Applications of solar Photovoltaic’s to power stand-alone area and street lighting

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Abstract. This paper is an introduction to the topics of photovoltaic solar energy conversion and with the help of solar illuminations; street lightings are employed in the surroundings of NIT JALANDHAR. The paper presents the Energy problem in the world: Growing consumption of energy. Solar radiation is described as a main source of renewable energy as well as possible applications of this energy by means of thermal conversion and photovoltaic conversion. The functionality of stand alone solar system is completely different than hybrid kind of solar system. Photovoltaic effect in the p-n junction and physical processes in the photovoltaic structures of solar cells are presented. The performance of each solar panel has been co-related through current and voltage (I-V) curve. The panel size and battery required to operate a better functionality is the key idea of solar photovoltaic system design and its smooth operation. The required number of batteries should be inline such a way that it does fulfil the requirement of power output.

Keywords: Renewable Energy, Photovoltaic, Solar radiation, p-n junction, solar cells.

1. Introduction

Photovoltaic conversion of solar energy involves a wide range of knowledge, energy problems properties of solar radiations reaching the earth surface’s, photovoltaic effect in the p-n junction properties of semiconductors which are important in photovoltaic conversion, technology in solar cells, construction of solar photovoltaic panel modules and arrays, control system of photovoltaic power station as well as ecological and economic problems of photovoltaic installations.

2. Basic theory of solar cell

Solar cells are of two types as per the concept of physics and these are N-Type and P-Type. When light falls on the semiconductor device it form generally two type of charges, i.e +ve and –ve change which is called Holes.

Fig.1 P-N Junction

Fig.2 Current flow direction
2.1 Solar Cell Modelling

Modeling of solar cell can be expressed by many ways in software packages like MATLAB & P-SPICE etc. and there are many methods to represent a model as like Mathematical block modeling, Embedded MATLAB Programming and Physical block modeling. Here physical block of solar cells are used for the modeling of PV module.

![Solar Cell Circuit](image)

**Fig. 3** solar cell circuit

**Fig. 4** Solar cell unit with dual diode

2.2 Photovoltaic conversion efficiency

The main outcome of any photovoltaic cell is its efficiency and which is defined by a formulation given below which contains the ratio of peak power to the value of output of solar power.

\[ \eta = \frac{P_{mp}}{I_{sc} \cdot A} \]

From the above given expression Vmp denotes the voltage when power is at its peak. I denotes solar intensity when considering unit meter square as area. A is denoting the area of exposed surface when solar radiation falls upon. The condition on which the pv system will give maximum efficiency depends upon the environmental conditions of power point tracking. If we anyhow manage to track maximum
radiation on the surface exposed we will get more and more radiation to convert into solar power and then store in the batteries for future usages.

2.3 The solar irradiation in Jalandhar, Punjab, India

Geographical information of Experimental set up. Latitude -31.3260152, Longitude- 75.5761829

Figure below shows the solar irradiance data of Jalandhar and optimum tilt of solar panels on monthly basis. Source: [http://www.synergyenviron.com](http://www.synergyenviron.com).

![Solar Irradiance Data](image1)

![Optimum Tilt of Solar Panels](image2)

Fig. 6 The solar irradiance data for Jalandhar

![Optimum Angle of Solar Panels Tilt](image3)

Fig. 7 Optimum angle of solar panels tilt at Jalandhar

3 Experimental specification & installation of Solar panel

Both figure and table shows the solar panel & specification of the panel installed at NIT Jalandhar.

![Solar Panel at Guest House](image4)

![Table 3.1 Specifications of Solar Panel](table1)

| Specification          | Value     |
|------------------------|-----------|
| (Pmax)                 | 120W      |
| (Vmp)                  | 17.70V    |
| (Imp)                  | 6.78A     |
| (Voc)                  | 21.60V    |
| (Isc)                  | 7.76A     |
| Maximum voltage of the system | 1000 V |
| Tolerance              | ±5%       |

4. Results and Discussions

In the present work the analysis of solar panel based on CFL lights have been done. Various parameters such as Battery sizing, number of modules and wire sizing have been calculated and results of which are presented in this paper.
(i) Load estimation under study

| Load | Watts | H/day | Number | Watt-Hr. |
|------|-------|-------|--------|----------|
| CFL  | 11    | 10    | 20     | 2200     |

(ii) Battery Sizing

\[ \text{DC Wh/day} = \frac{\text{Days/Week} - 7}{\frac{\text{Watts} \times \text{daily use (hours)} \times \text{days per week}}{7}} = \frac{22 \times 10 \times 7}{7} = 220 \text{Wh/day} \]

(iii) Daily energy supplied to inverter

Good inverters provide efficiency as high as 97%. Let us consider the inverter efficiency as 93%, then the energy supplied by the battery to inverter input should be

\[ = \frac{2200}{0.93} = 2365.59 \text{ Wh} \]

(iv) Deciding the system voltage

Here the conversion of DC Voltage to AC voltage will play an important role because when it comes across inverter the voltage will become AC. But before that the voltage will remain DC. The typical terminal voltage of a sample PV System is taken as 12V. And for the design and its fabrication we also employed a 12V battery.

