RENEWABLE ENERGY TECHNOLOGY

Prepared By:

Dr. Md. Rifat Hazari

Assistant Professor

Modified By:

S M Imrat Rahman

Senior Lecturer

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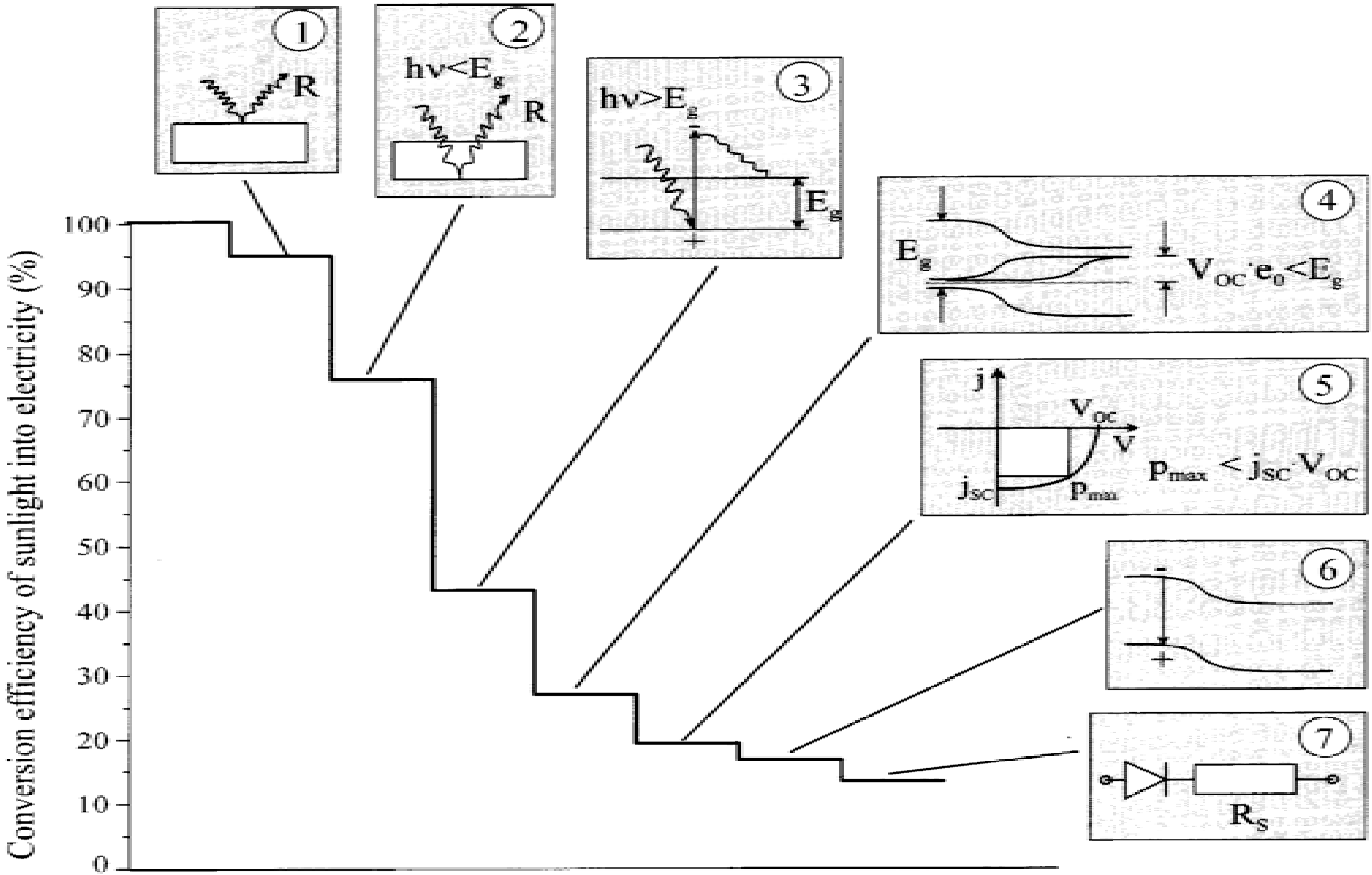
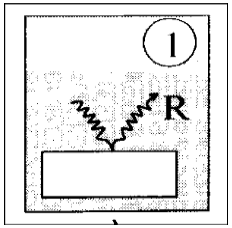
American International University-Bangladesh

