Renewable Energy Sources

Prepared by

Sourav Kumar Mishra.

Wind Energy:

Wind is simply air in motion that carries kinetic energy with it. The kinetic energy is converted into first mechanical and then electrical energy by generation. Being clean and eco-friendly, wind energy has the limitation of its intermittent nature like solar energy. Wind potential is a localized concept in comparison with solar energy. Power fluctuations due to uncertainty of wind, variations in magnitude and directions of wind velocities, structural instability due to heavy gusts and cyclonic storms are also some of the problems associated with wind-energy-conversion systems. It can be harnessed in a clean and inexhaustible manner through the application of technically advanced and efficient systems.

Wind energy conversion:

The circulation of air in the atmosphere is caused by the non-uniform heating of the earth's surface by the sun. The air immediately above a warm area expands; it is forced upwards by cool, denser air which flows in from surrounding areas causing a wind. The nature of the terrain, the degree of cloud cover and the angle of the sun in the sky are all factors which influence this process.

The energy accessible in the wind varies as the cube of the wind speed, so an understanding of the characteristics of the wind resource is critical to all aspects of wind energy exploitation.

Three factors determine the output from a wind energy converter; 1) the wind speed 2) the cross-section of wind swept by rotor; and 3) the overall conversion efficiency of the rotor,

The power in the wind is proportional to the cube of the wind speed, as given by

$$P = \frac{1}{2} C_p A \rho V^3$$

$P . S = \frac{1}{2} Cp \; A$

If

P = mechanical power in the moving air (watts),

ρ = air density (kg/m^3),

A = area swept by the rotor blades (m^2), and

V = velocity of the air (m/sec),

Here Cp is an efficiency factor called 'the power coefficient'. Note that the power P is proportional to A and to the cube of wind speed V. Thus whereas doubling A may produce twice the power, a doubling of wind speed produces eight times the power potential. The power coefficient Cp also varies with wind speed for individual machines.

Efficiency limit for wind energy conversion:

The optimum rotation rate depends on the ratio of the blade tip speed to the wind speed, so small machines rotate rapidly and large machines slowly.

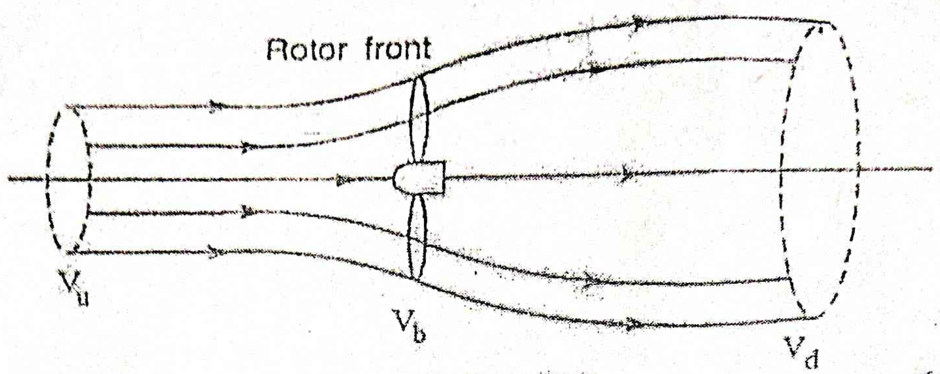
The fraction of free-flow wind power that can be extracted by a rotor is called the power co-efficient; thus

$$\text{Power coefficient} = \frac{\text{power of wind rotor}}{\text{power avialable in the wind}}$$

$$\text{or in other words} = \frac{\text{Maximum power in wind rotor}}{\text{Total power available}}$$

Where power available is calculated from air density, rotor diameter and free wind speed. The maximum theoretical power coefficient is equal to 16727 or 0.593. This value cannot be exceeded by a rotor in a free-flow wind-stream.

Bitz limit:



forces on wind turbine

Wind flow is considered incompressible and hence the air stream flow diverges as it passes through turbine. Also the mass flow rate of wind is assumed constant at far upstream and at far downstream through the rotor.

Assume,

V_b= Velocity of wind at blades at the rotor
V_u= Velocity of wind at upstream
V_d= Velocity of wind at downstream
A = Area of blades (rotor area)
M= Mass flow rate of wind
ρ = air density (kg/m^3)

Average of wind velocity at the rotor $V_b = \frac{V_u + V_d}{2}$ ---- (1)

The power output P of the wind turbine is the rate of work done, using the mass flow rate of equation,

and M = $\rho A V_b$

P = power in the upstream of wind − power in the downstream of the wind

$= \frac{1}{2}MV_u^2 - \frac{1}{2}MV_d^2$

$= \frac{1}{2}M(V_u^2 - V_d^2)$ ---- (2)

Substituting the value of M in above equ.(2)

$P = \frac{1}{2}\rho A V_b (V_u^2 - V_d^2)$ ---- (3)

Substituting the value of $V_b = \frac{V_u + V_d}{2}$ in above equation (3)

Hence, $P = \frac{1}{2}\rho A \left(\frac{V_u + V_d}{2}\right)(V_u^2 - V_d^2)$

$= \frac{1}{4}\rho A (V_u + V_d)(V_u^2 - V_d^2)$

$= \frac{1}{4}\rho A (V_u^3 - V_u V_d^2 + V_d V_u^2 - V_d^3)$ ------ (4)

For maximum turbine output P, differentiating the above equ. (4) with respect to V_d and equate to zero to obtain,

$$\frac{dP}{dV_d} = 3V_d^2 + 2V_u V_d - V_u^2 = 0$$

The above quadratic equation has two solutions, i.e. $V_d = \frac{1}{3}V_u$ and $V_d = V_u$

For power generation $V_d < V_u$ hence $V_d = \frac{1}{3}V_u$ can be substituted in equ.(4)

$= 0.593 \left(\frac{1}{2}\rho A V_u^3\right)$

We know that, total power in wind stream is $P_{Total} = \frac{1}{2}\rho A V_u^3$

Therefore, $P_{max} = 0.593\ P_{Total}$

Maximum theoretical efficiency η_{max} (also called power coefficient C_P) is the ratio of maximum output power to total power available in the wind.

Power coefficient $= C_P = \frac{P_{max}}{P_{total}} = 0.593$ (the factor 0.593 is also known as the bitz limit)

Advantages and disadvantages of wind energy system:

The advantages of wind energy systems are:

1. Wind energy is a renewable source of energy and can be tapped, free of fuel cost.
2. The wind energy based electricity produces electricity in an environmentally friendly way.
3. It can supply electric power to remote accessible areas like hilly areas.
4. Public opinion is in favour of wind technology rather than fossil fuels and nuclear power generation. People do accept a wind turbine closer to their homes comparing to the fossil fuel based systems.
5. Wind power generation is cost effective.
6. It is economically competitive with other modes of power generation.
7. Wind energy development is dynamic and an exciting addition to the landscape which increases public awareness of energy generation and conservation.
8. It is reliable and has been used for centuries.

Disadvantages:

1. Wind energy has low energy density and normally available at only selected geographical locations away from cities and load centers.
2. Wind speed being variable, wind energy is irregular, unsteady and unpredictable.
3. Wind turbine design is complex and needs more research and development work due to widely varying atmospheric conditions where these are made to operate.
4. Large units are less capital cost per kWh, but require capital intensive technology. In contrast, small units are more reliable but have higher capital cost per kWh.
5. Wind energy systems require storage batteries which contribute to environmental pollution.
6. Wind farms are established in locations of favorable wind. These locations are in open areas away from load centers. Consequently, the connection to state grid is necessary.
7. Wind energy systems are capital intensive and need government support.

Types of converters: The wind power converters are divided into two types

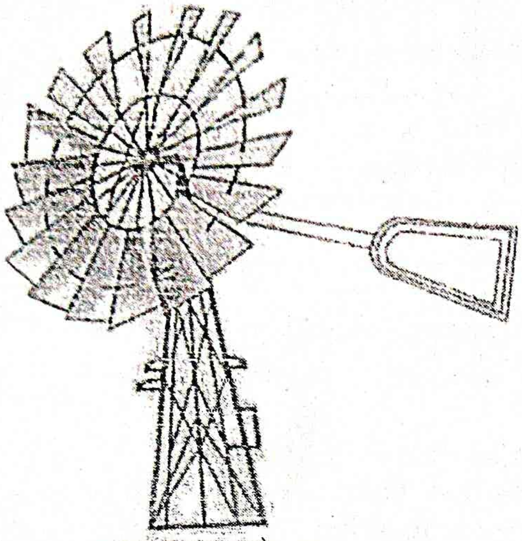
1. Horizontal axis turbines 2. Vertical axis wind turbines:

1. Horizontal axis turbines: These turbines can be further divided into three types:

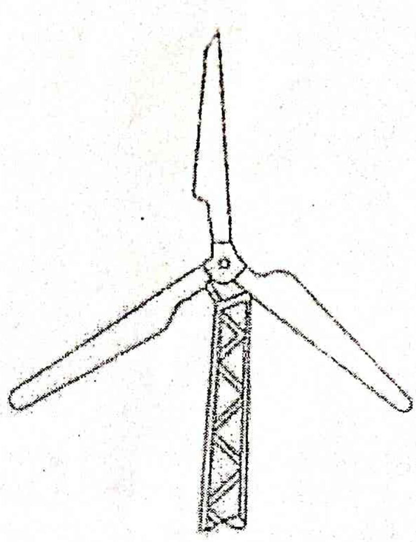
A. Dutch-type wind mills: Dutch type wind mills: Man has used Dutch type wind mills for a long time. These wind mills operated on the thrust exerted by wind. The blades generally four were inclined at an angle to the plane of rotation. The wind, being deflected by the blades, exerted a force in the direction of rotation.

B. Multi-blade type wind mills: The multi blade rotor is fabricated from curved sheet metal blades. The width of blades increases outwards from the center. Blades are fixed at their inner ends on a circular rim. They are also welded near their outer edge to another rim to provide a stable support. The number of blades used ranges from 12 to 18, as shown in fig.

Modern multi blade wind mills drive a reciprocating pump which is placed directly over the well. The criterion for site selection concerns water availability and not windiness. Therefore the mill must be able to operate at slow winds. The large numbers of blades give a high torque, required for driving a centrifugal pump, even at low winds.



