Visvesvaraya Technological University Belgaum, Karnataka-590 018

A Project Report on

"Converter Topology for Solar Wind Hybrid System"

Project Report submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Engineering
In
Electrical & Electronics Engineering

Submitted by

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2019-2020

CMR INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

AECS Layout, Bengaluru-560 037

Certificate

Certified that the project work entitled **"Converter Topology For Solar Wind Hybrid System"** carried out by Mr. Chandra Kiran P, USN 1CR16EE016; Mr. DV Bhuvan, USN 1CR16EE019; Ms. Janani R Kumar, USN 1CR16EE031; Ms. Kavya Shree K, USN 1CR16EE034 are bonafied students of CMR Institute of Technology, Bengaluru, in partial fulfillment for the award of Bachelor of Engineering in Electrical & Electronics Engineering of the Visvesvaraya Technological University, Belgaum, during the year 2019-2020. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library.

The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

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DECLARATION

We, [Mr. **Chandra Kiran P (1CR16EE016),** Mr. **DV Bhuvan (1CR16EE019),** Ms. **Janani R Kumar (1CR16EE031),** Ms. **Kavya Shree K (1CR16EE034)],** hereby declare that the report entitled **"Converter Topology For Solar Wind Hybrid System"** has been carried out by us under the guidance of **Mr. Kashif Ahmed,** Assistant Professor, Department of Electrical & Electronics Engineering, CMR Institute of Technology, Bengaluru, in partial fulfillment of the requirement for the degree of **BACHELOR OF ENGINEERING in ELECTRICAL & ELECTRONICS ENGINEERING**, of Visveswaraya Technological University, Belgaum during the academic year 2019-20. The work done in this report is original and it has not been submitted for any other degree in any university.

Place: Bengaluru
Date:

Chandra Kiran P (1CR16EE016)
DV Bhuvan (1CR16EE019)
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Abstract

Renewable energy sources have become a popular alternative for electrical energy source where power generation in conventional ways is not practical. In the last few years, the photovoltaic and wind power generation have been increased significantly. In this study, we proposed a converter topology for a hybrid energy system which combines both solar panel and wind turbine generator as an alternative for conventional source of electrical energy. A simple and effective maximum power point tracking (MPPT) algorithm has been used to track and monitor the operating point at which maximum power can be coerced from the PV and wind turbine hybrid system under continuously changing environmental conditions. The converter topology for the hybrid system is designed such that it allows the two sources to supply the load separately or simultaneously, depending on the availability of the energy sources. The entire hybrid system is described along with comprehensive simulation results that discover the feasibility of the system. The entire hybrid system is described given along with comprehensive simulation results that discover the feasibility of the system. A software simulation model is developed in MATLAB/Simulink.

Acknowledgement

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of the people who are responsible for the completion of the project and who made it possible, because success is an outcome of hard work and perseverance, but steadfast of all is encouraging guidance. So, with gratitude we acknowledge all those whose guidance and encouragement served us to motivate towards the success of the project work.

We take great pleasure in expressing our sincere thanks to ***Dr. Sanjay Jain****,* ***Principal, CMR Institute of Technology, Bengaluru*** *for providing an excellent academic environment in the college and for his continuous motivation towards a dynamic career.*

We would like to convey our sincere gratitude to ***Dr. K Chitra****,* ***Head of Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru*** *for her invaluable guidance and encouragement and for providing good facilities to carry out this project work.*

We would like to express our deep sense of gratitude to ***Mr. Kashif Ahmed, Assistant Professor, Electrical and Electronics Engineering, CMR Institute of Technology, Bengaluru*** *for his exemplary guidance, valuable suggestions, expert advice and encouragement to pursue this project work.*

We are thankful to all the faculties and laboratory staffs of ***Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru*** *for helping us in all possible manners during the entire period.*

Finally, we acknowledge the people who mean a lot to us, our parents, for their inspiration, unconditional love, support, and faith for carrying out this work to the finishing line. We want to give special thanks to all our friends who went through hard times together, cheered us on, helped us a lot, and celebrated each accomplishment.

Lastly, to the ***Almighty****, for showering His Blessings and to many more, whom we didn't mention here.*

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INTRODUCTION

1.1 Introduction to the Hybrid System

Due to the rapid increase in the power demand and growing concern on global warming and climate change, the renewable energy sources play an important role in the field of electrical energy sector for the production of electricity supply. The renewable energy system can be constructed as a stand-alone system for the domestic applications or grid-connected system to supply the AC power to utility system. Few other reasons include advantages like abundant availability in nature, eco-friendly and recyclability. Many renewable energy sources like solar, wind, hydel and tidal are there. Among these renewable sources solar and wind energy are the world's fastest growing energy resources. With no emission of pollutants, energy conversion is done through wind and PV cells. The hybrid solar photovoltaic (PV) and wind generation system become very attractive solution particularly for stand-alone applications, and reduce the size of energy storage needed to supply continuous power. Both solar and wind energy sources have great potential for power generation. The PV systems generate DC power, while the wind systems generate AC power. The two sources are integrated together to supply a common load. The Wind and Solar energy systems are highly unreliable due to their unpredictable nature. None of these are available round the clock. Thus, hybridizing solar and wind power sources provide a more reliable source of power generation. When any of the two sources is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the difference.

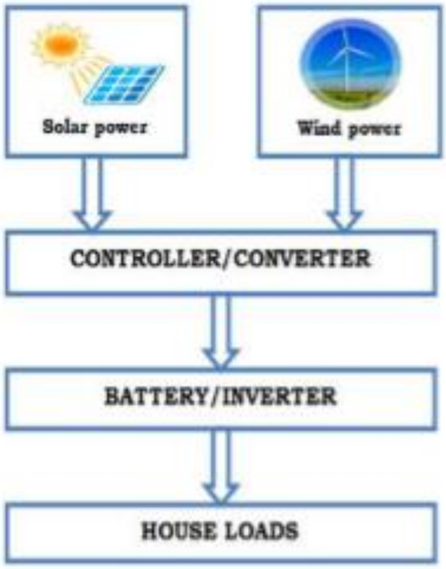

Fig 1. Solar-Wind Hybrid System Representation

1.2 Objective of the Thesis

By integrating the two renewable resources: solar and wind energy into an optimum combination, the impact of the variable nature of solar and wind resources can be partially resolved and the overall system becomes more reliable and economical to run. The main objective is to analyze and design a converter feasible for the designed solar and wind hybrid system. The various DC-DC converters were studied and simulated using MATLAB to come up with a suitable converter topology for the hybrid system designed in MATLAB. The idea is to provide direct DC supply from the hybrid system to the loads.

The step by step objectives are:

- To study and model the PV cell and PV panels.
- To study the characteristic curves and effect of variation of environmental conditions like temperature and irradiation on them.
- To trace the maximum power point of operation of the PV panel irrespective of the changes in the environmental conditions and model the MPPT algorithm.
- To study and simulate the wind power system and track its maximum power point.
- To study and simulate the various DC-DC converters.
- To design the hybrid system with a suitable DC-DC converter topology.

1.3 Layout of the Thesis

The hybrid system model has been designed combining the solar PV energy system, wind energy system, MPPT algorithm and the DC-DC converter. The layout of the design is shown below.

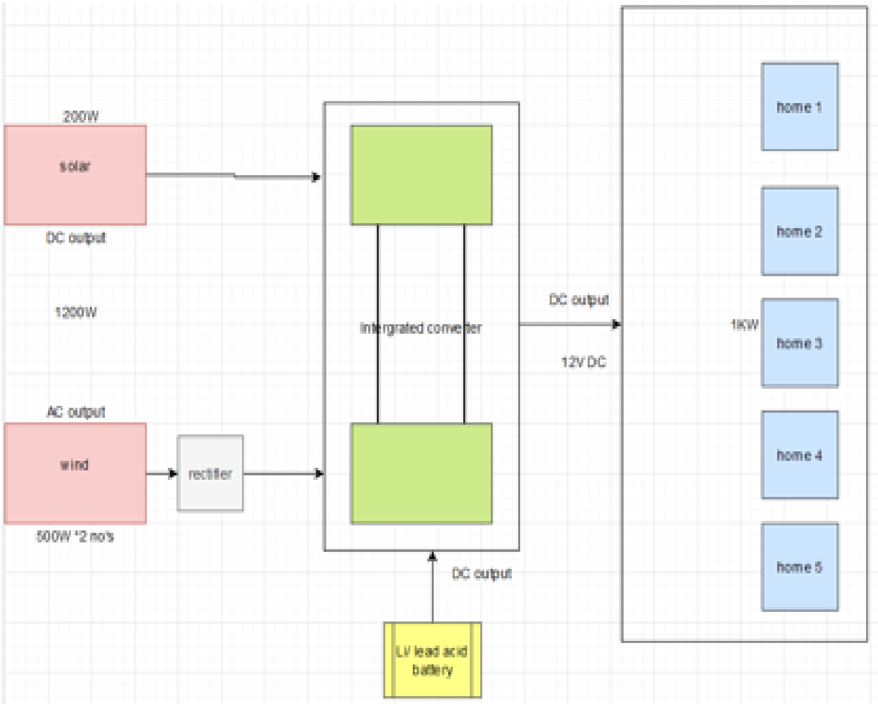

Fig 2. Block diagram of hybrid system layout.

Several hybrid solar-wind power systems with Maximum Power Point Tracking (MPPT) control have been proposed earlier. A separate DC-DC buck and buck-boost converter connected in fusion with the rectifier stage has been used to perform the MPPT control for each of the renewable energy power sources. Most of the hybrid systems use boost converter. We are using a Cuk and SEPIC integrated converter for the solar and wind hybrid system designed. The Cuk-SEPIC fused converters have the capability to eliminate the high frequency current harmonics. So, no additional input filters are needed. Fusion of Cuk-SEPIC converter works well for individual as well as for simultaneous operation of the two supply sources. It also supports the wide input range from the PV and wind sources. The DC output of the PV energy system is directly given to the converter, while the AC output of the wind energy generation system is first rectified and converted to DC before giving it to the converter. The below figure shows the simple representation of the integrated system design.

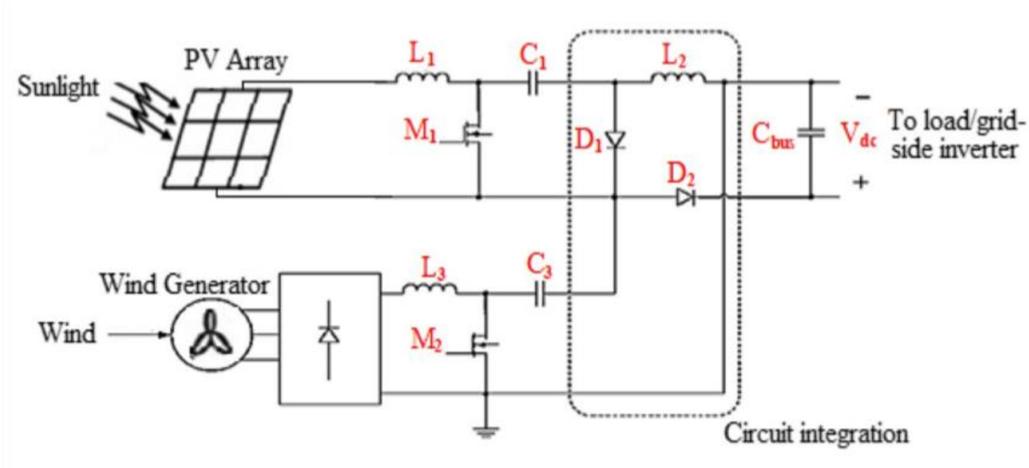

Fig 3. Solar-Wind hybrid integration with DC-DC converter

CHAPTER 2

LITERATURE REVIEW

A lot of research work is being conducted to enhance the power efficiency of non-conventional energy sources and make it more reliable and beneficial. Hybrid generation systems uses more than one source, so that we can extract energy from different sources at the same time which enhances the efficiency. The main challenge in the literature is with regard to optimal sizing design, power electronics topologies and control of the system. The working of PV /Wind hybrid system is understood. The different topologies that can be used for the hybridization of more than one system and also about advantages and disadvantages of hybrid system were studied.

Literature survey was carried out step-wise for the below:

- Solar – basic details and understanding of PV cell and module, and their modelling was studied along with the behavior of the PV module at varying environmental conditions like solar irradiation and temperature.
- Wind - working and modelling of wind turbine and generator, using wind design equations was studied along with techniques to extract maximum power from the wind energy system.
- MPPT- different Maximum Power Point Tracking techniques, their advantages and disadvantages and why MPPT control is required were studied.
- Converters – different types of DC-DC converters, their working, advantages and disadvantages were studied.
    1. Buck Converter
    2. Boost Converter
    3. Buck – Boost Converter
    4. LUO Converter
    5. Cuk Converter
    6. SEPIC Converter
    7. Integrated converter

- Hybrid System – Integration and design of the complete hybrid system for direct supply to load was understood.

  The hybrid wind and solar energy systems using conventional boost converter is studied.

  The hybrid wind and solar energy systems using CUK-SEPIC fused converter is studied and simulated.

- MATLAB/Simulink – Understanding the tool and using it to simulate and try out the various design configurations.

CHAPTER 3

MODELLING AND DESIGN

3.1 PV Energy System

A solar cell is the building block of a solar panel. A photovoltaic module is formed by connecting many solar cells in series and parallel. Considering only a single solar cell. It can be modelled by utilizing a current source, a diode and two resistors. This model is known as a single diode model of solar cell. Two diode models are also available but only single diode model is considered as shown in the below figure.

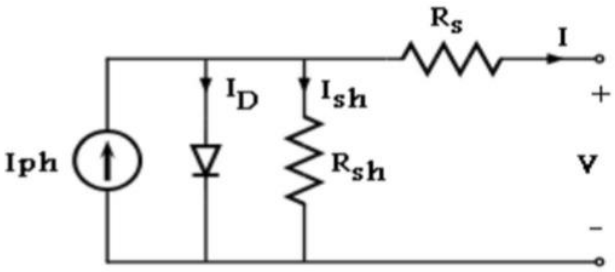

Fig 4. Simple circuit representation of PV cell

The characteristic equation for a photovoltaic cell is given by,

I = Iph – Id – Ish

I = Iph – Io [exp {q (V+Rs I)/ (A K_b T)} – 1] - (V+Rs I)/Rsh

Where,

Iph = photocurrent,

Id = diode current,

Io = saturation current,

A = ideality factor,

q = electronic charge 1.6x10-9,

K_b = Boltzmann's gas constant (1.38x10-23),

T = cell temperature,

Rs = series resistance,

Rsh = shunt resistance,

I = cell current,

V = cell voltage.

