Non-Conventional Energy Resources
Unit-I

Introduction: Various non-conventional energy resources- Introduction, availability, classification, relative merits & demerits. Theory of solar cells, Solar cell materials, Solar cell array, Solar cell power plant, Limitation.

1.1 Energy: Energy can be defined as the capacity of any object to do work.

The study of various forms of energy and its conversion from one form to another is called **energy science.** The applied part of energy science useful to human beings is called the **energy technology.**

1.2 Indian and Global Energy Sources: Energy sources may be classified in to the following types:
1. Primary & Secondary energy sources, 2. Commercial & Non-commercial sources, 3. Renewable & Non-renewable energy sources.

1.2.1 Primary & Secondary energy sources:

Primary energy sources are those which are found or stored in nature. **e.g.** coal, oil, natural gas and biomass like wood etc. **Other primary energy sources** are as found on earth are nuclear energy from radioactive substances, geothermal energy, potential energy due to earth's gravity etc.	**Secondary energy sources** are usually converted from primary energy sources. **e.g.** the electricity sources converted from oil, natural gas or coal etc.

1.2.2 Commercial & Non-commercial energy sources:

Commercial energy sources are those which are available in the market and can purchased at a definite price from the producing agencies. **e.g.** electricity, coal, oil etc.	**Non-commercial energy sources** are those which are not available in commercial market for a price. These are also called **traditional fuels.** **e.g.** agro waste, animal dung etc.

1.2.3 Renewable & Non-renewable energy sources.

Renewable energy is energy obtained from the sources that are essentially inexhaustible. **Examples of renewable resources** include wind power, solar power, geothermal energy etc.	**Non-renewable energy** is the conventional fossil fuels such as coal, oil, gas etc. This form of energy is exhaustible and likely to deplete with time.

1.3 Non-conventional Energy Sources Relevant to India:

There is separate Ministry in the Government of India to exclusively focus on this important area of power generation. National Electricity Policy lays down that the state Electricity Regulators Commissions should prescribe a proportion of power which should be produced and supplied to the grid through the non-conventional sources.

1.3.1 Need to develop Non-conventional Sources of Energy:
1. Conventional sources are energy are reducing with phrase of time. **e.g.** oil is likely to last up to 2025 and coal another 200 years.
2. Conventional sources are one of the main cause of air pollution which is causing **global warming** and climate change.
3. It causing reduction in agricultural production per capita.
4. Reduced fresh water supply.

1.3.2 Present Status of Non-conventional Energy Sources:

(i) Solar Energy:
- A potential for 30MW/km^2 in India.
- Solar Photovoltaic (SPV) contributes 2.5% of power generation from renewable energy. It aggregate capacity of 47 MW have deployed for various applications.
- Maximum efficiency possible below 30%. But Carbon Nano Tube (CNT) based PV cell hold promise of higher efficiency upto 35%.

- Generation cost is still 4 times higher than a thermal power plant.
- Gujarat has been a leader in solar power generation and contributes 2/3rd of the 900 MW of photo-voltaic in the country.

(ii) Wind energy scenario:

- India ranks fifth amongst the wind-energy-producing countries of the world after USA, China, Germany and Spain and produces 12009 MW as on 30 June 2011.
- Gross wind energy potential: 65,000 MW and technical potential: 45,000 MW.
- States with high potential: Tamil Nadu, Gujarat, Andhra Pradesh, Karnataka, Kerala, Maharashtra.
- Capital cost of wind power projects ranges from Rs. 5-6 corer/MW and the cost of generation is estimated to be Rs. 2.5-3/kwh.

(iii) Bio-fuels:

- These fuels are in preliminary stages of development, and will take several years to develop.
- But no surplus oil seeds available for bio-fuels. In this case, Jatropha seems to available alternative.
- India has 60 million acres waste-land, and 30 million of that is suitable for Jatropha plantation.