Multi-blade wind mills

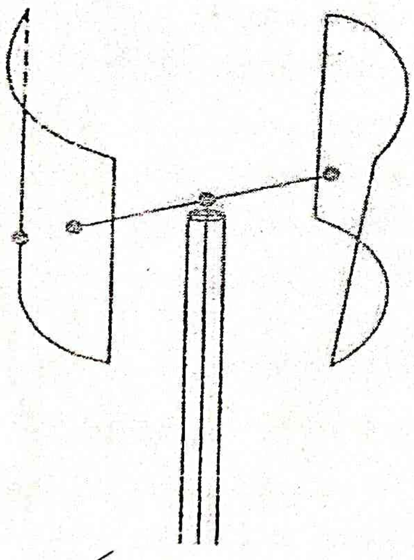


Propeller type wind mills

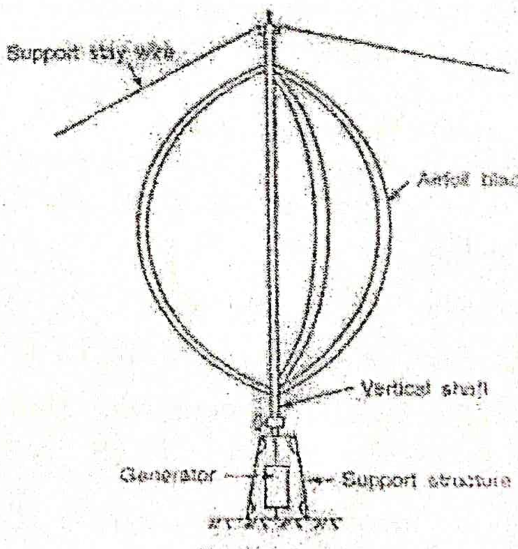
C. Propeller type wind mills: The propeller type rotor comprises two or three aerodynamic blades from strong but light weight material such as fiber glass reinforced plastic. The diameter of rotor ranges from 2m to 25m. The blade slope is designed by using the aerodynamic theory as for aircraft.

2. Vertical axis wind turbines: These types of turbines are two types:

A. The savonius rotor: The savonius rotor comprises two identical hollow semi-cylinders fixed to a vertical axis. The inner sides of two half-cylinders face each other to have an S-shaped cross section as shown in fig. Irrespective of wind direction, the rotor rotates due to pressure difference between the two sides. This rotor possesses high solidity* so as to produce a high starting torque and hence this rotor is suitable for water pumping.



Savonius rotor



Darrieus rotor

The Savinous rotor is inexpensive and simple, and the material required for it is generally available in any rural area, enabling onsite construction of such wind mills. However its utility is limited to pump the water because of its relatively low efficiency.

Solidity*: It is the ratio of the blade area to the swept area*)

Swept area*: This is the area covered by the rotating rotor)

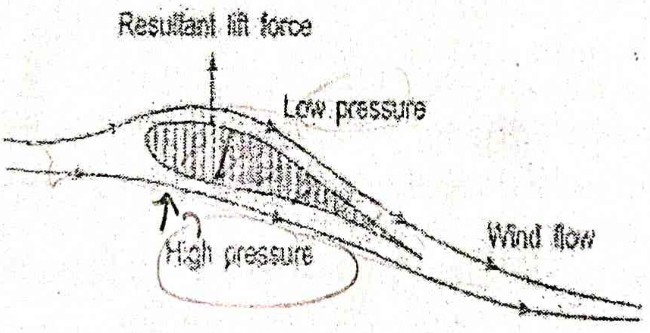
3. The darrieus rotor: This rotor has two or three thin curved blades of flexible metal strips. It looks like an egg beater and operates with the wind coming from any direction. Both the ends of the blades are attached to a vertical shaft as shown in fig. Lift is the driving force, creating maximum torque when the blade moves across the wind.

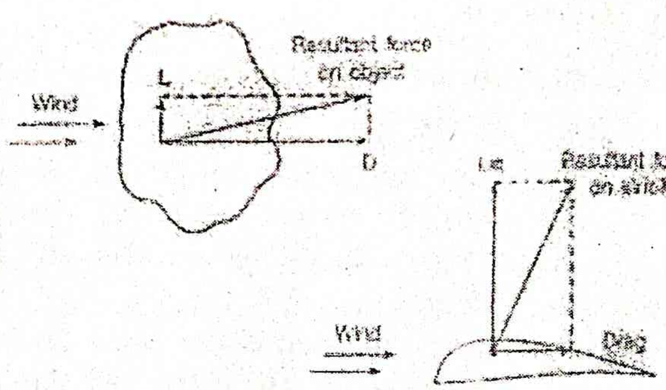
The Darrieus rotor, with its high efficiency and high speed, is perfectly suited for electrical power generation. The cost of construction is low because the generator and the gear assembly can be located at ground level, drastically reducing the cost of the tower. However, then it is unable to take advantage of the high wind speeds available at higher altitudes.

Di erences between HAWT and VAWT:

S.N.	Performance parameter	HAWT	VAWT
1	Power genera on e dency	50-60%	Above 70%
2	Electromagne c interference	Yes	No
3	Steering mechanism of the Wind	Yes	No
4	Gear box	Above 10KW: Yes	No
5	Blade rota on space	Quite large	Quite small
6	Noise	5-60 dB	0-10dB
7	Star ng wind speed	High (2.5-5 m/sec)	Low (1.5 -3 m/sec)
8	Failure rate	High	Low
9	Maintenance	complicated	Convenient
10	Rota ng speed	high	Low
11	E ect on birds	More	Less
12	Cable connec ons	Di cult	Easy

Aerodynamics of wind rotors: Aerodynamics deals with the movement of solid bodies through the air. In wind turbines, aerodynamics provides a method to explain the relative motion between airfoil and air. Airfoil is the cross-section of the wind turbine blade. When the wind passes over the surface of the rotor blade, it automatically passes over the longer or upper side of the blade, creating a low pressure area above the airfoil as shown in fig.



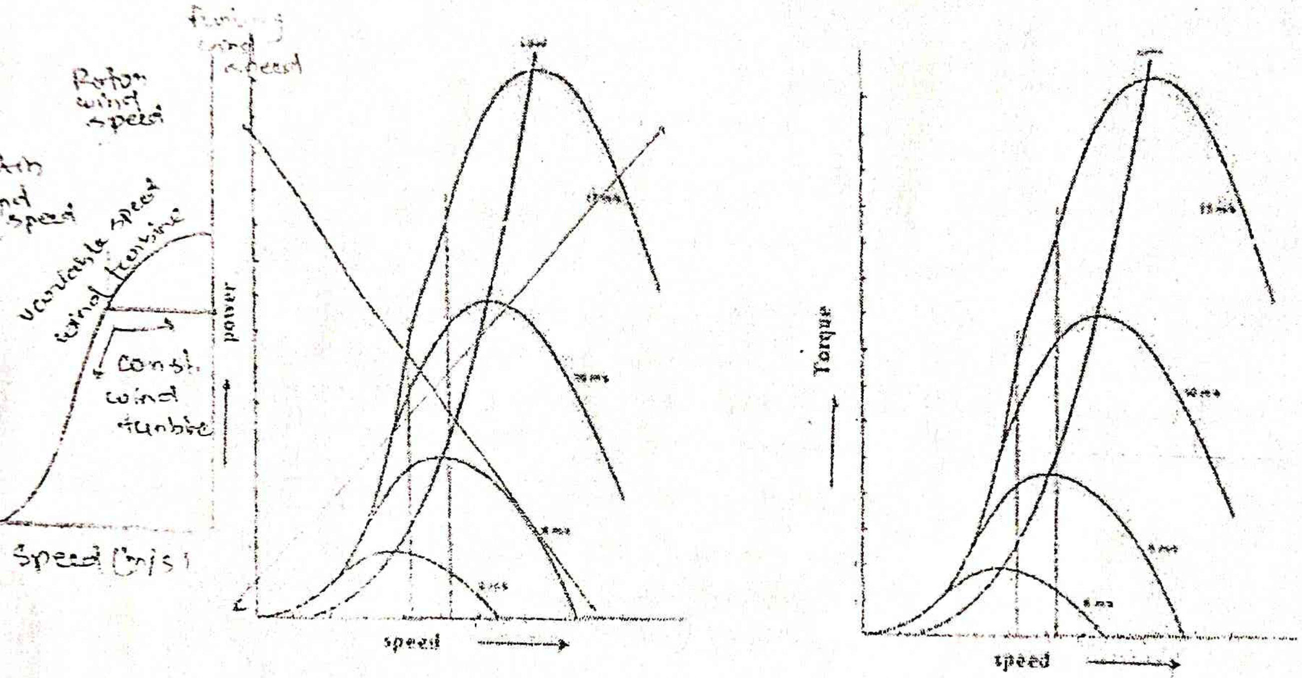


The pressure difference between the top and bottom surfaces results in a force called the aerodynamic lift that causes the airfoil to rise. As the blades can only move in a plane with the hub as their center, the lift force causes rotation about the hub. The turbine thus extracts energy from the wind stream by converting the winds linear kinetic energy into rotational motion. In addition to lift force, a drag force perpendicular to the lift force also acts on the blade which impedes rotor rotation. The prime objective in wind turbine blade design is the desired lift-to-drag ratio of the blade.

Power VS speed characteristics of wind turbines: The wind turbine power curves shown in fig. illustrate how the mechanical power that can be extracted from the wind depends on the rotor speed ($P = \frac{1}{2} C_p A \rho V^3$). For each wind speed there is an optimum turbine speed at which the extracted wind power at the shaft reaches its maximum.

Torque VS Speed characteristics of wind turbines:

Fig. shows the propeller turbine for any wind speed, the torque reaches a maximum value at a specific rotational speed, and this maximum shaft torque varies approximately as the square of the rotational speed. In the case of electricity production, the load torque depends on the electrical loading, and by properly choosing the load, the torque can be made to vary as the square of the rotational speed.



- **Wind turbine control systems:** Wind turbines require certain control systems. Horizontal axis wind turbines have to be oriented to face the wind. In high winds, it is desirable to reduce the drive train loads and protect the generator and the power electronic control equipment from overloading.

The following are the some of the control strategies for the turbine control systems:

- 1. Pitch angle control: This system changes the pitch angle of the blades according to the variation of the wind speed. On pitch-controlled machine, as the wind speed exceeds its rated speed, the blades are gradually turned about the longitudinal axis and out of the wind to increase the pitch angle This reduces the aerodynamic efficiency of the rotor, and the rotor output power decreases. When the wind speed exceeds the safe limit of the system, the pitch angle is so changed that the power output reduces to zero and the machine shifts to the "stall" mode. After the heavy wind passes, the pitch angle is reset to the normal position and the turbine is restarted The pitch angle control arrangement is shown in fig. The input variable to the pitch controller is the error signal arising from the difference between the output electrical power and the reference power. The pitch controller operates the blade actuator to alter the pitch angle. During operation below the rated speed the control system activities to pitch the blade at an angle that maximizes the rotor efficiency. The generator must be able to absorb the mechanical power output and deliver to the load. Hence, the generator output power needs to be simultaneously adjusted.

