PERFORMANCE IMPROVEMENT STUDY OF PV CELL WITH SOLAR TRACKING SYSTEM

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ABSTRACT
Solar photovoltaic energy is free, environmentally clean and it is considered as one of the most promising alternative sources of energy. The increase percentage of the output of panel and discharge differ with the solar radiation along daytime. The objective of this study is to generate maximum power by tracking the sun throughout the day. This paper deals with program, construction and to design solar tracking system with reflecting mirror using a stepper motor and microcontroller named Arduino system to increase the efficiency of solar photovoltaic (PV) panel. The efficiency of 12.86% and 10.14% are recorded for panel with and without mirror respectively. The application of mirror is an efficient and an effective way to enhance the performance of solar photovoltaic cell with the same panel area.

Keywords: Solar energy, photovoltaic panel, Stepper motor, Reflecting mirror, Tracking system, Microcontroller, Green technology.

1. INTRODUCTION

The solar photovoltaic (PV) systems and technology are becoming a promising option for electricity generation, because the fossil fuels are reducing gradually in our plant. The solar power output is the amount of 166 PW out of which 85 PW reaches the Earth. This shows not only that solar power is well over 500 times our current world 15 TW power consumption, but also that all other sources are less than 1% of solar power output (Glaser, 1968; Mendoza, 2005; Abbott, 2010). For the world energetic demand, it is a huge free resource. The one of the main solar active technologies is the direct conversion of sunlight into electricity in PV cells, the two others being concentrating solar power (CSP) and solar thermal collectors for heating and cooling (Oliveira, 2007). To increase the capability of the solar cells, solar tracking and solar light concentrations could be employed individually or in combination. Basically solar tracking employs mechanism that continually points the PV modules directly to the sun (David et al. 1981).

Tracking mechanism and mirror concentrating element has been seriously investigated and widely adapted in solar PV technology. In this study, the first employing the 2-axis sun tracking system, the second employing mirror concentrating system, and the third employing a basic fixed system, a base system, to be used as comparator (Effendy Ya'Acob et al. 2013). The mirror concentrator embedded in the 2×CPV technologies adopted V-through concept of configuration with enhancement in mirror concentration. By the study of recent papers which implies and enhances the optical efficiency of V-through technology in solar PV application creates alternative means of reducing the overall built-up area, quantity of module, and heat dissipation and thus significantly lowers down the installation cost (Solanki et al. 2008; Maiti et al. 2011; Tang and Liu, 2011; Chong et al. 2012; Riffat and Mayere, 2013).The radiation, that is, not scattered or reflected and reaches the surface directly is called direct or beam radiation and the scattered radiation reaching the ground is called diffuse radiation (Mousazadeh et al. 2009).The role of concentration photovoltaic systems is basically to collect both beam and scattered irradiation, which do not reach the photovoltaic cells. Besides photovoltaic, the concentrator also has other applications such as thermal power applications (Lewandowski and Simms, 1987; O'Gallagher and Winston, 1988; Xiao et al. 2012). The photovoltaic system is one, among all renewable systems which has a great chance to replace the conventional energy resources. Solar panel mainly consists of semiconductor. Silicon (Crystalline) is used as the major components of solar panels, which containing maximum 25.6±0.5% efficiency (Martin et al. 2014). The most appropriate and proven technology are the solar trackers to increase the efficiency of solar panels through keeping the panels aligned with the sun's position.

