GOVT CO-ED POLYTECHNIC

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Experiment No: 1

AIM: Make a list of various non-conventional energy sources with its specifications, and explain its working using suitable diagram.

Theory:

A plenty of energy is needed to sustain industrial growth and agricultural production. The existing sources of energy such as coal, oil, uranium etc. may not be adequate to meet the ever-increasing energy demands. These conventional sources of energy are also depleting and may be exhausted at the end of the century or beginning of the next century.

Consequently, sincere and untiring efforts shall have to be made by the scientists and engineers in exploring the possibilities of harnessing energy from several non-conventional energy sources.

The various non-conventional energy sources are as follows:

1. Solar energy
2. Wind energy
3. Energy from biomass and biogas
4. Ocean thermal energy conversion
5. Tidal energy

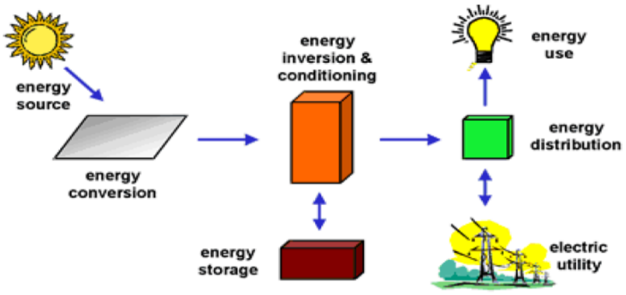
Solar energy specifications:

Solar Photovoltaic

PV systems are like any other electrical power generating systems, just the equipment used is different than that used for conventional electromechanical generating systems. However, the principles of operation and interfacing with other electrical systems remain the same, and are guided by a well-established body of electrical codes and standards. Although a PV array produces power when exposed to sunlight, a number of other components are required to properly conduct, control, convert, distribute, and store the energy produced by the array. Depending on the functional and operational requirements of the system, the specific components required may include major components such as a DC-AC power inverter, battery bank, system and battery controller, auxiliary energy sources and sometimes the specified electrical load(appliances).

Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather).

In most cases, a battery charge controller is used in these systems to protect the battery from overcharge and over discharge.



Major photovoltaic system components.

Wind Energy

Wind is essentially air in motion, which carries with it kinetic energy. The amount of energy contained in the wind at any given instant is proportional to the wind speed at that instant. Wind results primarily by unequal heating of the earth's surface by the sun. About 2% of the total solar flux that reaches the earth's surface is transformed into wind energy. Solar energy meets clouds, uneven surfaces, and mountains while reaching the earth. This unequal heating causes temperature, density, and pressure differences on the earth's surface that are responsible for local wind formation.

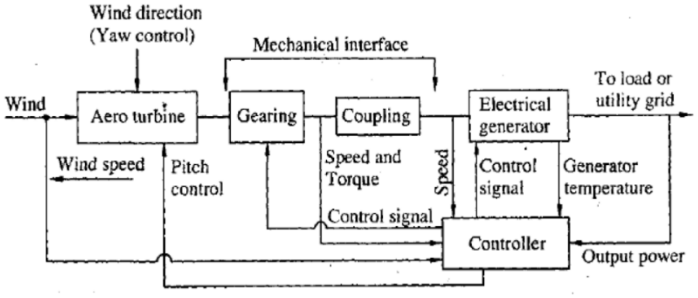
The total power of the wind stream is equal to the time rate of kinetic energy.

$$K.E. = (\tfrac{1}{2})mV^2$$

The amount of air passing in unit time through an area A with velocity V

$$M = A.V\ m^3/s$$

The main components of a wind energy conversion system (WECS) in the form of block diagram. A wind energy conversion system converts wind energy into some form of electrical energy. In particular, medium and large scale WECS are designed to operate in parallel with a utility AC grid. This is known as a grid-connected system. A small system, isolated from the id, feeding only to a local load is known as autonomous or isolated power system.



Wind Energy Conversion System

Result:

Thus, various non-conventional energy sources with its specifications has been studied successfully.

Experiment No: 2

AIM: Enlist applications of various non- conventional energy sources available in lab.

Theory:

A plenty of energy is needed to sustain industrial growth and agricultural production. The existing sources of energy such as coal, oil, uranium etc. may not be adequate to meet the ever-increasing energy demands. These conventional sources of energy are also depleting and may be exhausted at the end of the century or beginning of the next century.

Consequently, sincere and untiring efforts shall have to be made by the scientists and engineers in exploring the possibilities of harnessing energy from several non-conventional energy sources.

