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Comparison of Solar Photovoltaic Energy Systems Fixed Installation configuration with Single Tracking System

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Abstract: *This paper describes the fixed PV systems tilt angle and the single tracking system. It looked at the performance of each system in terms of the voltage output and compares the two to find a better performing system. This paper also through the experiment which was conducted seek to verify a phenomenon already established by previous research to determine if the comparison done at a smaller scale would provide similar results. The experiment had an Arduino based control system. The experimental setup used two light dependent resistors (LDRs) which were fixed onto the PV module. Any correction signal generated due to inequality of voltage outputs of the two LDRs was used actuate a servo motor which would rotate at an angle proportional to the magnitude to the correction signal, that is, for tracking system. The two configurations have been successfully built and demonstrated and the results obtained are consistent with what previous research has established that the tracking system has a higher performance output than a fixed system. Further work would include dual tracking system with optimized life cycle cost.*

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I. Introduction

Electrical power/Energy is an essential commodity for human live. It is used in different spheres such as in household applications, manufacturing, mining, agriculture, wildlife and tourism. It also is used in commercial sectors and other institutions such as government departments. It can therefore be concluded that Energy is an important commodity for the betterment of human life. Access to reliable and affordable energy services by the general population mitigate poverty and can lead to development [1]. Energy availability and consumption can be influenced by different factors such as population because if the area has a sizeable number of inhabitants it puts pressure on the available energy resources [1]. Another factor which can put energy availability and consumption under strain is consumption patterns by the users. This can be attributed to different energy requirements which may vary from one household to another and from one place to another. In urban centres energy is needed for a wide range of activities and products such as transportation, industry, construction, infrastructure, domestic appliances and products [1], while in rural areas the need could be different.

However, some remote areas are experiencing energy supply challenges. Some of these are associated with geographic location of a place to be electrified such as remote location where distance and or terrain is not favourable [2]. Most of these areas are generally far away from national grid which makes it excessively expensive to reticulate power to them [3]. Other challenges resulting to lack of electricity are inaccessibility, e.g,. in deltas[4]. To provide such areas with electricity one viable option is to provide PV energy system as a standalone. Another factor favouring RES is their user friendliness to the environment [5]. Unlike other sources such as coal, they do not release gases which are harmful to the environment during the processes of electric power generation [6].

The photovoltaic energy systems generate electricity by converting solar energy into electrical energy. Figure 1 depicts a simplified diagram of PV system. The tracking system would thus optimally supply adequate power even during low solar irradiation levels such as during winter season in the southern hemisphere to communities living in the rural areas hence improving access to livelihood activities such as electricity supply to schools, clinics, kgotla, businesses and this would ultimately lead overall improvement of social welfare of the of people

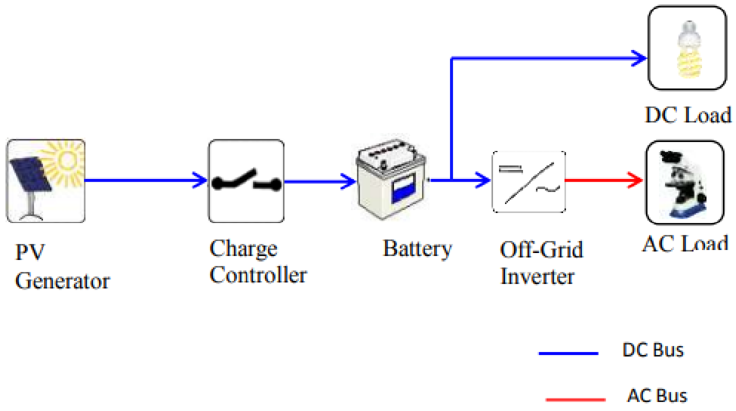

Figure 1 – Shows principle of operation of solar PV system [7]

In figure 1 the PV module/ generator received solar energy from the sun and convert converts it into electrical energy. From the output of the PV module, the DC voltage and current obtained and are used to charge the battery. The battery in turn supplies DC load with electrical power. It is also possible in some configurations to have the power from the PV module directly powering DC load without presence of the battery. The charge controller is there to project the battery from undercharging and over discharging. Where the load to be powered is AC load, an inverter is used to electrical DC parameters from the battery DC to AC. Regarding the configurations, designs, installations, and other specifications there are different standards such as international standards, association standards, and national standards, e.t.c, which give detailed information on how those can best be achieved

The rest of the paper is arranged as follows: Section II deals with PV module installation for both fixed and tracking configurations. Section III details experimental setup. Section IV deals with procedure, Section V deals with Results, Analysis and Discussions, and Section VI deals with Conclusions and Future work.