In recent days, solar trackers get popularized around the world to harness solar energy in most efficient way. This is far more cost effective solution than purchasing additional solar panels (Sayran et al. 2010; Rashmi, 2012). For most of the solar systems to collect maximum amount solar radiation, the solar tracking is necessary. A high degree of concentrator accuracy is required to ensure that the reflected sunlight is directed to the absorber, which is at the focal point of the reflector. Over 40% efficiency can be increase by using solar tracking system. The renewable energy sources and the technologies are associated with them are equally important to household and industrial purposes. The use of solar tracking system with the reflecting mirror in our project gives the 12.86% efficiency and silicon (Crystalline) based solar photovoltaic panel performs the maximum efficiency near about 25.6±0.5%. So finally we can increase the efficiency of microcontroller named Arduino system of about 38.46%.
The aim of this study was to design and construct the tracking mechanism for maximizing the solar panel efficiency. To determine solar intensity, current, voltage

and efficiency of the device and helping to reduce domestic energy demand from power utilities.

2. MATERIALS AND METHODOLOGY

2.1 Materials and Design

We have used commercially available stepping motor which is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller), as long as the motor is carefully sized to the application in respect to torque and speed. Switched reluctance motors is very large stepping motors with a reduced pole count, and generally are closed loop commutated. The performance of Stepper motor is strongly dependent on the driver circuit and receives the signal from the microcontroller. Torque curves may be extended to greater speeds if the stator poles can be reserved more quickly, the limiting factor being the winding inductance. To overcome the inductance and switch the winding quickly, one must increase the drive voltage. This leads further to the necessity of limiting the current that this high voltage may otherwise induce. In photovoltaic solar panel system, the voltage and current are measured by using the multimeter.

2.1.1 Microcontroller (Arduino)

The use of Arduino microcontroller controls the overall system, which is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. The program memory in the form of OTP ROM or NOR flash is also often included on chips, as well as a typically small amount of RAM. It is designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications. The common are mixed signal microcontrollers, integrating analog components needed to control non-digital electronic systems. Arduino UNO microcontroller is used for controlling the direction of stepper motor and the program is set up on the microcontroller and also compare with the set point.

2.2 Project Design Methodology

The design of solar tracking system is the basic components of the study. The solar panel is covered with a frame and the reflecting glass (Mirror), which will improve the output and design. It will help to increase the fall of the sun rays over the panel. The design criteria depend on the following factors: i) capacity of the panel; ii) dimension of the panel; iii) structural materials of selection; iv) stepper motor selection etc.

In this study, a good foundation is a very important thing for balancing the solar tracker because of having adequate strength to hold the total system. Here the panel and mirror are stay in the frame. A experimental set of solar tracking system is shown in the figure 2.

2.2.1 Circuit diagram of the system

The design of a circuit diagram represents an electrical circuit. A pictorial circuit diagram uses simple images of components, while a schematic diagram shows the components and interconnections of the circuit using standardized symbolic representation. The presentation of the interconnections between circuit components in the schematic diagram does not necessarily correspond to the physical arrangements in the finished device. The Figure 3 shows that the circuit diagram of the microcontroller.