Yaw control This control orients the turbine continuously along the direction of wind flow. In small turbines this is achieved with a tail-vane In large machines this can be achieved using motorized control systems activated either by a fan tail (a small turbine mounted erpendicular to the main turbine). Yawing produces a loud noise, and it is desirable to estrict the Yaw control in large machines to reduce the noise.

Power electronic control: (Note: this method explained in double output system of Induction generator)

Conversion to electrical power: By nature, wind is not a steady state source of energy, therefore, it cannot run to meet the needs of the consumers at all times. Necessarily, it has to be integrated with other source to provide a constant backup. Wind electric generators operate in one of the following three modes.

i) Standalone mode ii) backup mode like wind-diesel iii) Grid-connected mode.

i) Standalone mode: This type of wind generator represents decentralized power generation where an individual consumer or a group of consumers install their own wind turbine. The generating capacity of the wind turbine is matched with the energy requirement. The two most promising applications of the wind energy conversion systems are:

a) Power supply for domestic use and battery charging:
A wind turbine coupled with generator of a capacity of 2.5kw to 5kw is useful for domestic power supply. It operates independently with battery and its charging equipment is as shown in fig. such installations are useful for remote mountainous regions where the extension of grid or supply of oil is difficult. In this type of wind turbines electric power can be produced at controlled frequency. As the wind changes speed the pitch of the blades so adjusted to control the frequency of turbine rotation. The power can be given to the domestic loads with a battery connected to an inverter.

b) Windmill water pump for irrigation and drinking purposes: A wind mill water pump comprises a wheel with pressed steel blades secured to a shaft. The wind mill is mounted on the top of the steel tower. The rotary motion of the wind mill is converted into reciprocating motion to pump the water.

c) Backup mode like wind-diesel: Wind energy being an intermittent, requires a backup of diesel generator to maintain a 24-hour power supply. In areas inaccessible to grid power, the emergency loads of hospitals, defense installations and communication services are met with a wind-diesel hybrid system, while the general loads of domestic and commercial establishments are fed by wind turbine systems.

d) Grid connected mode: This type of wind generator represents power generation where the wind generating system is synchronized directly to grid. The generating frequency of the wind turbine is matched with the grid frequency. This type of system is generally applicable to large type of power generating wind turbines.

Induction generators and synchronous generators:

Induction generators:

The induction AC generator is strictly an induction machine, since the same device can be a motor or a generator. This generality of design allows induction generators to be cheaper than synchronous generators. The usual arrangement is that the stator windings (coils) are connected to the AC grid, so producing a rotating magnetic field around the shaft of the machine

The key component of the asynchronous generator is the squirrel cage rotor. It is the rotor that makes the asynchronous generator different from the synchronous generator. The rotor consists of a number of copper or aluminium bars which are connected electrically by aluminium end rings. The rotor is placed in the middle of the stator, which in this case, once again is a 4 pole stator which is directly connected to the three phases of the electrical grid.

One reason for choosing this type of generator is that it is very reliable and tends to be comparatively inexpensive. The generator also has some mechanical properties which are useful for wind turbines, like the generator slip and a certain overload capability.

When the supply is connected, the machine will start turning like a motor at a speed which is just slightly below the synchronous speed of the rotating magnetic field from the stator and there is a magnetic field which moves relative to the rotor. This induces a very strong current in the rotor bars which offer very little resistance to the current, since they are short circuited by the end rings. The rotor then develops its own magnetic poles, which in turn become dragged along by the electromagnetic force from the rotating magnetic field in the stator.

Since the magnetic field rotates at exactly the same speed as the rotor, there will be no induction phenomena in the rotor and it will not interact with the stator. If speed is increased above 1500 rpm then the rotor moves faster than the rotating magnetic field from the stator, which means that once again the stator induces a strong current in the rotor. The more the speed of the rotor, the more power will be transferred as an electromagnetic force to the stator, and in turn converted to electricity which is fed into the electrical grid.

Synchronous generators:

An alternator or synchronous generator is an electromechanical device that converts mechanical energy to electrical energy in the form of alternating current.

Most alternators use a rotating magnetic field with a stationary armature but occasionally, a rotating armature is used with a stationary magnetic field; or a linear alternator is used.

Alternators generate electricity using the same principle as DC generators, typically, a rotating magnet, called the rotor turns within a stationary set of conductors wound in coils on an iron core, called the stator. The field cuts across the conductors, generating an induced EMF (electromotive force), as the mechanical input causes the rotor to turn.

The rotating magnetic field induces an AC voltage in the stator windings Often there are three sets of stator windings, physically offset so that the rotating magnetic field produces a three phase current, displaced by one-third of a period with respect to each other.

Usually they run at synchronous speed and require DC field excitation.

Differences between Synchronous and Induction generators:

	Synchronous generators	Induction generators
1	Synchronous generator generates the power only at synchronous speed	Induction generator generates the power only at asynchronous speed.
2	Induction generator needs AC supply for its excitation	Synchronous generator requires DC supply for excitation purpose.
3	They require brushes and hence brush maintenance	They don't require brushes and thus no brush maintenance
4	Cost is high	Costs less
5.	No complicated circuit for filed excitation	Asynchronous generators require relatively complicated electronic controllers for excitation.

Grid connected and self excited induction generator operation:

There are two ways of exciting an induction generator. Based on the excitation induction generators are classified into two basic categories:

1. Constant voltage, Constant frequency generators
2. Variable voltage, variable- frequency generators

Constant- voltage, Constant-frequency generators: The generators derives its excitation rom the utility bus as shown in fig.(a). The generated power is fed to the supply system when the rotor is driven above synchronous speed. Machines with a cage type rotor feed only through the stator and generally operate at negative slip. But wound rotor machines can feed power through the stator as well as the rotor to the bus over a wide speed range.

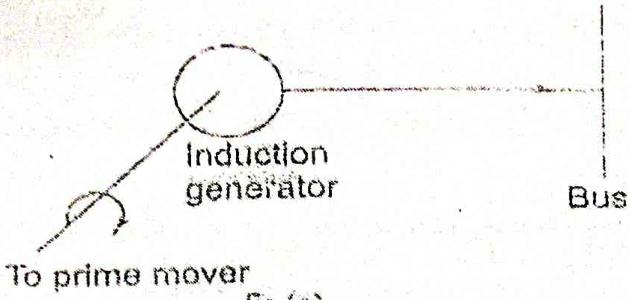
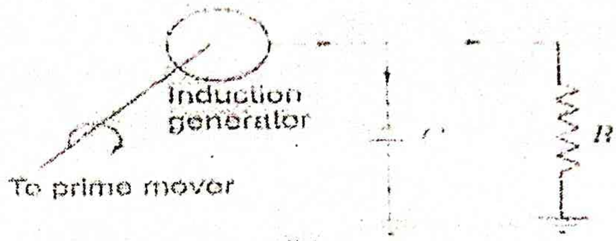


fig.(a)



(b)

2) Variable-voltage, variable-frequency generators: Here a set of capacitor banks are connected across the induction machine, helps build up the terminal voltage as shown in fig. But the building up of the voltage also depends on factors such as speed, capacitor value, and load. The squirrel cage induction machine is generally used as a self excited induction generator.

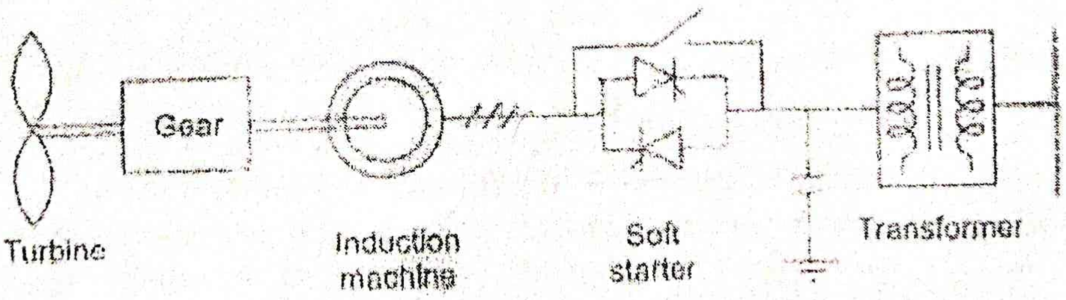
Constant voltage and constant frequency generation with power electronic control:

As induction machine in the generating mode operates fundamentally in the same manner as in the motoring mode except for the reversal of power flow. The stator winding remaining to connect to the utility grid, if the rotor is driven by a prime mover above the synchronous speed in the direction of the air gap field, the mechanical power of the prime mover is converted into electrical power.

The type of power generation in constant voltage and constant frequency can be divided into single output system and double output system. The power conversion will be done by using the power electronic control which will be easily operated and connected to the grid.

Single output systems:

The wind power system in this type uses the squirrel cage induction generator, which provides the power output only through the stator winding. As shown in fig. a grid-connected squirrel cage induction generator coupled to a turbine through a gear box. The gear steps up the rotor speed to a value matching a 50 Hz frequency with the utility grid. Because of its coupling to the grid, the speed varies over a very small range above synchronous speed, usually around 1 %.



In a pitch-regulated system the electrical output power regulated by a control system, which alters the blade pitch angle to extract the maximum energy at wind speeds below the rated wind speed; the power output is governed towards a limiting value at wind speeds above the rated speed.

Usually, the turbine accelerates the induction machine to synchronous speed using wind power; the machine is then connected to the grid. To limit the sudden inrush currents, soft-start circuits utilizing phase controlled anti- parallel thyristors are frequently employed to he most common approach of the reactive power compensation is connecting the capacitor banks to the utility system where the wind turbines are connected.

We know, $P = VI\cos\theta$

$$I = \frac{P}{V\cos\theta}$$

Hence, if the value of $\cos\theta$ decreases current 'I' will increase, and subsequently I^2R losses will increases. Finally it will reduce the terminal voltage of the induction generators. Therefore to offset the value of reactive power the capacitor banks are used in wind operated induction generators.

Characteristics of wind power plant:

All wind machines share certain operating characteristics, such as cut-in, rated and cut-out wind speeds.

Cut-in Speed

Cut-in speed is the minimum wind speed at which the blades will turn and generate usable power. This wind speed is typically between 10 and 16 kmph.

Rated Speed

The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power. For example, a "10 kilowatt" wind turbine may not generate 10 kilowatts until wind speeds reach 40 kmph. Rated speed for most machines is in the range of 40 to 55 kmph. At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases. The output of most machines levels off above the rated speed. Most manufacturers provide graphs, called "power curves," showing how their wind turbine output varies with wind speed.

Cut-out Speed

At very high wind speeds, typically between 72 and 128 kmph, most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed. Having a cut-out speed is a safety feature which protects the wind turbine from damage. Shut down may occur in one of several ways. In some machines an automatic brake is activated by a wind speed sensor.

