PIE Tech

POLLACHI INSTITUTE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE and Affiliated to Anna University)

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Department of Electrical and Electronics Engineering

Regulation 2021

IV Year – VII Semester

EE3033- HYBRID ENERGY TECHNOLOGY

EE 3033 HYBRID ENERGY TECHNOLOGY

UNIT - I

INTRODUCTION TO HYBRID ENERGY SYSTEMS

PART-A

1. what do you mean by hybrid energy system?

The renewable energy sources are intermittent in nature, thereof, hybrid combination of two or more power generation technologies, along with storage can improve system performance. An example of PV-wind-diesel generator represents hybrid energy systems.

2. what is need for hybrid energy system?

Many hybrid systems are stand-alone system which operate "off-Grid" i.e, not connected to an electricity distribution systems. For the times when neither the wind nor the solar system are producing most hybrid systems provide power through batteries and/or an engine generator powered by conventional fuels, such as diesel. If the batteries run low, the engine generator can provide power and recharge the batteries.

3. List the classification of hybrid energy system:

There are many possible configuration of hybrid energy systems, which operate differently under the influence of numerous climatic condition. These hybrid energy systems are classified as

- Hybrid wind - Solar system
- Hybrid diesel - wind system
- Hybrid wind - hydro "
- Hybrid - fuel cell - solar "
- Hybrid - Solar - thermal - "

4. what are the importance of hybrid energy systems?

The hybrid renewable energy application can be used to harvest the energy produced in different time periods. Hybrid power generation and hybrid energy storage provide many benefits to the electricity grid operation grid infrastructure, power system and end user.

5. List few advantages and disadvantages of hybrid energy system.

Advantages :

a. Continuous power supply
b. Utilize energy in the best way
c. High efficiency
d. Load management

Disadvantage :

a. Complicated Controlling process
b. High installation cost
c. High maintenance cost

6. what are the different Conventional and Renewable Energy Sources?

Conventional : Fossil fuel, CNG, Coal, oil, Natural Gas

Renewable : Solar, wind, Bio energy, hydro, Tidal, ocean energy

7. List few environmental impacts of Renewable Energy.

Electricity from renewable energy sources provides between 90.99 %. less greenhouse gases (GHGs) compared with coal fired plants and cause 70-90 %. less pollution.

Focusing on renewable energy source others than fossil fuels and coal might help in avoiding environmental impacts, specifically from air pollution and GHGs.

8. What is the total installed capacity of Renewable Energy in India?

As of July 2023, Renewable energy source, including large hydropower have a combined installed capacity of 179.322 GW.

wind power - 42.8 GW

Solar power - 67.07 GW

Biomass - 10.2 GW

Small hydro - 4.94 GW

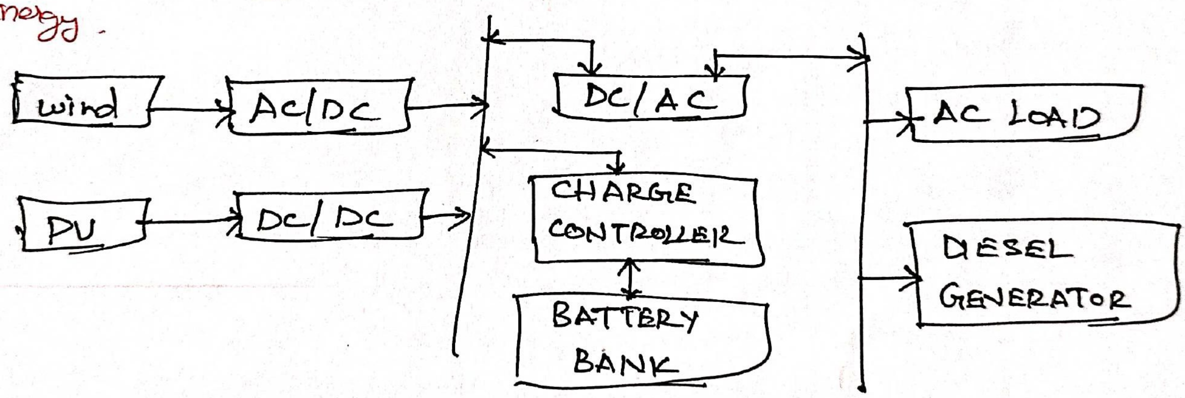
waste to energy - 0.55 GW

Large Hydro - 46.85 GW

9. What is the total installed capacity of Renewable Energy in world?

By end of 2022, Global renewable generation capacity amount of 3372 GW growing the stock of renewable power by record 295 GW or by 9.6 per cent

10. Draw the block diagram of Solar - wind - fuel cell - Diesel hybrid energy.



1. With neat diagram explain solar - wind fuel cell diesel hybrid energy system.

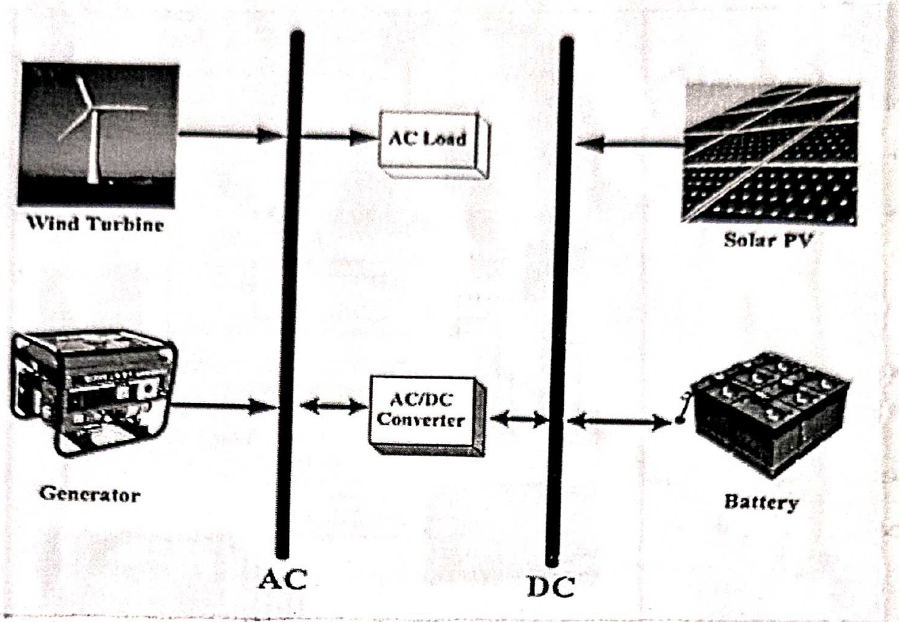
Combining several different types of power sources will form the system called "Hybrid power system". Hybrid power system combine two or more energy conversion devices, or two or more fuels for same device, that when integrated overcome limitation inherent in either. Hybrid power systems are designed ~~to~~ for the generation and use of electrical power.

Hybrid system capture the best feature of each energy resource and can provide "grid quality" electricity, with a power range from 1kw to several kilowatts. They can be developed as new integrated designs within small electricity distribution systems (mini-grids) and can also be retrofitted in diesel based power generations.

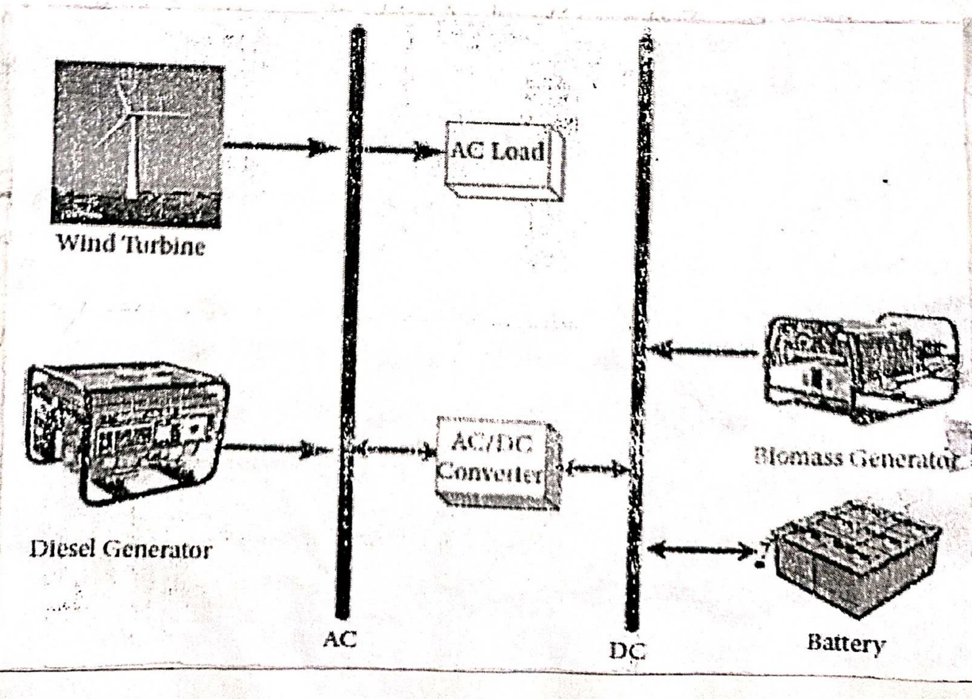
The standalone hybrid solar / wind / FC / power generation system ~~load~~ has been designed, constructed and located in a remote area. The constructed power generation system ~~provide~~ produces electric power to supply power in remote area

The configuration of standalone hybrid solar / wind / FC power generation system is shown in figure. The hybrid system consist of PV array, WECS, two unidirectional DC/DC converters dedicated to a PV array and WECS a unified MPPT and control unit, a single phase DC/AC inverter, a fuel cell system. The FC system itself consist of a FC controller, an electrolyzer, a hydrogen tank, and a FC stack connected to a dedicated unidirectional DC/DC converter.

Supplementary electric energy needed under unavoidable environmental condition such as cloudy sky is produced by the FC stack used as a standby power source. The PV array, WECS and FC stack have been connected to the DC bus through the three identical unidirectional DC/DC converters, and the MPPT controller concurrently tracks the MPPs of the PV array and WECS. To track the two MPPs, the DC link voltage is used as a reference voltage by the MPPT controller. The circuit of the three identical unidirectional DC/DC converters dedicated to the PV array WECS, FC stack.



2. with neat diagram explain wind - biomass - diesel hybrid energy System.



The hybridization of two or more renewable source into the system might reduce this problem by offering system reliability and improved efficiency.

A tiny version of the conventional electricity grid is called as microgrid. In microgrid, the coverage area of the grid, the amount of generation, and the consumption of electricity are limited. Microgrid have become a part of the "smart grid" concept which allows a two-way flow of information and electrical power.

In microgrid, it has been a common fashion to integrate two or more energy source offering both AC and DC buses. These types of microgrid are referred to as hybrid microgrids.

In hybrid microgrids, also known as a hybrid renewable energy system, there are several types of sources and load connected. Mostly the source include renewable-based source like Solar-PV or wind turbine and the load contain various AC/DC fixed or deferable load.

Biomass energy, on the other hand, is not as famous as solar or wind till today, but it has a great potential to be used as a sustainable solution for electricity. Biomass is abudant mostly in remote areas from animal husbandry, farming etc., which can easily be used as a source of energy. Biomass energy is comparatively stable and is more convenient for transportation and storage.

The integration of biomass based electricity to generation in Solar/PV wind based HRES could show a significant impact in solving the scarcity of electricity in the country.

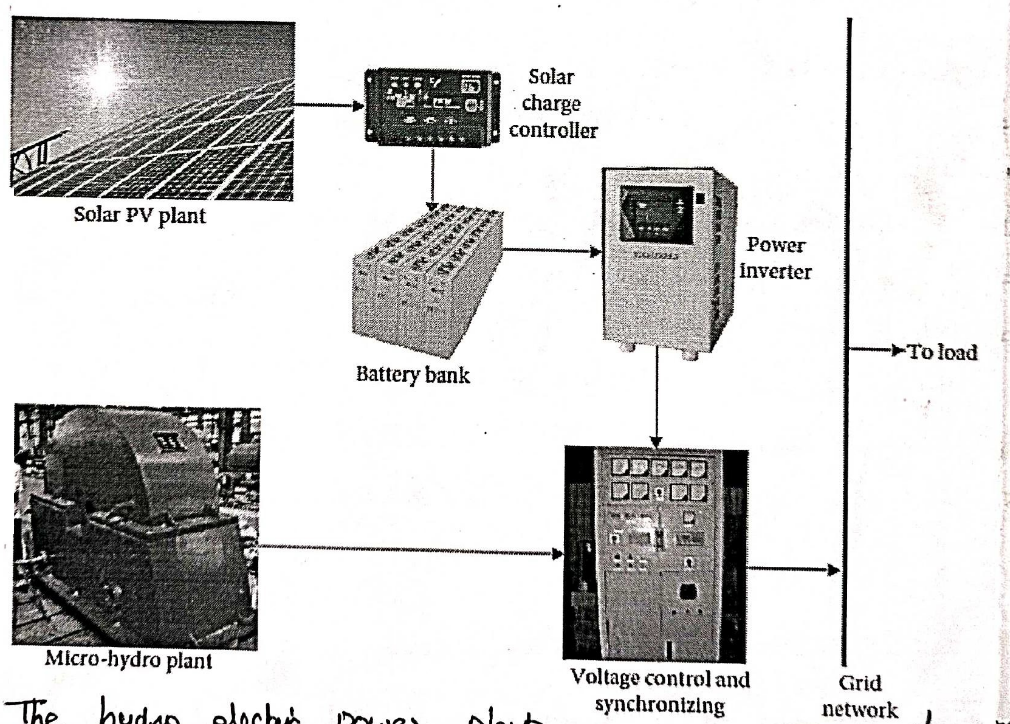
3. With neat diagram explain micro-hydel PV hybrid energy system.

At present, the power plant in the world, generally still use fossil fuel power plants, namely coal and oil. Fossil fuel consist of 18% gas, 30% coal and 48% oil. It is well known that fossil fuel will eventually run out because they cannot be renewed.

Besides, air pollution, global warming and climate anamolies are negative impacts resulting from the use of fossil fuel power plants. Based on these factors, a power plant that is derived from renewable energy source is developed for example, hydro, solar, geothermal, wind, biomass and so on. Energy supply produced by renewable energy tends to be more environmentally friendly.

optimal model of hybrid power plants derived from solar and hydropower. Hybrid power generation is defined as a power generation system that combines two or more plants with different energy sources. Generators are generally used for isolated grids, so these Synergi Synergies are obtained which produce provide economic and technical advantage.

The Configuration applied is a parallel hybrid system because it has advantages in continuity and is not dependent on each other. Solar and hydro hybrid power plant configurations are shown in fig.



The hydro electric power plant, of newable energy that is pollution-free kinetic energy of water to produce mechanical energy in the form of a hydro turbine spin, which is then used to turn a generator to produce electrical energy.

Hydropower is the oldest energy conversion technology in the world. Small scale hydropower began to be used in general since the early 20th century.

Micro hydropower has a scale power lower than 100 KW. The condition of the hydro that can be utilized as an electricity producing resource is that which has a particular flow and height capacity because electricity generated by micro-hydropower is also very dependent on the height of the waterfall and hydro discharge.

Electrical energy from the micro-hydro plant with a power range of 5-100 KW can be used to drive irrigation pump, agricultural and rural activities, workshops, agricultural equipment, education and others which can increase population income and the ability and expertise of the community.

4. Elaborate the present Indian scenario of conventional and renewable sources.

India is world 3rd largest consumer of electricity and world's 3rd largest renewable energy producer with 40% of energy capacity installed in the year 2022 (160 GW of 400 GW) coming from renewable source.

Ernst & Young's 2021 Renewable Energy Country attractiveness Index (RECAI) ranked India 3rd behind USA and china.

India has committed for a goal of 500 GW renewable energy capacity by 2030. In line with this commitment, India's installed renewable energy capacity has been experiencing a steady upward trend. From 94.4 GW in 2021, the capacity has gone up to 119.1 GW in 2023.

In 2016, Paris agreement intended Nationally Determined Contribution targets, India made Commitment of producing 50% of its total electricity from non-fossil fuel source by 2030. India has also set a target of producing 175 GW by 2022 and 500 GW by 2030 from renewable energy.

As of September 2020, 89.22 GW solar energy is already operational projects of 48.21 GW are at various stages of implementation and projects of 25.64 GW capacity are under various stages of bidding.

Global rank:

Country	Score	RECAI Ranking
USA	70.7	1
China	68.7	2
India	66.2	3.

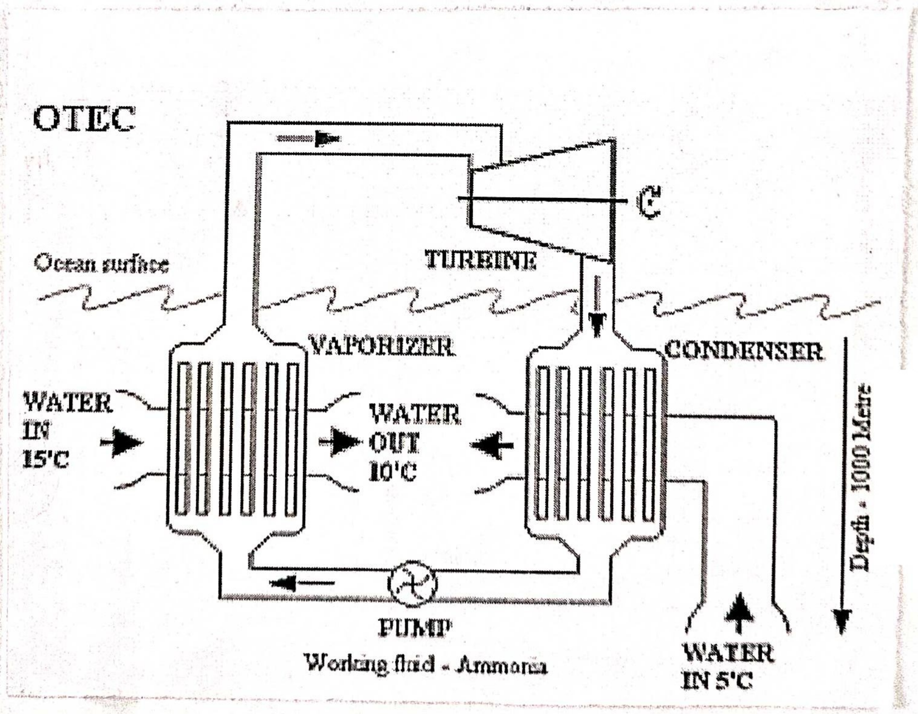
Grid connected total including non-renewable and renewable:

Type	Source	Installed capacity	Share
Non-Conventional Renewable.	Coal	205.1	56.09%.
	Gas	25.0	6.84%.
	Diesel	0.5	0.14%.
	Nuclear	6.7	0.36%.
		237.3	63%.
Renewable	Large hydro	45.7	12.05%.
	Small "	4.7	1.29%.
	Solar	38.8	10.61%.

wind	38.7	10.59 %
Biomass	0.2	0.05 %
waste to Power	0.2	0.05 %
	135.0	37 %
Total	365.6	100.00 %

5. Explain the principle and characteristic of ocean energy.

Ocean water movement creates a vast store of kinetic energy (energy in motion) in various forms of renewable energy viz. wave energy, tidal energy, ocean current energy, salinity gradient energy and ocean thermal gradient energy which can be harnessed to generate electricity.



Types of ocean energy:

Tidal energy: Like conventional hydroelectric dams, power plants are built on river estuaries and hold back huge amounts of tidal water twice a day which generates electricity when released. India is expected to have 9000 MW of tidal energy potential.

wave energy: This is generated by the movement of a devic either floating on the Surface of ocean or moored to the ocean floor.

Current energy: It is very similar to the wind above the oceans, underwater turbines, large propellers tethered to the seabed, are moved with the marine currents to generate electricity.

Ocean Thermal Energy Conversion (OTEC):

This technology which uses ocean temperature differences from the surface to depths lower than 1000 meters to extract energy.

Research focuses on two types of OTEC technologies

closed: In a closed cycle method, a working fluid (ammonia) is pumped through a heat exchanger for evaporation and the steam runs a turbine. The vapour is turned back to fluid (condensation) by cold water found ~~as~~ at the depths of ocean where it returns to heat exchange.

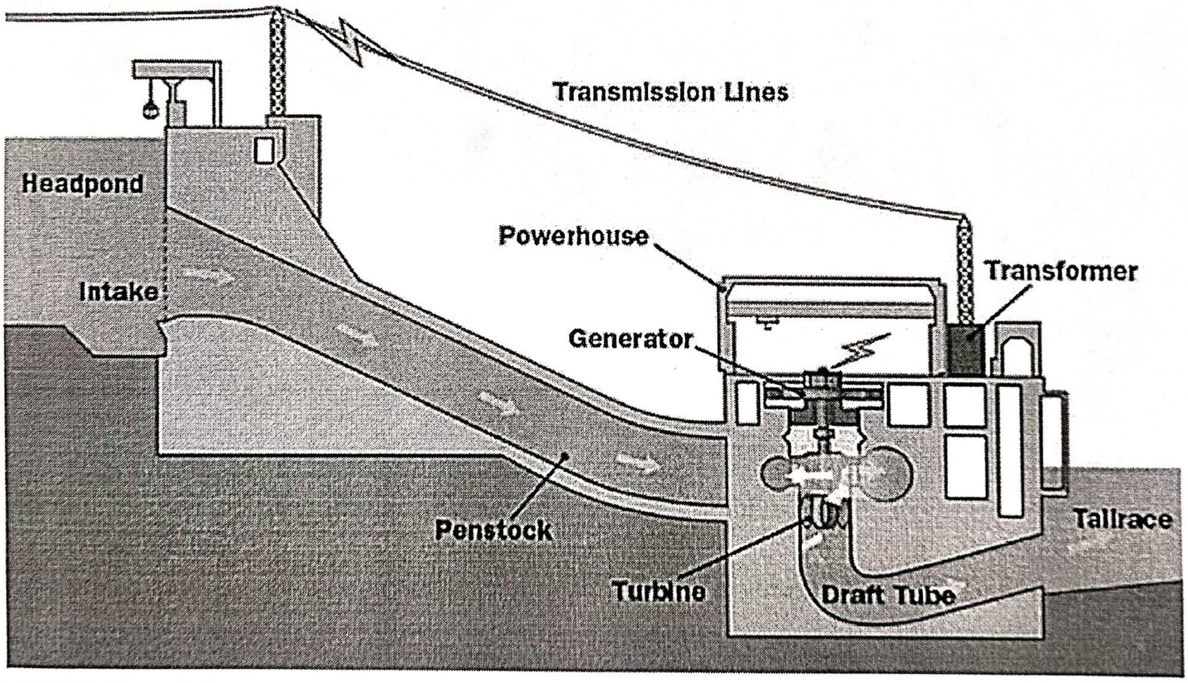
open: In open cycle method, the warm surface water is pressurized in a vaccum chamber and converted to steam which runs the turbine. The steam is then condensed using cold ocean water from lower depths.

6. Explain the principle and characteristic of hydro energy:

Hydropower or hydroelectricity is a renewable energy that utilizes energy of fast flowing water to generate electricity. The use of hydropower for various purposes is not a modern concept its application can be seen a thousand year ago.

Components of Hydroelectric Power Plant:

Hydropower plants are generally constructed in the hilly area across the rivers, ocean or other water bodies, where the dams and large water reservoir can be easily built. Different types of hydroelectric power plants are constructed as per requirements. but every hydroelectric plant consist of some basic components which are.



1. Reservoir:

A reservoir is the most essential part of HPP. It stores the water and supply it down the hydro turbine for electricity generation.