The various non-conventional energy sources available in lab are as follows:

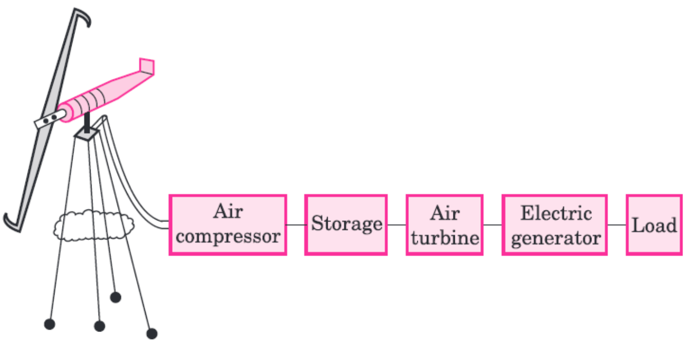
1. Solar energy
2. Wind energy

Applications of Solar Energy:

1. Heating and cooling of residential building.
2. Solar water heating.
3. Solar drying of agricultural and animal products.
4. solar distillation on a small community scale.
5. Salt production by evaporation of sea water or inland brines.
6. Solar cookers.
7. Solar engines for water pumping.
8. Food refrigeration.
9. Solar furnaces.
10. Solar photovoltaic cells, which can be used for photoelectric conversion.

Applications of Wind Energy:

1. <u>Pumping application:</u> Pumping water from main reservoir to auxiliary storage using horizontal axis-based wind mill system.
2. <u>Direct heat applications:</u> Mechanical motion derived from wind power can be used to drive heat pumps or to produce heat from friction of solid materials, or by the churning of water or other fluids. This heat may then be stored in materials with a high heat capacity.
3. <u>Electric generation applications:</u> Wind power can be used in centralized utility applications to drive synchronous a.c. electrical generators. In such applications, the energy is fed directly into power networks through voltage step up transformers.



System with compressed-air storage.

The temperature of air is raised when it is compressed without loss of heat (i.e. adiabatic compression). In this case, less heat will need to be added to the air, when it is eventually used to drive a turbine at a given efficiency.

Result:

Thus, the applications of various non- conventional energy sources available in lab has been listed successfully.

Experiment No: 3

AIM: List the various parts of a small wind power training system.

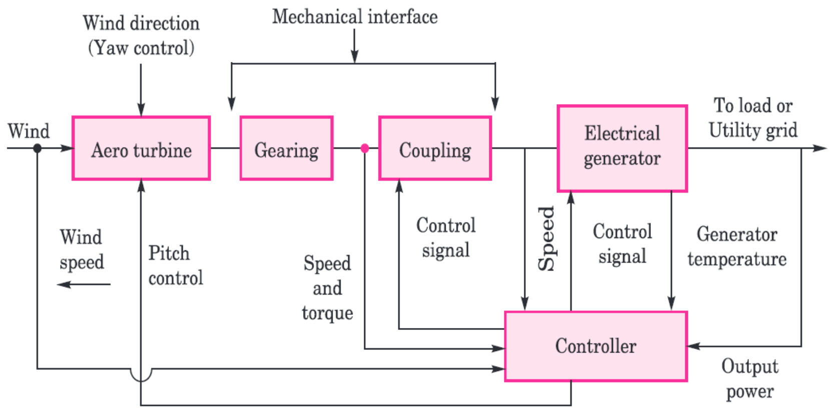
Theory:

Wind is essentially air in motion, which carries with it kinetic energy. The amount of energy contained in the wind at any given instant is proportional to the wind speed at that instant. Wind results primarily by unequal heating of the earth's surface by the sun. About 2% of the total solar flux that reaches the earth's surface is transformed into wind energy. Solar energy meets clouds, uneven surfaces, and mountains while reaching the earth. This unequal heating causes temperature, density, and pressure differences on the earth's surface that are responsible for local wind formation.

The total power of the wind stream is equal to the time rate of kinetic energy.

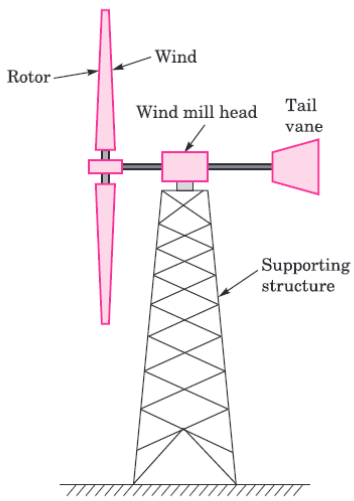
$$K.E. = (\tfrac{1}{2}) m V^2$$

Block Diagram:



Basic components of a wind electric system.

