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# Comparative Analysis of Calculation of Solar Panel Efficiency Degradation

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***Abstract*— Output efficiency of solar panel is degrading day by day due to accumulation of dust and other dirt on PV Panel surface which badly affects the operation of load connected to it. This paper includes a comparative survey of unclean and clean solar PV panels to calculate its output efficiency reduction due to presence of dust and dirt on surface. The main motive behind this survey is to find out minimum acceptable output current referred as 'threshold current' by using which multiple applications can be designed in future for solar panel efficiency improvement. In the survey, different sunlight intensities are considered and the effects on panel output were examined practically. On the basis of maximum output power, overall efficiency degradation is calculated mathematically.**

***Keywords—solar PV panel, dust accumulation, threshold current, sunlight intensity, output power, efficiency degradation.***

## I.INTRODUCTION

Solar energy is richly available in nature that too free of cost! Solar PV module converts the sunlight energy into electrical energy and for further use this electrical energy is stored in battery in form of chemical energy [1]. For better performance and maintenance, PV modules requires continuous monitoring. Several methods used for continuous monitoring of PV panel and on the basis of such monitoring results, user can apply various maintenance aids. With the help of Ethernet, GSM and GPRS several monitoring systems are developed. The proposed technique uses GSM for the communication of data [2]. In [3], the use of ACS712 current sensor and voltage sensor with GSM system made it possible to monitor both the solar panel and the battery. Real time clock-chip is used for real time recording in [4].

An instant monitoring infrastructure of a renewable energy generation system that is constituted with a wind turbine and solar panel arrays is introduced in [5]. The monitoring was based on current and voltage measurements of each renewable source. The observing software analyzes the saved data, daily, weekly and monthly. In [6], a customized cost-effective solution that allows monitoring and the quick performance predicting of PV systems has been done successfully. Researchers have designed an in- house system with a maximum power point tracker (MPPT) serving as a PV load with sensors system to collect climatic parameters including dust, wireless Radio, and a LabVIEW based monitoring and recording station. The protection circuit and sunlight detection circuit were also designed for the solar power system [7]. The direct link between model parameters and I-V curves has been established which provides a clear knowledge on how the PV module is affected by temperature and irradiance [8]. The proposed system in [9] operates in any geographical location providing 24*7 monitoring. An innovative roof-mounted energy system constituted by a hybrid solar system has been developed for domestic use [10].

Our main focus is to design a solar panel monitoring system, which measures the parameters of solar panel such as output current, output voltage, output power, solar radiation intensity etc. It can measure solar panel parameters under the sunlight at different locations. Through these measured parameters, acceptable value of current can be calculated by using which several applications can be made to work automatically on the surface of solar panel to make it clean for better efficiency.

## II. HARDWARE DESIGN

Hardware of this system comprised of Solar Panel, Charge Controller, DC Load, Battery and Sense Resistor etc. as shown in Fig.1 below:

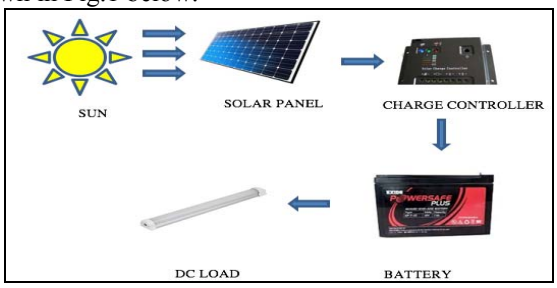


Fig.1 Basic Blocks of Proposed System



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Charge controller is a device which will maintain battery charge within some specified limit (20% to 80%). It will not allow battery to get over charge (>80%) and over discharge (<20%).DC tube light has been used as a load which is directly connected to battery output. So the main theme behind all system work is like, Solar Panel charges the battery and battery is getting discharged by DC tube light connected at its output. Sense resistor is connected at the negative output pin of solar panel and negative pin of charge controller. The voltage across this sense resistor is measured on hourly basis during entire sample days. As value of sense resistor is known to us, we can easily determine value of current flowing through it by mathematical calculations motivated by Ohm's law.

Fig. 1 shows basic building blocks of proposed system.

## III. EXPERIMENTAL RESULTS AND ANALYSIS

Estimation of Output Power:

The survey has been done for 30 days. Two solar panels have been used. One panel is kept unclean for overall duration of survey while other panel kept clean. Several parameters have been checked for each panel listed as below:

A. Voltage across Sense resistor (V)
B. Current across Sense resistor (I)
C. Panel output voltage (Vo)
D. Output Power (P)
E. Sunlight Intensity

At the last day of survey, it has been observed that, unclean solar panel's output voltage got reduced as compared to that of clean panel. Table 1 below shows the readings for both clean and unclean solar panel at very 1st day whereas Table 2 shows the readings for both clean and unclean solar panel last day.