The characteristic equation of a solar module is dependent on the number of cells in parallel and number of cells in series. It is observed from experimental results that the current variation is less dependent on the shunt resistance and is more dependent on the series resistance.

$I = Iph – Io\ [\exp\{qV/ K_b T\} – 1]$

The figure below shows the modelling of photo current block in a similar way the whole solar module is modelled using the above equations.

Photo-current $$I_{ph} = [I_{sc} + k_i \cdot (T - 298)] \cdot \frac{G}{1000}$$

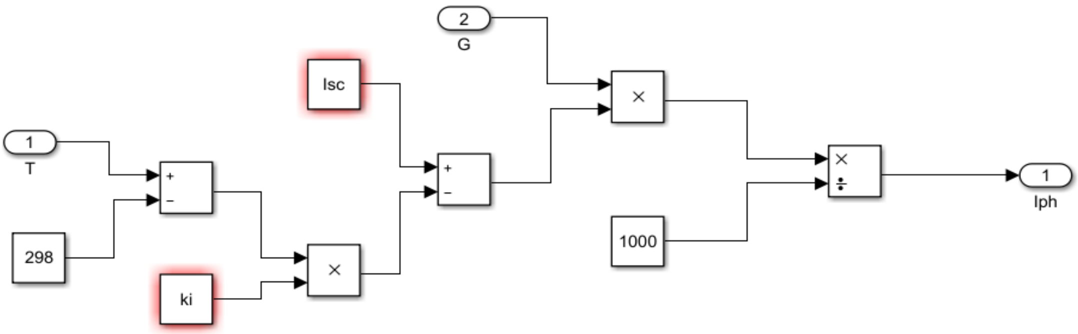

Fig 5: modelling of photo current block

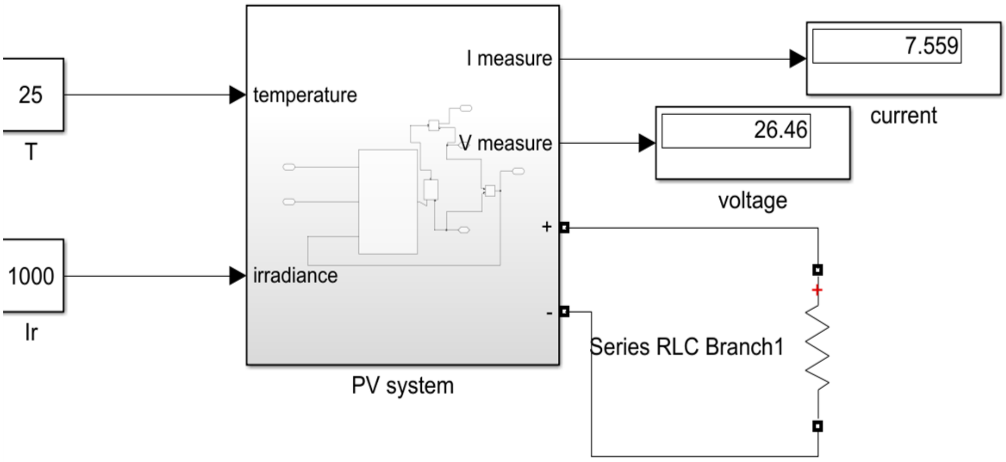

Fig 6: solar panel model

The I-V and P-V curves for a solar cell are given in the following figure. It can be seen that the cell operates as a constant current source at low values of operating voltages and a constant voltage source at low values of operating current.

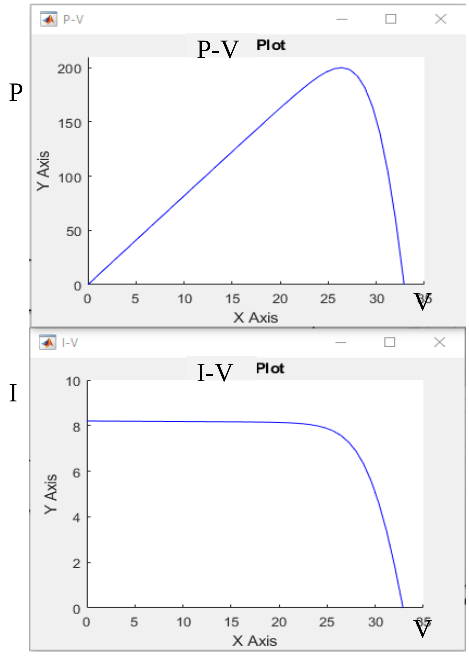

Fig 7: Solar panel P-V, I-V characteristics

3.2 Wind Energy System

Let us discuss about the factors on which generation of electricity from wind turbines depend on. The amount of electricity produced from a wind turbine depends on three factors:

1) Wind speed

The power available from the wind is a function of the cube of the wind speed. Therefore, if the wind blows at twice the speed, its energy content will increase eight-fold. Turbines at a site where the wind speed averages 8 m/s produce around 75-100% more electricity than those where the average wind speed is 6 m/s.

2) Wind turbine availability

This is the capability to operate when the wind is blowing, i.e. when the wind turbine is not undergoing maintenance. This is typically 98% or above for modern European machines.

3) The way wind turbines are arranged

Wind farms are laid out so that one turbine does not take the wind away from another. However other factors such as environmental considerations, visibility and grid connection requirements often take precedence over the optimum wind capture layout.

Coming to the modelling of the wind turbine, the power equation for any wind turbine is as given below:

$P = 0.5\rho A v^3 C_p$

Where,

ρ is the air density, $\rho = 1.23 kg/m^3$

A is the swept area, $A = \pi r^2$, here r is the blade length of the wind turbine

V is the velocity of the wind

C_p is Betz's Coefficient

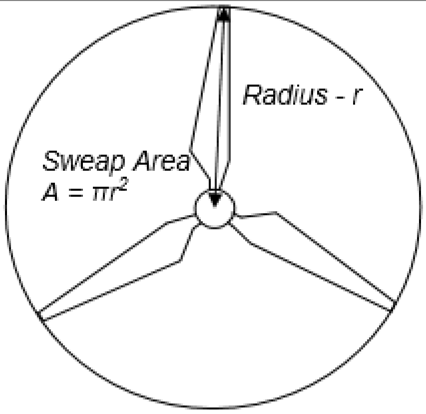

Fig 8. Spin Area of Wind Turbine.

A German physicist Albert Betz concluded in 1919 that no wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy turning a rotor. To this day, this is known as the Betz Limit or Betz' Law. The theoretical maximum power efficiency of any design of wind turbine is 0.59 (i.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine). This is called the "power coefficient" and is defined as:

$C_{p\ max}$= 0.59

Also, wind turbines cannot operate at this maximum limit. The p C value is unique to each turbine type and is a function of wind speed that the turbine is operating in. Once we incorporate various engineering requirements of a wind turbine - strength and durability in particular - the real-world limit is well below the Betz Limit with values of 0.35-0.45 common even in the best designed wind turbines. Realistically we have taken the value to be 0.4 as C_p.

TIP SPEED RATIO (TSR) = $\frac{\text{tip speed of lade}}{blade\ speed}$

The tip speed ratio is a very important factor in the different formulas of blade design. Generally, can be said, that slow running multi bladed wind turbine rotors operate with tip speed ratios like 1-4, while fast runners use 5-7 as tip speed ratios. But mostly we consider it be 7 these days.

Speed of the turbine can be calculated in RPM as:

$$N = \frac{TSR.v.60}{6.28.r}$$

Where TSR is the tip speed ratio

V is the velocity

R is the blade length

Angular speed w can be calculated as:

$$w = \frac{2.\pi.N}{60}$$

The above used expression is coded into a user defined MATLAB block to obtain either torque or speed as the output based on requirements as to which of these you are planning to feed to the Permanent Magnet Synchronous Generator (PMSG) as input. Generally, these wind mills have gears in them to amplify the torque and speed based on specifications. But in order to the same we can use a gain block in MATLAB.

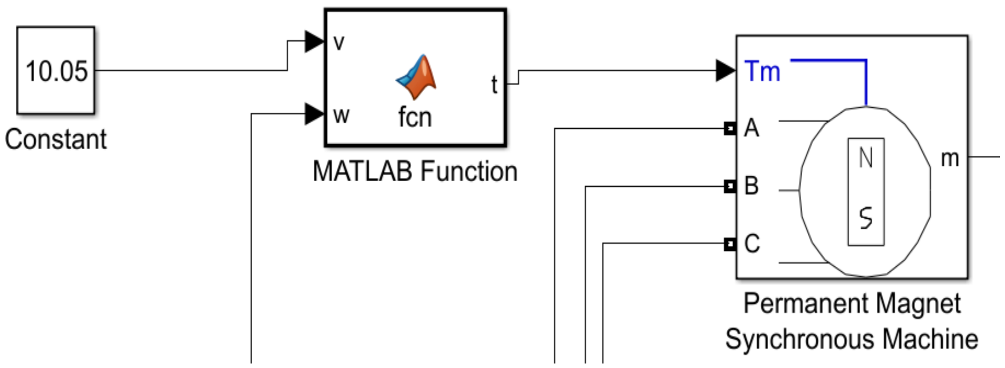

Fig 9. PMSG Block.

In the above model torque is given as the input using the below formula

$$P = \frac{T}{w}$$

Where,

P is the rated power of the turbine,

T is the torque generated,

W is the angular speed.

But for our model we have used a SI fundamental, in which we have given N(rpm) as the input.

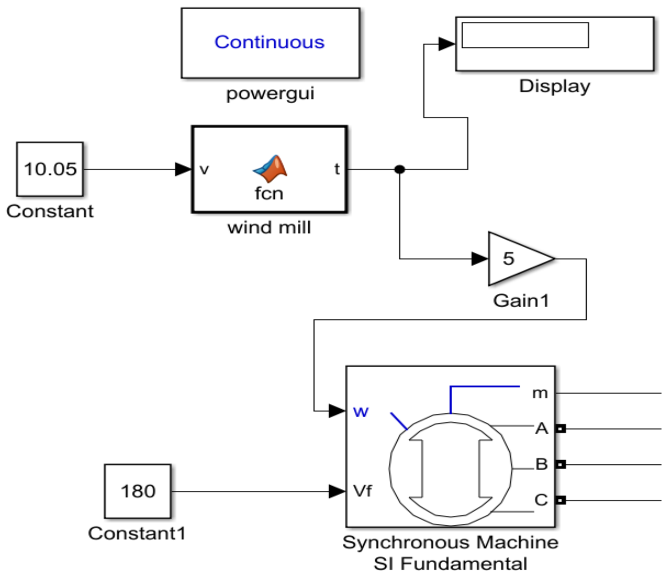

Fig 10. SI Fundamental model

Conversion the AC output to DC has to be done for the wind energy system. The output generated by PMSG, Si fundamental or any synchronous machine is Alternating in nature. Our converter system is completely a DC system supplying DC even on the load side. It is necessary to convert the ac output to DC with the use of three phase 6 pulse rectifiers or a universal bridge.

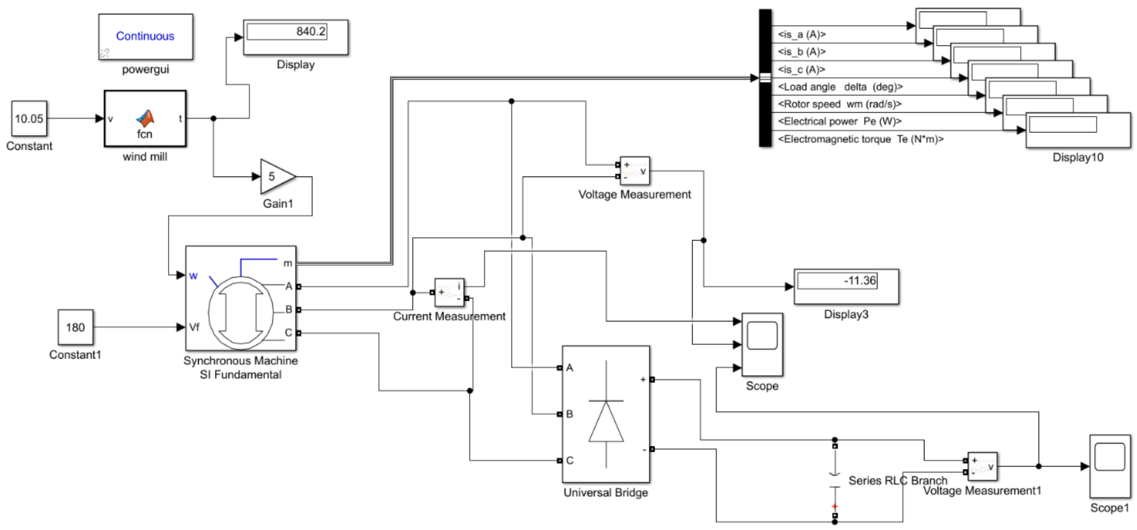

Fig 11. Model of wind turbine.

3.3 MPPT Algorithm

Let us discuss about the factors on which generation of electricity from wind turbines depend on. The amount of electricity produced from a wind Maximum power point tracing (MPPT) system is an electronic control system that can be able to coerce the maximum power from a PV system. It does not involve a single mechanical component that results in the movement of the modules changing their direction and make them face straight towards the sun. MPPT control system is a completely electronic system which can deliver maximum allowable power by varying the operating point of the modules electrically. MPPT is commonly used with wind turbines and PV solar systems to maximize power extraction under all conditions. The operating point where maximum power can be drawn is known as the maximum power point (MPP) of operation of the system. Tracking of this point is done to ensure that the operating point of the system is on or near the MPP.

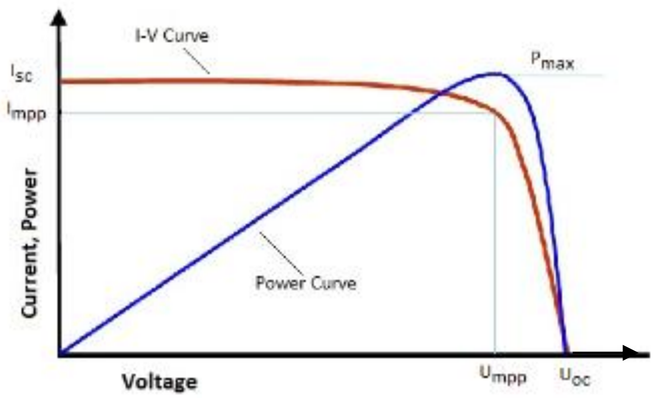

Fig 12. P-V and I-V characteristics.

