A Proficient Solar Panel Efficiency Measurement System: Using Current Measurements

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***Abstract*—This paper includes a comparative survey of clean and unclean solar photovoltaic panels, with an identical load connected. The primary concern of this survey is to address the basic essential circuitry for solar photovoltaic based multiple applications. This survey will focus primarily on output currents of both clean and unclean solar photovoltaic panels and according to that acceptable threshold current has been obtained across sense resistors. In this work, different intensities of the incoming sunlight are captured and its effect on solar panel output are analyzed experimentally. The output power, which generates during entire sample days is calculated and according to that overall efficiency is determined by mathematical calculations.**

Keywords— renewable energy; solar energy; solar photovoltaic panel; threshold current

I. INTRODUCTION

Solar photovoltaic (PV) technology converts sunlight into electricity directly without any other additional energy conversion step. India is blessed with a large amount of sunlight. We receive solar radiation the range of 4 to 7 kWh/m^2/day [1]. Such amount of radiation is good enough to generate electricity to fulfill our entire electricity requirement using solar PV technology. Importantly, the energy can be generated in any area, where there is need, by installing the solar PV.

The solar PV panel faces few problems like lesser conversion efficiency around 9% to 17% under low radiation intensities. In addition, the output power generated by these solar panel varies with different weather conditions. Apart from this, the V-I characteristic of the solar panel varies with irradiation and temperature [2]. Generally, both V-I and V-P curves have a Maximum Power Point (MPP) [3]-[7] at which solar panel provide maximum output power. The output power generated by solar PV panel is always less than the maximum output power (P_{max}) because standard test condition (STC) at which Maximum Power Point is defined is practically variable [12]. The position of the sun in the sky during a day time highly affects amount of incoming light to the earth's surface. It is also affected by other various factors like dust and dirt particles, water vapor, smog etc. It is therefore necessary to measure the real intensities of sun radiation for those particular applications areas. Moein Jazayeri et al [8]-[10] has successfully done calculations of sun`s position in the sky and analyzed its effects on solar panel output characteristics. Several cell production technologies and methods have been developed to achieve maximum power output of the solar panels. Falah Mustafa et al [5], used a mirror reflection technique for greater power output generation of the solar PV panels.

This paper focuses on obtaining the maximum accepted threshold current after which an efficiency of solar panel will go on decreasing and it will not be worthy to use such panel to get proper output results.

II. DESIGN AND IMPLEMENTATION

A. Block Diagram

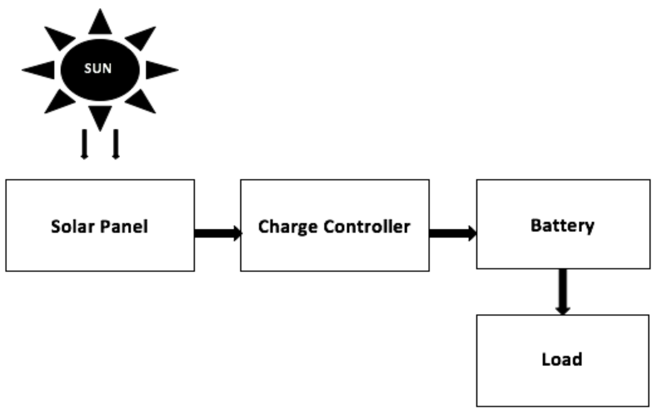

Fig. 1. Block Diagram

Fig. 1 shows the basic blocks of the design consisting of Solar PV Panel, Charge Controller, Battery and Load. Solar panel catches sunlight and turns it directly into electricity or electrical signal. This generated electricity gets stored in battery for future use. Here charge controller is placed in between solar panel and battery. A charge controller is nothing but a voltage and/or current regulator which prevents the batteries from overcharging. The voltage and current flowing from the solar panels to the battery are regulated by this charge controller. It will make battery to charge in between 20% to 80%, initiate alarms and disconnection of load in the event of fault. Means, battery will neither get over discharged nor over charged. The last block is of load after battery. We can use any kind of DC load here as we have not inserted inverter block within. For the use of AC appliances to work on solar panels we need to add inverter block in above block diagram so that it can convert DC power supplied by solar panel into AC.

