Design of photovoltaic system

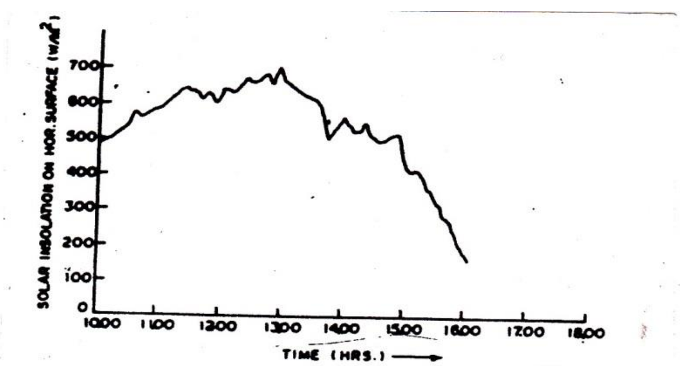
Photovoltaic systems are already economically viable systems in isolated locations for loads of less than 1 KW. In such cases the system is generally a low voltage d.c. simple photovoltaic system consists of one or mote arrays of solar cells, storage battery, blocking diode and a battery charge limiter. The design of such a system would involve:

- **Calculation of array size**
- **Calculation of battery capacity**

4.5.1 Calculation of array size

A. Approximate calculations

This calculation of the size of the array requires data of mean daily insulation at the place of installation. Insulation data of major cities of the world are available from records of weather stations located there. A typical record for New Delhi, India is shown in Fig.4.11 .



Variation of Solar insolation with time on a typic

The monthly solar insolation is averaged for a day to obtain solar insolation KWH/M2 day. In case the mean daily insolation data of a particular prospective place is not available, it can be approximately computed from the duration of sunshine hours in that region.

Mean horizontal daily insolation in KWHIM2 = number of peak sunshine hour (h_{pss})

Also = (yearly insolation in KWH/M^2) / 365

From the insulation data, one can compute the required photovoltaic system output necessary for a given daily load requirement in Watt Hours. Considering system losses to be 20%, the system output can be computed as:

System output =(Daily load in Watt Hours + 20% system loss) / Peak sunshine hours (h_{pss})

Example:

As an example the system output would be computed for a 100 watt load needed for 24 hours at 24 V for a location with mean horizontal insolation= 2169KWM/M^2 year

Considering a location computations are
Mean horizontal insulation = 2169 KWH/M^2 year
No. of peak sunshine hours h_{pss} = 2169/365 = 5.94
Load in Watt Hours/day 100 x 24 = 2400 Watt Hours
Therefore system output = 2400 + 2400 x 0.2 / 5.94 = 484.4 watts

For a 24V output,
System current = 484.4 / 24 = 24.2 A

Therefore the array amperage is 20.2 A at 24 V output

B. More exact computation would involve consideration of:

* Battery charging efficiency $\eta_{B.C.}$

* Battery self- discharge level η S.D.

* Variability factor η V

Variability factor allows for variation in data at the installation to that available for the nearest from weather stations in similar climatological zones. the variability factor also incorporates variation in data from year to year. Taking lead-acid batteries as energy storage medium

$\eta_{B.C.} \sim 0.9$, $\eta_{S.D.} \sim 0.97$ and with $\eta_{V} \sim 0.85$

Array output = System output. (Watt Hours) / η_V x $\eta_{B.C}$ x $\eta_{S.D}$ x h_{pss}

Therefore, at 24 V,

System current = 2400 / 0.85x0.9x0.97x24x5.94 = 22.68A

The two approaches yield system current within 10% of each other. If however $\eta_V \sim 0.95$, the two calculations yield identical results.

Planning a Stand Alone PV System

Stand alone or autonomous systems are not connected to the grid. Some stand alone systems known as PV-hybrid systems or island system, may also have another source of power, wind turbine, bio-fuel or diesel generator, etc.

A stand alone system varies in size and type, but 20Wp - 1KWp are quite common. The stand alone system is also known as an off grid system.

Stand –Alone system (Off-Grid systems) use a photovoltaic system to supply electricity to a consumer unit directly or via a battery, independently of other energy sources. These systems are suitable for small devices and equipment not close to an electricity supply (e.g. street lighting, water pumps, radio and signal equipment).

Description of a stand alone PV system

Solar Panels (PV) Modules

The DC electricity produced by the solar panel or module(s) is used to charge batteries via a *solar charge controller.* Any DC appliances that are connected to the battery will need to be fused. DC lights are normally connected to the charge controller. Any AC appliances are powered via an *inverter* connected directly to the batteries. Inverters used in grid tie and stand alone systems are different and should not be interchanged.

Configuration

The solar panels need to be configured to match the system DC voltage, which is determined by the battery. System voltages are typically, 12V DC and 24V DC, larger systems will operate at 48V DC.

The operating voltage of a solar panel in a stand-alone system must be high enough to charge the batteries. For example, a 12V battery will require 14.4V to charge it. The solar panel must be able to deliver this voltage to the battery after power losses and voltage drop in the cables and charge controller and in conditions in which the solar cells operate at a high temperature. A solar panel with a Voc of about 20V is required to reliably charge a 12V battery.

Charge Controllers

A charge controller is designed to protect the battery and ensure it has a long working life without impairing the system efficiency. Batteries should not be overcharged and the function of the charge controller is to ensure that the battery is not over charged.

- Charge controllers are designed to function as follows:
- protect the battery from over-discharge, normally referred to as **low voltage disconnect (LVD)** that disconnects the battery from the load when the battery reaches a certain **depth of discharge (DOD)**.
- protect the battery from over-charging by limiting the charging voltage - this is important with sealed batteries - it is usually referred to as **high voltage disconnect (HVD)**.
- prevent current flowing back into the solar panel during the night, so called reverse current.

Batteries

The power requirements of stand alone pv systems are rarely in sync with the battery charging. Appliances and loads need to be powered when there is sufficient solar radiation, during overcast weather and during the night. Bad weather may last for several days and the daily charging and discharging of the batteries takes its toll on them. Batteries that are able to handle the constant charging and discharging are known as *deep cycle* batteries. Batteries need to have a good charging efficiency, low charging currents and low self-discharge.

Battery Ah Efficiency

The Ah efficiency of a battery describes the relationship between Ah that are put into the battery and the Ah that are taken out. Under ideal conditions a new deep-cycle battery would be 90% efficient.

Choosing the most appropriate battery

The important characteristics to look for are:

- capacity

- cycle life
- price / performance
- size and space requirements
- Ah efficiency
- self-discharge rate
- installation - vertical or horizontal
- environmental - will batteries be placed near water supplies or in wildlife parks etc

Cables and Accessories

Cables need to be UV resistant and suitable for outdoor applications. It is very important to keep power losses and voltage drop in the cable to a minimum. It is recommended that this be less than 3% between the the array and the batteries and less than 5% between the battery and DC loads.