CHAPTER 1

ENERGY CONSERVATION

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1. Meaning of Energy Conservation

Let us start with the basic and straight forward definition of energy conservation:

"Energy conservation means conserving or saving energy by using less amount of energy."

We may be using this energy for carrying out an activity, job or service. So, a better definition of energy conservation can be given as under:

"Energy conservation means conserving or saving energy by using less amount of energy for carrying out a given activity, job or service."

The above definition is good enough to define the concept of energy conservation, but it is silent about the context or application. We can talk about conservation of personal energy, or energy consumed by a device, gadget or equipment, or energy consumption in a house (domestic use), office or building, or energy consumption of an organization. Let us talk in the bigger and general context, i.e. ***energy conservation in an organization***, which may be a business company, an educational institution, a factory or an industry, etc. Secondly, when we say 'conserve energy or use less amount of energy in an organization', it remains a vague statement. So, the final definition of energy conservation should be stated as under:

"***Energy conservation means conserving or saving energy by using less amount of energy in an organization, without adversely affecting the productivity of the organization and comfort of the users."***

2. Forms of Energy

Energy exists in different forms, such as mechanical energy, heat or thermal energy, light or optical energy, gravitational energy, sound energy, hydraulic energy, electrical energy, chemical energy, nuclear or atomic energy, and so on. One form of energy can be converted into another form to facilitate its use. Energy is used mainly in three forms:

(a) ***Electrical Energy:*** This is the most versatile and most widely used form of energy these days. It is used for lighting, ventilation, cooling, heating, mechanical work, and so on.

(b) ***Fuel Energy:*** Used for building and industrial heating and in motor vehicles by converting thermal energy of fuel (petrol/diesel/compressed gas) into mechanical energy.

(c) **Chemical Energy:** Used for energy storage and chemical processing.

While discussing the subject of energy conservation, our ***focus will be primarily on conservation of electrical energy or electricity***. As fuel energy is the second most important form of energy used, we shall spend some time on fuel conservation measures for vehicles.

3. Energy, Power and Efficiency

3.1 Energy and Power

Energy is defined as the capacity of a body or system to do work. It is denoted by 'E' and its unit in SI system is ***joule (represented by symbol J).***

Power is defined as the rate of doing work or the amount of energy consumed (or delivered) per unit time. It is denoted by 'P' and its unit in SI system is ***joule per second (J/s) or watt (W)***. Two situations are possible: Power flow may be either constant or it may change with time.

(a) If power flow is taking place at a constant rate (that is, if power is constant), then the two quantities are related to each other by the following equations:

$$\text{Power} = \text{Energy} / \text{Time}$$

$$\text{Energy} = \text{Power} \times \text{Time}$$

(b) On the other hand, if power flow is changing with time (that is, if power is a function of time), then their relationship is given by the following equations:

$$P(t) = dE(t) / dt$$

$$E(t) = \int P(t)\, dt$$

3.2 Efficiency

Energy efficiency means "percentage of the total energy input to a machine or equipment or service that is consumed in doing useful work or in converting to useful output". The remaining part of the input energy is wasted as heat or sound energy etc., or in doing some useless work, or in producing some useless output. In a simple language, "***energy efficiency is the ratio of the output energy to the input energy".*** Thus, it is commonly expressed as under:

$$\text{Energy Efficiency} = \frac{\text{Output energy}}{\text{Input energy}} \times 100 \quad \text{(percent)}$$

Similarly, "***power efficiency is the ratio of the output power to the input power",*** that is

$$\text{Power Efficiency} = \frac{\text{Output power}}{\text{Input power}} \times 100 \quad \text{(percent)}$$

As energy is equal to power multiplied by time, the numerical values of energy efficiency and power efficiency are equal. Therefore, we just call it as ***efficiency of the device***.

In many cases, where the input and output energies have different forms and units, the energy efficiency cannot be measured as a percentage. For example, the efficiency of a lamp is stated as the ratio of its light output in lumens to the electrical input in watts, that is

$$\text{Efficiency of a lamp} = \frac{\text{Light output in lumens}}{\text{Electrical power input in watts}} \qquad \text{(lumens per watt)}$$

3.3 Some Examples from Electrical Engineering

Electrical devices or equipment fall basically under two categories: electric loads and electric generators. We will now discuss the above concepts with examples of these two types of devices/equipment.