**Table 1 At very first day**

| TIME | PANEL 1 Voltage | PANEL 1 Current | PANEL 1 Output Voltage | PANEL 1 Output Power | Sunlight Intensity | PANEL 2 Voltage | PANEL 2 Current | PANEL 2 Output Voltage | PANEL 2 Output Power |
|---|---|---|---|---|---|---|---|---|---|
| **9:30** | 0.68 | 1.21 | 17.1 | 20.7 | 863 | 0.68 | 1.21 | 17.1 | 20.7 |
| **10:00** | 0.79 | 1.41 | 17.9 | 25.2 | 998 | 0.78 | 1.39 | 17.9 | 24.9 |
| **10:30** | 0.86 | 1.54 | 18.5 | 28.5 | 1056 | 0.86 | 1.54 | 18.5 | 28.5 |
| **11:00** | 1.01 | 1.8 | 18.8 | 33.8 | 1105 | 1.00 | 1.79 | 18.8 | 33.7 |
| **11:30** | 1.10 | 1.96 | 19.1 | 37.4 | 1112 | 1.09 | 1.95 | 19.1 | 37.2 |
| **12:00** | 1.15 | 2.05 | 19.7 | 40.4 | 1116 | 1.17 | 2.09 | 19.7 | 41.2 |
| **12:30** | 1.16 | 2.08 | 20.4 | 42.4 | 1117 | 1.17 | 2.09 | 20.4 | 42.6 |
| **1:00** | 1.15 | 2.05 | 20.4 | 42.6 | 1119 | 1.14 | 2.04 | 20.8 | 42.4 |
| **1:30** | 1.15 | 2.06 | 20.4 | 42.0 | 1213 | 1.18 | 2.11 | 20.9 | 44.1 |
| **2:00** | 1.11 | 1.98 | 20.2 | 42.0 | 1114 | 1.11 | 1.98 | 21.2 | 42.0 |
| **2:30** | 1.15 | 2.05 | 20.8 | 42.6 | 1198 | 1.18 | 2.11 | 20.8 | 43.9 |
| **3:00** | 0.77 | 1.38 | 19.6 | 27.0 | 998 | 0.79 | 1.41 | 19.6 | 27.6 |
| **3:30** | 0.70 | 1.25 | 19.8 | 24.8 | 921 | 0.69 | 1.23 | 19.8 | 24.4 |
| **4:00** | 0.70 | 1.25 | 18.7 | 23.4 | 882 | 0.71 | 1.27 | 18.7 | 23.7 |
| **4:30** | 0.67 | 1.20 | 18.0 | 21.6 | 860 | 0.68 | 1.21 | 18.0 | 21.8 |

Table 2 At last day

| TIME | PANEL 1 Voltage | PANEL 1 Current | PANEL 1 Output Voltage | PANEL 1 Output Power | Sunlight Intensity | PANEL 2 Voltage | PANEL 2 Current | PANEL 2 Output Voltage | PANEL 2 Output Power |
|---|---|---|---|---|---|---|---|---|---|
| **9:30** | 0.49 | 0.87 | 16.8 | 14.62 | 638 | 0.23 | 0.41 | 16.1 | 6.60 |
| **10:00** | 0.65 | 1.16 | 17.2 | 19.95 | 832 | 0.41 | 0.73 | 16.5 | 12.05 |
| **10:30** | 0.60 | 1.07 | 16.9 | 18.08 | 750 | 0.38 | 0.67 | 16.2 | 10.85 |
| **11:00** | 0.71 | 1.26 | 17.4 | 21.92 | 896 | 0.46 | 0.82 | 16.8 | 13.78 |
| **11:30** | 0.71 | 1.26 | 17.5 | 22.05 | 892 | 0.46 | 0.82 | 16.9 | 13.86 |
| **12:00** | 0.73 | 1.30 | 17.9 | 23.27 | 915 | 0.46 | 0.83 | 17.2 | 14.28 |
| **12:30** | 0.79 | 1.41 | 17.9 | 25.24 | 964 | 0.46 | 0.83 | 17.1 | 14.19 |
| **1:00** | 0.85 | 1.51 | 18.0 | 27.18 | 983 | 0.60 | 1.07 | 17.8 | 19.05 |
| **1:30** | 0.94 | 1.69 | 18.5 | 31.26 | 1085 | 0.60 | 1.08 | 16.9 | 18.25 |
| **2:00** | 1.10 | 1.97 | 19.1 | 37.62 | 1100 | 0.60 | 1.08 | 16.7 | 18.04 |
| **2:30** | 1.06 | 1.91 | 18.9 | 36.10 | 1090 | 0.58 | 1.03 | 16.5 | 17.00 |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **3:00** | 0.73 | 1.30 | 16.7 | 21.71 | 899 | 0.46 | 0.83 | 16.0 | 13.28 |
| **3:30** | 0.73 | 1.30 | 16.8 | 21.84 | 890 | 0.46 | 0.82 | 16.1 | 13.20 |
| **4:00** | 0.60 | 0.91 | 16.5 | 17.82 | 748 | 0.38 | 0.67 | 15.9 | 10.65 |
| **4:30** | 0.51 | 0.89 | 16.4 | 14.92 | 665 | 0.24 | 0.42 | 15.8 | 6.64 |

From the above two tables it is observed that, during first day, Sunlight intensity was very good and Panel1 & Panel2 were having approximately same output power. In the last day of survey, light intensity is enough good but output powers of both the panels are with very bad difference in between. The values of output powers and efficiencies are calculated in next section.

