MODELING AND SIMULATION OF HYBRID WIND/PHOTOVOLTAIC STAND-ALONE GENERATION SYSTEM

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IN
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SUBMITTED BY:

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CANDIDATE'S DECLARATION

I RICHA SAHU, Roll No – 2k16/C&I/14 student of M.Tech (Control & Instrumentation), hereby declare that the project Dissertation titled "MODELING AND SIMULATION OF HYBRID WIND/PHOTOVOLTAIC STAND-ALONE GENERATION SYSTEM" which is submitted by me to the Department of Electrical Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "MODELING AND SIMULATION OF HYBRID WIND/PHOTOVOLTAIC STAND-ALONE GENERATION SYSTEM" which is submitted by RICHA SAHU, whose Roll No. is 2k16/C&I/14, Electrical Engineering Department, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

The worries for condition due the regularly expanding utilization of petroleum products and quick consumption of this asset have prompted the development of alternative source of energy such as solar energy. This paper recommends that how to expand the effectiveness of a sun powered PV Energy framework by the headway in Conventional DC to DC Boost converter .This paper additionally proposes the investigation of modelling and simulation using MATLAB of solar PV energy system to enhance its output using DC-DC boost converter. This boost converter increases the output voltage of the solar energy system. The simulation results of this system are presented and compared. This result verifies that with the help of the boost converter system has the advantages of high efficiency. Renewable energy sources have become a popular alternative 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 hybrid energy system which combines both solar panel and wind turbine generator as an alternative for conventional source of electrical energy like thermal and hydro power generation. A software simulation model is developed in Matlab/Simulink.

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List of abbreviations

PV	Photo Voltaic
MPPT	Maximum Power Point Tracking
DC	Direct Current
MATLAB	MATrix LABoratory
P&O	Perturb and Observe
IC	Incremental Conductance
Fig	Figure
PMSG	Permanent magnet synchronous generator
MPP	Maximum power point

List of symbols

I_{PV}	Photocurrent current
I_O	Reverse saturation current of diode
V	Voltage across the diode
A	Ideality Factor
V_T	Thermal voltage
R_S	Series resistance
R_p	Shunt resistor of the cell
K_I	Cell's short circuit current temperature coefficient
G	Solar irradiation in W/m^2
G_{STC}	Nominal solar irradiation in W/m^2
I_{PV_STC}	Light generated current under standard test condition
I_{0_STC}	Nominal saturation current
E_g	Energy band gap of semiconductor
T_{STC}	Temperature at standard test condition
q	Charge of electrons
I_{SC_STC}	Short circuit current at standard test conditions
V_{OC_STC}	Short circuit voltage at standard test conditions
K_V	Temperature coefficient of open circuit voltage
N_S	Number of series cells
N_P	Number of parallel cells
P_M	Power captured by wind turbine

β	Pitch angle (in degrees)
R	Blade radius (in meters)
V	Wind speed (in m/s)
p	The number of pole pair in the generator
ϕ	Flux
t	Number of turns
V_0	Output of buck-boost converter
V_w	Input of buck-boost converter
P	Wind power
Ω	Rotor speed

CHAPTER-1

INTRODUCTION TO HYBRID SYSTEM

1.1 INTRODUCTION

Power (Energy) is a vital component for human economic development and growth. With the increase in population, people's demand for energy is also growing. Fossil energy holds are draining and won't have the capacity to address the issues of social advancement in the future. Additionally, broad utilization of non renewable energy sources has harmed our living condition. Therefore, the world has turned its regard for sustainable power sources.

Among them, sun based energy(Solar Energy) has pulled in individuals' consideration since it has high calibre of Energy, is safe and reliable, and does not bring about contaminating outflows. Besides, sun energy can nearly be discovered all around, and isn't limited to particular land territories. Because of their diminishing expenses and adaptable arrangements, photovoltaic frameworks will without a doubt turn into a promising environmentally friendly power energy innovation to accomplish economic advancement Due to the critical condition of industrial fuels which comprise oil, gas and others, the improvement of renewable energy sources is constantly improving. This is why renewable energy sources has turn into more important these days.

Few additional reason comprise advantages like ample accessibility in nature, environmental and recyclable. renewable sources solar and wind energy are the world's fastest rising energy resources. With no secretion of pollutant, energy translation is done through the PV cells and wind.

In this, a solar wind hybrid power generation system model is simulated and studied. A solar wind hybrid system is more profitable as individual energy generation system isn't entirely trustworthy. When any one of the system is at halt the other be able to resource power. A figure of hybrid system is shown below :

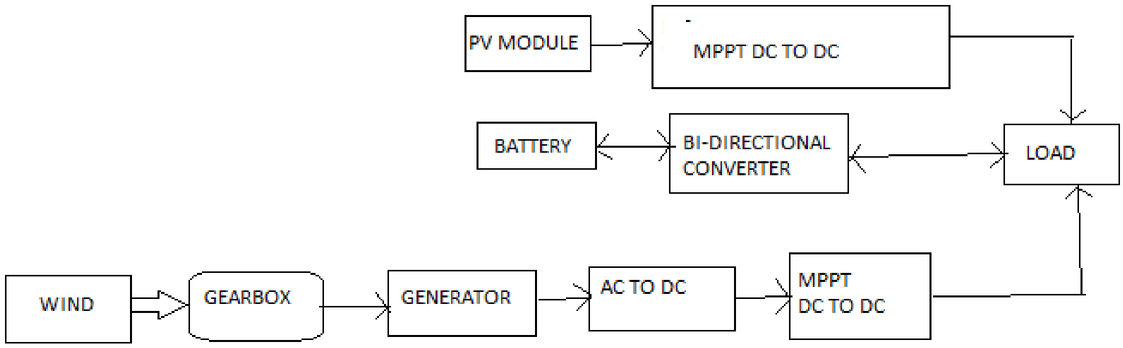

Fig 1.1: Block diagram of hybrid system

The accessible base load plants aren't able to stream electricity as per demand. therefore these energy sources may be utilized to bridge the gap among supply and demand throughout peak loads. The complete hybrid system comprises of PV and the wind systems. The system is powered by the solar energy which is in abundance existing in environment.

PV modules, maximum power point tracing systems build the Photovoltaic energy system. The light incident on the Photovoltaic cells is changed into electrical energy via solar energy harvesting means. The maximum power point tracking system with Perturb & absorb algorithm is used, which extracts the maximum possible power from the Photovoltaic modules. The ac-dc converter is used to converter ac voltage to dc. Gear box, Wind turbine, Generator and an AC - DC converter are integrated in the wind energy system.

The wind turbine is used to change wind energy to rotating mechanical energy and this energy accessible at the turbine shaft is converted to electrical energy using a generator. To drive the maximum power from wind system we used maximum power point tracing system. Both the energy system is used to charge battery using bi-directional converter.

Hybrid generation systems that use other than a only power source can significantly increase the certainty of load hassles all the time. Even higher generating capacity may be attained by hybrid system. In backup system we can able to afford oscillation free output to the load nevertheless of weathers situation. To get the energy output of the photovoltaic system converted to storage energy, and steady power delivered by the wind turbine, an capable energy storage mechanism is mandatory, which may be realize by the battery bank.

1.2 LITERATURE REVIEW

Due to high demand of energy and limited availability of conventional energy, non-conventional sources become more popular among researchers. A lot of research work is going on to enhance the power efficiency of non-conventional sources and make it more reliable and beneficial.

Hybrid generation system uses more than one source, so that we can extract energy from different sources at the same time which enhances the efficiency. From [2],[3] the working of PV /Wind hybrid system is understood, different topologies that can be used for the hybridization of more than one system and also about advantages and disadvantages of hybrid system. From [1], [4] and [5] basic details of PV cell, PV module, PV array and their modeling are studied. Also, the behavior of PV modules at varying environmental conditions like solar irradiation and temperature are studied. Behavior of PV module during partial shading condition and also how it's bad effects can be minimized is explained in [6]-[8]. Different MPPT techniques, their advantages and disadvantages and why MPPT control is required is explained in [9]-[11].The wind energy system, its working and also techniques to extracts the maximum power from the wind energy system is understood from [13]-[17]. From [18]-[20] study about different type of bi-directional converters, their working and how to use them in battery charging and discharging is carried out.

In recent years, introduction of photovoltaic (PV) system has accelerated all over the world[8].The sun is the source of light and heat energy hence the abundant energy offered by the Sun is thousand times higher than the total energy consumption used by the world in present time[6]. The use of renewable energy resources like solar energy and wind energy is increasing rapidly for electricity generation purpose. Solar energy can be converted in to electricity by using photovoltaic cell. A PV cell can convert photon energy into the form of electrical signals, this method of power generation do not harm to ecosystem hence PV power generation systems are becoming popular for generation in small scale as well as in large scale production. Most PV arrays use an inverter to convert the DC power into alternating current that can power the motors, loads, lights etc. The modules in a PV array are usually first connected in series to obtain the desired voltages; the individual modules are then connected in parallel to allow the system to produce more current.

CHAPTER-2

SOLAR PV ENERGY SYSTEM

History

In 1839, a French man of science Edmund physicist projected that few materials have the flexibility to supply electricity once exposed to daylight (Sunlight). However physicist explained the Photoelectric impact and also the nature of sunlight in 1905. Photoelectric impact state that once photons or sunlight strikes to a metal surface flow of electrons can take place. Later Photoelectric impact became the fundamental principle for the technology of Photo electric power generation. the primary PV module was factory-made by Bell laboratories in 1954. There ar 2 main sorts of solar power technology: photo voltaics (PV) and solar thermal.

2.1.1 PV CELL MODEL

The PVcell is a device which converts solar energy into electricity[5].A PVcell contains of a PN junction fabricated on a thin wafer or layer of semiconductor[7].

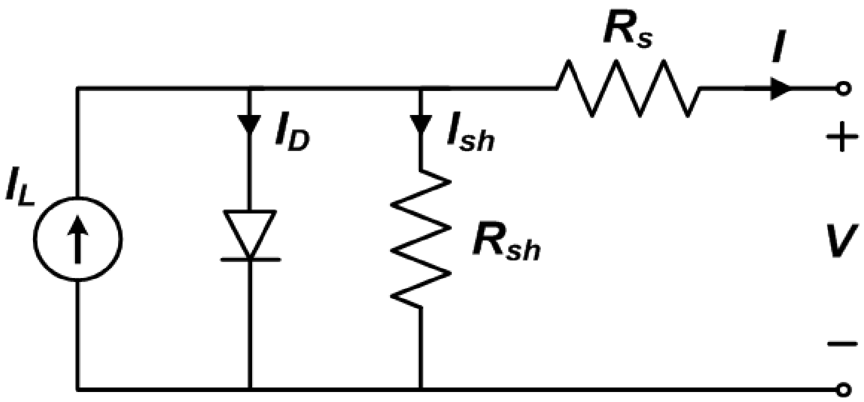

Fig. 1.PVcell equivalent circuit [3]

A photovoltaic energy system is especially high-powered by solar power. The configuration of PV system is manifested in figure a pair of. It contains PV modules or arrays, that convert solar power within the kind of solar irradiation into electrical energy.

The dc-dc converter changes the amount of the voltage to match it with the electrical appliances that are provided by this technique. This DC -DC convertor could also be either buck or boost or buck-boost dependent on the desired and accessible voltage levels.

The MMPT system coerce the utmost power from the Photovoltaic modules. A bi-directional converter that is ready to provide the current in each the directions is employed to charge the battery once there's a power excess and that’s why the energy stored by the battery is discharged into the load once there's a power deficit.

The use of non conventional energy resources like solar power and wind energy is increasing speedily for electricity generation use. Solar power can regenerate into electrical energy by using cell. A PV cell will convert photon energy into the shape of electrical signals, this methodology of power generation don't damage to ecosystem therefore PV power generation systems have become common for generation in tiny scale in addition as in massive scale production.

The principle used to produce electricity by the PVmodule is that the same as that used to generate electricity from the chemical action employing a standard battery. The essential working of solar panels depends on the semi-conductor property of Si.

The semiconductor may be a characteristic matter that has revolutionized the approach electronic appliances work. this is often the fundamental simulation of 72 solar cells. The solar panel is employed to charge the battery. The solar panel additionally provides the load throughout the day time once the light supply is high.

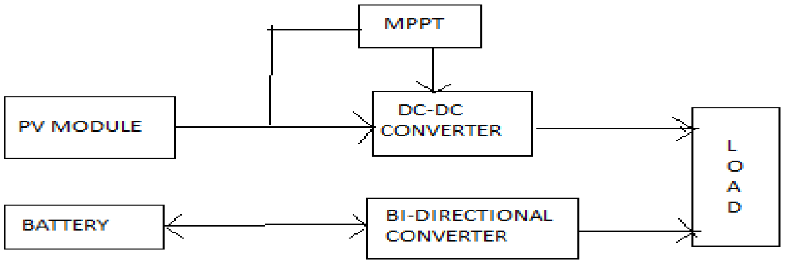

Fig.2 Overall block diagram of PV energy system

2.1.2 PV MODULE

A single cell produce very low voltage (around 0.4), thus more than one PV cells will be joined either in serial or in parallel or as a grid (both serial and parallel) to make a PV section as shown in fig.3.2. after we want higher voltage, we tend to connect PV cell in series and if load mandate is high current then we tend to join PV cell in parallel.

