# APPENDIX A

## A.1 ENERGY

### Introduction

Energy is one of the major inputs for the economic development of a country. The consumption of energy is increasing at a fast pace while available resources remain limited. The global need for energy is increasing on an average by about 15% every year. Out of the total amount of primary energy, around 80% comes from fossil fuels. The current consumption of fossil fuels, particularly oil, is not sustainable in the long term. Energy, that we use, can be classified into several types:

(i) Primary energy and secondary energy
(ii) Commercial and non-commercial energy
(iii) Renewable and non-renewable energy

### Primary and Secondary Energy

Primary energy refers to all types of energy extracted or captured directly from natural resources.

+ Solar, wind, geothermal, tidal, biomass, etc.
+ fossil fuels, crude oil and its products coal, natural gas, nuclear, etc.

Primary energy sources are mostly converted in industrial utilities into secondary energy sources; for example coal, oil or gas converted into steam and electricity. Primary energy can also be used directly, for example, coal or natural gas can be used as a feedstock in fertiliser plants. Primary energy is transformed by energy-conversion processes to more convenient forms of energy such as electricity, steam, etc. These forms of energy are called secondary energy.

### Commercial Energy and Non-Commercial Energy

#### *Commercial Energy*

Energy that is available in the market for a definite price is known as commercial energy. No matter what the method of energy production is, whether it is from fossil fuels, nuclear or renewable sources, any form of energy used for commercial purposes constitutes commercial energy. The most important forms of commercial energy are electricity, coal, refined petroleum products and natural gas.

#### *Non-Commercial Energy*

Any kind of energy which is sourced within a community and its surrounding area, and which is not normally traded in the commercial market is termed non-commercial

energy. Non-commercial energy sources include fuels such as firewood, cattle dung and agricultural wastes, which are traditionally gathered, and used mostly in rural households for water heating, for drying grain, fish and fruits; animal power for transport, treating, lifting water for irrigation, crushing sugarcane, etc., wind energy for lifting water and electricity generation.

## Non-renewable and Renewable Energy

*Renewable energy* is the energy obtained from natural sources which are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.

A non-renewable resource is a natural resource which cannot be produced, grown, replenished or used on a scale which can sustain its consumption rate. These resources often exist in a fixed amount, or are consumed much faster than nature can create them. Natural resources such as coal, oil and natural gas take millions of years to form naturally and cannot be replaced as fast as they are being consumed now. These resources will deplete with time.

## Energy Security

Energy security for a nation is to reduce its dependency on the imported energy sources for its economic growth.

## Energy Intensity

Energy intensity is energy consumption per unit of GDP. Energy intensity indicates the development stage of the country.

India's energy intensity is 3.7 times of Japan, 1.55 times of USA, 1.47 times of Asia and 1.5 times of the world average.

Energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels.

## Energy Sustainability

Energy sustainability means meeting the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability is achieved by

(i) Promoting the use of renewable energy sources.
(ii) Designing technologies to improve energy efficiency.

Coal and other fossil fuels that have taken hundreds of million of years to form are likely to deplete soon. We have consumed nearly 60% of all resources. The fossil sources (coal, oil, etc.) are continually diminishing with increasing consumption and will not exist for future generation, clearly explained in Figure A.1.



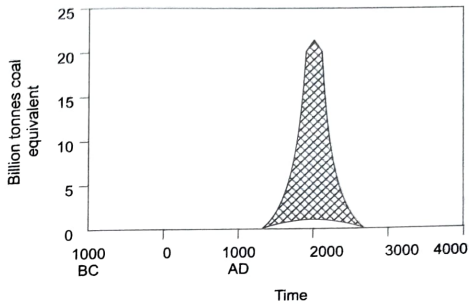


**Fig. A.1 Consumption of Fossil Fuels**

## Energy Conservation and Efficiency

Energy conservation means growth of energy consumption is reduced in physical terms. Energy conservation, therefore, is the result of several processes or developments such as productivity increase or technological progress.

Energy conservation means reducing energy consumption through using less of an energy service.

### *Ways to Save Energy at Home*

(i) Turn off lights while leaving the rooms and use dim lights in balconies, etc.
(ii) Use natural light.
(iii) Switch off appliances when not in use.
(iv) Use compact fluorescent bulbs instead of normal bulbs.
(v) Use alternate source of energy like solar.