Example#1: CFL

Let us consider an electric lamp, which is the simplest type of electrical energy load used in houses, offices, streets and almost everywhere for lighting. Let us talk of a ***compact fluorescent lamp (CFL)*** with the following specifications: 10W, 240V AC, 50Hz, 450 lumens.

This lamp is designed to work on 240V, 50Hz, AC supply (which is the standard supply for domestic use) and take an electrical power input of 10W from the supply line and give an optical power output of 450 lumens. If the lamp works for, say, 300 hours in a month, then its energy consumption in a month can be calculated as under:

$$\begin{aligned}\text{Electrical energy consumed} &= \text{Electrical power input} \times \text{time duration} \\ &= 10 \text{ watts} \times 300 \text{ hours} \\ &= 3000 \text{ watt-hours} \\ &= 3.0 \text{ kilo-watt-hours or kWh or units of electricity}\end{aligned}$$

Note: 1 unit of electricity = 1 kWh = 1000 Wh of electrical energy

Moreover,

$$\begin{aligned}\text{Efficiency of the lamp} &= 450 \text{ lumens} / 10 \text{ watts} \\ &= 45 \text{ lumens per watt (lum/W)}\end{aligned}$$

Example#2: LED Lamp

Let us now consider another type of electric lamp, a ***light-emitting-diode (LED) lamp***. It is the latest and most efficient type of electric lamp. Let us take up an LED lamp with the following specifications: 7W, 240V AC, 50Hz, 420 lumens.

This lamp is also designed to work on 240V, 50Hz, AC supply, but take an electrical power input of only 7W from the supply line and give an optical output of 420 lumens. If this lamp also works for 300 hours in a month, then its energy consumption in a month will be only 2.1 units of electricity as calculated below:

Electrical energy consumed = Electrical power input × time duration
= 7 watts × 300 hours
= 2100 watt-hours
= 2.1 kilo-watt-hours or kWh or units of electricity

Moreover,
Efficiency of the lamp = 420 lumens / 7 watts
= 60 lumens per watt (lum/W)

It is worth comparing the efficiencies of the two lamps considered in Examples 1 and 2. The efficiency of the CFL lamp is 45 lum/W, whereas that of the LED lamp is much more, it is 60 lum/W. In other words, the LED is lamp is more energy-efficient than the CFL lamp by

((60 – 45) / 45) * 100 percent
or, 33.3%

Example#3: Electric Generator

Next, let us consider an electric generator, which converts a mechanical power input to an electrical power output. Let us assume following specifications of its ***output ratings***: 2MW, 3.3kV, AC, 50Hz, 0.8 power factor and 94% efficiency. These specifications say that under rated (normal) conditions, this AC (alternating current) generator will give an output power ***up to*** 2MW with a voltage of 3.3kV (or 3300V) and a frequency of 50Hz. We shall ignore the power factor rating at this stage.

Under the rated (normal) conditions of working, the generator output power can be anything from zero to 2MW depending upon the load connected at its output terminals. However, the voltage and frequency will remain 3.3kV and 50Hz, respectively. The power output can change with time. Therefore, the energy delivered by the generator during any time duration will be equal to the integral of the power over that time. Thus,

Electrical energy delivered = $\int P(t)\, dt$

Moreover, the efficiency at the rated output power of 2MW is specified as 94%. Both energy efficiency and power efficiency are the same. So, we may write it as under:

$$\text{Efficiency of the generator} = \frac{\text{Electrical output power (watts)}}{\text{Mechanical input power (watts)}} \times 100$$

$$= 94\%$$

The generator efficiency is specified as 94% when it delivers the rated output power, that is, 2MW. It is worth noting that the efficiency of all machines is maximum at their rated output and reduces as the output goes above or below the rated value.

Example#4: Electric Motor

Lastly, let us consider an electric motor, which converts an electrical input power to a mechanical output power. Let us assume following specifications of its ***output ratings***: 3-phase, 415V, AC, 50Hz, 2HP and 85% efficiency. The specifications state that it is designed to work on 3-phase AC supply of 415V and 50Hz and it can produce a mechanical output power (called, shaft power) ***up to*** 2HP (horse power). The actual mechanical power produced will be ***as*** required to drive the mechanical load connected to its shaft.