Coming to the necessity of MPPT, in the Power Vs Voltage characteristic of a PV module shown we can observe that there exist single maxima i.e. a maximum power point associated with a specific voltage and current that are supplied. The overall efficiency of a module is very low around 12-15%. So, it is necessary to operate it at the crest power point so that the maximum power can be provided to the load irrespective of continuously changing environmental conditions. This increased power makes it better for the use of the solar PV module. A DC/DC converter which is placed next to the PV module extracts maximum power by matching the impedance of the circuit to the impedance of the PV module and transfers it to the load. Impedance matching can be done by varying the duty cycle of the switching elements.

Now, coming to the MPPT algorithm, there are many algorithms which help in tracing the maximum power point of the PV module. Some of the main algorithms in use are:

a. P&O algorithm

b. IC algorithm

c. Parasitic capacitance

d. Voltage based peak power tracking

e. Current Based peak power tracking

We have implemented the Perturb and Observe (P&O) algorithm in the hybrid model. Each and every MPPT algorithm has its own advantages and disadvantages. Perturb and observe method is widely used due its simplicity. It is also known as hill climbing method. In this algorithm we introduce a perturbation in the operating voltage of the panel. Perturbation in voltage can be done by altering the value of duty-cycle of dc-dc converter.

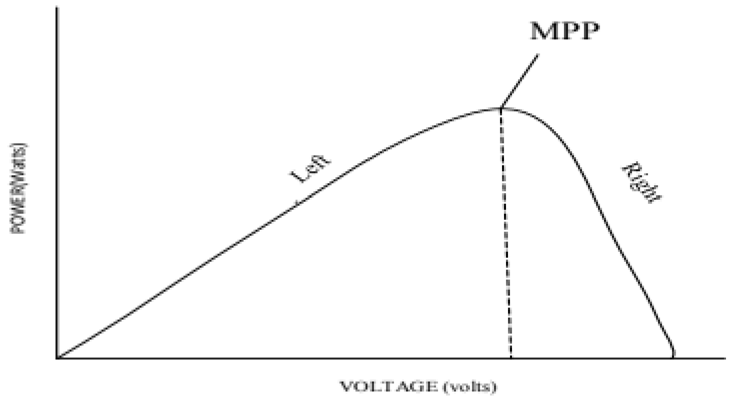

Fig 13. P-V curve for basic understanding of P&O algorithm

The above graph shows the p-v characteristics of a photovoltaic system, by analyzing the p-v characteristics we can see that on right side of MPP as the voltage decreases the power increases but on left side of MPP increasing voltage will increase power. This is the main idea we have used in the P&O algorithm to track the MPP. The flow chart of P&O algorithm is manifested in the below figure.

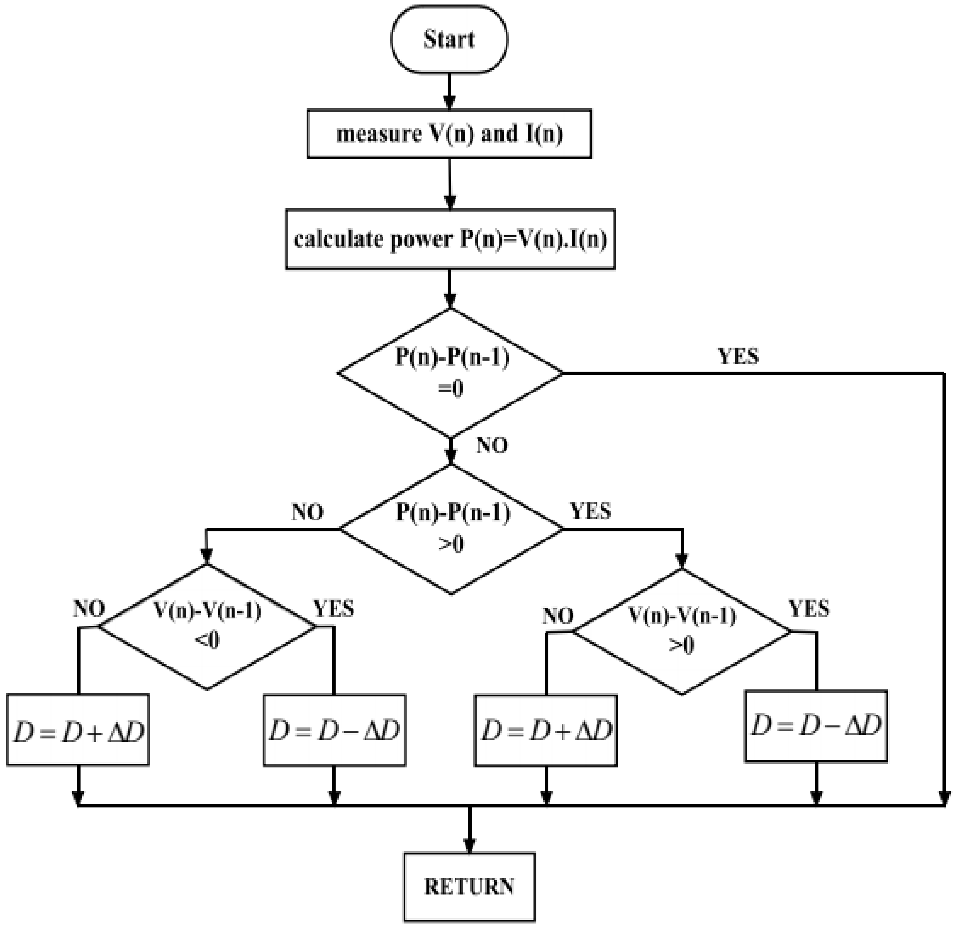

Fig 14. Flow chart of P&O algorithm.

As we can see from the flow chart first of all we measure voltage and current, by using these values we calculate power, calculated power is compared with previous one and accordingly we increase or decrease the voltage to locate the Maximum Power Point by altering the duty cycle of converter. In this method, the time complexity is very less but on reaching very close to the MPP, it does not stop but keeps perturbing on both directions.

3.4 Hybrid System

For the integration of the solar-wind hybrid system, Cuk-SEPIC converter is used. PV array is the input to the Cuk converter and wind source is the input to the SEPIC converter. The converters are fused together by reconfiguring the two existing diodes from each converter and the sharing the Cuk output inductor by the SEPIC converter. This configuration allows each converter to operate normally individually in the event that one source is unavailable. When only wind source is available, the circuit operates as a SEPIC converter and the voltage conversion relationship is given by:

$$\frac{V_{dc}}{V_w} = \frac{d_2}{1 - d_2}$$

Where,

V_{dc} - output voltage to the load,

V_W - output voltage of wind system,

d_2 – duty cycle of SEPIC converter

When only PV source is available, the circuit acts as a Cuk converter and the voltage conversion is given by:

$$\frac{V_{dc}}{V_{pv}} = \frac{d_1}{1 - d_1}$$

Where,

V_{PV} – output voltage of PV system,

d_1 – duty cycle of Cuk converter

3.5 DC-DC Converters

Now, let us discuss the different converters available, simulation of those converters and the results. Also, we will come across the integrated converter that is feasible for our Hybrid system.

A converter is an electrical circuit which accepts a DC input and generates a DC output of a different voltage, usually achieved by high frequency switching action employing inductive and capacitive filter elements. A power converter is an electrical circuit that changes the electric energy from one form into the desired form optimized for the specific load. A converter may do one or more functions and give an output that differs from the input. It is used to increase or decrease the magnitude of the input voltage, invert polarity, or produce several output voltages of either the same polarity with the input, different polarity, or mixed polarities such as in the computer power supply unit.

DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is generally BJT, MOSFET or IGBT. There are various types of dc-dc converters that can be used to transform the level of the voltage as per the supply availability and load requirement. Some of them are discussed below:

- Buck Converter
- Boost Converter
- Buck – Boost Converter
- LUO Converter
- Cuk Converter
- SEPIC Converter

<u>BUCK CONVERTER:</u>

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination.

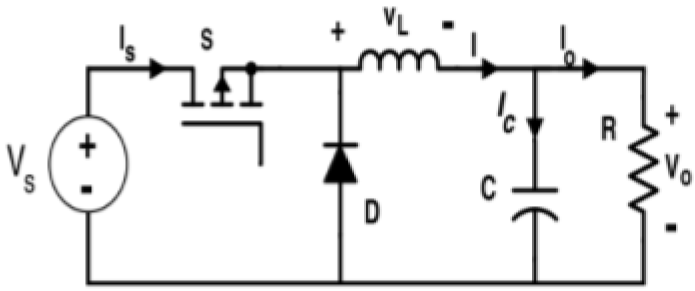

Fig 15: Buck converter circuit

Working:

The working of a buck converter can be broken down into two modes.

Mode 1-Switch ON:

when the switching transistor is switched on, it is supplying the load with current. Initially current flow to the load is restricted as energy is also being stored in L1, therefore the current in the load and the charge on C1 builds up gradually during the ‘on’ period. Notice that throughout the on period, there will be a large positive voltage on D1 cathode and so the diode will be reverse biased and therefore play no part in the action.

Mode 2-Switch OFF:

When the transistor switches off as shown in Fig 3.1.3 the energy stored in the magnetic field around L1 is released back into the circuit. The voltage across the inductor is now in reverse polarity to the voltage across L1 during the ‘on’ period, and sufficient stored energy is available in the collapsing magnetic field to keep current flowing for at least part of the time the transistor switch is open.

The back EMF (Electro-Motive Force) from L1 now causes current to flow around the circuit via the load and D1, which is now forward biased. Once the inductor has returned a large part of its stored energy to the circuit and the load voltage begins to fall, the charge stored in C1 becomes the main source of current, keeping current flowing through the load until the next ‘on’ period begins.

Advantages:

1. As the inductor is placed in the load side the ripple in the output current i.e. load current is reduced there by giving fruitful operation of the load since there is a capacitor to limit the ripples in the output voltage.
2. It is the simplest configuration have least number of elements (source, load, inductor, capacitor, diode and a fully controlled switch, each one).
3. It is the basic unit for other isolated convertor like forward, push-pull, half bride and full bridge etc.
4. It has so many applications like solar photo voltaic cell, Electrical and hybrid vehicles, robotics.

Disadvantages:

1. Slow transient response
2. Normally Input filter is required
3. High output ripple

Simulation Model:

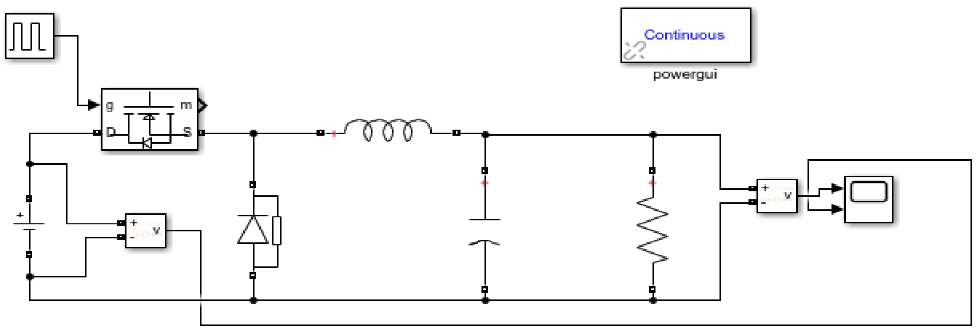

Fig 16: Buck converter MATLAB simulation model

Output:

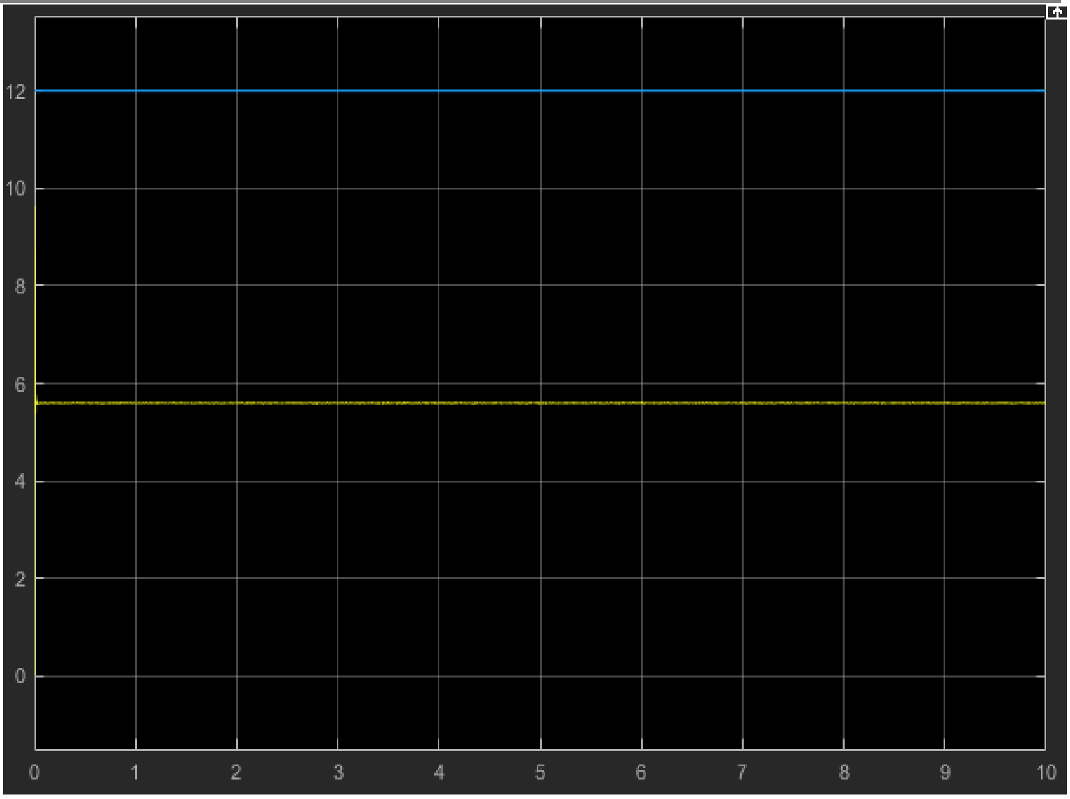

Fig 17: Buck converter simulation output

BOOST CONVERTER:

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination.