(iv) Geothermal Energy:

- Geothermal energy supplies more than 10,715 MW to 24 countries worldwide which is expected to generate 67,246 GWh of electricity in 2010.
- It is reliable source of energy which is available continuously throughout the year and independent of weather condition.
- India has reasonably good potential for geothermal; the potential geothermal provinces can produce 10,600 MW of power.
- At present there are no operational geothermal plants in India. There is also no installed geothermal electricity generating capacity as of now and only direct uses (e.g. Drying) have been detailed.
- India's Gujarat state is drafting a policy to promote geothermal energy.
- **Potential Sites**:
  (a) Puga Valley (J&K), (b)Tatapani (Chhattisgarh), (c)Godavari Basin Manikaran (Himachal Pradesh)
  (d) Bakreshwar (West Bengal), (e) Tuwa (Gujarat), (f) Unai (Maharashtra), (g) Jalgaon (Maharashtra).

1.4 Installed Power Generation Capacity In India (as on 30th March 2013):

Fuel	MW	%age
Total Thermal	141713.68	66.91
Coal	121619.88	57.42
Gas	18903.05	8.92
Oil	1199.75	0.56
Hydro	39416.40	18.61
Nuclear	4780.00	2.25
RES (MNRE)	25,856.14	12.20
Total	2,11,766.22	100

1.5 Sector-wise allocation:

Sector	MW	%age
State Sector	86,343.35	40.77
Central Sector	62,963.63	29.73
Private Sector	62,459.24	29.50
Total	2,11,76.22	

1.6 Solar Energy: Sun is the fundamental source of all type of energy. The sun releases the enormous amount of energy due to continuous nuclear fusion reaction taking place in it. It sends the energy in the form of radiations at the rate of 3.7×10^{20} MW. However, the energy received by the earth is about 1.85×10^{11} MW.

1.6.1 Advantages of Solar Energy:
1. It is available in abundance and free of cost. It is inexhaustible form of energy and will be sufficient to sustain as far as we think of our existence.
2. It is free from pollution and having low operating and maintenance cost.
3. No elaborated arrangements are needed for transportation, storage or handling as in the case of fossil fuels.
4. The operation of Solar thermal energy ranges from Solar cookers of 1 kW to power plant of 200 MW.

1.6.2 Disadvantages of Solar Energy:
1. Availability depends on several conditions, like weather, climate, month, time of day, and during the year.
2. Needs very large collector area to harness solar energy involving high capital cost.
3. Solar collectors, panels and cells are relatively expensive to manufacture although prices are falling rapidly.
4. Solar power is used to charge batteries so that solar powered devices can be used at night. However, the batteries are large and heavy and need storage space. They also need replacing from time to time.

1.7 Solar Cell: Solar Cells are solid electronic devices used to convert the electromagnetic energy of solar radiation directly into direct current electricity. Thus a solar cell is a transducer which converts the sun's radiant energy directly into electricity and is basically a semiconductor diode capable of developing a voltage of 0.5-1V and current density of 20-40 mA/cm^2 depending on the materials used and the sun light conditions. This makes the system far more convenient and compact compared to thermal methods of solar energy conversion.

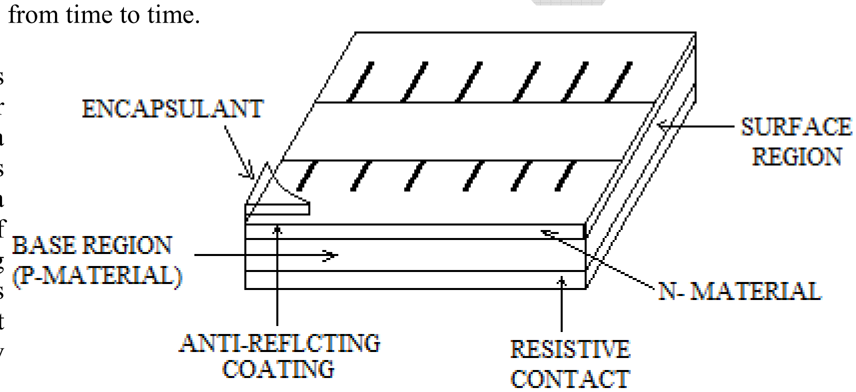
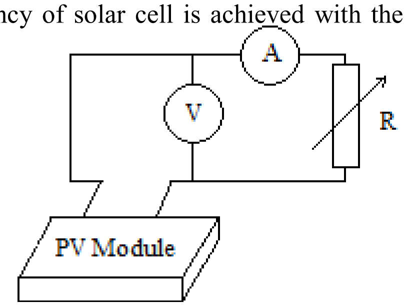