Note: 1 horse-power (HP) = 746 watts (W)

Efficiency of the motor at the rated output power of 2HP is specified as 85%. Both energy efficiency and power efficiency are the same. So, we may write it as under:

$$\text{Efficiency of the motor} = \frac{\text{Mechanical output power (watts)}}{\text{Electrical input power (watts)}} \times 100$$

$$= 85\%$$

The motor efficiency is specified as 85% when it delivers the rated output power, that is, 2HP. Like all machines, the efficiency of the motor will reduce as the output power becomes less than or more than the rated output.

If the mechanical power output of the motor changes with time, the electrical power input will also change as per the above efficiency equation. Thus, the electrical energy consumed by the motor during any time duration will be equal to the integral of the power taken over that time. Thus,

$$\text{Electrical energy consumed} = \int P(t)\, dt$$

4. Why Energy Conservation?

4.1 Energy Conservation Equation

Following phrase is often used to promote the concept of energy conservation:

"1 unit of energy saved = 1 unit of energy generated"

This is an under-statement of the benefits of energy conservation. The fact is that when one unit of electrical energy (electricity) is required for use, at least 1.25 units of energy must be generated. Out of this, at least 20% is lost during its transmission and distribution, leaving behind only one unit of energy for use by the consumer. Secondly, in India, when one unit of electricity is generated by burning coal in a thermal power plant, at least 0.8 kg of C_2O and other greenhouse gases are emitted into environment causing air pollution and global warming. So, if 1.25 units of electricity are generated in a thermal power plant, at least 1 kg of these gases would be emitted. Thirdly, the consumer pays Rs. 4 to 8 for every unit of electricity used by him. Therefore, the energy conservation equation should be written as below:

"1 unit of energy saved = 1.25 units of energy generated + 1 kg of greenhouse gas avoided + Rs. 4 to 8 saved by the consumer"

4.2 Major Reasons or Benefits

There are four major reasons for conserving electrical energy (or benefits of electrical energy conservation) given below:

(a) To reduce the requirement of energy generation (Reduction in energy generation)
(b) To protect environment (Protection of environment)
(c) To reduce electricity bill of the consumer (Reduction in electricity bill)
(d) To minimize health hazards (Minimization of health hazards)

These reasons/benefits are discussed in detail in Sub-sections 4.3 to 4.6.

4.3 Reduction in Energy Generation

As said earlier, if 1 unit of energy is conserved (saved), then the requirement of energy generation will reduce by about 1.25 units. This reduction in energy generation will lead to two direct benefits:

(a) ***Reduction in the capital investment on energy generation, transmission and distribution infrastructure:*** Which means that the capital investment (funds) required for construction of (i) power generating plants, (ii) power transmission lines and (iii) power distribution network will reduce.

(b) ***Conservation of non-renewable resources of energy:*** Which means that the non-renewable resources of energy, like coal, petroleum and petroleum gas, used for generating electricity in thermal power plants, can be saved for future. The saved coal can be used by steel and other industries, for which it is more important. The saved petroleum products can be used to meet higher-priority requirements, like automobiles, aircrafts, ships and domestic cooking (by gas).

4.4 Protection of Environment

Following are the benefits of energy conservation related to environment:

(a) ***Reduction in air pollution:*** In India, largest part of electrical energy is generated in thermal power plants by burning the fossil fuels, namely, coal, oil and gas. These thermal power plants are the biggest source of air pollution in India. As a consequence of energy conservation, if less electrical energy is to be generated, then we shall certainly prefer to reduce thermal power generation in the first place. This will give us the biggest benefit of protecting our environment by burning less amount of fossil fuels and consequently releasing less carbon-dioxide and other poisonous gases into the atmosphere. It must be noted that India is one of those developing/developed countries that have the highest levels of air and water pollution. Therefore, reduction in air pollution should be considered as the most important reason or benefit of energy conservation for countries like India.