Betz Limit (power coefficient)

It is the flow of air over the blades and through the rotor area that makes a wind turbine function. The wind turbine extracts energy by slowing the wind down. The theoretical maximum amount of energy in the wind that can be collected by a wind turbines rotor is approximately 59.3%. In practice, the collection efficiency of a rotor is not as high as 59.3%. A more typical efficiency is 35% to 45%. A complete wind energy system, including rotor, transmission, generator, storage and other devices, which all have less than perfect efficiencies, will deliver between 10% and 30% of the original energy available in the wind.

Wind Power

The wind power is generated due to the movement of wind. The energy associated with such movement is the kinetic energy and is given by the following expression:

$$P = \frac{1}{2} C_p A\rho V^3$$

Thus whereas doubling A may produce twice the power, a doubling of wind speed produces eight times the power potential. The power coefficient Cp also varies with wind speed for individual machines.

Capacity factor: The capacity factor of a wind turbine is the actual energy output of a wind turbine during a given time period, usually one year, compared to its theoretical maximum output [illegible]

The capacity factor (CF) is

CF = [illegible] / ([illegible] plate rating [illegible])

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<u>Capacity factor:</u> The capacity factor of a wind turbine is the actual energy output of a wind turbine during a given time period, usually one year, compared to its theoretical maximum energy output.

The capacity factor is (CF) is

$$CF = \frac{KWh\ produced}{8760 \times name\ plate\ rating\ of\ wind\ turbine\ kW}$$

Applications of wind power: There are various applications of wind energy such as water pumping, milling grains, mechanical power, sailing etc., however, the most predominant use of wind energy is the power generation. Modern wind mills are normally called as wind turbines are also called as wind energy conversion systems, and those used to generate electricity are described as wind energy conversion systems.

Pumping applications: Wind mills are extensively used for pumping applications where low wind speeds are available and loads are isolated from power supplies.

Direct heat applications: Mechanical motion derived from wind power can be used to drive heat pumps or to produce heat. Examples of possible wind powered agricultural process heat applications include green house applications, crop drying, milk processing, ventilation etc.,

Electric power generation applications: Wind power can be used in centralized utility applications to drive synchronous a.c. electrical generators. Most of the wind power systems are integrated with other type of power generating units(solar, hydro, biomass, biogas, Diesel generator) called hybrid systems; which will increase the reliability of the system.

Examination Questions: (NOV 2012)

1. Derive the expression for power extracted from wind. What is the maximum theoretical power that can be extracted from wind and under what condition?(10 marks)
2. What are the differences between single output and double output induction generator (DOIG) system? Explain with schematic block diagram, the functionalities and operations of various components of DOIG as applied to grid connected wind energy generating system (10 marks)

Examination Questions: (NOV 2013):

1. Draw and label an airfoil of the blade of a WECS (2 Marks)
2. Explain the design specialty of an air foil to produce a higher lift force? (2 Marks)
3. Explain the aerodynamics operation in a wind turbine? Taking a Darrieus rotor justify the resultant rotational force developed on the blade is unidirectional. Use suitable vector diagrams to explain (10 marks)

Examination Questions: (Back/Special 2013):

1. What is betz limit? (2 Marks)
2. Derive the efficiency limit for wind energy conversion(2 Marks)
3. Write down the differences between HAWT and VAWT (5 Marks)
4. Draw the neat diagram of HAWT and explain its components (5 Marks)

Other Important questions:

1. Explain about Peltier cooling
2. Write short notes on solar radiation and spectral composition of solar radiation
3. What are the advantages and disadvantages of wind power?
4. Explain about the types of wind rotors and explain each of the rotors
5. Explain the torque Vs speed and Power vs speed characteristics of wind turbines
6. Explain about single and double output systems
7. Write short note on reactive power compensation of wind turbines, wind power characteristics, wind power applications
8. What are the various methods of wind turbines controls?
9. What are the differences between synchronous and induction generators
10. Explain about constant voltage and constant frequency wind generators

Module III

Biomass Power: Biomass refers to solid carbonaceous material derived from plants and animals. These include residues of agriculture and forestry, animal waste and discarded material from food processing plants.

The material of plants and animals, including their wastes and residues, is called biomass. It is organic, carbon-based, material that reacts with oxygen in combustion and natural metabolic processes to release heat. Such heat, especially if at temperatures of above 400^{0}C, may be used to generate work and electricity. The initial material may be transformed by chemical and biological processes to produce bio fuels, i.e. biomass processed into a more convenient form, particularly liquid fuels for transport. Examples of biofuels include methane gas, liquid ethanol, methyl esters, oils and solid charcoal. The term Bioenergy is sometimes used to cover biomass and bio fuels together.

Advantages of Bioenergy:

1. The initial investment is comparatively low, compared to other methods, since sophisticated or expensive equipment is not needed.
2. Processing biomass for fuel from sewage and wastes reduces the environmental hazards.
3. The techniques for raising such plants are simple and similar to conventional agriculture. Hence they can be readily used in the rural areas of developing countries.
4. Small units can be located near to the accumulation of waste; hence accumulation waste in those areas can be minimized.
5. The by-products of such system can be easily recyclable and used as fertilizers for plants.
6. The methods of power productions are relatively low polluting.
7. Bio-gas can be distributed through pipes for domestic use and it can be stored in a container which can transfer to consumers.
8. In rural areas hygienic and sanitation conditions are improved.

Disadvantages and limitations:

1. The land area required is relatively large and hence this method is ruled out for areas where land cost is high.
2. Collection and transportation of biomass become expensive due to high moisture contents.
3. Since the gas cannot liquefied ordinarily there is storage problems, it cannot be bottled like LPG into cylinder.
4. Relatively low concentration of biomass per unit area of land.
5. Requires regular maintenance

Operating principle:

The initial energy of the biomass-oxygen system is captured from solar radiation in photosynthesis. When released in combustion the biofuel energy is dissipated, but the elements of the material should be available for recycling in natural ecological or agricultural processes.

Biomass being organic matter from terrestrial and marine vegetation renews naturally in a short span of time, thus classified as a renewable source of energy. It is a derivative of solar energy as plants grow by the process of photosynthesis by absorbing CO_2 from the atmosphere to form hexose(dextrose, glucose, etc.,) expressed by the relation

$$6CO_2 + H_2O \xrightarrow[\text{photosynthesis}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

Biomass does not add CO_2 to the atmosphere as it absorbs the same amount of carbon in growing the plants as it releases when consumed as fuel. It is a superior fuel as the energy produced from biomass is carbon neutral.

Combustion and fermentation:

Combustion: Direct combustion is the main process adopted for utilizing biomass energy. It is burnt to produce heat utilized for cooking, space heating, industrial processes and for electricity generation. This utilization method is very inefficient with heat transfer losses of 30-90% of the original energy contained in the biomass. The losses can be prevented by using efficient cook-stove for burning solid fuels.

The direct combustion of biomass is the simplest method of utilization of this material to produce heat. This method is known as the thermo-chemical method of bioconversion. In most developing countries, biomass combustion provides the largest component of total national fuel use. This is due to the extensive use of firewood for cooking and occasional heavy industrial use of biomass for sugarcane milling, tea drying, oil-palm processing and paper making.

The various applications include:

a) Domestic cooking and heating B) Crop drying C) Process heat and electricity

a) Domestic cooking and heating: Biomass is burnt to provide heat for cooking, comfort heat (space heat), crop drying, factory processes and raising steam for electricity production and transport. Traditional use of biomass combustion includes (a) cooking with firewood, with the latter supplying about 10-20% of global energy use (a proportion extremely difficult to assess) and (b) commercial and industrial use for heat and power, e.g. for sugarcane milling, tea or copra drying, oil palm processing and paper making. Efficiency and minimum pollution is aided by having dry fuel and controlled, high temperature combustion.

Efficiently burnt dry wood, in which the initially produced un burnt gases and tars burn in a secondary reaction, emits only CO_2 and H_2O with fully combusted ash.

Cooking efficiency and facilities can be improved by

1. Using dry fuel.
2. Introducing alternative foods and cooking methods, e.g. steam cookers.
3. Decreasing heat losses using enclosed burners or stoves, and well-fitting pots with lids.
4. Facilitating the secondary combustion of un burnt flue gases.
5. Introducing stove controls that are robust and easy to use.
6. Explanation, training and management.

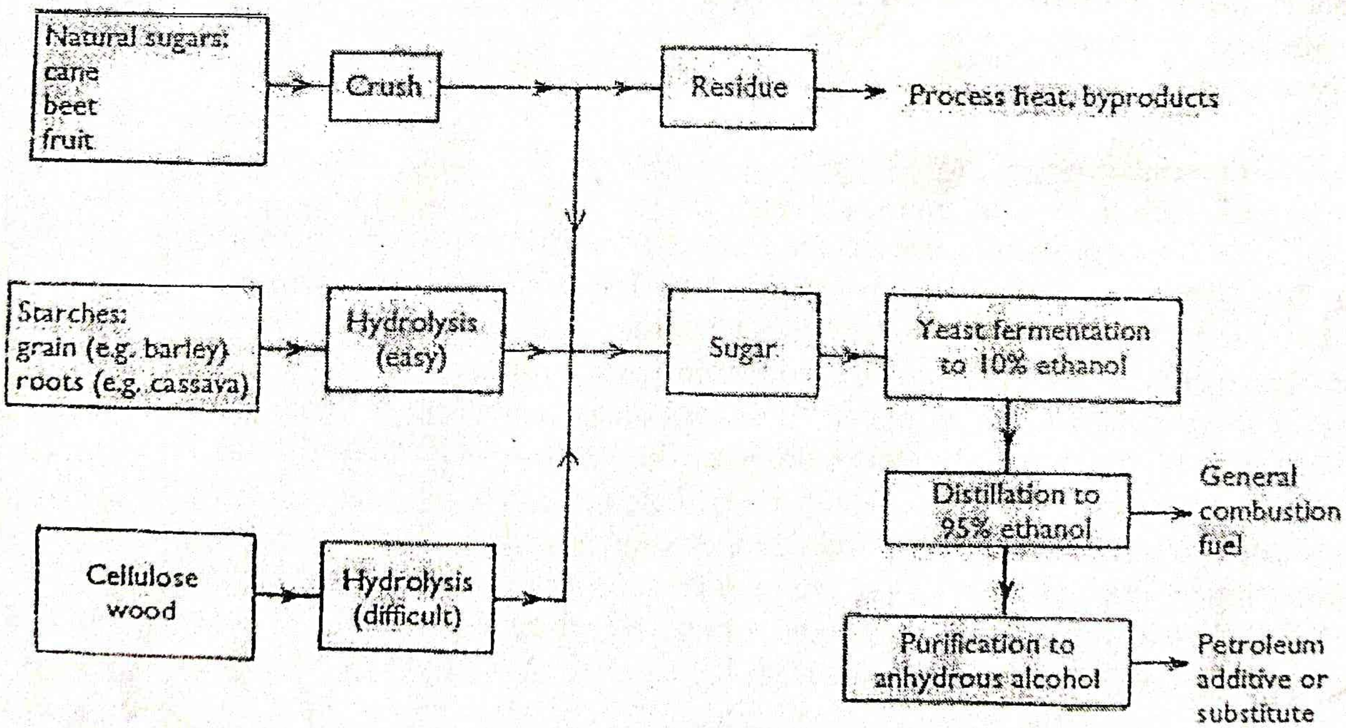
b) Crop drying: The drying of crops (e.g. fruit, copra, cocoa, coffee, tea), for storage and subsequent sale, is commonly accomplished by burning wood and the crop residues, or by using the waste heat from electricity generation. The material to be dried may be placed directly in the flue exhaust gases, but there is a danger of fire and contamination of food products. More commonly air is heated in a gas/air heat exchanger before passing through the crop. Combustion of residues for crop drying is a rational use of biofuel, since the fuel is close to where it is needed.