Fig. Solar cell

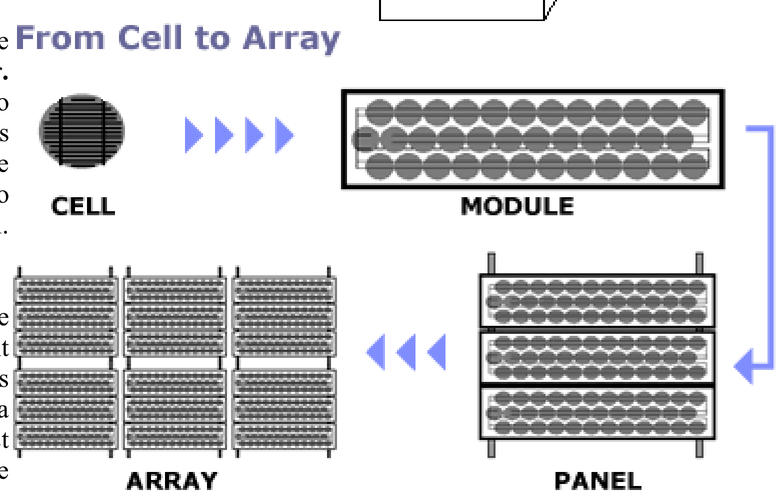
1.8 Solar Cell Materials: Solar cells are made of different materials and Silicon (Si) is one used in nearly 90% applications. The choice of the materials depends on the energy gap, efficiency and cost. The maximum efficiency of solar cell is achieved with the band energy of 1.12 eV – 2.3 eV. Other commonly used Materials are
Cadmium Telluride (CdTe), Gallium Arsenide (GaAs), Zinc Telluride (ZnTe) etc.



1.9 Performance Characteristic of Solar Cell: Performance characteristics of PV cell is dependent on solar radiation, climate conditions etc. The cell is tested at standard test conditions of 1000 W/m^2 solar radiation and 25 ^{0}C cell temperature.

The testing setup is shown in figure. When the circuit is open, the flowing current is zero and this open circuit voltage (V_{oc}) is nearly 0.6 V.

1.10 Photovoltaic Array: A typical silicon cell can produce upto 0.6 V and upto 6 Amp i.e. equivalent to about 3 W power**.** The cell size varies from 1 cm to about 10 cm across. To increase power output, cells are electrically connected in series and parallel to absorb as much light as possible to produce desired voltages and current. A number of cells are combined to form a **Module.** When modules are combined we get a Panel. Panels are combined to get an **array.**



1.11 Photovoltaic Power Generation: The maximum possible output of a solar array is about 300 W/m^2. Figure shown in next page shows the basic structure of a solar cell power plant. This scheme is suitable for feeding a local load as also for feeding a grid. The photo voltaic array produces dc power and this must be converted into ac power for local use and feeding into the grid. Some form of energy storage is invariably used so that at time of excess generation, the energy may be stored so that it can be used at the time of low generation.

1.12 Solar Cell Power Plant:

Depending on the method of utilization there can be two configurations:

1. Stand alone system 2. Grid connected system

1.12.1 Stand Alone System:

This system having following characteristics:

- Operates autonomously and independently.
- Commonly used for backup power where connecting to grids are very costly.
- Can be used to power DC loads and by the use of an inverter it may used for AC loads also.
- Hybrid stand alone systems may include other power producing devices also for backup.

Stand alone systems may be of any one of the categories:

- Direct Coupled Stand alone system.
- Stand alone system with Battery storage.
- Stand alone system with battery and charge control.
- Stand alone system with AC and DC loads.
- Hybrid Stand alone systems.