Components of Wind Energy Generation System:



- Rotor – to convert the kinetic energy of the wind into rotational energy
- Generator – to convert the rotational energy into electrical energy
- Tower and foundation – provide stability for the turbine in high-speed winds, and elevates the turbine to a height where wind speeds are high enough to generate the rated power.
- Yaw mechanism with tail – turns the SWT into the direction of the wind so that the rotor can operate most effectively.
- Furling mechanism – a mechanical means of power control, whereby the turbine turns away from winds that exceed a permissible limit.
- Slip rings and electrical cabling – transmits the generated electricity from the turbine at the top of the tower, down to the energy storage or conversion system at the base.
- Energy storage or conversion system – In many applications batteries are used to store the generated electricity, while often an inverter is used to convert the generated electricity to a form suitable for grid-connection.
- Electrical control system, with over-speed and lightning protection electronic control of the rotor speed ensures that the turbine does not destroy itself in extreme wind conditions.

Result:

Thus, various parts of a small wind power generation system have been listed successfully.

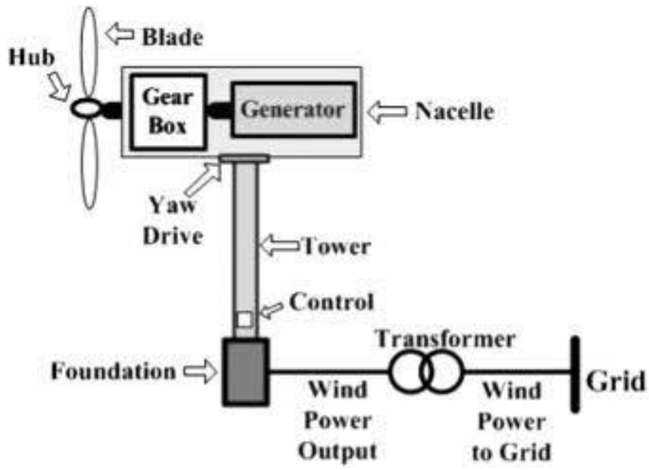
Experiment No: 4

AIM: Dismantle the given small horizontal axis wind turbine and write the name of different parts.

Theory:

Renewable Energy in particular Wind and Solar has become mainstay in meeting energy needs having achieved grid parity in term of costs as well as technical need. The wind energy has proved a highly successful energy option with installation of over 560 GW worldwide end of December 2018. It is estimated that viable wind power potential across globe is 72 TW, which is four times more than the current World's total energy demand. The major wind generator installation is in USA, some of the European countries and Asian countries like China and India and other countries catching up with the rest.

Small Horizontal Axis Wind Turbine Cross-sectional View



Procedure:

- Collect the information about horizontal axis wind mill.
- List components of horizontal axis wind mill.
- Explain details of working of components of horizontal axis wind mill.
- Note the ratings of each component in a tabular form.

Result:

Thus, the given small horizontal axis wind turbine has been dismantled and studied successfully.

Experiment No: 5

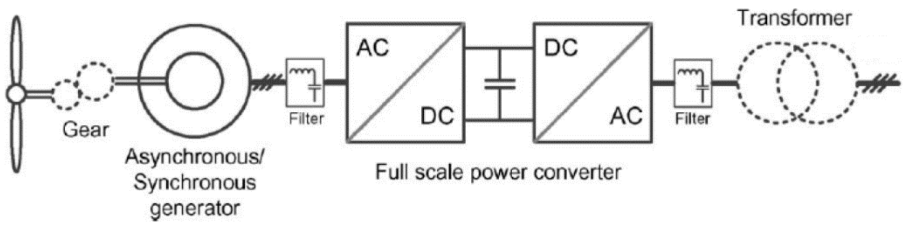
AIM: Identify the power electronic devices and circuits in the small wind turbine.

Theory:

A small wind turbine generally consists of the following components: A rotor with a variable number of blades for convert the power from wind to mechanical power, an electric generator, control and protection mechanisms, & power electronic components for feeding electricity into a battery bank, the public grid or, occasionally, into a direct application such as a water-pump.

The only difference between furling and soft-stall control is the addition of the DC-DC converter that allows the power to be controlled. With the DC-DC Converter between the rectifier and load, the transmitted power to the load can be controlled according to prescribed power/rpm schedule.