### *Ways to Save Energy at Industry*

(i) Avoid repeated rewinding of motors.
(ii) Use only treated water in boilers.
(iii) Maintain diesel engines regularly.
(iv) Carry out preventive maintenance and condition monitoring schedule regularly.
(v) Undertake regular energy audits.

The benefits of energy conservation for various players are given in Table A.1.

Table A.1

| Industry | Nation | Globe |
|---|---|---|
| • Reduced energy bills | • Reduced energy imports | • Reduced GHG and other emissions |
| • Increased competitiveness | • Avoided cost can be used for poverty reduction | • Maintains a sustainable environment |
| • Increased productivity | • Conservation of limited resources | |
| • Improved quality | • Improved energy security | |
| • Increased profits | | |

## A.2 THERMAL POWER STATION

### Introduction

The total installed capacity of power in India is 278734 MW as of September 2015 (from the Ministry of Power). The total thermal capacity is 194200 MW which constitutes almost 70% of production. India expects its growth in electric power generation over the next couple of decades which is largely met by thermal power plants.

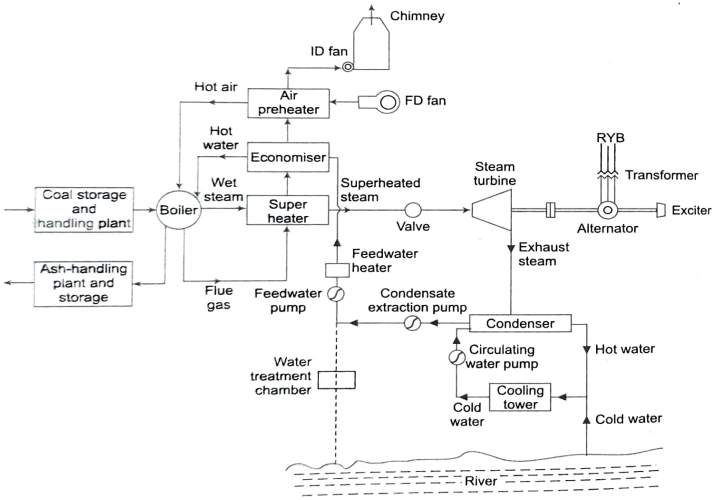


Fig. A.2 Thermal Power Plant



A thermal power station works on the principle of the Rankine cycle. Water is converted into steam in the boiler by utilising the heat energy produced by the combustion of coal. The steam produced in the boiler is expanded in the steam turbine and the exhaust steam is condensed by using a condenser and condensed steam is again fed to the boiler. The turbine which is coupled mechanically to the alternator converts the mechanical energy of the turbine into electrical energy. The electrical energy produced is transmitted and distributed to various consumers.

This power station is suitable if coal and water are available in large quantities and a large amount of power is to be generated.

### Coal Storage

Through road or rail, coal arrives at the power station and is stored in a coal storage. Coal is stored to prevent coal strikes, transportation failure and coal shortages.

### Coal-handling Plant

From the coal storage, coal is delivered to a coal-handling plant. In the coal-handling plant, the coal is cut into small pieces to increase the combustion with less air. By using a conveyor, coal is transported to the boiler.

### Ash Storage and Handling Plant

The coal is burnt in the boiler and ash produced is given to the ash-handling plant for handling the ash and is stored in ash storage for disposal.

### Steam Boiler

A steam boiler is a device used to convert the water into steam by absorbing the heat produced due to coal combustion.

**Types**

(i) Water-tube boiler
(ii) Fire-tube boiler

### Superheater

The steam is superheated in a superheater (temperature of the steam is raised above the water-boiling temperature) by utilising the heat from the flue gas.

The steam is superheated to increase the efficiency of the power station and eliminates the corrosion of turbine blades.

The superheated steam from the superheater is given to the steam turbine through the main valve.

### Economiser

It heats the feedwater supplied to the boiler by using a part of heat from flue gas. The feedwater is heated to increase efficiency of the boiler and to save the fuel by some percentage.

### Air Preheater

It increases the temperature of air supplied for burning of coal by deriving heat from flue gases.