Mostly there are a unit thirty six or 76 cells normally PV modules. Unit we tend to are using having fifty four cells. The front facet of the moduleis transparent generally build from low-iron and transparent glass material, and also the PV cell is compressed. The potency of a unit isn't nearly as good as PV cell, as a result of the glass cover and frame replicates some quantity of the incoming radiation.

2.1.3 PV ARRAY

A PV array is basically interconnection of some PV modules in serial and/or parallel. The power generated by individual modules may not be sufficient to meet the requirement of trading applications, so the modules are secured in a grid.

In array, the module is connected like as cells are connected in a module. During the Making of Photovoltaic array usually, to generate more current based on the requirement the modules are firstly connected in serial manner to find the required voltage, and then strings so obtained are connected in parallel.

The output simulation circuit of a solar PV energy system is shown in Figure below. It includes a current source & a diode, a series resistance & a shunt resistance.

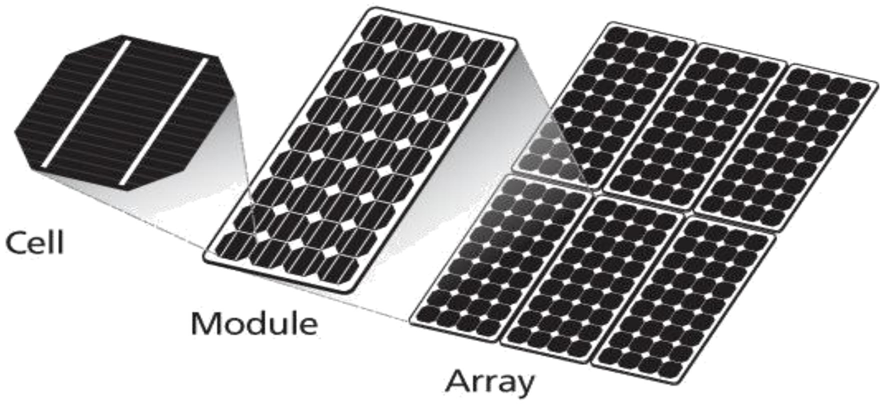

Fig.2.3 Phot0voltaic system

2.2 WORKING OF PV CELL

The basic theory convoluted in operating of associate distinct PV cell is that the photoelectric result affording to that, once a photon particle hits a PV cell, once delivering energy from shaft the electrons of the semiconductor get agitated and hop to the conduction band from the valence band and become liberated to move. Movement of electrons ability, positive & negative terminal and conjointly build potential between these 2 terminals. Once an external circuit is coupled among these terminals an electrical current begin flowing over the circuit.

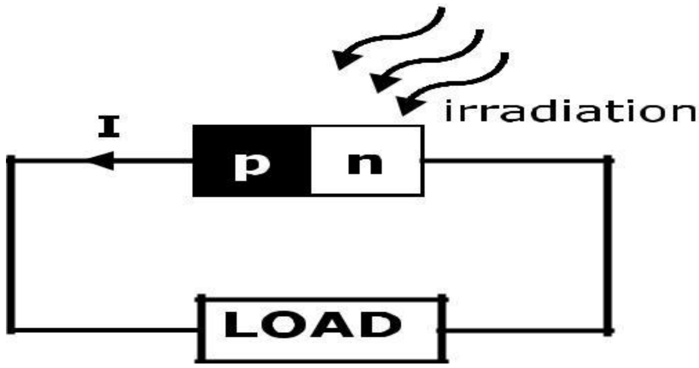

Fig 2.4 Working 0f PV cell [1]

2.3 MODELING OF PV CELL

The photovoltaic system converts daylight on to electricity without taking any disastrous impact on the environment. the fundamental phase of PV array is PV cell, that is simply an easy p-n junction device. The fig.2.4 manifests the equivalent circuit of PV cell.

Equivalent circuit contains a current source (photocurrent), a diode parallel to hat, a resistor in series describing an internal resistance to the flow of current & a shunt resistance that expresses a leakage current. the current provided to the load is given as.

$$I = I_{PV} - I_0 \left[\exp \left(\frac{V + IR_S}{aV_{T0}} \right) - 1 \right] - \left(\frac{V + IR_S}{R_p} \right) \ldots\ldots\ldots(2.1)$$

Where

I_{PV} – Photocurrent current,

I_O – diode's Reverse saturation current,

V – Voltage across the diode,

A – Ideality factor

V_T – Thermal voltage

R_S – Series resistance

R_p – Shunt resistance

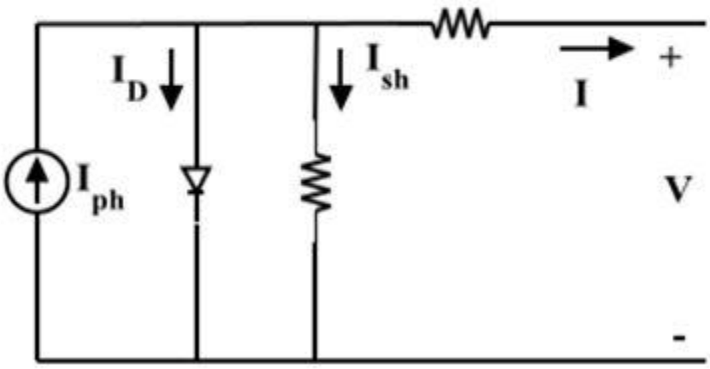

Fig 2.5 Equivalent Diagram of Single diode

PV cell photocurrent can be explained as.

$$I_{PV} = (I_{PV-STC} + K_1 \Delta T)\frac{G}{G_{STC}} \quad (2.2)$$

Where,

KI – cell's short circuit current Temperature coefficient

G – solar irradiation in W/m2

GSTC – nominal solar irradiation in W/m2

IPV_STC – Light generated current under standard test condition

The reverse saturation current varies as a cubic function of temperature, which is represented as

$$I = I_{0-STC}\left(\frac{T_{stc}}{T}\right)^3 \exp\left[\frac{qE_g}{ak}\left(\frac{1}{T_{stc}} - \frac{1}{T}\right)\right] \quad (2.3)$$

Where,

I_{0_STC} – Nominal saturation current

E_g – Energy band gap of semiconductor

T_{STC} – temperature at standard test condition

q – Charge of electrons

The reverse (I_O) saturation current can be written as a function of Temp as given

$$I_0 = \frac{I_{0-STC} + K_1 \Delta T}{\exp\left(\frac{V_{0c-STC} + K_1 \Delta T}{aV_T}\right) - 1} \quad (2.4)$$

V_{OC_STC} – short circuit voltage at standard test condition

K_V – temperature coefficient of open circuit voltage

Many authors planned a lot of developed models for higher accuracy and for various functions. In a number of the models, the impact of the recombination of carriers is denoted by an additional diode. Some authors additionally recycled 3 diode models including stimulates of another effect that don't seem to be considered in previous models. on the other hand due to effortlessness we be likely to use single diode model for our work.

Efficiency of a PVcell doesn't rest on the difference within the shunt resistance Rp of the cell however efficiency of a PVcell critically depends on the deviation in resistance Rs. As Rp of the cell is reciprocally proportional to the shunt leakage current to ground therefore it is assumed to be very large worth for a really small leakage current to ground.

As the total power generated by a single PVcell is extremely low, we tend to used a mixture of PVcells to meet our desired demand. This grid of PVcells is knows as PV array. The Photovoltaic array equations is explained as:

$$I = I_{PV}\ N_P - I_0\ N_P\ [\ \exp\ (\frac{V+IR_S(\frac{N_S}{N_p})}{aV_{T0}}) - 1] - (\frac{V+IR_S(\frac{N_S}{N_p})}{R_p(\frac{N_S}{N_p})})\ ] \qquad (2.5)$$

N_S– Number of series cells

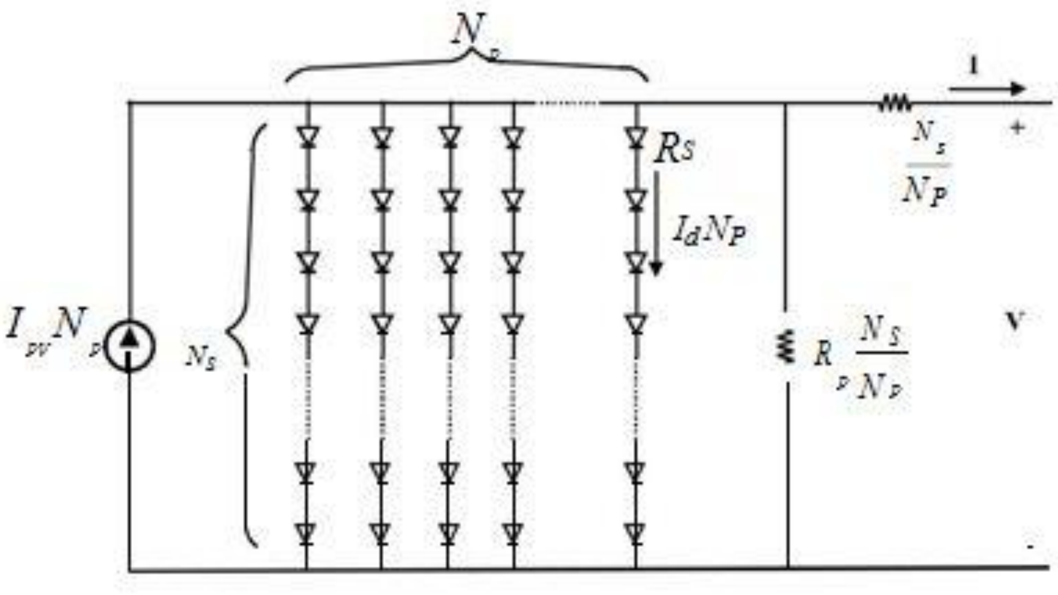

Fig.2.6 Representation of PV module

A small alteration in series resistance will have an effect on extra on the efficiency of a PV cells however un similarity in shunt resistance doesn't have an effect on a lot of. For very small leakage current to ground, shunt resistance anticipated to be infinity and may be treated as open. when seeing shunt resistance infinity, the mathematical expression of the model are often expressed as.

$$I = I_{PV}\ N_P - I_0\ N_P\ [\ \exp\left(\frac{V+IR_S(\frac{N_s}{N_p})}{aV_{T0}}\right) - 1 \quad (2.6)$$

I-V and P-V characteristics of PV module are shown in figures 2.7 and 2.8 respectively.

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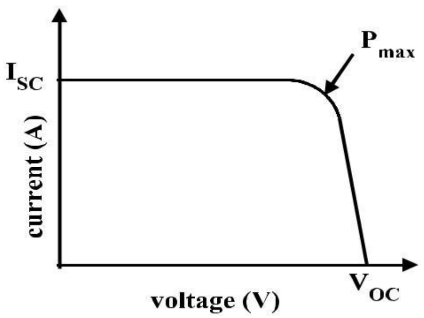


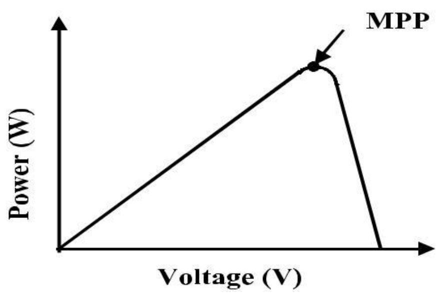


Fig. 2.7 IV characteristics

Fig. 2.8 PV characteristics

The two key factors that are used to relate the electrical routine are the open-circuit voltage of the cell VOC and short-circuit current of the cell Isc.

