To Design a solar PV System .

Solar photovoltaic system or solar power system is one of renewable energy system which uses PV modules to convert sunlight into electricity. Depending on the types of load it can be used directly as DC or converted to AC. The electricity generated can be either stored or use directly or fed back into grid line or combined with one or more generators or more renewable energy sources. Solar PV system is very reliable and clean source of electricity that can suit a wide range of applications such as residence, industry, agriculture etc.

Major system components

Solar PV system includes different components that should be selected according to the system type, site location and applications the major components for solar PV system are:

- PV module - converts sunlight into dc electricity.
- Solar charge controller- regulates the voltage current coming form the PV panels and going to battery and prevents battery overcharging and prolong the battery life.
- .• Inverter - converts dc output of PV panel into a clean ac current for ac appliances or fed back into grid line.
- Battery - stores energy for supplying to a load when there is a demand.
- Load – is electrical appliances that connected to solar PV system such as lights, radio, TV, computer, refrigerator, etc.
- Auxiliary energy sources-is diesel generator or other renewable energy sources.

Solar PV system sizing:

Determination of total power consumption

The first step in designing a solar PV system is to find total power consumption of loads that needs to be supplied by the solar PV system. Steps are:

i) Calculation of total watt-hours per day for each load used and then to find total watt-hours for all loads.

ii) Calculate total watt-hours per day needed from the PV modules.

iii) Multiply the total appliances watt-hours per day by 1.3 (due to the energy lost in the system) to get the total watt hours per day which must be provided by the panels.

Size the PV modules

To find out the sizing of PV modules, the total peak watt produced is needed. The peak watt (w_p) produced depends on the size of the PV module and climate of site location.

a) **Calculate the total watt-peak rating needed for PV modules**

Divide the total watt-hours per day needed from the PV modules by 3.43 (energy loss in the system) to get the total watt-peak rating required for the PV panels needed to operate the appliances.

b) Calculate the number of PV panels for the system

Divide the answer obtained in item (a) by the rated output watt-peak of the PV modules available. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required.

Inverter sizing

An inverter is used in the system where ac power output is needed. The input rating of the inverter should never be lower than the total watt of loads. The inverter must have the same norminal voltage as the battery.

For stand-alone systems, the inverter size should be 25-30% bigger than the total Watts of load. In case of load is motor or compressor than inverter size should be minimum 3 times the capacity of those load and must be added to the inverter capacity to handle surge current during starting.

For grid tie systems or grid connected system, the input rating of the inverter should be same as PV array to allow for safe and efficient operation.

Battery sizing

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle change and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the loads at night and cloudy days.

To find out the size of battery, calculations are as follows:

1. Calculate total Watt-hours per day used by load.
2. Divide the total Watt-hours per day used by 0.85 to account for battery losses.
3. Divide the answer obtained in item 2 by 0.6 for depth of discharge.
4. Divide the answer obtained in item 3 by the nominal battery voltage.
5. Multiply the answer obtained in item 4 with days of autonomy (the number of days that is needed by the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery.

Battery capacity (Ah)

$$= \frac{\text{Total Watt-hours per day used by the loads x day of autonomy}}{\text{0.85(battery loss) x 0.6(depth of charge) x nominal battery voltage.}}$$

Solar charge controller sizing

The solar charge controller is typically rated against amperage and voltage capacities. Solar charge controller should have enough capacity to handle the current from PV array.

According to standard practice, the sizing of solar charge controller is to take the short circuit (lsc) of the PV array, and multiply it by 1.3

Solar charge controller rating = Total short circuit current of PV array x 1.3.

Example: A house has the following electrical appliance usage:

- One 18 Watt fluorescent lamp with electronic ballast used 4 hours per day.
- One 60 Watt fan used for 2 hours per day.
- One 75 Watt refrigerator that runs 24 hours per day with compressor run 12 hours and off 12 hours.

The system will be powered by 12 V DC, 110Wp PV module.
Find out the number of module needed, Inverter size, Battery size and charge controller size.

1. Total power consumption demands

Total appliance use = (18 W x 4 hours) + (60W x 2 hours) +
(75W x 24 x 0.5 hours)
= 1,092 Wh/day

Total PV panels energy needed =1,092 x 1.3
= 1,419.6 Wh/day

2. Size the PV panel

a) Total Wp of panel capacity needed = 1,419.6 / 3.4
= 413.9Wp

b) Number of PV panels needed = 413.9 / 110
= 3.76 modules

Actual requirement = 4 modules

So this system should be powered by at least 4 modules of 110 Wp PV module.

3. Inverter size

Total watt of all appliances = 18 + 60 + 75 = 153 W
For safety, the inverter should be considered 25-30% bigger size.
The inverter size should be about 190 W or greater.

4. Battery size

Total appliance use = (18 W x 4 hours) + (60 W x 2 hours) + (75 W x 12 hours)
Nominal battery voltage = 12 V
Days of Autonomy = 3 days

Battery capacity

$$= \frac{[(18 \text{ W} \times 4 \text{ hours}) + (60 \text{ W} \times 2 \text{ hours}) + (75 \text{ W} \times 12 \text{ hours})] \times 3}{(0.85 \times 0.6 \times 12)}$$

$$= 535.29 \text{ Ah}$$

Total Ampere-hour required 535.29 Ah

So the battery should be rated 12 V 600 Ah for 3 day autonomy.

5. Solar charge controller size

PV modules specification

P_m = 110Wp, V_m= 16.7 VdcI_m= 6.6 A
V_{oc}= 20.7 A I_{sc}= 7.5 A

Solar charge controller rating = (4 strings x 7.5 A) X 1.3 = 39 A

So the solar charge controller should be rated 40 A at 12 V greater.

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 .

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})

<u>Example:</u>

As an example the system output would be computed for a 100 watt load needed for 24 hours at 24 V.

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. <u>More exact computation</u> would involve consideration of:

* Battery charging efficiency $\eta_{B.C.}$
* Battery self- discharge level $\eta_{S.D.}$
* 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

$\eta_{B.C.} \simeq 0.9$

$\eta_{S.D}$. $\simeq$ 0.97
and with $\eta_V \simeq$ 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 $\eta_V \simeq$ 0.95, the two calculations yield identical results.