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SUMMER RESEARCH FELLOWSHIP-2022
8-WEEK REPORT

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Guide's Signature

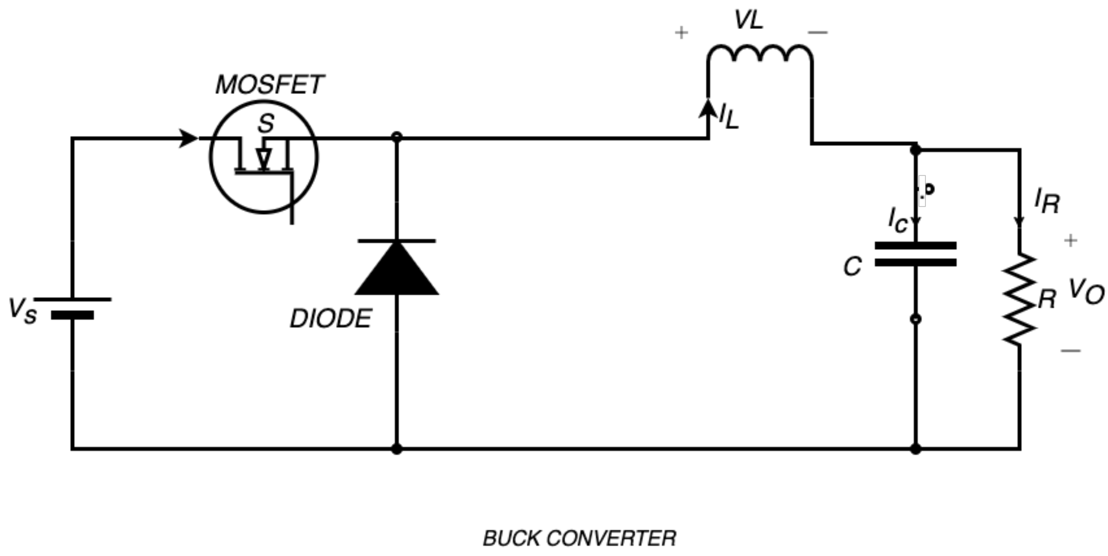
-TABLE OF CONTENT-

TITLE- UNDERSTANDING THE CONCEPT OF DC-DC CONVERTERS

I initiated my work with the literature survey part where I understood how important are these DC-DC converters. As these DC-DC Converters, can help in to improve the circuit's efficiency, ripple, and load-transient response. I further stepped into its types where I explored the differences between Isolated and Non-Isolated type of DC-DC converters. Under Non-Isolated converters I introspected the following converters: -

- Buck converter

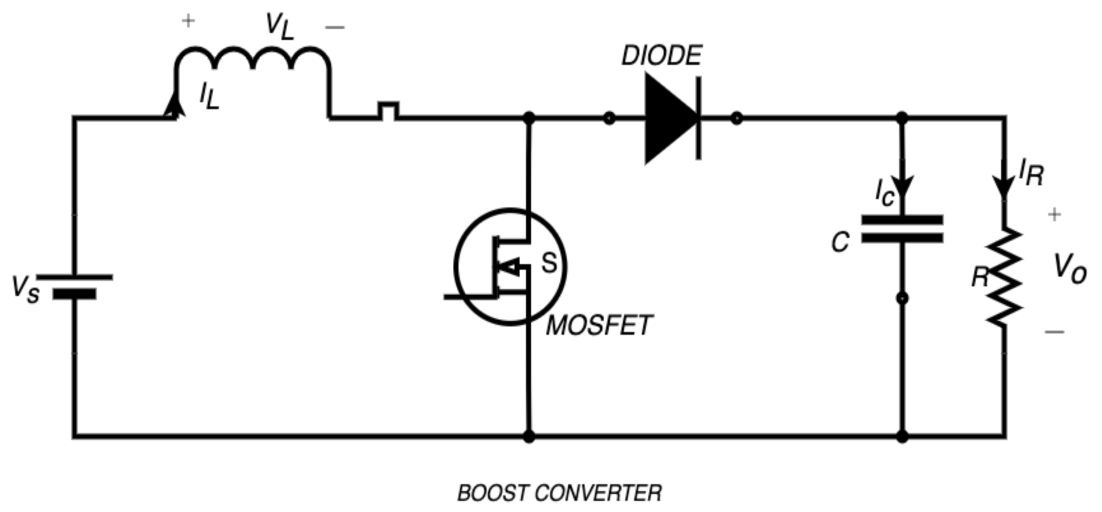
A Buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage from its input (supply) to its output (load) as shown in fig(a). This is an a replacement for linear regulators with comparatively very high efficiency.



Fig(a) Buck Converter

- Boost converter

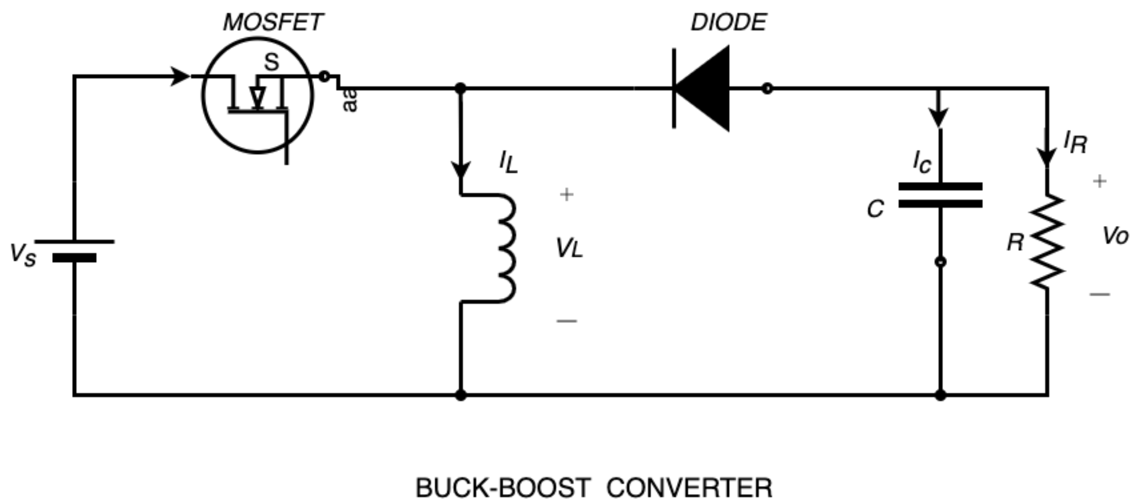
A Boost converter (step-up converter) is a DC-DC converter that steps up voltage (while stepping down current) from its input (supply) to its output (load), as shown in fig(b)



Fig(b)Boost Converter

- Buck-Boost converter

The Buck–Boost converter is a type of DC-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. As shown in fig(c).
It can perform the role of both buck and boost converter, but the output is inverted.



Fig(c) Buck-boost Converter

-MATLAB SIMULATION-

- After understanding how they work, I simulated them on MATLAB platform to get a better understanding about it's working and the waveforms. I designed the converters for a given set of values of V_s, V_o, Load power, and switching frequency and theoretically calculated values for the duty cycle, inductor and capacitor that will operate the converter in Continuous Conduction mode (CCM) or Discontinuous Conduction mode (DCM).
- While simulating, I understood about the concept of critical Inductance, critical capacitance, and boundary condition and how they are related to duty cycle, switching frequency, voltage and current ripple. Thereafter I noted the use of inductors and capacitors in all these converters.
- I discovered why we use DC-DC Buck converters and not just linear regulators (efficiency is very low as maximum energy is dissipated as heat) Basically, there are 2 types of Voltage regulators, Linear regulator and Switching regulators. These switching regulators are also called switched mode power supply (SMPS) and DC-DC converter is an example of SMPS. For switching voltage regulators, as we are providing switching, we will come across ripples that we have to remove using filters. We prefer LC filters to remove these ripples. Greater the switching frequency, lesser value of L and C is required.
- The simulation helped me to understand that the role of inductor is not only to limit current but also to store energy. Without inductor we will get a higher ripple current as the current is only supplied for a fraction of the cycle, whereas with an inductor the current can be supplied continuously. Hence ripple will reduce. Explored about the reason why MOSFET's are used here and not IGBT's. Also understood their differences and for what applications these switches are used.