A variable speed wind turbine configuration with power electronics conversion corresponds to the full variable speed-controlled wind turbine, with the generator connected to the load or to the grid through a power converter as shown in Figure below.

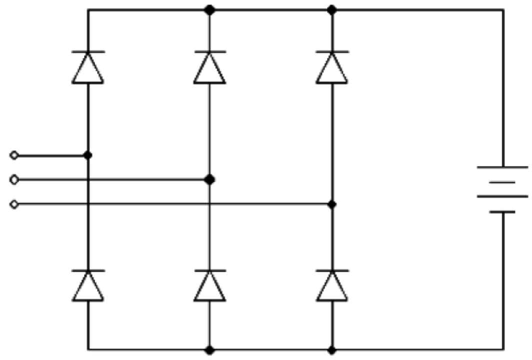


The earliest and still most widely used power electronic circuit for this purpose uses an AC/DC/AC technology in which the variable frequency, variable voltage from the generator is first rectified to DC and then converted to AC and fed to the grid or load. The continuous variation of wind speed will result in a DC link voltage varying in an uncontrolled manner. In order to get variable speed operation and stable dc bus voltage, a boost dc-dc converter could be inserted in the dc link.

AC/DC/AC converters for power electronic interface:

A three-phase bridge rectifier is commonly used in wind power applications. This is a full-wave rectifier and gives six-pulse ripples on the output voltage. Each one of six diodes conducts for 120°. The pair of diodes which are connected between that pair of supply lines having the highest amount of instantaneous line-to-line voltage will conduct. The three phase bridge rectifier is shown in Figure in next page

Three Phase Bridge Rectifier



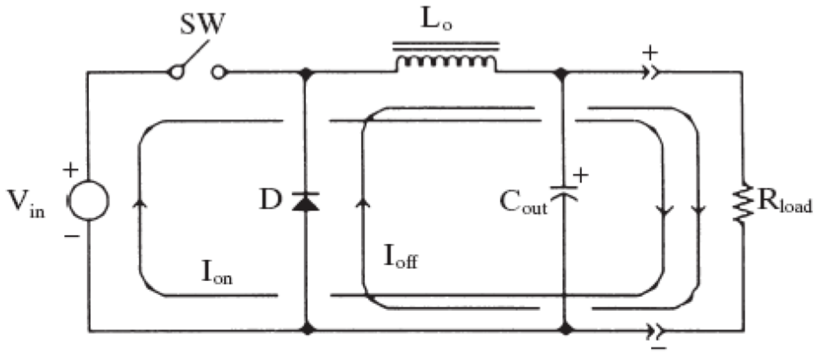
If *Vm* is the peak value of the phase voltage, then the average and rms output voltage is calculated with

$$Vdc = 2/(2\pi / 6) \int_0^{\pi/6} \text{sqrt}(3)\, Vm\cos \omega t \; d(\omega t) = 1.654Vm$$

DC/DC converters:

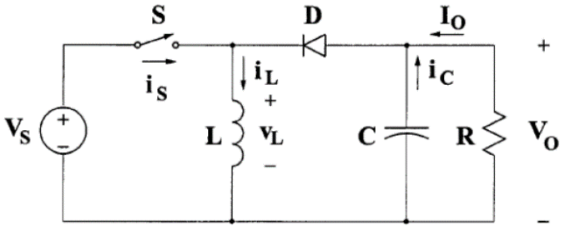
Dc converters can be used as switching-mode regulators to convert to dc voltage, normally unregulated, to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is normally IGBT or MOSFET. The following range of DC-to-DC converters, in which the input and output share a common return line, are referred to as "three-terminal switching regulators".

Buck regulators



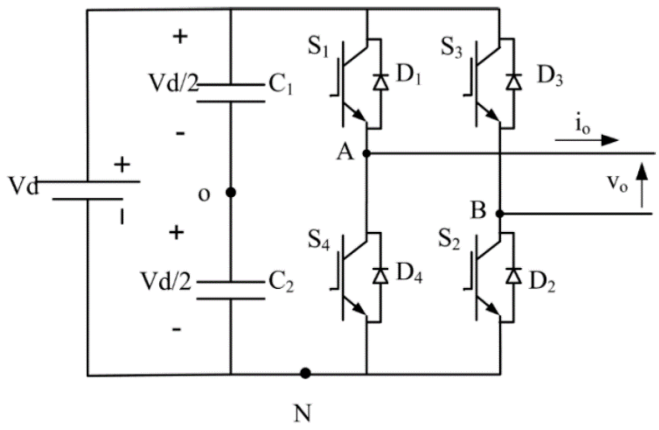
Buck-boost regulators

A buck-boost regulator provides an output voltage that may be less than or greater than the input voltage. The output voltage polarity is opposite to that of the input voltage. Figure below shows the power circuit of a typical buck-boost regulator.