The maximum power stated as

$$P_{max} = V_{max} I_{max} \quad (2.7)$$

The parameters used for the modelling of PV module are given below table 2.1 [2]

Sl.no.	Parameter	Value
1	I_{mp}	7.61 A
2	V_{mp}	26.3 V
3	I_{sc}	8.21 A
4	P_{max}	200.143 W
5	V_{oc}	32.9 V
6	K_V	-0.1230 V/K
7	K_i	0.0032 A/K
8	N_s	54
9	N_p	4

TABLE 2.1

Parameters of the PV array at 25^0C, $1000w/m^2$

2.4. SHADING EFFECT

When a unit of it's shaded it starts generating less voltage & current as compare to unshaded . once modules area unit connected in series, same current can flow in entire circuit however shaded portion cannot able to produce same current however have to permit an equivalent current to flow, thus shaded portion starts operating like load and starts overwhelming power. Once shaded part start to act as load then this condition is understood hot-spot drawback. Without appropriate protection, drawback of hot-spot might arise and, in plain cases, the system might get damaged [6]. to scale back the damage during this we have a tendency to use a bypass diode [8]. Diagram of PVarray in shaded condition is shown here:

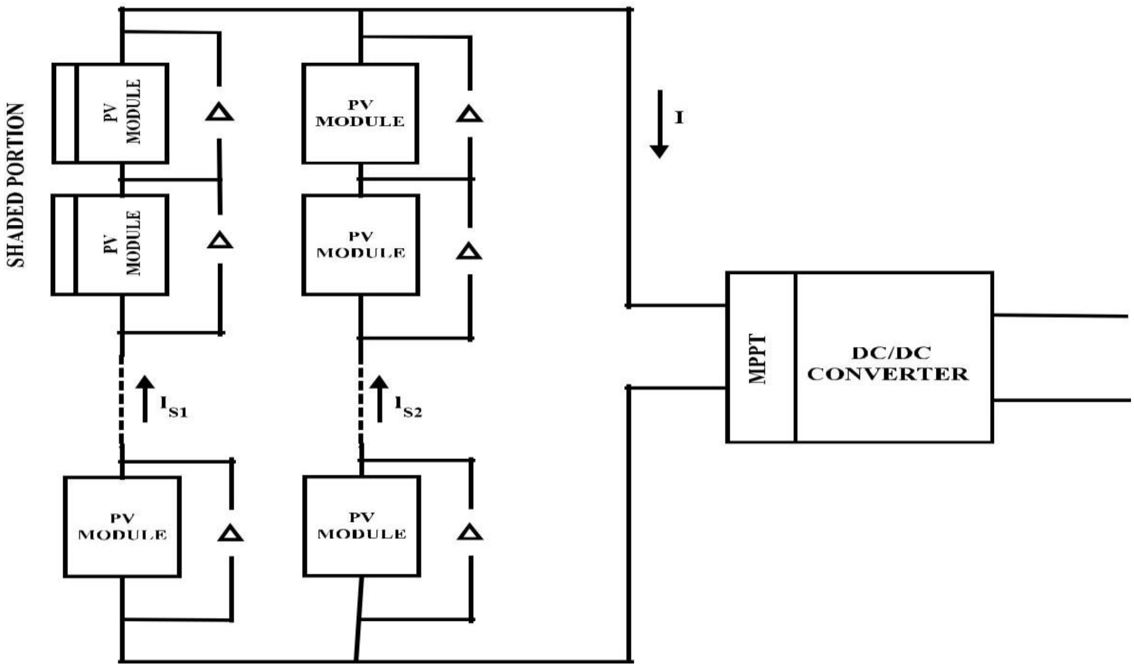


Fig 2.9 PV Array in Shaded condition

Due to fractional shading or total shading PV characteristic become a lot of non-linear, having multiple maximum power point [7]. Therefore for this condition tracking of MMPT (maximum power point) become very monotonous. we able to simply see the consequence of shading on PV characteristics within the diagram given below.

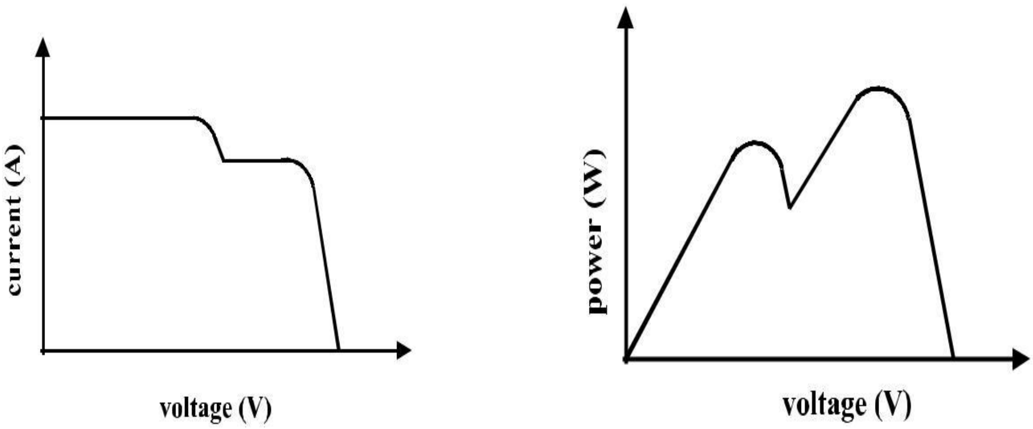


Fig. 2.10 Effect of partial shading on I-V & P-V characteristics

There is expenditure of power because of the loss funded by reverse current which ends in heat of shaded cell.

2.5 MAXIMUM POWER POINT TRACKING

Maximum power point tracing (MPPT) system is system that capable of coercing the maximum power from a PV system. It doesn't involve one mechanical element that leads to the measure of the modules changing their route and build them face straight regarding the sun. MPPT system could be a completely electronic system which might deliver maximum acceptable power by varied the operative purpose of the units electrically [9].

2.5.1 NECESSITY OF MMPT(MAXIMUM POWER POINT TRACKING)

In the PowerVs voltage characteristic of a PV module shown in fig 2.8 we are able to see that there occur single maxima i.e. a maximum power point related to a selected voltage and current that area unit delivered. the proficiency of a module is extremely low around twelve-tone music. therefore it's mandatory to control it at the crest power point in order that the maximum power may be provided to the load however of constantly changing environmental Conditions. This increased power varieties it better for the utilization of the solar PV module. A DC/DC convertor that is placed just after PV module extract maximum power by corresponding the electric resistance of the circuit to impedance of the PV module and transfers it to the load. Impedance matching may done by fluctuating the duty cycle of switching features [10].

2.5.2. MPPT algorithm

There are few algorithms which help in drawing the MMPT (maximum power point) of the PV modules they are

a) P&O algorithm
b) IC algorithm
c) Parasitic capacitance
d) Voltage based peak power tracking
e) Current Based peak power tracking

2.5.3. Perturb and observe

MPPT algorithmic program has its individual benefits and drawbacks. Perturb & observe (P&O) method is generally used due its simplicity.In this algorithm we tend to announce a perturbation within the operative voltage of the panel. Perturbation in voltage is often done by fluctuating the value of duty-cycle of dc-dc convertor.

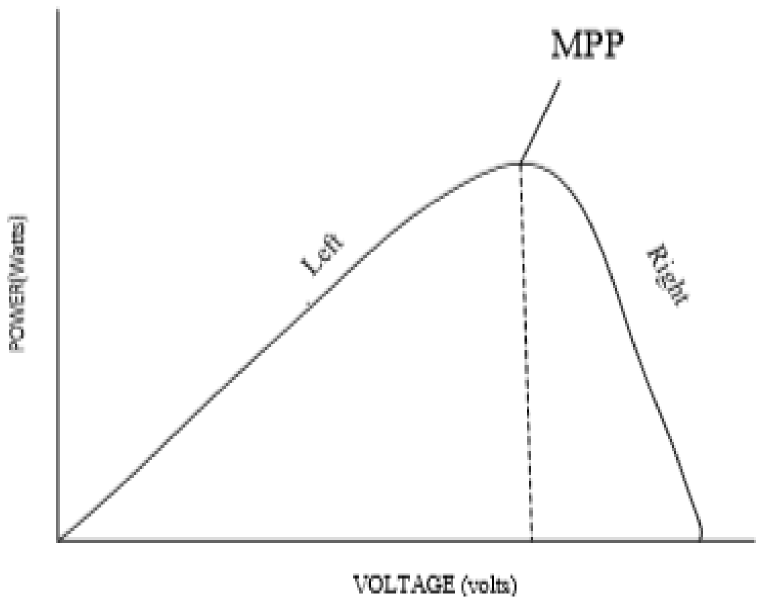


Fig. 2.11 P-V characteristics (basic idea of P&O algorithm)

Fig 2.11 show the PVcharacteristics of a PVsystem, by analyzing the PVcharacteristics we able to see that on right facet of MPP because the voltage decreases the power will increase however on left facet of MPP increasing voltage will increase power. this can be the most plan we've utilized in the P&O algorithmic program to track the MPP [11]. The flow chart of P&O algorithmic program is manifested in figure 2.12.

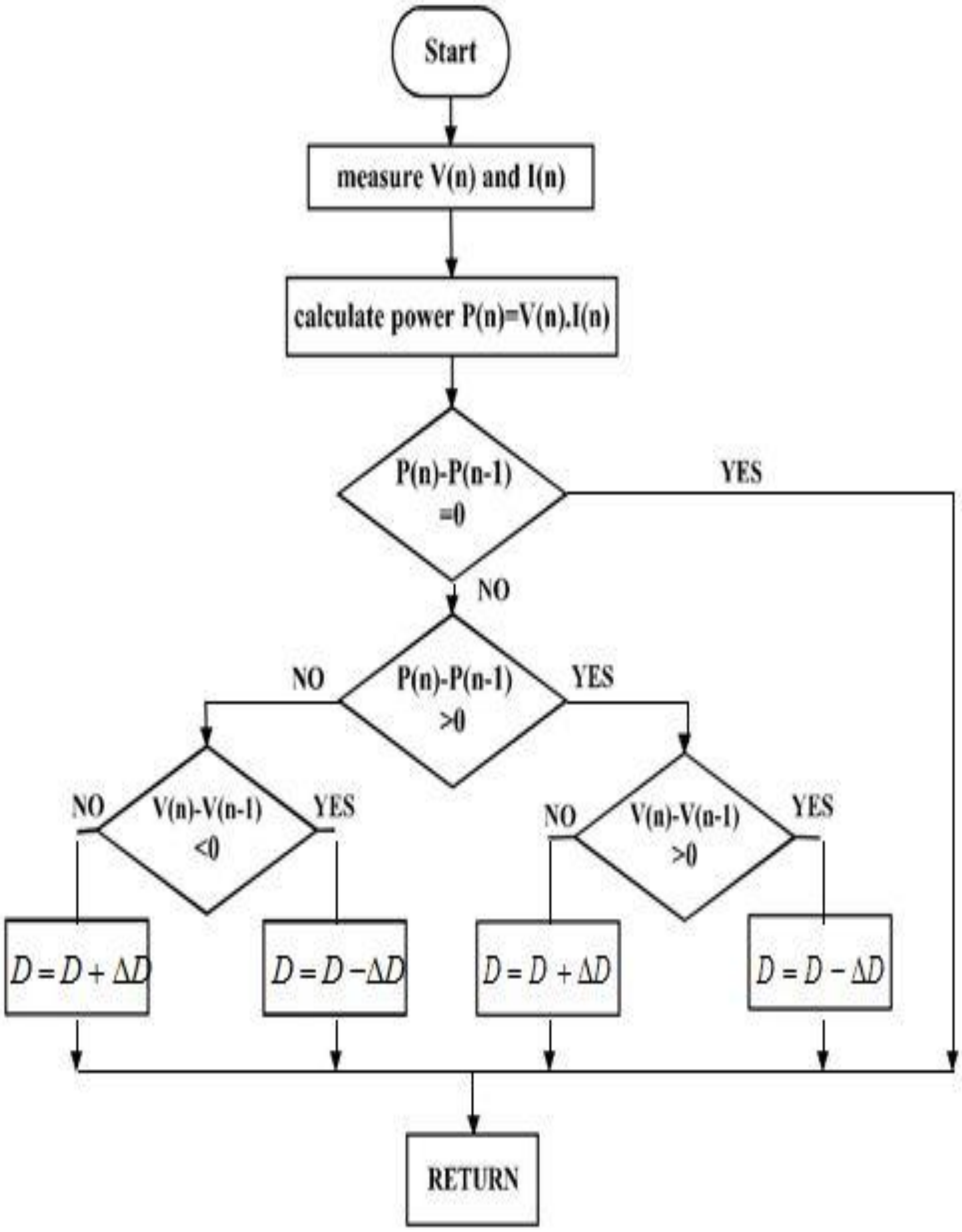


Fig.2.12 Flowchart of Perturb & Observe MPPT algorithm

CHAPTER-3

DC-DC CONVERTER

3.1 TYPES OF DC-DC CONVERTER

DC-DC convertor is associate electric circuit whose main application is to transform a dc voltage from one level to a different level. it's almost like a transformer in AC source, it will ready to step the voltage level up or down. The variable dc voltage level may be regulated by controlling the duty ratio (on-off time of a switch) of the converter.

There are numerous forms of dc-dc converters that may be used to transform the amount of the voltage as per accessibility availability and load demand. a number of them are mentioned below.

a. Buck converter

b. Boost converter

c. Buck-Boost converter

Each of them is explained below.

3.1.1 Buck converter:

The practicality of a buck converter is to cut back the voltage level. The circuit diagram of the buck converter is manifested in figure 3.1

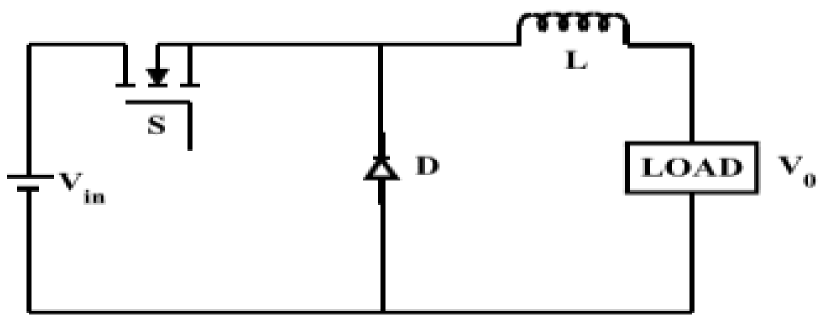


Fig. 3.1 circuit diagram of buck converter

When the switching component is in state of conduction the voltage showing across the load is Vin and also the current is equipped from source to load. Once the switch is off the load voltage is zero and also the direction of current remains the same. Because the power flow from source side to load side and the load side voltage remains less than the source side voltage. The output voltage is set as a perform of source voltage using the duty ratio of the gate pulse given to the switch. it's the product of the duty ratio and also the input voltage.