By a forced draught fan, air from the atmosphere is passed through an air preheater before supplying air to the boiler. It increases thermal efficiency.

### Steam Turbine

The heat energy in the steam is converted into mechanical energy.

**Types**

(i) Impulse turbine
(ii) Reaction turbine

### Condenser

The exhaust steam from the turbine is given to a condenser. The condenser condenses the steam so that steam is converted into water, which is used as feedwater to the boiler. It increases plant efficiency.

### Cooling Tower

During the condensation process, heat energy in the steam is taken up by the cooling tower. Water from a river, lake or sea is used to cool the steam.

### Feedwater Heater

It increases the temperature of the feedwater given to the boiler. The dissolved oxygen and $CO_2$ are removed in the heater. This increases the overall efficiency of the plant.

### Alternator

It is coupled to the steam turbine and converts mechanical energy into electrical energy. The alternator is hydrogen-cooled or air-cooled.

### Water-treatment Chamber

During the process, some part of steam and water is lost and is compensated by supplying some water. The feedwater is purified in a water-treatment chamber to avoid scaling of tubes in the boiler.

#### *Advantages*

(i) Fuel cost is low.
(ii) Initial cost is less.
(iii) Transmission cost is low, due to location near load centre.
(iv) Less production cost compared to a diesel plant.

#### *Disadvantages*

(i) High maintenance cost.
(ii) High operating cost.
(iii) It pollutes the atmosphere.
(iv) Water is required for operation of power plant.



## A.3 HYDROELECTRIC POWER STATION

### Introduction

As per the available data from the Ministry of Power, as on October 2015, at present, 15.2% or 42.283 MW of the total power production in India is from hydro power plants. Hydro power plays an important role because it provides power at a lower price. The generation of hydro power depends on the quantity of water and it is also seasonal.

The generating station which converts the hydraulic energy into electrical energy is known as a hydroelectric power station.

The reservoir is formed by constructing a dam across a river or lake and water from the catchment area collects at the dam. A pressure channel is taken from the reservoir and water is brought to the penstock through a surge tank. Water is given to a turbine through a steel pipe called penstock. The water turbine converts hydraulic energy into electrical energy. The alternator is mechanically coupled to a water turbine and converts mechanical energy of the turbine into electrical energy.

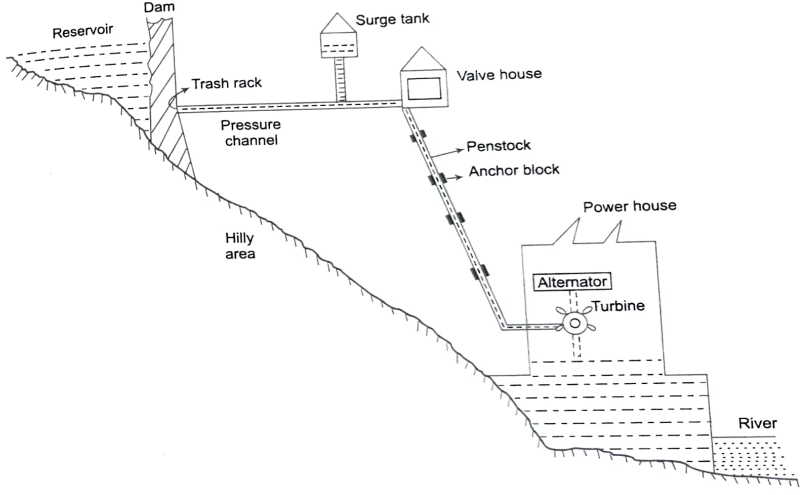


**Fig. A.3 Hydroelectric Power Plant**

### Reservoir

Water during the rainy season is collected and stored for use during dry season.

### Dam

It is constructed across the river. It develops the reservoir and increases the working head.

### Spillways

These are used to discharge the excess water in the dam if the water level reaches the maximum capacity. It acts as safety for the dam.

### Intake

It allows the water to flow into conduits under controlled conditions.

### Trash Rack

In order to prevent debris from entering the turbine, trash racks or screens are used. If debris enters, it will damage turbine blades.

### Penstock

The pipe which connects the surge tank and turbine is called penstock.