Figure 1 Block diagram of the project design methodology

Figure 2 An instrumental set up of solar tracking system

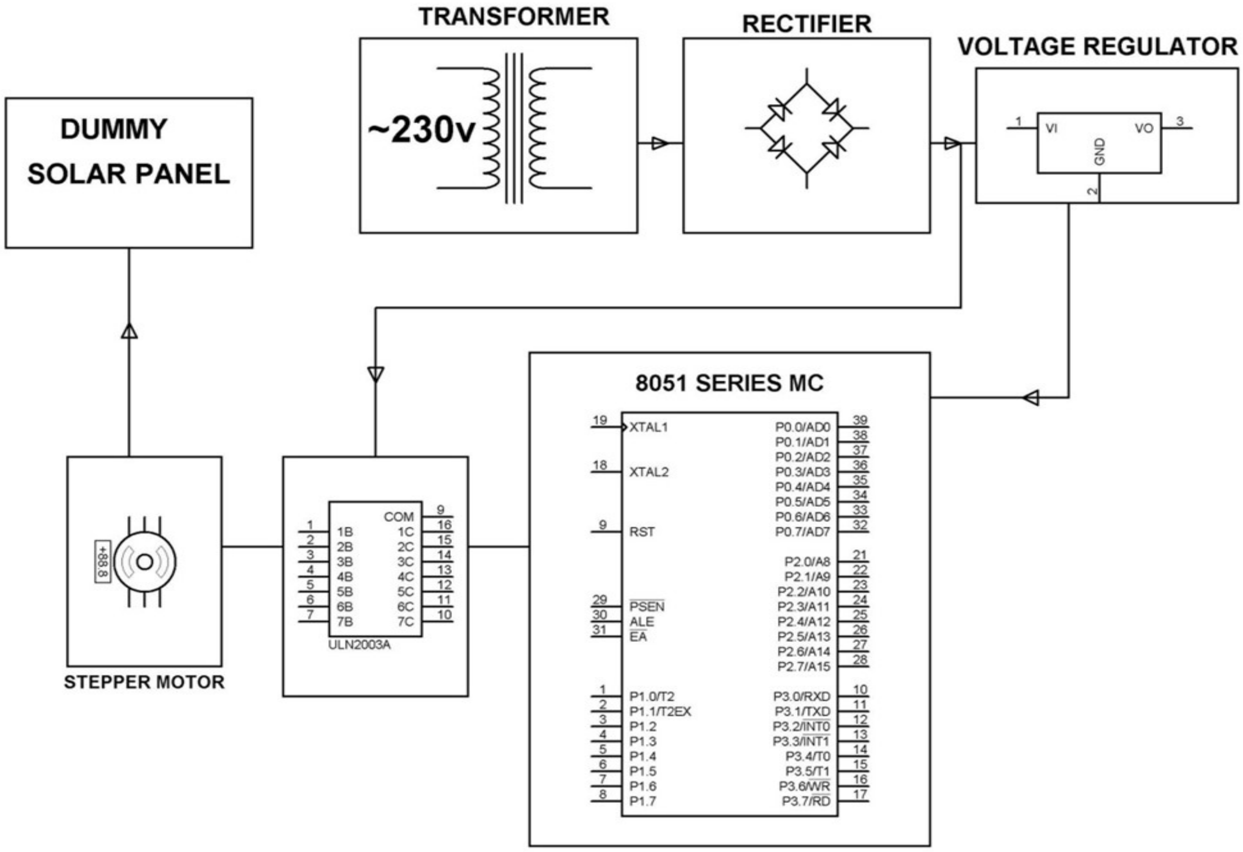

Figure 3 Circuit diagram of the system

3. RESULTS AND DISCUSSION

3.1 Effect of Tracking System

The actual effect increases with the application of reflector on the photovoltaic panel the incident. Consequently, temperature of the panel increases due to extra solar radiation. Therefore, it is necessary to evaluate in what extend the power and efficiency of the panel increased with application of reflector. It is clear that the performance of the tracked PV module with reflector increase is shown in the **Table 1**. In this table, the power is gradually decreasing after 3.00 pm. The total experimental process is done in summer season.

Table 1 Effect of stationary reflector on the photovoltaic panel

Time	Non tracked (PV module)			Tracked (PV module with Reflector)		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
09.00 am	18.5	0.15	2.78	19.1	0.21	4.01
10.00 am	18.6	0.16	2.98	19.2	0.22	4.22
11.00 am	18.7	0.17	3.18	19.4	0.24	4.66
12.00 pm	18.9	0.19	3.59	19.5	0.25	4.88
01.00 pm	19.2	0.22	4.22	19.8	0.28	5.54
02.00 pm	19.2	0.22	4.22	19.9	0.29	5.77
03.00 pm	19.6	0.26	5.096	20.2	0.32	6.464
04.00 pm	19.0	0.20	3.80	19.8	0.28	5.54

3.2 Intensity Measurement

The solar intensity is the most important part of the solar photovoltaic panel and solar power mostly depends on it. The higher the solar intensity gives the higher the PV power. The relationship between the electrical power generated and radiant sun light can be demonstrated with the aid of measuring equipment called photovoltaic Trainer. The intensity of the sun was calculated by using this instrument which is covered with the following parts: (a) tilting support on caster, (b) variable resistor with slider, (c) solar module, (d) temperature sensor, (e) illuminance sensor and (f) connector. The **Figure 4** shows the intensity of different times of the day and the maximum solar intensity is found at 3.00 pm.