II. PV module installation (tracking versus fixed installation)

a. Tracking configuration

There are various configurations of installing solar photovoltaic energy systems. One of them is tracking system. With this one the common tracking systems are single tracking and dual tracking. Single tracking could be pivoting on the vertical reference position and as the sun moves from sunrise position to sunset, the system rotates from facing towards the easterly position towards westerly position with all-time facing direction of the sun. Figure 2 shows single axis tracking along the vertical reference position. With this system the tilt angle is fixed while the orientations varies Also single tracking could be whereby the system rotates at the horizontal reference position. With this tracking, orientation is fixed and the tilt angle varies. For systems in southern hemisphere the panel is facing north. During mornings and sunsets the tilt angle is maximum and towards noon the tilt angle reduces and in process more solar energy from the sun. This solar energy is converted into the electrical energy output. The module also responds to the seasons of the year by varying the tilt angle as seasons change. During winter the sun as moved away from southern hemisphere not much solar energy is obtained. Tracking can also be dual whereby the PV module structure pivots both on vertical and horizontal reference positions. This configuration is more efficient when comparing it with the single axing tracking it because it can track the optimal position of the sun whereby the solar energy received is maximum.

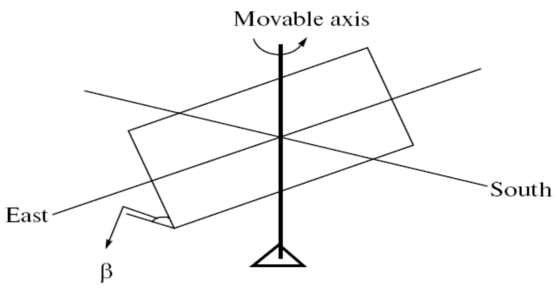

Figure 2 – Single axis tracking [8]

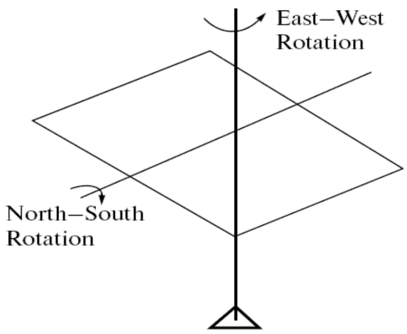

Figure 3 – Dual axis tracking [8]

b. Fixed configuration

With this system the PV module is orientation and tilt are fixed. They do not charge with position of the sun irrespective of the time of the day of day of the year. While this configuration is the most common due to its non-complexity costs, it is less efficient that the tracking system. As it is fixed, when the sun moves away from the direction where the module is facing, the module surface tends to receive less radiation than if it was directly facing the sun. This results even in less power output.

II. Experimental setup

The following equipment were used in the experiment:

Pollycrystalline PV module with the following specifications, maximum output power of 0.5 watts, maximum output current of 90 mA and maximum output voltage of 5.5V; A 3-pole analogue servo motor with a pulse width of 500-2400 µs and of the following characteristics: a torque of 1.80 kg-cm at a voltage of 4.8V, Speed of 0.12s/60^o at a voltage of 4.8V; Aurduino Uno Atmega 328 was used on automatic control circuit of tracking system configuration. It had the following characteristics: Operating temperature of -40°C to 85°C, operating voltage of 1.8 V to 5.5 V, low power consumption at 1 MHz, 1.8V, 25°C, and with active mode, power-down mode and power-save mode of 0.2 mA, 0.1 µA, and 0.75 respectively; Two light-dependent resistors (LDRs) which were to be attached to the PV module to sense the solar irradiance.

III. Procedure

As the experiment was done in the southern hemisphere, the system installation was such that the PV module faced north. One of the LDRs was fixed on the eastern side (LDR2) of the panel and other one on the western side (LDR1) of the panel. This means that the LDRs have same tilt angle and orientation with the PV module at any time. The configuration was the same for both the fixed and tracking system. For tracking system, it was single tracking system

Figure 3(a) – Demonstration of tracking system

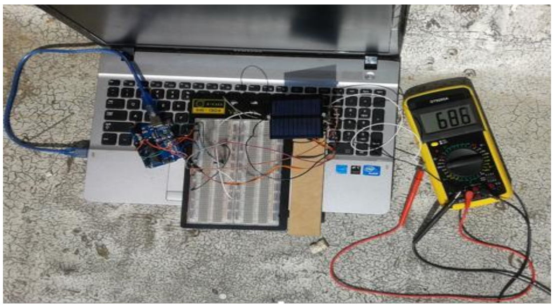

Figure 3(b) – Demonstration of tracking system with increased voltage output

The operation of servo motor was influenced by difference between the output of LDR1 and 2. This output difference acts as a correction signal which activates the actuator, that is servo motor, and amount at which the servo motor rotates is proportional to the magnitude of this correction signal. The direction of rotation of the motor is also determined by the biasedness of the correction signal, that is, by comparing the outputs of the two LDRs and determining which one contributes more to the correction signal. If the outputs of the two LDRs is the same there is no rotation of the servo motor because the value of correction signal will be zero.

IV. Results, Analysis and Discussions

a. Fixed System Configuration

The LDRs outputs are shown in Table1 and Figure 4 respectively. Table 1 shows voltage output readings as recorded since 0630 hours in the morning until 1830 hours in the afternoon. The Readings were plotted against time as shown in Graph 1 to observe the voltage profile throughout the day. The results show that in the mornings (from sunrise) the output voltages of both sensors are low, however, the LDR1 is even much lower than the LDR2 output. This is due to the reason that in the mornings there is not much solar radiation. The LDR1 reading much lower readings are as a result of its position with respect to the sun's position of sunrise. It is fixed of west side of the PV module and this puts it a bit on the shadow of the module frame and obstructing it to receive the radiation. Around noon, the LDRs' outputs are almost the same and maximum because they are generally receiving re same amount of solar radiation. During later afternoon, the LDR1 receives more radiation than LDR1 hence have voltage output more than LDR2.