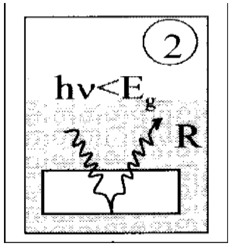
Solar Cell Performance Losses



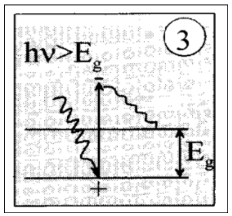
Solar Cell Performance Losses



The reflection losses at the top surface of the cell can be eliminated by putting antireflection coating composed of a thin optically transparent dielectric layer on the top surface of the cell.

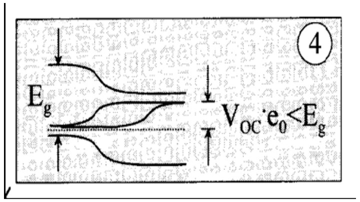


There is a minimum energy level (and thus the maximum wavelength) of photons that can cause the creation of a hole-electron pair. For silicon, the maximum wavelength is 1.15m. Radiation at higher wavelengths does not produce hole-electron pairs but heats the cell.

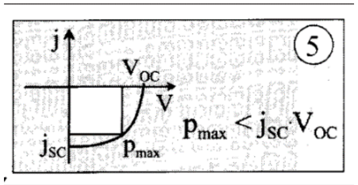


Each photon causes the creation of a single-hole pair, and the energy of photons in excess of that required to create hole-electron pairs is also converted into heat.

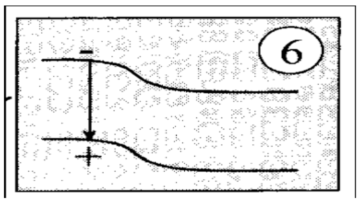
Solar Cell Performance Losses



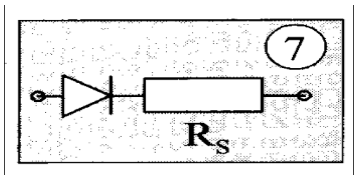
The open circuit voltage is physically limited to values less than the bandgap voltage.



Since I-V curve is not perfectly rectangular, only 80% of the maximum power is achieved.



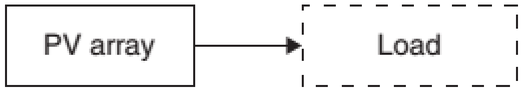
Recombination losses due to photon generated carriers not reaching the electrical contacts gives raise to a loss.



The electrical series resistance in the cell itself, its contacts and in the external circuitry lead, contributes to the loss.

Direct Coupled PV System

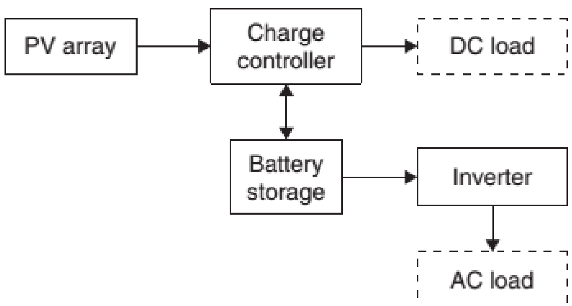
- In a direct coupled PV system, the PV array is connected directly to the load.
- Therefore, the load can operate only whenever there is solar radiation, so such a system has very limited applications. The schematic diagram of such a system is shown in following figure.
- A typical application of this type of system is for water pumping, i.e., the system operates as long as sunshine is available, and instead of storing electrical energy, water is usually stored.