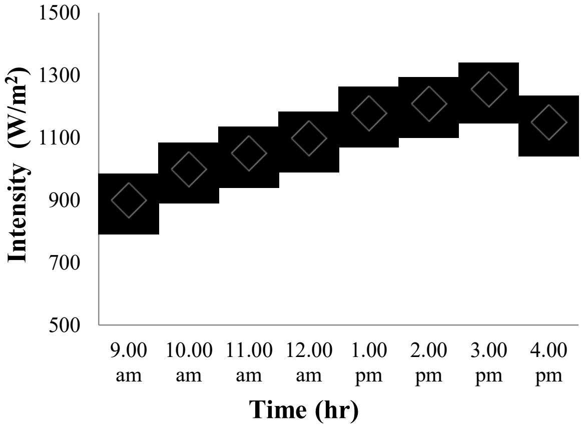

Figure 4 Intensity measurement by using photovoltaic Trainer (10 May 2015)

3.3 Effect of Voltage

Voltage increases with respect to the day time because intensity increases from 9.00 am to 3.00 pm. After 3.00 pm the intensity decreases as a result, the voltages automatically decrease. At 3.00 pm, the maximum voltages of non-tracked and tracked PV module are 19.6V and 20.2V respectively. The Figure 5 shows difference of voltage output resulted between with tracking and without tracking system.

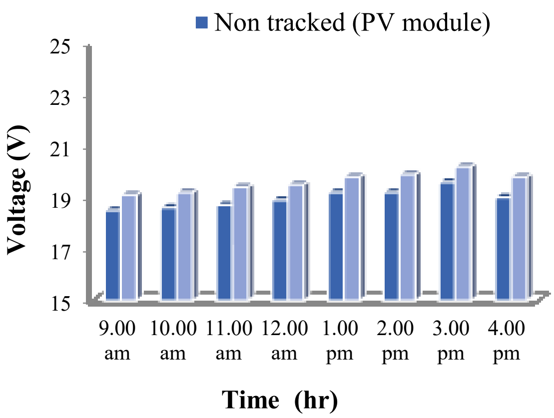

Figure 5 Response of the output voltage at different times of the day (10 May 2015).

3.4 Effect of Current

As voltage increases with increase in intensity, current output also increases with respect to the day time between 9.00 am to 3.00 pm. At 3.00 pm, the maximum current of non-tracked and tracked PV module are 0.26A and 0.32A respectively. After 3.00 pm the intensity decreases so the current automatically decrease. The Figure 6 shows difference of current output between with tracking and without tracking system.

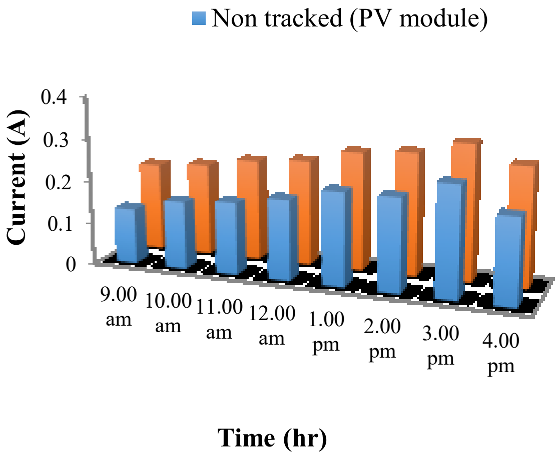

Figure 6 Response of the output current at different times of the day (10 May 2015)

3.5 Efficiency Analysis

Solar cell efficiency is the ratio of the electrical output of a solar cell to the incident energy in the form of sunlight. The energy conversion efficiency (η) of a solar cell is the percentage of the solar energy to which the cell is exposed that is converted into electrical energy. The Table 2 shows that the efficiency of non-tracked (PV module) and the Table 3 shows that the efficiency of the tracked (PV module).