I completed the MATLAB simulation for all these converters and my theoretical results were matching with my simulated results.

-MATLAB SIMULATION-

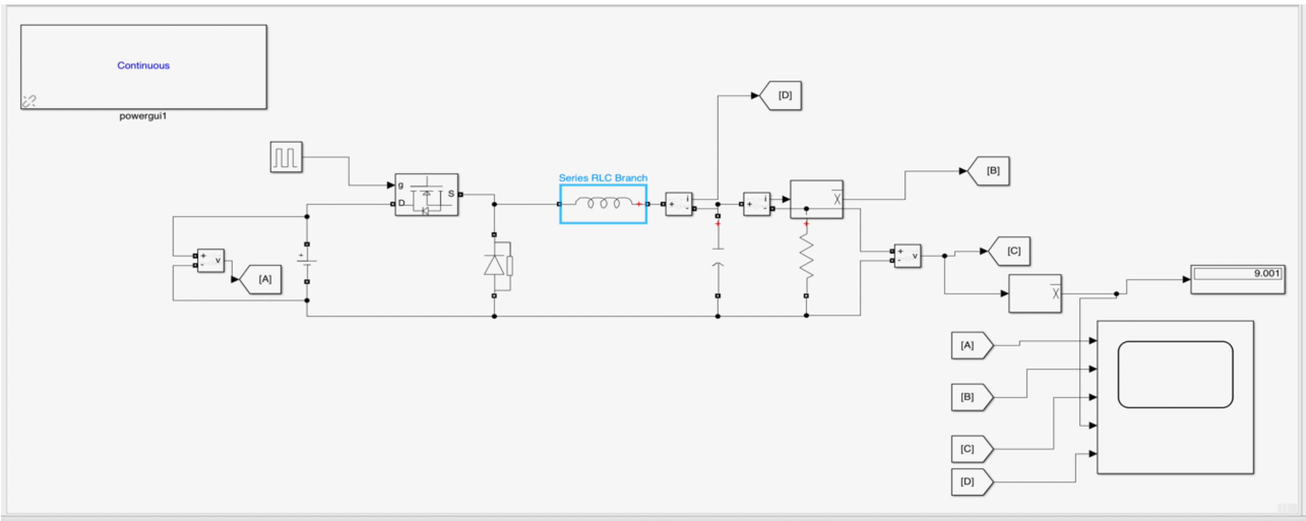


Fig- BUCK CONVERTER

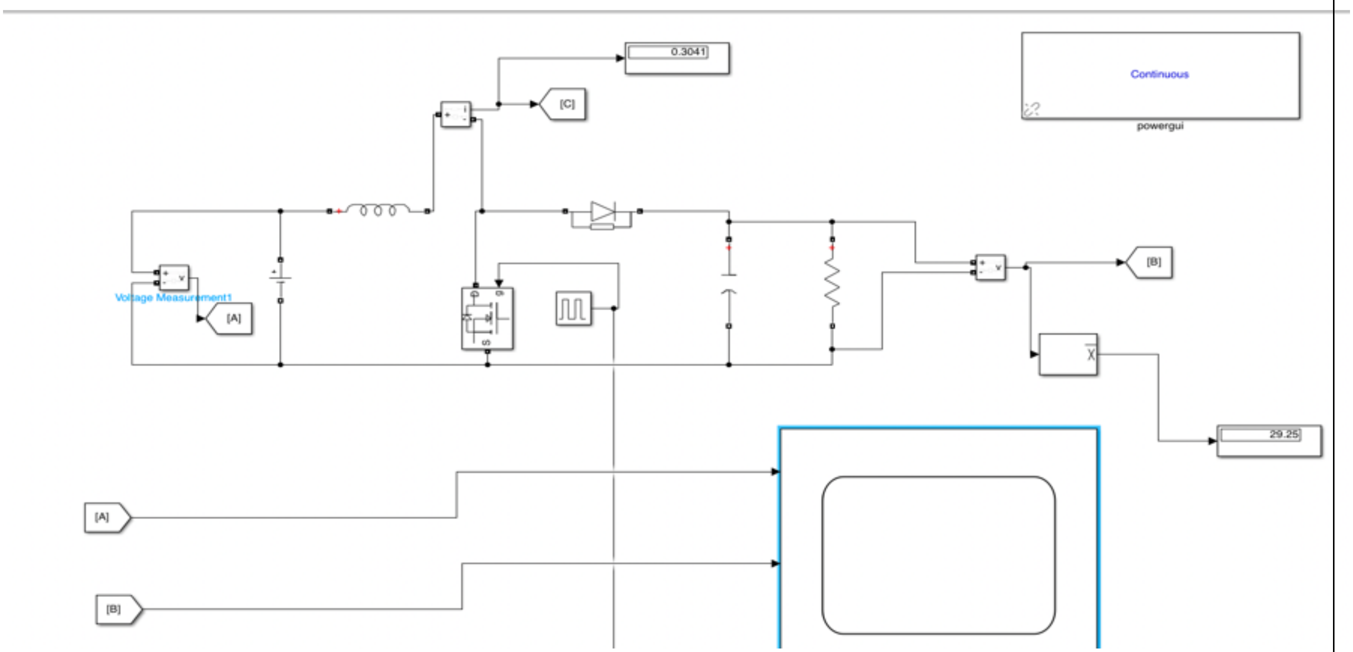
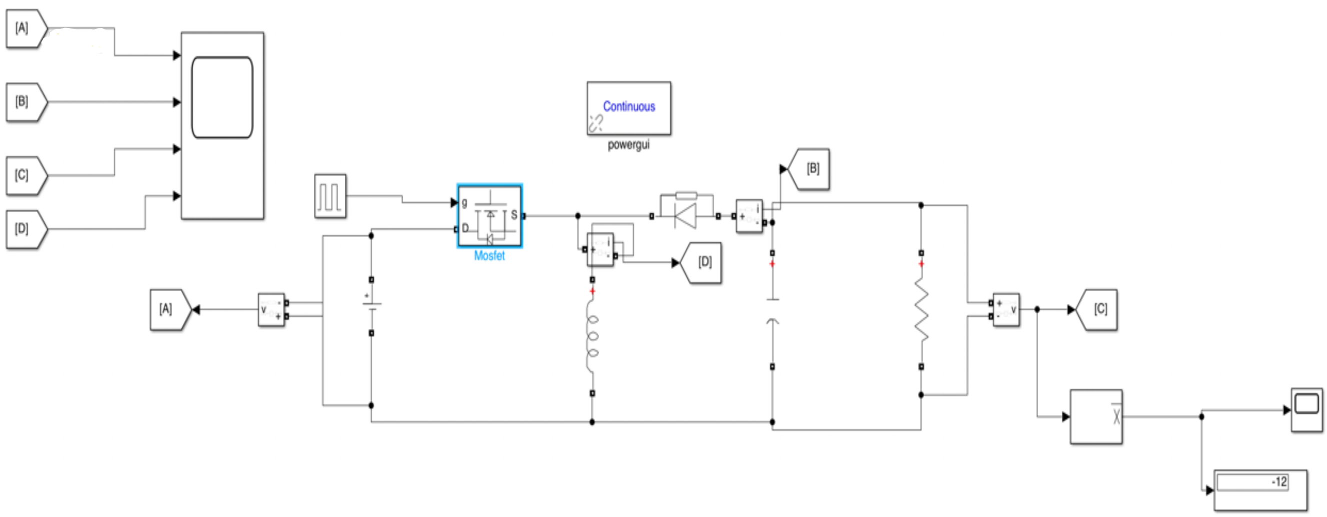


