Experimental and Social study on Solar PV Characteristics and Maximum Power Point Tracking of a PV Source

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Abstract— The study was conducted at IIT Bombay,India. Today around 25000 villages in India [1] and 1.1 billion people in the world [2] are facing acute shortage of energy. In this ever growing economical world, solar energy provides a better clean alternative as an energy source. However due to high costs of purchase and installation this technology is not able to reach the remote and rural areas of the world which still run on traditional fuel sources. Thus there is a need to research and harness the maximum potential of solar energy. The project's main objective was to extensively study characteristics of Solar PV modules and conduct experiments of Maximum Power Point Tracking (MPPT) used in Solar PV modules for varied radiations. In the experiment, I used a solar PV panel and a variable resistor, to extract the graphs of P-V (power-Voltage) and I-V (current-voltage) and to find out the point at which the graph yielded maximum power output from the Solar Panel. As a further extension of the project I have studied the applications of Solar Cells and their proper implementation in an Indian context.

Index Terms— Solar Cells, Maximum Power Point Tracking, Power Electronic system, PV modules, Power-Voltage graph, radiations, Solar energy

1 INTRODUCTION

The world energetic consumption is still dominated by the use of nonconventional sources like fossil sources, natural gases, and nuclear sources. The main drawback of the use of these sources is that they are exhaustible and they contribute to the pollution of the environment[3]. Today around 25000 villages are without electricity and thousand others have grid power supply but still face huge power cuts. There is an urgent need for the country to resort to cheap alternative energy sources so that more and more villages and remote areas become electrified and farms become mechanized. This in turn will increase the productivity of agriculture (which is the occupation of around 60% of the population) which will lead to increased exports and GDP. This can be potentially achieved by making rural areas electrified through increasing efficiency of Solar PV modules and decreasing its cost.
Therefore, achieving optimized result is of utmost importance which is why this research paper has been made.

1.1 Objectives of the project:

(i) Tracking the maximum Power output of a PV source and extraction of I-V and P-V graphs along with its analysis
(ii) Recommendations on ways in which applications of Solar Cells (especially Solar LED street lighting system) can be effectively implemented in India using LDRs, Solar tracking panels etc.
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2 METHODOLOGY:

This Socio-Scientific project has been made by presenting a holistic view of the efficiency and its increment along with its proper implementation. Various experiments of manually simulating MPPT were conducted at IIT-Bombay electrical engineering department. The data was compiled and P-V and I-V graphs were extracted to find out the point of Maximum Power Output. A study was also conducted in a school in Pune wherein through a questionnaire, the pros and cons of using Solar LED street lights was studied on a large scale. Furthermore, surveys were conducted in four villages near Pune to gain information about the, Perfect sunshine hours, output yield of using Solar PV modules in this area and the people's response to the undertaking. These 50 questions have been consolidated into 10 questions in the form of a survey and attached to this report as sample.

3.1. Materials required and process:

The study was conducted using a sunset industries energy techmake solar PV module with the following specifications-

S.No.	Item	Value
1.	Max Voltage	17.3V
2.	Max Current	1.74A
3.	Max power	30W
4.	Current (sc)	1.93A

5.	Cut-off voltage	20.8V

This study focuses on finding and analyzing the maximum power and voltage output of the PV module and so other components of solar LED lighting system were not included. A char

ge controller (pulse width modulation/MPPT) has not been used and with the help of galvanometer and variable resistance the voltage, current and power output of the module was changed. Thus by manually adjusting the Variable resistance, various data for current, voltage and corresponding power yielded by the Solar panel for varying radiations were noted. The point where variable resistor produced current and voltage in such a way that maximum power was obtained was tracked, thus simulating the function of MPPT.

Further I-V (current-voltage) and P-V (power-voltage) graphs were plotted to analyze and track the point at which the current and voltage yield maximum/optimized power.

3.2. Observation

The following table shows the tracked data-

a) 8 June 2015 at 12 pm

Table 3.2.1

Current (ampere)	Voltage (voltage)	Output Power (watt) (power= VxI)
1.7	0.1	0.17
1.6	10.07	16.112
1.5	15.7	23.55
1.5	15.8	23.7
1.4	16.07	23.9
1.4	17.15	24.01
1.4	17.33	24.26
1.3	17.75	23.075
1.1	18	19.8
0.9	18.1	16.3

b) 5 April 2015 at 4 pm

Table 3.2.2

Current (ampere)	Voltage (voltage)	Power (watt) (Power=VxI)
1.5	0.1	0.01
1.5	10.266	15.4
1.4	14.14	19.8
1.4	14.35	20.1
1.3	15.8	20.5
1.2	17.28	20.736
1.1	17.5	19.25
1	17.7	17.7

c) Automatic switch was researched and experimented in the study. Following is the information about it- **Automatic light-sensitive switch**- These switches actually have LDR (Light Dependent resistor)[4] which usually increase their resistance with increase in light intensity. These are used in street lights to automatically power on and shut down street lights during dusk and dawn respectively. This would help decrease energy wastage due to human error of not switching off street lights during the day.

