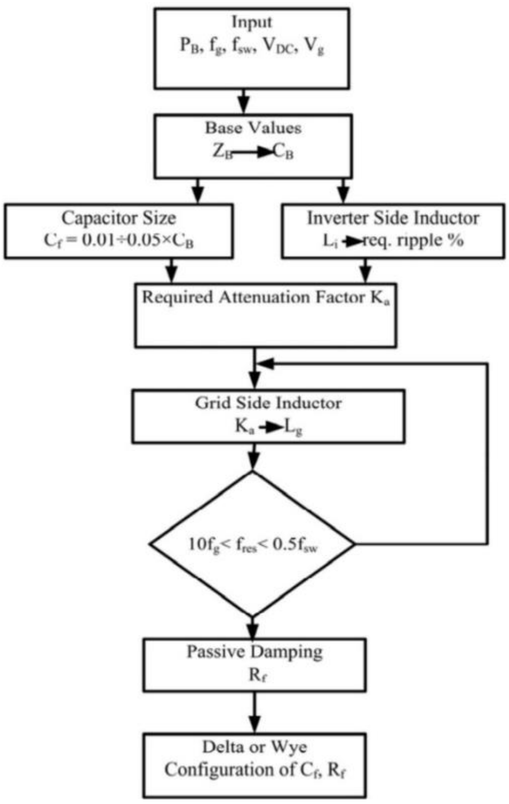
V_{PCC}=grid voltage



General schematic for grid-interconnected dc power source

Filter Design Procedure

- Several characteristics must be considered in designing an LCL filter such as current ripple, filter size, and switching ripple attenuation.
- The reactive power requirements may cause a resonance of the capacitor interacting with the grid.
- Therefore, passive or active damping must be added by connecting ting a resistor in series with the capacitor.



LCL Filter Design Flowchart

The following parameters are needed for the filter design:

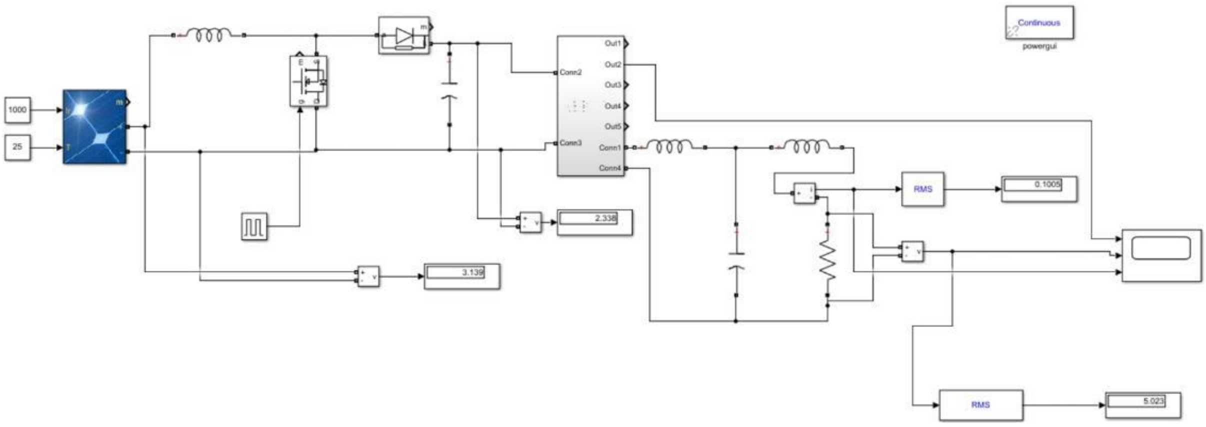
- RMS voltage(inverter output)
- Rated active power
- DC-link voltage
- Grid frequency
- Switching frequency
- Resonance frequency

With all the specifications, we have got system parameters (theoretically) as the following:

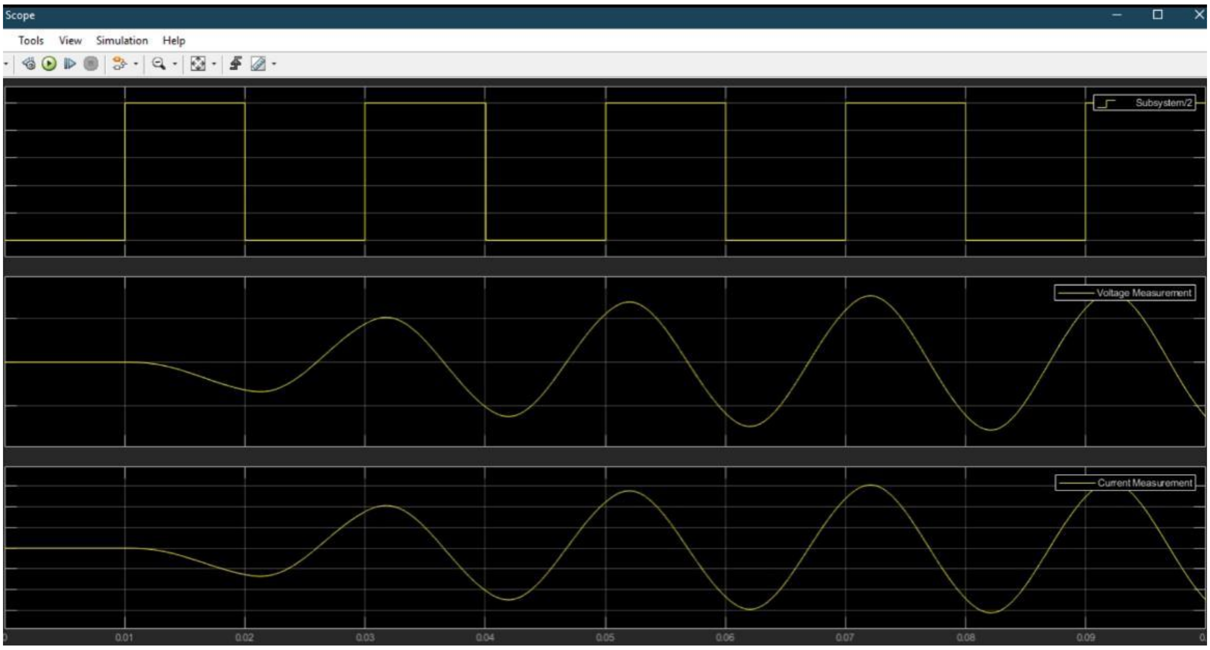
System Parameters	Name	Value
f_g	Frequency of utility grid	50H
f_{SW}	Carrier frequency of PWM inverter	10kHz
P_B	Active power rating of solar PV	6kW
V_g	Voltage of utility grid	230V
V_{DC}	Inverter input voltage	500V
L_i	Inductor of inverter side	6.77mH
L_g	Inductor of grid side	0.25mH
C_f	Filter capacitance	6uF
R_f	Damping resistor	2.11ohm

Table of System Parameters

Simulation in the MATLAB Simulink



Simulation Results



Conclusion:

We were able to simulate solar net metering system in Simulink and verify the results using physical hardware components also.

References:

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