Design of a Solar Photovoltaic System for Central Canteen of Delhi Technological University

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Abstract:

Photovoltaics is a method of converting the solar energy contained in the sun to produce electrical energy for use in different applications[1]. The Solar PV system finds applications in many areas of daily needs as well as commercial uses. Some prominent applications are outdoor lighting applications (like roadside flashers, highway safety signs, bus shelters, garden lights and portable lanterns) , telecommunication systems (Mobile towers, Microwave, TV or Radio repeaters, Telemetry stations and Radio telephones) , navigation applications (Railroad signals, buoys, Airport approach systems, offshore oil platforms) , cathodic protection applications (Well heads, oil and gas pipelines), Remote habitat applications (Rural home lighting systems, Remote village electrification, Schools, Hospital & clinics, Cottage industries), Power source for mobile applications (Mobile recreational vehicles, Electric vehicle charging systems, Boats). The solar photovoltaic system mainly consists of solar panels (the main energy conversion stage), MPPT & charge controller stage, battery and an inverter stage to convert the DC power to AC power for subsequent use as most appliances operate on AC. In this study, a design consideration for the solar photovoltaic application in central canteen of Delhi Technological University is presented.

1. Photovoltaic system configuration

There are various system configurations that are used in a solar PV system depending on the application.

1.1 Simple DC system : In this system a MPPT/Controller is employed to control the DC output which is then subsequently fed to the DC loads. In this system the modules are connected in series or parallel arrangement depending upon whether more current or more voltage is needed. A Simple DC system further consists of 2 types viz. with battery or without battery system depending upon the climatic conditions and the application for which the system is employed.

1.2 AC power system : In this system an inverter stage is added to the system to convert the DC to AC so as to run AC loads which form the majority of loads in the power system. An accompanying battery is also employed so as to pump the extra energy into it when a surplus amount of energy is generated. In this system care has to be taken so as to create the AC voltage and current of rated voltage and rated frequency (50 Hz in India) for optimal operation of loads also.

1.3 AC - DC combined system : In this system provision for supplying both types of loads viz. AC as well as DC loads is there with an accompanying battery so as to pump the extra energy into it when a surplus amount of energy is generated.

1.4 PV generator hybrid system : Owing to the intermittent nature of the solar energy this system is very popular and is in prominent use in areas where grid power is not available. In this system a generator is used apart from the AC – DC combined system so as to supply the required energy when the PV power is not available for prolonged periods of time.

1.5 Grid connected PV system : This system is the most reliable of the above systems. Owing to the intermittent nature of the solar energy this system will be hailed as the PV system of the future. In this system the PV system will be installed in parallel to the present system to inject the energy into the grid so as to supply for our increasing energy demands. The system owner can hence reduce their electricity bill as they will be paid by the utility company (according to the per unit cost) the total cost of the units generated by them.

2. Batteries

Batteries are an integral part of the solar PV system. They serve multiple purposes in a solar PV system so as to maximize the energy yield from the system. Some important purposes served by the batteries are

2.1 Energy Storage – Batteries store electrical energy in the form of chemical energy and supply the energy as and when required by the consumer like in night hours when PV system is not active and is not generating energy.

2.2 Voltage and current stabilization – Batteries act as constant voltage and current sources so they supply power at constant voltage and current to the consumer and help improve the power quality at the consumer's end. This is important because the PV system generates power at variable voltage and current and hence it has to be smoothed out to a constant voltage and current as our equipments are rated at specific voltages and currents.

2.3 Supplying of surge currents – Sometimes due to rise in demand at the load side, more current has to be supplied to supply the demand at peak demand periods. Hence batteries come into play as they supply the extra current and hence power as and when required by the loads.[3]

To measure battery capacity a quantity known as C-rate is used. A C-rate is the rate at which the battery is discharged relative to its maximum capacity. C-rate gives us the A-h of the battery. From the C-rate if we want to find the energy we can do so by the voltage of the battery.

$$Wh = Ah*V$$

3. Charge Controllers

Charge Controller is a power electronic equipment which serves multiple purposes. It basically consists of a DC to DC converter circuit which steps up the voltage level of the generated voltage from the PV system. It also incorporates a Maximum Power Point Tracking (MPPT) controller that tracks and operates the PV system at its maximum power point. Some of the main functions of charge controllers are given below

- Prevent battery overcharge

- Prevent Battery deep discharge
- Provide Load Control Functions
- Divert energy to an auxiliary load or to a dump load
- Serve as a wiring centre
- Interface and control backup energy sources
- Provide status information such as the voltage, current, SOC (State of Charge) etc.

We now illustrate the following configurations of controllers which are prevalent in the industry:

3.1 Simple Series Path Configuration without over discharge protection – In this configuration the PV array, charge controller, battery and load are connected radially and hence the energy can only flow unidirectionally. This doesn't leave any choice for the charge controller to direct the power to an alternate path in cases of overcharging of the battery.

3.2 Simple Series Path Configuration with deep discharge protection – In this configuration the battery is protected from deep discharge problem by connecting the battery in parallel configuration with the charge controller[4].

3.3 Auxiliary Load Path Configuration with Deep discharge Protection – In this an alternate load path in terms of auxiliary load is provided along with the former configuration in order to protect from deep discharge of battery.

3.4 Parallel Path Configuration with Deep discharge Protection – In this configuration the battery is directly charged by the PV system and the charge controller is connected in the next stage with the parallely connected primary load and the auxiliary load.