### Surge Tank

A surge tank is provided near the valve house. It protects the penstock from bursting due to sudden closing of turbine gates. When electrical loads are switched off, the gates of the turbine need to be closed suddenly.

When gates are closed suddenly, water in the lower end of the penstock is stopped. So the penstock can burst. The surge tank is a small reservoir or tank which prevents the bursting of the penstock by absorbing the pressure of water, thus, abnormal pressure in the conduit is overcome.

#### *Advantages*

(i) No fuel is required.
(ii) Maintenance and operating charge is less.
(iii) Low running cost.
(iv) No pollution.
(v) No problem of fuel transportation.

#### *Disadvantages*

(i) High initial cost.
(ii) Located in remote or hilly area.
(iii) Transmission losses are more.
(iv) Operation depends on rainfall.

## A.4 NUCLEAR POWER STATION

### Introduction

The total nuclear power production in India is 5780 MW which is 2.1% of total power production.



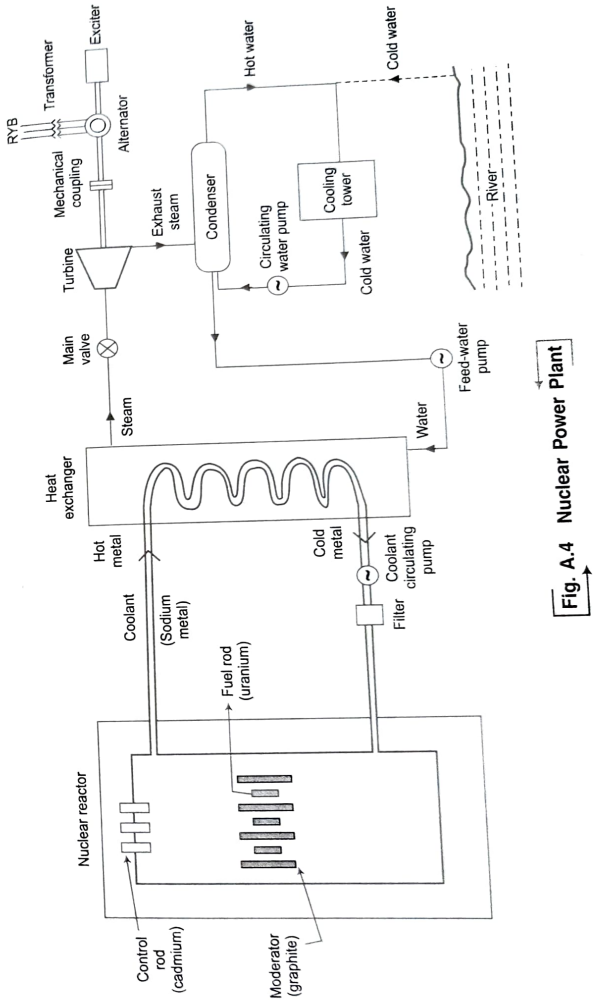


Fig. A.4 Nuclear Power Plant

In a nuclear power station, heat energy is produced by nuclear fission of uranium ($U^{235}$) or thorium ($Th^{232}$) in a nuclear reactor. The water is converted into steam by utilising heat energy. The steam energy is converted into mechanical energy by a steam turbine. The alternator which is coupled mechanically to the turbine produces electrical energy.

The main feature in a nuclear power station is that a large amount of electrical energy can be produced with small amount of nuclear fuel.

### Fission

The nuclei of a heavy atom is broken into two equal parts with release of huge amount of energy. This is known as nuclear fission.

Energy release is due to mass defect, i.e., mass of final product comes out to be less than initial product. This mass defect is converted into heat energy according to Einstein's theory $E = mc^2$.

### Chain Reaction

By bombarding uranium nuclei with slow-moving neutrons, nuclear fission is done. Thus, huge amount of energy is released and fission neutrons are emitted. These neutrons cause further fission. If it continues, in a very short time, a huge amount of energy is released causing explosion.

### Nuclear Reactor

The nuclear fuel is subjected to nuclear fission in a reactor. It controls the chain reaction once the fission starts and is caused by controlled chain reaction.

### Fuel Rods

It contains fission material and releases huge amount of energy when bombarded.