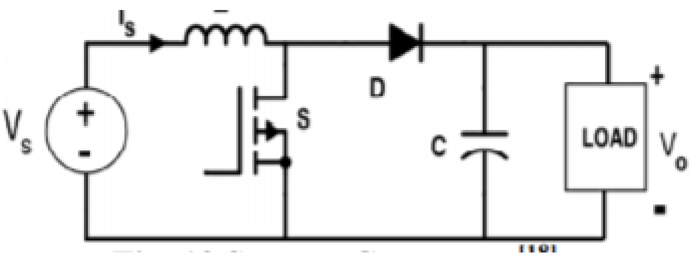

Fig 18: Boost converter circuit

Working:

The working of a boost converter can be broken down into two modes.

Mode 1- Switch ON:

After closing switch P-N junction diode attains reverse biased mode of operation due to which there is a linear increment in current which will start flowing through inductor L(charging).

Mode 2- Switch OFF:

After opening the switch P-N junction diode attains a forward biased mode and L releases stored energy and afterword current starts flowing via L and C. In this way process gets repeated which results in stepping up of the voltage transferred to load.

Advantages:

1. This converter is able to step up the voltage at lowest component count possible. But you may think that the buck-boost converter is also capable of boosting the voltage with the same number of components. The point is the boost converter is capable of giving higher boost than buck-boost converter without deteriorating its efficiency much. For the boost of 2 buck boost converter will have at least 10% less efficiency than the boost converter.
2. The input current is continuous which is very desirable for sources like PV or battery.
3. The switch used here has the common ground with the source which makes the drive circuit and control circuit arrangement easier.
4. The output voltage is positive as opposed to the buck-boost converter which makes the control is easy.

Disadvantages:

1. The charging current of the output capacitor is discontinuous resulting in larger capacitor size and EMI issues.
2. As similar to the buck-boost converter, the efficiency is poor for high gain i.e. very large duty cycle. Therefore, high gain operation cannot be achieved with this converter.

efficiency can be as poor as 60% for a duty cycle of 0.7. Whereas it has highest efficiency for duty cycle of 0.5.

3. This converter cannot step-down the voltage which is crucial for many applications like PV. To extract the maximum power from a PV panel there can be sometimes where you may need to step-down. Hence, this converter cannot provide you a large limit of maximum power point tracking.
4. There is no isolation from input to output which is very critical in many applications like the power supply of gate driver of power semiconductors.
5. This converter is difficult to control similar to the buck-boost converter. The transfer function of this converter contains a right half plane zero which introduces the control complexity. Although the buck converter is free from this disadvantage.

Simulation design:

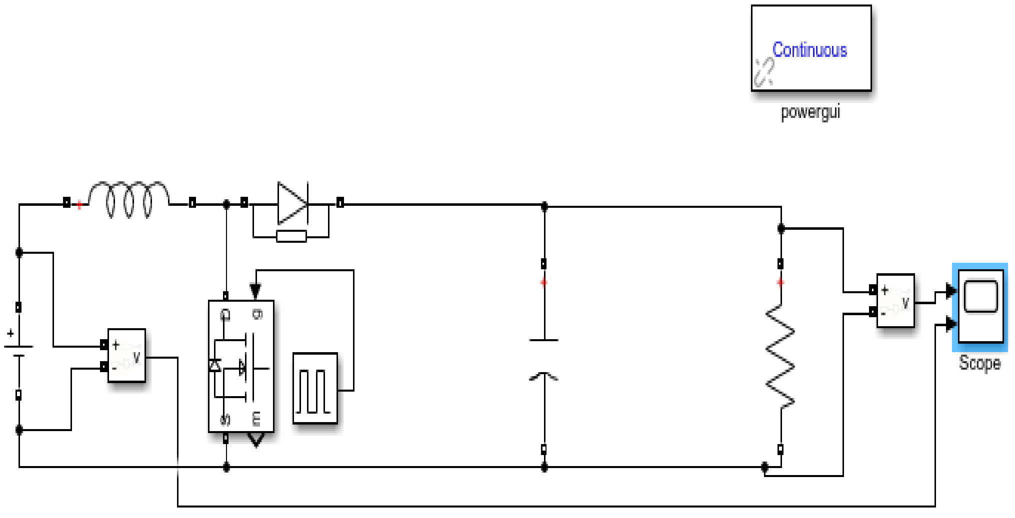

Fig 19: Boost converter MATLAB simulation model

Results:

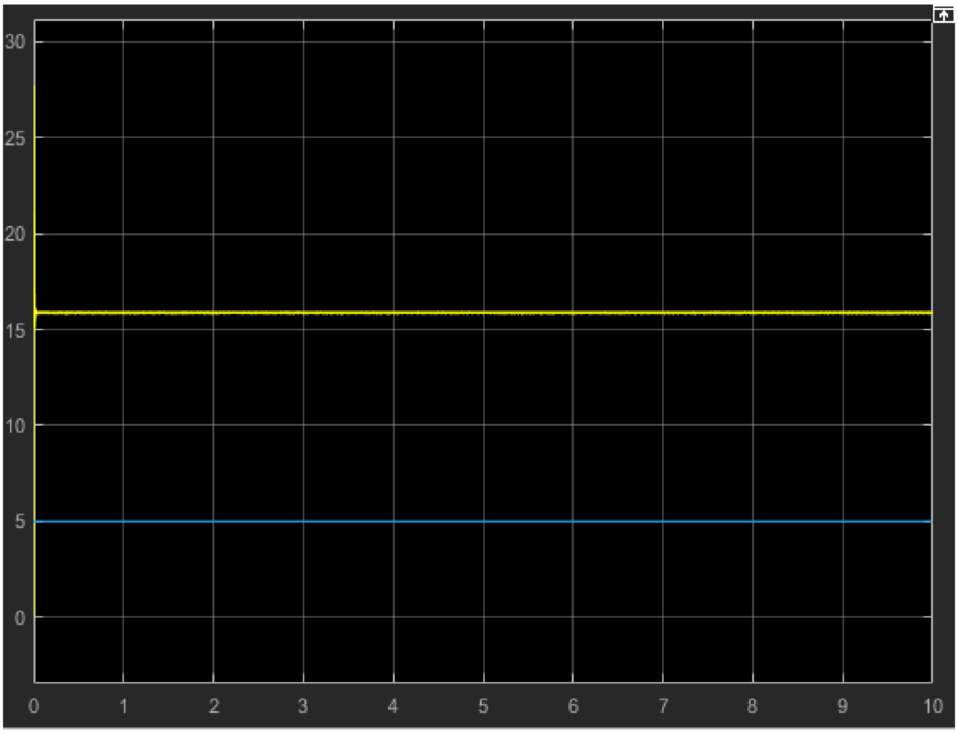

Fig 20: Boost converter simulation output

BUCK-BOOST CONVERTER:

A Buck-Boost converter is a type of switched mode power supply that combines the principles of the Buck Converter and the Boost converter in a single circuit. Like other SMPS designs, it provides a regulated DC output voltage from either an AC or a DC input.

By combining these two regulators designs it is possible to have a regulator circuit that can cope with a wide range of input voltages either higher or lower than that needed by the circuit. Fortunately, both buck and boost converters use very similar components; they just need to be re-arranged, depending on the level of the input voltage.

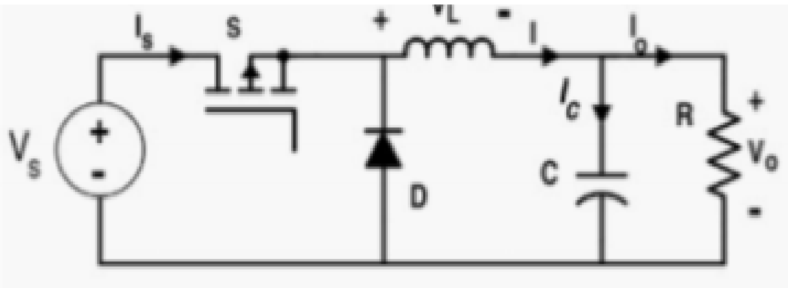

Fig 21: Buck-Boost converter circuit

Working:

The Buck Boost converter can be operated in two modes

Mode -1 Switch ON:

When switch in ON for a time t_{on}, the diode will be open circuited since it does not allow currents in reverse direction from input to output. During this state the inductor charges and the inductor current increases.

Mode – 2 Switch OFF:

When switch in OFF the diode will be forward biased as it allows current from output to input (p to n terminal) and the Buck Boost converter circuit can be redrawn. The inductor now discharges through the diode and RC combination.

Advantages:

1. Buck-boost converters offer a more efficient solution with fewer, smaller external components.
2. They are able to both step-up or step-down voltages using this minimal number of components while also offering a lower operating duty cycle and higher efficiency across a wide range of input and output voltages.
3. Buck-boost converters are also a lot less expensive when compared to other converters.
4. Buck-boost converters are very versatile, often used to carry out control unit functions.
5. These can range from low power, high efficiency integrated circuits for portable electronics to large industrial high-power DC-DC converters.

Disadvantages:

1. They cannot achieve high gain because efficiency is too poor for it (i.e. very small or very large duty cycle only – no in-between).
2. There is also no isolation from the input to output side, rendering it unsuitable for certain applications.

Simulation Model:

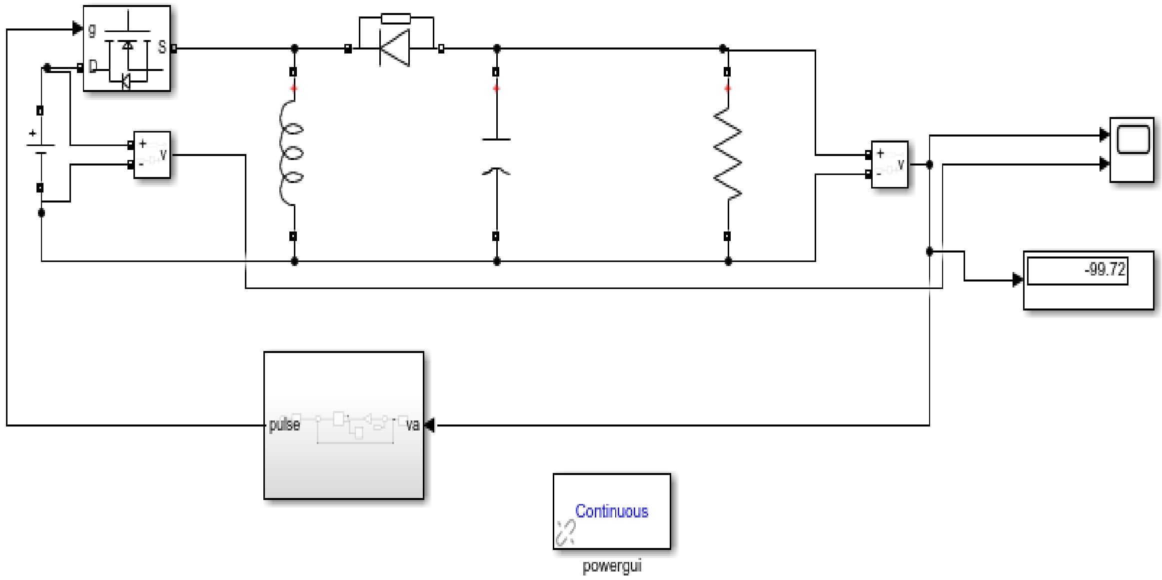

Fig 22: Buck - Boost converter MATLAB simulation model

The Buck-Boost model, being a combination of Buck converter and Boost converter allows the step-up as well as step-down operation of the voltage.

Output:

The below graphs show the step-up and step-down results depending on the operation.

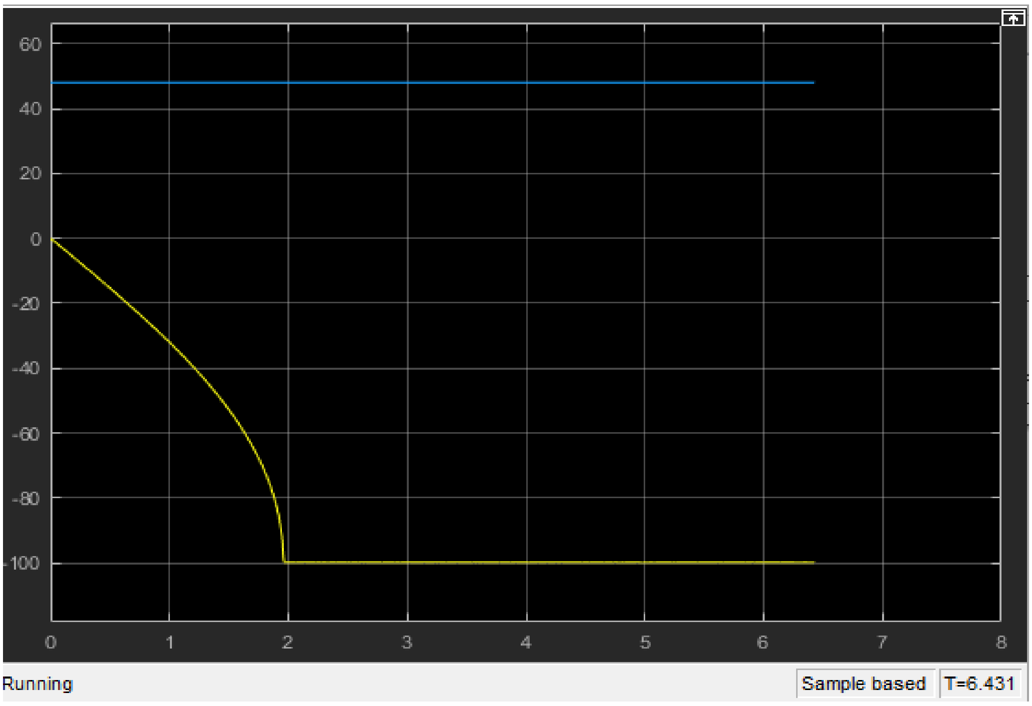

Fig 23: Boosted mode output.