2. Forebay:

A forebay is an area to temporary store the water before flowing it down the turbine. It stores the excess water in the case of rainy seasons and supplies it during dry season.

3. Dam:

A dam is the most expensive element of HPP. It is a barrier constructed across the water bodies to restrict the flow of naturally flowing water and to raise the water level in the reservoir.

4. Spillways:

In case of heavy rainfall or flood situations, the water level in the reservoir may rise beyond its storage capacity that may affect the proper functioning of HPP. To prevent this situation, a hydraulic turbine structure called a spillway is built at the side of dam.

5. Tail race:

The water left the HPP after being generated electricity by the hydro turbine is carried away from that area through a channel called tailrace.

6. Penstock:

penstock are the channel or large pipes at the HPP that carries the water down the turbines at the power station from the reservoir. The penstock are generally made of steel or reinforced cement concrete (RCC)

7. Water Intakes:

The water intake includes the structure that collect the water stored in the reservoir or forebay and direct it towards the turbine through the penstock.

8. Sluice:

Sluice are part of water intake structure. The flow of water through the penstock is controlled by the sluice.

9. Surge Tank:

The sudden water surge due to the changes in the water flow may result in variation in the pressure that can damage the components of hydropower plant. To control the pressure changes, small cylindrical water storage tanks called surge tanks are used.

10. Powerhouse:

A powerhouse is a separate room or building at the hydroelectric power stations, which consist of various electrical and hydraulic components.

11. Turbine:

The water turbine are used to convert the potential energy and kinetic energy of water into mechanical energy. The fast flowing water running down from elevated surface is directed towards the blades of turbine, and the turbine blade start spinning due to the force on the blades by the water. (Impulse, Reaction turbine)

12. Draft tube:

The draft tube is conduit pipe of appropriate diameter that connected from turbine runner to tail race.

13. Generator:

The electric generator used at ~~by~~ HPP converts mechanical to electrical energy.

14. Transformer:

The electricity generated by HPP is not of appropriate voltage that can be used at homes or other purpose. Transformers step up voltage to grid voltage.

15. Electricity Transmission:
power generated at HPP is transmitted over long distance for user/consumer utility.

Types of Hydroelectric Power Plant:

Types of HPP to be built depend on various requirement such as immediate or delayed requirement of electricity, load or Storage purpose.

~~Based on~~
The following are types of HPP

1. Run-of-River HPP
2. HPP with Reservoir
3. Pumped storage HPP
4. offshore HPP.

EE3033-HYBRID ENERGY TECHNOLOGY

UNIT-III

POWER CONVERTERS AND ANALYSIS OF SOLAR PV SYSTEMS

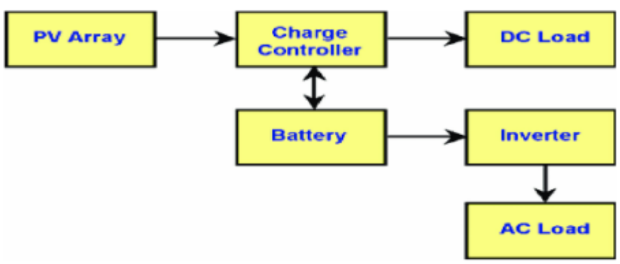
1. Define stand alone PV system.

- A standalone solar PV system is a system that uses solar photovoltaic (PV) modules to generate electricity from sunlight and does not rely on the utility grid or any other source of electricity.
- It provides power for various applications, such as lighting, water pumping, ventilation, communication, and entertainment, in remote or off-grid locations where grid electricity is unavailable or unreliable.
- A stand alone photovoltaic (PV) system is an electrical system consisting of array of one or more PV modules, conductors, electrical components, and one or more loads.

2. List the types of solar PV systems.

There are three main types of solar PV systems: (a)grid-tied(b)hybrid and (c)off-grid.

3. Draw the block diagram of solar PV systems.



4. How to select the inverter in solar PV systems?

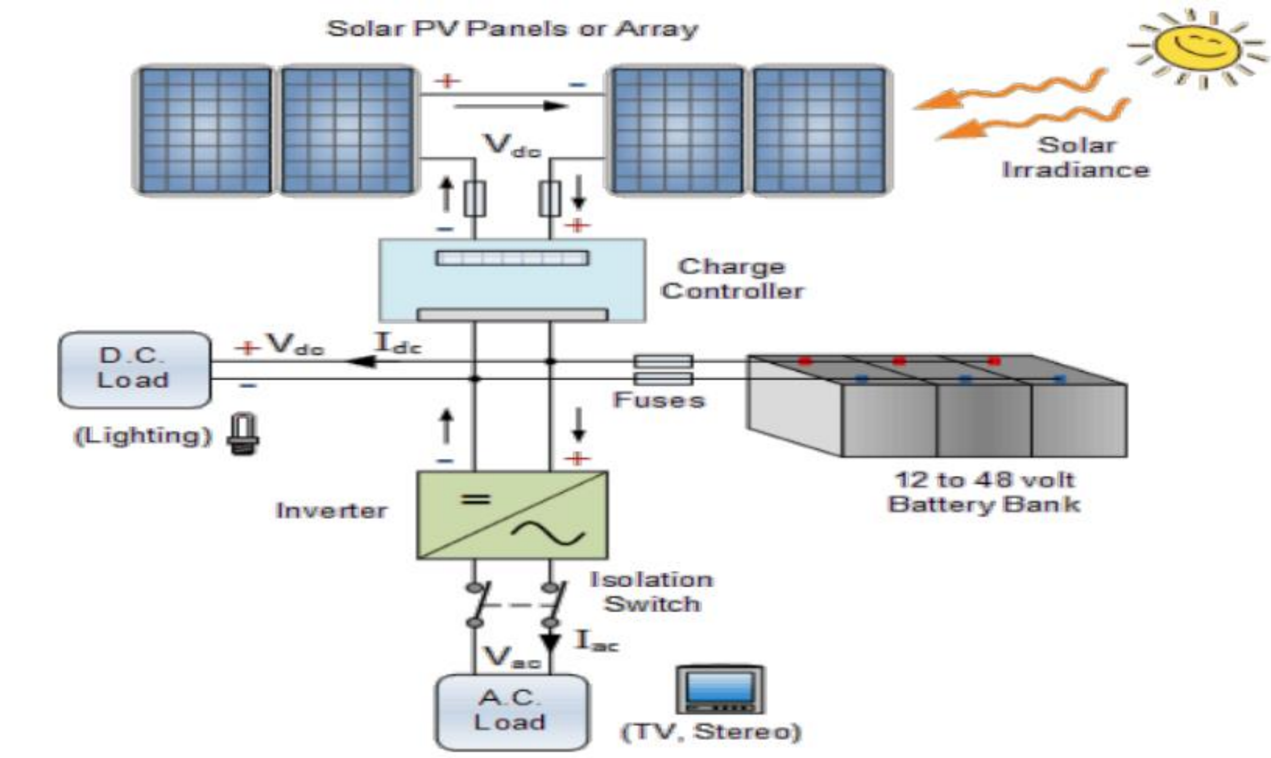
Efficiency of the inverter signifies the percentage of DC power from the solar panels that is converted to AC power. It is usually the primary consideration for selecting an inverter. Higher the efficiency, lower the losses associated with the inverter. The inverter must have an efficiency of > 95 % at full load.

5. What is array sizing?

Array sizing is important aspect in PV system design. Designing a PV array has various criteria and constraints which include the site layout conditions, local shading issues, linear shading issues, inverter voltage and current ratings, site solar irradiation etc.

1. Draw the schematic diagram of standalone solar photo voltaic system. Explain their functions.

- A standalone solar PV system is a system that uses solar photovoltaic (PV) modules to generate electricity from sunlight and does not rely on the utility grid or any other source of electricity.
- A stand alone photovoltaic (PV) system is an electrical system consisting of an array of one or more PV modules, conductors, electrical components, and one or more loads.



<u>A standalone solar PV system typically consists of four main components:</u>

- Solar PV modules or arrays that convert sunlight into direct current (DC) electricity.
- A charge controller or a maximum power point tracker (MPPT) regulates the voltage and current from the solar PV modules to the battery and the load.
- A battery or a battery bank that stores the excess electricity generated by the solar PV modules during the day and supplies it to the load when needed, especially at night or during cloudy weather.
- An inverter that converts DC electricity from the battery or the solar PV modules to alternating current (AC) electricity for AC loads.
- An off-grid or **Stand Alone PV System** is made up of a number of individual photovoltaic modules (or panels) usually of 12 volts with power outputs of between 50 and 100+ watts each.
- These PV modules are then combined into a single array to give the desired power output. A simple *stand alone PV system* is an automatic solar system that produces electrical power to charge banks of batteries during the day for use at night when the suns energy is unavailable.
- A stand alone small scale PV system employs rechargeable batteries to store the electrical energy supplied by a PV panels or array.
- Stand alone PV systems are ideal for remote rural areas and applications where other power sources are either impractical or are unavailable to provide power for lighting, appliances and other uses.

- In these cases, it is more cost effective to install a single stand alone PV system than pay the costs of having the local electricity company extend their power lines and cables directly to the home as part of a grid connected PV system.
- **Batteries** – Batteries are an important element in any stand alone PV system but can be optional depending upon the design. Batteries are used to store the solar-produced electricity for night time or emergency use during the day. Depending upon the solar array configuration, battery banks can be of 12V, 24V or 48V and many hundreds of amperes in total.
- **Charge Controller** – A charge controller regulates and controls the output from the solar array to prevent the batteries from being over charged (or over discharged) by dissipating the excess power into a load resistance. Charge controllers within a standalone PV system are optional but it is a good idea to have one for safety reasons.
- **Fuses and Isolation Switches** – These allow PV installations to be protected from accidental shorting of wires allowing power from the PV modules and system to be turned "OFF" when not required saving energy and improving battery life.
- **Inverter** – The inverter can be another optional unit in a standalone system. Inverters are used to convert the 12V, 24V or 48 Volts direct current (DC) power from the solar array and batteries into an alternating current (AC) electricity and power.
- **Wiring** – The final component required in and PV solar system is the electrical wiring. The cables need to be correctly rated for the voltage and power requirements.

2. With suitable analysis how to design and size solar battery system?

- The battery type recommended for using in solar PV system is deep cycle battery.
- Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years.
- The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days.
- Batteries store excess energy created by Solar PV system to be used at time when there is no Sun energy.
- A battery is much like a piggy bank. The battery's capacity for holding energy is rated in amp-hours: 1 amp delivered for 1 hour = One Ampere-Hour. Battery capacity is listed in amp hours at a given voltage, e.g. 220 amp-hours at 6 volts. For example, 220 amp-hour battery will deliver 11 amps for 20 hrs. This rating is designed to compare different batteries to the same standard and is not to be taken as aperformanceguarantee.

Batteries are electro-chemical devices sensitive to climate, charge/discharge cycle history, temperature, location and usage patterns. Batteries can discharge rapidly and yield more current than the charging source can produce by itself.

To find out the size of battery, calculate as follows:

1. Calculate total Watt-hours per day used by appliances.
2. Divide the total Watt-hours per day used by 0.85 for battery loss.
3. Divide the answer obtained in item 2 by 0.6 for depth of discharge.
4. Divide the answer obtained in item 3 by the nominal battery voltage.
5. Multiply the answer obtained in item4 with days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery.

$$\text{Battery Capacity (Ah)} = \frac{\text{Total Watt-hours per day used by appliances}}{(0.85 \times 0.6 \times \text{nominal battery voltage})} \times \text{Days of autonomy}$$

3. Briefly explain the working principle of Grid tied SPV system.

- A *grid connected PV system* is one where the photovoltaic panels or array are connected to the utility grid through a power inverter unit allowing them to operate in parallel with the electric utility grid.
- In a grid connected PV system, also known as a "grid-tied", or "on-grid" solar system, the PV solar panels or array are electrically connected or "tied" to the local mains electricity grid which feeds electrical energy back into the grid.
- The main advantage of a grid connected PV system is its simplicity, relatively low operating and maintenance costs as well as reduced electricity bills.
- Since grid tied systems feed their solar energy directly back into the grid, expensive back-up batteries are not necessary and can be omitted from most grid connected designs.
- Also, as this type of PV system is permanently connected to the grid, solar energy consumption and solar panel sizing calculations are not required, giving a large range of options allowing for a system as small as 1.0kWh on the roof to help reduce electricity bills, or a much larger floor mounted array that is large enough to virtually eliminate electricity bills completely.
- Grid connected PV systems always have a connection to the public electricity grid via a suitable inverter because a photovoltaic panel or array (multiple PV panels) only deliver DC power. As well as the solar panels, the additional components that make up a grid connected PV system compared to a standalone PV system are:

- Inverter – The inverter is the most important part of any grid connected system. The inverter extracts as much DC (direct current) electricity as possible from the PV array and converts it into clean mains AC (alternating current) electricity at the right voltage and frequency for feeding into the grid or forsupplyingdomesticloads.

Electricity Meter – The electricity meter also called a Kilowatt hour (kWh) meter is used to record the flow of electricity to and from the grid. Twin kWh meters can be used, one to indicate the electrical energy being consumed and the other to record the solar electricity.

AC Breaker Panel and Fuses – The breaker panel or fuse box is the normal type of fuse box provided with a domestic electricity supply and installation with the exception of additional breakers for inverter and/or filter connections.

- Safety Switches and Cabling – A photovoltaic array will always produce a voltage output in sunlight so it must be possible to disconnect it from the inverter for maintenance or testing. Isolator switches rated for the maximum DC voltage and current of the array and inverter safety switches must be provided separately with easy access to disconnect the system.

4. List out the functions of charge controller in PV system.

- The solar charge controller is a device used to control the solar panel to charge the battery and at the same time give the load control voltage to the voltage sensitive device.

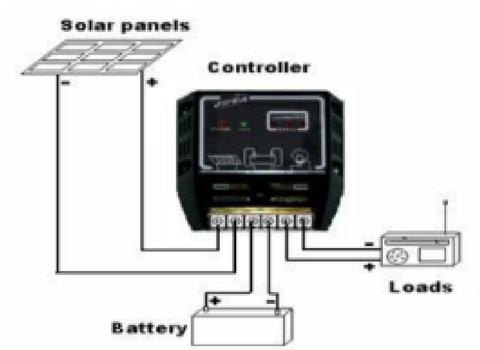
A solar charge controller is fundamentally a voltage or current controller to charge the battery and keep electric cells from overcharging. It directs the voltage and current hailing from the solar panels setting off to the electric cell. There are three different types of solar charge controllers, they are:

1. Simple 1 or 2 stage controls
2. PWM (pulse width modulated)
3. Maximum power point tracking (MPPT)

The most essential charge controller basically controls the device voltage and opens the circuit, halting the charging, when the battery voltage ascents to a certain level. More charge controllers utilized a mechanical relay to open or shut the circuit, halting or beginning power heading off to the electric storage devices.

Generally, solar power systems utilize 12V of batteries. Solar panels can convey much more voltage than is obliged to charge the battery. The charge voltage could be kept at the best level while the time needed to completely charge the electric storage devices is lessened. This permits the solar systems to work optimally constantly. By running higher voltage in the wires from the solar panels to the charge controller, power dissipation in the wires is diminished fundamentally.

The solar charge controllers can also control the reverse power flow. The charge controllers can distinguish when no power is originating from the solar panels and open the circuit separating the solar panels from the battery devices and halting the reverse current flow.



- The solar charge controller regulates and controls the charging and discharging conditions of the battery, and controls the power output of the solar cell components and the battery to the load according to the power requirements of the load. It is the main control part of the entire solar power supply system.

- **Load over current and short-circuit protection:** After the load current exceeds 10A or the load is short-circuited, the fuse is blown and can be used after replacement.

- **Overvoltage protection:** When the voltage is too high, the output is automatically turned off to protect the device from damage.

- **Lightning protection:** In the event of a lightning strike, the varistor can prevent lightning strikes and protect the controller from damage.

- **Reverse battery connection protection:** The battery "+" and "-" polarity is reversed, and it can continue to be used after correction.

- **Battery open circuit protection:** If the battery is open circuit, if the solar battery is charged normally, the controller will limit the voltage across the load to ensure that the load is not damaged. If at night or when the solar battery is not charged, the controller itself cannot electricity, there will be no movement.

- **Overcharge protection:** When the charging voltage is higher than the protection voltage, the battery is automatically disconnected to charge the battery. After that, when the voltage drops to the holding voltage, the battery enters the floating charge state. When the recovery voltage is lower than the floating charge, the floating charge is turned off and enters the equalizing charge state.

- **Over-discharge protection:** When the battery voltage is lower than the over-protection voltage, the controller automatically turns off the output to protect the battery from damage; after the battery is recharged, it can automatically restore the power supply.

- The solar charge controller is typically rated against Amperage and Voltage capacities. Select the solar charge controller to match the voltage of PV array and batteries.

- For the series charge controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration).According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV array, and multiply it by 1.3

Solar charge controller rating = Total short circuit current of PV array x 1.3

5. List the types of solar PV systems and explain in detail.

- **Grid-connected solar photovoltaic (PV) systems**, otherwise called utility-interactive PV systems, convert solar energy into AC power.

- **Stand-alone or off-grid PV systems** can be either DC power systems or AC power systems. In both systems, the PV system is independent of the utility grid.

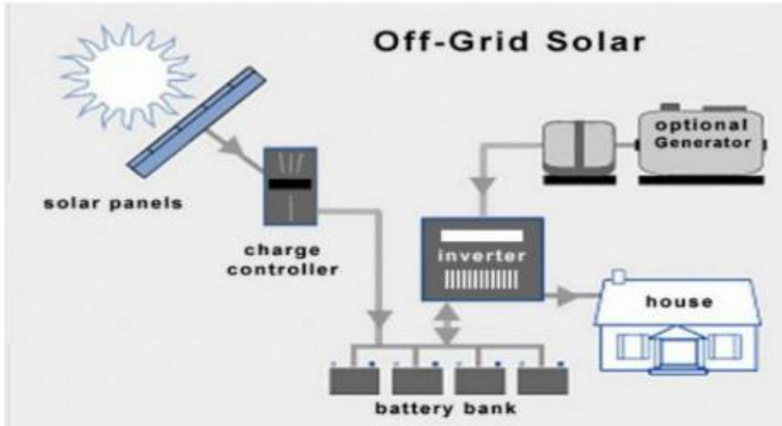
- Solar PV systems are integrated with other power sources, such as diesel generators or renewable sources like wind, to implement the hybrid PV system.

[A]PVDirectSystem

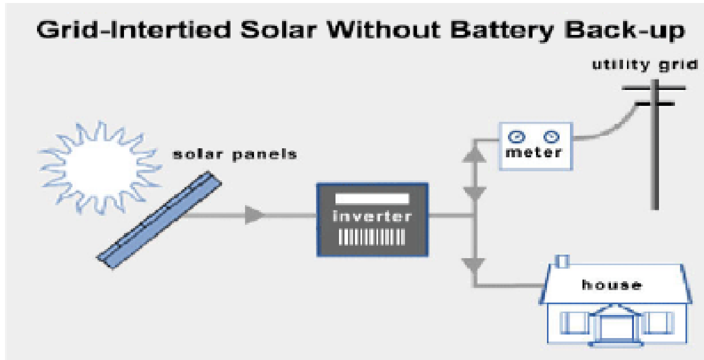
These are the simple most of solar PV systems, with the fewest components : the Solar Panels and the load. Because they don't have batteries and are not hooked up to the grid, they only power the loads when the sun is shining. They are appropriate for a few applications e.g. water pumping or attic ventilation fan.

[B]Off-GridSystem

Also referred to as stand-alone systems, it is designed to be independent of the power grid. Batteries are used to store energy when the sun is not an available during cloudy days or at night. This type of system will require regular attention to battery electrolyte levels and terminal corrosion.



- Independence from the utility grid
- Rate increases, blackouts, or brownouts do not apply
- In remote areas, it is cost effective than extending a grid
- Encourages energy efficiency
- Batteries require maintenance and has limited life
- More components means more complexity
- Batteries decrease system efficiency
- It is more expensive than a grid-direct system
- When the batteries are fully charged, potential power from the PV array is not utilized
- If the PV system fails, back-up electricity is required to run load
- Most off-grid systems use a backup generator for non-sunny days. They are expensive, noisy, dirty, and require fuel and regular maintenance
- **[C]GridTiedSystem**
  A grid-connected solar photovoltaic (PV) system, otherwise called a utility-interactive PV system, converts solar energy into AC power.
- The solar irradiation falling on the solar panels generates photovoltaic energy, which is DC in nature. Using a DC-DC converter, the total photovoltaic DC voltage from the solar panels is raised to a higher DC level.
- A DC-DC converter is not an essential part of a grid-connected solar PV system, but it can control the variations in the photovoltaic system and regulate DC voltage.
- The inverter in a PV system converts the DC voltage (either the DC voltage from the solar panels or the DC-DC converter output voltage) into AC voltage.
- As this AC voltage is integrated into the grid, the inverter converts the photovoltaic energy into AC power with a frequency that matches the utility grid. The voltage and power quality requirements of the grid are satisfied by the inverter AC output.
- Usually, a metering system is installed along with the solar PV system. In residences, when the PV system power is capable of supplying the complete load, utility grid power is not consumed.
- When PV power is scarce, the remaining power is consumed from the grid. If the PV power generated is in excess, it is supplied to the grid. The solar PV system supplies power only when the grid is energized.
- These are most common type of PV systems. They are also known as on-grid, grid-tied, grid-intertied, or grid-direct systems.
- System components comprised of the PV array and inverter. Grid-connected system is similar to regular electric powered system except that some or all of the electricity comes from the sun. The drawback of these battery less systems is that they provide no outage protection—when the utility grid fails, these systems cannot operate.)

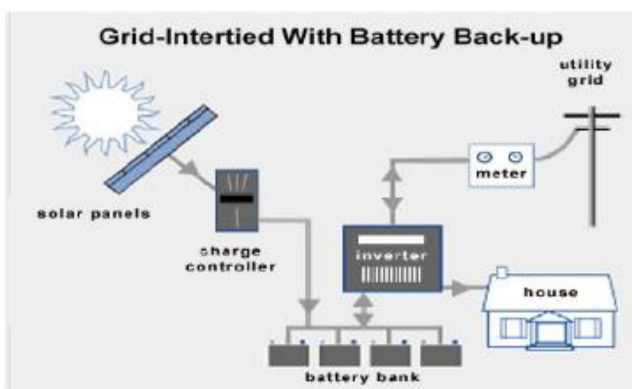


- grid-tied-system
- Increased design flexibility because the system does not have to power all of the home's loads
- It is less expensive compared to stand-alone or grid-tied with battery backup systems
- It requires the least amount of maintenance
- If the system produces more than the loads need, then the extra energy is exchanged with the utility grid
- Grid-direct systems have a higher efficiency because batteries are not part of the system

- Higher voltage means smaller wire size
- Electricity costs are fixed for the life of your system
- There is no power to the home when the grid goes down

[D]Grid-tiedwithbattery-backupsystem:

This type is very similar to an off-grid system in design and components, but adds the utility grid, which reduces the need for the system to provide all the energy all the time.



- grid-tied-with-battery-backup
- Designated loads have power when the grid goes down
- Batteries require maintenance
- Requires rewiring circuits from main service panel to a separate subpanel
- More components mean more complexity
- Batteries decrease system performance because of their efficiency losses

- More expensive than a grid-direct system
- Typically only provides modest backup – usually not all of the loads are backed up

[E]Hybridsystem.

Hybrid system tries to combine multiple sources of power to maximize availability of power. It may source energy from sun, wind or diesel generator and back it up with battery.