3.1.2 Boost converter:

The practicality of boost converter is to extend the voltage level. The circuit configuration of the boost converter is manifested in figure 3.2.

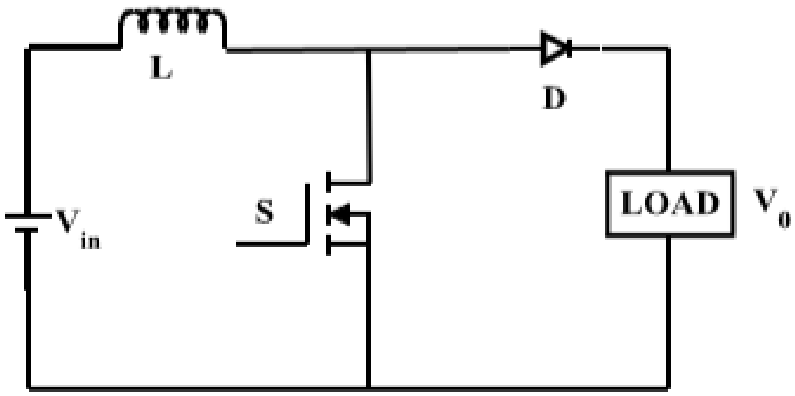


Fig. 3.2 circuit diagram of boost converter

The current carried by the inductance start rising and stores energy throughout ON time of switching component. This circuit is said in charging state. Throughout OFF condition the reserve energy of inductance start dissipating into the load in conjunction with the supply. The output voltage level exceeds that of input voltage and depends on inductance time constant. The load side voltage is that ratio of source side voltage and also the duty ratio of the switching device.

3.1.3 Buck-Boost converter:

The practicality of a buck-boost converter is to set the amount of load side voltage to either bigger than or less than that of the source side voltage. The circuit configuration of the buck-boost converter is manifested in figure 3.3.

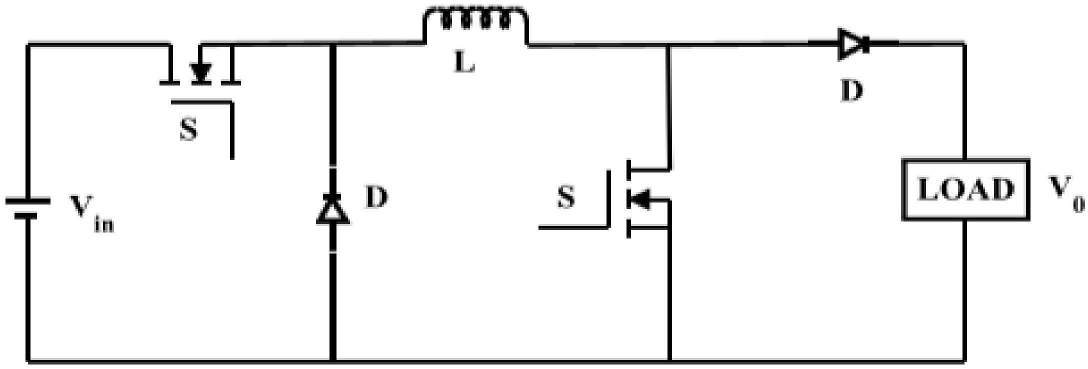


Fig. 3.3 circuit diagram of buck-boost converter

When the switches are within the state of conduction, the current carried by the inductance starts rising and it stores energy. The circuit called charging state. whereas the switches are within the OFF state, this stored energy of the inductance is dissipated to the load through the diodes. Output voltage varied supported the On-time of the switches.

The buckboost converter acts as each buck and boost converters depending on duty cycle of switches. For the duty ratio but five hundredth it acts as a buck converter and for the duty ratio exceeds than five hundredth it acts as boost converter.

As the voltage may be stepped each up and down, we have a tendency to use buck-boost converter for our convenience in our work.

CHAPTER-4

WIND POWER SYSTEM

4.1 HISTORY

Some 5000 years ago, foremost wind power was used to navigate ships within the Nile. The Europeans used it to pump water and grind grains in 1700 & 1800 .The first windmill that generated electricity was installed in 1890 in U.S. Grid connected generator with a capability of as 2 MW was commissioned in 1979 on Howard Knob Mountain near Boon. A 3-MW rotary engine was commissioned in 1988 on Berger Hill in Orkney, Scotland [14]. the electrical power developed from wind is employed in lighting the buildings that are at distant places and not connected to the grid. these days alternative energy generators is available in tiny size suitable for standalone system and bigger utility-generators that would be connected to the electricity grids. In 2003, the worldwide wind power capability was concerning 39,294 MW and india wind power capability was 1550 MW [15].

4.2 SYSTEM CONFIGURATION

The schematic figure of the wind energy structure is manifested in figure below.

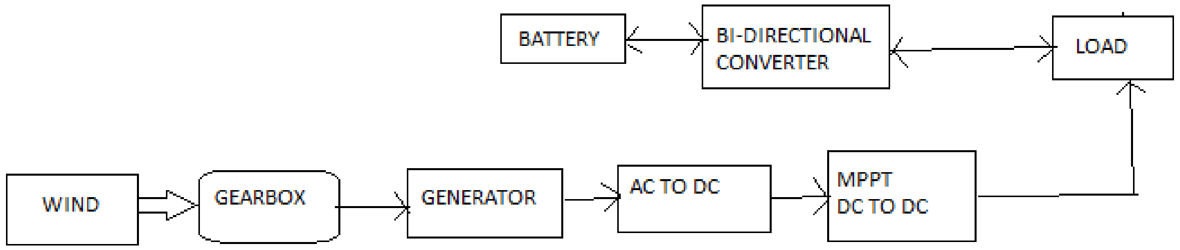


Fig. 4.1 Block Diagram of wind Energy system

This system includes of a turbine that transforms wind's mechanical energy into rotating motion, a gear box to match the turbine speed to generator speed, a generator that converts energy into current, a rectifier that converts ac voltage to dc, a controllable dc-dc converter to trace the maximum PowerPoint, A battery is charged and discharged through Bi Directional device.

4.3 WIND TURBINE

Generally a wind turbine consists , a collection of rotor blades rotating around hub, a gearbox-generator set placed within the nacelle. the essential elements of a wind turbine system are shown in diagram below.

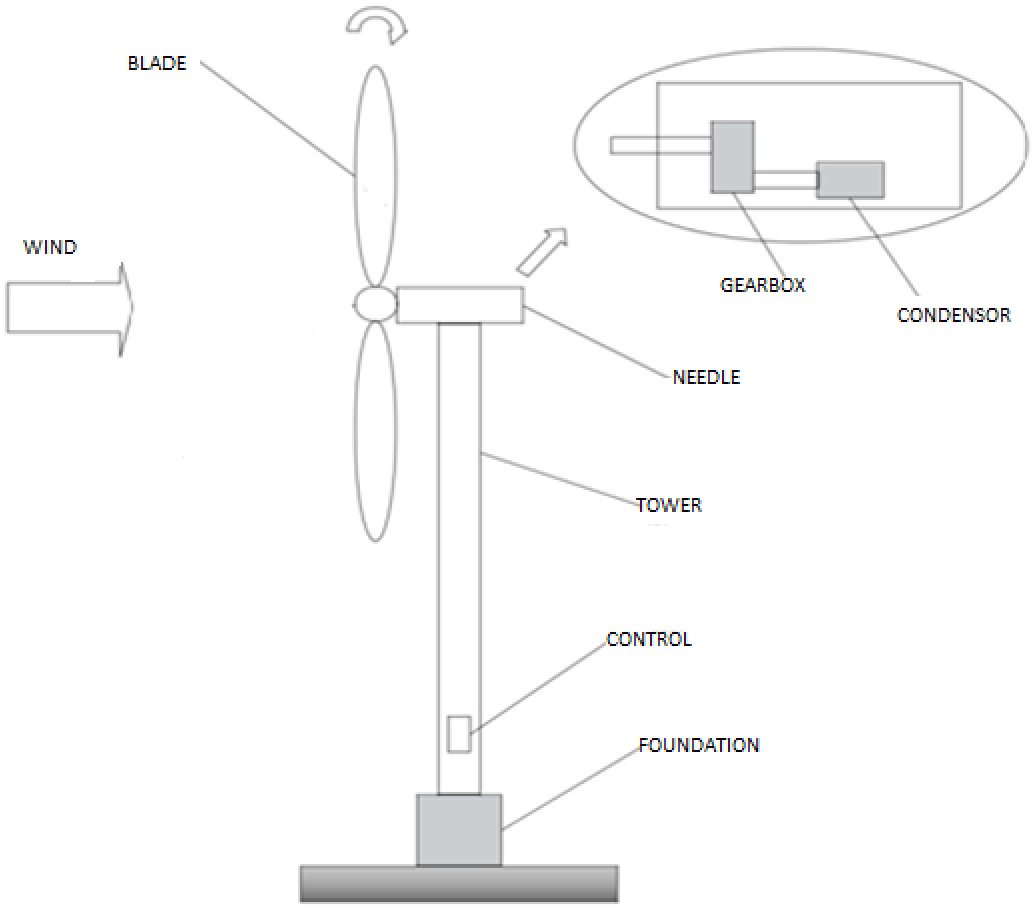


Fig. 4.2 Major turbine components [21]

Based on axes the wind are categorised into 2 kinds: the vertical axis wind turbine and therefore the horizontal axis wind turbine [21].

4.3.1 MODELING OF WIND TURBINES

A wind turbine converts kinetic energy of air i.e. wind power into mechanical power i.e. rotating motion of the turbine that may be used directly to run the machine or generator. Power captured by turbine blade may be a concomitant of the blade form, the pitch angle, speed of rotation, radius of the rotor [21]. The equation for the ability generated is shown below. —

$$C_M = \frac{1}{2}\pi\rho C_p(\lambda,\beta)R^2V^3$$

Where

P_M– Power captured by wind turbine

ρ –Air density

β –Pitch angle (in degrees)

R– Blade radius (in meters)

V– Wind speed (in m/s)

The term λ is the tip-speed ratio, given by the equation

$$\lambda = \frac{\Omega R}{V} \quad (4.2)$$

Where

Ω - Rotor speed of rotation (in rad/sec)

C_P can be expressed as the function of the tip-speed ratio (λ)

$$P_M = \frac{1}{2}\left(\frac{116}{\lambda_1} - 0.4\beta - 5\right) exp^{\frac{-16.5}{\lambda_1}} \quad (4.3)$$

$$\lambda_1 = \left[\frac{1}{\frac{1}{\lambda+0.089} - \frac{0.035}{\beta^3+1}}\right] \quad (4.4)$$

Where

C_P – Wind turbine power coefficient

λ –Tip- speed ratio

λ_1–Constant

4.4 GENERATOR

The shaft of the turbine is mechanically coupled to the rotor head of the generator, so the mechanical power developed by the turbine (by K.E. to energy conversion) is transmitted to the rotor head. This rotor structure has a rotor winding (either field or armature). In each the cases, we tend to get a moving conductor during a stationary magnetic field or a stationary conductor in moving magnetic field. In either case, electrical voltage is generated by the generator principle.

4.4.1 TYPES OF GENERATORS

Generators will be primarily classified on the kind of current. There are AC generators and DC generators. however in either case, the voltage generated is alternating. By adding a commutator, we tend to convert it to DC. thus for convenience, we tend to opt for AC generator.

In the AC generators, we are able to further classify them supported the rotor speed. There are synchronous generators (constant speed machine) and asynchronous generators (variable speed machine or the induction machine).

In the synchronous generators we've got salient pole rotor and therefore the cylindrical (non-salient pole) rotor. based on speed requirement/availability, we will opt for cylindrical rotor for high-speeds & salient pole rotor for low speed.

Another classification is based on the magnetic field. The magnetism will be done by either magnet or an electro-magnet. so as to reduce the supply demand, we tend to opt for the magnet synchronous generator (PMSG) for the power generation using wind energy.

An induction motor running with negative slip will operate as induction generator. however this generator isn't self-exciting and this should be excited by a source of mounted frequency. It already desires an exciter for stator. thus this machine should be fed by 2 supplies and therefore it's referred to as doubly fed induction machine or generator.

The doubly fed induction generator (DFIG) and permanent magnet synchronous generator (PMSG) are appropriate for wind power generation. we tend to using PMSG in our work.

4.4.2 PERMANENT MAGNET SYNCHRONOUS GENERATOR

A synchronous machine generates power in large amounts and has its field on the rotor and therefore the armature on the stator coil. Rotor is also of salient pole type cylindrical type.