C) Process heat and electricity: Steam process heat is commonly obtained for factories by burning wood or other biomass residues in boilers, perhaps operating with fluidized beds. It is physically sensible to use the steam first to generate electricity before the heat degrades to a lower useful temperature. The efficiency of electricity generation from the biomass may be only about 20-25% due to low temperature combustion, so 75-80% of the energy remains as process heat and a useful final temperature is maintained. Frequently the optimum operation of such processes treats electricity as a by-product of process heat generation, with excess electricity being sold to the local electricity supply agency, as in modern sugarcane mills. Perhaps the easiest way to use energy crops and biomass residues is co-firing in coal-burning power stations. The combustion method is adapted for the known mixture of coal and biomass. Such substitution (abatement) of coal may be one of the most effective ways for biomass to reduce greenhouse gas emissions.

Fermentation: Fermentation is the breakdown of complex molecules in organic compound under the influence of yeast, bacteria, enzymes etc., Fermentation is a well established and widely used technology for the conversion of grains and sugar crops into Ethanol. Ethanol is a volatile liquid fuel that may be used in place of refined petroleum. It is manufactured by the action of micro-organisms and is therefore a fermentation process. Ethanol has emerged as the major alcohol fuel and is blended with petrol.

Ethanol production and use:

Ethanol, C_2H_5OH, is produced naturally by certain micro-organisms from sugars under acidic conditions, i.e. pH 4 to 5. This alcoholic fermentation process is used worldwide to produce alcoholic drinks. The most common micro-organism, the yeast Saccharomyces cerevisiae, is poisoned by C_2H_5OH concentration greater than 10%, and so stronger concentrations up to 95% are produced by distilling and fractionating (below Figure). When distilled, the remaining constant boiling point mixture is 95% ethanol and 5% water. Anhydrous ethanol is produced commercially with azeotropic removal of water by co-distillation with solvents such as benzene. Only about 0.5% of the energy potential of the sugars is lost during fermentation, but significant amounts of process heat are required for the concentration and separation processes. This process heat may be provided from the combustion or gasification of otherwise waste biomass and from waste heat recovery.



Ethanol production

The sugars may be obtained by the following routes, listed in order of increasing difficulty.

1. Directly from sugarcane: Usually commercial sucrose is removed from the cane juices, and the remaining molasses used for the alcohol production process. These molasses themselves have about 55% sugar content. But if the molasses have little commercial value, then ethanol production from molasses has favorable commercial possibilities, especially if the cane residue (bagasse) is available to provide process heat. In this case the major reaction is the conversion of sucrose to ethanol:

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{yeast} 4C_2H_5OH + 4CO_2$$

In practice the yield is limited by other reactions and the increase in mass of yeast. Commercial yields are about 80% of those predicted by above equation. The fermentation reactions for other sugars, e.g. glucose, $C_6H_{12}O_6$, are very similar.

2. From sugar beet: Sugar beet is a mid-latitude root crop for obtaining major supplies of sugar. The sugar can be fermented, but obtaining process heat from the crop residues is, in practice, not as straightforward as with cane sugar, so ethanol production is more expensive.

3. From starch crops. Starch crops, e.g. grain and cassava, can be hydrolyzed to sugars. Starch is the main energy storage carbohydrate of plants, and is composed of two large molecular weight components, amylose and amylopectin. These relatively large molecules are essentially linear, but have branched chains of glucose molecules linked by distinctive carbon bonds. These links can be broken by enzymes from malts associated with specific crops, e.g. barley or corn, or by enzymes from certain moulds (fungi). Such methods are common in whisky distilleries, corn syrup manufacture and ethanol production from cassava roots.

Anaerobic digester:

Anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste and/or to produce fuels. Much of the fermentation used industrially to produce food and drink products, as well as home fermentation, uses anaerobic digestion.

The digestion process begins with bacterial hydrolysis of the input materials. Insoluble organic polymers, such as carbohydrates, are broken down to soluble derivatives that become available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. These bacteria convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. It is used as part of the process to treat biodegradable waste and sewage sludge. As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere.

Anaerobic digestion is widely used as a source of renewable energy. The process produces a biogas, consisting of methane, carbon dioxide and traces of other 'contaminant' gases. This biogas can be used directly as fuel, in combined heat and power gas engines or upgraded to natural gas-quality biomethane. The nutrient-rich digestate also produced can be used as fertilizer.

With the re-use of waste as a resource and new technological approaches which have lowered capital costs, anaerobic digestion has in recent years received increased attention among governments in a number of countries to support the renewable energy sources against to the escalating prices of petroleum products.

Anaerobic digester (commonly referred to as an AD) is a device that promotes the decomposition of manure or "digestion" of the organics in manure to simple organics and gaseous biogas products. Biogas is formed by the activity of anaerobic bacteria. Microbial growth and biogas production are very slow at ambient temperatures. These bacteria occur naturally in organic environments where oxygen is limited. Biogas is comprised of about 60% methane, 40% carbon dioxide, and 0.2 to 0.4% of hydrogen sulfide. Manure is regularly put into the digester after which the microbes break down the manure into biogas and a digested solid. The digested manure is then deposited into a storage structure. The biogas can be used in an engine generator or burned in a hot water heater. AD systems are simple biological systems and must be kept at an operating temperature of 100 degrees F in order to function properly.

There are two major types of biogas designs promoted in India
1. Floating Drum
2. Fixed Dome

The floating drum is an old design with a mild-steel, Ferro-cement or fiberglass drum, which floats along a central guide frame and acts as a storage reservoir for the biogas produced. The fixed dome design is of Chinese origin and has dome structure made of cement and bricks. It is a low-cost alternative to the floating drum, but requires high masonry skills and is prone to cracks and gas leakages. Family biogas plants come in different size depending on the availability of dung and the quantity of biogas required for cooking. The average size of the family is 5-6 persons, and thus biogas plant of capacity 2-4 m^3 is adequate. The biomass requirement is estimated to be 1200 liters for a family.

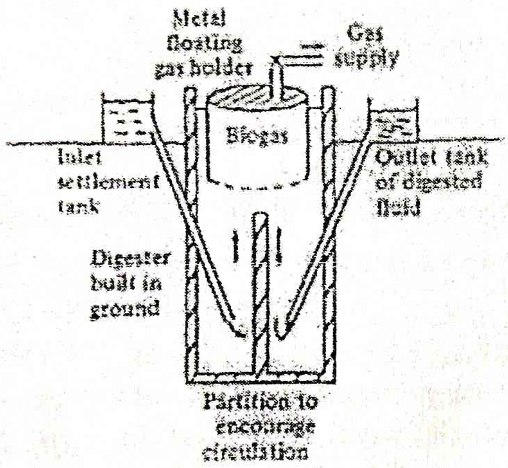
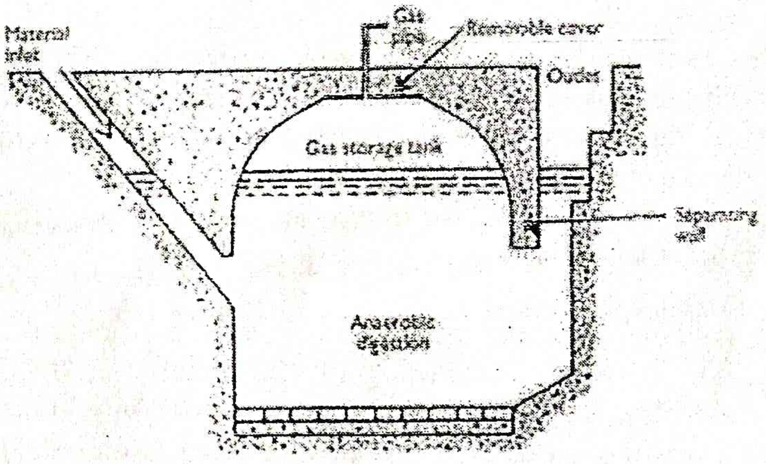


Fig.1 : Floating drum



2. Fixed Drum

Indian gobar gas system: This design will come under the category of Floating drum. Gobar means cow dung, mainly used for this system. The fig.1 shows the principles of the method. Material is placed in the inlet settlement tank to separate out non-digestible straw and inclusions. The flow moves slowly through the buried brick tank in about 14–30 days to the outlet, from which nutrient-rich fertilizer is obtained. Gas pressure of 10cm water column is maintained by the heavy metal gas holder, which is the most expensive item of the design. The holder is lifted regularly (approximately six-monthly intervals) so that any thick scum at the top of the fluid can be removed. Daily inspection of pipes, etc. and regular maintenance are essential. Lack of maintenance is the predominant reason for the failure of biogas digesters generally.

Chinese digester: This design will come under the category of fixed drum. The main feature of the design is the permanent concrete top which enables pressurized gas to be obtained. The flow moves slowly through the buried brick tank in about 14–30 days to the outlet, from which nutrient-rich fertilizer is obtained. As the gas evolves its volume replaces digester fluid and the pressure increases. Frequent (daily) inspection of pipes, etc. and regular maintenance are essential to avoid clogging by non-digestible material.