- Multiple sources of generation allows for complementary sources and backup. For instance, when it is sunny out the PV array will charge the battery; if it is cloudy and windy, a wind turbine can charge the batteries
- Array size and battery bank capacity can typically be reduced and not having to oversize for periods of no sun
- More complex system design and installation
- Multiple power sources can increase upfront expenses
- Wind turbines and generators require regular maintenance.

UNIT-IV
ANALYSIS OF POWER CONVERTERS FOR HYBRID ENERGY SYSTEMS

PART-A

1. State the merits of PWM inverters.

- PWM enables the control of the average and/or RMS inverter output voltage. So it can regulate against load changes and DC supply voltage changes.

- By controlling the width of the chunks taken out of the output voltage over each cycle, the output voltage waveform can be shaped to minimize output harmonics. This ensures that the output voltage waveform has low harmonic distortion (i.e. is close to being a sine wave) with only minimal extra filtering.

- PWM allows the above benefits to be gained while operating the inverter semiconductors in **switch mode** rather than in linear mode. This minimizes the heating in these devices and maximizes inverter efficiency.

1. **Efficiency**: PWM inverters are known for their high efficiency, which means they can convert DC power to AC power with minimal energy loss.
2. **Voltage Control**: PWM inverters can control the output voltage by adjusting the width of the pulses, allowing for precise voltage regulation.
3. **Low Harmonic Distortion**: They produce low harmonic distortion in the output waveform, making them suitable for sensitive electronic equipment.
4. **Cost-Effective**: PWM inverters are often more cost-effective compared to other types of inverters, making them a popular choice for various applications.
5. **Compact Size**: They can be designed to be compact in size, making them suitable for space-constrained applications such as solar power systems and electric vehicles.

2. How grid integrated system for solar PV differs from wind energy system?

Small-scale electricity production, such as solar photovoltaic (PV), is usually connected to the low voltage distribution grid while wind turbines are connected to the medium voltage distribution grid or regional transmission grid.

3. What is the significance of matrix converter?

Matrix converters (MCs) are AC-AC power conversion topologies widely explored and applied in the industry for their attractive features of sinusoidal input and output currents, considerable size reduction, and reliable operation due to the omission of bulky passive components.

4. What are the major problems associated with grid interaction of wind energy systems?

Transient Stability and Power Quality Problems: ➢

- During a transient fault in the power network, the rotor speed of the wind generator goes very high, active power output goes very low, and terminal voltage goes very low or collapses.
- The intermittent nature of wind power can impact grid stability, causing frequency deviations and voltage fluctuations. The intermittent nature of wind power, stemming from varying wind speeds, can significantly influence grid stability.

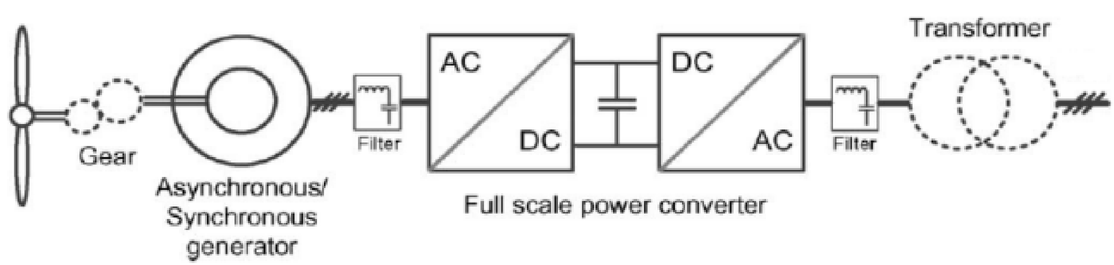
5. What is bidirectional Inverter?

The bidirectional inverter can convert the alternating current from the mains or generator into direct current to charge and store the battery.

A bidirectional inverter is a device that can convert direct current (DC) power into alternating current (AC) power and vice versa. This means it can convert power from a battery or other DC power source into AC power for use in a home or on the grid, and it can also convert AC power from the grid into DC power to charge a battery or for other DC applications. Bidirectional inverters are commonly used in renewable energy systems, electric vehicles, and energy storage systems to manage the flow of power between different sources and loads.

PART-B

1. Design circuit diagram of a power electronic circuit to interface wind electrical system to the grid.



(i)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 fig.

(ii)The grid-connected inverters will inject the active power to the grid with minimum total harmonic distortion (THD) of output current and voltage.

(iii)The grid voltage and inverter output voltage will be synchronized by zero-crossing circuit. The generator can be self-excited asynchronous generator (SEIG), or permanent magnet synchronous generator (PMSG). The stator windings are connected to the load or to the grid through a full-scale power converter.

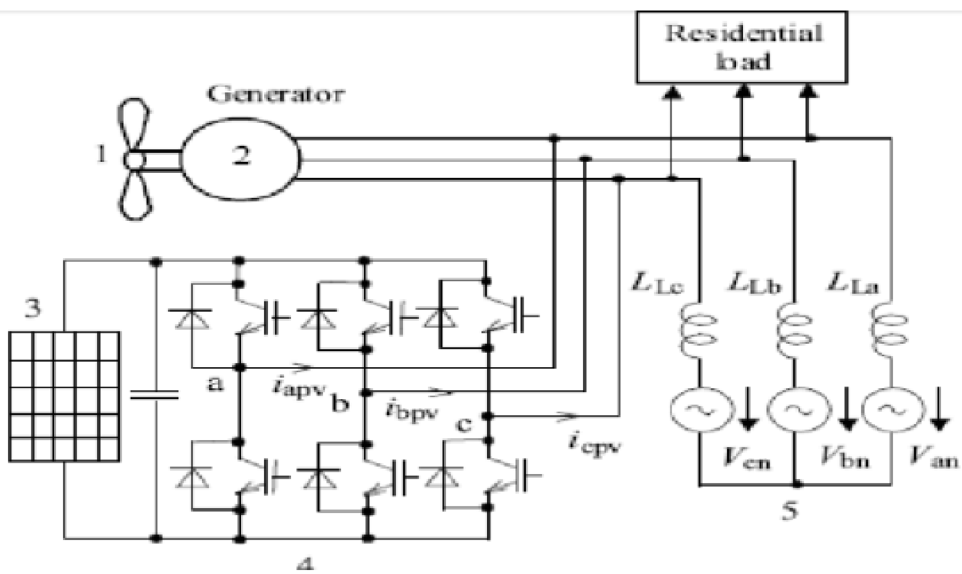
(iv)Some variable speed WTSs are gearless. In these cases, a direct driven multi-pole generator is used.

Power electronic converters for wind turbine system:

(i)A permanent magnet generator has no excitation control and output voltage is proportional to the rotor speed. Therefore, in control of wind turbine, the rotor speed is obtained via the output voltage measurement. The earliest and still most widely used power electronic circuit for this application 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.

(ii)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].

As there is active power flows uni directionally from the PMSG to the dc link through a power converter, only a simple diode rectifier can be applied to the generator side converter in order to obtain a cost-efficient solution.

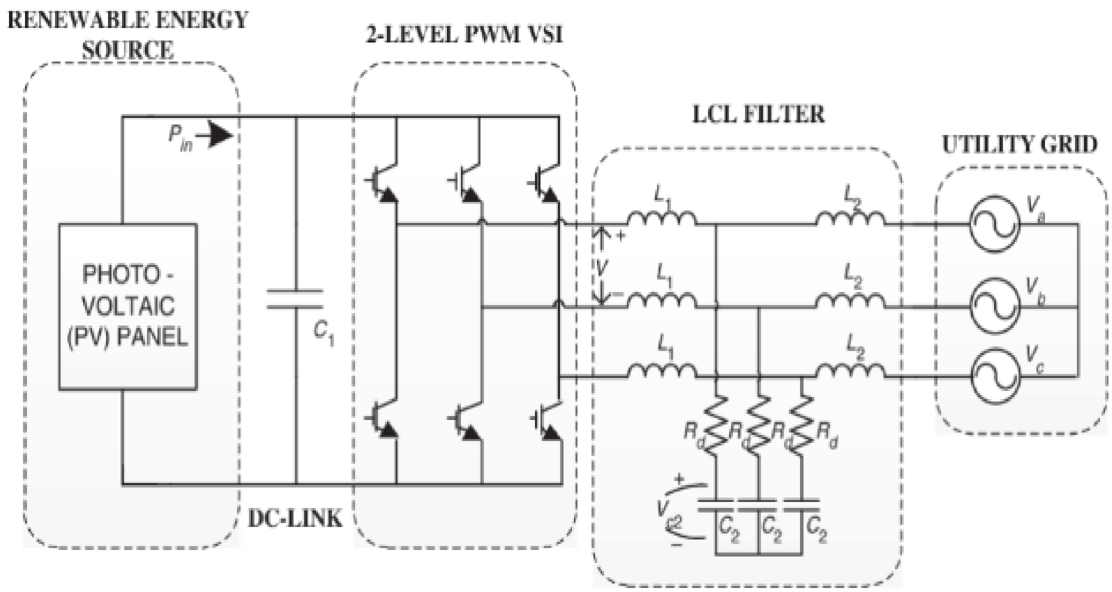


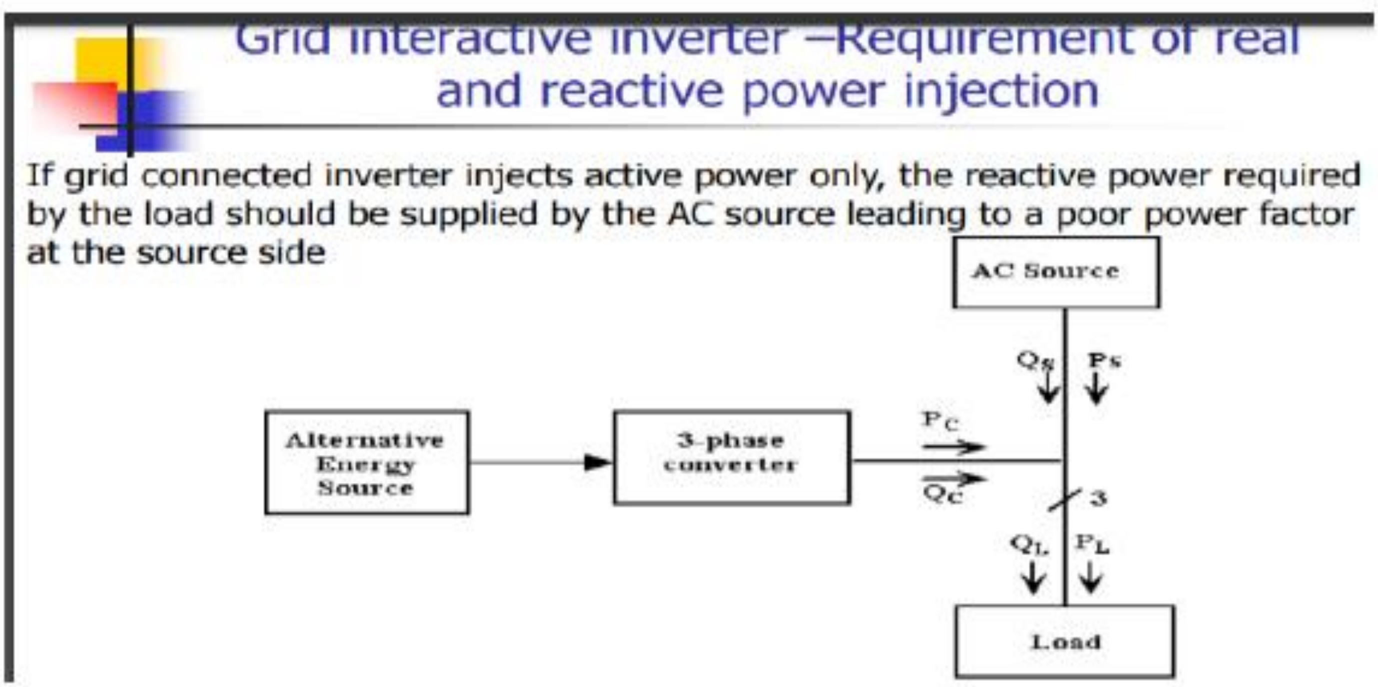
2. Discuss the control strategy used in grid interactive inverters.

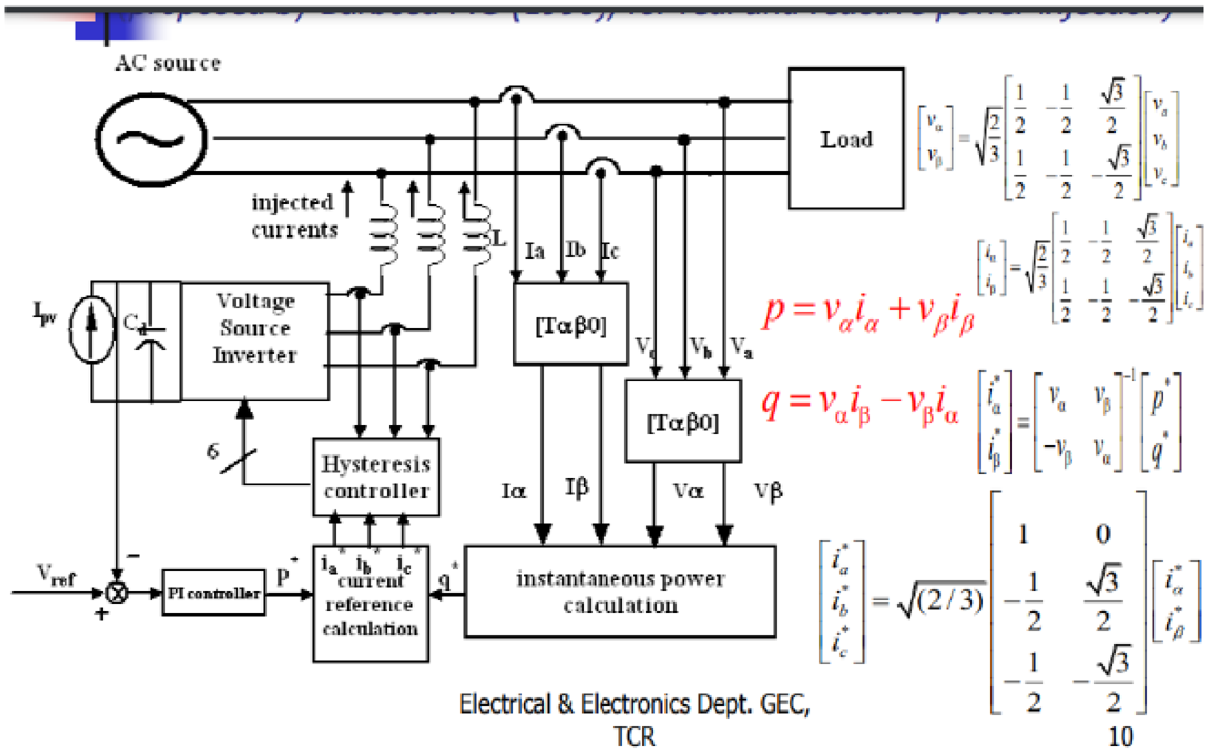
- 60% of Energy consumption is from fossil fuel resulting an emission of 6.5 billion tons of CO2 into atmosphere – environment pollution, global warming ¬ Fossil fuel sources like coal, oil etc. are getting depleted day by day ¬
- Distributed generation with renewable sources (solar cells, wind power etc.) may be a solution to these problems ¬ Since power content of these sources are varying and to make voltage, frequency etc., acceptable to the present transmission system Grid interactive inverters are essential.

• The control strategy adopted here decouples the active and reactive power loops, thus achieving desirable performance with independent control of active and reactive power injected to the grid. The startup transients are also controlled by the implementation of this particular control method.

• The main objectives of implementing this control strategy are to control the active and reactive power injection to the grid independently and to maintain pure sinusoidal form of grid current.



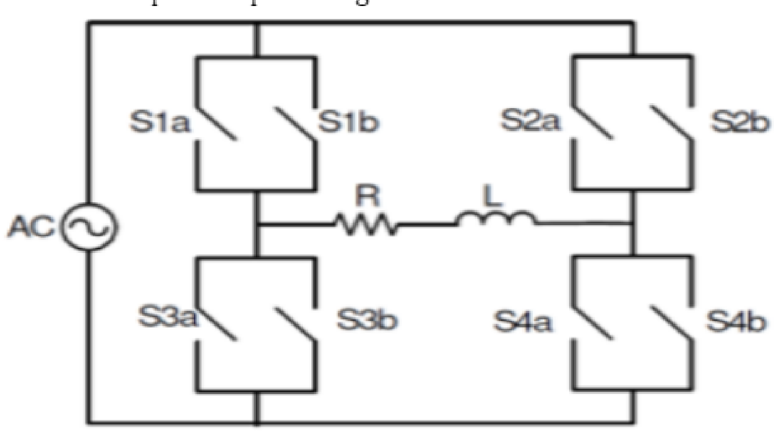




3. Design the circuit of matrix converter? Explain that operation and analyze it in detail. Also briefly state its advantages and limitations.

MATRIX CONVERTERS

- A matrix converter is defined as a converter with a single stage of conversion.
- It utilizes bidirectional controlled switch to achieve automatic conversion of power from AC to AC.
- It provides an alternative to PWM voltage rectifier double sided.
- Matrix converters are characterized by sinusoidal waveforms that show the input and output switching frequencies.
- The bidirectional switches make it possible to have a controllable power factor input.
- Its voltage ratio that is output to input voltage is limited.



- It contains four bi-directional switches with each switch having the ability to conduct in both forward blocking and reverse voltage.
- Space Vector Modulation SVM:
- SVM refers to a method of algorithm used to control the PWM. It creates AC waveforms that drive AC motors at various speeds.
- The switches are under control to ensure that no two switches in the same leg are ON at the same time. Simultaneous ON states could result in the DC supply shorting.
- This leads to eight switching vectors where two are zero and six are active vectors for switching.

The matrix converter has several advantages over traditional rectifier-inverter type power frequency converters.

- It provides sinusoidal input and output waveforms, with minimal higher order harmonics and no sub harmonics.
- it has inherent bi-directional energy flow capability; the input power factor can be fully controlled.
- it has minimal energy storage requirements, which allows to get rid of bulky and lifetime-limited energy-storing capacitors.

But the matrix converter has also some disadvantages.

- **it has a maximum input output voltage transfer ratio limited to @ 87 % for sinusoidal input and output waveforms**

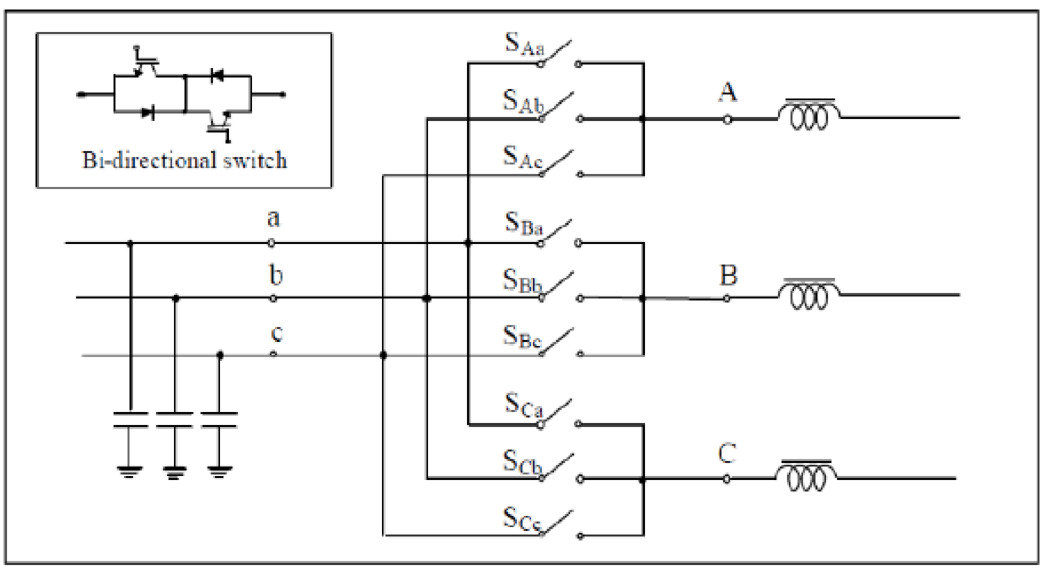
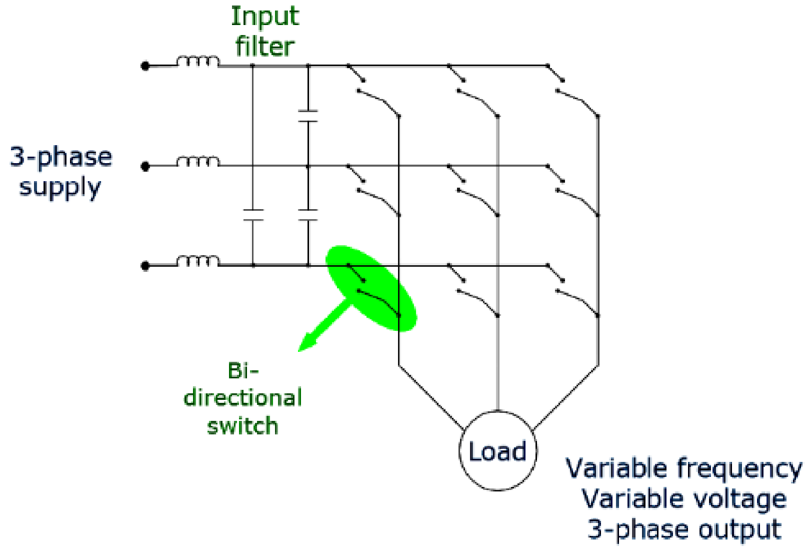


Fig.2.1 Circuit scheme of a three phase to three phase matrix converter.
a,b,c are at the input terminals. A,B,C are at the output terminals.

Basic Ideas

- Switching pattern and commutation control must avoid line to line short circuits at the input
- Switching pattern and commutation control must avoid open circuits at the output
- Each output phase can be connected to any input phase at any time
- Switch duty cycles are modulated so that the "average" output voltage follows the desired reference (for example a sinusoidal reference)

• Modulation is arranged so that the "average" input current is sinusoidal when the input voltage, output reference and output current are sinusoidal



Modulation Control

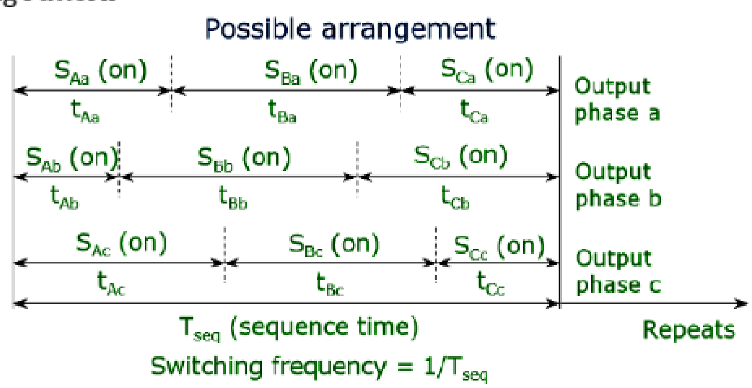
A number of modulation strategies have been proposed. All of them allow flexible control with the following features:

• Continuous control of output voltage amplitude from zero up to a maximum limit.

• Continuous control of output frequency up to a maximum feasible limit of approximately 1/10 of the switching frequency.