Fig- BOOST CONVERTER



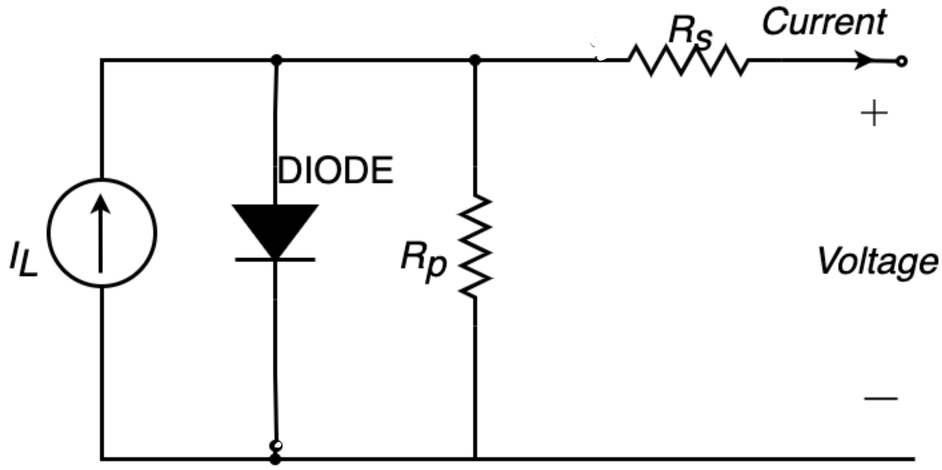
BUCK- BOOST CONVERTER

Design Parameters: -

Parameters	Buck	Boost	Buck-Boost
Critical Inductance	$62.25\ \mu H$	$96\ \mu H$	$45 \mu H$
Critical Capacitance	$100\ \mu F$	$48\ \mu F$	$100 \mu F$
Voltage Ripple	5%	5%	5%
Duty cycle	0.5	0.6	0.6

-PV CELL MODELLING-

After exploring these non-isolated converters, I jumped to understand the basic modelling of PV cell as shown in fig (d). I dipped in to understand why it has a diode, a Series resistor and a Parallel resistor in its model. I also crafted the mathematical modeling of a PV cell on MATLAB platform. Also learnt to use software's like Inkscape, Visio and Draw.io to draw my own circuit diagrams.



Fig(d) - PV CELL MODEL

I came across with terms like Fill Factor and tried to understand how it is different from efficiency. I tried to understand the significance of higher Fill Factor, how it is dependent on Shunt resistance and Series resistance. I also tried to understand the significance of these resistances.

The building block of PV technology is the PV cell, which is a specially designed p-n junction (or multiple junctions for multilayer PV cells) using a semiconductor material.

PV CELL MODELLING:

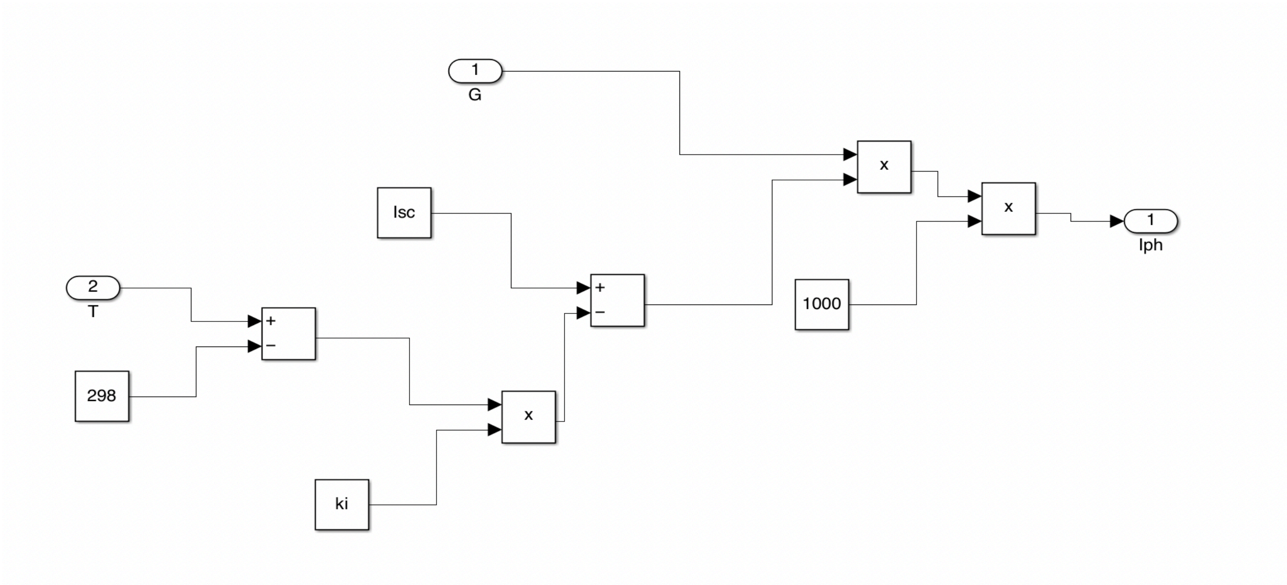


Fig- Photo Current

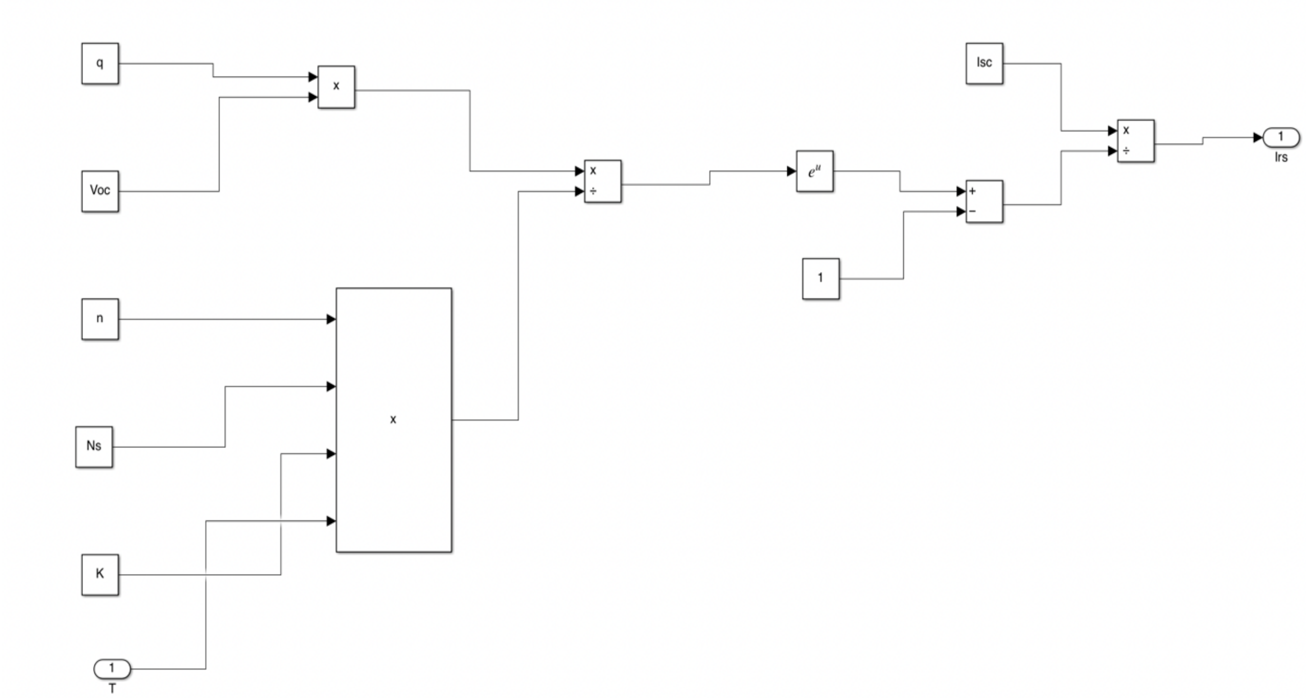


Fig- Reverse saturation Current

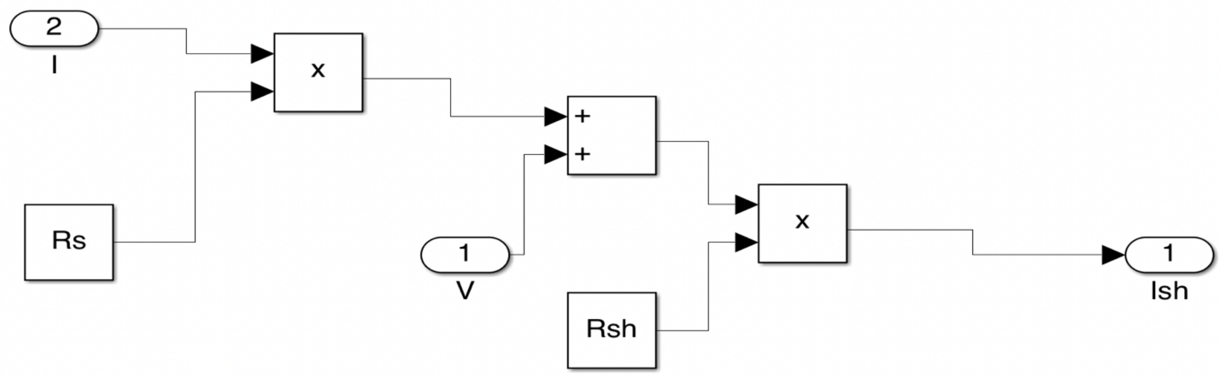


Fig- Shunt Current

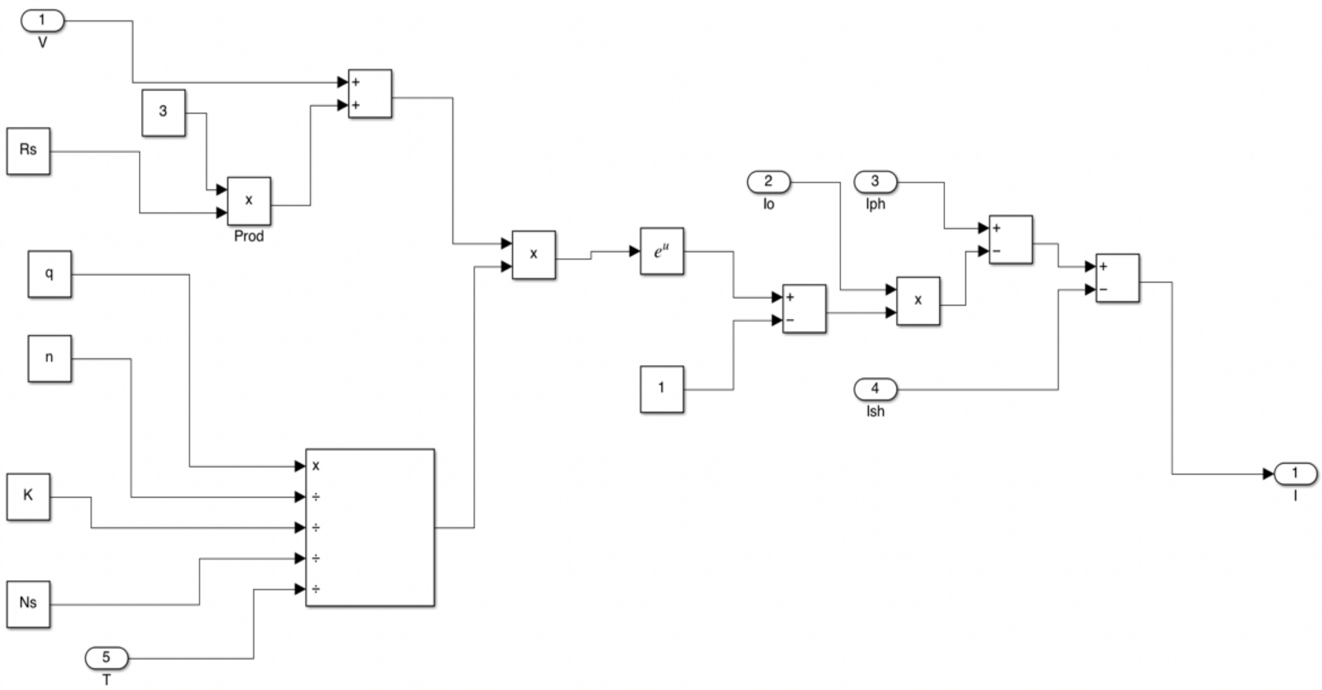


Fig- Saturation Current

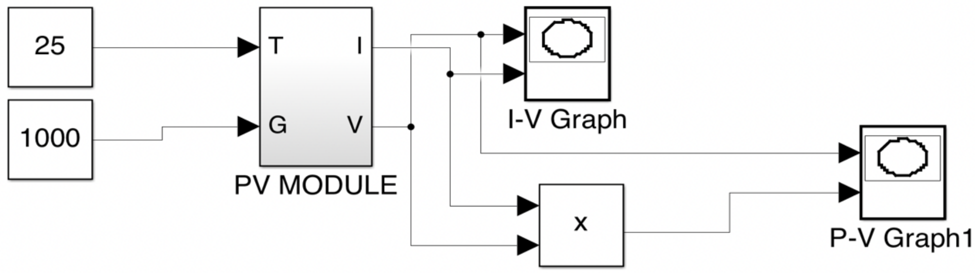


Fig- Complete Circuit

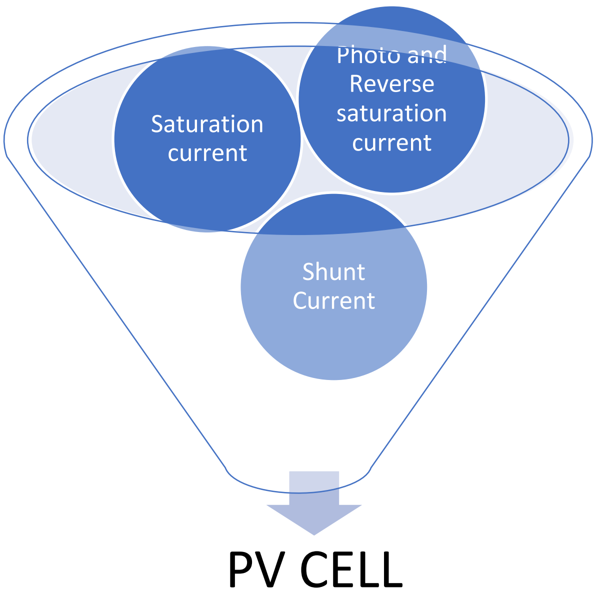
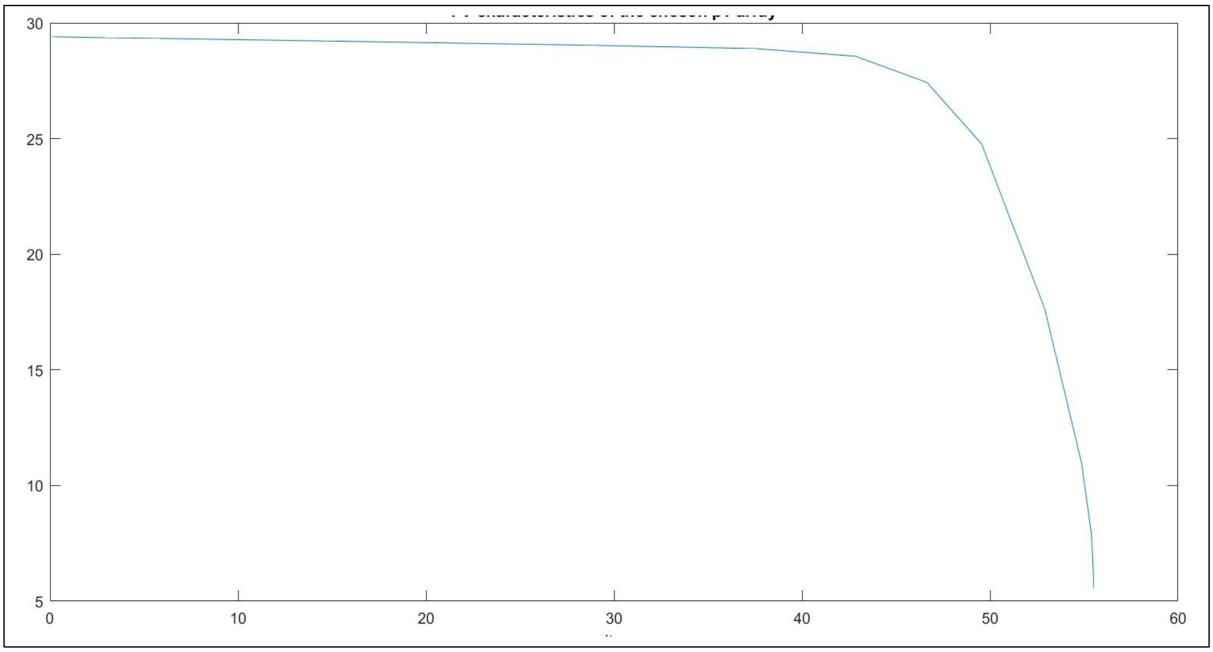