In the magnet synchronous generator, the force field is obtained by employing a permanent magnet, however not an magnet. the sector flux remains constant during this case and therefore the supply needed to excite the field winding isn't necessary and slip rings aren't needed. All the other things stay identical as normal synchronous generator.

The EMF generated by a synchronous generator is given as follows

$$E = 4.44 \cdot f \cdot \phi \cdot t$$

Where, F is the frequency

Φ is the flux

t is the number of turns

4.5 MPPT OF WIND POWER

Wind power Vs wind speed characteristics of wind power system is given in diagram below

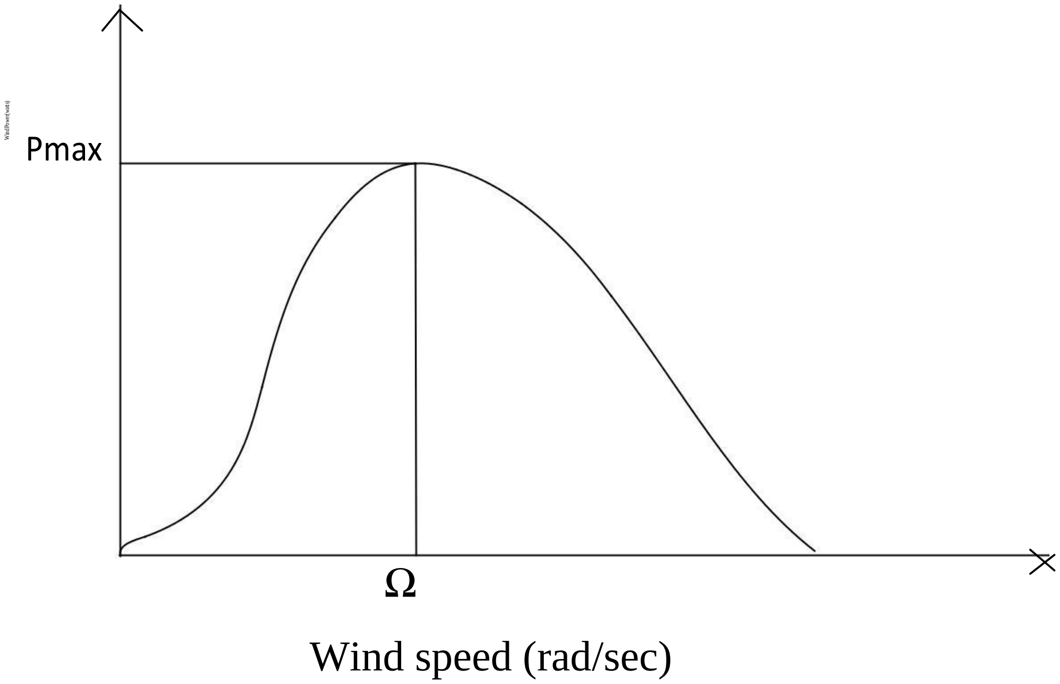


Fig. 4.3 Power vs. speed characteristics of wind turbine

At maximum power point

D

$$\frac{p}{d\Omega} = 0 \qquad (4.5)$$

From chain rule

$$\frac{dp}{d\Omega} = \frac{dp}{d\mathrm{D}} * \frac{dD}{d\mathrm{V_w}} * \frac{d\mathrm{V_w}}{d\Omega_\mathrm{e}} * \frac{d\Omega_\mathrm{e}}{d\Omega} \qquad (4.6)$$

$$\frac{dD}{dV_w} = \frac{-D^2}{V_o} = 0 \qquad (4.7)$$

Where

P– Wind power

Ω– Rotor speed

Ω_e – Generator- phase voltage angular speed.

V_W– Rectifier output voltage

D– Duty cycle of converter

For buck-boost converter

$$V_o = \frac{D}{1-D} V_w \qquad (4.8)$$

Where

V_0 –Output of buck-boost converter

V_W – Input of buck-boost converter

From equation (4.7) we can write

As we can see from equation (4.8) that $\frac{dD}{dV_W}$ having negative and non –zero value.

The rotor speed of wind turbine can be correlated with generator-phase voltage angular speed as:

$$\Omega_e = p \cdot \Omega$$

$$d\Omega_e / d\Omega = p > 0 \qquad (4.9)$$

Output voltage of the rectifier which is proportional to output voltage of generator can be written as

$$V_{ph} = 4.44 \cdot f \cdot \phi \cdot t$$

And $f \propto \Omega_e$

So

$\frac{dV_{ph}}{d\Omega_e} > 0$ As $V_{ph} \propto V_W$

$$\frac{dV_{ph}}{d\Omega_e} \approx \frac{\boldsymbol{dV}_w}{\boldsymbol{d\Omega_e}} > \boldsymbol{0} \tag{4.10}$$

Where

V_{ph} – Generator output

f – Frequency of rotor

ϕ – Flux

t– Number of turns

From equation (4.8), (4.9), (4.10) we see that $dD/(dV\_w)$, $\frac{d\Omega_e}{d\Omega}$ and $\frac{dV_w}{d\Omega_e}$ are non-zero value. So $\frac{dp}{d\Omega} = 0$ can be possible if and only $(\frac{dp}{dD})$ if becomes zero . From the above equations we can concludes that operating point at which the crest power can be coerced is traced by varying duty- cycle of converter [13].

CHAPTER-5

BATTERY CHARGING

5.1 INTRODUCTION

Battery is a storage device that is stores the excess power generated and uses it to provide the load additionally to the generators once power is needed. each PV and wind energy systems (explained within the last chapters) are integrated i.e. connected to a typical DC bus of constant voltage and also the battery bank is also connected to the DC bus. Any power transfer whether from generator to battery bank or generator to load or from the battery bank to the load takes place via this constant voltage DC bus. because the power flow related to battery isn't uni-directional, a bidirectional converter is required to charge and/or discharge the battery just in case of excess and/or deficit of power respectively.

5.2 BI-DIRECTIONAL DC-DC CONVERTERS

Bi-directional DC-DC converters are called therefore because of their ability of permitting the power flow in each the directions, depending on the need. There are several applications for the bidirectional converter like Hybrid Vehicles, Uninterruptable Power supplies (UPS) and also storage systems powered by Fuel cells and additionally renewable energy systems.

5.2.1 CLASSIFICATION

Based on the isolation between the input and output side, the bidirectional converters are classified into two types which are given below :

a. Non Isolated type

b. Isolated type

5.2.1.1 NON-ISOLATED BI-DIRECTIONAL DC-DC CONVERTERS

A basic non-isolated bidirectional converter will be derived from the unidirectional converters by using bi-directional switches. Basic buck and boost converters don't permit the bidirectional power flow because of the presence of the diodes that are unidirectional devices. This drawback can be resolved by employing a MOSFET or IGBT with an anti-parallel diode that permits flow of current in each the directions [18].

The various non-isolated type bidirectional DC-DC converters are given below

a. Multilevel converter
b. Switched capacitor converter
c. Cuk/Cuk type
d. Sepic/Zeta type
e. Buck-Boost converter
f. Coupled inductor converter
g. Three-level converter

5.2.1.2 ISOLATED BIDIRECTIONAL DC-DC CONVERTERS

The isolated type converters will operate in wide power ranges. The electrical isolation is achieved by employing a power transformer within the circuit. however the transformer operates just for AC supply. Introducing AC link within the circuit will increase the complexness of the circuit.

Based on the configuration, the isolated bidirectional DC-DC converters will be classified into two types:

a. A current fed isolated bidirectional DC-DC converter
b. A voltage fed isolated bidirectional DC-DC converter

The various isolated type bidirectional converters are:

1. Fly-back converter

2. Forward fly-back converter
3. Half bridge converter
4. Full bridge converter

5.2.2 BI-DIRECTIONAL CONVERTER FOR BATTERY CHARGING

As mentioned earlier, the bidirectional converter has several applications and here within the work, the converter is employed for charging and discharging the battery based on the surplus and deficit of the power respectively.

When there's a surplus of energy, i.e. the availability is larger than demand then the battery is charged, permitting the converter to control in forward direction. once there's a deficit in power i.e. the availability is a smaller amount than demand then the battery starts discharging supplying the deficit of power to the load. this needs the converter to control in reverse direction. Charging/discharging of the battery is completed by the help of a bidirectional converter [20]

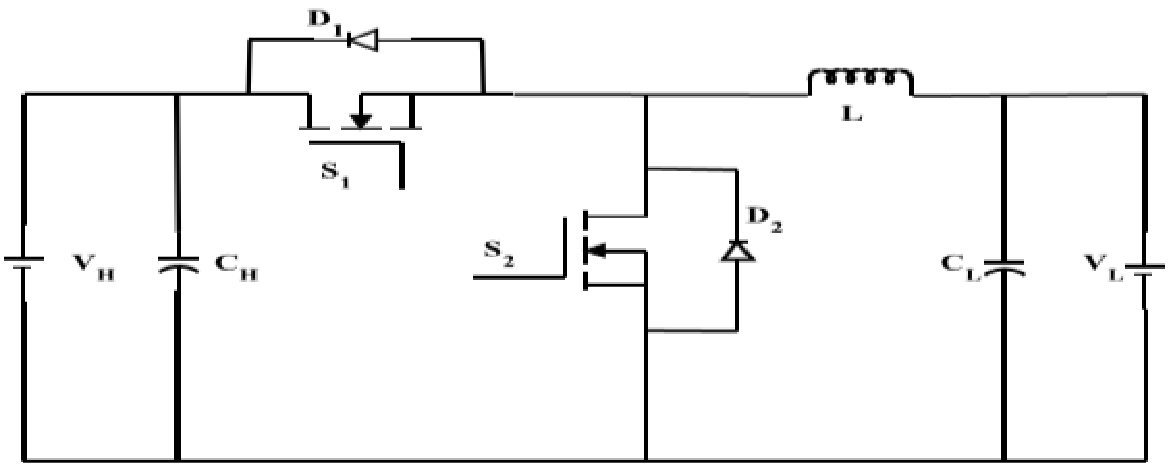


Fig. 5.1 Circuit diagram of the bidirectional converter

CHAPTER-6

RESULTS AND DISCUSSIONS

6.1 RESULTS

Simulation results of PV module

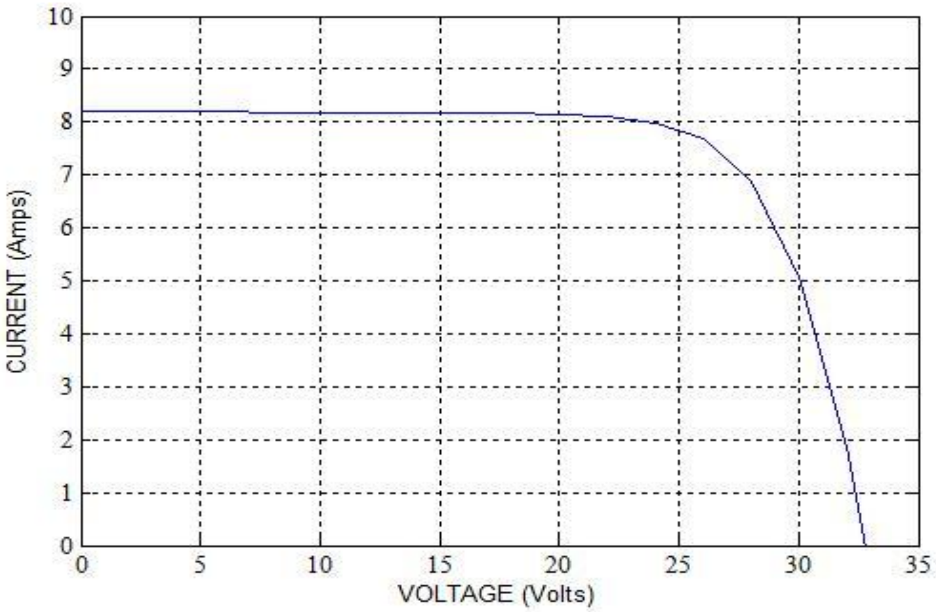


Fig. 6.1 V-I curve of PV module

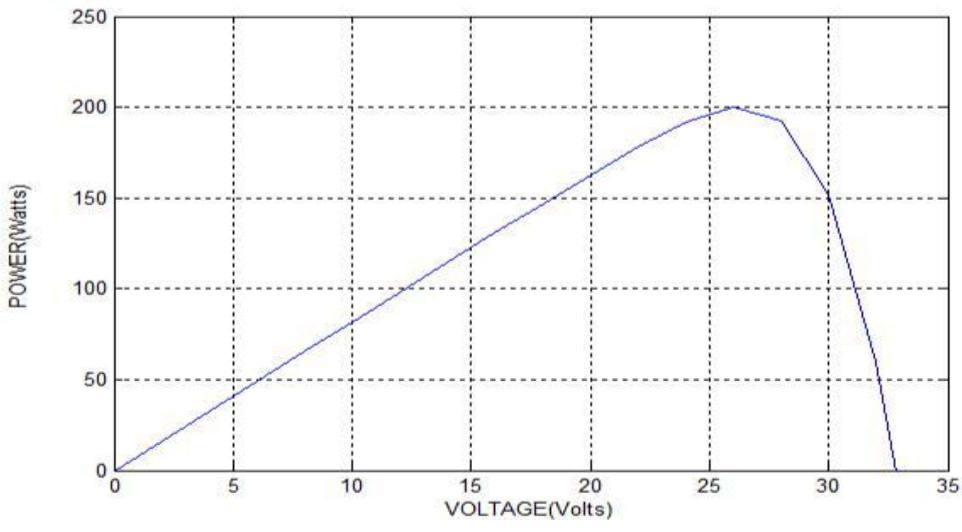


Fig. 6.2 P-V curve of PV module

Fig 6.1, 6.2 represent the I-V and P-V characteristics of a PV module. From fig 6.1 we can see that short circuit current (I_{sc}) of PV module is approximately 8.2A and open circuit voltage (V_{oc}) is approximately 32.9 volts. From fig 6.2 we can observe that maximum power is approximately 200W and it occurs at a current of 7.61A and voltage at 26.3V approximately.