B. Experimental Setup

Fig. 2. Experimental Setup of Proposed System

Experimental set-up mainly consists of two 40 Watt Solar Panels, two charge controllers, two batteries (12V 12Ah each), two tube lights (7 Watt each) and two resistors (0.56 ohm each) as shown in Fig. 2. One bunch of set-up is referred as a clean set-up and other one is referred as unclean set-up as we are not cleaning the solar panel of this set-up regularly. The main concept behind all such assembly is that, solar panel will charge the battery and battery will be discharged by load i.e. tube light. So, there is a continues cycle of discharging and charging of battery used. Charge controller is mainly having three input ports. One for solar panel output, second one for battery and last one for load connected. Battery used here are of Exide Batteries which are maintenance free with absorbent Glass Mat Technology. These batteries are with qualities like low self discharge, long designed service life, excellent discharge performance, environment friendliness, wide suitability of ambient temperature range. The DC LED tube lights are used in the mentioned assembly as a load. The resistors used here are called sense resistors across which voltage is being measured regularly.

C. Solar Intensity Measurement

Fig. 3 shows the device used for Measurement of Solar Radiation Intensity either in W/m^2 or in BTU / (ft^2 x h). It measures the transmission and solar power up to 634 BTU/(ft^{2}xh) and 2000 W/m^2 respectively. Basically this device is with two modes of operations. The power per unit area of incident solar radiation is measured in power mode whereas the percentage of solar power transmission of the material is calculated in transmission mode.

Fig. 3. Solar Power Meter

E.g. how much percentage of solar power will be transmitted through the window. Power Meter is with facility to read display with remote sensor technology. It is having an option of data hold to hold the value on its display. Locations with maximum or minimum power are identified by using Max/min function.

III. RESULTS AND DISCUSSION

A. Threshold Current Estimation

For the specific time period, survey has been done in order to see the rate which solar panel's current is reducing day by day as an effect of dust accumulation on it. The survey includes the parameters as mentioned in TABLE I below.

TABLE I.

Sr. No.	Time	Vr (Volts)	I (mA)	Vout (Volts)	P (Watts)	Sunlight Intensity

Sense Resistor Rsense is connected at the output side of solar panel, whose value is known. Voltage Vr is the voltage across Rsense. By using Ohm's Law value of I is calculated here. I denote current across Rsense. For different radiations, respective voltage readings are taken across the resistor Rsense. And current I have been calculated. As time changes i.e. from morning to evening, current amount also changes respectively. During afternoon session maximum current flows from Rsense as compared to that of morning session. At evening, Current again reduces as radiations from sun goes on decreasing. Solar Panel output voltage Vout is also measured for different solar radiations through out a day. Now, on multiplying these two parameters i.e. Vout and I, the amount of output power Pout is estimated. The effect of solar radiations on Pout has been represented in graphical form. As output power changes, efficiency also changes accordingly. As it is ratio of Pout and input power Pin. After all this, an acceptable current value is being selected beyond which efficiency decrease is not acceptable. This current is denoted as threshold current. In this paper we are accepting plus-minus 15% of change in current value. Thus, the threshold current after all the analysis is said to be as 1.6 mA.

IV. GRAPHICAL REPRESENTATION

A. *Solar Radiation Measurement*

For the specific period of duration say 20 days, survey is done. By using Solar Power Meter shown in Fig. 3. Solar Radiations are measured after every half an hour in a day.
Fig. 4 below show solar radiations for 1st 5 days.

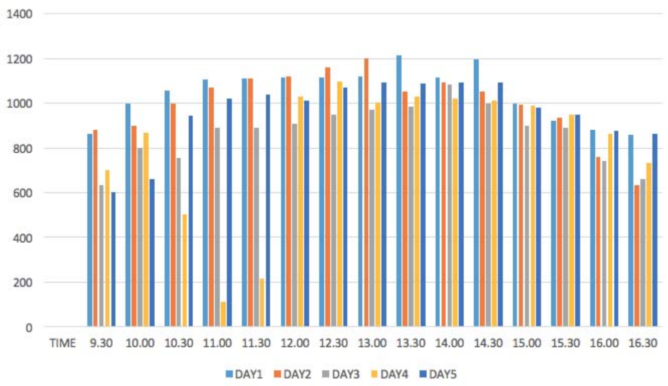

Fig. 4.