The most commonly used photoresistive light sensor is the **ORP12** Cadmium Sulphide photoconductive cell[5]. This light dependent resistor has a spectral response of about 610nm in the yellow to orange region of light. The resistance of the cell when unilluminated (dark resistance) is very high at about 10MΩ's which falls to about 100Ω's when fully illuminated (lit resistance)[6] as shown in the figure below.

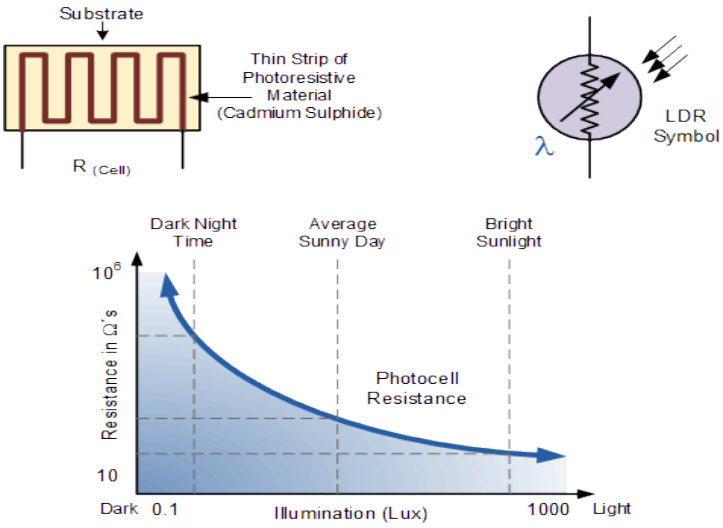
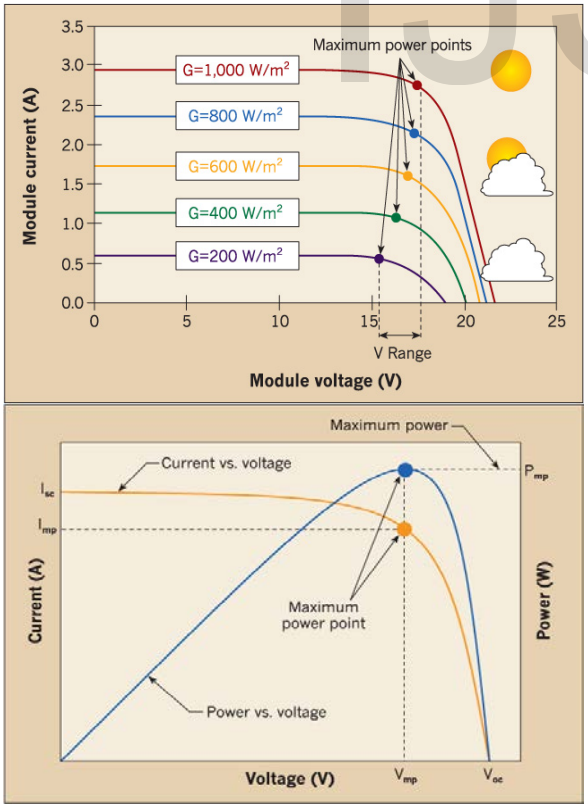


Figure 3.2. Working of LDR

The LDRs work on the principle that the valence electron in the material of the resistor gets sufficient energy to get excited and cross the band gap and thus the conduction of electron starts (and resistance decreases.).

4. RESULTS

1) The data of table 3.2.1 and 3.2.2 have been plotted and the point of maximum Power has been tracked as shown below



Thus using micro inverters fitted with MPPT improves the power output as shown by the above graphs. Alternatively, it was studied that instead of installing one micro inverter (which includes the inverter and the MPPT) a single traditional solar inverter can be used for a batch of Solar PV modules and each PV module fitted with Power optimizer. The advantage of using this type of system is that it is cheaper as compared to the cost of installation of each micro inverter to the PV module. Further it was also observed that this type of system yields approximately the same efficiency as that of micro inverter installed PV module.