Fig- PV Mathematical Modelling

I-V GRAPH

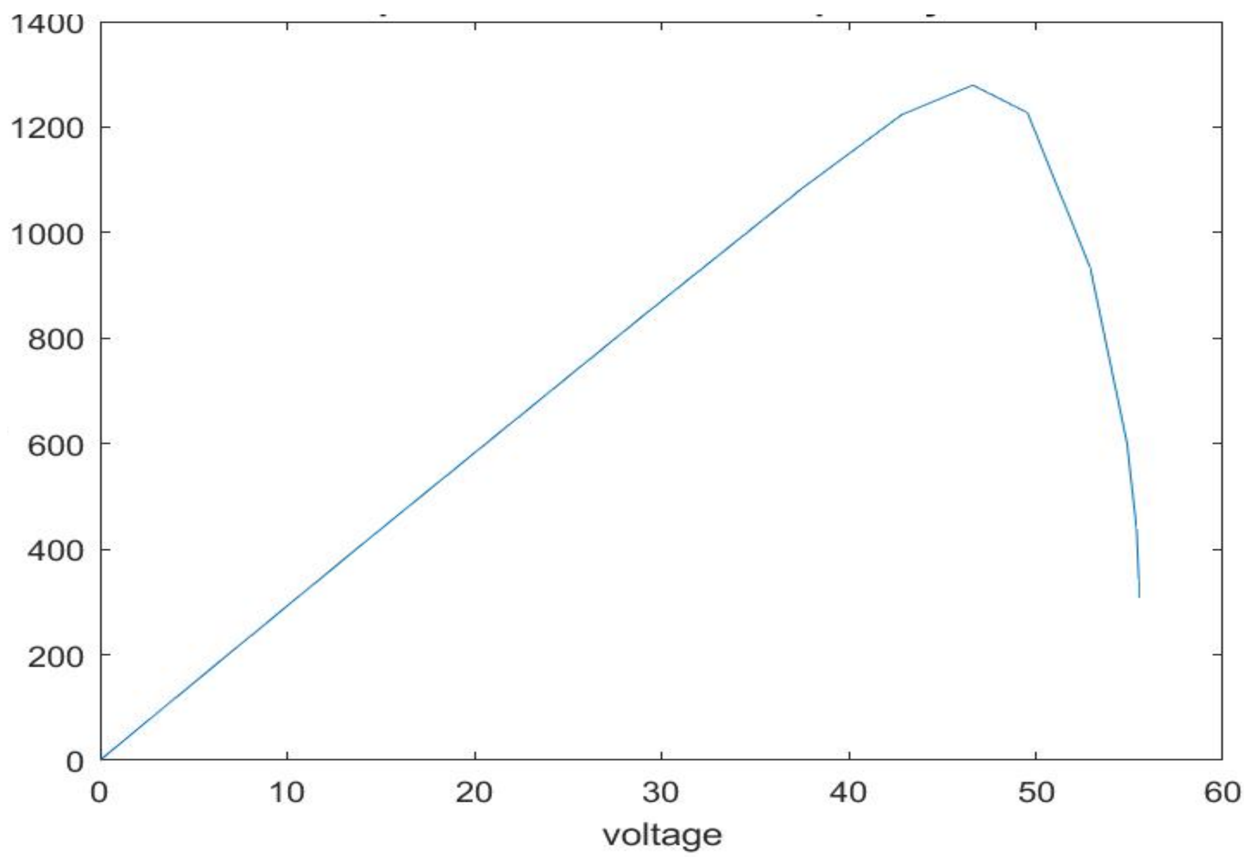
Current(A)



Voltage (Volt)

P-V GRAPH

Power(W)



-MPPT USING BUCK, BOOST, BUCK-BOOST-

Firstly talking about PV technology, It is capable of converting sunlight directly into electricity. The building block of PV technology is the PV cell, which is a specially designed p-n junction (or multiple junctions for multilayer PV cells) using a semiconductor material. In order to produce more useful power and voltage, multiple cells are combined into modules, multiple modules are combined in series/parallel arrangements into array. Series combination will increase the array voltage, but comes with performance and reliability penalties. Parallel combination of PV modules requires each module to be maintained at the same voltage. This will be accomplished by the DC-DC converter, which will determine the operating voltage of the PV array based on the MPPT algorithm.

This efficient maximum power point tracking (MPPT) method plays an important role to improve the efficiency of a photovoltaic (PV) generation system.Here I will be sharing about the impact of these DC-DC converters on PV systems

The basic function of DC-DC converter in PV system is like intermediate power processor which changes the current and voltage levels such that maximum power can be extracted from the PV array. Changing voltage and current level is nothing but converting a given fixed load to a variable load. In order to achieve Maximum power transfer in this case, our load resistance must be equal to the PV system's resistance.

While comparing among Buck, Boost and Buck-Boost Converter, I will opt Buck-boost converter as its advantage lies in the ability to buck and boost based on the duty cycle ratio. By pairing these up with a feedback loop, we can retain a constant output voltage with varying input voltages (high or low). With the help of buck-boost converter we can have wide range of load operating for the PV system.

The clear disadvantage (in case of sources like solar panels) is that they are discontinuous current converters which means that they draw current discontinuously from the source which means that the capabilities of the source are limited by the converter.