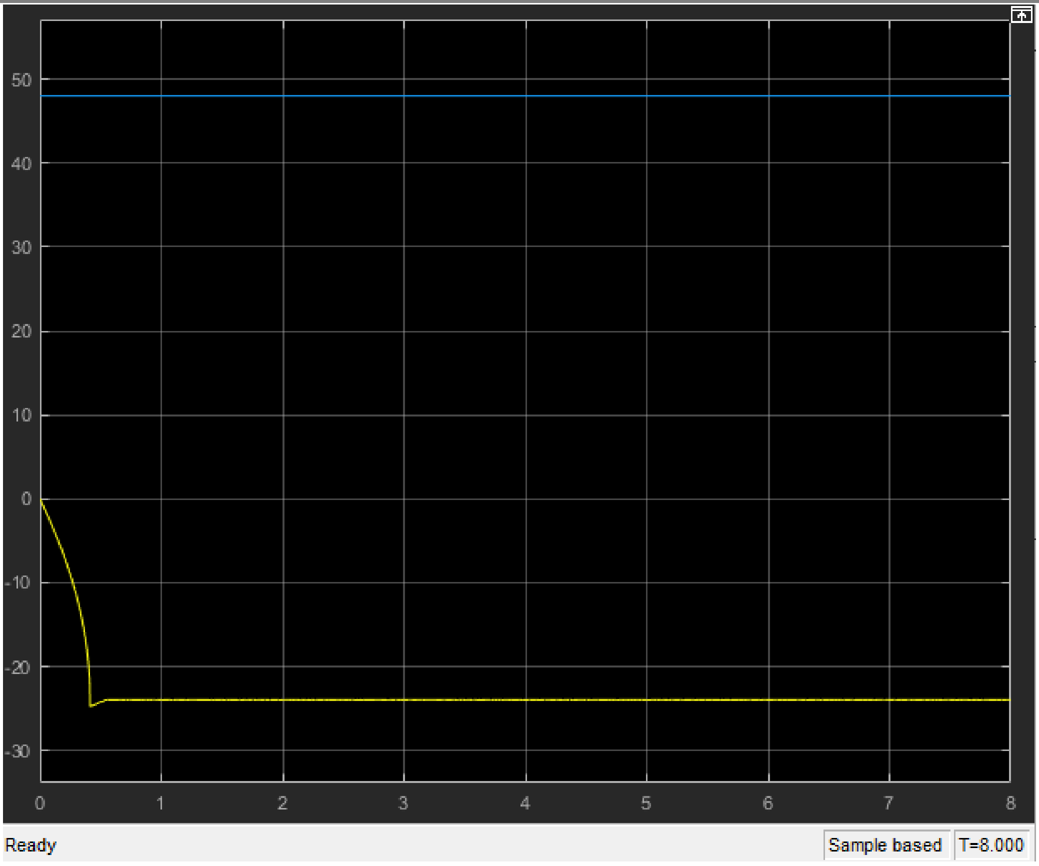

Fig 24: Buck mode output.

LUO CONVERTER:

LUO converter is the developed converter derived from the buck-boost converter. In this proposed model the additional filter elements in the Luo-converter eliminate the output ripples and effectively enhance the output voltage level.

The Luo converter has one inductor, one power switch and two diodes. And also has filter for reduce the harmonics of the output voltage. When power switch is turned on inductor get energized and the voltage is going to output capacitor through diodes. The capacitor is discharging the voltage across the load.

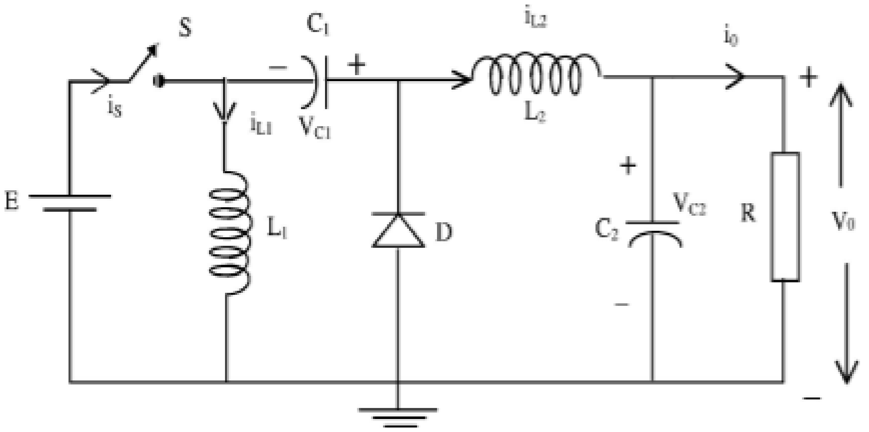

Fig 25: LUO converter circuit

Working:

Mode 1 – Switch ON:

When the switch is ON, the inductor L1 is charged by the supply voltage E. At the same time, the inductor L2 absorbs the energy from source and the capacitor C1. The load is supplied by the capacitor C2.

Mode 2 - Switch OFF:

When the switch is OFF, the current is drawn from the source becomes zero. Current iL1 flows through the freewheeling diode to charge the capacitor C1. Current iL2 flows through C2 –R circuit and the freewheeling diode D to keep itself continuous.

Advantages:

1. High efficiency
2. Easy to control the speed
3. Switching losses are reduce

Disadvantages:

1. low-efficiency and high capital cost.

Simulation Model:

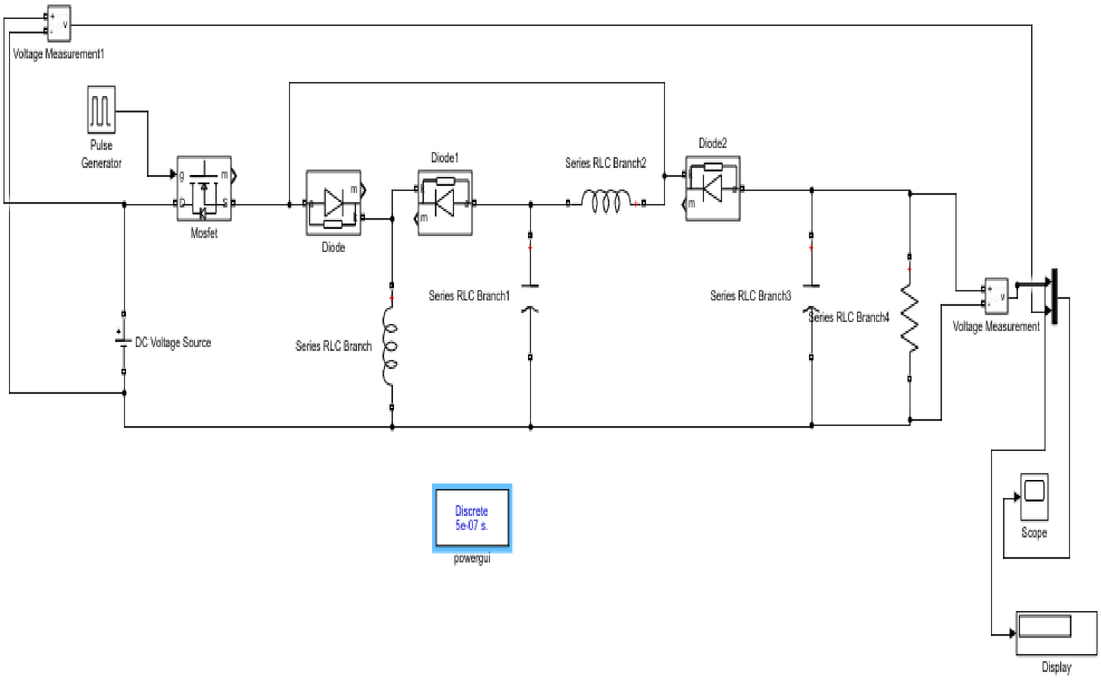

Fig 26: LUO converter MATLAB simulation model

Results:

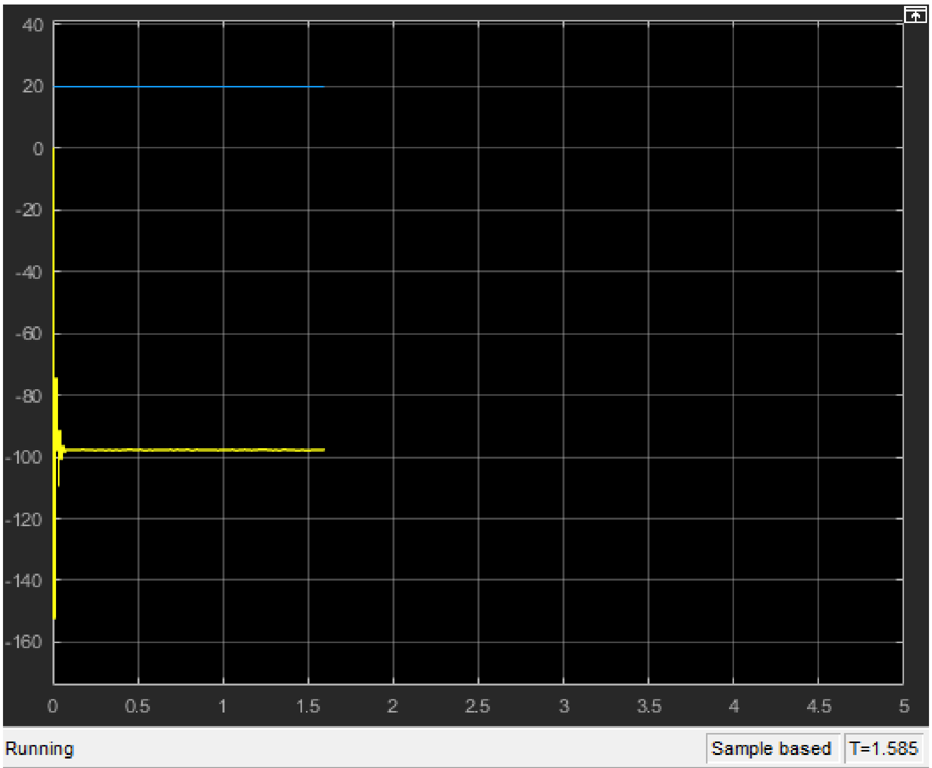

Fig 27: LUO converter simulation output

<u>CUK CONVERTER:</u>

Cuk converter is a dc-dc converter with output voltage value can be higher or lower than the input voltage, but the output voltage of the converter has a reverse polarity of the input voltage.

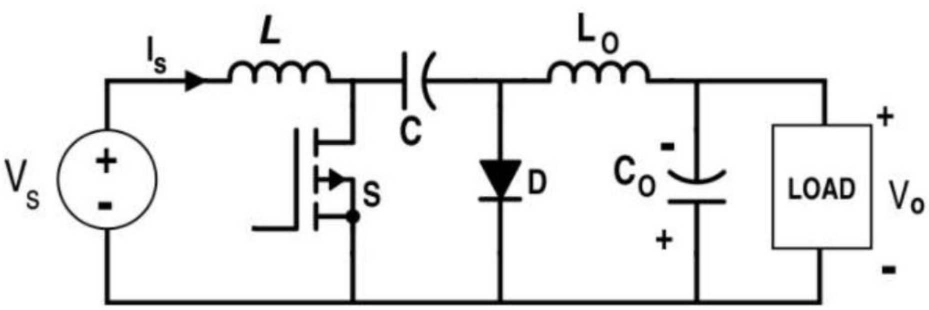

Fig 28: Cuk converter circuit

Working:

Mode 1 – Switch ON:

When the switch S is turned on, the source Vs charge the inductor as a result, the current through the inductor L rises. The current through Vs, L, S forms a current loop. Meanwhile, since VC>VO, the capacitor C discharge and the diode D has the inverse voltage which is regarded as open circuit. The energy stored in the capacitor was transferred to capacitor Co and load and inductor Lo. In the other words, the voltage of capacitor Co increases and the current of inductor rises.

Mode 2 – Switch OFF:

When the switch is off. In this mode, the capacitor C is charged by supply voltage and inductor L as the source through the inductor L and diode D. Also, because of the Voltage VC>VS, the inductor current decreases. At the same time, the energy stored in the inductor Lo is transferred to the load thereby the current of inductor.

Advantages:

1. Cuk converter uses L-C type filter, so peak-peak ripple current of inductors is less.
2. Continuous input current.
3. Continuous output current.
4. Provides energy to the load in both the modes of operation.

Disadvantages:

1. Requires large capacitor with large current carrying capacity.

Simulation Model:

The below figure shows the simulation model of the Cuk converter with discrete mode .