Schematic diagram of a direct coupled PV system.

Stand-Alone Applications

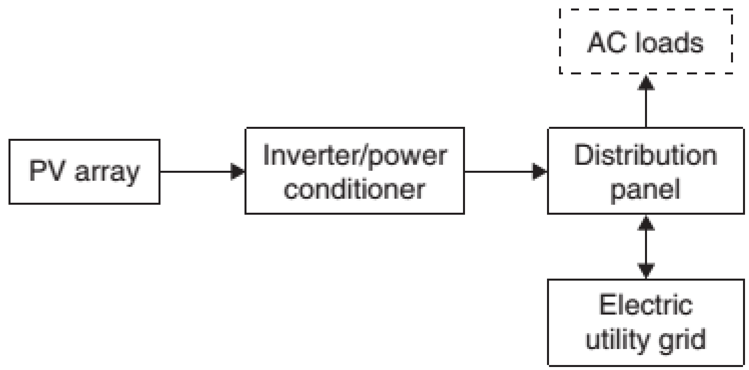
- Stand -alone PV systems are used in areas that are not easily accessible or have no access to an electric grid.
- A stand-alone system is independent of the electricity grid, with the energy produced normally being stored in batteries.
- A typical stand-alone system would consist of a PV module or modules, batteries, and a charge controller.
- An inverter may also be included in the system to convert the direct current generated by the PV modules to the alternating current form required by normal appliances. A schematic diagram of a stand-alone is shown in figure. As can be seen, the system can satisfy both DC and AC loads simultaneously.



Schematic diagram of a stand-alone PV application.

Grid-Connected System

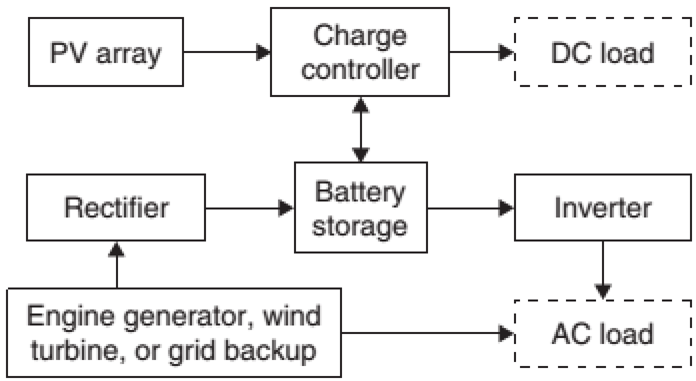
- Nowadays , it is usual practice to connect PV systems to the local electricity network.
- This means that, during the day, the electricity generated by the PV system can either be used immediately (which is normal for systems installed in offices, other commercial buildings, and industrial applications) or be sold to one of the electricity supply companies (which is more common for domestic systems, where the occupier may be out during the day).
- In the evening, when the solar system is unable to provide the electricity required, power can be bought back from the network.
- In effect, the grid is acting as an energy storage system, which means the PV system does not need to include battery storage. A schematic diagram of a grid-connected system is shown in following Figure.



Schematic diagram of a grid-connected system.

Hybrid-Connected System

- In the hybrid-connected system, more than one type of electricity generator is employed.
- The second type of electricity generator can be renewable, such as a wind turbine, or conventional, such as a diesel engine generator or the utility grid.
- The diesel engine generator can also be a renewable source of electricity when the diesel engine is fed with biofuels.
- A schematic diagram of a hybrid connected system is shown in figure below.
- Again, in this system, both DC and AC loads can be satisfied simultaneously.



Schematic diagram of a hybrid connected system.