Efficiency, $\eta = \frac{V\times I}{A\times i}$

Where,
V = Voltage (V)
I = Current (A)
A = Surface area (m^2)
i = Solar intensity (W/m^2)

Efficiency is the major part of our study. The maximum efficiency with tracked is 12.86% and non-track is 10.14%. It is mainly depends on the intensity of the solar energy, surface area, voltage and current. The Figure 7 shows that the efficiency of the solar panel.

Table 2 Efficiency analysis of non-tracked (PV module)

Time	Voltage (V)	Current (A)	Length (m)	Wide (m)	Area (m2)	Intensity (W/m2)	Efficiency η %
9.00am	18.5	0.15	0.195	0.215	0.04	900	7.70
10.00am	18.6	0.16	0.195	0.215	0.04	1000	7.44
11.00am	18.7	0.17	0.195	0.215	0.04	1050	7.56
12.00am	18.9	0.19	0.195	0.215	0.04	1100	8.16
1.00 pm	19.2	0.22	0.195	0.215	0.04	1180	8.95
2.00 pm	19.2	0.22	0.195	0.215	0.04	1210	8.73
3.00 pm	19.6	0.26	0.195	0.215	0.04	1256	10.14
4.00 pm	19.0	0.20	0.195	0.215	0.04	1150	8.26

Table 3 Efficiency analysis of tracked (PV module)

Time	Voltage (V)	Current (A)	Length (m)	Wide (m)	Area, (m2)	Intensity, (W/m2)	Efficiency ŋ, %
9.00 am	19.1	0.21	0.195	0.215	0.04	900	11.14
10.00 am	19.2	0.22	0.195	0.215	0.04	1000	10.56
11.00 am	19.4	0.24	0.195	0.215	0.04	1050	11.08
12.00 am	19.5	0.25	0.195	0.215	0.04	1100	11.07
1.00 pm	19.8	0.28	0.195	0.215	0.04	1180	12.16
2.00 pm	19.9	0.29	0.195	0.215	0.04	1210	11.92
3.00 pm	20.2	0.32	0.195	0.215	0.04	1256	12.86
4.00 pm	19.8	0.28	0.195	0.215	0.04	1150	12.05

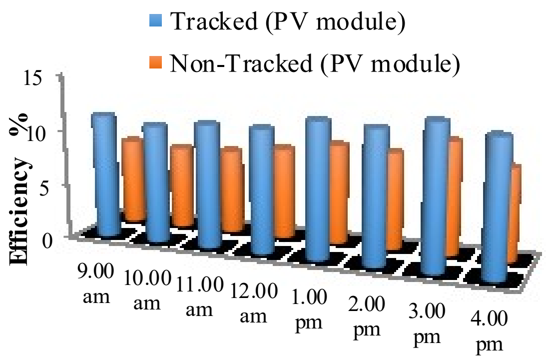

Figure 7 Efficiency of photovoltaic panel with track or without track

4. CONCLUSION

The microcontroller based solar tracking system with mirror booster has been fabricated and the efficiency of solar panel with tracking device was obtained about 12.86% whereas without tracking system it was resulted 10.14%. We also get the higher voltage and current without track are 19.6 V and 0.26 A, and with track 20.2 V and 0.32 A respectively under the solar intensity 1256 W/m2. The proposed circuit design with stepper motor and Arduino is simple and self-contained, and very easy for programming. The proposed methodology is an innovation so far. It achieves the following attractive features are simple and cost effective control implementation, bulky but it is effective for large power generation.

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