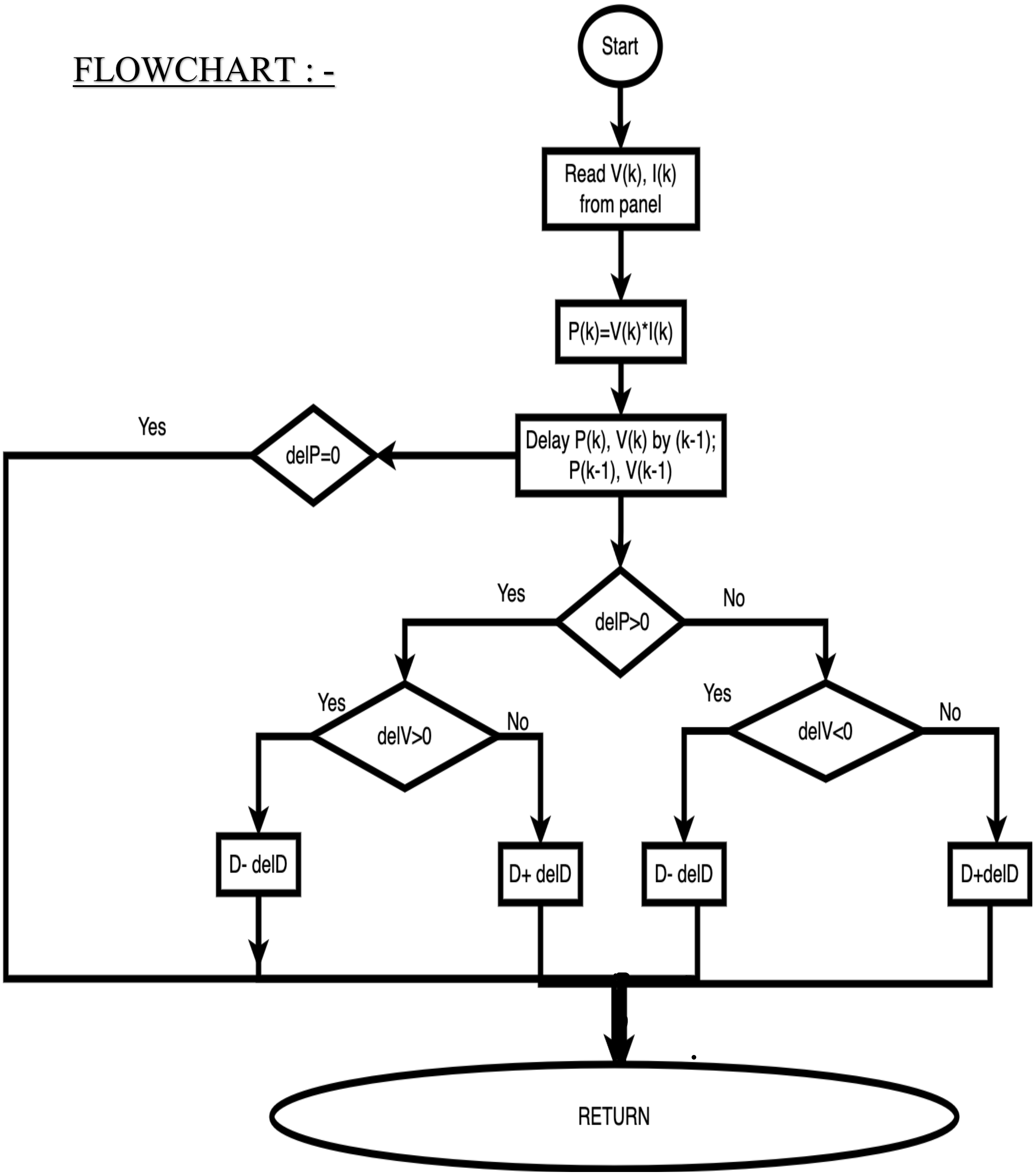
The advantage of Buck or Boost converter is that, they step down or step up the input voltage respectively with better efficiency without getting inverted, compared to buck-boost converter.

For MPPT we used P & O algorithm and I.C algorithm and did a basic study about these algorithms.

P & O ALGORITHM-

As we know, P&O method is used for tracking the MPP. In this technique, a minor perturbation is introduced to, cause the power variation of the PV module. The PV output power is periodically measured and compared with the previous power.

FLOWCHART : -



If the output power is increased, the same process is continued otherwise perturbation is reversed. In this algorithm perturbation is provided to the PV

module or the array voltage. The PV module voltage is increased or decreased to check whether the power is increased or decreased. When an increase in voltage leads to an increase in power, this means the operating point of the PV module is on the left of the MPP and vice versa.
This MPPT algorithm is simple, easy to implement, and low cost with high accuracy.

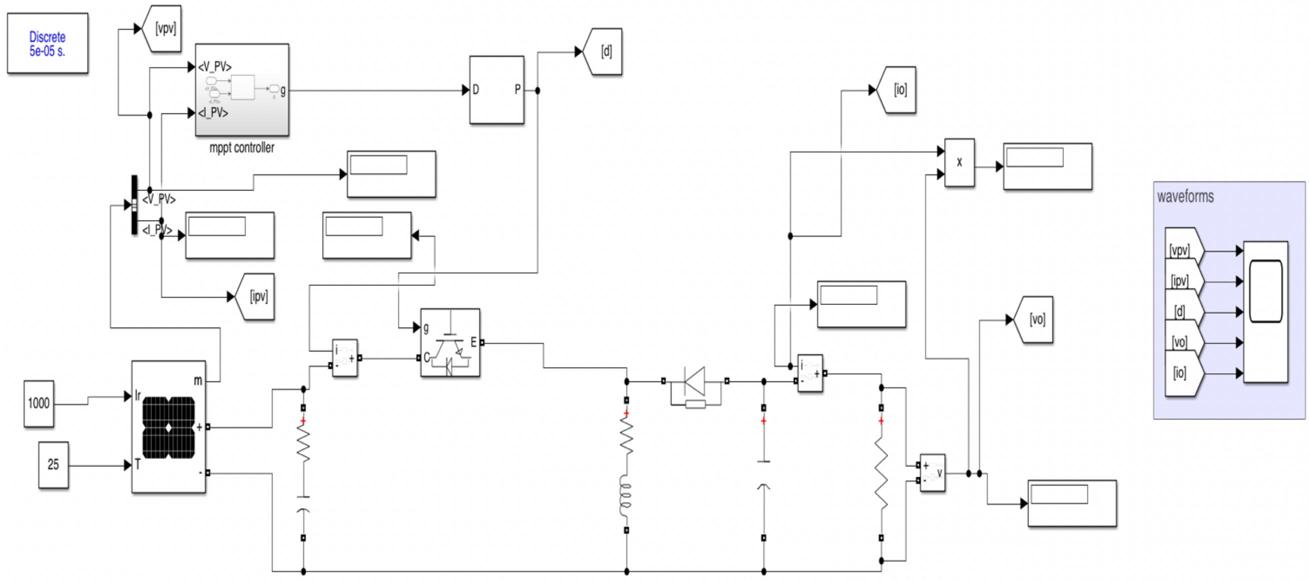


Fig- MPPT with Buck-Boost Converter

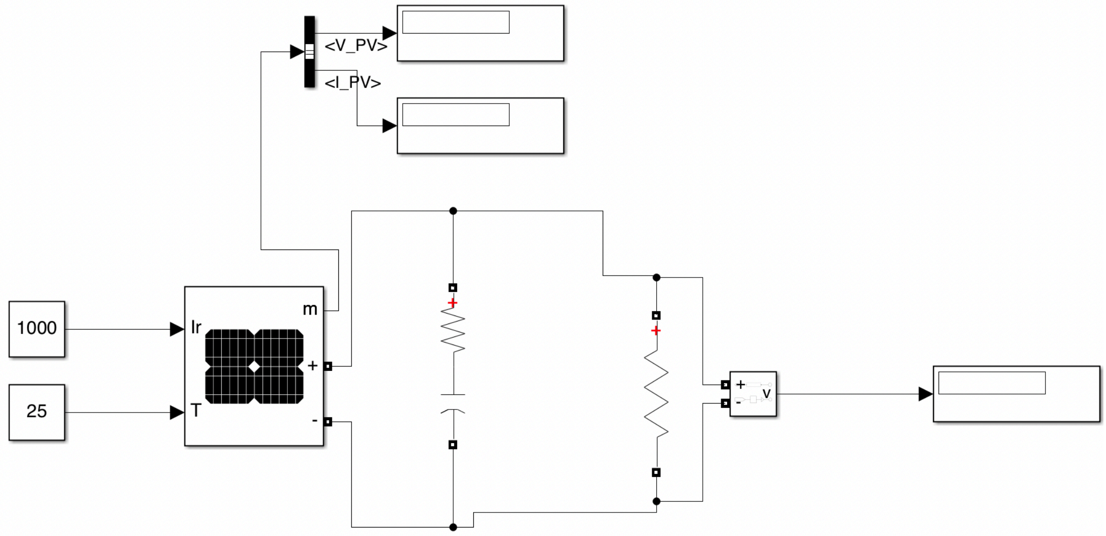
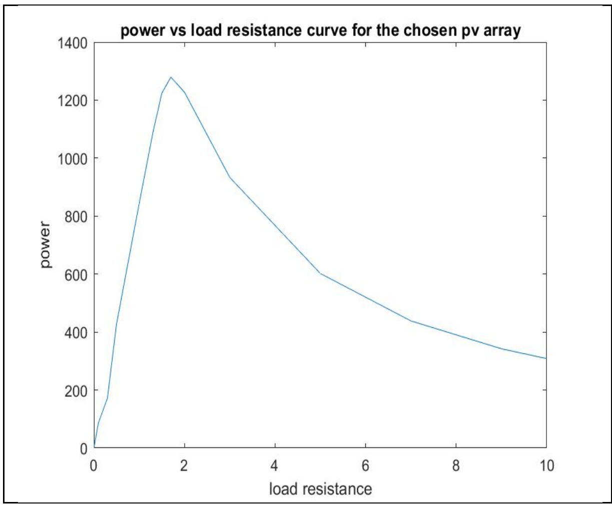