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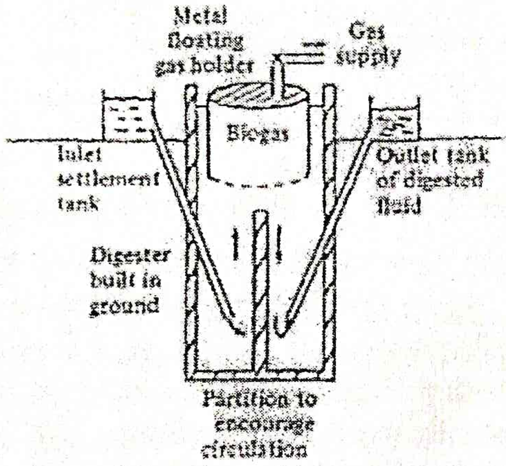

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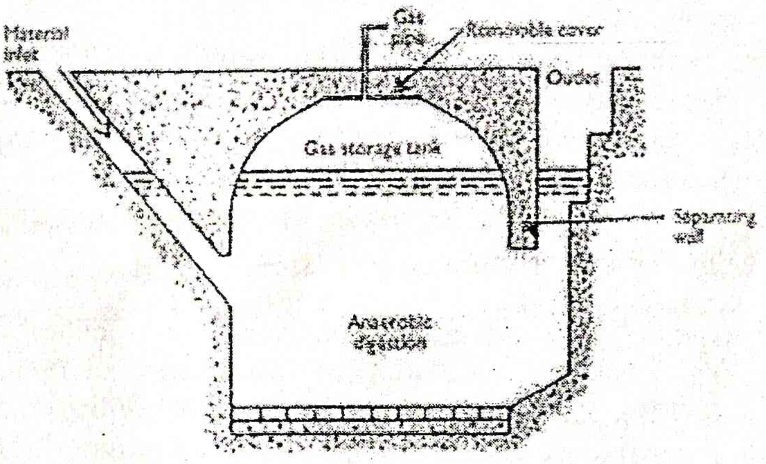

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Applications of Anaerobic digestion:

Using anaerobic digestion technologies can help to reduce the emission of greenhouse gases in a number of key ways:

- Replacement of fossil fuels
- Reducing or eliminating the energy footprint of waste treatment plants
- Reducing methane emission from landfills
- Displacing industrially produced chemical fertilizers
- Reducing vehicle movements
- Reducing electrical grid transportation losses
- Reducing usage of LP Gas for cooking

Bio gas:

Biogas typically refers to a gas produced by the breakdown of organic matter in the absence of oxygen. It is a renewable energy source, like solar and wind energy. Furthermore, biogas can be produced from regionally available raw materials such as recycled waste and is environmentally friendly.

Biogas is produced by anaerobic digestion with anaerobic bacteria or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops. Biogas comprises primarily of methane and carbon dioxide and may have small amounts of hydrogen sulphide and moisture.

The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel. Biogas can be used as a fuel for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.

Biogas can be compressed, the same way natural gas is compressed to CNG, and used to power motor vehicles.

Wood gassifier: A wood gas generator is a gasification unit which converts timber or charcoal into wood gas, consisting of atmospheric nitrogen, carbon monoxide, hydrogen, traces of methane, and other gases, which - after cooling and filtering - can then be used to power an internal combustion engine or for other purposes. Historically wood gas generators were often mounted on vehicles, but present studies and developments concentrate mostly on stationary plants.

Advantages:

Wood gas generators have a number of advantages over use of petroleum fuels:

1. They can be used to run internal combustion engines (or gas turbines, for maximal efficiency) using wood, a renewable resource, and in the absence of petroleum or natural gas, for example, during a fuel shortage.
2. They have a closed carbon cycle, contribute less to global warming, and are sustainable in nature.
3. They can be relatively easily fabricated in a crisis using materials on hand.
4. They are far cleaner burning than a wood fire or a gasoline-powered engine.
5. When used in a stationary design, they reach their true potential, as they are feasible to use in small combined heat and power scenarios.

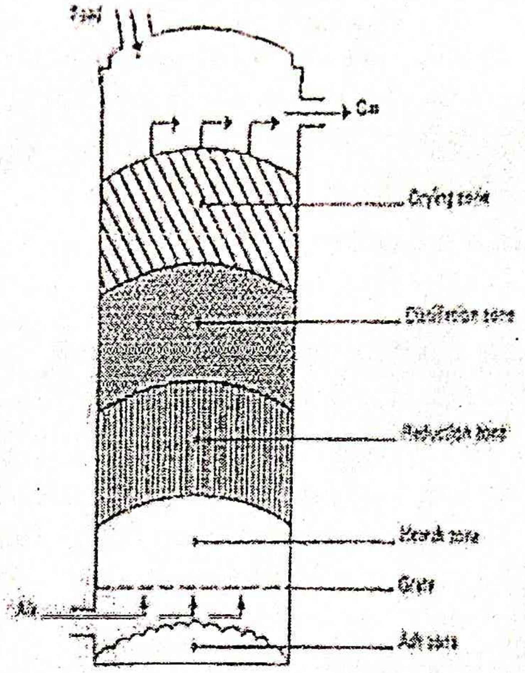
Disadvantages:

The disadvantages of wood gas generators are:

1. The large specific size
2. Relatively slow starting speed; the time to heat the initially cold batch of wood to the necessary temperature level can take many minutes and in bigger plants even hours until the designed power is reached

3. The primary combustible fuel-gas produced during gasification is carbon monoxide: it is an intentional fuel-product, and is subsequently burned to safe carbon dioxide in the engine (or other application) along with the other fuel-gases; however, continuous exposure to carbon-monoxide can be fatal to humans even in small to moderate concentrations.

One of the gassifier model widely which used is known as a counter-flow gassifier. It was the natural evolution from charcoal kilns. In this type of gassifier, the air enters at the bottom. The producer gas is drawn off at the top. The gassifier achieves the highest efficiency as the hot gas passes through the fuel bed and leaves the gassifier at low temperature. The producer gas is produced in the reduction zone that leaves the gassifier together with the pyrolysis products and steam from the drying zone. The resulting gas is rich in hydrocarbons and is suitable only for direct heating purposes in industrial furnaces. If it is to be used for electricity generation by I.C. engines, it has to be cleaned thoroughly. Figure shows the schematic diagram of an up-draught-type gassifier or counter-flow gassifier.



Pyrolysis: Biomass is heated either in the absence of air or by the partial combustion of some of the biomass in a restricted air or oxygen supply to produce a hydro carbon. The products are extremely varied, consisting of gases, vapors, liquids and oils. The output depends on temperature, type of input material and treatment process. In some processes the presence of water is necessary and therefore the material need not be dry. If output of combustible gas is the main product, the process is called gasification.

Pyrolysis is a type of thermolysis, and is most commonly observed in organic materials exposed to high temperatures. It is one of the processes involved in charring wood, starting at 200–300 °C. In general, pyrolysis of organic substances produces gas and liquid products and leaves a solid residue richer in carbon content, char. Extreme pyrolysis, which leaves mostly carbon as the residue, is called carbonization.

The process is used heavily in the chemical industry, for example, to produce charcoal, activated carbon, methanol, and other chemicals from wood, to convert ethylene dichloride into vinyl chloride to make PVC, to produce coke from coal, to turn waste into safely disposable substances, and for transforming medium-weight hydrocarbons from oil into lighter ones like gasoline.

Pyrolysis also plays an important role in several cooking procedures, such as baking, frying, and grilling.

Pyrolysis differs from other high temperature processes like combustion and hydrolysis in that it usually does not involve reactions with oxygen, water, or any other reagents. In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs.

The term has also been applied to the decomposition of organic material in the presence of superheated water or steam (hydrous pyrolysis), for example, in the steam cracking of oil.

Pyrolysis uses and occurrences:

Fire

Pyrolysis is usually the first chemical reaction that occurs in the burning of many solid organic fuels, like wood, cloth, and paper, and also of some kinds of plastic. In a wood fire, the visible flames are not due to combustion of the wood itself, but rather of the gases released by its Pyrolysis.

Cooking

Pyrolysis occurs whenever food is exposed to high enough temperatures in a dry environment, such as roasting, baking, toasting, or grilling. It is the chemical process responsible for the formation of the golden-brown crust in foods prepared by those methods.

Charcoal

Pyrolysis has been used since ancient times for turning wood into charcoal on an industrial scale. Besides wood, the process can also use sawdust and other wood waste products.

Charcoal is obtained by heating wood until its complete pyrolysis (carbonization) occurs, leaving only carbon and inorganic ash. In many parts of the world, charcoal is still produced semi-industrially, by burning a pile of wood that has been mostly covered with mud or bricks.

Plastic waste disposal

Pyrolysis can also be used to produce liquid fuel similar to diesel from plastic waste. Pilot Jeremy Roswell plans to make the first flight from Sydney to London using diesel fuel from recycled plastic waste.

Wood stoves:

A wood-burning stove is a heating appliance capable of burning wood fuel and wood-derived biomass fuel, such as wood pellets. Generally the appliance consists of a solid metal (usually cast iron or steel) closed fire chamber, a fire brick base and an adjustable air control. The fuels considered are firewood/tiny sticks/sawdust/other fine and pulverisable agro-residues like coir waste, bagasse, leafy residues and even dried urban waste in a well-defined manner. The aim of the design is to provide a combustion behavior close to what is obtainable in gas stoves, with a facility to have some control on power, reduce emissions, maximize the efficiency of heat transfer into the vessel, minimum tending and low cost.

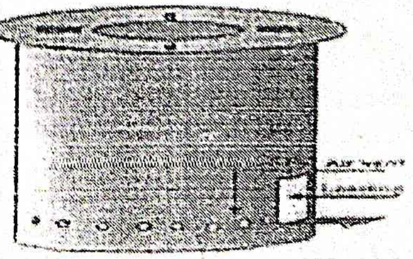


Figure shows a wood burning stove, designed to make better use of wood as a cooking fuel. Normal design of wood stoves will release more smoke. But, some designs allow wood burning without much smoke. In the stove shown in Fig. is simpler and cheaper, but has less control and less flexibility. Air reaches the fuel from below, through a grate. Since the fire is contained and the heat is channeled towards the pot, the efficiency is high. This tove is well suited for use with charcoal as a fuel, since charcoal burns cleanly without smoke.

Some advanced stoves are connected by ventilating stove pipes to a suitable chimney, which will fill with hot combustion gases once the fuel is ignited. The chimney or flue gases must be hotter than the outside temperature to ensure combustion gases are drawn out of the fire chamber and up the chimney.

Bio diesel:

A variety of grains and seeds contain relatively high concentrations of vegetable oils that are of high caloric value. It can be used as liquid fuels. However, the high viscosity of these raw vegetable oils (20 times that of diesel), would lead to serious lubrication oil contamination. On the other hand, chemical modification of vegetable oils to methyl or ethyl esters yields excellent diesel engine fuel without the viscosity problems. Biodiesel is the generic name given to these vegetable oil esters. This is a process in which organically derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. The biomass-derived ethyl or methyl esters can be blended with conventional diesel fuel. It is used as a neat fuel (100% biodiesel). Biodiesel can be made from soybean, sunflower, cottonseed, corn, groundnut (peanut), sunflower, rapeseed, waste vegetable oils and animal fats, etc. Therefore, biodiesel is made from renewable biological sources such as vegetable oils and animal fats and as an alternative diesel fuel.