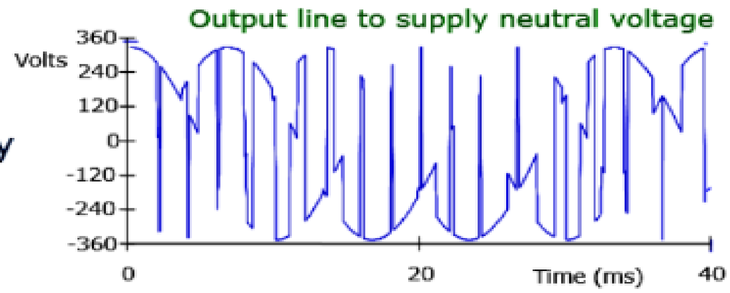
• Control of input displacement factor: unity, leading and lagging regardless of output power factor DC-AC and AC-DC conversion is an inherent feature by setting either the input or output frequency to zero.

Example Switching Pattern

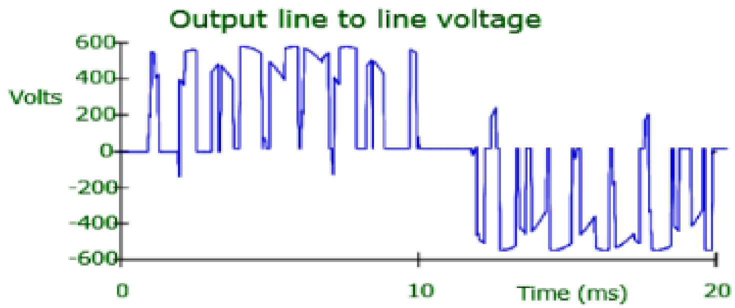


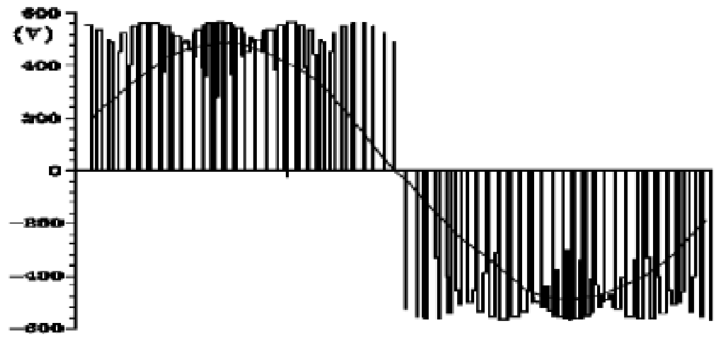
Illustrative Output Waveforms (Fin > Fout)

50Hz in - 25Hz out
switching frequency
500Hz



Low switching
frequency
shown for visual
clarity

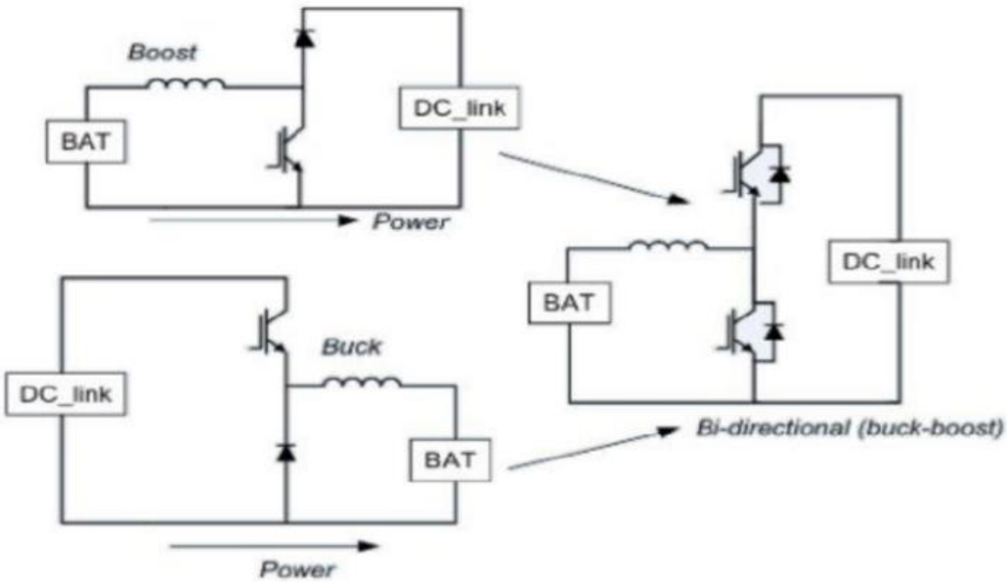




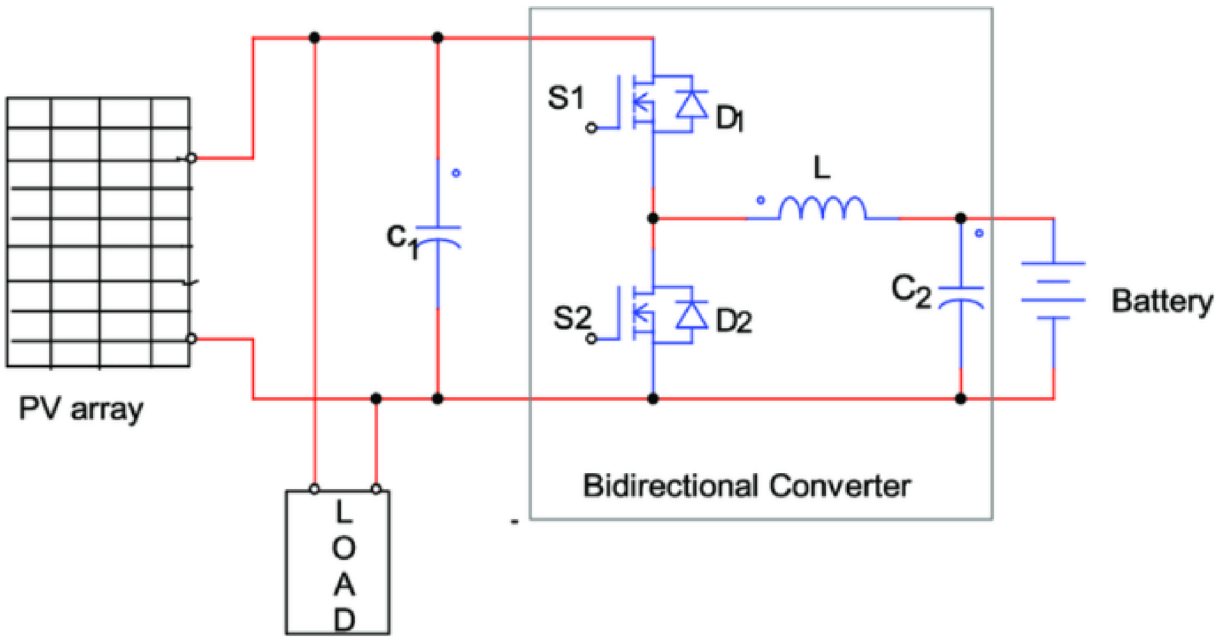
b) Matrix converter

4. With suitable analysis, explain the operation of bidirectional converter. Mention its advantages and limitations.

- A bi-directional DC-DC converter provides the required bidirectional power flow for battery charging and discharging.
- The duty cycle of the converter controls charging and discharging based on the state of charge of the battery and direction of the current.
- A Bi-directional converter is something where power can flow at both direction.
- That means we can feed power to the load and the load can also feed the power back to the source.
- A bidirectional DC to DC converter is a power electronic device that can convert DC power from one voltage level to another in both directions.
- This means it can convert power from a higher voltage to a lower voltage (buck mode) and from a lower voltage to a higher voltage (boost mode).
- Bidirectional DC to DC converters are commonly used in applications where power needs to flow in both directions, such as in energy storage systems, electric vehicles, and renewable energy systems.
- They are essential for efficiently managing power flow between different energy storage devices and the electrical grid.



- Bi-directional converters are suitable for dc power flow in both directions.
- Mostly used in energy storage in battery bank, renewable energy systems etc.
- There are two types,
- Isolated DC-DC Converters
- Non Isolated DC-DC Converters
- **Isolated DC-DC Converter:** Advantages :
- Isolated DC-DC converters have high voltage isolation from several hundreds to thousand volts depending on the type of standard .
- Output can be configured to be either positive or negative or floating ground for various equipment.
- **Non isolated DC-DC Converter:**
- A non-isolated dc-dc converter has a dc path between its input and output, the input and the output of a non-isolated converter share the common ground.
- Step up voltage is done without transformer.
- Advantages:
- Circuit is simple
- Reduced switching losses and number of switches.
- Circuit helps to reduce ripple content.
- peak to peak Voltage and current are low.
- Non isolated dc-dc-dc can be classified as Buck mode and Boost mode

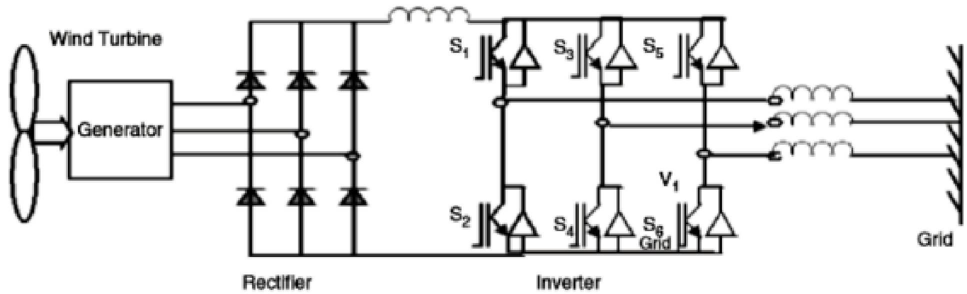


- Bi-directional DC to DC converters Advantages:
- Energy efficiency: Bi-directional DC to DC converters can help improve energy efficiency by allowing power to be transferred in both directions.
- Increased flexibility: Bi-directional DC to DC converters offer greater flexibility in power distribution and management. They can be used to connect different DC voltage sources with different voltage levels, enabling power transfer in either direction as needed.
- Improved system reliability: By allowing power to flow in both directions, bi-directional DC to DC converters can help improve system reliability. This is because they can provide a backup power source if the primary source fails.
- Reduced system complexity: Bi-directional DC to DC converters can help reduce system complexity by eliminating the need for separate converters for power flow in different directions.
- Control complexity: Bi-directional DC to DC converters require complex control systems to manage power flow in both directions, which can increase system complexity and cost.
- Voltage stability: Bi-directional DC to DC converters may have stability issues with respect to voltage regulation and power flow management.

5. Design AC-DC-AC converters.

The general configuration is shown in the Fig.
It consists of the following components:

- Wind generator.
- Rectifier.
- Inverter.

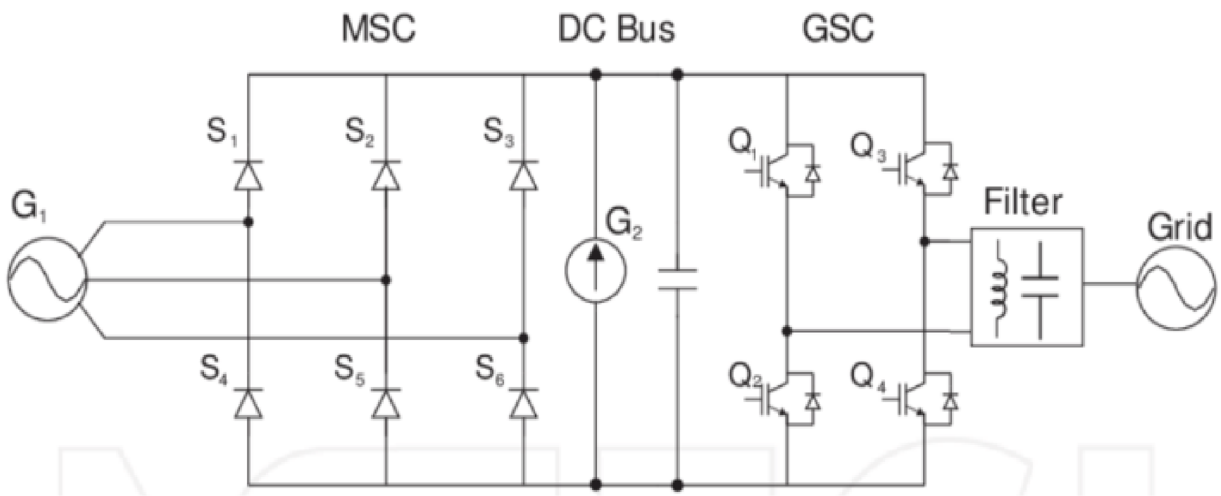


Grid-connected wind energy system through AC/DC/AC converter.

The generator may be DC, synchronous (wound rotor or permanent magnet type), squirrel-cage wound rotor, or brush-less doubly-fed induction generator. The rectifier is used to convert the variable voltage variable frequency input to a DC voltage.

This DC voltage is converted into AC of constant voltage and frequency of desired amplitude. The inverter will also be used to control the active/reactive power flow from the inverter. In case of DC generator, the converter may not be required or when a cyclo-converter is used to convert the AC directly from one frequency to another.

A forced-commutated three-phase controlled rectifier is required to obtain a desired voltage in the DC-link for different flywheel speeds and different wheel motor loads .



- The AC/DC converter must behave like a voltage boost in order to work as a forced-commutated rectifier. In other words, the DC-Link voltage must be larger than the peak DC voltage generated by the rectifying diodes in passive mode.
- The inductance performs the boost voltage operation in combination with the capacitor and acts at

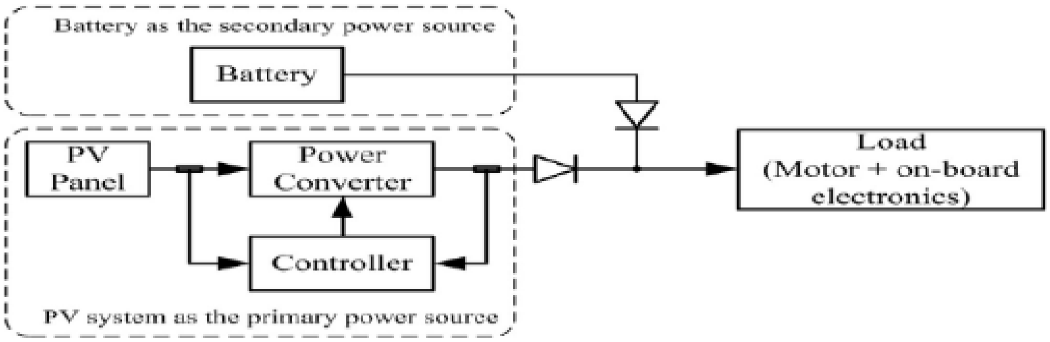
the same time as a low-pass filter for the AC line current.

- Modern power electronics depend heavily on DC/AC converters because they make it possible to convert DC sources to AC, which is the norm for the majority of electrical applications.
- These converters are crucial for a number of applications, including motor drives, uninterruptible power sources, electric cars, and renewable energy systems.
- The main parts such as circuit topologies, modes of operation, pulse-width modulation (PWM) strategies, and performance metrics of these converters are all covered in this chapter.
- There are two types of inverters- Voltage source inverters (VSI) and current source inverters (CSI).
- In VSIs, the desired AC output voltage waveform is produced by the inverter while the input DC voltage remains constant.
- However, the desired AC output current waveform is produced by CSIs, which use a constant input current.
- Since, VSIs and CSIs are duals, it is possible to understand how they function by comparing their respective dualities in voltages and currents. First, we go through the fundamentals of VSIs.

UNIT-V
CASE STUDIES FOR HYBRID RENEWABLE ENERGY SYSTEMS

PART-A

1 .Draw the basic block diagram of hybrid energy systems



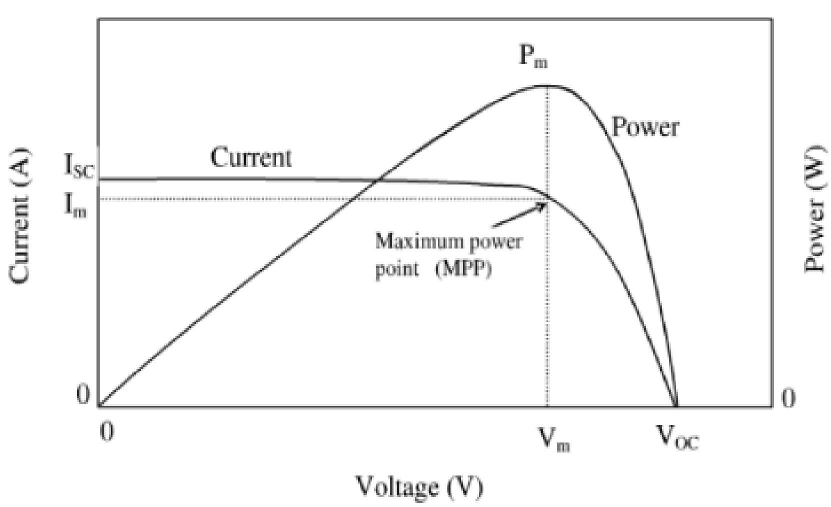
2. List the different types of hybrid energy systems.

- Photovoltaic + Wind.
- Photovoltaic + Hydraulic.
- Hydraulic + Wind.
- Solar Thermal + Biomass.

3. What is the need for hybrid energy systems?

Hybrid systems can increase the amount of dispatchable renewable energy generation as well as the reliability of rural energy access. A hybrid energy system combines multiple types of energy generation and/or storage or uses two or more kinds of fuel to power a generator.

4. Draw the PV characteristics of solar PV system and mark the maximum point.



5. Applications for hybrid energy systems.

Hybrid systems can be used over numerous places for different usages.

- **Automotive:** When it comes to automotive, hybrid systems can be used along with internal combustion systems. Hence when there is the availability of sunlight to be used as a source of energy, one can avail the option, and on the other hand, one can also switch to the internal combustion system as required.

- **Manufacturing process:** Different manufacturers and companies can use solar panels as the main power supply for their units. Most industries these days require a heavy amount of power supply, and by using a hybrid system, one can get relaxation from the dependence on the grid.

- **Smart grids:** Smart grids are one of the most used grid systems these days. Usage of the hybrid system in such power grids is very common. Since the smart grids use digital and newer technology to auto-regulate the system, the usage of a hybrid system to keep switching between the sources of energy becomes essential.

PART-B

1. Design circuit diagram of Solar-Wind-Fuel Cell-Diesel Hybrid Energy source and explain in detail.

Hybrid Energy Systems

A hybrid energy system usually consists of two or more renewable energy sources used together to provi increased system efficiency as well as greater balance in energy supply A hybrid system can combine wind, sol with an additional resource of generation or storage. They may range in size from relatively large island grids o many megawatts to individual household power supplies on the order of one kilowatt.

Hybrid power systems that deliver alternating current of fixed frequency are an emerging technology fo supplying electric power in remote locations. They can take advantage of the ease of transforming the A power to higher voltages to minimize power loss in transferring the power over relatively long distances. Large systems, nominally above 100 kW, typically consist of AC-connected diesel generators, renewable sources, loads, and occasionally include energy storage subsystems. Below 100 kW, combinations of both AC and DC-connected components are common as is use of energy storage. The DC components could inclu diesel generators, renewable sources, and storage. Small hybrid systems serving only DC loads, typically le than 5 kW, have been used commercially for many years at remote sites for telecommunications repeater stations and other low power applications.

In general, a hybrid system might contain AC diesel generators, DC diesel generators, an AC distributio system, a DC distribution system, loads, renewable power sources (wind turbines, or photovoltaic powe sources), energy storage, power converters, rotary converters, coupled diesel systems, dump loads, lo management options, or a supervisory control system. Hybrid systems might also include biomass o hydroelectric generators. A schematic of the possibilities for hybrid systems is illustrated in the following figure.

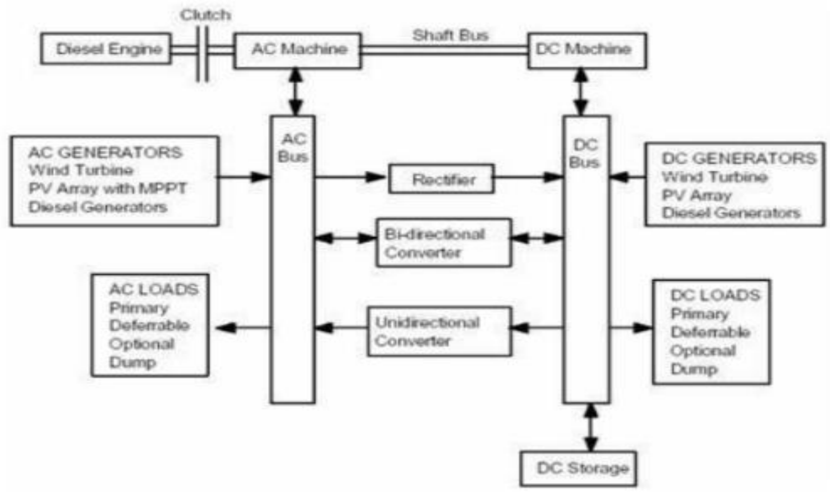


Fig. 25. Hybrid energy storage system

Examples of hybrid systems Wind-solar hybrid system

As the wind does not blow all the time nor does the sun shine all the time, solar and wind poweralone are poor power sources. Hybridizing solar and wind power (min wind speed 4-6m/s) sources together with storage batteries to cover the periods of time without sun or wind provides a realistic form of power generation. The system creates a stand-alone energy source that is both dependable and consistent which is called the solar-wind hybrid system. Generally, these solar wind hybrid systems are capable of small capabilities. The typical power generation capacities of solar wind hybrid systems are in the range from 1 kW to 10 kW.Major components of solar-wind hybrid power plant are Solar PV modules, Wind turbine Regulation and conversion units, Inverters and electronic controllers, Battery Bank Generator (if required).

Working

The hybrid solar wind turbine generator uses solar panels that collect light and convert it to energy along with wind turbines that collect energy from the wind.

- Solar wind composite power inverter has inputs for both sources, instead of having to use two inverters and it contains the required AC to DC transformer to supply charge to batteries from AC generators.
- Hence the power from the solar panels and wind turbine is filtered and stored in the battery bank.
- For the times when neither the wind nor the solar system are producing, most hybrid systems provide power through batteries and/or an engine generator powered by conventional fuels, such as diesel.

- If the batteries run low, the engine generator can provide power and recharge the batteries.
- Adding an engine generator makes the system more complex, but modern electronic controllers can operate these systems automatically.
- An engine generator can also reduce the size of the other components needed for the system.
- Keep in mind that the storage capacity must be large enough to supply electrical needs during non charging periods

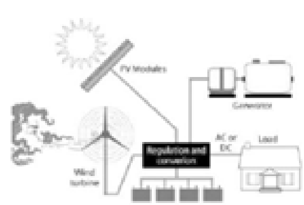


Fig. 26. Wind-solar hybrid system

Wind–hydro hybrid system

Hydropower generation is to convert potential energy in water into electrical energy by means of hydropowe generators. As a renewable and clean energy source, hydropower accounts for the dominant portion of electric generated from all renewable sources. In many locations of the world, hydropower is complementary with win power, while the seasonal wind power distribution is higher in winter and spring but lower in summer and fall, hydropower is lower in the dry seasons (winter and spring) but higher in the wet seasons (summer and fal Thus, the integration of wind and hydropower systems can provide significant technical, economic, an systematic benefits for both systems. Taking a reservoir as a means of energy regulation, "green" electricity can be produced with wind–hydro hybrid systems.

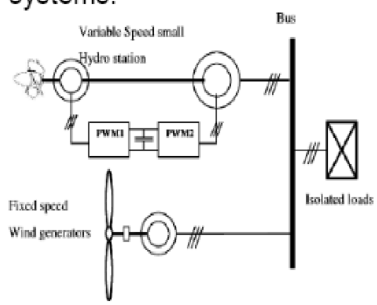


Fig. 27. Wind–hydro hybrid system

Wind–hydrogen system

Hydrogen is an energy carrier and can be produced from a variety of resources such as water, fossil fuels, a biomass. As a fuel with a high energy density, hydrogen can be stored, transported and then converted in electricity by means of fuel cells at end users. It is widely recognized that wind power, solar power and othe renewable energy power generation systems can be integrated with the electrolysis hydrogen production syst to produce hydrogen fuel. The largest wind to- hydrogen power system in the UK has been applied to a buildir that is fuelled solely by wind and "green" hydrogen power with the developed hydrogen mini grid system technology. In this system, electricity generated from a wind turbine is mainly used to provide to the building and excess electricity is used to produce hydrogen using a state-of- the-art high-pressure alkaline electrolyser.