Fig. 5 below shows solar radiations for next 5 days

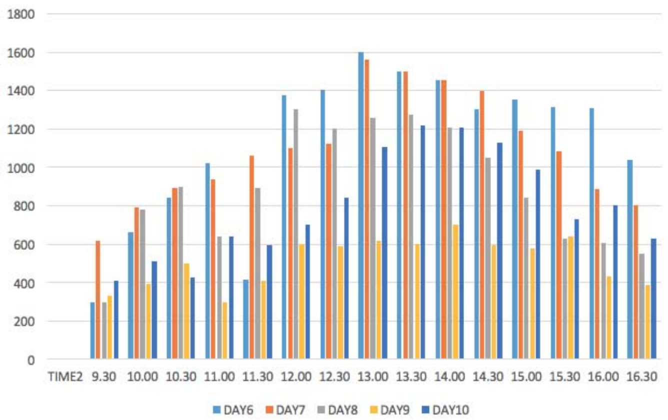

Fig. 5.

Fig. 6 shows solar radiations for next 5 days and Fig. 7 shows solar radiations for last 5 days.

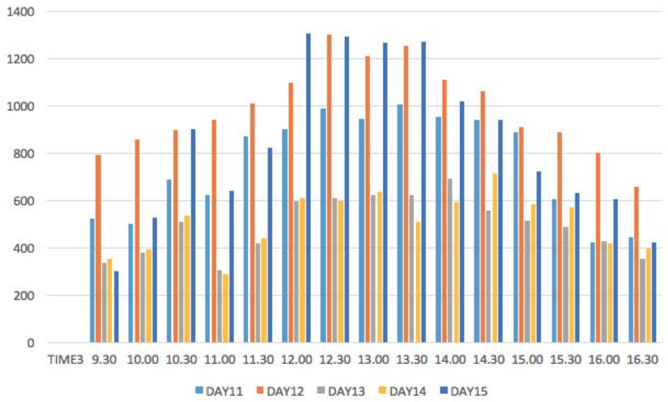

Fig. 6.

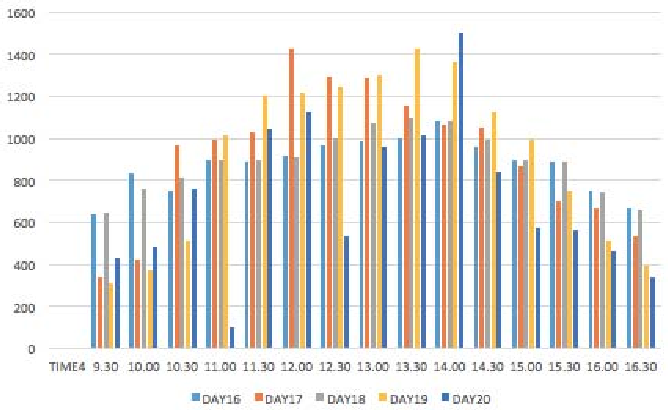

Fig. 7.

All of the above graphs clearly says that, the solar radiation intensity is high during afternoon in between 12:30 pm to 2:30 pm. And in the morning as well as evening time radiation intensity is minimum.

B. *Voltage Measurement*

On the daily basis voltage flowing through each solar panel is measured regularly. Fig. 8 below shows voltage measurement graph for clean solar panel whereas Fig. 9 shows voltage measurement graph for unclean solar panel. These voltages are measured across sense resistors.

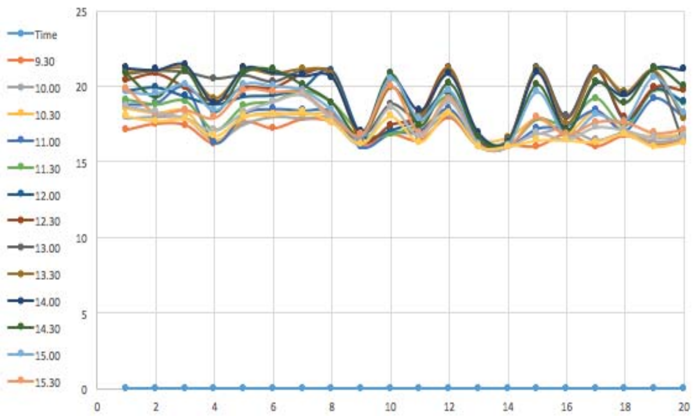

Fig. 8. Voltage Measurement for Clean Solar Panel (Panel1)