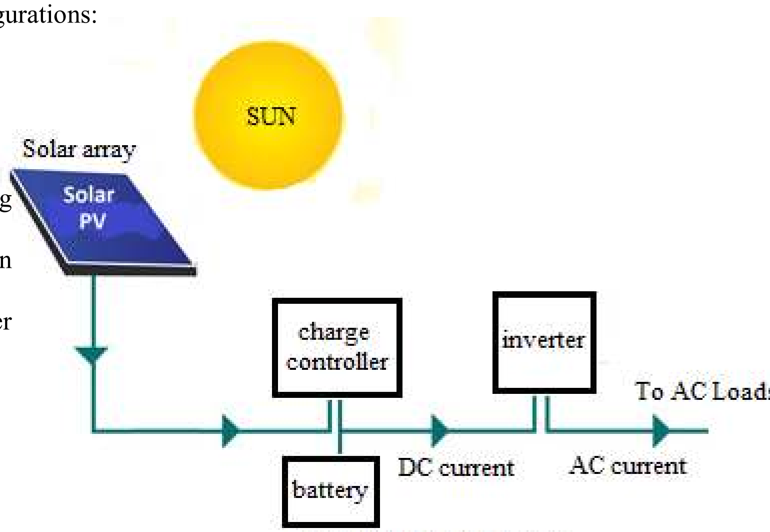


Fig. Stand Alone System

1.12.1(a) Direct Coupled Stand Alone System:

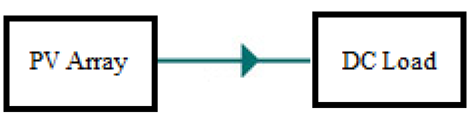


Fig. Direct coupled stand alone systems

- In this the solar array is directly connected to the DC load.
- There is no energy storage.
- It can be used only in sunshine hours.
- Basically uses for water supply pumps for agricultural purpose.

1.12.1(b) Stand Alone System with Battery Storage:

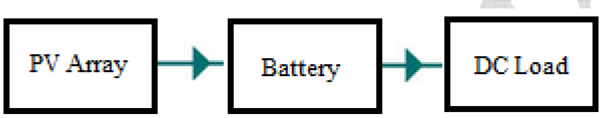


Fig. Stand alone system with battery storage

- In this the PV array charges the battery and the battery supplies DC power to the loads.
- There is no charge control and is susceptible to overcharge and over discharge.

1.12.1(c) Stand Alone System with Batteries and Charge Control:

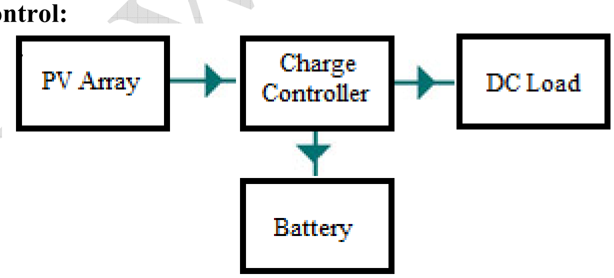


Fig. Stand alone system with batteries and charge control

- This has got charge control for controlling the charge / discharge.

1.12.1(d) Stand Alone Systems with AC and DC Loads:

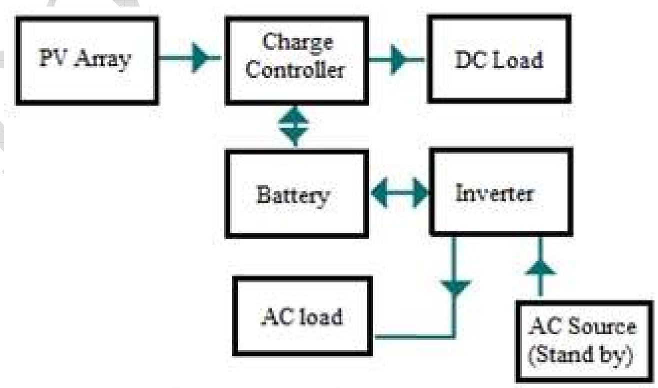


Fig. Stand alone system with AC and DC loads

- This system can be used to power AC as well as DC loads
- It needs inverter in the circuit.
- In addition the main AC supply also may be used for charging only in the case of emergency.

1.12.1(e) Hybrid Standalone Systems:

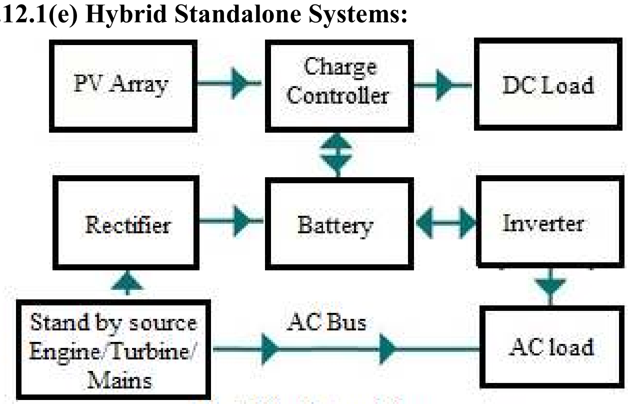


Fig. Hybrid stand alone system

- In such systems one or more sources in addition to the PV panels are used.
- Sources like stand by engines, turbines, fuel cells etc may be used in conjunction with PV arrays which reduces the dependency on any single source.
- This also reduces battery storage capacity and size of PV arrays.