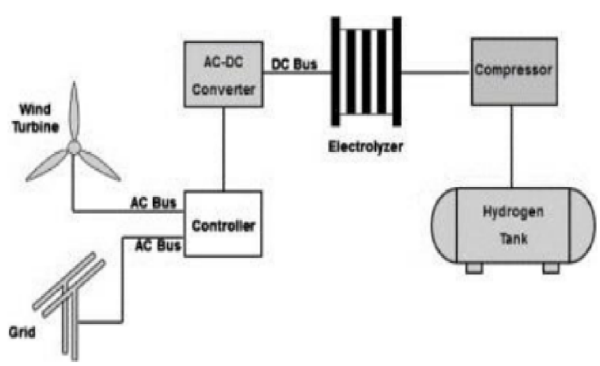


Fig. 28. Wind–Hydrogen system Wind–diesel power generation system

Wind power can be combined with power produced by diesel engine-generator systems to provide a stab supply of electricity. In response to the variations in wind power generation and electricity consumption, diese generator sets may operate intermittently to reduce the consumption of the fuel. It was reported that a viab wind–diesel stand-alone system can operate with an estimated 50–80% fuel saving compared to power sup from diesel generation alone. Till now, many new techniques have been developed and a large number of win diesel power generation systems have been installed all over the world. According to the proportion of wind us in the system, three different types of wind–diesel systems can be distinguished: low, medium, and hig penetration wind–diesel systems. Presently, low penetration systems are used at the commercial level, where solutions for high penetration wind–diesel systems are at the demonstration level. The technology trends inclu the development of robust and proven control strategies

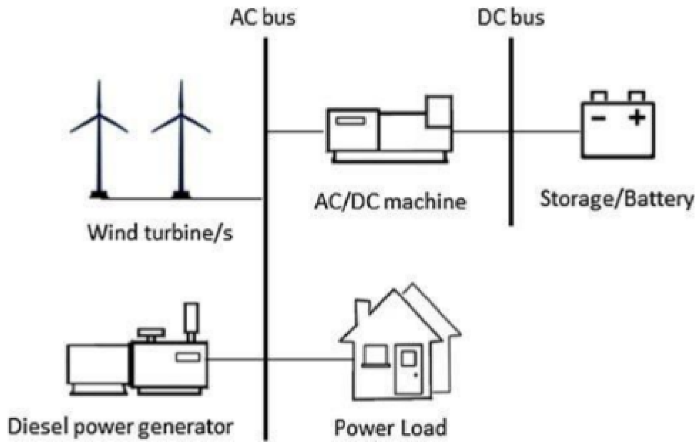


Fig. 29. Wind–diesel power generation system

2. Switched configurations of diesel –PV Hybrid systems.

Hybrid/diesel-electric propulsion is the technology where a diesel internal combustion engine (ICE) drives a generator to produce energy for an electric motor in a vehicle. The use of a hybrid system is mostly the cause of a high demand for electronic usage other than the electronic motor in a vehicle.

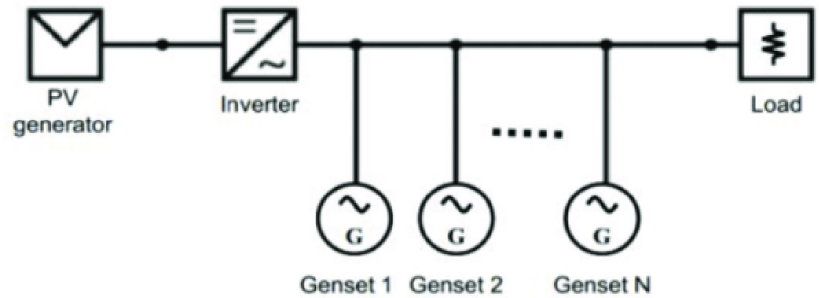
It is also popular for vehicles when entering emission restricted areas and using only the battery energy for short periods of time. A hybrid propulsion system is not to be confused with a full electric propulsion system, where there are not any fuel powered generators present.

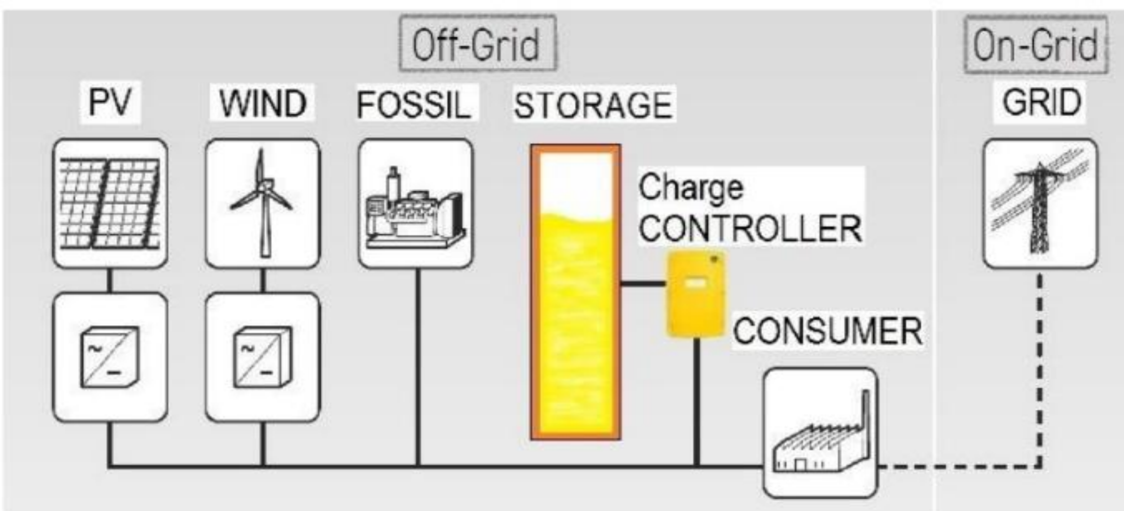
Hybrid/diesel-electric propulsion is used in many different vehicles. In all hybrid systems there is an internal combustion engine, generator, battery pack and an electric motor.

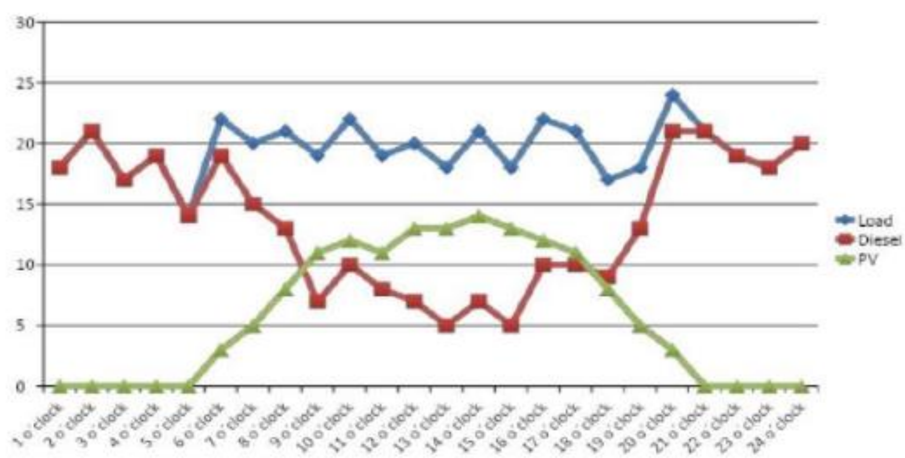
Hybrids use energy efficiently by turning the internal combustion engine off when the demand for electricity is low or when the battery is fully charged. Such systems are known as start-stop systems. The internal combustion engine in hybrid systems are not geared and only have one operating speed, this results in a well optimized engine due to the isolated condition.

In some regions of the world, there is an insufficient or no power supply at all. Therefore, diesel generators are often used to provide electricity.
Due to the increasing costs of diesel and its transport to often remote areas as well as the declining prices

for PV technology, the demand for PV diesel hybrid solutions in these areas is increasing.Such a hybrid system consists of one or more diesel generators, a PV system and an intelligent control system. This control system ensures that the diesel generator is deployed in the event of an output drop of the PV system, thus contributing sufficiently to improving stability of the grid.





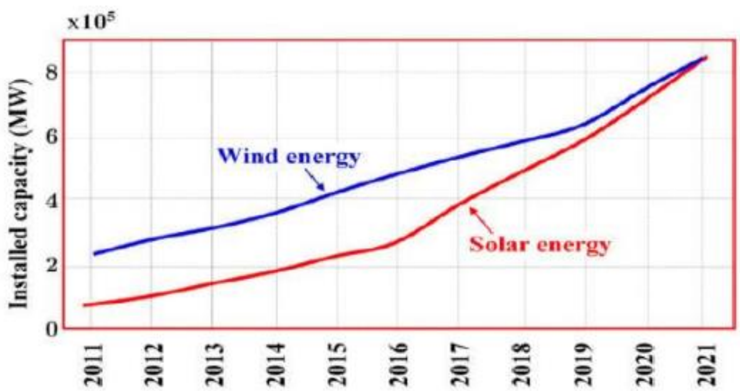


Load balancing for a constant supply of demand. $E_{diesel} = E_{load} - E_{PV}$

The advantages compared to a pure diesel generator are not only lower fuel costs and reduced risk due to greater planning reliability, but also environmental protection due to lower CO2 emissions.

3. Show the power electronic system used for hybrid solar photo voltaic and wind energy system.

The overexploitation of non-renewable fossil resources has led to dangerous warming of our planet due to greenhouse gas emissions. The main reason for this problem is the increase in global energy demand. The rising prices of oil and gas have pushed governments around the world to turn to renewable energy, especially solar and wind power. However, exploitation of these two sources individually is not always easy because of their intermittent and irregular characters. Therefore, the obvious solution is the hybridisation of these two sources, which, when used alongside other systems such as batteries, increases the reliability, availability, and efficiency of these renewable sources.



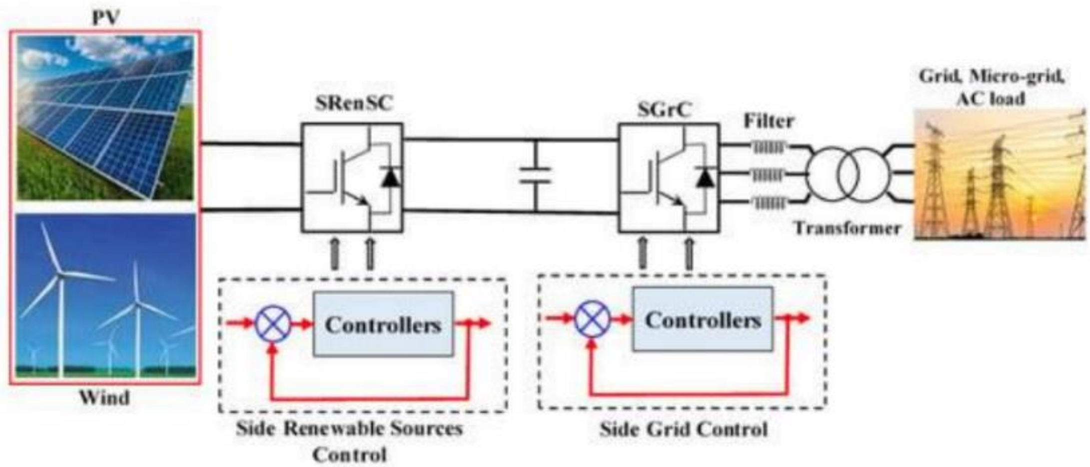
The performance of solar photovoltaic systems (SPVSs) and wind energy conversion systems (WECSs) is mainly based on environmental factors, i.e., irradiation/temperature and wind speed, respectively. The electric production of SPVSs and WECSs cannot be accurately predicted because the availability of these quantities is very intermittent and irregular in nature, and therefore, it is not possible to use one of them to continuously generate electrical power.

Therefore, a hybrid renewable energy system (HRES) with a combination of different types of renewable energies such as solar, wind, and hydro would be a good solution for continuous power generation.

he technological evolution of power electronics has considerably boosted the use of renewable energies by improving their quality and efficiency. Several authors have discussed the different topologies of converters used in photovoltaic and wind systems and have classified them into the following four large families

AC–DC converters;

1. DC–DC converters;
2. DC–AC converters;
3. AC–AC converters.



4. What is the purpose of PWM techniques?

The main reason for using PWM is that it allows for controlling the average amount of power delivered to a load or the output. They are also used for voltage regulation and modulation in communications.

A common control method in power electronics for managing the output voltage of converters, particularly DC/AC inverters, is pulse width modulation (PWM). The basic concept behind PWM is to adjust the output pulse width in order to regulate the average output voltage. With PWM, a fixed DC input voltage source can produce a sinusoidal output waveform with variable frequency and amplitude.

PWM methodologies in inverters provide fine control over the output voltage waveform in VSIs, enabling accurate voltage regulation as well as current regulation. With the usage of PWM, it is also possible to control the output waveform's harmonic distortions which ultimately leads to improved power quality and lowering system losses. In contrast to the fundamental square-wave modulation techniques, PWM in inverters offers advantages in terms of improved control over output voltage, frequency, and harmonics.

The common PWM methods, as well as their impacts on inverter performance, harmonic content, and distortion, are covered in single-phase inverters and three-phase inverters in the section below.

Types of PWM Techniques

PWM comes in a variety of forms for single-phase inverters. These cleverly designed procedures take into account the inverters' activity in only permitted switching states in order to prevent any potential damage. To prevent the source from being shorted, for instance, the switches in the same leg of VSIs are never switched on. The typical PWM methods for full-bridge single phase inverters are listed below

Single-Pulse Width Modulation

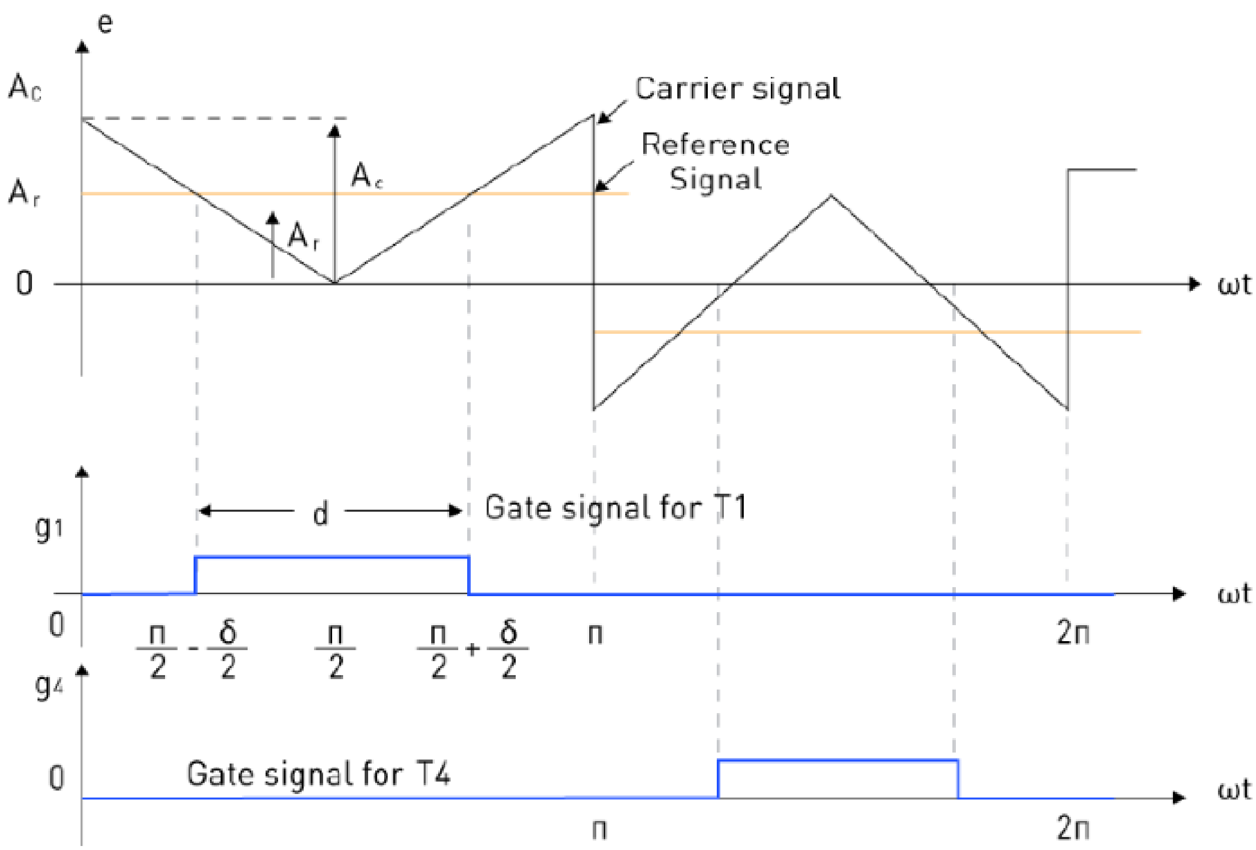


Figure 24: Single Pulse Width Modulation Gating Signals Generation

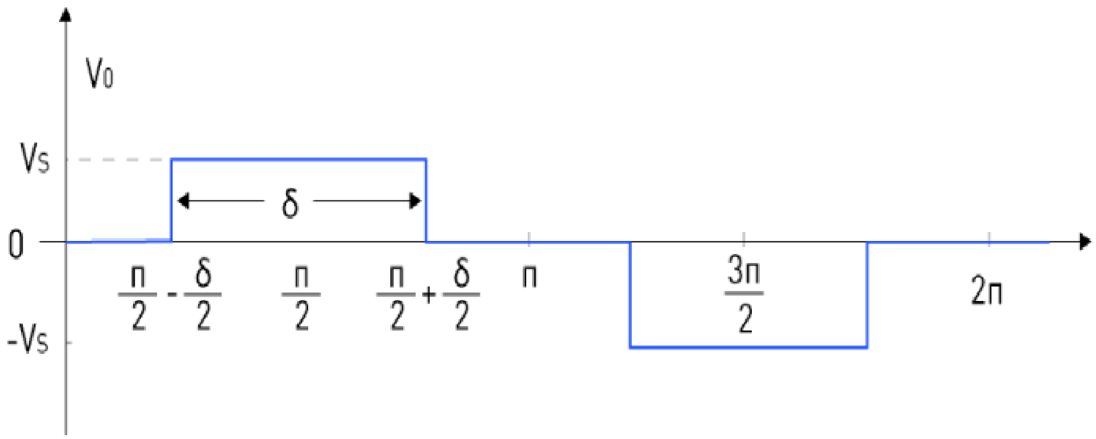


Figure 25: Single Pulse Width Modulation Output Waveform

Figure 24 illustrates the single-pulse width modulation; a straightforward PWM approach that includes creating gating pulses with adjustable width and position. When the modulation index M, which is the ratio of the reference signal Ar to the maximum value of the carrier signal Ac, varies, the position and breadth of this pulse inside each half-cycle also changes, or modulates.

Figure 25 depicts a single-phase full-bridge inverter. A carrier signal is compared to a reference signal to produce gating pulses for switches T1 (and T2), referred to as g1, and T3 (and T4), referred to as g4 as indicated in Figure 24. The positive magnitude of reference and carrier signal determine g1, while g4 is determined by their negative magnitudes. Figure 25 displays the output voltage as a result.

The third harmonic is prominent in this PWM. The distortion factor (DF) is defined as the ratio of the root mean square of harmonics to the fundamental component, with second-order attenuation (division by the square of each harmonic order). It takes into consideration the fact that the output filter would more effectively attenuate harmonics. DF grows as M decreases, implying lower output voltages. Finally, an acceptable value of M is approximately 0.8, where the DF is the smallest.

Multiple-Pulse Width Modulation

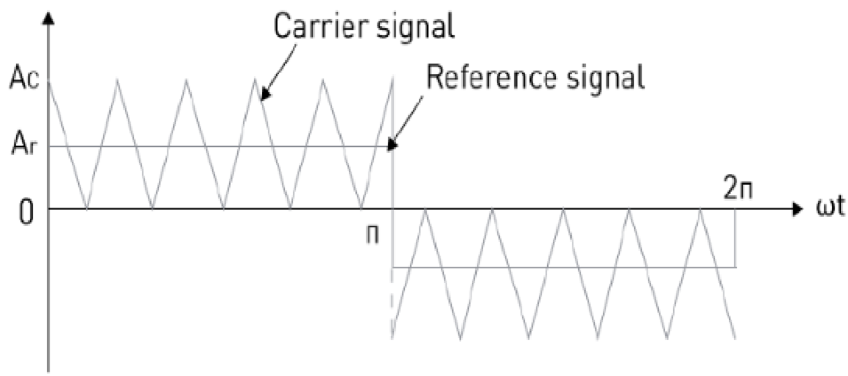


Figure 26: Gate Signal Generation in Multiple-Pulse Width Modulation

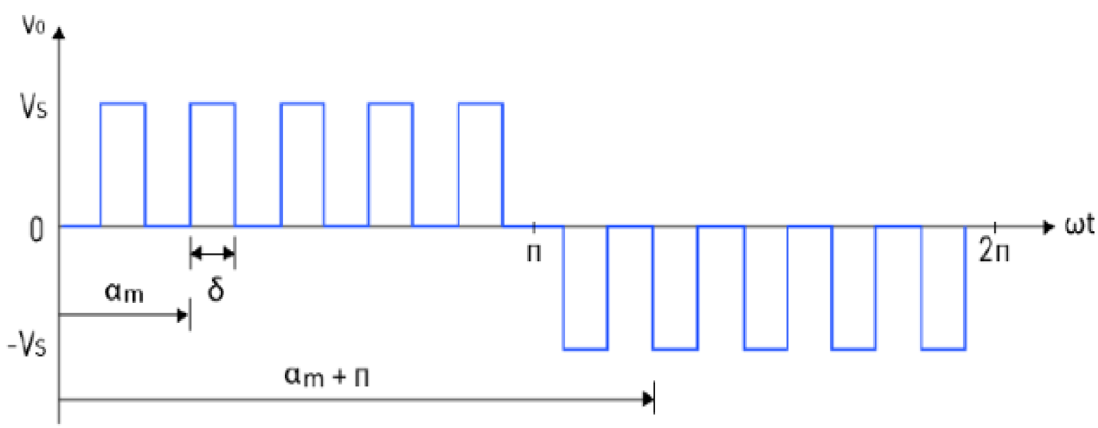


Figure 27: Output Voltage in Multiple-Pulse Width Modulation

A train of pulses can be produced in each half-cycle of the output voltage to lower the output harmonic content. As illustrated in Figure 26, several gating pulses can be created by comparing a reference signal to a triangle carrier signal. As with single pulse width modulation, g1 is determined by a single sinusoidal comparison, and g4 is determined by a comparison with 180° out of phase. The number of pulses in each half-cycle is determined by the carrier frequency. Furthermore, the frequency of the reference signal influences the frequency of the output signal. Finally, the modulation index regulates the output RMS voltage. Figure 27 depicts the resultant output voltage waveform.

When compared to single-pulse width modulation, the DF for multiple-pulse width modulation is substantially lower. However, switching losses rise as the number of switching cycles increases.