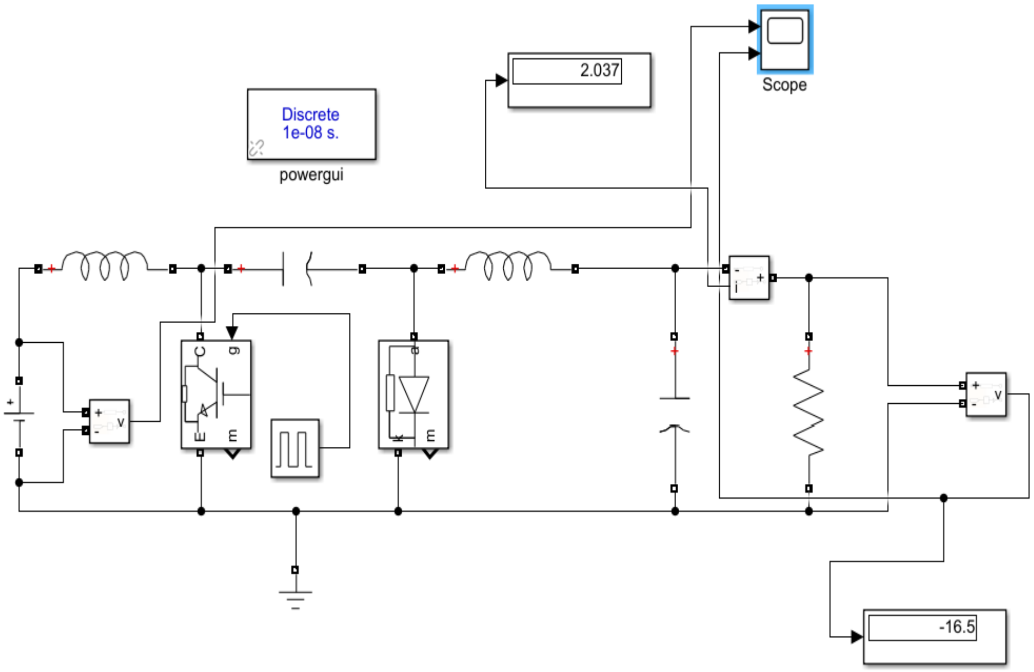

Fig 29: CUK converter MATLAB simulation model

Result:

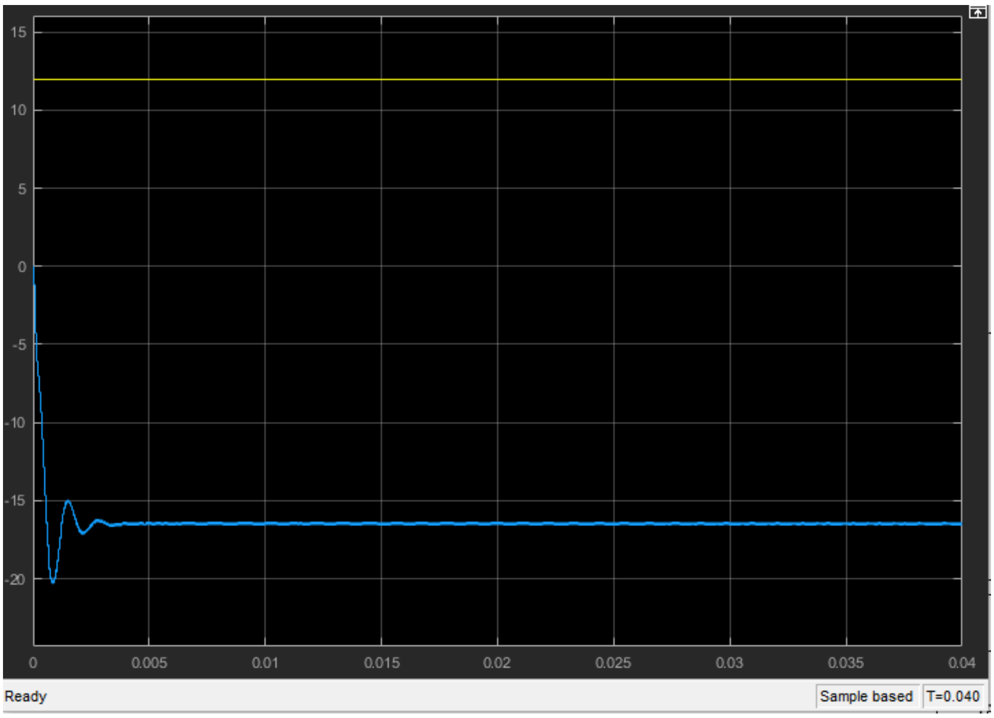

Fig 30. Cuk converter simulation output.

SEPIC CONVERTER:

The single-ended primary-inductor converter is a type of DC/DC converter that allows the electrical potential at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the control switch. We will get non inverted output voltage with the help of SEPIC converter. This type of conversion is handy when the designer uses voltages (e.g., 12 V) from an unregulated input power supply.

The switch of the SEPIC can be controlled by varying the duty cycle of the gate pulse in order to control the output voltage. Though the SEPIC is like a buck-boost converter, it has the unique feature of giving a noninverted output. A series capacitor is used to couple the energy from the input to the output. The SEPIC responds quickly to a short-circuit condition and works in a true shutdown mode, when the switch is turned off. The SEPIC transfers energy between the capacitors and inductors, through the switching operation in order to convert the input voltage from one voltage to another. The amount of energy transferred is controlled by changing the duty cycle of the switch which can either be MOSFET or IGBT.

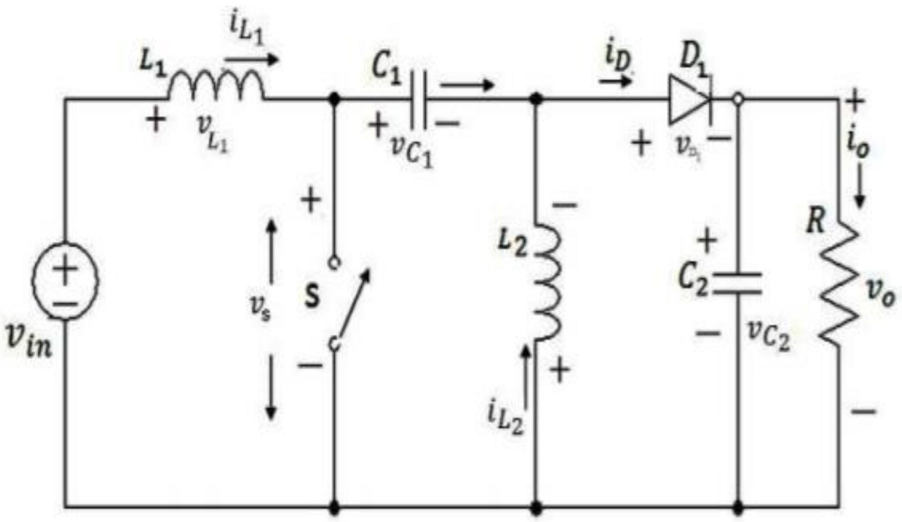

Fig 31: SEPIC converter circuit

Working:

The diode is the switching device in SEPIC. It gets switched on, when anode voltage is more than cathode voltage. As it is unidirectional one, during MOSFET switched on condition, no current flows through diode as the voltage across the diode is negative. When the MOSFET turns off, coupling capacitor start charging and inductor L2 is discharging through the diode. So, initially current is at peak value and then current is slowly decreases. When capacitor C1 starts charging, the current through it gets decreased and when it discharges, the current through it gets increased. In SEPIC, during Ton period, capacitor C1 starts discharging through the inductor, so current in the capacitor starts increasing, but in a reverse direction. So current is negative. During Toff, capacitor C1 starts charging and current is in the forward direction. When the MOSFET is switched on, inductor L1 is charging through the MOSFET. Hence current through the inductor and the MOSFET is increased to a definite value till the MOSFET turns off. When the MOSFET is off, inductor L1 current gets decreasing. Current through both the inductors is same as both the inductors charging and discharging simultaneously.

Advantages:

1. Either steps up or steps down its input voltage.
2. Produces non-inverted voltage output.
3. Non-pulsating input current reduces the EMI and eliminates the need of input filters for battery sources.
4. Reduced output ripple, high efficiency and high voltage transfer gain.

Disadvantages:

1. Since the SEPIC converter transfers all its energy via the series capacitor, a capacitor with high capacitance and current handling capability is required.
2. The fourth-order nature of the converter also makes the SEPIC converter difficult to control, making it only suitable for very slow varying applications.
3. The resistances in the inductors and the capacitors can also have large effects on the converter efficiency and output ripple.

MPPT for solar module:

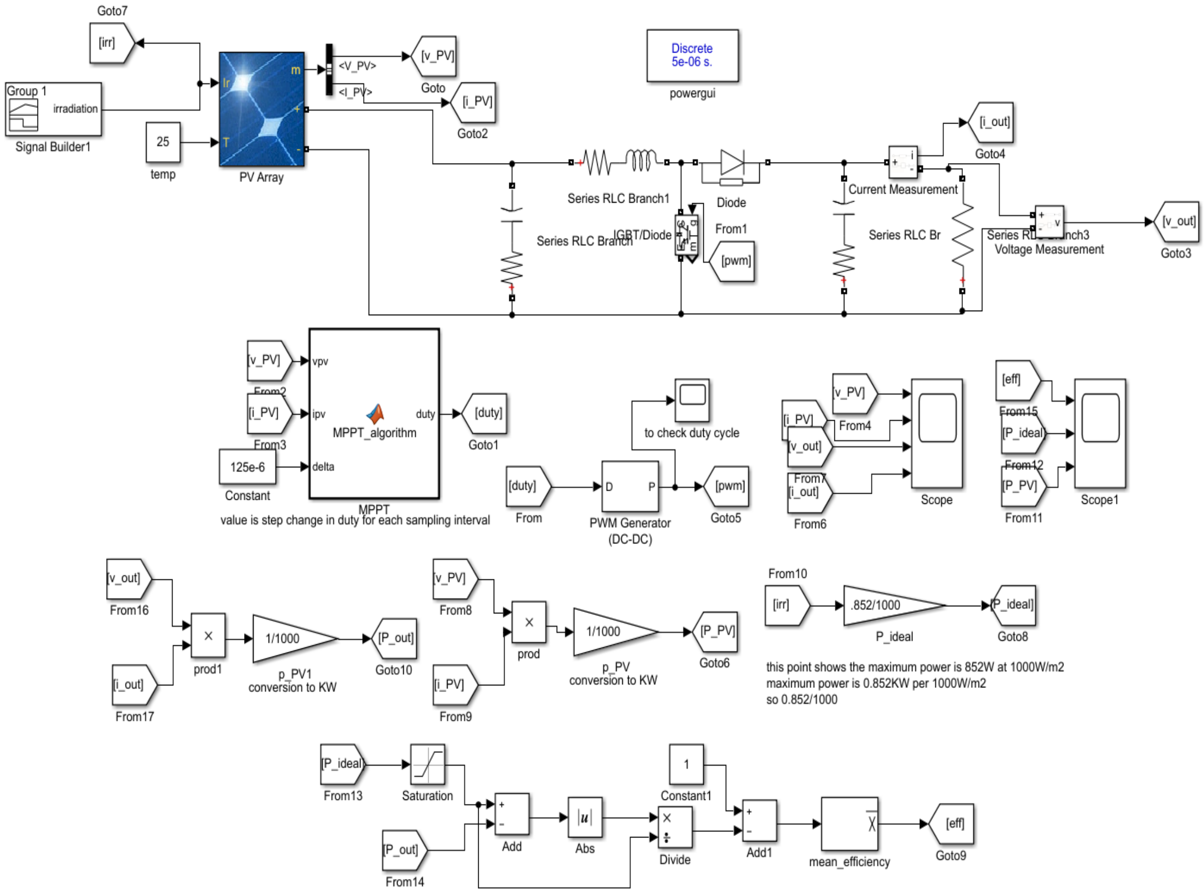

Fig 32: MPPT for solar with Boost converter

The solar panel produces maximum power of 852W at 58V for which we have implemented MPPT. The output of the PV array is given to a boost converter. We are taking current Ipv and voltage Vpv from the panel directly using a go to block and sending the same to MPPT Algorithm block. The MPPT algorithm based on the values of Ipv and Vpv, tries to generate maximum power from the panels Ppv at all given conditions therefore produces frequent changes in the duty cycle which is given to the converter switch. These panels are being given a variable irradiance as input, so all the outputs will follow irradiance. We have also calculated the mean efficiency here. Irradiance is given in such a way that the value keeps changing in order to demonstrate the MPPT algorithm.