### Moderator

The moderators are made of graphite or beryllium. They are used to slow down the neutrons used for bombarding. This increases the fission and reduction of fuel for chain reaction.

### Control Rods

Control rods are made of cadmium and are strong neutron absorbers. It regulates the supply of neutrons for fission. The heat production and rate of chain reaction are controlled by pushing or pulling control rods. It is done automatically based on load requirement.

### Coolant

The coolant generally used is sodium metal. The heat produced in the reactor is taken up by the coolant and it exchanges the heat to the heat exchanger.

### Heat Exchanger

The coolant gives up heat which is used to produce the steam. The coolant is again fed to the reactor.



### Steam Turbine

The steam is given to the turbine through the main valve. The energy in the steam is converted into mechanical energy. The exhaust steam is given to the condenser. The condenser condenses the steam which is fed to the heat exchanger through a feedwater pump.

### Alternator

It converts the mechanical energy into electrical energy.

#### *Advantages*

(i) Requires less space.
(ii) Economical.
(iii) Fuel required is very small.
(iv) Running charge is low.

#### *Disadvantage*

(i) Radioactive pollution.
(ii) High maintenance cost.
(iii) Problem in disposal of fission products.
(iv) High capital cost.

## A.5 SOLAR ELECTRICAL ENERGY

### Introduction

The total commissioned capacity up to May 2015 (MNRE) is 3883.5 MW.

There are two ways of generating electrical energy from the sun:

- Solar–thermal electricity
- Photovoltaic electricity

There are two basic types of solar thermal power stations; power tower and parabolic through collector.

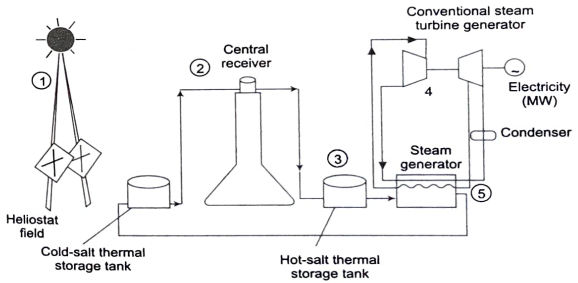


**Fig. A.5 Solar Thermal Power Station**

## Power Towers

A typical power tower operation is described as follows:

(i) Sunlight is concentrated and directed from a large field of heliostats to a receiver on the tall tower.
(ii) Molten salt from the cold-salt tank is pumped through the central receiver where it is heated to 566°C.
(iii) The heated salt from the receiver is stored in the hot-salt thermal storage tank.
(iv) Molten salt is pumped from the hot-salt tank through a steam generator that creates steam which drives a steam turbine, generating electricity.
(v) Cold salt at 288°C flows back to the cold-salt thermal storage tank and is reused.

## Parabolic Trough Collector

It uses a series of specially designed parabolic curved, trough-shaped reflectors that focus the sun's energy onto a receiver tube running at the focus of the reflector. Because of its parabolic shape, a trough can focus the sun at 30 times to 100 times its normal intensity (concentration ratio) on the receiver pipe located along the focal line of the trough, achieving operating temperatures higher than 750°F.

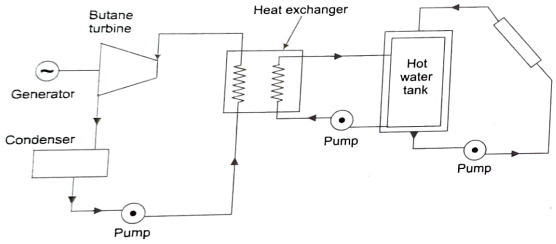


**Fig. A.6 Parabolic Trough Collector**

## Steam Condenser

The steam condenser is a device in which the exhaust steam from the steam turbine is condensed. The main purpose of a steam condenser in a turbine is to maintain a lowback pressure on the exhaust side of the steam turbine.

## Turbine

A steam turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft.



## Generator

In electricity generation, a generator is a device that converts mechanical energy to electrical energy for use in an external circuit.

### *Working*

Solar thermal power generation systems work same as power generation using fossil fuels, but instead of using steam produced from the combustion of fossil fuels, the steam is produced by heat collected from sunlight. Solar thermal technologies use concentrator systems to achieve the high temperatures needed to heat fluid.