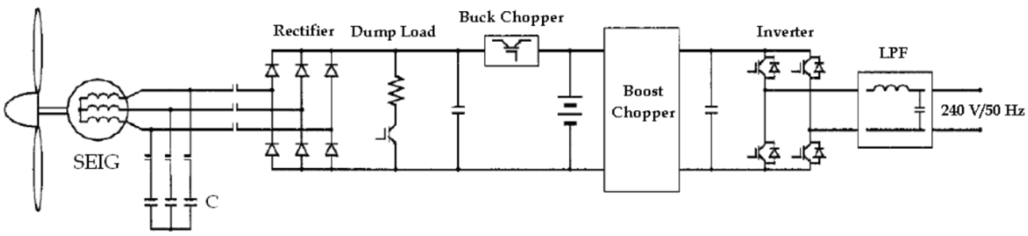


Inverters

DC-to-ac converters are known as inverters. The function of inverter is to change a dc input voltage to symmetric ac output voltage of desired magnitude and frequency. The output voltage could be fixed or variable at a fixed or variable frequency. A variable output voltage can be obtained by varying the input dc voltage and maintaining the gain of inverter constant. The output voltage waveforms of ideal inverters should be sinusoidal. However, the waveforms of practical inverters are non-sinusoidal and contain certain harmonics.



Wind Turbine With All The Power Electronic Components



Result:

Thus, the power electronic devices and circuits in the small wind turbine has been studied successfully.

Experiment No: 6

AIM: Draw the plot of generated power versus wind speed for a small wind power trainer.

Theory:

The overall purpose of a wind turbine is to produce electrical power from wind. Quantifying this power output is necessary, on the one hand, for the financial planning of any wind energy project. On the other hand, besides the pure amount of energy production, also the dynamics of the power conversion contains essential information about, e.g. mechanical and electrical performance of the turbine and power quality.

Based on the fact that a wind turbine converts the wind power into available electrical power, one can assume the following relation:

$$P(u) = c_p(u)P_{wind}(u)$$

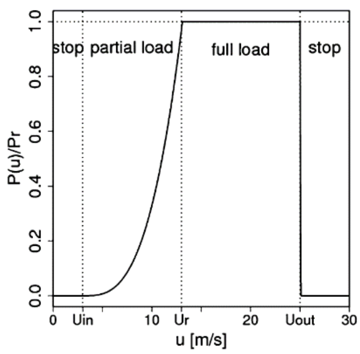
where $P_{wind}(u)$ is the power contained in the wind passing with speed u through the wind turbine, and $P(u)$ is the electrical power extracted. The power coefficient $c_p(u)$ represents the amount of power converted by the wind turbine. Because the input $P_{wind}(u)$ cannot be controlled, improvements in wind power performance involve increasing the power coefficient $c_p(u)$. Momentum theory can be applied to determine this coefficient.

The wind power P wind (u) is derived from momentum theory for the wind passing with speed u through the rotor of area p D ^{2}/4:

$$P_{wind}(u) = \frac{\rho}{2}\frac{\pi D^2}{4}u^3$$

where ρ is the air density.

The figure below shows Static (steady-state) power curve P (u) of an active stall controlled wind turbine showing the different power operation states: stop, partial and full load.



Result:

Thus, a the curve for generated power $P_{wind}(u)$, versus wind speed u, for a small wind turbine has been plotted successfully.

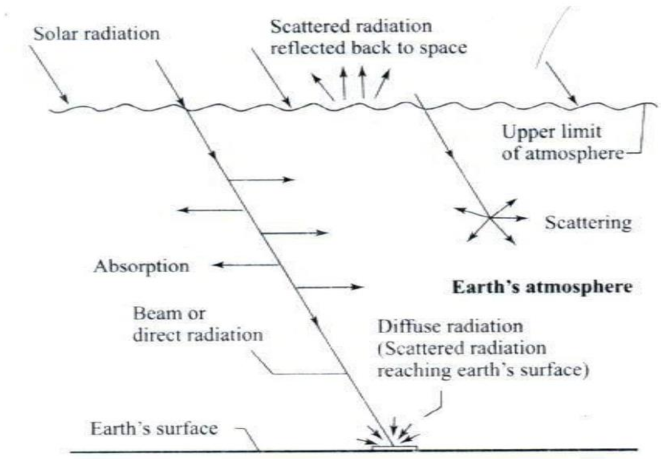
Experiment No: 7

AIM: Measure the solar irradiance level of a given locality for a given time duration using *pyranometer*.

