The Performance Of Automated Time Dependent Solar Tracker In Calabar

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Abstract— **The performance of automated time dependent solar tracker in Calabar was carried using few measuring einstruments. These include solar tracker, compass, voltmeter, ammeter, solar panel and connectors (wires). Tracker based and the stationary solar panels were set up and connected to the voltmeter and ammeter in the respectively in the morning (8;00)GMT and the experimental readings were taken simultaneously for 5 days and results recorded. Results showed that the system is able to track for ten hours (8:00 to 17:00) GMT hours, at every one hour, the system tilts the solar panel at 10^0 for 10 times and then return to initial position (19:00 GMT) at sun rise. Results also showed that there is a strong relationship between solar radiation and solar panel output energy as tracker based solar panel yields more than 40% increase of energy over a stationary solar panel.**

Keywords—Solar Panel, Tracker, Stationary, Maximum and Minimum

1. INTRODUCTION

Energy is found to be very important in the study of Science and Engineering. It can be defined as the ability to move an object (Mehling, 2017). Energy can also be seen as that content of matter that can be transformed into work, heat or radiation. Energy comes in various forms, such as motion, heat, light, electrical, chemical, nuclear, and gravitational (Demirel, 2012). There are many sources of energy in the world which is classified into four groups. They include energy from the Sun, kinetic forces of the earth and atmosphere, heat energy pool in the earth crust and hydrocarbon materials on earth (solid, liquid and gas).

Among all these, the sun is earth's natural source of power driving the circulation of global wind and ocean currents, even the cycle of water evaporation and condensation that creates rivers, lakes, the biological cycles of photosynthesis and life (Harriet, 2018). For instance, without energy from the sun, the flow of streams, lakes, rivers and ocean current which are used as hydro power source would not have been possible. However, this energy from the sun is called solar energy (John, 2011). Moreover, since the sun rises from east and sets in the west, the output power of the photovoltaic cell is usually not optimized because of the stationary position of the PV with respect to the earth rotation. Therefore, this is a way of finding a solution to fully harness or tapping a maximum energy from the sun by using a dynamic system called automated time dependent solar tracker.

In this paper, an automated time dependent solar tracker is configured to 1 hour mode in which the solar panel tilts through an angle of 10^0 per hour for 10 consecutive times in a day and return and then its initial position at sun rise respectively.

2. REVIEW OF RELATED WORKS

In solar tracking, passive and active trackers methods are mostly considered. Researchers have explored these methods aimed at optimizing solar panel output power. For instance in passive solar tracking, Narendrasinh et al. (2015), used Zomework principle to track the sun and achieved 25% increase compared to a fixed solar panel. Clifford et al. (2004), designed a novel passive solar tracker, which is passively activated by aluminum/steel bimetallic strips and controlled by a viscous damper. Computer modeling and experimental results predict an increase in efficiency of up to 23% over fixed solar panels. For active solar tracker, Deepthi et al. (2013), compared the efficiencies of single axis tracking system and dual axis tracking system with fixed mount. The MATLAB simulated results proves that the single axis and dual axis solar panels have efficiencies which are said to be 13% and 25% more than that of the fixed solar panel. Qi-Xun et al.(2015), also worked on solar automatic tracking system that generates power for lighting greenhouses. The COSMOS Motion simulation analysis shows that solar tracking system generated about 20% to 25% more power than the fixed solar panel.

3. MATERIALS AND METHOD

3.1 MATERIALS

The materials used are listed in Table 1.

Table 1.1: Materials used to construct the experimental solar tracker.

Equipment	Model	Rating/Range
Solar tracker self designed	Polycrystaline	11V/2.5W
Compass	Set	East, West, North & South
Ammeter	MASTECH MY68	10A
Battery	Lithium	6V/1200mAH

2.2 METHOD

The automated time dependent solar tracker is installed in an open area while a solar panel was kept stationary as shown in Figure 1 below, and the following steps were taken;

Step1**:** The solar tracker was installed with the aid of the compass to rotate in the locating East - West direction.

Step 2**:** The solar tracker was configured and set to 1 hour mode starting from 7:00am.

Step 3: Voltmeters and ammeters were used to obtain voltage and current readings from the tracker based and stationary solar panels respectively. The readings were taken every 1hour starting from 8:00am and ended at 5:00pm. The experimental test and measurements were repeated everyday for 5 days. The results obtained were then evaluated.

Figure 1.0: Experimental Set up of Solar Tracker

4. RESULTS AND DISCUSSION

The results shown in Table (1.2 to1.6) are the data obtained from a tracker based and stationary solar panels in Calabar, while Figure (1.2 to 1.11) is the graphical and Bar chart presentation of the data. The data shows the performances of each solar panel as their voltages and current were obtained and analyzed in terms of power in WattHour.