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Table 1 – LDRs Voltage outputs of fixed system recorded over a range of time from sunrise to sunset

TIME	LDR2 (V)	LDR1 (V)
0630Hrs	1.477	0.489
0730Hrs	2.804	1.061
0830Hrs	3.203	1.672
0930Hrs	3.990	1.199
1030Hrs	4.130	3.226
1130Hrs	4.500	3.208
1230Hrs	4.990	4.990
1330Hrs	4.888	4.990
1430Hrs	4.941	4.976
1530Hrs	3.878	4.941
1630Hrs	3.824	4.873
1730Hrs	2.639	3.964
1830Hrs	1.031	2.708

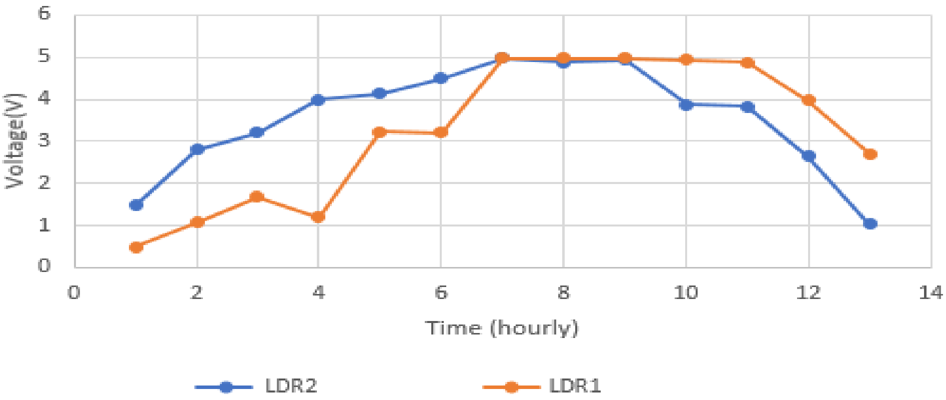

Figure 4 – Shows a one-day voltage profile of LDRs output for fixed system

b. Tracking System Configuration

As shown in Table 2 and Figure 5both LDRs give generally the same output voltage and similar voltage profile throughout the day, that is, from morning to the late afternoon. This is due to the reason that at any point in time the PV module faces towards direction of the sun and in process, both the LDRs get same amount of solar radiation. The maximum output voltage was recorded around solar noon.

Table 2 – LDRs Voltage outputs of tracking system recorded over a range of time from sunrise to sunset

TIME	LDR1 (V)	LDR2 (V)
0630Hrs	1.487	1.477
0730Hrs	2.893	2.804
0830Hrs	3.990	3.203
0930Hrs	3.990	3.990
1030Hrs	4.149	4.130
1130Hrs	4.590	4.500

1230Hrs	4.990	4.990
1330Hrs	4.888	4.990
1430Hrs	4.976	4.985
1530Hrs	4.892	4.941
1630Hrs	3.873	4.790
1730Hrs	3.940	3.964
1830Hrs	2.708	2.815

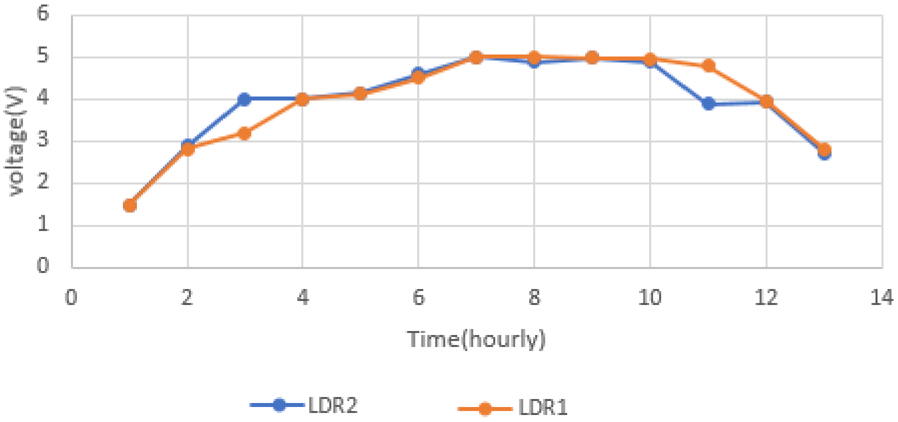

Figure 5 – Shows a one-day voltage profile of LDRs output for tracking system

V. Conclusion And Future Work

Solar tracking system has proven to be better configuration in terms of voltage output as evidenced on the results obtained. At any particular point the average output voltage of the LDRs of the tracking system was higher than that of the fixed system. The exception was only around noon where all the sensors received same solar radiation hence generally having same output voltage. Further work would include dual tracking system with optimized life cycle cost.

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