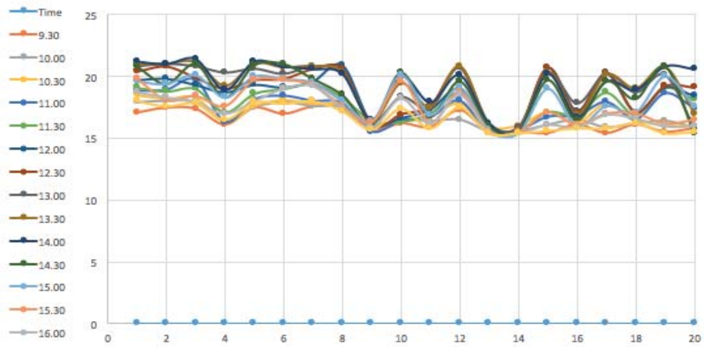

Fig. 9. Voltage Measurement for Unclean Solar Panel (Panel2)

C. *Current Measurement*

1) *Daily Analysis*

On daily basis current flowing through each solar panel is also calculated. This calculation is done according to Ohm's Law. Fig. 10 below shows current measurement graph for clean solar panel whereas Fig. 11 shows current measurement graph for unclean solar panel.

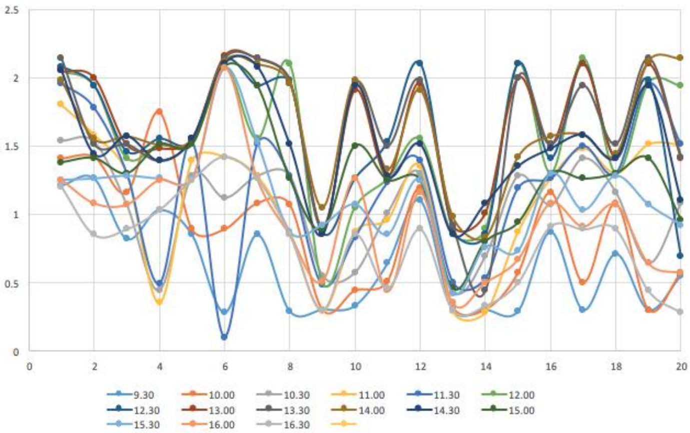

Fig. 10. Current Measurement for Clean Solar Panel (Panel1)

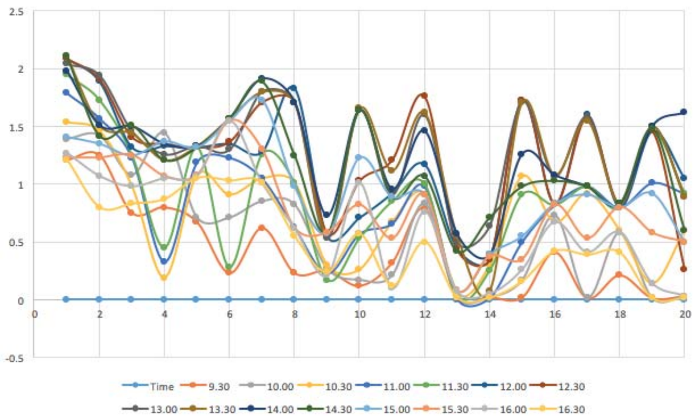

Fig. 11. Current Measurement for Unclean Solar Panel (Panel2)

Taking one day as a sample to understand things more better. Considering 15th day.