(b) ***Halting the global warming***: It is well known that carbon dioxide and other greenhouse gases are released when fossil fuels are burnt for power generation or other purposes. These greenhouse gases are responsible for a global rise in the temperature on earth, estimated to be nearly 2^0C at present. This phenomenon is called as global warming. Further global warming must be stopped by minimizing the burning of fossil fuels. As explained above, energy conservation will lead to reduction in power generation and hence to burning less fossil fuels in thermal power plants. This would help to stop further global warming.

(c) ***Reduction in environmental hazards:*** The other benefit of energy conservation related to the environment is reduction in the possible environmental hazards, such as the following:

i. ***Deforestation*** that is usually required for construction of water dams for large hydro-electric power plants.
ii. ***Flooding*** from a possible breach in a large water dam on a severe earthquake.
iii. ***Radioactive emissions*** can take place from a nuclear power plant due to some technical failure or a security lapse.

4.5 Reduction in Electricity Bill

An electricity bill is raised by the electricity supplier, generally on a monthly basis. The amount of bill is equal to the charges per unit of electricity (which is called as ***electricity tariff***) multiplied by the number of number of units of electricity consumed by that consumer.

So, if the consumer conserves or saves some electrical energy, his bill gets reduced. In case of a domestic consumer, he can improve the quality of his and his family's life by spending the saved money on other useful things. If the consumer is a business organization, the organization will save some expenditure on energy and thus make more profits.

4.6 Minimization of Health Hazards

Excessive use of energy in any form has some adverse effects on the health of the user. Given below are some examples:

(a) Excessive lighting in the working area can cause stress, headache, fatigue or even high blood pressure to the users.
(b) Prolonged exposure to air-conditioner set at a temperature below 23^0C can*:*
  - Trigger respiratory illness
  - Cause chest infection or bronchitis
  - Cause cold, flu, sinus, bloody nose, body aches, sore joints or arthritis
  - Lead to dry skin or itching
  - Lead to dry and lusterless hair
  - Lead to dry eyes.
(c) Switching suddenly from a hot and humid outdoor to an extremely cold and dry air-conditioned room, or vice a versa, can cause serious health problems.
(d) It is suspected that excessive use of air conditioning plays a major role in obesity.

Therefore, use of electricity within reasonable limits will not only result into conservation of electricity but also minimize health problems or hazards for the users.

5 Electrical Energy Conservation Measures

Once an organization is convinced of the benefits of energy conservation, here are the measures recommended for achieving the same:

(a) Spread awareness and sensitize all energy users in the organization
(b) Stop wastage of energy in the organization
(c) Improve energy efficiency in the organization
(d) Carry out systematic energy management of the organization
(e) Generate renewable energy on-site.

It should be noted that to assess the potential of energy conservation in an organization through the measures stated at (b) and (c), the organization should begin with a detailed technical ***energy audit.*** The energy audit can have an additional aim of assessing the scope of generating renewable energy on-site for the measure stated at (e). The five measures are described in Sub-sections 5.1 to 5.5 below. Further details of ***Energy Management*** and ***Energy Audit*** will be taken up in Chapter 2.

5.1 Awareness Creation and Sensitization

Every organization has some scope of energy conservation, and the percentage value may typically lie between 10% and 30%. This potential can be fully realized only through an active participation of all concerned persons, that is, the owners, the management, the employees and all other users of electrical energy in the organization. They all need to be made aware and sensitized about the necessity and benefits of energy conservation and their expected roles in this exercise.

Some means of creating awareness and sensitization are listed below:

i. Special talks and lectures by subject experts from within and outside the organization.
ii. Hold events like workshops, road shows and demonstrations focusing on the necessity and benefits of energy conservation on a regular basis, on National Energy Conservation Day (15^{th} December) and other important days.
iii. Display well-designed posters and banners reminding all electricity users of their expected roles in energy conservation programme.
iv. Set up an “Energy Conservation Committee” at the organization level.
v. Take up “Energy Conservation” as a “Mission” of the organization.