### *A. Calculation at 1st Day:*

For Clean Solar Panel,
Output Power of can be calculated as,

$$Pout1 = Vo*I \quad (1)$$

$$= 20.4 * 2.06 = 42.02 \text{ Watt}$$

Input Power of can be calculated as,

$$Pin1 = Sunlight\ Intencity*Area\ of\ Panel \quad (2)$$

$$= 1213 * (Length * Breadth)$$

$$= 1213 * (666\ mm*464\ mm)$$

$$= 374.85\ Watt$$

Efficiency of Clean Solar Panel during first day can be calculated as,

$$Efficiency = \frac{Pout1}{Pin1} \quad (3)$$

$$= \frac{42.02\ Watt}{374.85\ Watt}$$

$$= \mathbf{11.21}\ \%$$

Similarly, For Unclean Solar Panel,
Output Power of can be calculated as,

$$Pout2 = Vo*I \quad (4)$$

$$= 20.9 * 2.11 = 44.10 \text{ Watt}$$

Input Power of can be calculated as,

$$Pin2 = Sunlight\ Intensity*Area\ of\ Panel \quad (5)$$

$$= 1213 * (Length * Breadth)$$

$$= 1213 * (666\ mm*464\ mm)$$

$$= 374.85\ Watt$$

Efficiency of Clean Solar Panel during first day can be calculated as,

$$Efficiency = \frac{Pout2}{Pin2} \quad (6)$$

$$= \frac{44.10\ Watt}{374.85\ Watt}$$

$$= \mathbf{11.76}\ \%$$

### *B. Calculation at Last Day:*

For Clean Solar Panel,
Output Power of can be calculated as,

$$Pout3 = Vo*I \quad (7)$$

$$= 19.1 * 1.97 = 37.63 \text{ Watt}$$

Input Power of can be calculated as,

$$Pin3 = Sunlight\ Intensity*Area\ of\ Panel \quad (8)$$

$$= 1100 * (Length * Breadth)$$

$$= 1100 * (666\ mm*464\ mm)$$

$$= 339.93\ Watt$$

Efficiency of Clean Solar Panel during first day can be calculated as,

$$Efficiency = \frac{Pout3}{Pin3} \quad (9)$$

$$= \frac{37.63\ Watt}{339.93\ Watt}$$

$$= \mathbf{11.07}\ \%$$

Similarly, For Unclean Solar Panel,
Output Power of can be calculated as,

$$Pout4 = Vo*I \quad (10)$$

$$= 16.5 * 1.03 = 17.00 \text{ Watt}$$

Input Power of can be calculated as,

$$Pin4 = Sunlight\ Intensity*Area\ of\ Panel \quad (11)$$

$$= 1100 * (Length * Breadth)$$

$$= 1100 * (666\ mm*464\ mm)$$

$$= 339.93\ Watt$$

Efficiency of Clean Solar Panel during first day can be calculated as,

$$Efficiency = \frac{Pout4}{Pin4} \quad (12)$$



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$$= \frac{17.00\ Watt}{339.93\ Watt}$$

$$= \mathbf{5.00}\ \%$$

Thus, from all above calculations we can say that, at the end of survey due to dust accumulation on panel surface its efficiency got reduced to approx. 50%. Which is not acceptable for normal working of Solar PV module. Thus, by making some basic assumptions we can decide one specified value of output current beyond which current reduction is not acceptable. This current is referred as threshold current. As at 1.03A value of current output efficiency becomes half of its original value, we can assume threshold current as 1.6A at which efficiency is 7.77%. That means after the value of 1.6A output current, solar panel surface should be cleaned properly so that its output voltage will increase and we will get proper output at its load.

## IV. CONCLUSION

In this paper, various output parameters of both clean and unclean solar panels computed under different sunlight intensities. The technique is very simple and easy. On the basis of voltage across sense resistors, output current of solar panel has been calculated mathematically. The results show that, the value of current raises as the sunlight radiations raises from the morning and at the evening, as light intensity decreases, the current also drops down. Due to which efficiency of panel also drops. The main important factor affecting this current reduction is dust accumulation on surface of solar panel. It has been experimentally proved that, due to accumulated dust day by day panel efficiency reduces up to 50%. And it will reduce further if any action is not taken against this reduction. For future extensions, least value of acceptable current can be considered as the value after which the surface of solar panel needs to make clean manually or automatically so that efficiency and working life of solar panel gets improved.

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