Table 2: Output Voltage, Current and Power Reading for day 1

Time (Hrs)	V_T (V)	I_T (A)	V_s (V)	I_s (A)	P_T (WHr)	P_s (WHr)
8:00	6.66	0.16	6.64	0.1	1.07	0.66
9:00	6.67	0.18	6.65	0.12	1.20	0.80
10:00	6.68	0.22	6.67	0.21	1.47	1.40
11:00	6.64	0.18	6.63	0.13	1.20	0.86
12:00	6.65	0.14	6.63	0.14	0.93	0.93
13:00	6.65	0.13	6.63	0.11	0.86	0.73

14:00	6.69	0.35	6.66	0.27	2.34	1.80
15:00	6.63	0.15	6.6	0.12	1.00	0.80
16:00	6.65	0.17	6.63	0.16	1.13	1.06
17:00	6.61	0.07	6.61	0.04	0.46	0.26

Table 3: Output voltage, current and energy reading for day 2

Time (Hrs)	V_T (V)	I_T (A)	V_S (V)	I_S (A)	P_T (WHr)	P_S (WHr)
8:00	6.6	0.2	6.5	0.10	1.32	0.65
9:00	6.6	0.2	6.6	0.08	1.32	0.53
10:00	6.64	0.10	6.63	0.08	0.66	0.53
11:00	6.63	0.09	6.62	0.07	0.60	0.46
12:00	6.65	0.15	6.65	0.15	1.00	1.00
13:00	6.66	0.13	6.64	0.11	0.87	0.73
14:00	6.64	0.09	6.63	0.08	0.60	0.53
15:00	6.63	0.09	6.63	0.08	0.60	0.53
16:00	6.63	0.07	6.62	0.06	0.46	0.40
17:00	6.63	0.08	6.62	0.04	0.53	0.26

Table 4: Output voltage, current and energy reading for day 3

Time (Hrs)	V_T (V)	I_T (A)	V_S (V)	I_S (A)	E_T (WHr)	E_S (WHr)
8:00	6.67	0.20	6.64	0.11	1.33	0.73
9:00	6.62	0.04	6.61	0.04	0.26	0.26
10:00	6.64	0.11	6.63	0.09	0.73	0.6
11:00	6.67	0.22	6.66	0.20	1.47	1.33
12:00	6.65	0.14	6.64	0.13	0.93	0.86
13:00	6.77	0.45	6.74	0.41	3.05	2.76
14:00	6.73	0.37	6.68	0.26	2.49	1.72
15:00	6.72	0.32	6.70	0.24	2.15	1.61
16:00	6.70	0.32	6.65	0.14	2.35	0.93
17:00	6.67	0.17	6.62	0.05	1.13	0.33

Table 5: Output voltage, current and energy reading for day 4

Time (Hrs)	V_T (V)	I_T (A)	V_S (V)	I_S (A)	E_T (WHr)	E_S (WHr)
8:00	6.77	0.26	6.67	0.10	1.76	0.67
9:00	6.69	0.2	6.66	0.17	1.34	1.13
10:00	6.74	0.33	6.72	0.28	2.22	1.88
11:00	6.64	0.1	6.64	0.09	0.66	0.6
12:00	6.66	0.11	6.66	0.11	0.73	0.73
13:00	6.65	0.09	6.63	0.07	0.6	0.46

14:00	6.67	0.15	6.65	0.09	1	0.6
15:00	6.71	0.29	6.68	0.21	1.95	1.4
16:00	6.67	0.15	6.64	0.08	1	0.53
17:00	6.64	0.04	6.63	0.03	0.27	0.2

Table 6: Output voltage, current and energy reading for day 5

Time (Hrs)	V_T (V)	I_T (A)	V_S (V)	I_S (A)	E_T (WHr)	E_S (WHr)
8:00	6.63	0.06	6.63	0.04	0.4	0.27
9:00	6.71	0.22	6.67	0.09	1.48	0.6
10:00	6.69	0.2	6.68	0.16	1.34	1.07
11:00	6.67	0.14	6.66	0.11	0.93	0.73
12:00	6.75	0.35	6.74	0.35	2.36	2.36

The output power of the solar panels was calculated using the formula below.

Power (Watt) = Voltage x Current (1.1)

Therefore, the percentage of accumulated energy of the solar tracker:

$$E_T(\%) = \frac{E_T - E_S}{E_S} \times 100 \quad (1.2)$$

Also, V_T = Output voltage of the tracker based solar panel in Volt.

V_S = Output Voltage of the stationary solar panel in Volt.

I_T = Output current of the tracker based solar panel in Ampere.

I_S = Output current of the stationary solar panel in Ampere.

E_T = Output energy of the tracker based solar panel in WHr.

E_S = Output energy of the stationary solar panel in WHr.

The graph in Figure (2 to 7) shows the trend of output energy of the tracker based (E_T) and stationary (E_S) solar panel recorded between (8:00 to 17:00) GMT in Calabar from (06/10/2020 -10/10/2020). In Figure 2, the maximum and minimum output energy (E_T) of the tracker based solar panel was 2.3WHr and 0.5WHr between (14:00 and 17:00) GMT respectively. While that of the stationary panel, (E_S) was 1.8WHr and 0.3WHr between (14:00 and 17:00) GMT respectively. The trend reveals that there is a clear significant difference between tracker based panel and stationary solar output energy, because the output energy of the tracker based panel is higher than that of the stationary energy. It was observed that when there is a variation in solar radiation or cloud cover, the output parameters (voltages and currents) also varies as shown in Table 2 and Figure 2. This implies that when there is a decrease in relative humidity, the output energy (Watt) of solar panel solar increases due to the increase in solar radiation (Ettah *et al.*, 2012; Anusha *et al.*, 2013).The result also reveals that at 12:00 GMT, the output energy of both solar panels (E_T, E_S) were equal as is expected, since they are appropriately at the same zenith angle (90^0) to the sun rays. At the end of 10 hours analysis for day 1, the tracker based solar panel generated a total power of 11.7WHr, while stationary solar panel produced 9.3WHr respectively.