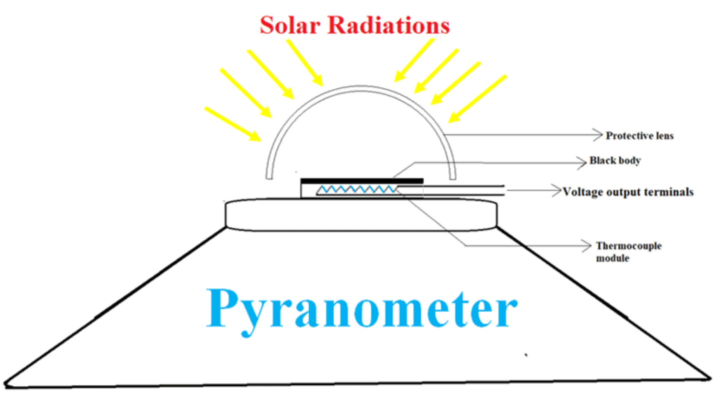
Theory:

Solar radiation received at the earth's surface without change of direction i.e, in line with the sun is called direct radiation or beam radiation. The radiation received at the earth's surface from all parts of sky's hemisphere (after being subjected to scattering in the atmosphere) is called diffuse radiation. The sum of beam radiation and diffuse radiation is called as total or global radiation.

A Pyranometer is an instrument which measure's either global or diffuse radiation falling on a horizontal surface over a hemispherical field of view. A sketch of Pyranometer measuring global radiation is shown in the figure below. Pyranometer consists of a black surface which heats up when exposed to solar radiation. Its temperature increases until the rate of heat gain by solar radiation equals the rate of heat loss by convection, conduction and radiation. The hot junctions of thermopile are attached to the black surface, while the cold junctions are located under a guard plate so that they do not receive the radiation directly. Asa result an emf is generated. This emf which is usually in the range of 0 to 10mV can be read, recorded or integrated over a period of time and is a measure of global radiation.

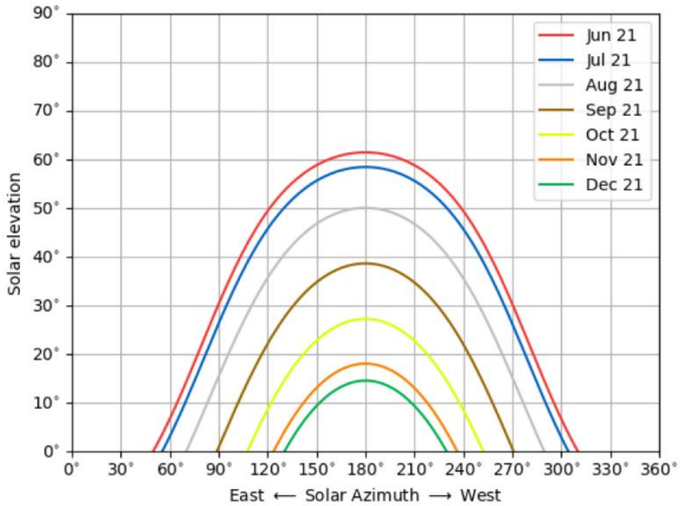


Solar radiation



Procedure:

- Select a suitable site for setting up the sensor. Adjust the height and inclination.
- Calibrate the sensor properly before taking measurements.
- Observe the trajectory of the sun before setting up your sensor.
- Do not put pyranometers close to light-coloured walls or reflective surfaces.
- Instruments with an analogue output, be it millivolts or amplified voltages or currents, need to be connected to a datalogger (a voltmeter).
- Program your datalogger to calculate the irradiance E in W/m^2 by dividing the instrument voltage output U in V by the sensitivity of the instrument S in $V/(W/m^2)$.
- Make sure the grounding has been performed properly.
- Note the data in tabular form and plot it as shown in figure below.



Result:

Thus, the solar irradiance level of a given locality for a given time duration using *pyranometer* has been measured successfully.