5.2 Stopping Energy Wastage

Some important steps that can be taken to stop wastage of electricity (electrical energy) in an organization are described below:

(a) Avoid over-use of lights, fans, air conditioners etc. (this can be achieved by making the users aware of the harmful effects of the overuse of electricity (see Sub-section 4.6).
(b) Switch off lights, fans, air-conditioners and other loads when not in use.
(c) Use more natural light than artificial lighting (using lamps of different types).
(d) Use more natural ventilation than forced ventilation (using fans and air blowers)
(e) Implement automatic control of lights, fans, air conditioners and other loads. This ***automatic control (or automation)*** may be done in two ways:

A. Automatic control of individual loads: One or more methods are used for the automatic control of individual loads:

i. Motion-based automatic control using motion sensors
ii. Motion-cum-light based automatic control using motion-cum-light sensors
iii. Day-light based automatic control using day-light sensors
iv. Occupancy-based automatic control using occupancy sensors
v. Time-based automatic control using timers
vi. Remote control using communication links.

B. Centralized control of loads: In this case, all the loads and suitable sensors are connected together on a data network. The loads are controlled from a single point using a ***personal computer (PC)*** or a ***programmable logic controller (PLC)***. Control decisions are taken by a well-written software program on the basis of sensor outputs received on the data network. Finally, suitable control commands (generally switch-on/switch-off commands) are sent to various loads on the same data network.

5.3 Energy Efficient Use

Another important measure to conserve electrical energy in an organization is to use the energy ***efficiently***. This can be achieved by taking actions such as the following:

i. **Use energy-efficient lights:** Fluorescent lamps (FLs) and compact fluorescent lamps (CFLs) are about five times more energy efficient than the traditional incandescent light bulbs, and LED lamps are about 50% more efficient than FL and CFL.
ii. **Use all energy-efficient equipments:** Modern pumps, motors and almost all industrial equipments use energy efficient technologies and, therefore, have about 20-40% higher efficiency over those made till the year 2000. For new installations, only these energy efficient equipments should be considered. For old installations, a ***cost-benefit analysis*** or a calculation of ***payback period*** should be made to decide whether replacement of the old equipment will be beneficial or not.
iii. **Use energy-efficient air conditioners:** The cost of the energy consumption of air-conditioners (ACs) in an organization is substantial these days. Depending on the nature of the organization, this consumption may be 20-40% of the total annual electricity bill. Therefore, large energy savings are possible by using air-conditioners of high energy-efficiency. The following 4 options are available in this regard:
   (a) Use microprocessor-based energy-saver device with the old air- conditioners having low energy efficiency. This can give an average energy saving of about 20%.
   (b) The Government of India, through its Bureau of Energy Efficiency (BEE), awards a star rating to every room AC now made in India. The lowest star rating is a single star and the highest is 5 stars. The energy efficiency is higher for a higher star rating. For every additional star, the efficiency increases by about 8%, that is, the energy consumption reduces by about 8%. So, use room ACs with higher star rating.

(c) Use ***Inverter ACs*** in place of ordinary window ACs. Inverter AC works on a gas compressor driven by an inverter. The inverter gives an energy saving of 10% – 40% depending on the cooling load.

(d) Use ***Variable Refrigerant Volume (VRV) or Variable Refrigerant Flow (VRF***) in place of ordinary split-type ACs. These ACs give an energy saving of 10% – 40% depending on the cooling demand.

iv. **Use energy-efficient refrigerators:** Unlike ACs, only two options are available for high-efficiency refrigerators:

(a) Refrigerator with high star rating from BEE

(b) Inverter refrigerator.

v. **Prevent air leakage:** Prevent air leakage through the building envelope (which means, outer walls of a building), so as to prevent the cooled air from leaking out of air-conditioned rooms into the atmosphere.

5.4 Energy Management

In a simple language, ***"energy management means monitoring and controlling energy consumption in an organization with the basic objective of energy saving or conservation".***

In addition, if there is on-site renewable energy generation, the energy management will also include controlling the same with the objective of its optimal utilization.

Detailed process, objectives, scope and various strategies of energy management will be dealt with in Chapter 2.

5.5 Renewable Energy Generation at Site

5.5.1 Important Terms

Let us first understand some of the important terms related to this topic.

(a) Energy Resource: An energy resource is a "supply or stock of energy", or a "supply or stock of something that can be used for producing energy continuously".

(b) Non-Renewable Energy Resources: These are the energy resources which will get depleted with time and, therefore, will not last forever. Examples are the fossil fuels (coal, oil and gas) used for producing electrical energy in thermal power plants and uranium used for producing electrical energy in nuclear power plants.