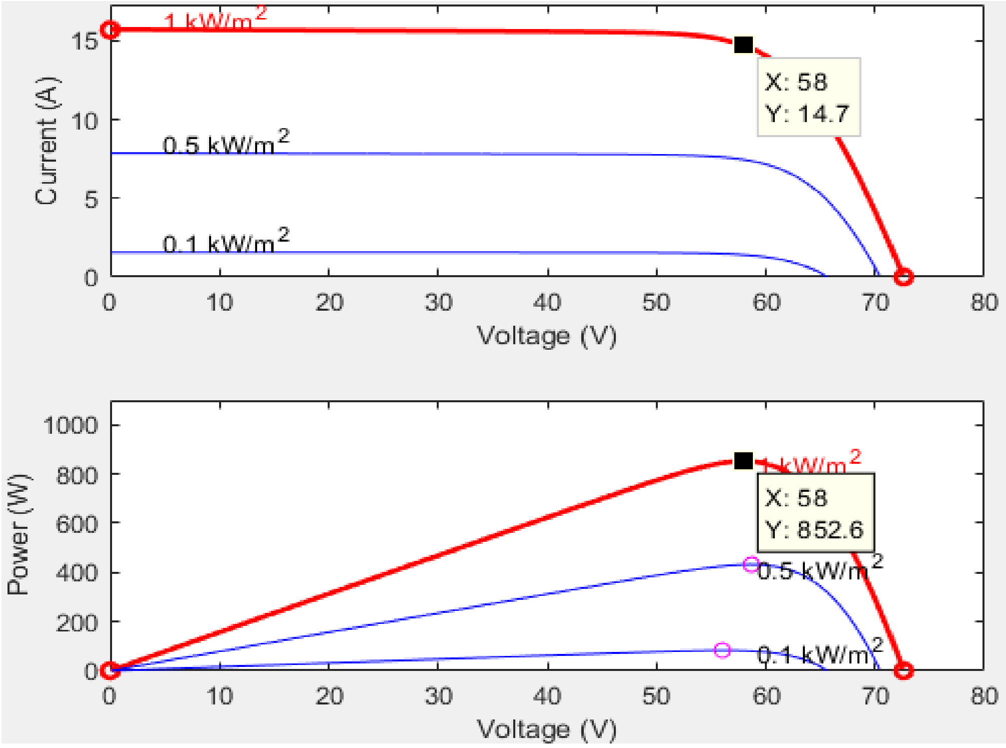

Fig 33: P-V, I-V characteristics of PV panel

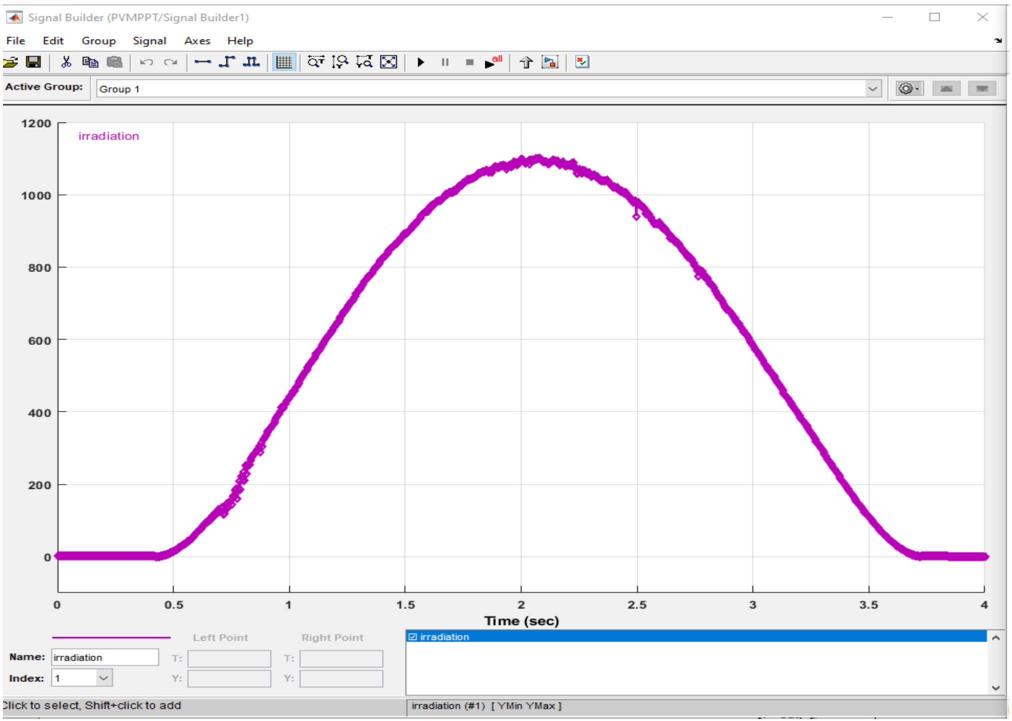

Fig 34: Varying Irradiance curve

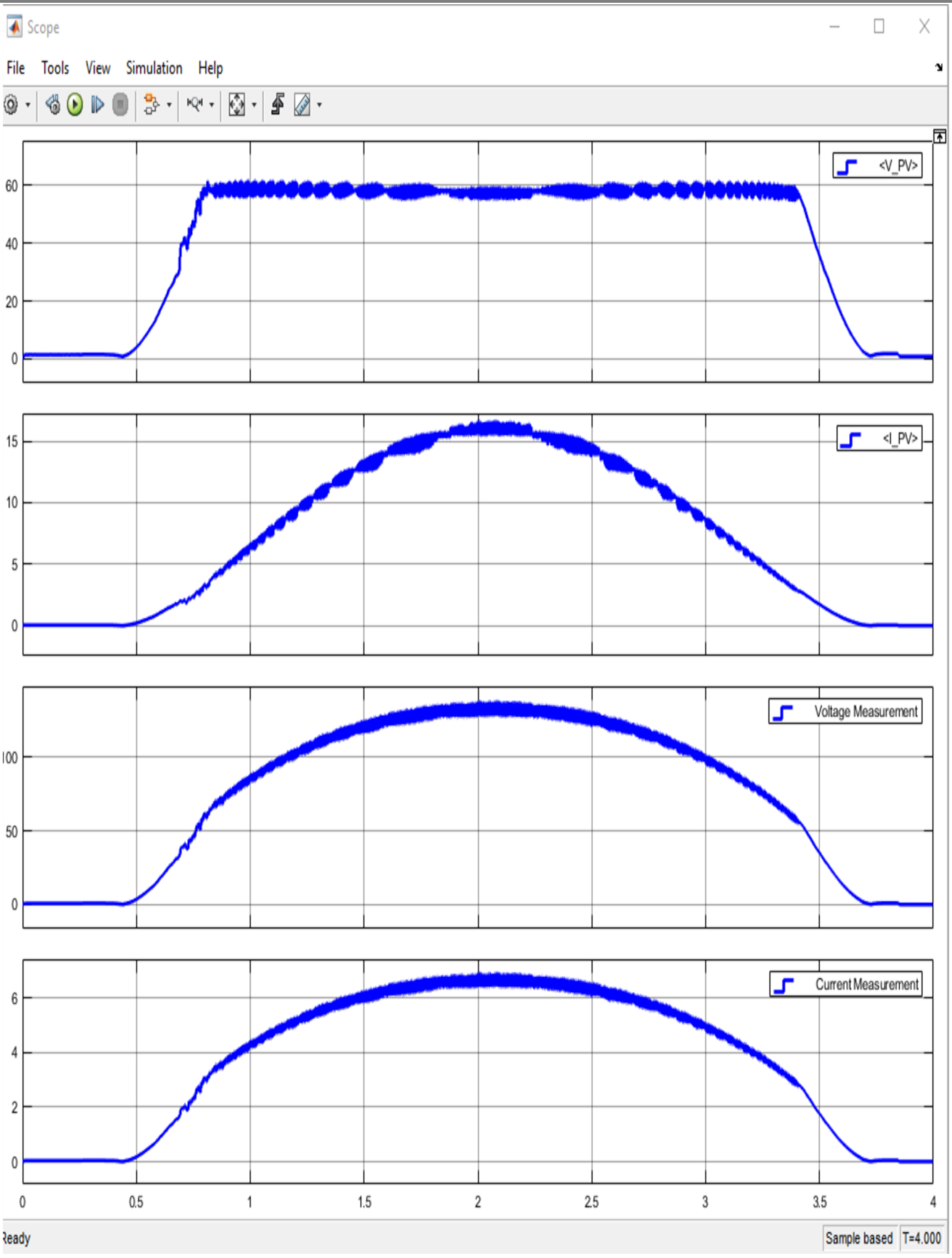

Fig 35: Vpv, Ipv and output across the load on the converter

The above output shows the voltage of the PV panel, current of the PV panel, voltage of the boost converter on the load side and current of the passing through the load. As you can see all these curves follow Irradiance curves as given on the input to the PV panel. Voltage of the PV panel is 58V but that on the converter side across the load it is 120V. The voltage has increased but the current has reduced post boost converter.

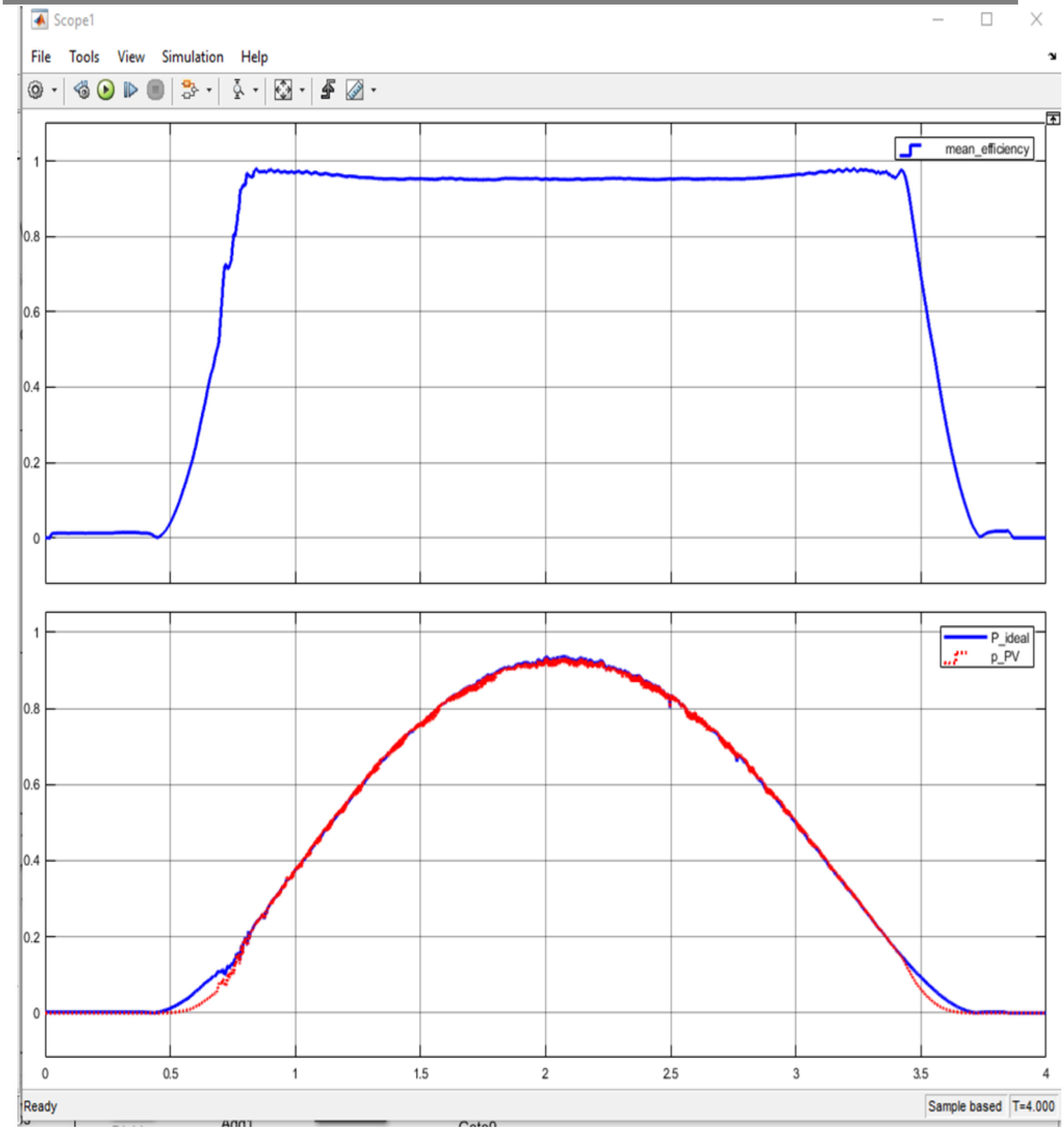

Fig 36: Mean efficiency and power.

The above graph shows the efficiency of the MPPT algorithm which is approx. 96 to 94 percent. The irradiance is multiplied with power/irradiance in order to obtain P-ideal which is the ideal condition of power generation based on changing irradiance value. But in the above graph you can see the PV panel power follows the P-ideal value due to the MPPT algorithm.

INTEGRATED CONVERTER:

Finalized converter for the solar and wind hybrid system. The integrated converter topology has reduced the circuit components and also increases the system efficiency. The features of the proposed integrated topology are:

1) The inherent nature of these two converters eliminates the need for separate input filters for power factor correction.
2) It can support step up/down operations for each renewable source (can support wide ranges of PV and wind input).
3) System works on the presence of both or any one of the Renewable resources.
4) Individual and simultaneous operation is supported.

A system diagram of the Integrated converter of a hybrid energy system is shown in Figure, where one of the inputs is connected to the output of the PV array and the other input connected to the output of a generator. The fusion of the two converters is achieved by reconfiguring the two existing diodes from each converter and the shared utilization of the Cuk output inductor by the SEPIC converter. This configuration allows each converter to operate normally individually in the event that one source is unavailable.

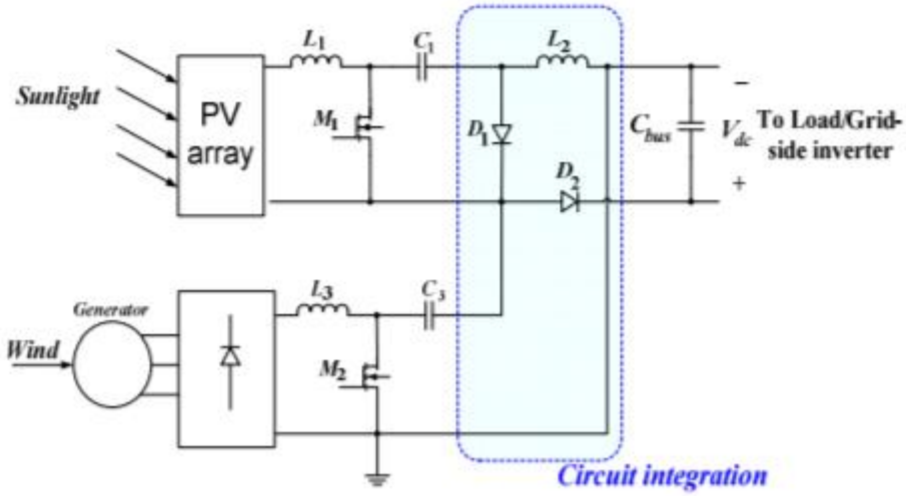

Fig 37: Integrated converter circuit Working:

Mode 1 (M1-ON, M2-ON):

In this mode both solar energy and wind energy is available, the switches M1 and M2 are turn ON. The capacitors C1 and C2 connected across diode D1 and D2 respectively then diodes D1 and D2 experience reverse biased. The equivalent circuit is as shown below.

$$I_{L1} = I_{pv} + \frac{V_{pv}}{L_1} t \quad (0 < t < d_1 T_s)$$

$$I_{L2} = I_{dc} + \frac{V_{C1} + V_{C2}}{L_2} t$$

$$I_{L3} = I_w + \frac{V_w}{L_3} t$$

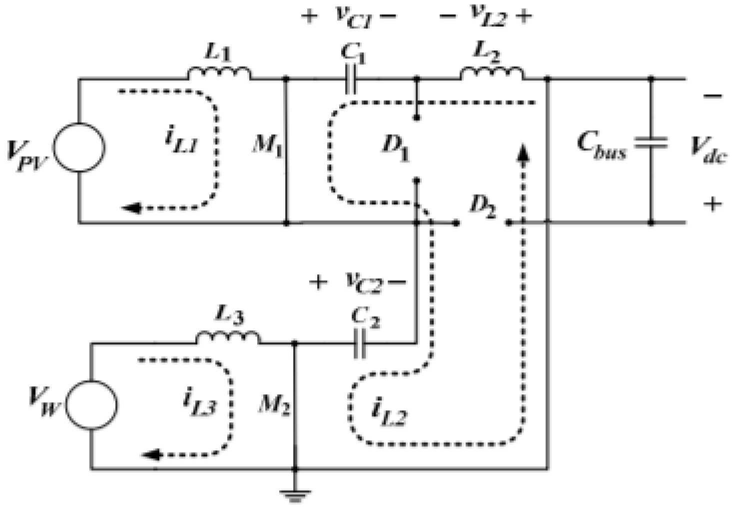

Fig 38: Integrated converter operation mode 1

Mode 2 (M1-ON, M2-OFF):

In this mode only solar energy is available and wind energy is not available. The switch M1 turns ON and switch M2 turns OFF. The diode D1 experience reverse biased. The inductor current in L3 forces diode D2 to conduct. The equivalent circuit is as shown in below figure.