Effect of variation of irradiation

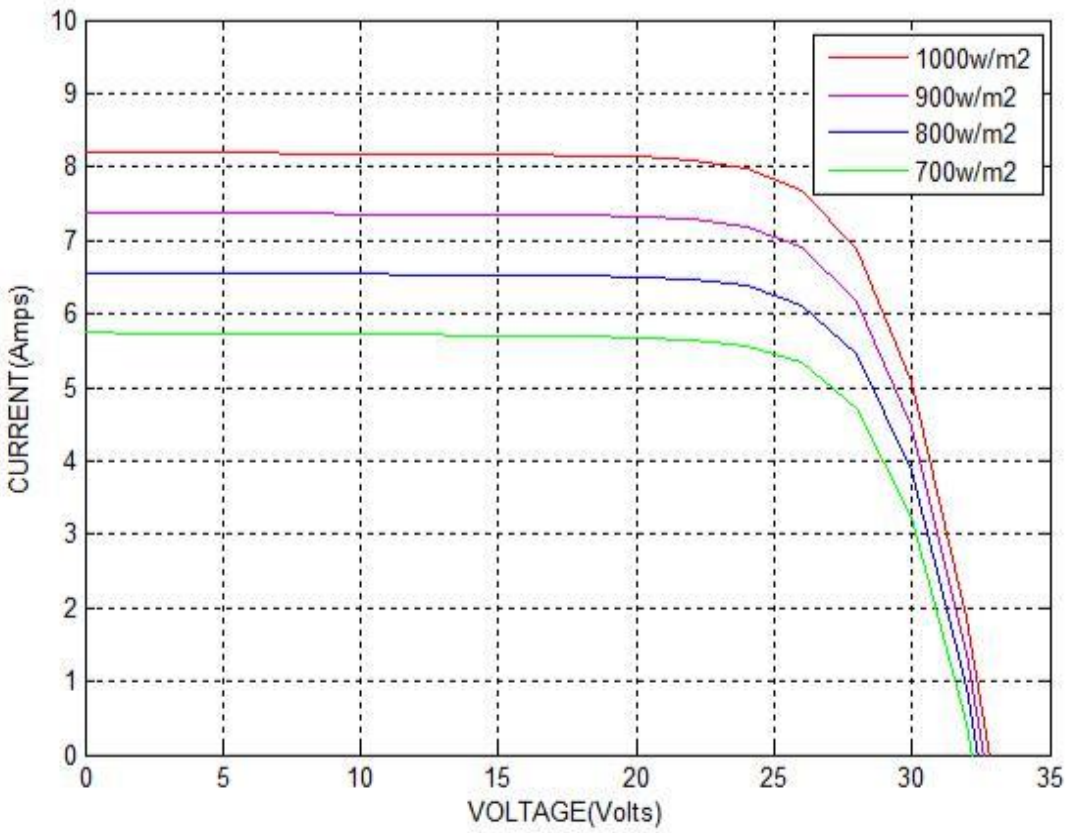


Fig. 6.3 Effect of variation of irradiation on I-V characteristics

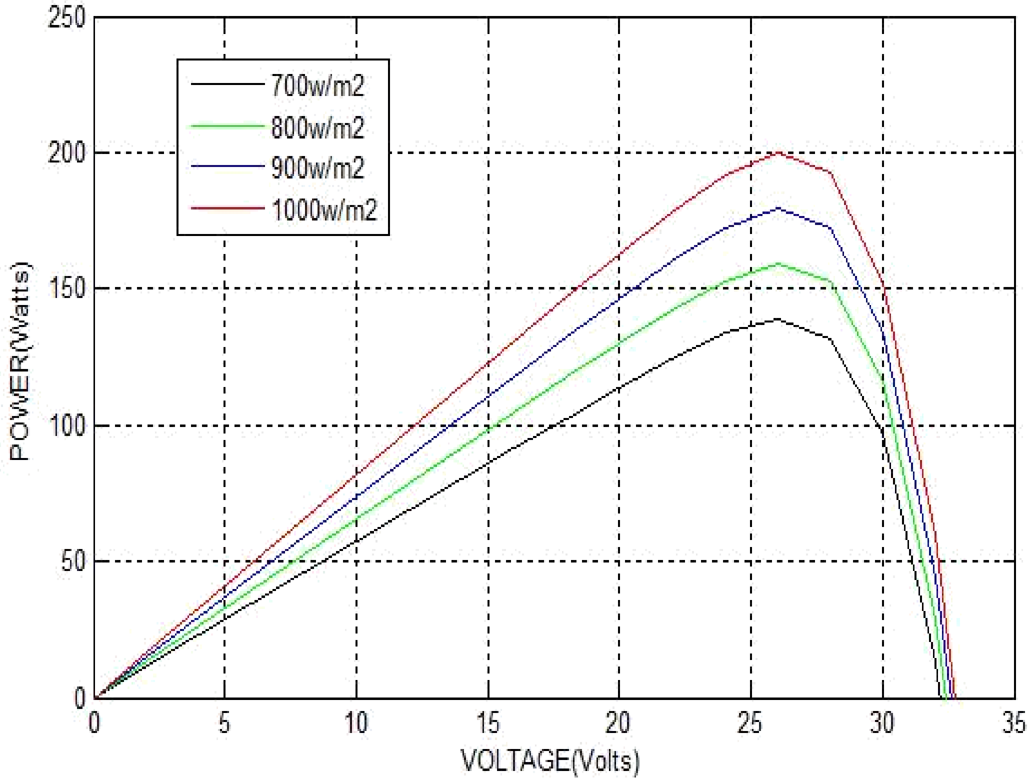


Fig. 6.4Effect of variation of irradiation on P-V characteristics

In fig 6.3, 6.4 we can see the effect of change in solar irradiation on PV characteristics. From fig 6.3 we observe that as we increase the solar irradiation short circuit current increases. Variation in Solar irradiation effects mostly on current, as we can observe from fig 6.3 as we increase solar irradiation from 700 w/m^2 to 1000 w/m^2 current increases from 5.7A to 8.2A approximately but effect of variation of solar irradiation on voltage is very less. Fig 6.4 shows the effect of variation of solar irradiation on P-V characteristics. As solar irradiation increases, power generated also increases. Increase in power is mainly due to increment in current.

Effect of variation of temperature

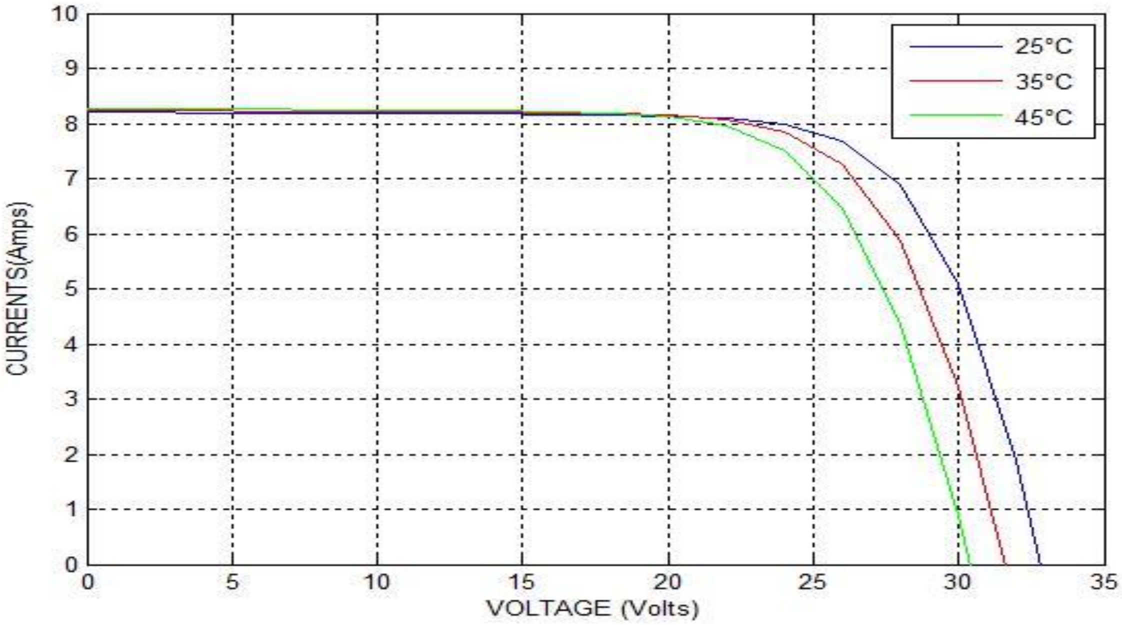


Fig. 6.5 Effect of variation of temperature on I-V characteristics

The outcome of variation of temperature on I-V characteristics is shown in the fig 6.5. From the fig 6.5 we can see the variation of temperature mostly effects voltage, as we increase the temperature voltage decreases but current remains almost unaltered. Fig 6.6 shows effect of temperature variation on the P-V characteristics. As temperature increases power generated decreases, because on increment of temperature voltage decreases.