Sinusoidal Pulse Width Modulation (SPWM)

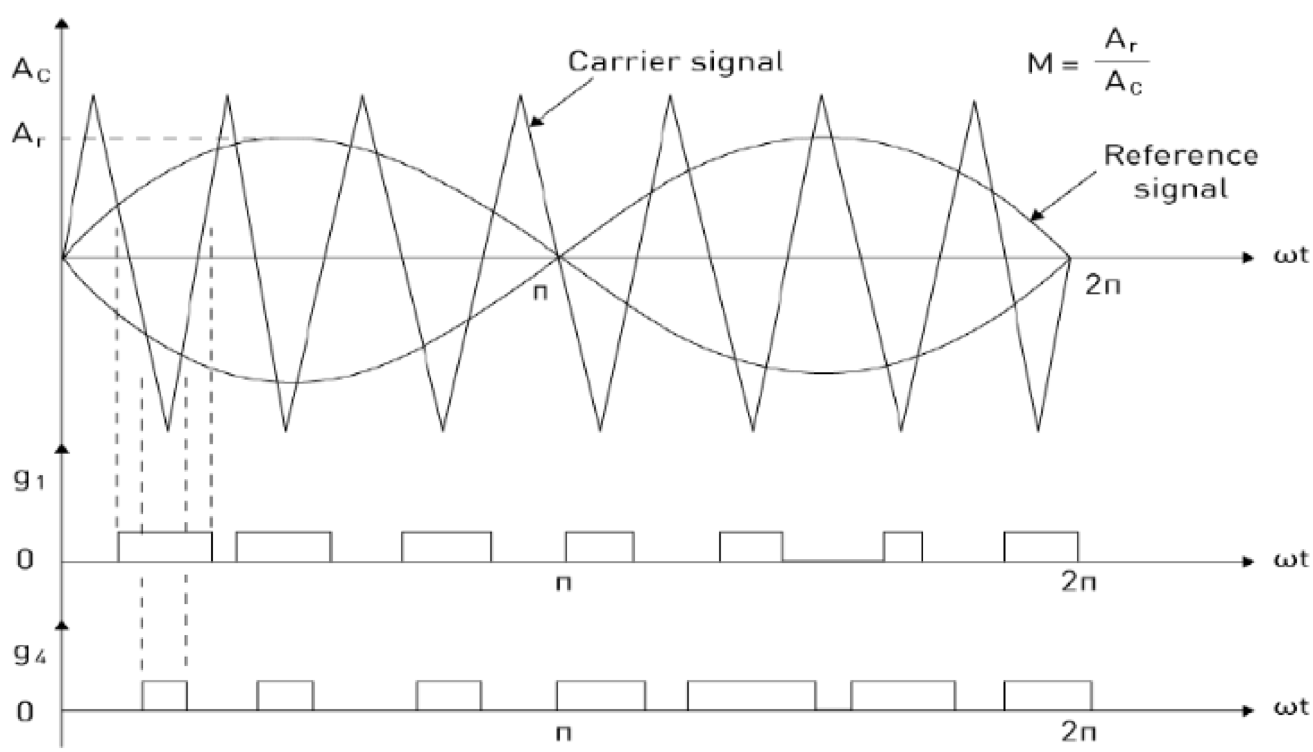


Figure 28: Gate Signal Generation in Sinusoidal Pulse Width Modulation

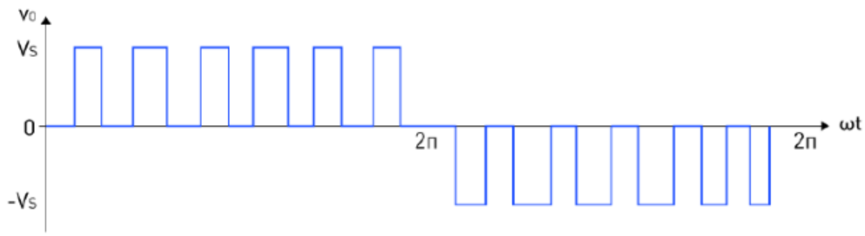


Figure 29: Output Voltage Waveform in Sinusoidal Pulse Width Modulation

Sinusoidal Pulse Width Modulation (abbreviated as SPWM) is a more complex type of PWM. In Figure 29, SPWM generates a pulse train for each gating signal g1 and g4 by comparing a sinusoi reference signal with a triangular carrier signal. Each pulse's width fluctuates in proportion to the amplitude of a reference sine wave at its center. The reference signal frequency determines the output signal frequency in SPWM. Furthermore, the peak amplitude of the reference signal influences the modulation index M, which controls the output RMS voltage. The number of pulses in each output signal cycle is determined by the carrier frequency. It is worth mentioning that no tw switches in the same bridge arm conduct at the same time. Figure 29 depicts a typical output volta waveform in SPWM. When compared to single and multiple-pulse width modulation methods, SPWM delivers greater harmonic rejection capabilities with much lower order harmonics and DF.

Other SPWM variations exist, such as where the carrier signal is only applied during the first and last 60-degree intervals of half cycles, which improves the output harmonic qualities.

Selective Harmonic Elimination (SHE)

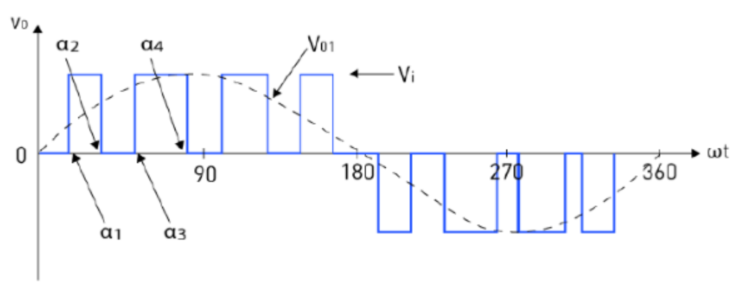


Figure 30: Typical Output Waveform for 3rd, 5th, and 7th Harmonic Elimination with SHE Modulation

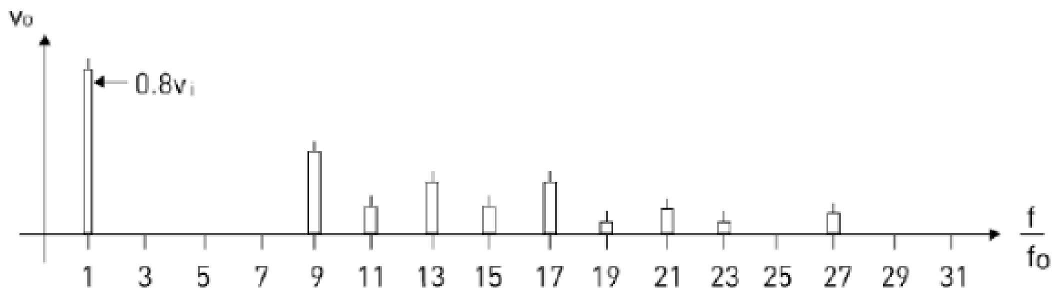


Figure 31: Gate Signal Generation in SHE Modulation

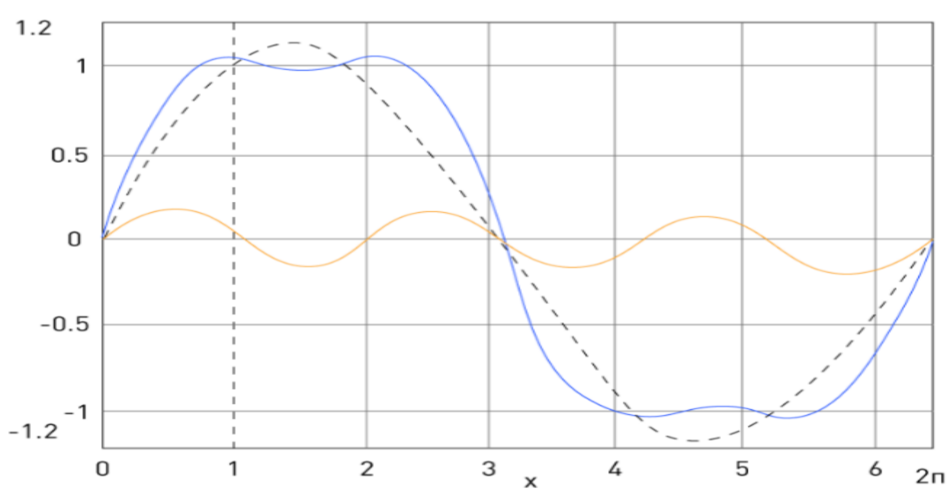
Selective Harmonic Elimination (SHE) is a PWM method for removing certain harmonics from the output waveform. Even harmonics are naturally present in the output; as a result, SHE seeks to reduce the odd harmonics in the single-phase inverter output. SHE entails calculating a series of nonlinear equations using sinusoids in order to obtain the ideal gate switching angles, such as α1, α2, α3, αN. In general, N half-cycle pulses (switching angles) are necessary to alter the fundamental component and eliminate N-1 harmonics. N nonlinear equations are solved to find the switching angles. Figure 30 depicts a typical output waveform with the removal of 3rd, 5th, and 7th harmonics. Figure 31 depicts the frequency spectrum corresponding to the produced output signal Figure 30.

Three-Phase Inverters

Three-phase inverters can be thought of as three single-phase inverters, with the output of each single-phase inverter shifted by 120-degree. Thus, the PWM methodologies discussed above for single-phase inverters are still applicable. In SPWM, for example, three sinusoidal references produced 120-degree apart are compared with the carrier signal to provide the appropriate gating signals for the phase.

There are various innovative ways for three-phase inverters that leverage their unique structure.

Third-Harmonic PWM



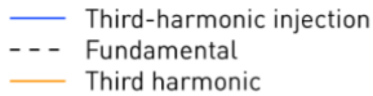


Figure 32: Reference Signal Generation in Third-Harmonic PWM

The reference signal in the third-harmonic PWM for three-phase inverters is made up of the fundamental signal as well as its third harmonic, as shown in Figure 32. The third harmonic component in the neutral terminal is effectively canceled when a third harmonic component is present in each phase. By offering a fundamental component that is around 15.5% greater than that of sinusoidal PWM, third-harmonic PWM offers superior dc supply voltage consumption than sinusoidal PWM.

Space-Vector Modulation

SVM is an advanced pulse width modulation (PWM) technology that is typically employed in three-phase inverter systems. It has advantages such as higher source usage and lower harmonic when compared to other approaches such as 180-degree conduction, SPWM, and so on. SVM is a digital modulating technique that generates PWM load line voltages that are on average equal to a given (or reference) load line value. SVM has received significant popularity in a variety of applications, including motor drives, renewable energy systems, and uninterruptible power supplies because of its ability to maximize inverter performance.

The fundamental distinction between SVM and traditional PWM approaches is in the mathematical formulation and production of switching patterns. The output voltage is represented as a vector in a complex plane known as the α-β plane by SVM, and the proper switching states are determined to yield the required voltage vector.

EE 3033 HYBRID ENERGY TECHNOLOGY

UNIT-V

CASE STUDIES FOR HYBRID RENEWABLE ENERGY SYSTEM

1. Why hybrid energy system is important?

A reliable, Continuous Supply of power is crucial for any operation. Using a fully automated battery System, hybrid generators supply uninterrupted power without delay time. The System can automatically detect a power outage and immediately power supply is obtained to home, business or Commercial etc.,

2. List the different hybrid energy system.

- Solar + wind
- Solar + Hydro
- Hydro + wind
- Solar + Thermal + Biomass.
- Diesel + PV
- Wind + PV + Fuell cell

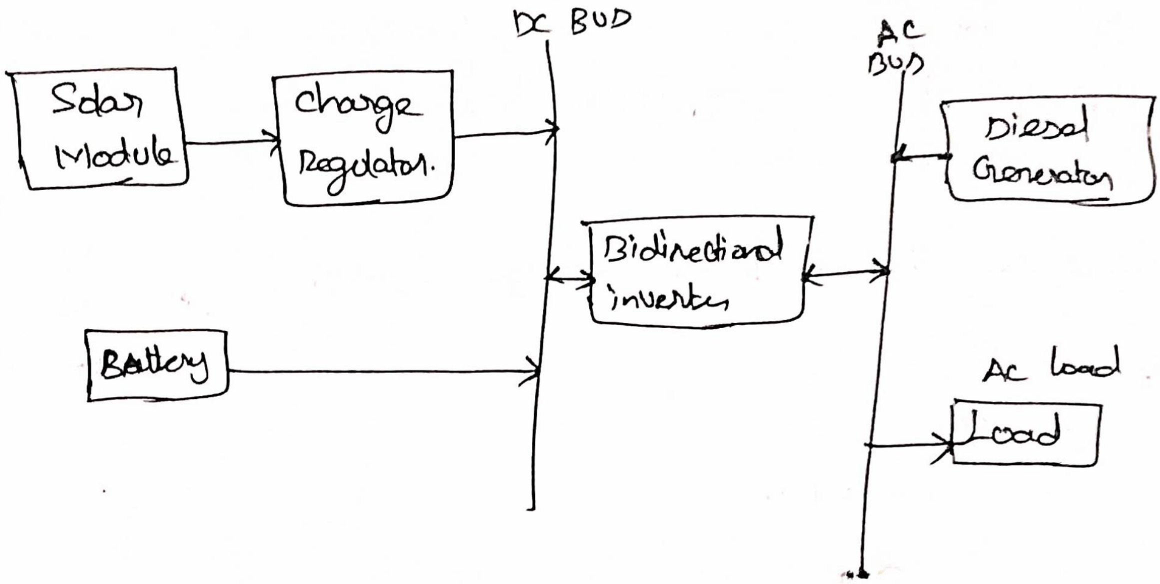
3. What is Cost analysis of hybrid System?

Depending on Total Net present Cost (TNPC) feasible System Configuration will be displayed at the optimization result window. The Combination of System Components is arranged from most effective cost to the least effective Cost. The optimization results are done for every Selection of Sensitivity Variables in HES.

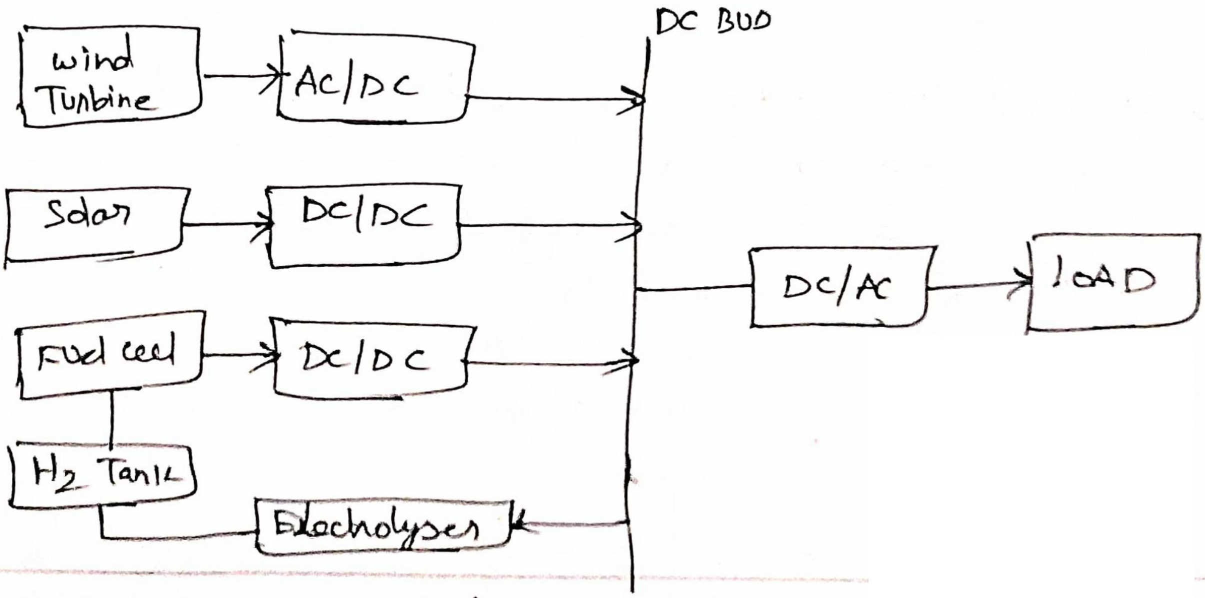
4. what is pv diesel hybrid System?

A pv diesel hybrid System Combines a Solar array with a diesel generator to generate electricity. The Solar array provide daytime power while the diesel generator Supplies backup power during the night or when there is no Sunlight.

5. Draw the pv - diesel hybrid System.



6. Draw the schematic of wind - pv - fuel cell hybrid System.



7. Give the application of fuel cell.

Fuel cell are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are also used to power fuel cell vehicles, including forklift, automobiles, buses, trains, boats, motorcycles and submarines.

8. What is MPPT?

Maximum power point Tracking (MPPT) is the major extract to maximum power from PV module by making them to operate at the most effective voltage.

9. what is the purpose of MPPT controller?

The MPPT charge controller ensures that the load receive maximum current ~~led~~ to be used (by quickly charging the battery). Maximum power point could be understood as an ideal voltage at which the maximum power is delivered to the loads, with minimal losses.

10. List out few hybrid power plants in India.

- Adani Green energy - world's largest 700 MW wind solar hybrid power plant in India.
- NLC - Solar Thermal, Neyveli
- Thermax - wind solar hybrid, Gujarat

PART - B

1. What is hybrid energy system? Explain in detail the range and different types of hybrid energy systems.

Integration of two or more renewable energy sources form a more reliable system is called a hybrid system.

Renewable energy systems (RES) are one of the most suitable and environmentally friendly solution to provide electricity with urban and rural areas. on-grid and off-grid electrification based on the generation of power through the installation of renewable energy power system in urban and rural household have been proven to be capable of delivering high quality and reliable electricity for heating, lighting and demands alike.

Range and Type of Hybrid Systems:

The combination of RES, such as PV arrays or wind turbine, with engine-driven generators and battery storage, is widely recognized as a viable alternative to conventional remote area power supplies (RAPS). These systems are generally classified as hybrid energy system (HES). Hybrid systems range from 1 Kw to several hundred watts.

Hybrid energy system generate AC electricity by combining RES such as PV array with an inverter, which can operate alternately or in parallel with a conventional engine driven generator.

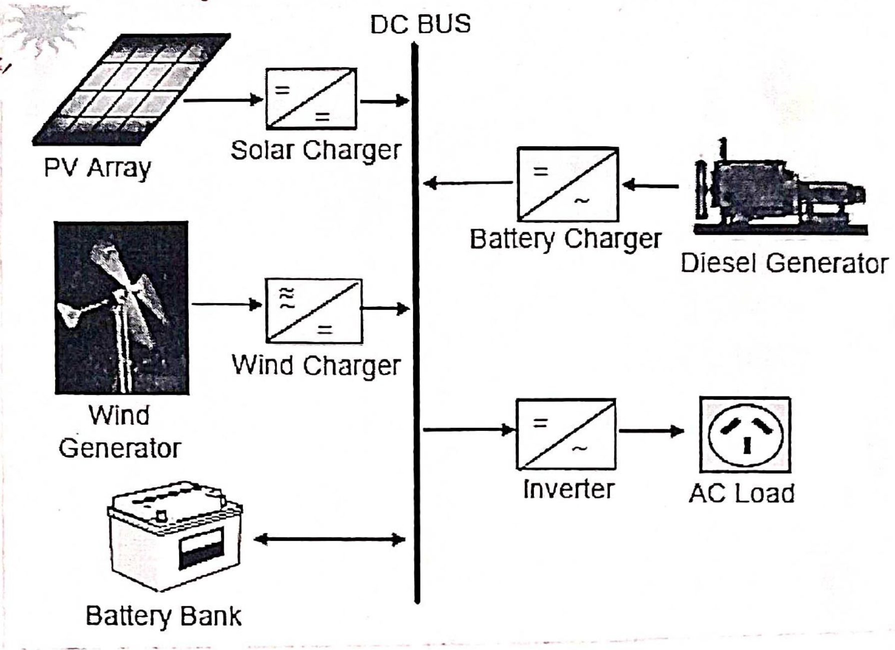
They can be classified according to their configuration as:

- Series hybrid energy system
- Switched hybrid energy system
- Parallel hybrid energy system.

The parallel hybrid Systems can be further divided to DC or AC Coupling.

1. Series Configuration :

1.(Dc)



In the Conventional Series hybrid System shown in fig, all power generators feed DC power into a battery. Each Component has therefore to be equipped with an individual charge Controller and in the case of a diesel generator with a rectifier. To ensure reliable operation of Series hybrid energy System both the diesel generator and the inverter have to be Sized to meet peak loads This result in a typical System operation where a large fraction of the generated energy is passed through battery bank, therefore resulting in increased cycling of the battery bank and reduced System efficiency. AC power delivered to the load is Converted from DC to regulated ~~DC~~ AC by an inverter or a motor generator unit.

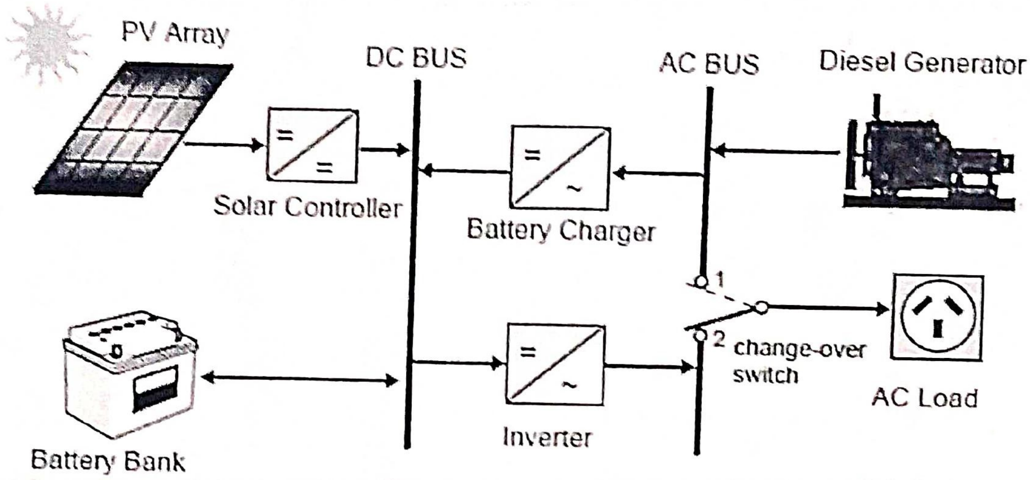
The power generated by the diesel generator is first rectified and subsequently converted back to AC before being supplied to the load, which incurs significant conversion losses. The actual load demand determines the amount of electrical power delivered by the PV array, wind generator, battery bank, or diesel generator. The solar and wind charger prevents overcharging of the battery bank from the PV generator when the PV power exceeds the load demand and batteries are fully charged. It may include MPPT to improve the utilization of available PV energy, although the energy gain is marginal for a well-sized system. The system can be operated in manual or automatic mode, with the addition of appropriate battery voltage sensing and start/stop control of engine-driven generator.

2. Switched configuration:

Despite its operational limitations, the switched configuration remains one of the most common installation in some developing countries. It allows operation with either the engine-driven generator or the inverter as the AC source, yet no parallel operation of the main generation source is possible. The diesel generator and the RES can charge the battery bank. The main advantage compared with the series system is that the load can be supplied directly by the engine-driven generator, which results in a higher overall conversion efficiency.

Typically the diesel generator power will exceed the load demand, with excess energy being used to recharge the battery bank.

During period of low electricity demand the diesel generator is switched off and the load is supplied from PV array together with stored energy. Switched hybrid energy systems can be operated in manual mode, although the increased complexity of system makes it highly desirable to include an automatic controller, which can be implemented with addition of appropriate battery voltage sensing and start/stop control of the engine-driven generator.