4. Design of a solar PV system

Approximate design is used for small PV systems. It neglects the temperature effect and the radiation effect .A typical solar PV system requires design of the PV modules, batteries , inverter and charge controller.

The following steps should be carried out while designing a solar PV system.

- Calculation of the load connected in Watts and their hours of operation (Energy in Wh)
- Estimating the voltage and current rating of the electronic components involved.
- Estimating the capacity, number and Ah ratings of the battery

- Determining the number , voltage and current rating of the PV modules.
- Estimating the wire size, junction box voltage and ampere rating, fuse rating [2].

5. Estimating the Size of a PV plant for the basic electricity requirements of the central canteen of the Delhi Technological University

The above mentioned steps will be discussed now in detail with the help of a practical case (Delhi Technological University's central canteen) where approximately 40 tube lights, 40 fans and an LCD TV works for 12 hours a day.

First of all load calculation is done. The total wattage of all the loads will be added up. The rated powers for a tubelight, fan and an LCD are 40 W, 100 W and 80 W respectively.

Hence

load (tubelights) $L_{1=}$ 40 W x 40= 1600 W

Load (fans) L_2= 100 W x 40 = 4000 W

Load (LCD) $L_{3=}$ 100 W

Total Load = $L_1+L_2+L_3$= 1600+4000+100 W= 5700 W

Since all the equipments are assumed to be functional for 12 hours a day

Therefore , Energy (Wh) = 5700 W x 12 h= 68400 Wh

Now in the second step we will estimate the size of the electronic circuitry involved. First of all an inverter is chosen so that it can produce the requisite power. Here the efficiency of solar inverter comes into play. Hence, the input power to the inverter should be

Power Input= (Power output/ Efficiency) x 100

Since a total output of 5700 watt is needed, assuming solar inverter efficiency to be 95% , the power input to the inverter or the VA rating of the inverter should be will be = (5700/95) x 100

= 6000 VA

Similarly, total energy input to the solar inverter should be = (68400/95) x 100 =72000 Wh

Considering the standard solar inverter 6000VA with 12 volts DC input and 230 V AC output , we have to limit the design the rest of our system to 12 volts.

While estimating the battery size we take into account the number of days when there is no sunlight (N_n). For example if we want to store energy for one extra day our battery size should be twice the calculated capacity. Another factor that needs to be taken into account is the depth of discharge of batteries(D_d) which indicates the percentage of total stored charge that can be used from the battery.

Hence considering all the above factors the total Ah capacity of the battery can be calculated as

= (Energy input to the inverter x N_n) / (D_d x Voltage of the system)

Considering N_n to be 2 and D_d to be 60%

Total Ah of the batteries = (72000 x 2)/ (0.60 x 12) = 20000 Ah

Number of batteries = (Total Ah of the batteries)/ (Ah of the single battery)

Considering the battery of 12 V,200Ah capacity

Number of batteries = (20000)/(200) =100

Now to calculate the number of PV modules we first need to take into account the battery efficiency , Assuming it to be 90%

Input energy to the battery =(Output energy/ battery efficiency) x 100

=(68400/0.90)

= 76000 Wh

Since the solar PV modules are rated for 1kW/m^2 of solar radiation intensity (Standard Test Conndition) and in a typical Indian scenario the solar radiation is 5 kWh/m^2/day, therefore daily sunshine hours = (5 kWh/m^2/day)/ (1kW/m^2)

= 5 h/day

Since we need to supply energy of 76000 Wh/day, daily energy supplied by SPV module

= 76000/5= 15200 watt peak

Hence to suffice daily needs a 15.2 kW_p peak power plant is needed.

Considering a solar PV panel of 100 W_p , 12V rating.

Total no of PV modules required = 15200/100=152 modules

Now these 152 modules have to be connected in parallel to attain the 15200 Wp, 12V system rating.

Now this 15200 Wp power is to be fed into the solar inverter. Hence the solar inverter rating has to be chosen accordingly.

The final step now is to choose the wire, junction box and the fuse ratings. These have to be selected according to the current rating of the system.

Load (L)	5700 W
Solar Inverter	6000VA ,12 volts DC input & 230 V AC output
Batteries	12 V, 200Ah- 100 batteries
Solar PV Modules	$100W_P$, 12V- 152 panels

Table 1: Specifications of the various components involved in the design of the solar PV plant.

6. CONCLUSION

India has set ambitious targets in the renewable energy sector through various programs and initiatives at both central and state levels. Renewable Energy sector is a very important thrust area in the present government of India. The government is well prepared to achieve the targets by 2022. In Delhi Technological University, a study has been made to install solar photovoltaic system at the rooftop of the central canteen which runs throughout the day and is frequented by all the students of the DTU. A total load of 15200 KWp has been calculated which will be met by 152 panels of 100Wp, 12V rating each. The DC power will be converted by the AC power by the solar inverter of rating 6000 VA, 12V.

7. REFERENCES

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Nomenclature

DC- Direct Current, AC- Alternating Current, SPV- Solar Photovoltaics, Wh- Watt-hour, Ah- Ampere-hour, L- Load, N_n- Number of days of autonomy, D_d- Depth of discharge of the battery, V- Voltage, W_p- Watt-peak, Hz- units of frequency (Hertz), MPPT- Maximum Power Point Tracking