(v) Determination of battery capacity for a given load

We generally consider the Batteries DoD in the range between 60% to 80%. Let us suppose a scenario where the Batteries are of 12V and power output is 75 AmpH capacities which having the DoD value as 70%. It reflects that out of 100 AmpH batteries capacities we have only 75\*0.7=52.5 AmpH is of usable.

The capacity of required charge \( = \frac{2365.59}{12} \text{ Ah} = 197.13 \text{A} \). Therefore the number of battery required

\[ = \frac{197.13}{75 \times 0.5} \text{Ah} = 3.75 \text{, i.e., it means that there will be need of 4 batteries of having 75 Ah capacities.} \]

We need to round off this number; thus we need 4 batteries to supply the required charge capacity. These 4 batteries should be connected in parallel. But 75 Ah batteries are of 12V only, so the battery bank needs to supply the charge at 12 V (system voltage). Therefore, in order to get 12V, four 12V batteries should be connected in parallel to get 12V terminal voltage and the capacity will get added.

(vi) Daily energy generated by PV panels:

Let us consider that battery efficiency is 85%. Therefore, the energy supplied at the input of battery terminal should be:

\[ = \frac{2365.59}{0.85} \text{Wh} \]
Suppose we have a circuit of the efficiency 90%. In this scenario the circuit controller input should be 3093.3 Wh. So what could be the amount of energy generation out of it is the value which has been found as 3093.38 Wh from the calculations. And this energy generation is on daily basis.

(vii) Solar radiation, capacity and number of panels:

Total Ah generated by the PV panels should be \( \frac{3093.38}{12} \) Ah = 257.78 Ah

The values which we take as reference for the solar input radiation is 1000 Watt per metre square. Generally as per the geographical conditions india witness the maximum solar radiation for 5 to 7 hours at peak time. And the value of corresponding output is 5000 Wh/msquare.

(viii) The amount of total current in Amp which should a solar panel produce is given by the expression:

\[
\frac{257.78 \text{ Ah}}{6 \text{h}} = 42.96 \text{ A}
\]

Therefore number of modules will be decided on the basis of panel rating of \( W_p \) and \( I_p \). This is 120Wp and 6.78A correspondingly. Number of modules = \( \frac{42.96}{6.78} = 6.33 \approx 7 \). So we need 7 module of 120Wp to provide us 42.96 A current.

(ix) Wire sizing

PV source circuit
\( I_{sc} \) per module = 7.76 A. Number of modules=7, \( I_{sc} = 7.76 \text{ A} \)
Considering Environmental Effect \( I_{sc} = 7.76 \times 1.25 = 9.7 \text{ A} \)
By 80% rule: \( I_{sc}=9.7 \times 1.25 = 12.125 \text{ A} \)
Wire size = 10 mm²

(x) Calculation

There are two bulbs running through each solar panel each of 11 watts. In most of the days it works for 10 hours per day so energy produced by the 10 panels.

\[= 22 \times 10 \times 10 \text{ Wh} = 2200 \text{ Wh} \approx 2.2 \text{ KWh}.\]

So 10 solar panels running for 10 hrs. Each day produces 2.2 KWh energy.
The unit cost of Electricity nowadays as per the Govt. is 6 Rupees/unit. So savings of electricity Bill each day is

\[= 2.2 \times 6 = 13 \text{ Rupees/day} = 4818 \text{ Rupees/year Savings}.\]

So if solar panels are replaced in the place of Electricity supply it can save enormous amount of money.

5. The Performance characteristics of solar panels on I-V curve
Fig. 9 I-V Curve of Solar Panel At Civil Deptt. No.2

Fig.10 I-V Curve of Solar Panel at Gate No.2

Fig.11 I-V Curve of Solar Panel at Hostel No. 1

Fig.12 I-V Curve of Solar Panel at main gate 1
Fig. 13 I-V Curve of Solar Panel at director’s house

Fig. 14 I-V Curve of Solar Panel at guest house

Fig. 15 I-V Curve of the Solar Panel at library gate 2

Fig. 16 I-V Curve of the Solar Panel at main gate 2
6. Conclusion

The analysis done for NIT Jalandhar solar panels installed it is concluded that if solar panels of Off-Grid type are mounted with Inverted and is connected with Grid and power is supply, it can save enormous amount of electricity Bill. If all the solar panels in NIT, Jalandhar are in working condition it can save Rupees 4818 Every year. The solar panels in Mechanical department and at hostel No.1 power output is the best among all as they produce around 86 % and 77 % Efficiencies. And solar panel at Main Gate 2 has the least efficiencies of 69 %.

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