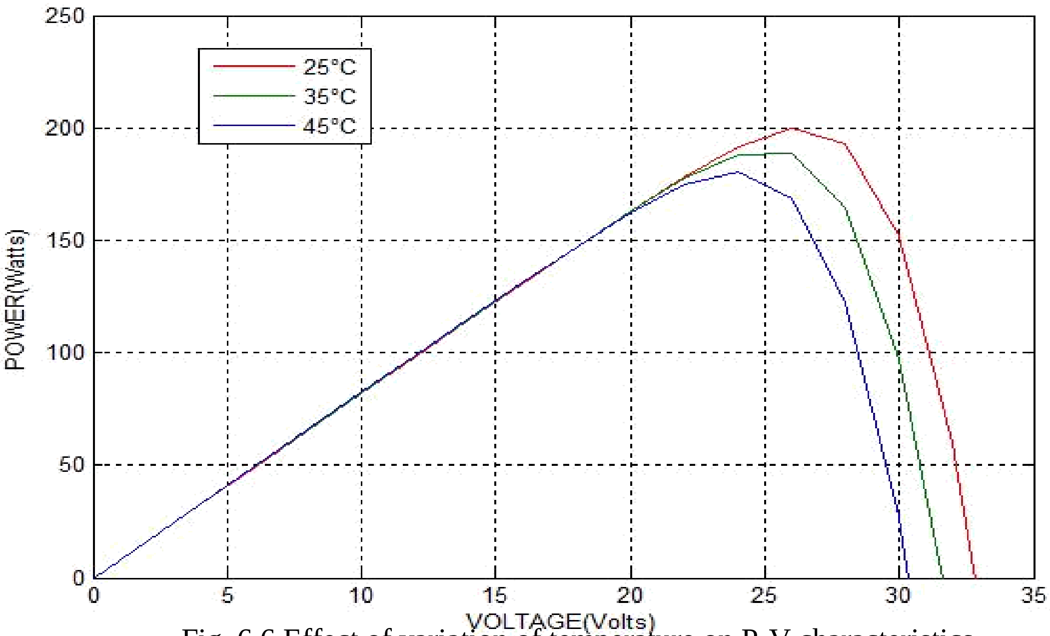


Fig. 6.6 Effect of variation of temperature on P-V characteristics

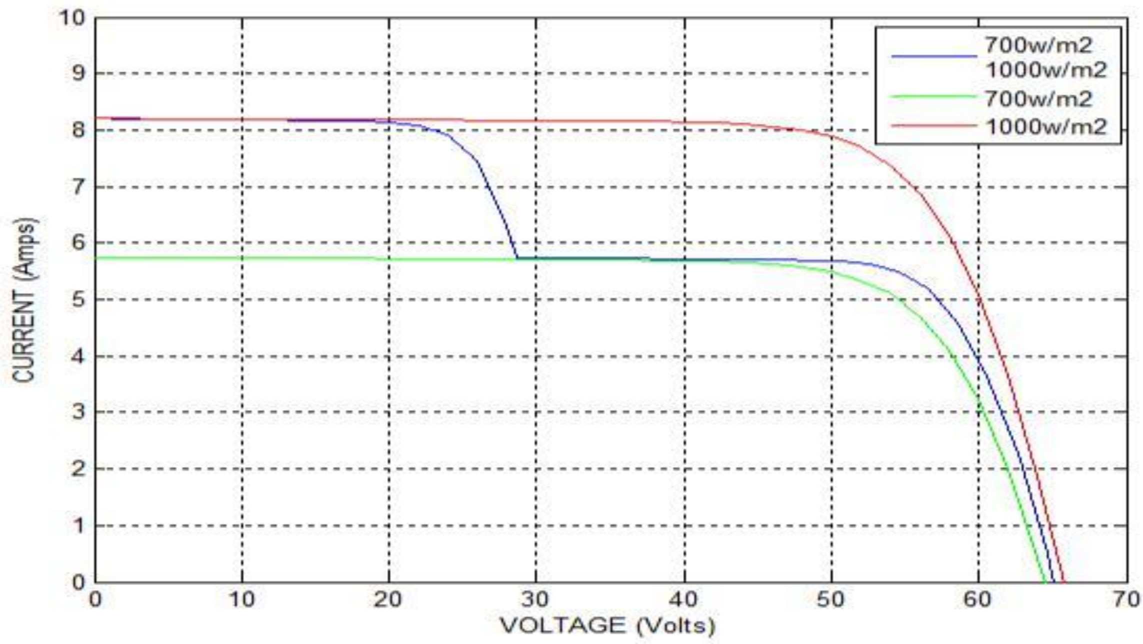


Fig. 6.7V-I characteristics in partial shading condition

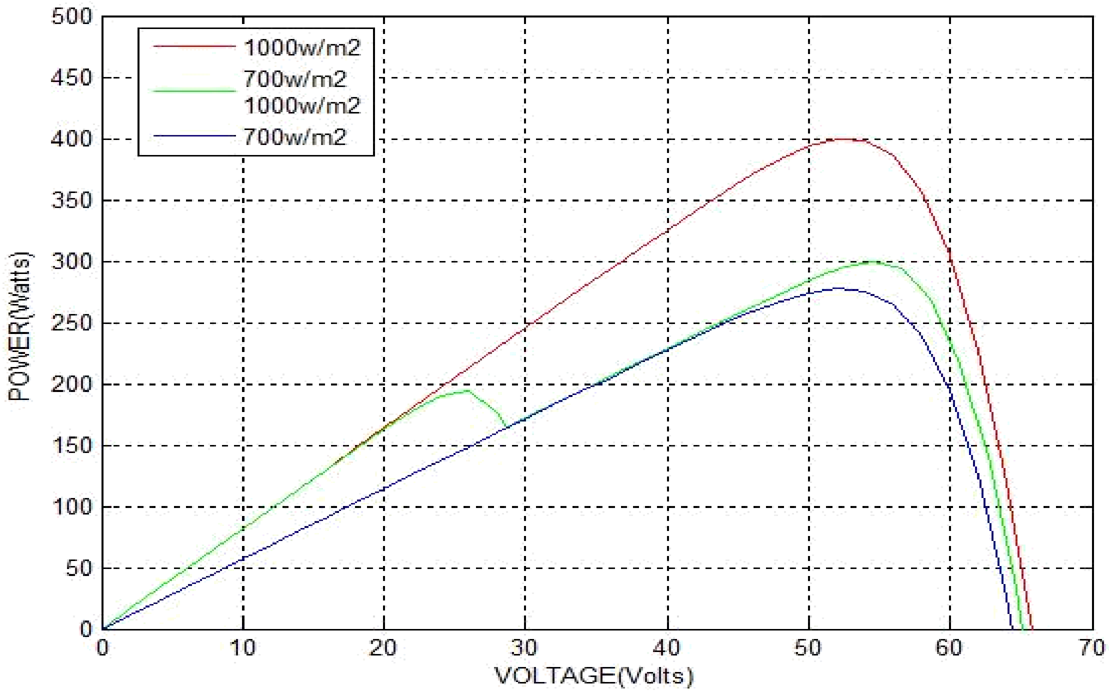


Fig.6.8 P-V characteristics in partial shading condition

I-V, P-V characteristics of a PV array in shading condition can be seen in fig. 6.7 and fig 6.8. As we can observe from fig 6.6 partially shaded PV modules generate less current than the unshaded module. Under partially shading condition we can observe more than one maximum power picks from fig 6.8.

Outputs after MPPT

Output power and output voltage after maximum power point tracing are manifested in the figures 6.9 and 6.10 respectively. As we observe from the fig 6.2, maximum power is achieved at voltage 26.3 volts; from fig 6.10 we can see we are able to track the output voltage where we can get the maximum power which is approximately 26.3 volts. From fig 6.9 we can see the maximum power which is approximately 200 watts can be tracked.

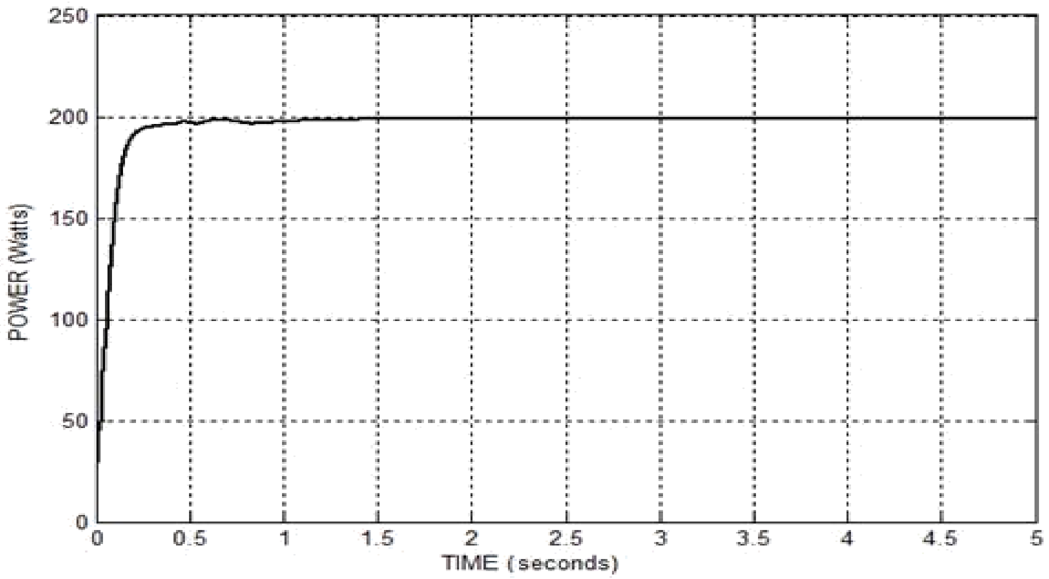


Fig. 6.9 Output power of PV module after MPPT

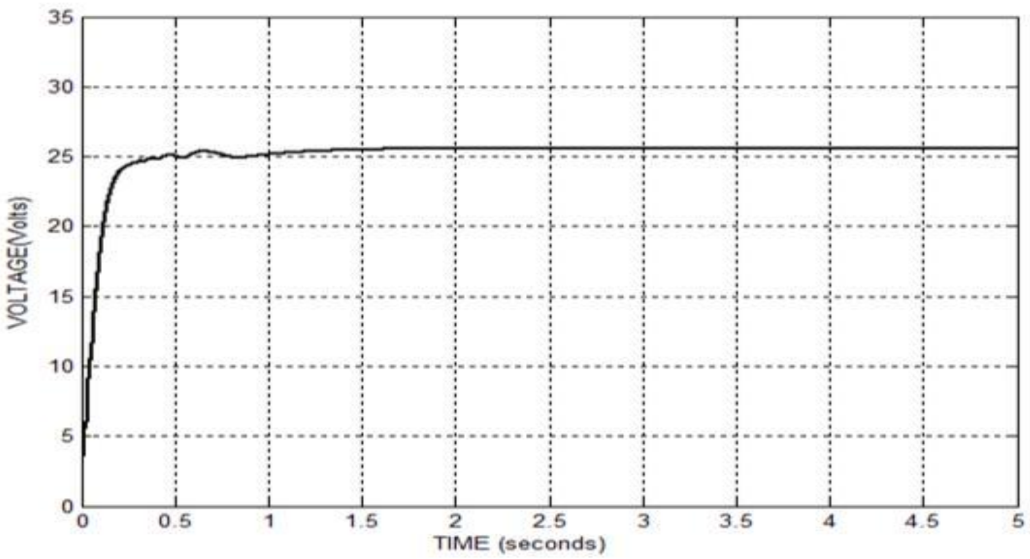


Fig. 6.10 Output voltage of PV module after MPPT

Simulation result of wind energy system

Fig 6.11 shows turbine power characteristics at different wind speed. From the fig 6.11 we can observe that as wind speed increases turbine output power also increases.

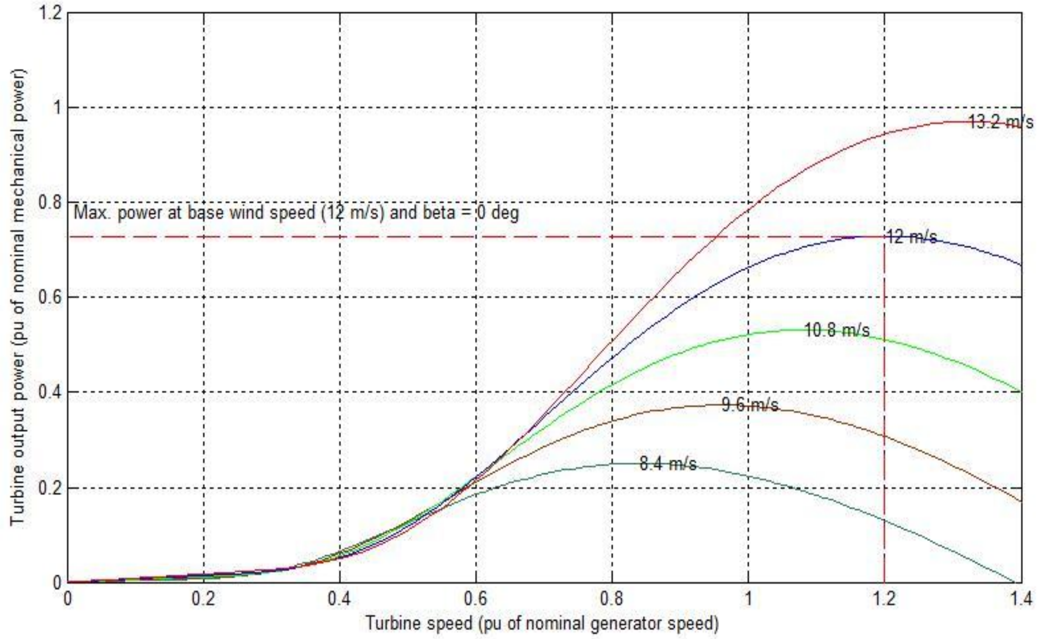


Fig 6.11 Turbine Power characteristics (pitch angle beta=0°)

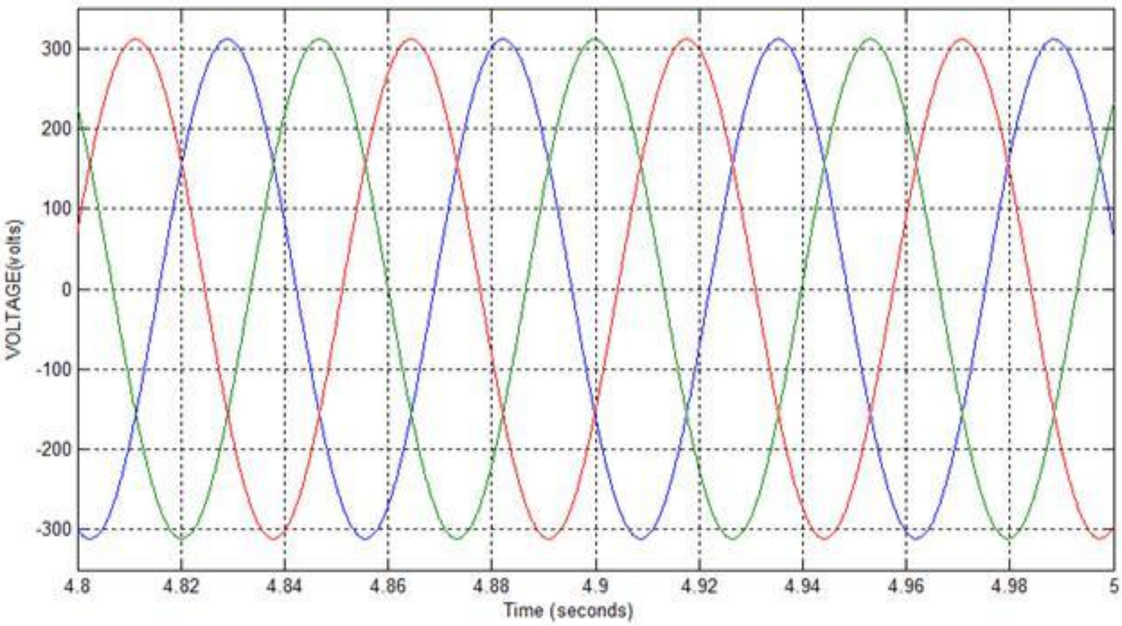


Fig 6.12 Three phase line output voltage of PMSG

PMSG output is shown in the fig 6.12.The point of operation of crest power of wind generator output is traced by a maximum power point tracing system is shown in the fig 6.13 given below. Output Voltage of wind generator at which maximum power is achieved is shown in the fig 6.14.