1.12.2 Grid Connected Systems:

- In this system the power generated by the PV array is fed to the grid or to the AC load directly.
- At the time of excess power generation the requirement of the loads is supplied to a commercial grid.
- The output from the inverter has to satisfy the norms of the quality of the electrical standard so that it can match the grid system.

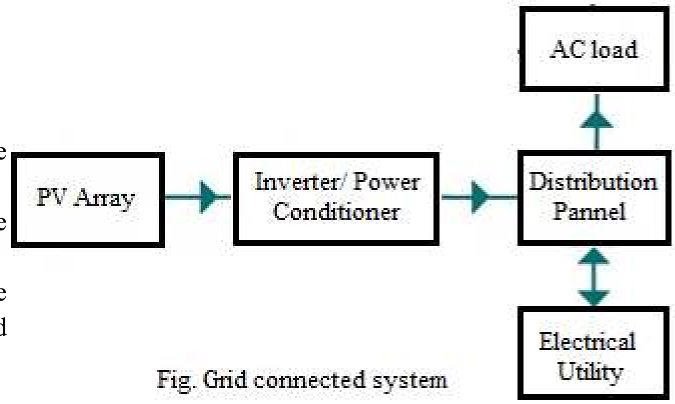


Fig. Grid connected system

1.13 Solar Cell Terminology:

1.13.1 Solar Cell Efficiency: The efficiency of a solar cell can be defined as:

$$Efficiency = \frac{Maximum\ power\ output}{Incident\ Intensity \times Area\ of\ the\ device\ exposed}$$

$$\eta = \frac{V_m . I_m}{Insolation \times Area}$$

Where, V_m = cell voltage
I_m = current

$$\eta = \frac{F_F \times V_{OC} \times I_{SC}}{Total\ Insolation}$$

$\mathbf{F_F}$ is called the fill factor
V_{OC} = open circuit voltage
I_{SC} = short circuit current

1.13.2 Quantum Efficiency (Q_E): Quantum efficiency may be defined as:

$$Q_E = \frac{\text{Number of electron hole pairs generated per unit area}}{\text{Number of photons striking the device}}$$

1.13.3 Spectral responsivity (S_R) $= \frac{\text{Electron flux(q)}}{\text{Photon energy (hc/}\lambda)} = \frac{q\,.\,\lambda}{hc}$

1.13.4 Fin Factor (F_F): It is the ratio of maximum power delivered by cell to power obtained with product of short circuit current.

$$F_F = \frac{P_m}{I_{SC} \times V_{OC}}$$

It varies between 0.6 to o.8 for Si.

1.14 Factor Affecting Efficiency of Solar Cell:

1. Reflection losses at the top surface. **2.** Shading due to charge collection grid. **3.** Incomplete absorption of energy due to limited cell thickness. **4.** Collection losses.

1.15 Advantages & Disadvantages of PV Systems:

1.15.1 Advantages:

- PV channel provides clean form of energy with any harmful greenhouse gas emissions thus it is environmentally friendly.
- These systems produce electricity in a direct electricity way of generation.
- These systems have no mechanical moving parts, expect in case of solar- tracking mechanical bases, hence having very low breakage or require less maintenance.
- Solar energy is especially appropriate for smart energy networks with distributed power generation – DPG is indeed the next generation power network structure!

1.15.2 Disadvantages:

- Solar panels efficiency levels are relatively low (maximum 30%) compared to the efficiency levels of other renewable energy systems.
- Solar power is a variable energy source, with energy production dependent on the sun. Solar facilities may produce no power at all some of the time, which could lead to an energy shortage if too much of a region's power comes from solar power.
- In case of land-mounted PV panel installations, they require relatively large areas for deployment; usually the land space is committed for this purpose for a period of 15-20 years – or even longer.