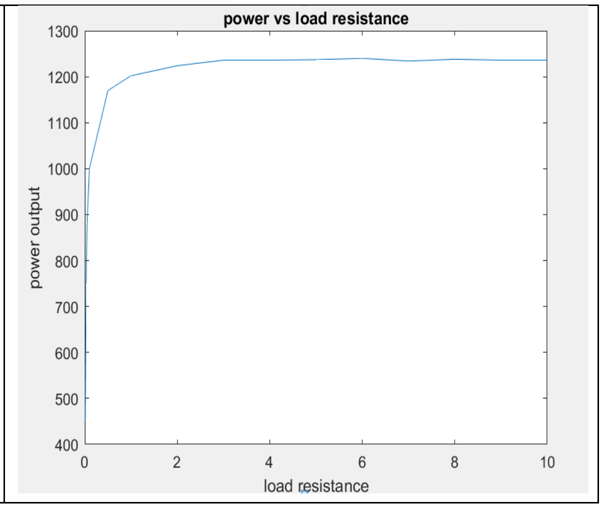
Fig- PV array directly connected to load (before MPPT)

Power Variation with Load:-

Before MPPT



After MPPT



Similarly, we did this with boost converter as shown in the fig below.

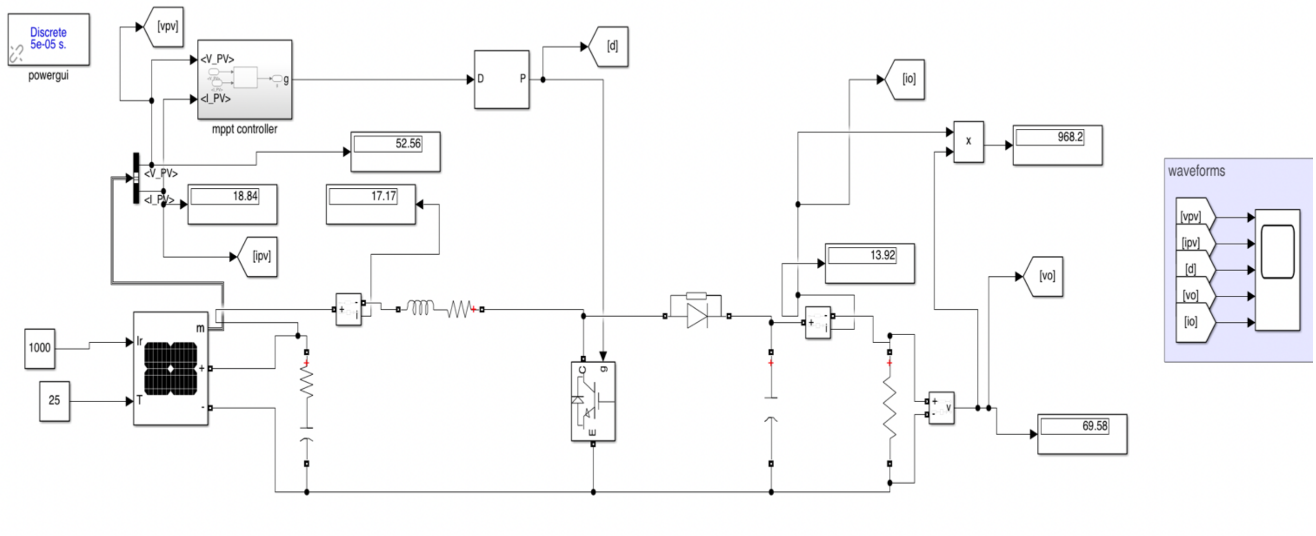


Fig- MPPT using Boost Converter

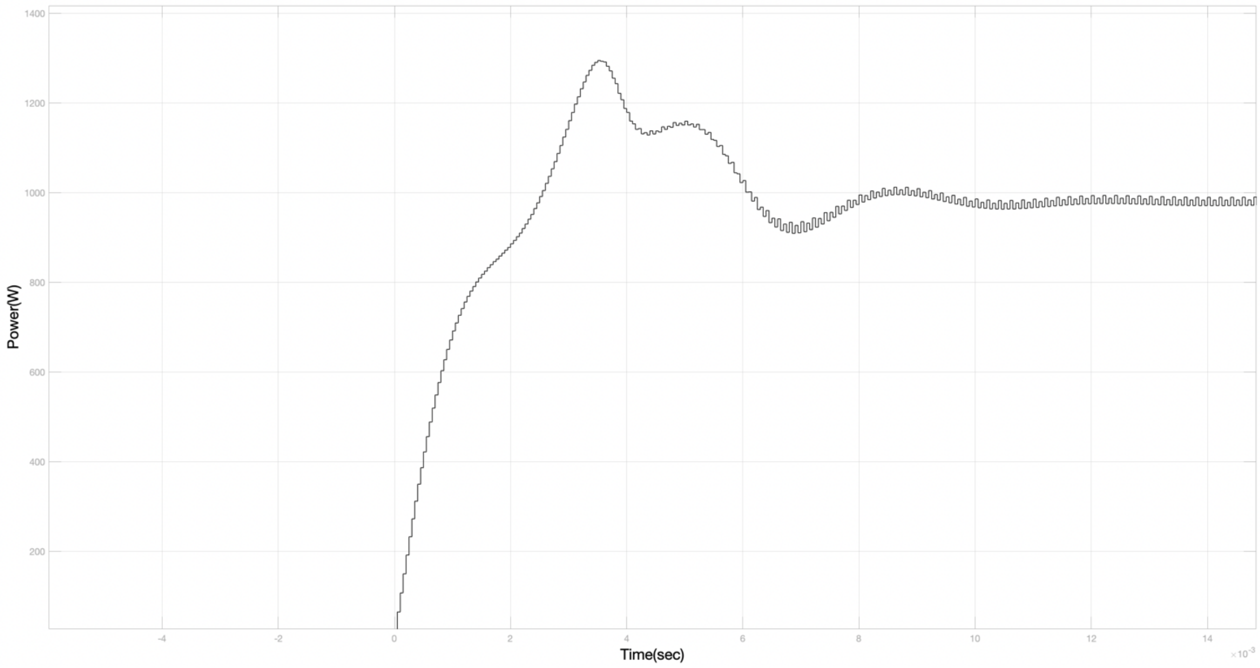


Fig- P & O Algorithm Power vs. Time Curve

-INCREMENTAL CONDUCTANCE ALGORITHM-

The incremental conductance algorithm depends on the slope of the P–V curve, which is affected by the solar irradiation level and load resistance. As the algorithm uses the current and voltage of the PV module in the calculation, the effect of solar irradiation and load changes on the current and voltage of the PV module must be considered in the algorithm.