Application

These are some of the most common PV applications:

- **Remote site electrification:**
  - Photovoltaic systems can provide long-term power at sites far from utility grids.
  - The loads include lighting, small appliances, water pumps (including small circulators of solar water heating systems), and communications equipment.
  - In these applications, the load demand can vary from a few watts to tens of kilowatts.
  - Usually, PV systems are preferred to fuel generators, since they do not depend on a fuel supply, which can be problematic, and they do avoid maintenance and environmental pollution problems.
- **Communications:**
  - Photovoltaics can provide reliable power for communication systems, especially in remote locations, away from the utility grid.
  - Examples include communication relay towers, travelers' information transmitters, cellular telephone transmitters, radio relay stations, emergency call units, and military communication facilities.
  - Such systems range in size from a few watts for callbox systems to several kilowatts for relay stations.
  - Obviously, these systems are stand-alone units in which PV-charged batteries provide a stable DC voltage that meets the varying current demand.
  - Practice has shown that such PV power systems can operate reliably for a long time with little maintenance.

Application

- **Remote monitoring:**
  - Because of their simplicity, reliability, and capacity for unattended operation, photovoltaic modules are preferred in providing power at remote sites to sensors, data loggers, and associated meteorological monitoring transmitters, irrigation control, and monitoring highway traffic.
  - Most of these applications require less than 150 W and can be powered by a single photovoltaic module.
  - The batteries required are often located in the same weather-resistant enclosure as the data acquisition or monitoring equipment.
  - Sabotage may be a problem in some cases; however, mounting the modules on a tall pole may solve the problem and avoid damage from other causes.

- **Water pumping:**
  - Stand-alone photovoltaic systems can meet the need for small to intermediate-size water-pumping applications. These include irrigation, domestic use, village water supply, and livestock watering.
  - Advantages of using water pumps powered by photovoltaic systems include low maintenance, ease of installation, and reliability.
  - Most pumping systems do not use batteries but store the pumped water in holding tanks.

Application

- **<u>Building-integrated photovoltaic:</u>**
  - Building-integrated photovoltaics(BIPV) is a special application in which PVs are installed in the roof of a building and are an integral part of the building structure, replacing in each case the particular building component.
  - To avoid an increase in the thermal load of the building, usually a gap is created between the PV and the building element (brick, slab, etc.), which is behind the PV, and in this gap, ambient air is circulated so as to remove the produced heat.
  - During wintertime, this air is directed into the building to cover part of the building load; during summer, it is just rejected back to ambient at a higher temperature.
  - A common example where these systems are installed is what is called zero-energy houses, where the building is an energy-producing unit that satisfies all its own energy needs. In another application related to buildings, PVs can be used as effective shading devices.
- **<u>Charging vehicle batteries:</u>**
  - When they are not used, vehicle batteries self discharge over time. This is a major problem for organizations that maintain a fleet of vehicles, such as the fire-fighting services.
  - Photovoltaics battery chargers can help solve this problem by keeping the battery at a high state of charge by providing a trickle charging current.
  - In this application, the modules can be installed on the roof of a building or car park (also providing shading) or on the vehicle itself.
  - Another important application in this area is the use of PV modules to charge the batteries of electric vehicles.

MATHEMATICAL PROBLEM

1. If the dark saturation current of a solar cell is 1.7×10^{-8} A/m^2, the cell temperature is 27°C, the short-circuit current density is 250A/m^2, and the voltage at maximum power is 0.47V, calculate the open circuit voltage, V_{oc}; current density at maximum power, I_{max}; maximum power, P_{max}; and maximum efficiency, η_{max}. What cell area is required to get an output of 20 W when the available solar radiation is 820 W/m^2?

2. A PV system is required to produce 250W at 24 V. Using the solar cells of Problem 1, design the PV panel, working at the maximum power point, if each cell is 9 cm^2 in area.

1. If, I_{sc} = 30mA, k=1.35 X 10^{-23} , I_0= 2 X 10^{-12}A, T=27^{0}C, Incident solar irradiance is 100W/m^2. Draw the I-V curve and P-V curve . Also find out R_{mpp}, FF and Efficiency. Use the range of V_L is given in following table.

V_L	0.5	0.51	0.52	0.53	0.54