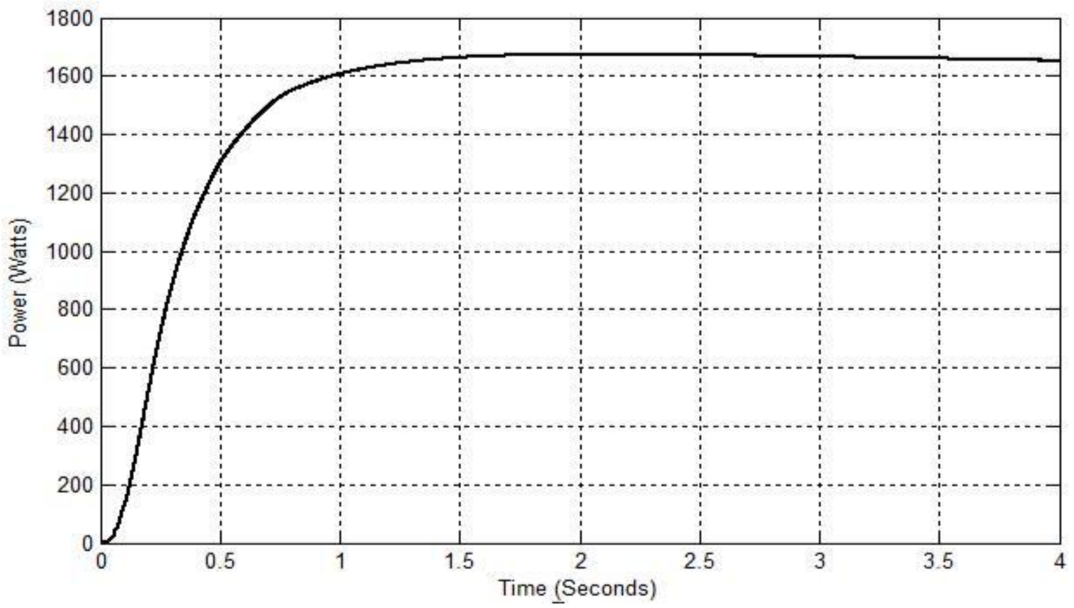


Fig 6.13 Output power of wind system after MPPT

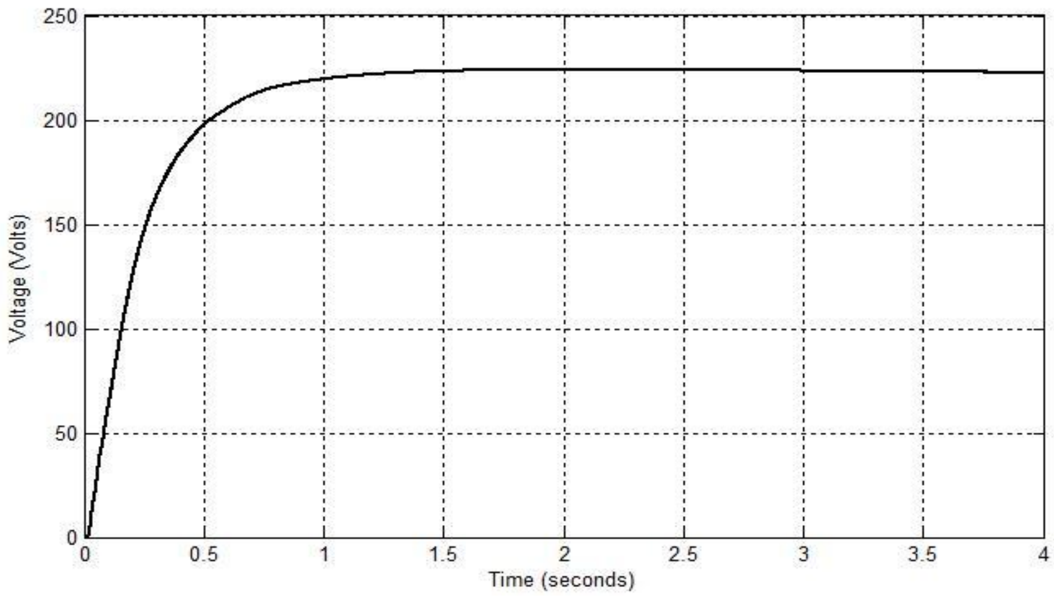
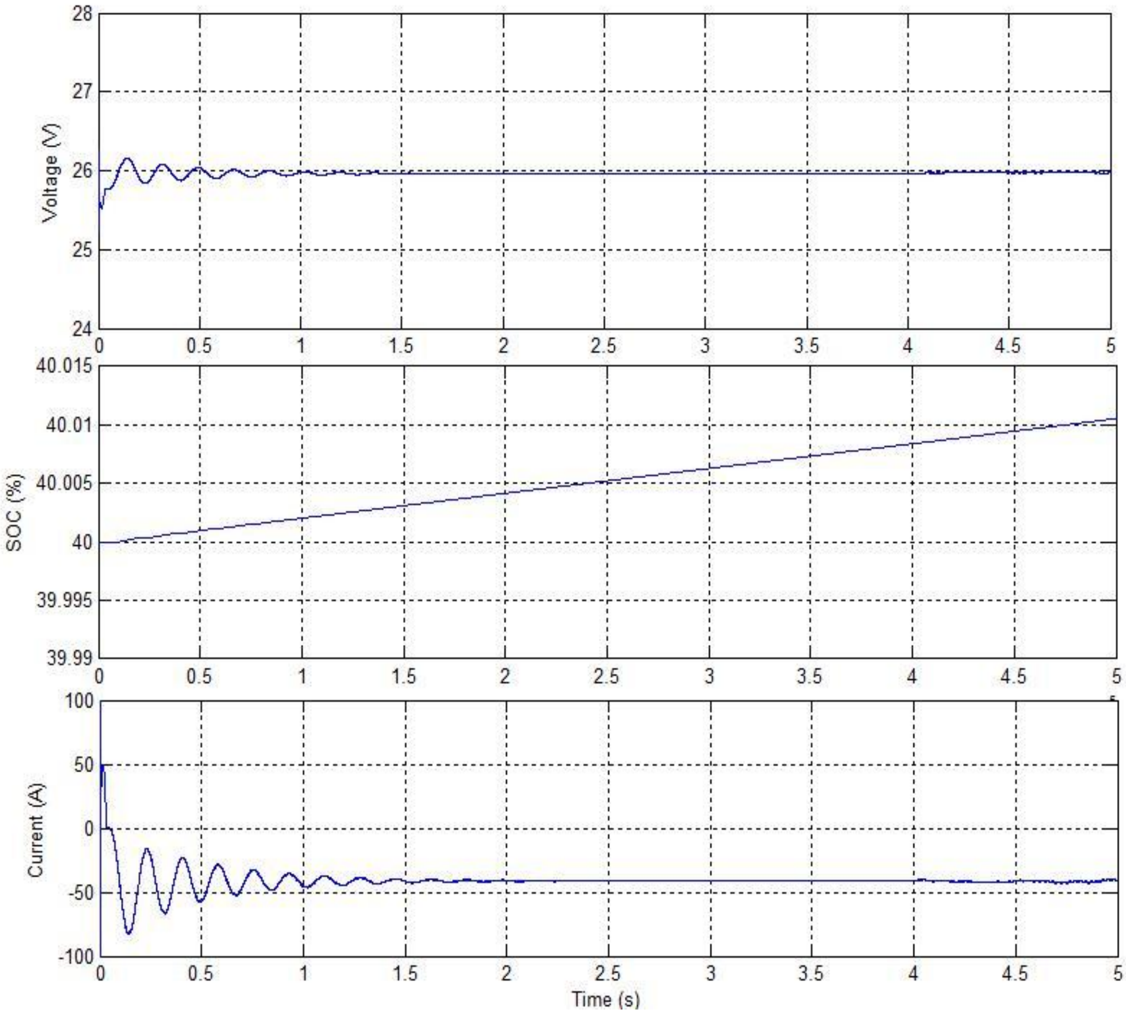


Fig 6.14 Output voltage of wind system at MPP

Simulation results of charging/ discharging



Fih 6.15 charging characteristics of battery

From fig 6.15 we can observe that during charging state of charge (SOC) of the battery is gradually increasing and also during charging current is negative. We can observe at 40% SOC battery voltage is around 26 volts, as state of charge of battery is increased battery voltage exceeded its nominal voltage.

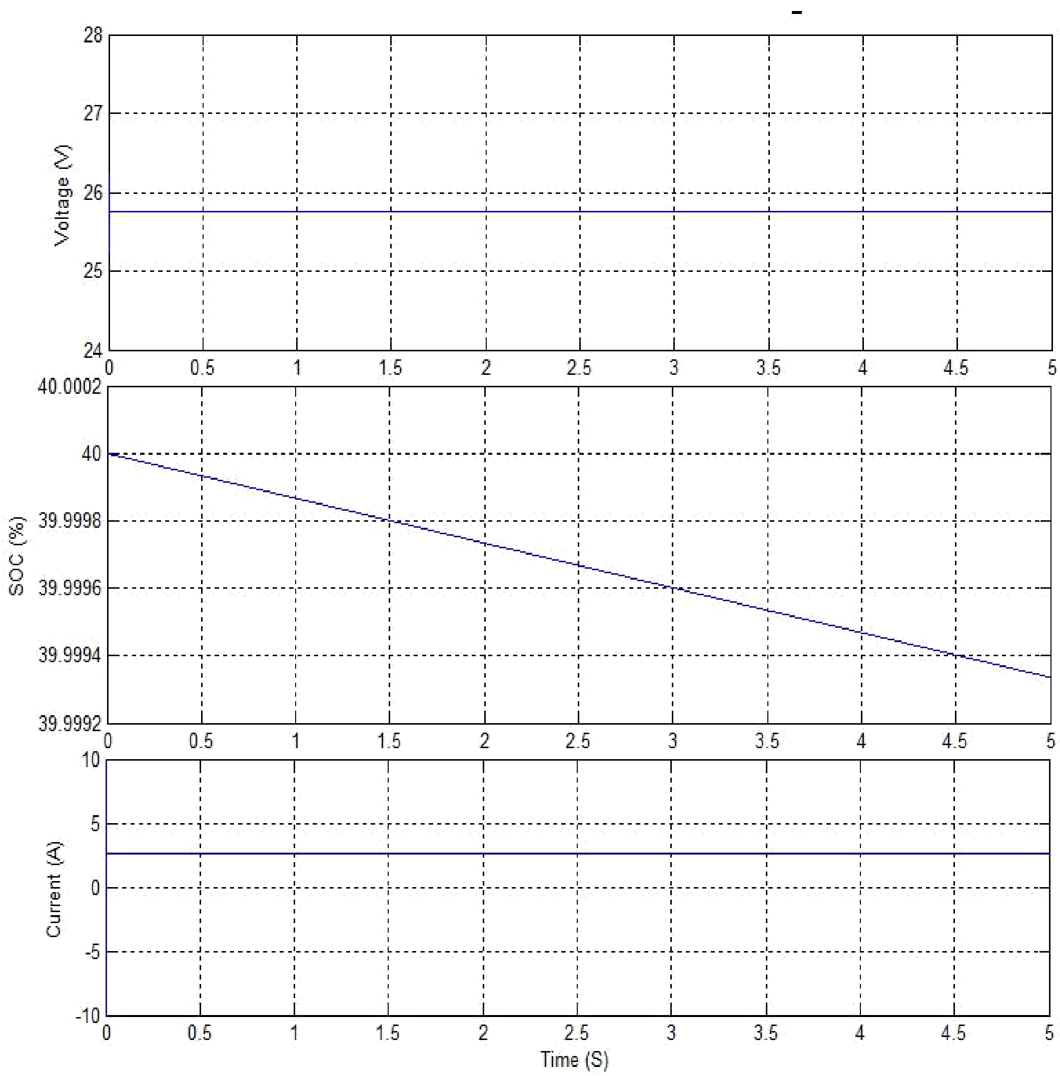


Fig 6.16 Discharging characteristics of battery

From fig 6.16 we can see during discharging, battery start supplying constant voltage and state of charge start decreasing and also during discharging current become positive, which shows battery is supplying the power to the load.

6.2 CONCLUSIONS

- PV cell, module and array are simulated and effect of environmental conditions on their characteristics is studied
- Wind energy system has been studied and simulated
- Maximum power point of operation is tracked for both the systems using P&O algorithm
- Both the systems are integrated and the hybrid system is used for battery charging and discharging

6.3 FUTURE SCOPE

- MPP can be tracked using different algorithms
- Battery charge controller can be designed for more reliable operation and better battery life

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