(c) Renewable Energy Resources: These energy resources are renewed or replenished automatically in the nature and, therefore, will last forever. Examples are: hydro-energy, solar energy, wind energy, tidal energy, wave energy and geo-thermal energy, which are used either directly or for producing electrical energy.

- ***(d) Renewable Energy:*** If the energy resource is renewed or replenished automatically in the nature, the energy produced qualifies as a renewable energy. Important examples are: photo-voltaic solar power, thermal solar power, wind power, large hydro power and small hydro power. Even nuclear power is considered renewable by many people as uranium is going to last for several hundred years.
- ***(e) Green Energy:*** If the impact of the energy generation on environment is negligible, then the energy so generated qualifies as a green energy. Photo-voltaic solar power, thermal solar power, wind power and small hydro power are good examples of green energy as well as renewable energy. Generation of large hydro-power requires construction of big water dams, which are considered by majority of people as bad for the environment. Hence, it is generally not considered as a green energy. Similarly, most of the people do not consider the nuclear energy as a green energy because of the harmful nuclear radiations likely to be emitted by nuclear power plants.
- ***(f) Distributed Energy:*** If the energy is generated in a distributed fashion (and not at a single location in a large power plant), such that the generation takes place at or very near to the primary points of consumption, then the energy so generated is called as distributed energy.

5.5.2 Examples

Following are the examples of “renewable, green and distributed” energy generation:

- (i) Roof-top photo-voltaic solar power generation
- (ii) Wind power generation
- (iii) Small hydro power

The first one in the list, i.e. roof-top photo-voltaic (PV) solar power generation, is based on the well-known ***photo-voltaic or photo-electric effect***. An array of PV cells is used here for the conversion of sunlight into electrical energy. Because of its several benefits (which will be discussed later), it is best suited for on-site power generation in majority of areas of India and other countries with abundant sun.

5.5.3 Layout and Working of Roof-Top PV Solar Power Plant

A typical layout of roof-top PV solar power plant is shown in the following figure. Its main components and working are briefly explained below:

- (a) The power plant converts the solar energy into electrical energy by employing a large number of ***photo-voltaic (PV) cells***, also called as ***solar cells.***
- (b) PV cell is basically a photo-sensitive diode, which produces a small DC power when solar light strikes the diode at its junction.
- ***(c)*** A large number of PV cells are mounted on a flat base and connected suitably in series (to get more output voltage) and in parallel (to get more current). This assembly is called as a ***PV panel.***