Sample Day: Day 15

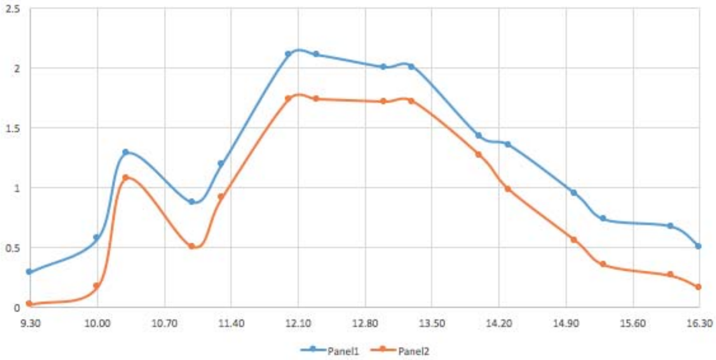

Fig.12. Current Measurement for Day 15.

The graph clearly shows that at 15th day, the output voltage of panel 1 i.e clean solar panel is larger than that of panel 2 i.e. unclean solar panel.

D. *Power Measurement*

Power is being calculated here as a product of output voltage Vout and current I. Fig. 13 and Fig. 14 below shows power measurement graph for 1st 10 days for clean panel and unclean panel respectively.

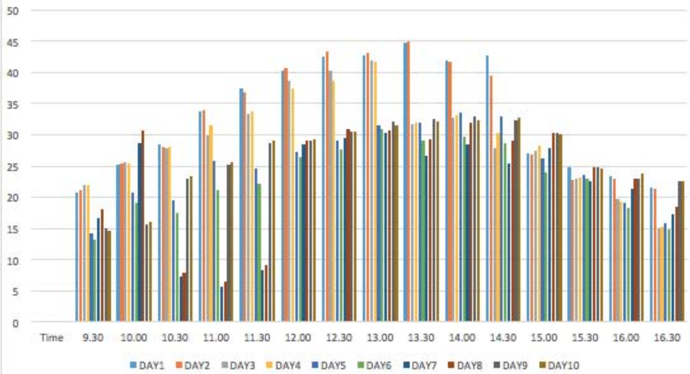

Fig. 13. Power Measurement for Clean Solar Panel for 1st 10 days (Panel1)

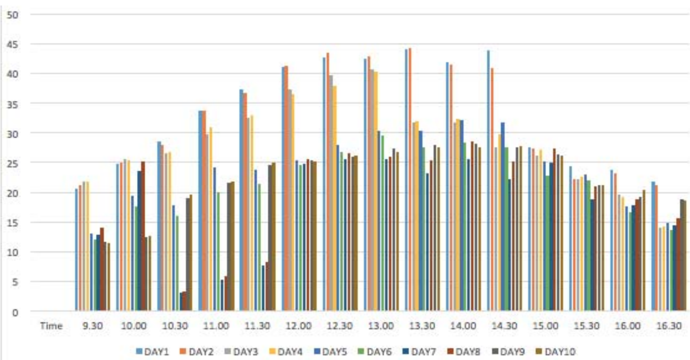

Fig. 14. Power Measurement for Unclean Solar Panel for 1st 10 days (Panel2)

Fig. 15 and Fig. 16 shows power measurement analysis for both clean and unclean solar panels in the next 10 days.

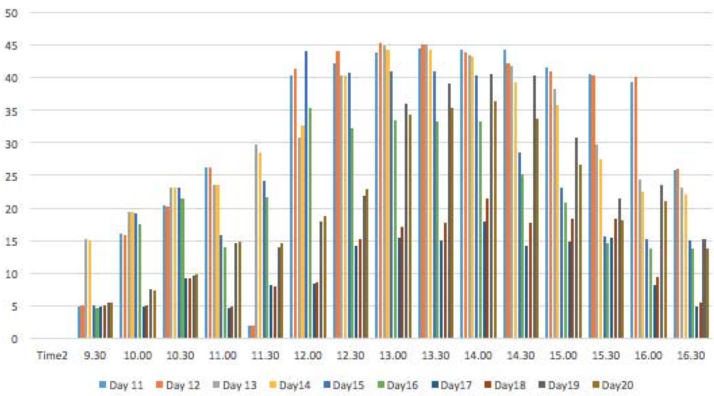

Fig. 15. Power Measurement for Clean Solar Panel for next 10 days (Panel1)