$$I_{L1} = I_{pv} + \frac{V_{pv}}{L_1} t \quad (d_2 T_s < t < d_1 T_s)$$

$$I_{L2} = I_{dc} + \frac{V_{C1}}{L_2} t$$

$$I_{L3} = I_w + \frac{V_w - V_{C2}}{L_3} t$$

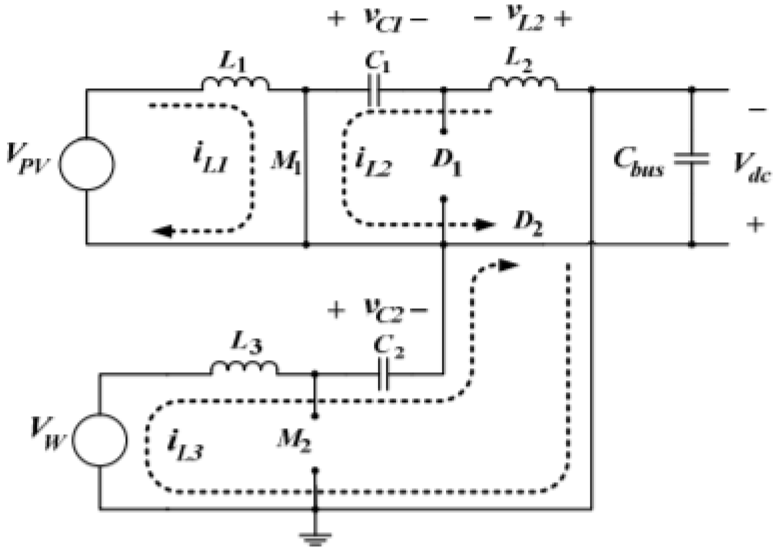

Fig 39: Integrated converter operation mode 2

Mode 3 (M1-OFF, M2-ON):

In this mode only wind energy is available and solar energy is not available. The switch M1 is turn OFF and switch M2 is turn ON. The current in the inductor L1 forces diode D1 to turn ON and diode D2 experience reverse biased. The equivalent circuit is as shown below.

$$I_{L1} = I_{pv} + \frac{V_{pv} - V_{C1}}{L_1} t \quad (d_1 T_s < t < d_2 T_s)$$

$$I_{L2} = I_{dc} + \frac{V_{C2}}{L_2} t$$

$$I_{L3} = I_w + \frac{V_w}{L_3} t$$

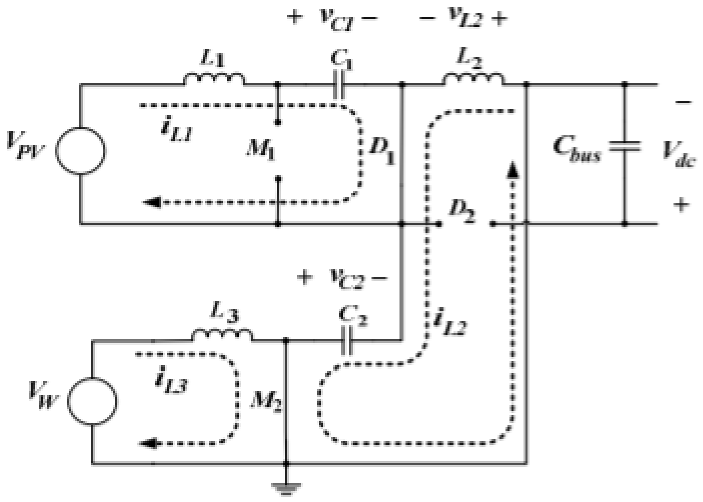

Fig 40: Integrated converter operation mode 3

Mode 4 (M1-OFF, M2-OFF):

In this mode both solar energy and wind energy is unavailable. The switches M1 and M2 both are turn OFF. The inductor current L1 and L3 forces diode D1 and D3 to conduct respectively. The equivalent circuit is as shown below.

$$I_{L1} = I_{pv} + \frac{V_{pv} - V_{C1}}{L_1} t \quad (d_2 T_s < t < T_s)$$

$$I_{L2} = I_{dc} - \frac{V_{dc}}{L_2} t$$

$$I_{L3} = I_w + \frac{V_{pv} - V_{c1}}{L_3} t$$

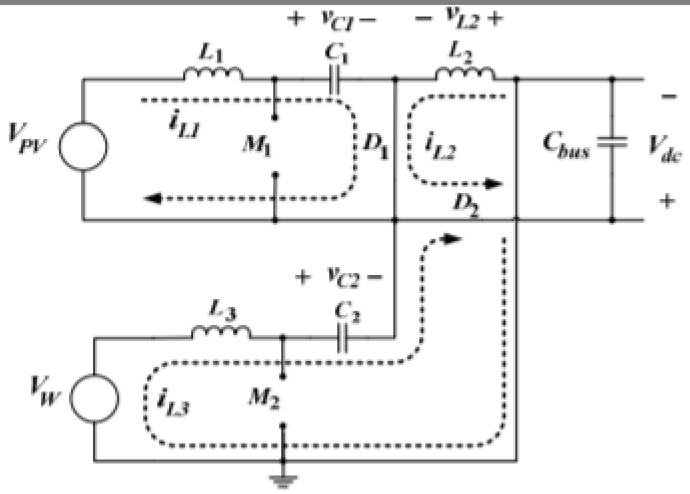

Fig 41: Integrated converter operation mode 4

Simulation Model:

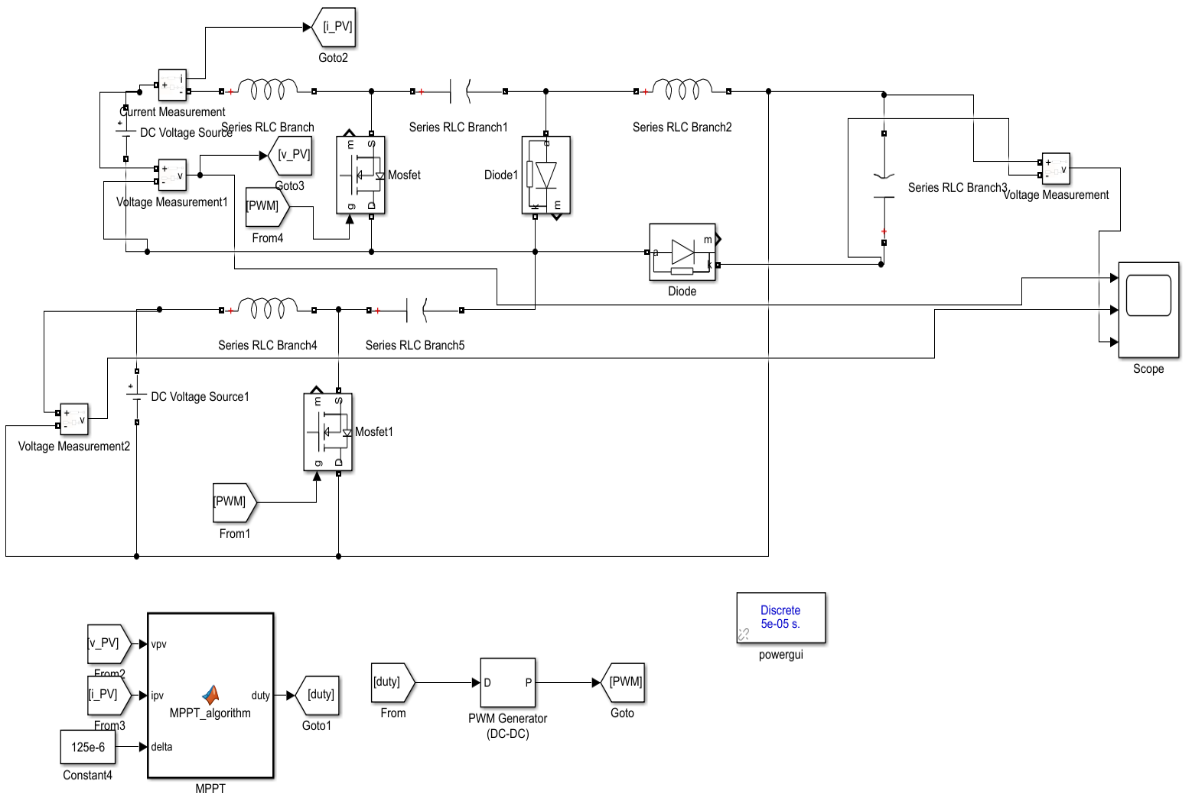

Fig 42: Integrated converter MATLAB simulation model

CHAPTER 4

ADVANTAGES AND APPLICATIONS

Advantages of Solar and Wind Energy Hybrid System:

1. Utilization of renewable sources in best way.
2. More reliable and efficient.
3. Continuous power supply.
4. Environment friendly.
5. Easy to install and maintain.
6. Low maintenance cost.

Advantages of Cuk-SEPIC integrated converter topology:

1. Individual converters are replaced by single converter called CUK-SEPIC converter.
2. They do not require supervisory control for switching because power electronic switches of the converters are responsible for switching
3. Additional input filters are not required to filter out high frequency harmonics because of inherent input filter.
4. Energy storage and transfer depends on capacitors of converter.
5. The design produces power at all time efficiently by using freely available renewable resources.
6. It supports both individual and simultaneous operation of sources.

Applications of Solar-Wind Hybrid System:

- Grid connected: The large power rating of hybrid systems, where the access of wind and sun irradiation is more, they can be connected to Grid. In these types of generation, if the system failed to generate power the Grid will supply the load.

- Stand alone: Almost all PV/Wind hybrid system applications are stand - alone not connected to the grid.
- Street lighting: The foremost application of SWHES is solar street lighting. Solar Street light become as Solar-Wind Hybrid Energy System lighting. Use of this reduces the load from conventional power plants.
- Household: Residential appliances can use power generated through hybrid solar wind energy system. Hybrid systems are used to supply electricity to different offices or other parts of the building in reliable manner.
- Remote Applications: like military services where it is impossible to provide conventional power supply these hybrid systems are useful.
- Ventilation system: The proposed systems are also used for ventilation purposes, these helps in running Bath fans, floor fans and ceiling fans in buildings.
- Power Pump: The designed PV/Wind energy system can also help to pump the water to any building. DC power operated pump can circulate the water through your home.
- Village Power: The proposed system is very useful in villages which are in valley and on hills, where it is not possible to send electricity.
- On shore: The wind blows more at coastal areas, Solar-Wind hybrid systems are installed near sea and on the boats for power generation.
- Commercial: In hotels, tourist places these hybrid systems give the required electric power.

Although, the main application of the designed PV/Wind Hybrid system is to supply DC power as a stand-alone system to the required appliances.

CHAPTER 5

RESULTS AND CONCLUSIONS

In the below output graph, we have maintained a constant input voltage of 150V from solar panels and 70V from wind turbine respectively and the corresponding output of the hybrid system (around 80V) is obtained as seen on the graph.

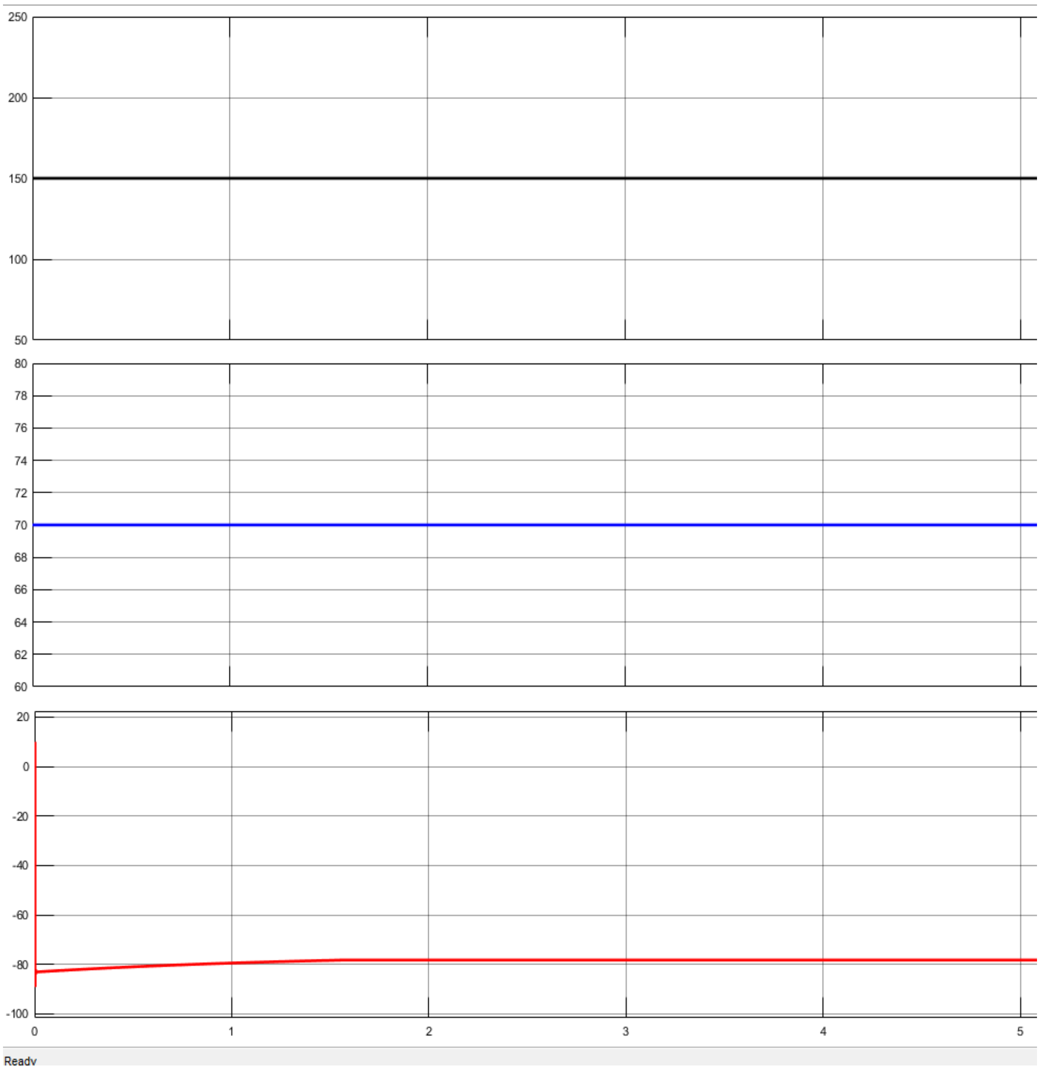

Fig 43. Integrated converter simulation output.

We can conclude by saying that, simulation of solar-wind hybrid system with suitable converter topology is executed and the objectives of the project were achieved. Various parameters were observed and found to be providing faithful results under error limits.

The following were implemented successfully using MATLAB:

- Simulation and modelling of PV system, Wind system and various converters.
- MPPT Algorithm is implemented successfully.
- Output from each of the stages are observed

So, we can conclude that this project can be implemented in real life.

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