### *Advantages*

(i) Available freely in nature.
(ii) No pollution.
(iii) Non-depleting source.
(iv) Does not disturb the ecological balance.

### *Disadvantages*

(i) Large area is required.
(ii) Climate affects the operation.
(iii) High initial cost.
(iv) Power production in daytime only.

## Solar Photovoltaic Technology

Direct conversion of solar energy to electricity takes place through photoelectric effect or photovoltaic effect. Photovoltaic effect is the process in which the two dissimilar materials in close contact produce an electrical voltage when struck by light or radiant energy.

### *PV Power Plant*

The elements included in a system of photovoltaic conversion are

(i) Solar panel
(ii) Charge controller
(iii) Inverter
(iv) Converter
(v) Batteries

PV systems are classified into two groups:

(i) Standalone PV power plant
(ii) Grid-connected solar PV systems

## Standalone PV Power Plant

PV systems not connected to the electric utility grid are known as OFF grid PV systems or standalone PV systems. Direct systems use the PV power immediately as it is produced, while battery storage systems can store energy to be used at a later time, either at night or during cloudy weather.

The most common use of standalone plants are

(i) Electrification of remote villages where conventional grid supply is not available

(ii) Power for hospitals, hotels, communication equipment, and railway stations

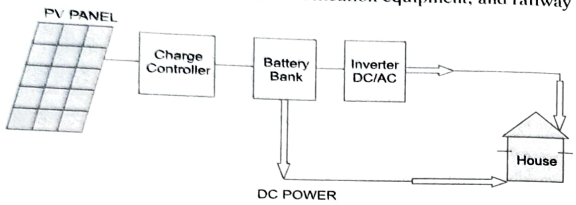


**Fig. A.7 Standalone Photovoltaic System**

## Grid-Connected Solar PV Systems

These systems are directly coupled to the electric distribution network and do not require battery storage. Grid-connected systems use an inverter that synchronizes with utility power. During the day, the solar electricity generated by the system is either used immediately or sold off to electricity-supply companies. In the evening, when the system is unable to supply immediate power, electricity can be bought back from the network.

The advantages of grid-connected solar PV systems over standalone PV power plants are the following:

(i) Smaller PV arrays can supply the same load reliably.

(ii) Less balance of system components are needed.

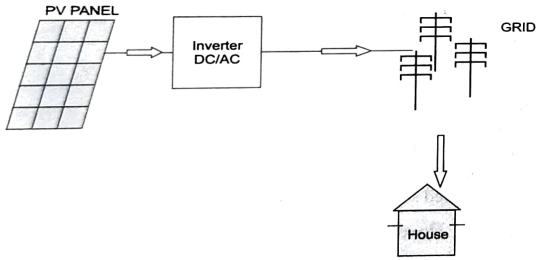


**Fig. A.8 Grid-connected Solar Photovoltaic System**



# A.6 WIND ENERGY

## Introduction

The electrical energy can be generated by absorbing energy contained in the wind. According to Indian Wind Energy Association, the total installed capacity of wind power plants is 23439.26 MW as of March, 2015, whereas Tamil Nadu has 7456.98 MW capacity. India is ranked fifth in the world as for installed capacity.

Though the wind energy is used for many applications such as water pumping, milling grains, etc., the use of wind energy for electricity generation is more important. Modern windmills are also called Wind Energy Conversion Systems (WECS).

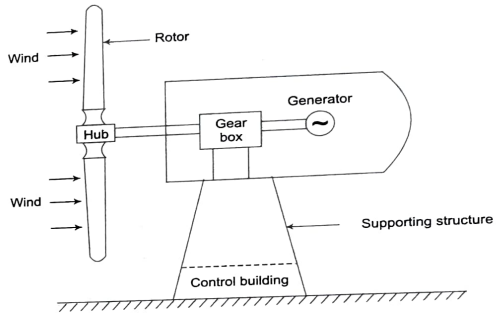


**Fig. A.9 Wind-power Plant**

## How is Wind Created?

The heat received from the sun creates low- and high-pressure regions on the earth. The heat differences help create wind. In warmer regions of the earth, the air is hot and is, therefore, at a high pressure compared to colder regions where the air is at a low pressure. Wind is the movement of air from areas of high pressure to low pressure.