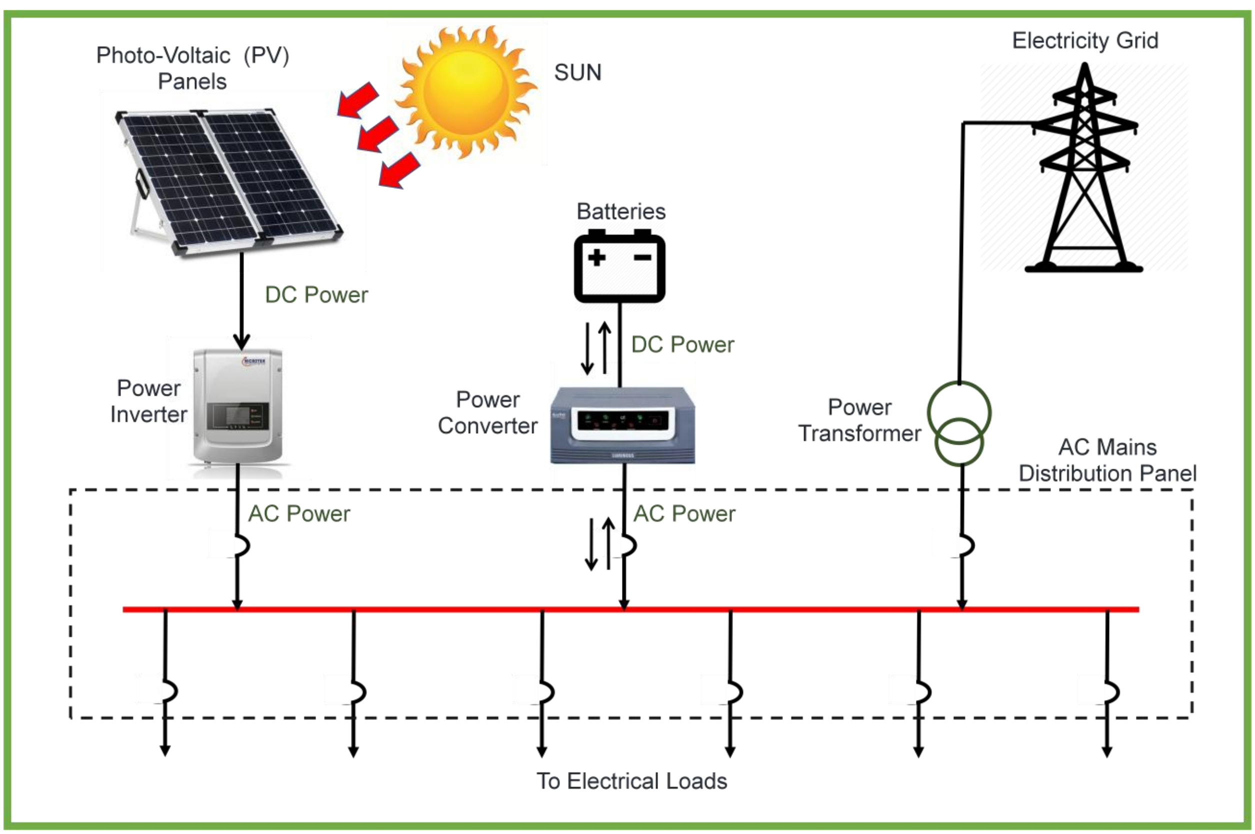
(d) A number of ***PV panels*** are fixed on the roof-top of a building and connected suitably in series and parallel to get a large DC power output.

(e) The ***DC power*** is converted into ***AC power*** by using an ***inverter***, also located on the same roof-top.

(f) The AC power is connected, using a power cable, to an ***AC mains distribution panel***, generally located in the basement or on the ground floor of the same building. This panel is designed to distribute the electrical power from a ***bus*** to all ***electrical loads*** located in that building. The power is distributed generally at 415V, 3-phase, 50Hz.

(g) In the absence of solar power, electricity is taken from ***Electricity Grid.*** The AC power from the grid is at a high voltage, which is stepped down to 415V using a ***power transformer*** before connecting it to the bus, as shown in the figure.

(h) A ***storage battery*** may be used for storing any extra energy generated by the solar power plant and later on supplying it to the loads, as and when required. The battery is connected to the bus through a ***power converter***, as shown in the figure. It converts AC power to DC power when battery is being charged from the AC bus and converts DC power to AC power when battery needs to supply power to electrical loads through the bus.



Typical Layout of a roof-top Solar Power Plant

(i) Each connection to the AC bus is made through a ***circuit breaker (CB)***, as shown in the figure. A circuit breaker is used to make (connect) and break (disconnect) a circuit as and when required.

(j) There are similar solar power units on the roof-tops of several buildings of the organization. Thus, the PV solar power plant is used for ***distributed energy generation*** to supply electricity within the organization.

5.5.4 Benefits of Roof-Top PV Solar Power Generation

Roof-top PV solar power plant is these days the best choice for renewable energy generation at site because of its several advantages given below:

(a) ***Everlasting energy resource:*** The sun, which is the energy resource for PV solar power generation, is ever-lasting. It will never be exhausted.

(b) ***Free energy resource:*** The sunlight, which is the input energy to PV solar power plant, comes totally free of cost from the nature.

(c) ***No environmental pollution:*** Generation of PV solar power does not cause any pollution of the environment.

(d) ***No transmission and distribution losses:*** The power generation is suitably distributed over the utilization area such that it is generated in parts physically close to the primary points of consumption. The generated power is connected directly to the distribution panel by a short cable. No transmission and distribution lines are required. So, there are no transmission and distribution losses here. In a conventional power system, these losses are generally 20-30% of the generated power.

(e) ***Low maintenance:*** There are no moving parts or machines, like steam turbine in a thermal power plant, hydraulic turbine in a hydro-electric power plant, wind turbine in a wind power plant, or any rotating-machine type electric generator (which is used in all these power plants). So, the maintenance of PV solar power plants is very easy and inexpensive. The only maintenance required is the washing of PV panels with water at regular intervals.