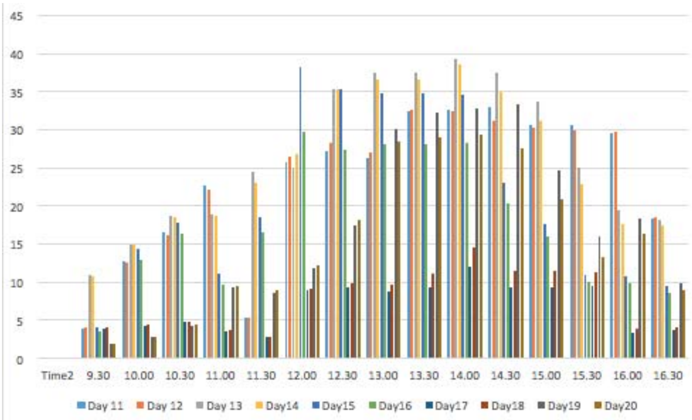

Fig. 16. Power Measurement for Unclean Solar Panel for next 10 days (Panel2)

On comparing all graphs, the output power of panel 2 decreases slowly day after day. To make this clearer, taking one day as a sample day. Considering 15th day. Fig.16 shows power measurement for day 15.

Sample Day: Day 15

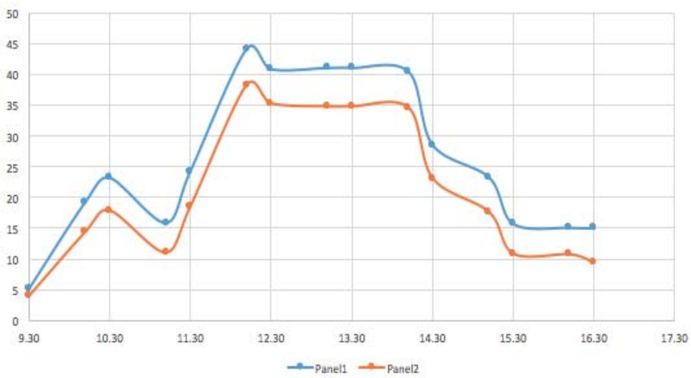

Fig. 17. Power Measurement for Day 15

Thus, the output power of clean panel i.e. panel 1 is maximum than that of unclean panel i.e. panel 2.

V. EFFICIENCY CALCULATION

A. For Clean Panel

For calculation of solar panel efficiency,

Efficiency = Pmax / (Radiation Intensity * Area) (1)

Pmax = Vmax * Imax = 21.2 * 2.1 = 44.52 W

Area of Panel = Length * Breadth

= 666 mm * 464 mm

= 0.309 m^2

Radiation Intensity = 1293

Thus, Efficiency = 44.52 / (0.309 *1293) = 11.14%

B. For Unclean Panel

For calculation of solar panel efficiency,

Efficiency = Pmax / (Radiation Intensity * Area) (2)

Pmax = Vmax * Imax = 20.7 * 1.73 = 35.811 W

Area of Panel = Length * Breadth

= 666 mm * 464 mm

= 0.309 m^2

Radiation Intensity = 1293

Thus, Efficiency = 35.811 / (0.309 *1293) = 8.96%

The efficiency got reduced to 8.96 % from 11.14 %.

C. Percent Decrease

The formula used to calculate Percent Decrease in efficiency is,

Percent Decrease = [(Efficiency of Clean Panel - Efficiency of Unclean Panel) / (Efficiency of Clean Panel)] * 100 (3)

Thus,

Percent Decrease = [(11.14 - 8.96) / 11.14] * 100

= 19.56 %

Above calculations proves that due to the continuous accumulation of dust on solar panel surface area, the efficiency of panel decreases by 19.56 %.

CONCLUSION

In this paper, Current vs Time characteristics of solar panel under different solar irradiance are investigated and the fluctuating amount of output power of solar panels under the clean and unclean condition has been determined. Different values of current across sense resistor has been verified experimentally with a 40W solar panel at different radiation levels. The technique is simple and appropriate. Proposed technique, the results show that the value of current increases with the sun radiations and at the end of the day current value also decreases as radiations intensity decreases. Due to which efficiency of panel also decreases. The example of day 15 will make it more clear that as surface of solar panel becomes more and more unclean, its output current, power and at the end efficiency goes on decreasing.

In the future work, the value of lowest acceptable estimated current can be considered as a threshold current after which the surface of solar panel needs to make clean automatically or manually to improve solar panel efficiency and working life.

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