## Wind Speed vs Power-generation Capability

Sites with more wind speed will generate more power. Table A.2 gives guidelines of the different wind speeds and their potential in producing electricity.

Table A.2

| Average wind speed (m/s) | Suitability for power generation |
|---|---|
| up to 4 | No good |
| 5 | Poor |
| 6 | Moderate |
| 7 | Good |
| 8 | Excellent |

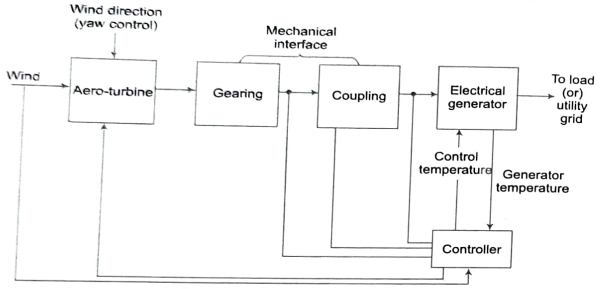


**Fig. A.10 Block Diagram of Wind Energy Conservation System**

## Wind-Energy Technology

There are generally two types of wind turbines: horizontal-axis and vertical-axis wind turbines.

Horizontal-axis wind turbines are most popular because of high efficiency.

## Components of a Wind-Turbine System

### *Tower*

The tower is a very crucial part of the wind turbine that supports all the other parts. The height of the tower depends upon the power capacity of wind turbines.

### *Nacelle*

Nacelle is the part of a wind turbine at the top of tower and houses all the components in the wind turbine. It houses the gear box, generator assemblies and any control equipment.

### *Rotor Blades*

Rotor blades are the mechanical part of a wind turbine that convert wind kinetic energy into mechanical energy.



### *Shaft (Low Speed)*

The low-speed shaft is connected directly to the rotor hub.

### *Shaft (High Speed)*

The high-speed shaft is connected to the low-speed shaft by gearbox and drives the generator.

### *Gearbox*

It connects the low-speed shaft to the high-speed shaft and increases the rotational speeds to values as required by most generators.

### *Generator*

The generator is an electrical device that converts mechanical energy to electrical energy for use in an electrical circuit.

### *Yaw Control*

It is necessary for the rotor axis to be aligned with the wind direction in order to extract as much of wind kinetic energy as possible.

### *Working of the Wind Turbine*

When the wind strikes the rotor blades, the blades start rotating. The rotor is directly connected to a high-speed gearbox. The gearbox converts the rotor rotation into high speed which rotates the electric generator. An exciter is needed to give the required excitation to the coil so that it can generate the required voltage.

### Advantages

(i) No fuel cost, because wind is available in nature.
(ii) No pollution.
(iii) Renewable.
(iv) Less maintenance.
(v) Automatic operation of wind turbine.

### Disadvantages

(i) Wind is unsteady and unreliable.
(ii) High initial cost.
(iii) Noise production during operation.

## A.7 ELECTRICAL SAFETY ASPECTS

There is always a potential danger of electric shock or fire wherever there are outlets, plugs, wiring, or connections. Some simple precautions can be taken that will significantly reduce the risk of electrical injury. Some of them are listed below:

(i) Do not work in live circuits; if unavoidable, use rubber gloves, mats, etc.
(ii) Use wooden or PVC insulated-handle screwdrivers when working on electrical circuits.
(iii) Do not touch a bare conductor.
(iv) Replace a fuse only after switching OFF circuit switches.
(v) Never extend wiring by using temporary wiring.

(vi) Stand on rubber mats while working or operating with switch panels, control gears, etc.

(vii) Always use safety belts while working on poles or high-rise points.

(viii) Do not connect earthing to water pipelines.

(ix) Only skilled persons should do electrical work.

(x) Wear all right protective clothing and use all necessary safety equipment.

(xi) If the victim is in contact with supply, break the contact by switching OFF or by removing the plug or pulling the cable free.

(xii) Wrap your hands with dry material if rubber gloves are not available.

(xiii) Do not give an unconscious person anything to eat or drink.

Promotion of energy efficiency will contribute to energy conservation and is, therefore, an integral part of energy-conservation promotional polices.