Intensification of local air pollution and magnification of global warming problems caused by CO2, through continued and increasing use of petroleum can be reduced by the use of biodiesel fuels.

The advantages of vegetable oils as diesel fuel

(i) liquid-nature portability;
(ii) heat content (80% of diesel fuel);
(iii) ready availability and
(iv) Renewability.

The disadvantages are

(i) Higher viscosity; and
(ii) Lower volatility.

<u>Bio diesel Combustion engine:</u>

Biodiesel can be blended in any proportion with mineral diesel to create a biodiesel blend or can be used in its pure form. Just like petroleum diesel, biodiesel operates in compression ignition (diesel) engine, and essentially require very little or no engine modifications because biodiesel has properties similar to mineral diesel. It can be stored just like mineral diesel and hence does not require separate infrastructure. The use of biodiesel in conventional diesel engines results in substantial reduction in emission of unburned hydrocarbons, carbon monoxide and particulate.

The main limitation of Biodiesel has higher brake-specific fuel consumption compared to diesel, which means more biodiesel fuel consumption is required for the same torque.

Biodiesel Applications:

Biodiesel can be extensively used for vehicles, heating processes, water pumping, agricultural appliances etc.,

Hybrid Systems

Need for Hybrid Systems:

As convention fossil fuel energy sources diminish and the world's environmental concern about acid deposition and global warming increases, renewable energy sources (solar, wind, tidal, biomass and geothermal etc) are attracting more attention as alternative energy sources. These are all pollution free and one can say eco friendly. These are available at free of cost.

In India wind and solar energy sources are available all over the year at free of cost whereas tidal and wave are costal area. Geothermal is available at specific location. To meet the demand and for the sake of continuity of power supply, storing of energy is necessary.

The term hybrid power system is used to describe any power system combine two or more energy conversion devices, or two or more fuels for the same device, that when integrated, overcome limitations inherent in either.

Range and type of Hybrid systems:

Usually one of the energy sources is a conventional one (which necessarily does not depend on renewable energy resource) powered by a diesel engine, while the other(s) would be renewable viz. solar photovoltaic, wind or hydro.

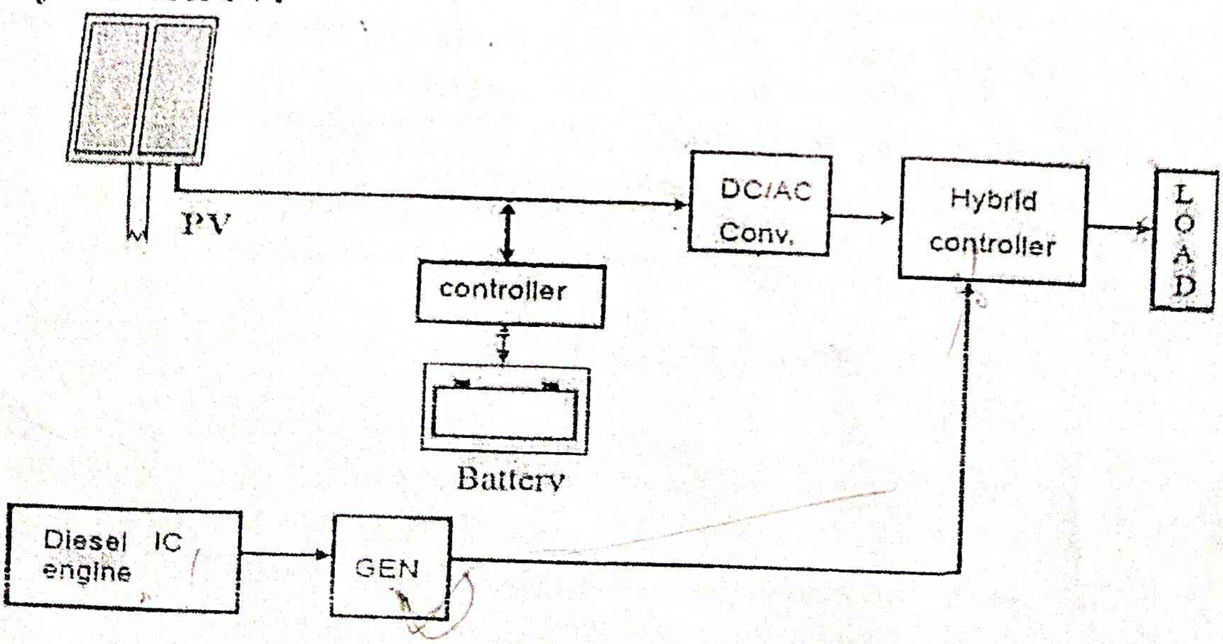
The design and structure of a hybrid energy system obviously take into account the types of renewable energy sources available locally, and the consumption the system supports. For example, the hybrid energy system presented here is a small-scale system and the consumption of power takes place during nights, so the wind energy component will make a more significant contribution in the hybrid system than solar energy. Although the energy produced by wind during night can be used directly without storage, a battery is needed to store solar and wind energy produced during the day.

In addition to the technical considerations, cost benefit is a factor that has to be incorporated into the process of optimizing a hybrid energy system. In general, the use of wind energy is cheaper than that of solar energy. In areas where there is a limited wind source, a wind system has to be over-dimensioned in order to produce the required power, and these results in higher plant costs.

It has been demonstrated that hybrid energy systems (renewable coupled with conventional energy source) can significantly reduce the total life cycle cost of a standalone power supplies in many off-grid situations, while at the same time providing a reliable supply of electricity using a combination of energy sources. Numerous hybrid systems can be integrated and these are as follows:

1. Diesel-PV,
2. Wind-PV,
3. Microhydel-PV,
4. Biomass-Diesel systems

Case study of Diesel-PV:



annually. Using diesel generator as a standby source will make utilization of hybrid systems more attractive. An economic feasibility study and a complete design of a hybrid system consisting of photovoltaic (PV) panels, a diesel generator as a backup power source and a battery system can give the power to remote loads.

The type of the hybrid system and its configuration depend mainly on the availability of the renewable source in the location selected for installing this hybrid system. The average daily solar radiation intensity and total annual sunshine hours will decide the range of solar panel.

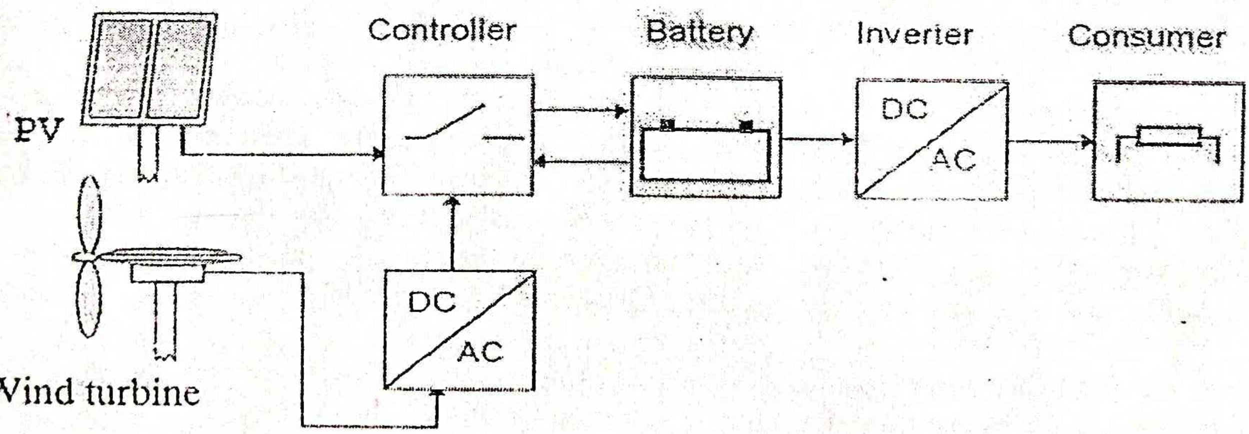
The energy generated by the PV panels and stored in the battery bank has priority to supply the load. When the battery is discharged to its minimum allowable level, the diesel generator as a backup source is switched on. In hybrid system diesel energy is only work as a backup source. When the demand on its peak then the available sources are insufficient for that then the diesel back is required.

Considering remote areas which are far away from the grid, this solution is the most feasible one compared with electrifying these remote areas from the grid.

Case study of Wind-PV:

Hybrid system based on photovoltaic is considered an effective option to electrify remote and isolated areas far from grid. This is true for areas that receive high averages of solar radiation annually. Combining with wind turbine where wind energy is adequate will make utilization of hybrid systems more attractive. An economic feasibility study and a complete design of a hybrid system consisting of photovoltaic (PV) panels and wind power generating system and a battery system can give the power to remote loads.

The type of the hybrid system and its configuration depend mainly on the availability of the renewable source in the location selected for installing this hybrid system. The average daily solar radiation intensity and total annual sunshine hours will decide the range of solar panel. The wind availability at the selected site is also main constraint for this type of hybrid system.