The proposed algorithm is shown in the flow chart in Fig below. When the irradiance changes, the current and voltage will be affected accordingly. This algorithm thus uses the instantaneous changes of current and voltage of PV modules. While the traditional incremental conductance algorithm makes a judgment on the position of the system operating point, the improved incremental conductance algorithm makes a judgment based on the directions of power, voltage and current. Considering the system at the left side of the MPP, for the system running in the positive direction ($dv > 0$) the duty cycle will continue to move in the disturbance direction of the previous step, while for the system running in the negative direction ($dv < 0$) the duty cycle will continue to move in the opposite direction of the disturbance of the previous step. Similarly, when the system is at the right side of the MPP, for the positive system running direction ($dv > 0$) the duty cycle will continue to move in the opposite direction of the disturbance of the previous step, whereas for the negative system operating direction ($dv < 0$), the duty cycle will continue to move in the direction of the disturbance of the previous step. Therefore, the algorithm can accurately and correctly judge the disturbance direction of the next step of the working point, thus solving the system misjudgement phenomenon in the traditional method.

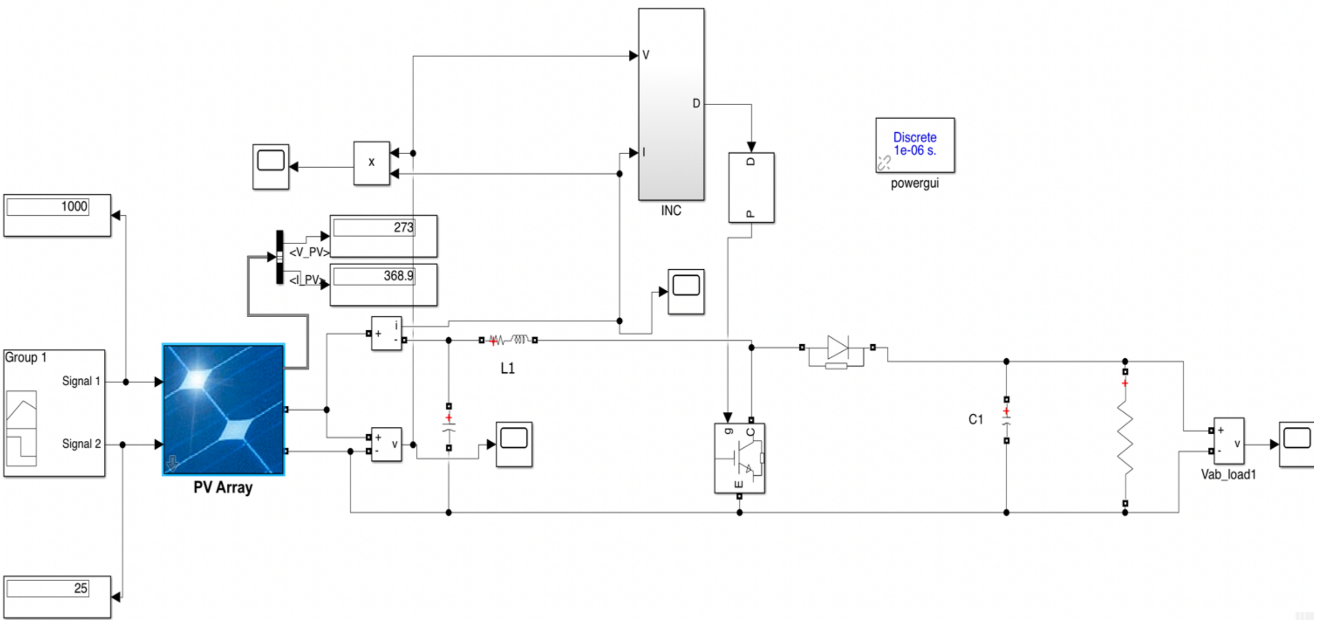


Fig- Incremental Conductance Algorithm MPPT using Boost Converter.

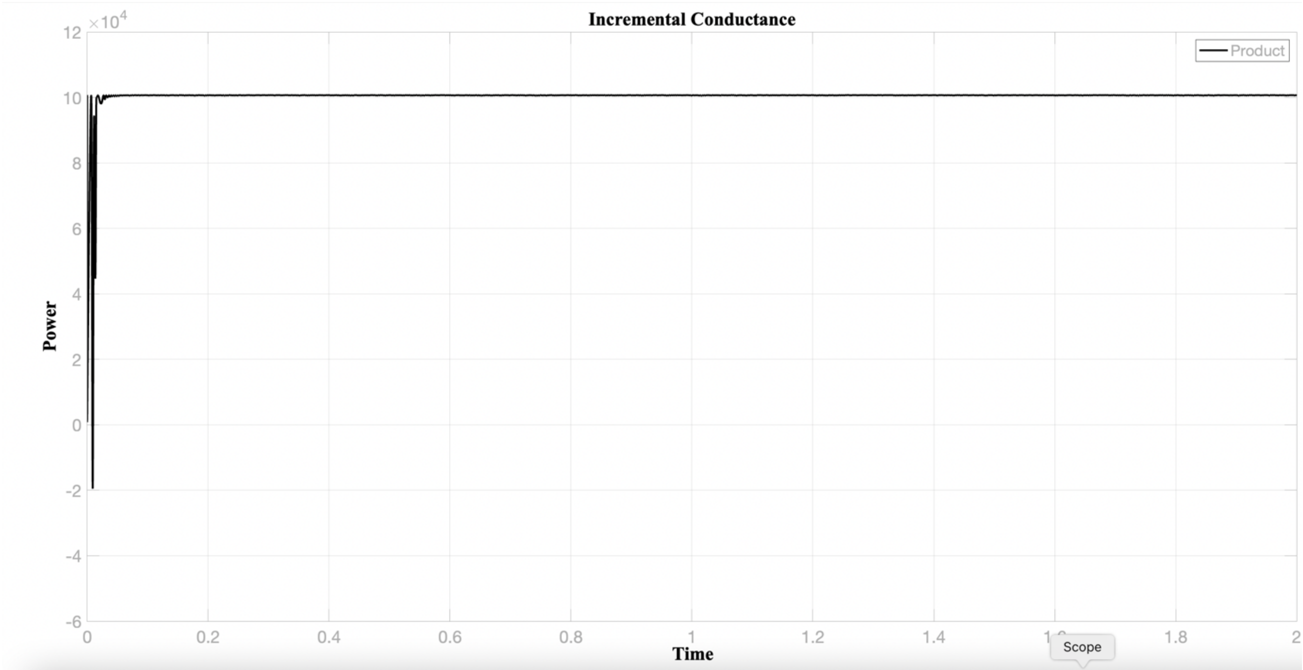


Fig- I.C Algorithm for MPPT , Power vs. Time Curve to determine settling.

APPENDIX-

Code for P & O Algorithm-

```
function d=PandO(v,i)
 persistent dpre ppre vpre
if isempty(dpre)
dpre=0.01;
end
if isempty(vpre)
vpre=0;
end
if isempty(ppre)
ppre=0;
end


deltad=50e-5;
p=v*i;

if (p-ppre) ~=0
    if (p-ppre)>0
        if (v-vpre)>0
            d=dpre-deltad;
        else
            d=dpre+deltad;
        end
    else
        if (v-vpre)>0
            d=dpre+deltad;
        else
            d=dpre-deltad;
        end
    end
else
    d=dpre;
end
if d>=0.9
    d=0.9;
end
if d <=0.01
    d=0.01;
end

dpre=d;
vpre=v;
ppre=p;
```

Code for I.C Algorithm: -

```
function y = MYMPP(u,i,uo,io,D);
m=0.4;
du=u-uo;
di=i-io;
d=0.00005;
if du==0
    if di==0
    m=D;
    else
        if di>0
            m=D-d;
        else
            m=D+d;
        end
    end
else
    if di/du== -(i/u)
    m=D;
    else
        if di/du> -(i/u)
        m=D-d;
        else
            m=D+d;
        end
    end
end
y = m;
end
```

-References-

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