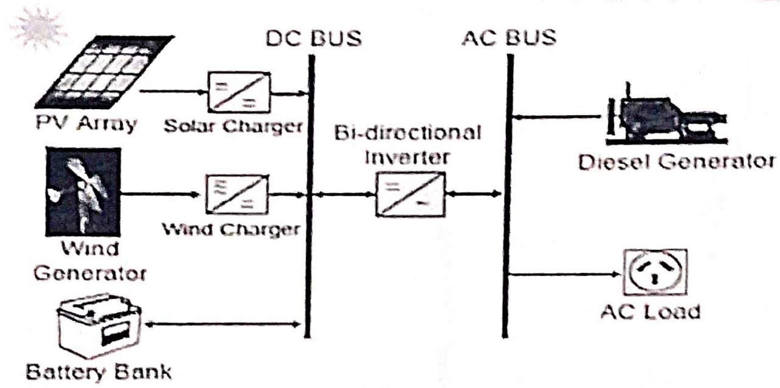


3. Parallel Configuration :

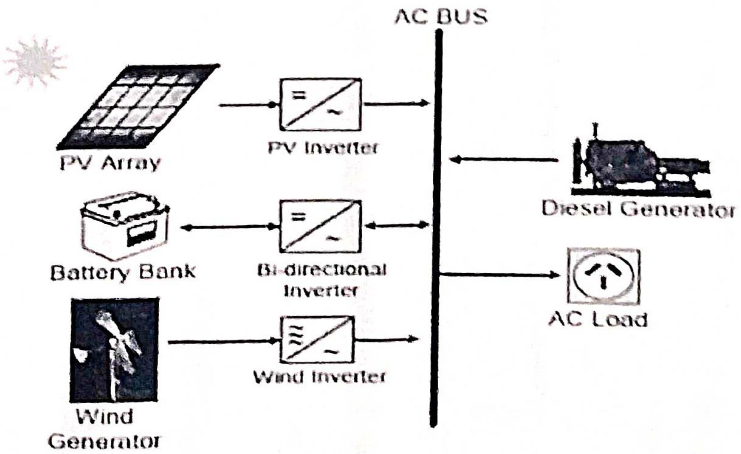
The parallel hybrid system can be further classified as DC and AC couplings as shown in fig. In both the schemes, a bi-directional inverter is used to link between the battery and an AC source (typically the output of a diesel generator). The bi-directional inverter can charge the battery bank (rectifier operation) when excess energy is available from the diesel generator or by the renewable sources. as well as act as a DC-DC converter (inverter operation). The bidirectional inverter may also provide "Peak shaving" as part of control strategy when the diesel engine is overloaded.

In Fig (a) the renewable energy source such as PV, and wind are coupled on the DC side. DC integration of RES results in "custom" system solutions for individual supply cases requiring high cost for engineering, hardware, repair and maintenance.

Furthermore power system expandability for covering needs of growing energy and power demand is also difficult. A better approach would be to integrate the RES on the AC side rather than on DC side as shown in Fig. b.



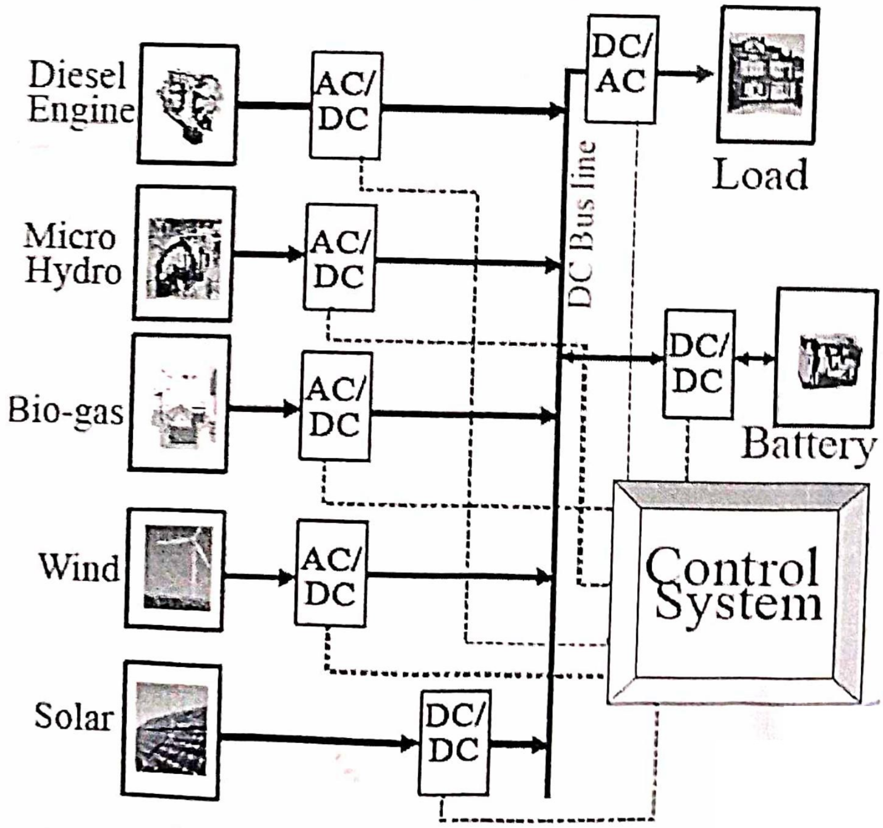
(a)



(b)

2. Explain in detail the various performance analysis of hybrid energy systems.

Hybrid power system incorporate several electricity generating components with usually one major control system which enable the system to supply electricity in the required quality. A typical hybrid system combines two or more energy sources, from renewable energy technologies such as photovoltaic panels, wind or small hydro turbines; and from conventional technologies usually diesel or LPG gensets (though biomass fed gensets are also a feasible option, if locally available). In addition it includes power electronics and electricity storage batteries.



Analysis of different hybrid powers:

This proposal is analyzed by using MATLAB simulator. For performance analysis total daily demand is taken randomly in KW rating. Where 50 KW is assumed as base load demand and load is considered for 12 hours of a day. Below fig represents daily demand in a random basis.

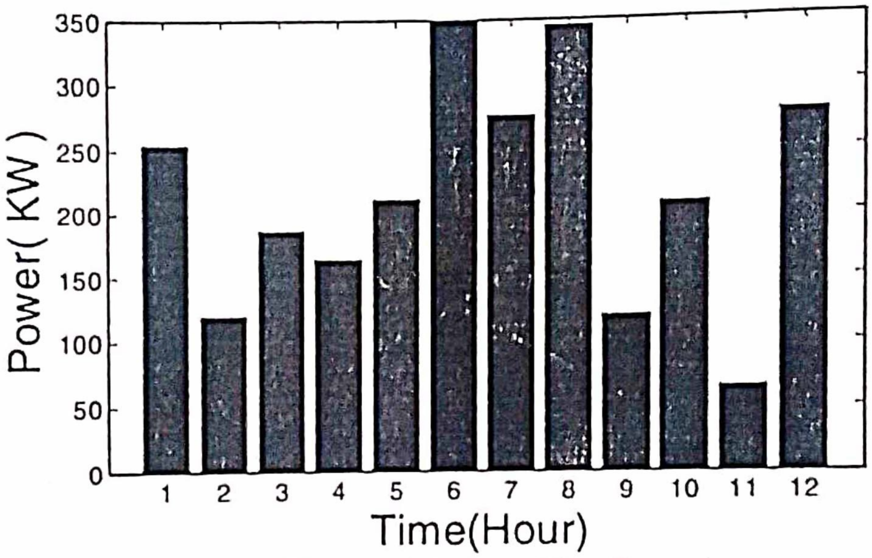


Fig: Total daily demand

In the proposed model it is designed that the base load (assumed 50 KW) of daily demand curve will be supplied by Micro Hydro power plant to minimize the cost. Below fig represent the power obtained from micro hydro plant.

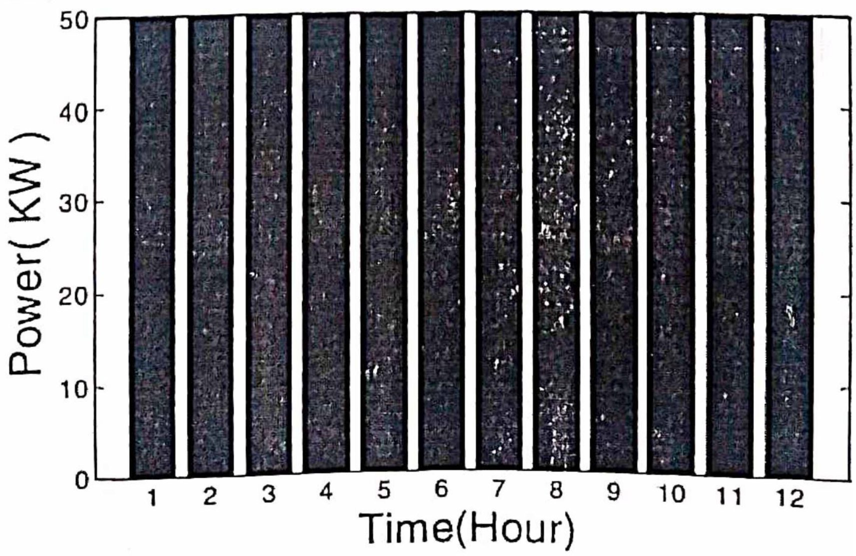


Fig: Power produced by Micro hydel power Plant.

So daily peak load is obtained by subtracting the power produced by Micro Hydro Power Plant from total daily demand curve. The peak load demand is shown in fig below.

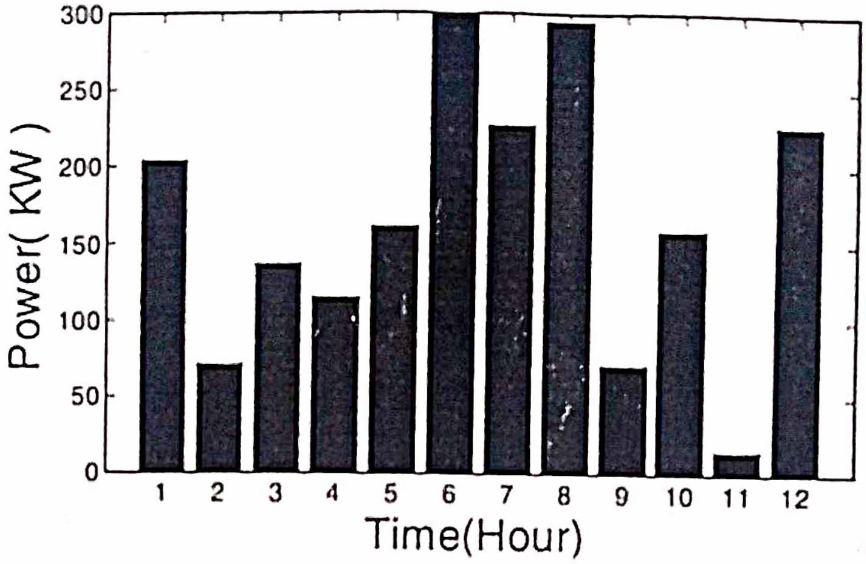


Fig: Daily peak load demand curve.

This peak load demand is primarily met by wind and solar power sources. Wind power varies with the speed of wind and solar power varies with the intensity of sun light. Below fig shows the power obtained from wind turbine and solar panel respectively.

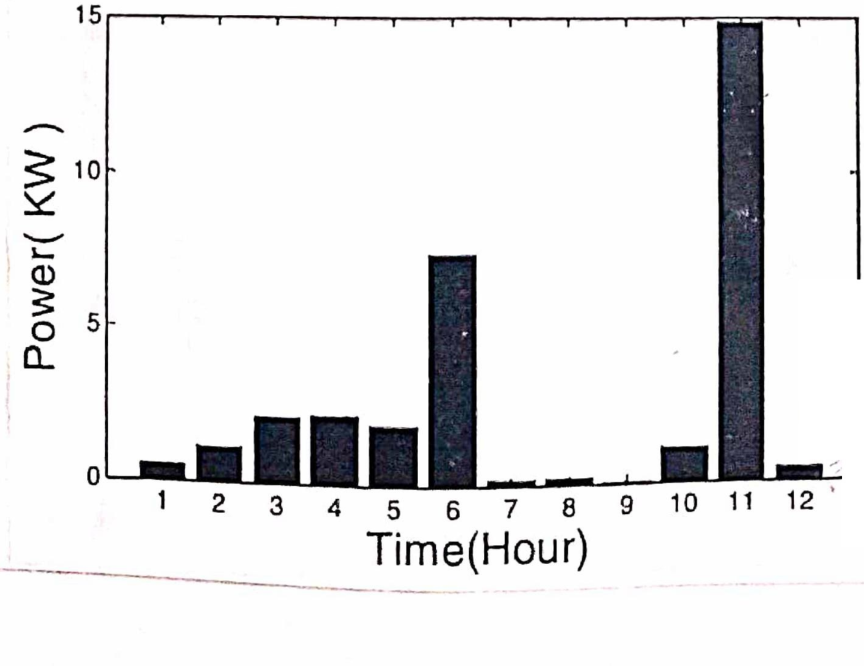


Fig: Power obtained from wind turbine.

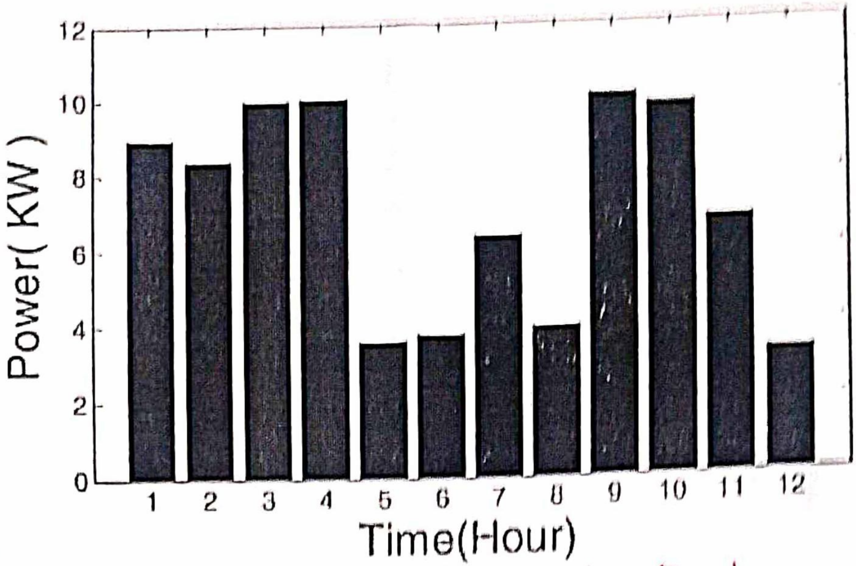


Fig: Power obtained from Solar Panel.

Below fig represents the Combined power obtained from Solar power plant and wind Turbine which is the summation of result obtained from above fig.

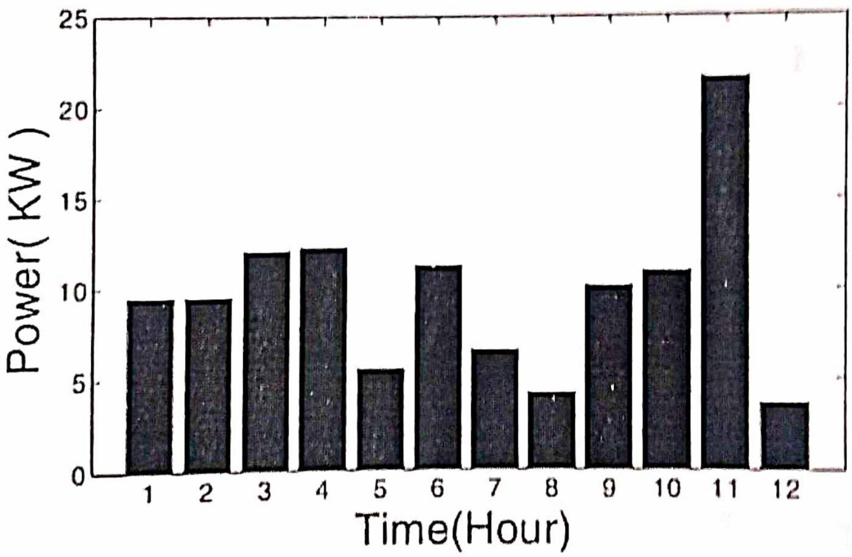


Fig: Combined power obtained from Solar power plant and wind turbine.

Below fig indicates power required from other Sources or Surplus power for storage. Positive portion indicates the power which is needed from Bio-gas plant and diesel engine power and the negative portion indicates the power which will store in the battery.

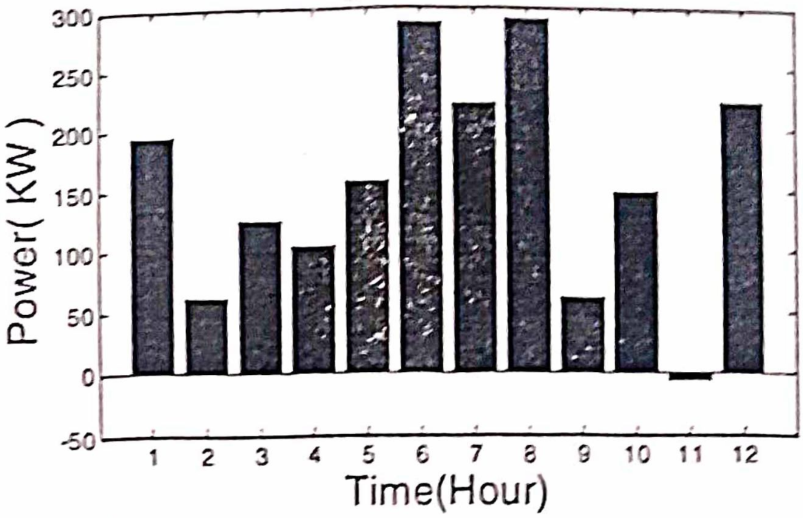


Fig. Additional power required or power to be stored

Below fig shows the ability to support the power demand by biogas and shows the additional power respectively. From the figure we can understand that the first few hours is supported by the biogas power plant and when there is no biogas available then the rest of the demand is fulfilled by the diesel power plant.

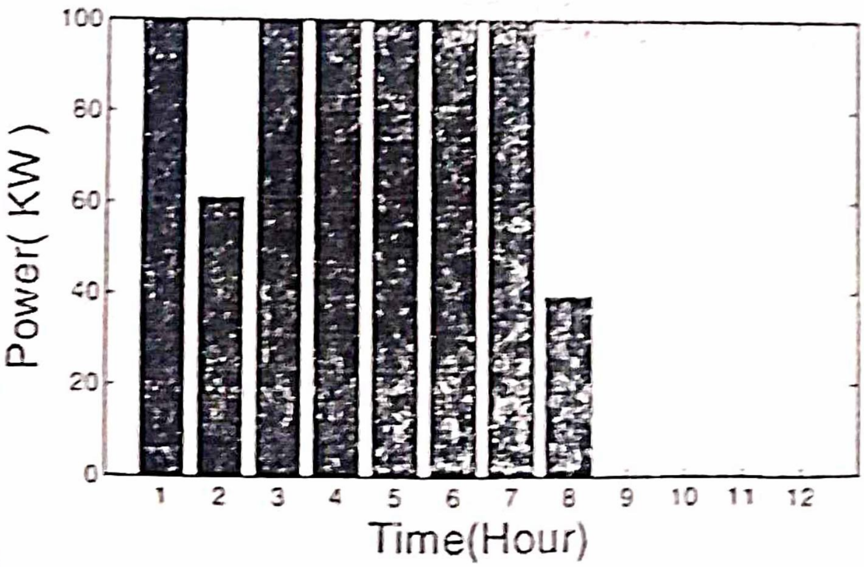


Fig: Ability to produce power by Biogas engine

Below fig shows the total power required from diesel engine in 12 hours which is the summation of power supplied by diesel engine when the demand is beyond gas engine rating and when no bio-gas is available and all other renewable power sources has supplied their highest load.

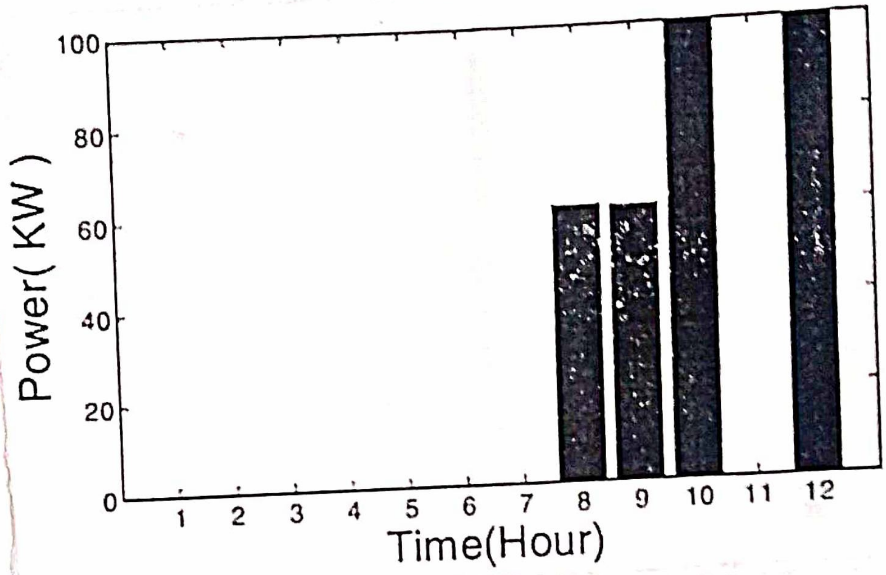


Fig: Additional power required from diesel engine.

Fig: Additional power required or Power to be Stored.

Thus from the performance analysis of hybrid power system we can come to the decision that total power from micro hydro, solar, wind, bio-gas and diesel engine meet the total daily power which satisfy the source selection criteria.

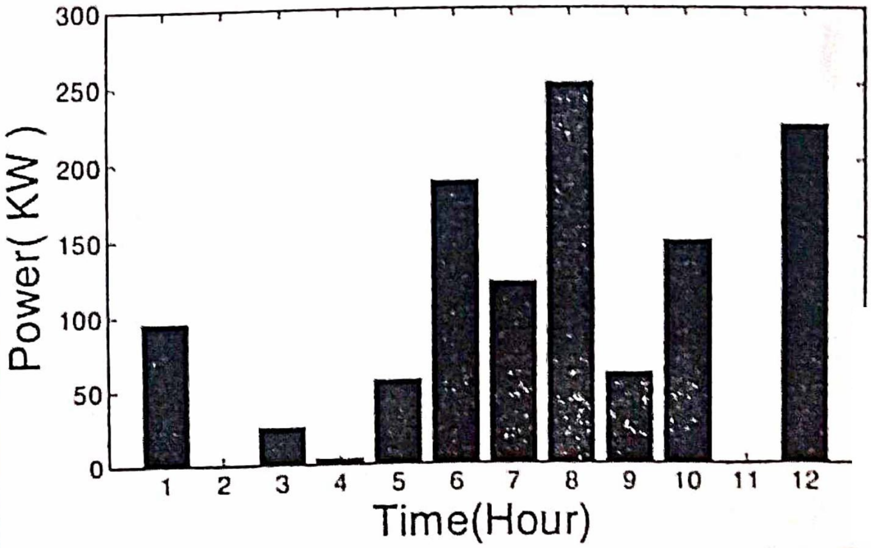


Fig: Total Power required from diesel engine

3. Explain in detail the cost analysis of hybrid energy System.

In the Cost advancement Strategy, HOMER (Hybrid optimization of Multiple Energy Resources) rate reproduces every framework design in the pursuit space and traces the Conceivable ones in the outline, Sorted by net present cost. Hence it shows a Subset of these overall optimization results by displaying only the least - net cost Configuration within each System Category or type.