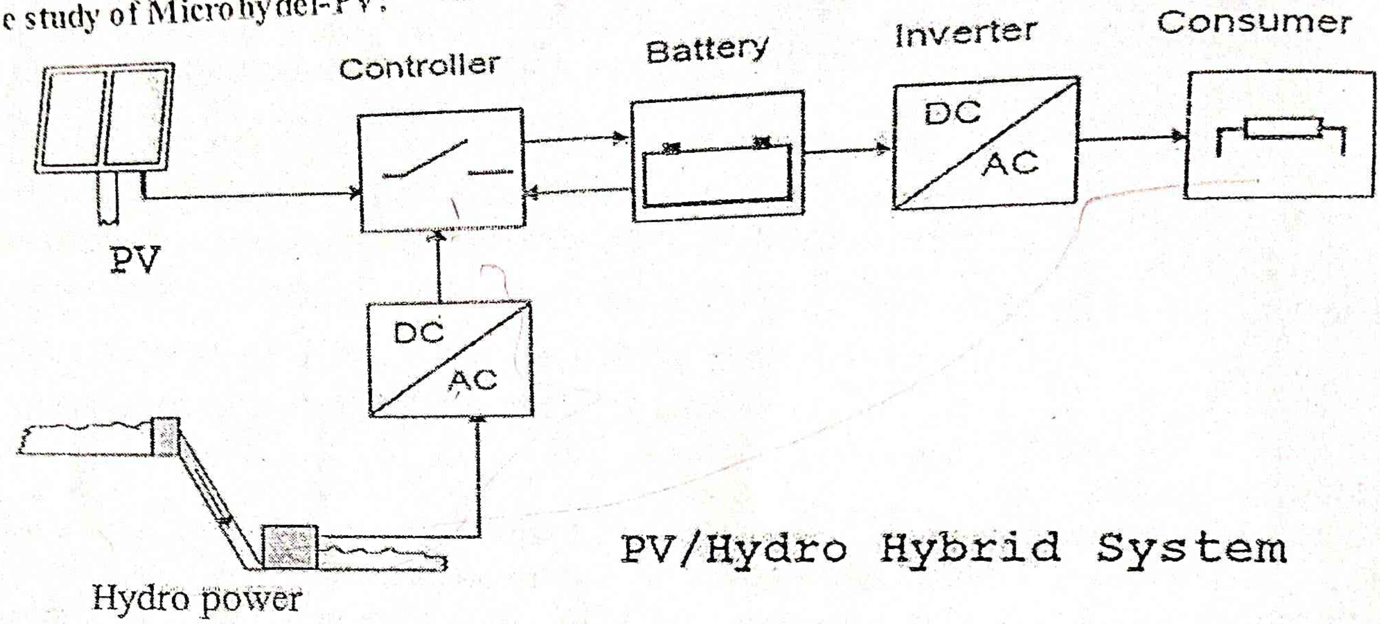


Wind/PV Hybrid System

During day time, DC Power generated by the Solar PV array is stored in the Battery Bank through a Hybrid Controller, which maximizes charging current and prevents excessive discharge/overcharge. Wind turbine generator starts generating power when wind speed exceeds cut-in speed of the Mini Wind Turbine (above 2.7 m/s). Output from the Wind Battery Charger is also stored in the Battery Bank through Hybrid Controller. During windy periods excess energy generated by the Wind Battery Charger is dissipated through a progressive heater (Dump Load). The wind turbine is self regulated type with protection for over speed. Energy stored in the battery is drawn by electrical loads through the inverter, which converts DC power into AC power.

Considering remote areas which are far away from the grid, this solution is the most feasible one compared with electrifying these remote areas from the grid.

Case study of Micro hydel-PV:



PV/Hydro Hybrid System

In remote and hilly areas, it is difficult to satisfy power demand all year long by hydro sources alone. In some remote areas, where this is the case, a judicious combination of other renewable sources to form a hybrid system can help solve rural electrification problems. One of these combinations is the use of PV together with hydro power system.

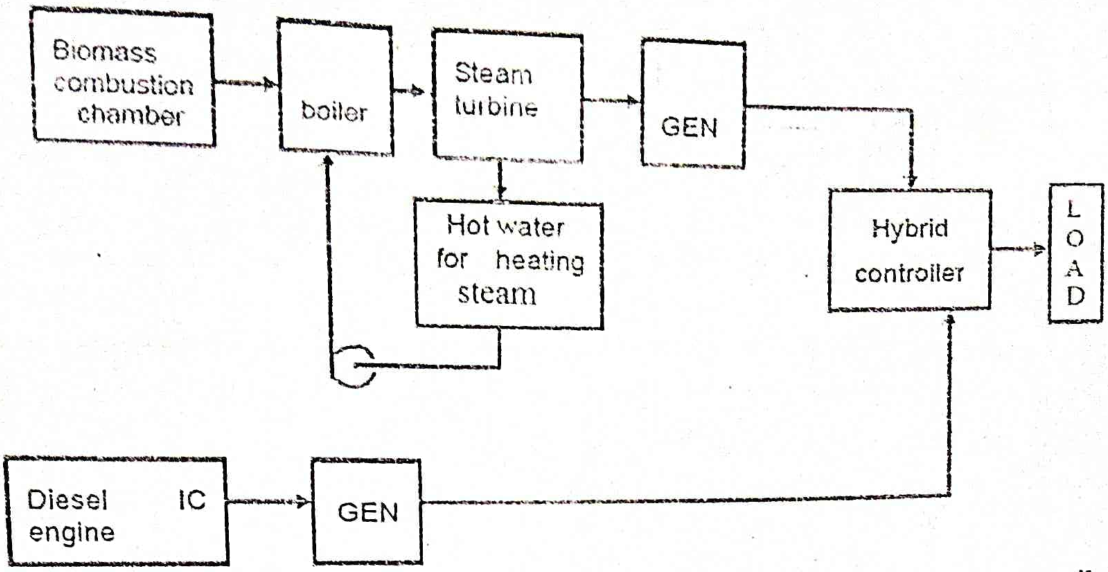
Hybrid system based on photovoltaic is considered an effective option to electrify remote and isolated areas far from grid. This is true for areas that receive high averages of solar radiation annually. Combining with locally available hydro power will make utilization of hybrid systems more attractive. An economic feasibility study and a complete design of a hybrid system consisting of photovoltaic (PV) panels and hydro power system generating system and a battery system can give the power to remote loads.

The type of the hybrid system and its configuration depend mainly on the availability of the renewable source in the location selected for installing this hybrid system. The average daily solar radiation intensity and total annual sunshine hours will decide the range of solar panel. The water availability at the selected site is also main constraint for this type of hybrid system. In this type of hybrid system care should be taken for the power generation on hydro power system, because with hydro power the cost of power generation is less.

When the water in the hydro power system is not enough to generate the power then during day time, DC Power generated by the Solar PV array is stored in the Battery Bank through a Hybrid Controller, which maximizes charging current and prevents excessive discharge/overcharge. If water is available to generate the power then the generator starts generating power. Output from the hydro power is converted in to DC and stored in the Battery Bank through Hybrid Controller. Energy stored in the battery is drawn by electrical loads through the inverter, which converts DC power into AC power.

Considering remote areas which are far away from the grid, this solution is the most feasible one compared with electrifying these remote areas from the grid.

Case study of Biomass-Diesel:



These types of systems are more useful where the agricultural wastes are available. By combing biomass operated steam turbine with diesel engine can be used as hybrid system.
In this type of biomass system the waste residues from industries and agricultural fields will be combusted in combustion chamber as shown in fig. The heat generated in the combustion chamber is passed to the boiler and water from the steam turbine will be passed through water heating system and passed to the boiler. Boiler converts the hot water in to steam and this steam runs the steam turbine and rotates the generator and supplied to the hybrid controller.

When the biomass products are not enough to feed the biomass combustion chamber then the diesel generator as a backup source is switched on. In this type of systems the care should be taken to depend on biomass based power generation only, because the power generation in this system is quite cheap when compared to the diesel engine. In most of the cases these type of hybrid systems are very useful where the industries are having biomass products as their residues.

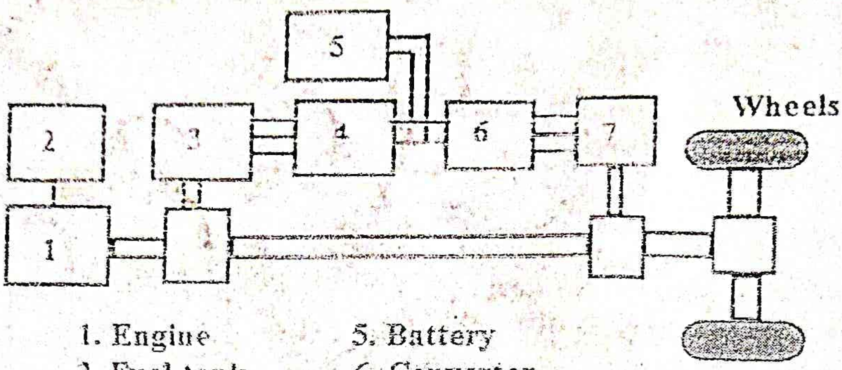
Electric and hybrid electric vehicles:

Electric Car:
An electric car has its wheels powered only by an electric motor; hence it has a large (well really high power) electric motor. Electric cars of various types have been introduced.

A Pure electric car carries a big battery, externally charged, that is the only source of power for the car. This type of alternate car to the usual gasoline powered car has two classic problems aside from cost; it has limited range and long fueling time.

Hybrid electric vehicles:

A hybrid electric vehicle (HEV) is a type of hybrid vehicle and electric vehicle which combines a conventional internal combustion engine (ICE) propulsion system with an electric propulsion system. The presence of the electric power train is intended to achieve either better fuel economy than a conventional vehicle or better performance. There are a variety of HEV types, and the degree to which they function as Electric Vehicles varies as well. The most common form of HEV is the hybrid electric car, although hybrid electric trucks (pick ups and tractors) and buses also exist.



1. Engine
2. Fuel tank
3. Generator
4. Charger
5. Battery
6. Converter
7. Electric motor

Modern HEVs make use of efficiency-improving technologies such as regenerative braking, which converts the vehicle's kinetic energy into electric energy to charge the battery, rather than wasting it as heat energy as conventional brakes do. Some varieties of HEVs use their internal combustion engine to generate electricity by spinning an electrical generator (this combination is known as a motor-generator), to either recharge their batteries or to directly power the electric drive motors. A hybrid-electric produces fewer emissions from its ICE than a comparably-sized diesel/petrol car

Examination Questions :(NOV 2012)

Short Answer Questions:

1. What are the main advantages of Bio mass energy? (2 marks)
2. What are the factors affecting the performance of a bio gas digester? (2 marks)
3. What are different types of hybrid generating systems in existence? (2 marks)

Long Answer questions:

1. Explain the process of gasification of solid bio-fuels. What is the general composition of gas produced and what is its heating value? What are its main applications? (10 marks)
2. What is the need for hybrid generating system? (4 marks)
3. Explain the working principle of hybrid electric vehicle with schematic block diagram. (6 marks)
4. Write short note on: Pyrolysis (5 marks)

Examination Questions :(NOV 2013)

1. What is Pyrolysis and what type of biomass conversion technology it comes under? (2 marks)
2. What is the need of a hybrid system and give examples of various types of hybrid combinations (2 marks)
3. What is gasification? What is the chemical reaction takes place during gasification? Describe how the down draft type gassifier operates with its complete labeled diagram? (5 marks)

Examination Questions :(Back/Special 2013)

1. Write short notes on a) wood stove b) bio diesel c) Pyrolysis (10 marks)
2. Write combustion engine application
3. Differentiate between floating drum and fixed dome type bio gas plant with suitable diagram?

Other Important questions:

1. Explain any case study of hybrid system
2. Explain the operating principle of biomass energy
3. Explain the advantages and disadvantages of biomass energy
4. Explain the process of Combustion and its applications
5. What is Fermentation? And explain the process of ethanol production
6. Explain the working of anaerobic digester
7. Write short note on wood gassifier biogas and wood stoves
8. Explain about bio diesel and its application.