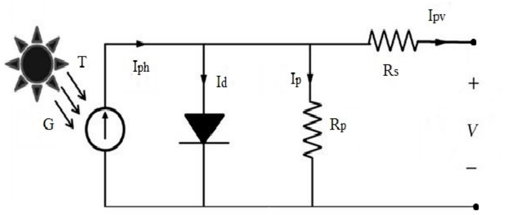
Experiment No: 8

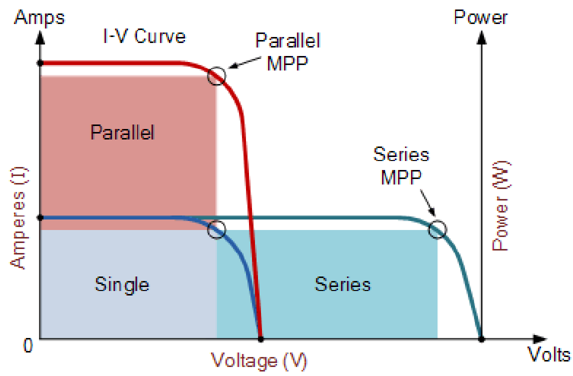
AIM: To measure the I-V characteristics of two PV modules connected in

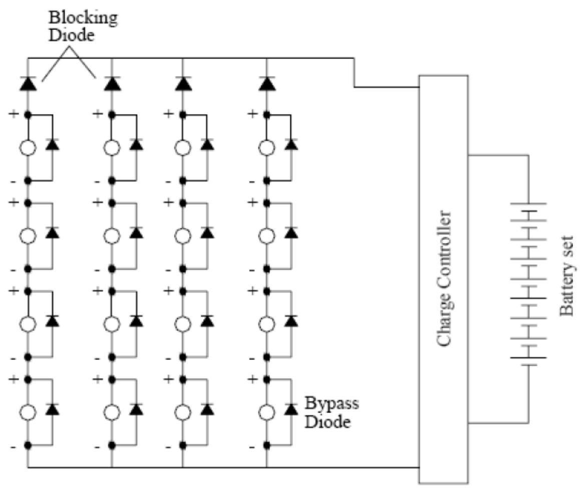
(i) Series. (ii) Parallel.

Theory:

A solar cell is a device that converts the energy of sunlight directly into electricity by the photovoltaic effect. Sometimes the term solar cell is reserved for devices intended specifically, to capture energy from sunlight. The most commonly known solar cell is configured as a large area p-n junction made from silicon. As a simplification, one can imagine bringing a layer of n-type silicon into direct contact with a layer of p-type silicon. In practice, p-n junctions of silicon solar cells are not made in this way, but rather by diffusing an n-type doping into one side of a p-type wafer (or vice versa) on of PV modules.







Solar cell can be represented by an equivalent circuit also. This circuit also includes the losses due to the solar cell manufacturing process. In this circuit Rs is the series resistance associated with the cell which is due to the grids above the solar cells and interconnection of solar cells. *Rsh* is the parallel resistance with cell which represents the leakage current through the cell. Equivalent circuit of cell is shown in Fig above.

PV module is characterized by its I-V and P-V characteristics. At a particular level of solar insolation and temperature it will show a unique I-V and P-V characteristics. These characteristics can be altered as per requirement by connecting both modules in series or parallel to get higher voltage or higher current as shown in Fig above. Therefore, if modules are connected in series, then power reduction is twice when connected in parallel. On changing the solar insolation, *Isc* of the module increases while the *Voc* increases very slightly, therefore there is overall power increase. In parallel connection power increment is twice than when connected in series.

Procedure:

- Select a suitable site for setting up the PV module. Adjust the height and inclination.
- Calibrate the sensor properly before taking measurements.
- Observe the trajectory of the sun before setting up your sensor.
- Instruments with an analogue output, be it millivolts or amplified voltages or currents, need to be connected to a datalogger (a voltmeter).
- First connect the PV modules in series and note the readings in tabular form.
- Measure I_{sc} V_{oc} V_m and I_m fill factor.
- Then connect the PV modules in parallel and note the readings in tabular form.
- Measure I_{sc} V_{oc} V_m and I_m fill factor.
- Observe the shading effect on measurement.
- Make sure the grounding has been performed properly.

Result:

Thus, the I-V characteristics of two PV modules connected in series and parallel mode, has been studied successfully.

Experiment No: 9

AIM: Connect a given solar module, solar battery, charge controller and inverter and measure the electrical parameters under normal solar radiation.