The Cost of the hybrid energy System (CHES) becomes the Sum of the Cost of its individual Components i.e, Solar PV System Cost (CSPV), fuel Cell Cost (CPEMFC), biomass gasifier Cost (CBG), battery Cost (CBAT), electrolyzer Cost (CELECTO), power Converter Cost (CPCON) and hydrogen tank Cost (CHTANK)

$$\therefore CHES = CSPV + CFC + CBG + CBAT + CELECTO + CPCON + CHTANK$$

Cost of each Component of hybrid energy System

$$C_i = N_i \times \left[CapC_i + (ReC_i + NR_i) + OMC_i \right]$$

where

i = Component of hybrid energy energy System (Solar PV / fuel cell / biomass gasifier / power Converter / electrolyzer / hydrogen tank)

Ni = Number / Size of hybrid energy System Component.

CapCi = Capital Cost hybrid energy System Component

ReCi = Replacement Cost hybrid energy System Component.

NRi = Number of replacement.

OMCi = operation and Maintenance Cost hybrid energy System Component.

HOMER first evaluates the specialized achievability of the framework and whether it can take care of the load demand. second it appraises the aggregate net present Cost (NPC) of framework, which is the life-cycle expense of framework, including the initial set up cost (IC), part replacement cost (RC), operation and maintenance cost (OM), fuel cost (FC), and the acquiring power cost (PC) from the network

HOMER simulator net present cost (NPC) by the accompanying equation

$$C_{NPC} = \frac{CAT}{CRF(i_r, P_L)}$$

$$CRF = \frac{i_r (1+i_r)^N}{(1+i_r)^N - 1}$$

where CNPC - Net present cost
CAT - Total annualized cost
CRF - Capital recovery factor
PL - Project life (20 years)

i_r = Real interest rate (6.3%)

N = No. of years.

4. Elaborate the Diesel - PV hybrid model with neat diagram.

In a PV - diesel hybrid System, Solar panels (PV) and generator(s) are connected and collaborate to supply all connected power consuming appliances with energy. These appliances are called load.

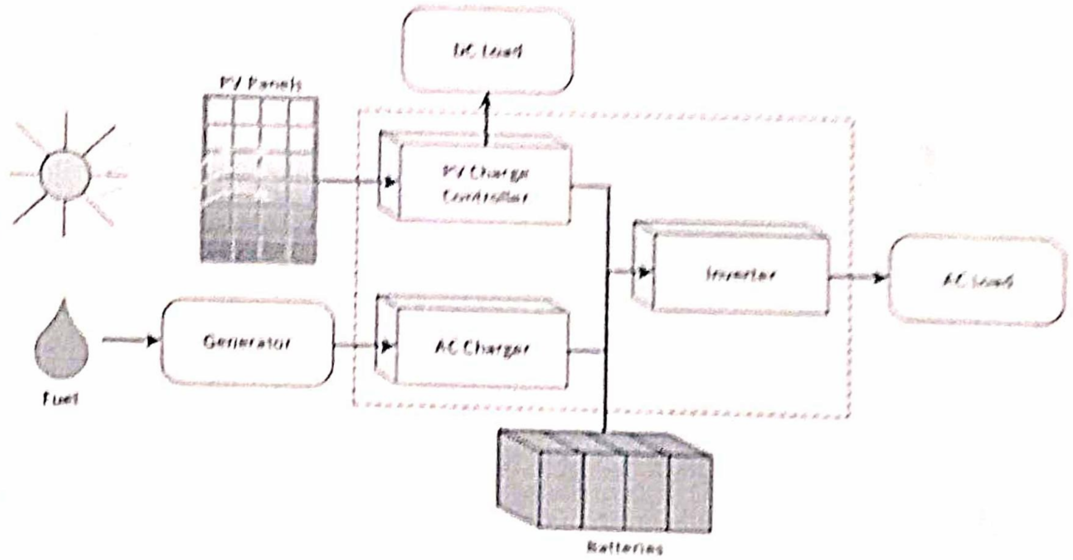


Fig: Schematic diagram of PV - diesel hybrid System.

Major Components are

- PV panels
- Generator
- Battery
- Load
- PV charge Controller.
- Inverter
- Fuses
- Breakers and Switches.

- PV Panels:

PV panels, called Solar panels generate electricity from Sun. The more Sunshine the falls on the panels, the more electricity is generated. It is therefore important that the panels are not shaded or dirty. Even a little shade reduces the performance considerably.

- Generator:

The generator generates electricity by using liquid fuel, mostly diesel, also gasoline or propane can be used.

Battery:

The battery is energy storage device. Electricity that is generated by PV panels or the generator which is not consumed directly by loads, will be stored in the batteries. The energy can then be used later when needed.

Load:

The load is all electrical appliances connected to the System. It can be lamps, refrigerators, computers, mobile phone chargers, TV, kitchen appliance and many more. The load can be AC or DC, depends on the requirement the power can be converted or inverted.

PV charge Controller:

The charge Controller is a very important Component for the long term Sustainability of the System. without the charge controller, the batteries can fail very soon. when the batteries are full, the Charge Controller prevents over charging of batteries. If the batteries do not have enough energy, the charge controller can cutt off loads.

Inverter:

An inverter can transform DC power into AC power. The electricity from Solar panel and in batteries is DC, but many loads are AC. Therefore it is Sometimes necessary to transform from DC to AC and vice versa.

Fuses:

A Fuse is a Safety device that can Shut off the electricity automatically. This will happen if there is a Short circuit in the System, or if too much Load is connected to the System. Fuses should never be by passed.

Breakers and Switches:

A breaker is a device that can be used to cut the power manually. A Central breaker can be used to cut the power to all loads. It is also usual to have breakers for different parts of a distribution System, making it possible to shut down selected sections.

5. Elaborate the wind - PV - Fuel cell with diagram.

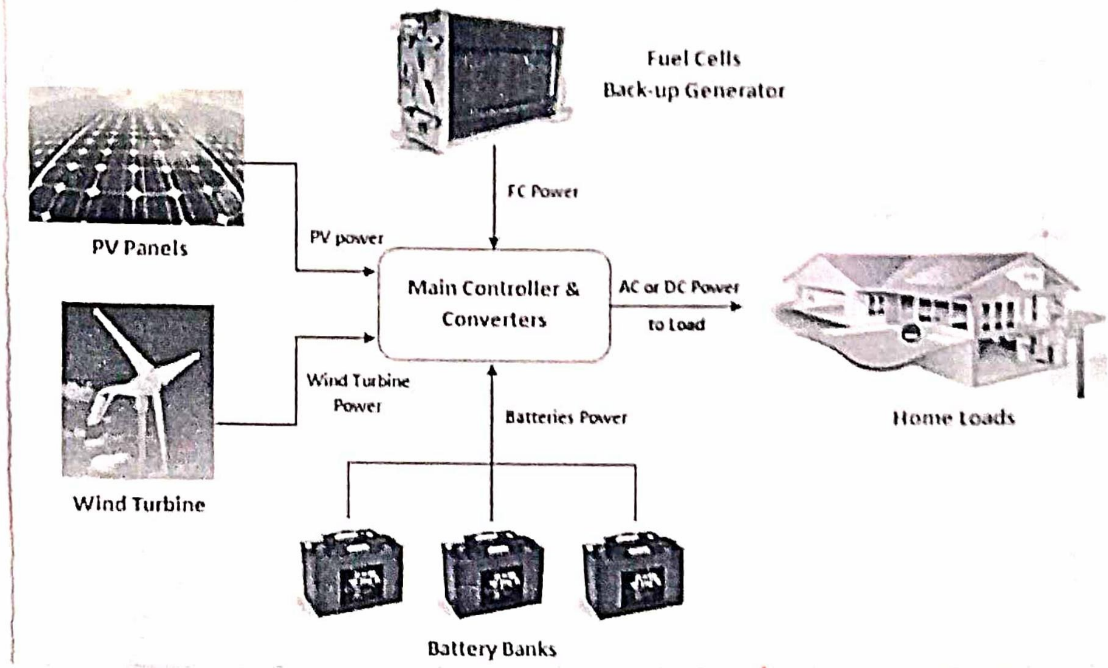


Fig: Schematic of wind PV Fuel cell hybrid System.

In power application and system design, modelling and simulation are essential to optimize control and enhance system operation. The dynamic simulation model for a hybrid power system comprises PV panels, wind turbine, fuel cells, battery bank converters and controllers.

The main controller have developed to ensure the continuous power supply for load demand. The implementation of PV/wind turbine / PEMFC / Li-ion battery system model. The block diagram of the developed model is shown in fig.

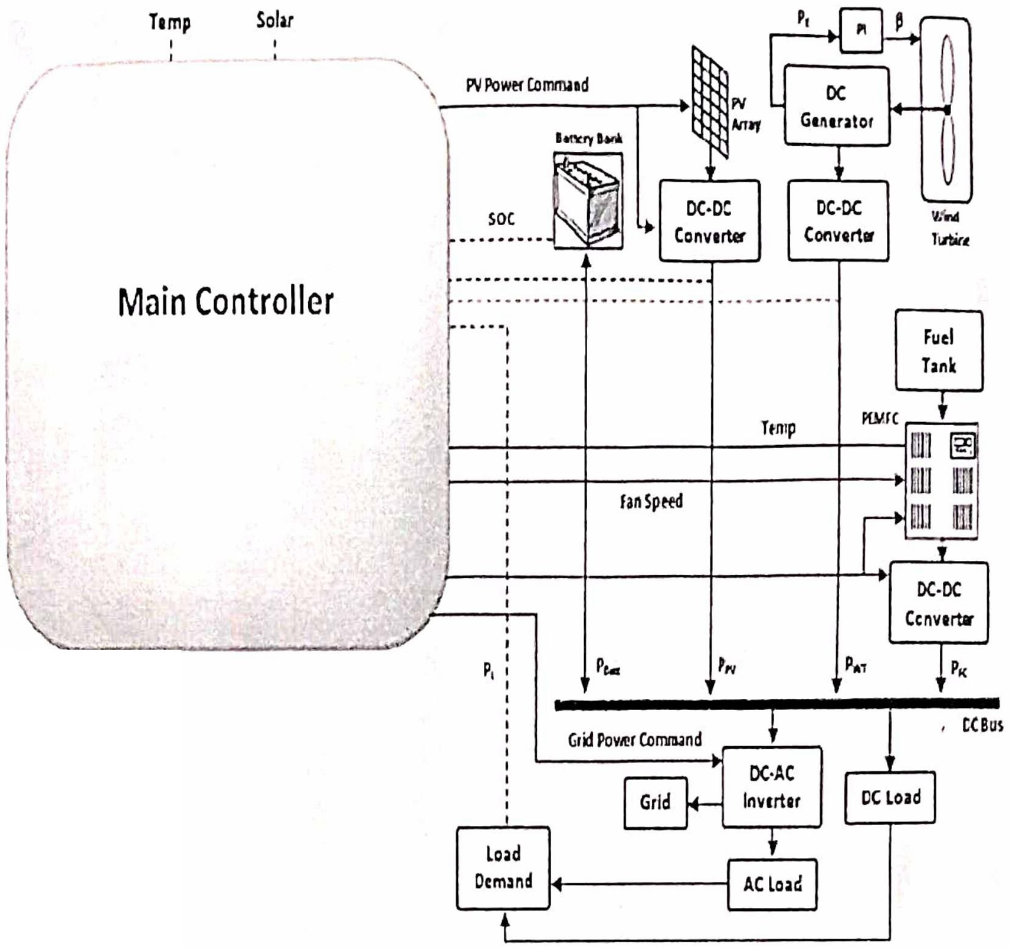


Fig: Block diagram of developed hybrid power System.

The scheme for energy management is Stand-alone hybrid power System. The proposed management System is designed to manage the power flow between the hybrid power system and energy storage elements in order to Satisfy the load requirements based on Artificial Neural Network (ANN) and fuzzy logic Controllers. The method offers an on-line energy management by a hierarchical Controller between four energy Source Comprise photovoltaic panels, wind turbine, battery storage and Fuel cell.

The proposed method includes a MPPT Controller in the first layer, to achieve the Maximum Power Point (MPP) for different types of PV panels, two different techniques will be presented (P&O and Neural Network). In the second layer an advance fuzzy logic controller will be developed to distribute the power among the hybrid system to manage the charge and discharge current flow for performance optimization. Finally in the third layer smart controllers are developed to maintain the stability of the PEMFC temperature and to regulate the fuell cell // battery set points to reach best performance.

6. Elaborate the Micro-Hydel PV with neat diagram.

The lack of an electrical network in remote ~~areas~~ areas and the prohibitively high connection cost of grid extension and rough topography often lead to exploration of other options. Standalone hybrid systems have turned into one of the most promising ways to satisfy the electrification requirements of these areas.

The present study investigates the possibility of using a stand-alone solar / micro hydro hybrid power system for low cost electricity production which can satisfy the energy load requirement of remote and isolated area.

The dimension of hybrid system are determined according to availability of renewable energy resources and the load energy requirements. Thereafter economic performance of the system is compared with that of other supply option such as grid extension or diesel generator.

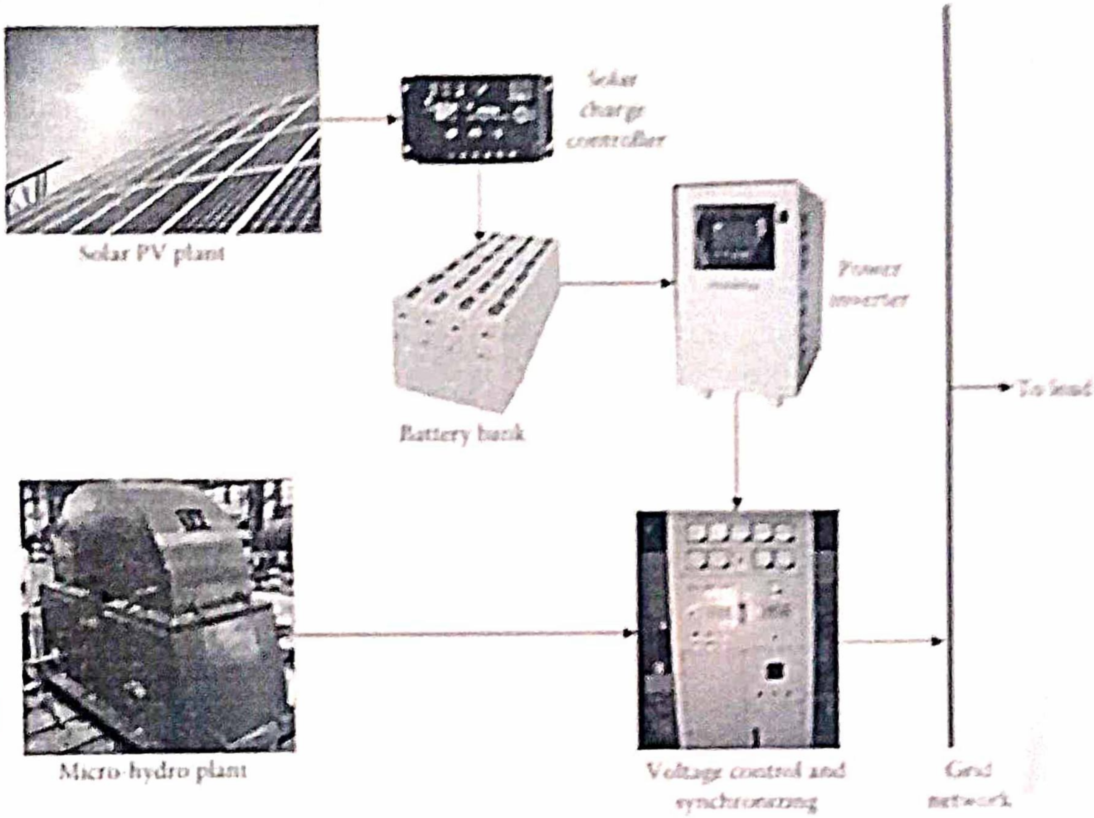


Fig: Structure of Micro-Hydel PV Hybrid System

Micro hydel (up to 100 kW) power station are low head (>3m) installation and provide decentralized power in mountain region, also in plains on canal falls in Remote areas.

Micro hydel-PV system as sunshine is available practically at all locations. Portable micro hydel sets are installed with solar. Micro hydel systems are provided with small dam store water to be used during nights when solar PV stops power supply. A battery bank may be provided for emergency power supply. Load management is carried out to maintain continuity of supply for 24 hours matching capacity of generating equipment.

7. Eloborate Biomass - Diesel - Fuell Cell with neat diagram.

Biomass is a renewable Source of energy because the waste residue will always exist in terms of scrap wood, mill residuals or forest resources. As plants use atmospheric CO_2 in the process of photosynthesis which Completes the carbon cycle, so it is renewable. The Carbohydrate produced by photosynthesis is in fact the Source of biomass.

DIFFERENT TYPES OF BIOMASS AND THEIR COMPOSITION

Biomass Type	Fixed Carbon (%)	Water Content (%)	Ash Content (%)	Volatile Matter (%)
1.Wood(dry)	14.5	7.8	0.2	77.5
2.Sugarcane	11.1	10.4	1.9	76.6
3.Coconut shells	22.0	4.4	3.1	70.5
4.Musturd husk	22.0	5.6	3.9	68.5
5.Bamboo whole	15.2	13.0	0.8	71.0
6.Wheat straw	16.3	10.1	6.4	67.2
7.Rice straw	14.4	7.6	18.6	59.4
8.Rice husks	17.2	10.6	16.1	56.1
9.Miscanthus grass	14.0	11.4	2.7	71.9
10.Buffalo gourd	12.3	10.0	4.2	73.5
11.Eucalyptus bark	15.1	12.0	4.2	68.7
12.Wood residue	12.2	26.4	4.0	57.4
13.Sawdust	9.3	34.9	0.7	55.1
14.Fir mill residue	6.5	62.9	0.2	30.4
15.Forest residue	7.3	56.8	1.4	34.5
16.Furniture waste	11.8	12.1	3.2	72.9
17.Wood agri-residue	12.7	30.3	2.3	54.7
18.Biomass mixture	16.5	8.8	11.4	63.3
19.Mixed waste paper	6.8	8.8	7.6	76.8
20.Land-clear wood	7.0	49.2	8.4	35.4

Structure of System:

It includes a Solar photovoltaic energy Source should be hybrid with other energy Source, whether used in either a Stand-alone or grid Connected mode. Stand-alone energy System are Very popular, especially in remote sites. The below figures Solar photovotaic, biomass (gasifier generator Set) fuell cell and diesel generator hybrid energy System. Here we Consider bio-mass, diesel generator and fuel cell as major Sources of hybrid energy Systems.

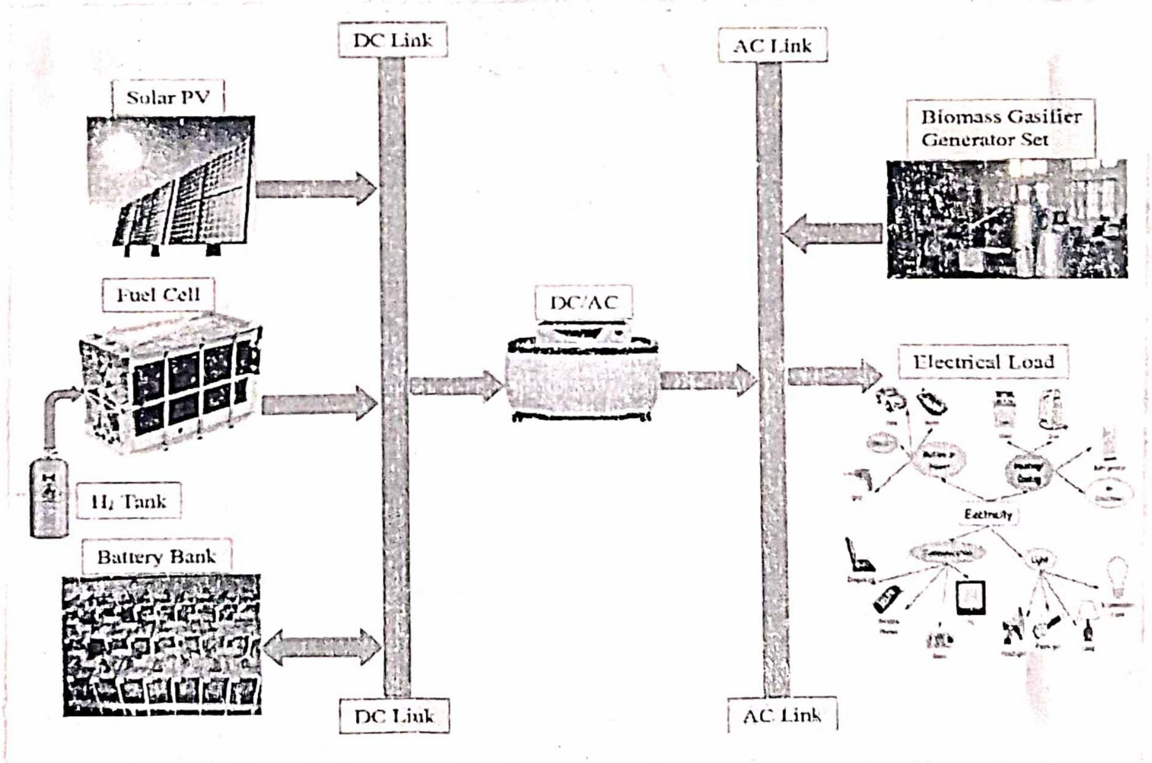


Fig: Biomass - Diesel - Fuel - Cell hybrid System (Including PV and Solar) with Supply link AC and DC.

Hybrid Energy System Components

Fuel cell:

A fuel cell is an electrochemical device that converts chemical energy directly into electrical power. Like a battery, an energy component comprises of a couple of terminals and an electrolyte. A fuel cell comprises a polymer electrolyte film sandwiched between two terminals (anode and cathode). In the electrolyte, no one but positive particles can exit and electrons are not permitted to go through. In this way, the stream of electrons needs a way to an outside circuit from anode to cathode. Varying operating conditions, the output voltage of fuel cell is

$V_c = V_{rev} - V_{act} - V_{ohm}$ = ohmic polarization

V_{conc} = mass transport

V_{act} = Activation polarization.

The cost of fuel cell varies widely depending on scale, power electronic requirement and reforming requirement.

Biomass (Gasifier)

The creation of generator gas (producer gas) called gasification, is the fractional burning of strong fuel (biomass) and happens at temperature of around 1000°C. The reactor is known as a gasifier. The burning items from complete ignition of biomass, for most part, contain nitrogen, water vapour, carbon dioxide and excess of oxygen.

However in gasification where there is an overflow of strong fuel (inadequate burning) the results of ignition are flammable gases like Carbon monoxide (CO), hydrogen (H_2) and hints of methane and non-helpful items like tar and tidy. The power production in the small scale biomass gasification plants is almost totally made via internal combustion engines (ICE). The overall system electrical efficiency

$$\eta_{elect} = \frac{P_{out} - P_{aux}}{(\text{Input biomass})_{LHV}}$$

$$\eta_{elect} = \frac{P_{net}}{(\text{Input biomass})_{LHV}}$$

P_{out} represents electrical power output of system

P_{aux} represent the power required by some of system components such as compressors, pumps, blowers, electrical generator etc

P_{net} represent the effective electrical power that the system can generate.

$(\text{Input biomass})_{LHV}$ - Input biomass Lower heating value. MJ/kg.

Diesel Generator:

Set of diesel generator is taken into account to meet out the peak load demands.