6 Low Energy Buildings

You may be surprised to know that the buildings account for about 40% of global energy use, although for a tropical country like India this figure is lower (about 30%). So, saving some of the energy used by/in buildings is very important. To achieve it, the concept of low-energy buildings must be understood.

The energy used by/in a building is comprised of three components:

i. Energy used in the production of construction materials.
ii. Energy used during the construction of the building
iii. Energy consumed during use of the building over its life-cycle.

The last component in general dominates, but the other two components are not negligible. The total energy used by the building can be reduced by 20 to 70% by incorporating 'passive designs' along with 'active systems' explained below. The extra cost of these features/provisions is estimated at 2 to 7% of the building cost.

A. ***Passive Designs:*** They include the following measures:
   i. Orientation of the building with respect to the south direction is selected to make the best use of sunlight.
   ii. Windows and roof-lights are located and designed to let in sunlight in winter when the sun is low, but block it in summer when the sun is high in the sky.
   iii. High levels of insulation and air tightness to prevent heat loss in winter and heat gain in summer.
   iv. Natural ventilation for cooling in summer.
   v. High-efficiency low-emissivity glazing that allows high levels of daylight in while restricting the penetration of infra-red rays that cause heating.
   vi. Low-carbon materials for building construction.

B. ***Active Systems:*** Following energy-efficient active systems can be incorporated:
   i. Energy-efficient lights, air-conditioners, refrigerators, etc.
   ii. Energy efficient equipment (water and sewage pumps, and motors)
   iii. Energy efficient machines (elevators and escalators)
   iv. Building automation to cut wastage of energy while enhancing comfort to users.
   v. Renewable energy generation on-site.

Along with the above measures, ***low-energy construction techniques*** should be employed to save some energy during construction of the building.

Some interesting definitions related to low-energy buildings are given below:

Zero-Energy Building: Zero-energy building (ZEB), also known as zero net-energy building (ZNEB) or net-zero energy building (NZEB), is a building with zero net-energy consumption, that is, the total energy used by the building on an annual basis is roughly equal to the renewable energy generated on the site.

Green Building: Green building, also known as green construction or sustainable building, is a building for which all the processes of its life-cycle, namely, planning, design, construction, operation, maintenance, renovation and demolition, are ***environment-friendly*** and ***resource-efficient***. It means that all the resources like electricity, water, manpower and construction materials are used efficiently and there is no adverse impact on the environment during the entire life-cycle of the building.

7 Fuel Conservation Measures for Vehicles

After electricity generation, road vehicles are the second largest source of air pollution in India. Fuel conservation in vehicles not only saves some fuel cost, but also reduces air pollution. Some important measures for the fuel conservation for vehicles are given below:

(a) ***Avoid rapid acceleration:*** Higher acceleration requires higher torque on the shaft. Higher torque requires the engine to produce more power by consuming extra fuel. This fuel wastage can be avoided by avoiding rapid acceleration, unless it is very essential.

(b) ***Avoid hard braking and sudden stopping:*** The vehicle driver should stay alert and anticipate traffic lights, stop signs and traffic merges, and apply brakes softly to decelerate slowly. Hard braking causes wasting the shaft power as heat at the brake-shoes. A sudden stopping will require another restart of the engine or acceleration from zero to full speed. In both the events, fuel is wasted.

(c) ***Drive at economical speed:*** For every vehicle, there is a most-economical speed, i.e. the speed at which fuel consumption per km is the minimum. The driver should try to drive the vehicle around this speed. Experiments have revealed that the fuel consumption increases by about 20% if the vehicle is run at 40% higher than the economical speed.

(d) ***Shut-off engine at halts:*** Engine should be stopped if the halt at a red-light is expected to last more than a minute to avoid fuel wastage.

(e) When starting out, shift up to the next gear as soon as possible without straining the engine.

(f) Keep engine properly tuned, otherwise fuel efficiency of the engine goes down.

(g) Keep tyres of the vehicle properly inflated, otherwise energy would be wasted in overcoming excessive friction between the tyres and the road.

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