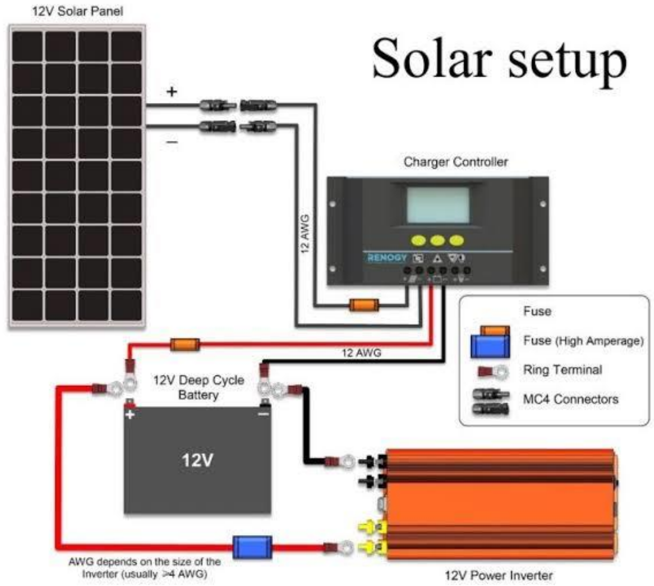
Theory:

A PV module converts energy from sun to electricity and such energy is further stored in a battery using suitable circuitry. Give below are important terms to remember before connecting various components of a solar module array:

Solar Cell - The basic photovoltaic device, which generates electricity when exposed to sunlight, shall be called a "Solar Cell".

Solar Panel - A group of modules fastened together, pre-assembled and interconnected, designed to serve as an installable unit in an Array shall be called "Panel".

Battery Bank - The Sun is not always available and it is not regular. However, loads are to be fed any time of the day. Therefore, power should be stored in a battery bank. Low maintenance Lead acid battery as per IRS: S 88/2004 or latest of specified capacity will be provided. The capacity of this battery bank is given in Ampere - Hour (AH) and bus bar voltage. The bus-bar voltage is decided by the voltage requirement of the load.



Charge controller- It is the interface between Array and battery bank. It protects the battery from overcharging and moderate charging at finishing end of charge of battery bank. Therefore, it enhances the life of the battery bank. It also indicates the charging status of batteries like battery undercharged, overcharged or deep discharged through LEDs indications. Some switches and MCBs are also provided for manual or accidental cut-off of charging.

Inverters- DC-to-ac converters are known as inverters. The function of inverter is to change a dc input voltage to symmetric ac output voltage of desired magnitude and frequency. The output voltage could be fixed or variable at a fixed or variable frequency.

Procedure:

- Select a suitable site for setting up the PV module. Adjust the height and inclination.
- Note the rated value Voc and Isc of PV module, inverter, batteries, charge controller.
- Calibrate the sensor properly before taking measurements.
- Observe the trajectory of the sun before setting up your sensor.
- Make the connection as per figure.
- Check that fuses are in healthy condition.
- Observe the shading effect on measurement.
- Make sure the grounding has been performed properly.
- Measure I_{sc} V_{oc} V_m and I_m fill factor.
- Note the readings in tabular form.

Result:

Thus, a given solar module, solar battery, charge controller and inverter have been connected and tested successfully.

Experiment No: 10

AIM: Verify the healthiness of a battery for a PV application.

Theory:

We use various kind of batteries to store the energy obtained from PV module using suitable charge controller. The Sun is not always available and it is not regular. However, loads are to be fed any time of the day. Therefore, power should be stored in a battery bank. Low maintenance Lead acid battery as per IRS: S 88/2004 or latest of specified capacity will be provided. The capacity of this battery bank is given in Ampere - Hour (AH) and bus bar voltage. The bus-bar voltage is decided by the voltage requirement of the load.

Following points ensure healthy operation of a battery during PV module operation:

- Install battery in a cool and dry place
- Use battery stand insulators for system voltages above 48V
- Use insulated tools when working on battery
- Whenever battery or cells are being disconnected or reconnected, first disconnect the complete battery from the inverter or electrical load before proceeding to take out or reconnect inter cell connectors. Failure to do so may result in heavy arcing/sparks.
- Top up flooded batteries with DM water at required intervals
- In case, the battery has been deep discharged beyond 100% capacity or discharged and not recharged for a long time, revival charge is to be carried out as soon as possible under expert guidance.
- Ensure maximum charging current till gassing voltage is reached
- Ensure tightness of inter cell or cable connectors

Result:

Thus, healthy condition of a battery for PV module application has been checked successfully.