2) The PV modules take only the perpendicular component of the falling sun radiation. So when PV panel is at 90 degrees to the sunrays power density falling on the PV module is maximum and hence power output is maximum. However the noted data clearly shows that at both, the maximum power output is not 30W instead it is 24.26W and 20.736W respectively. Ideally at 12pm sunlight is in its maximum intensity so power should have reached somewhere about 30W at least considering non-ideal conditions. However this was not the case. This is because the angle between sun and PV module at both times was around 70 degree. Thus the total solar radiation was divided into two components- usable perpendicular soar radiation and non-usable horizontal solar radiations and thus maximum power could not be reached. The table below shows the difference in power output levels when Solar Panel is perpendicular to sun rays and when it is at 70 degree angle to the rays

S No.	Power output (in Watt) when Solar PV panel is not perpendicular to	Power output (in Watt) When Solar PV panel is at an angle of 90° to sunrays
1	24.26	29.8
2	24.01	28.3
3	23.55	25.6
4	20.736	23.4
5	17.7	20.9

3) It has also been noted that instead of manual switch which is used to reduce cost to power on and shut off the solar LED

system should be replaced with automatic photosensitive switches. This is because energy lost when LED system is forgotten to switch off would easily more than compensate the cost tried to save by using automatic photosensitive switches

Manual Switch:

- INITIAL COST: nil (only that of installing the manual central switch board)

-ELECTRICAL LOSSES AND MAINTENANCE: There is a high chance of the manual switch malfunctioning in which case it would be required to change the complete switch board. Also the energy would be wasted if the LEDs are left on even in day time which would reduce the energy stored for night. This would in-turn result in insufficient voltage to light up the street lights.

Automatic Photosensitive Switch:

-INITIAL COST: initial cost is present although it is not very high due to LDRs

- ELECTRICAL LOSSES AND MAINTENANCE-Almost nil.

5. SURVEY-

The survey was conducted in 4 villages near Pune. A total of 75 people were surveyed. Like other villages in India the main occupation in these villages is also agriculture. All these villages face long power cuts. Also due to long power cuts their water pumps do not work which lead to water shortage for both personal consumption and for agriculture Many surveys which contained a combined of more than 50 questions were made. A consolidated survey containing 10 questions and its results are given below.

Sr. No.	Question	Options	Percentage
1	How long are the power cuts in your area?	2 hrs 4 hrs >4 hrs	22% 36% 42%
2	Is your area adequately lighted during the night?	Yes No	32% 68%
3	Do you know about Solar LED street lighting system?	Yes No	27% 73%
4	How much is your electricity needs fulfilled by the current grid electricity system?	>50% 50% <50%	34% 51% 15%
5	Do you know about LED lamps?	Yes No	38% 62%
6	Are you willing to pay more taxes if the government installs street lighting system	Yes No Depends/can't say	51% 24% 25%
7	Do you think streetlights will help decrease crime rates and increase standard of living?	Yes No	77% 23%
8	Are you comfortable with the current lighting system or would you like to resort to Solar LED street lighting?	Would like to use the alternative Comfortable with the present condition	71% 29%
9	How many hours do you work after sunset?	2 hrs 4 hrs >4hrs	18% 56% 26%
10	How much are you willing to pay extra as taxes if the government installs Solar LED street lights?	INR 100 INR300 >INR 300	56% 24% 20%

5.1. Results of the Survey-

6. CONCLUSIONS AND RECOMMENDATIONS

The study, experiments and the survey yield the following results:

1. MPPT used in micro inverters increase the efficiency of the solar PV modules significantly. Thus their usage is gaining wide spread popularity. However the cost of installation of such a system is high. Another approach was studied which indicates that a single traditional inverters (much cheaper than installing hundreds of micro inverters) can be used for a batch of solar PV modules fitted with their individual Power optimizer. This tends to decrease the purchase and installation cost while keeping the efficiency of the system same. The latter system is especially helpful for increasing power output of old Solar PV modules fitted with traditional inverter without MPPT because changing the solar inverter is not required and power optimizer can be directly installed in each panel to yield optimized result.

2. Along with MPPT/Power optimizer the power output of the solar cell can be significantly increased by using tracking solar panels. These solar panels track the angle of elevation of the sun at all given times and accordingly adjust the panel so that the module is perpendicular to the sunrays.

3. Although in urban areas most of the solar technology is used with automatic Light-sensitive switches now-a-days, this practice seems to be absent in the rural areas. Thus automatic Light-sensitive switches must be used instead of an integrated manual main switch to save power.

4. Analysis of the survey**:** In the rural areas where the survey was conducted majority people face power cuts for more than 4 hours which hinders their work leading to low production. Most of them, however, are ready to pay more tax to the government to install the alternative efficient solar energy technology in these areas. 56% of the people are willing to pay up to INR 100 to switch to this alternative energy source. Thus further decrease in cost and increase in efficiency of Solar energy technology will help this energy source reach the remote and under developed regions of India.

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