The graph in Figure 3 reveals that the maximum energy of the tracker based solar panel is 1.3WHr at (8:00 and 9:00) GMT, while the stationary solar panel (E_S) produced a maximum of 1WHr at 12:00 GMT. The minimum output energy of the tracker based panel (E_T) was 0.5W at (16:00, 17:00) GMT, while stationary was 0.3W at 17:00 GMT. It was observed that when the sun intensity increases with change in solar panel angle, the output current I_T of the tracker based solar panel increases more than the stationary output current I_S of the solar panel and vice versa as presented in Table (2 to 6). This is in support of the findings that at maximum solar radiation, when solar panel is orthogonal to the sun angle, the shot circuit current (I_{SC}) increases which leads to increase in output power of the solar panel (Okan *et al.*, 2006; Bhupendra, 2013). Examination of the output energies of E_T and E_S for day 2 reveals that, the tracked based solar panel produced 7.96WHr while the stationary solar panel is 5.6WHr.

The trend in Figure 4 also shows that the maximum and minimum output energy of the tracker based solar panel (E_T) is 3.1WHr at 13:00 GMT and 0.3WHr at 9:00 GMT respectively, while the stationary solar panel produced a maximum and minimum output energy (E_S) of 2.8WHr at 13:00 GMT and 0.3WHr at 17:00 GMT respectively. Further observation from the graph shows that in the hours of (9:00 to 13:00) GMT, there was no significant difference in power output between tracker based (E_T) and the stationary (E_S) solar panels. Between (9:00 to 13:00) GMT, the weather was cloudy which made both solar panels (E_T, E_S) to produce almost the same output parameters (voltage and current). This is explained by the fact that whenever there is cloud cover, there are much water droplets in the atmosphere, which tend to scatter the sun incident rays thereby making both solar panels (E_T, E_S) to generate almost equal voltages and currents (Mekhilef *et al.*, 2012). In this case, both solar panels appear or behave as if there is no difference in angle between them and the sun rays.

However, between 14:00 to 17:00 GMT, there is a clear significant difference between the output energy of the tracker based (E_T) and stationary solar panel (E_S), because a relative increase in sun intensity and orthogonality of the solar panel with respect to the sun rays leads to increase in output power of the solar panel (Sobuj *et al.*, 2012). At the end of 10 hours analysis for day 3, the total output energy of tracker based panel (E_T) is 15.9WHr while that of the stationary solar panel (E_S) produced is 11.1WHr.

Figure 5 shows that the maximum and minimum output energies of the tracker based solar panel (E_T) is 2.2WHr and 0.3WHr and was obtained at 10:00 GMT and 17:00 GMT respectively. The maximum and minimum output energy of the stationary solar panel (E_S) produced are 1.9W and 0.2W at 10:00 GMT and 17:00 GMT, respectively. This trend implies that the tracker based (P_T) solar panel produced higher output power than stationary solar panel over 10 hours period as shown in the graph of Figure 5. Day 4 analysis shows that in 10 hours Comparative test, the tracker based produced energy (E_T) of 11.5WHr, while the stationary solar panel energy (E_S) generated is 8.2WHr.

Figure 6 shows that the maximum and minimum output energy of the tracker based solar panel (E_T) are 2.4WHr at 12:00 GMT and 0.4WHr at 8:00 GMT. The stationary solar panel produced a maximum and minimum output energy of 2.4WHr at 12:00 GMT and 0.3WHr at 8:00 GMT, respectively.

Although day 5 was relatively cloudy, parts of the day experienced drizzles and shiny sunshine. This weather condition tends to either degrade or optimize output power of both panels (E_T, E_S) as shown in Table 6 and Figure 6. This implies that, when light falls on water droplets in the atmosphere, three cases occur; it may be refracted, reflected or diffracted (Mekhilef *et al.*, 2012). So this reduces the amount of solar intensity reaching the solar panel and result in low output power. The experimental results for day 5 show that, the total power of the tracker based solar panel (P_T) is 14.2WHr, while that of the stationary solar panel (P_S) is 10WHr.

Figure (7 to 11) show a multiple bar chart representing tracker based solar panel output energy (E_T) and stationary solar panel output energy (E_S) against time from 8:00 to 17:00 hours. From the chart in Figure 7 to 11, it is observed that the output power of the tracker based solar panel (E_T) from 8:00 to 17:00 hours produced higher power output than the stationary solar panel (E_S) except at 12:00 GMT, where the output power were equal. The probable reason for the equality in the output energy is that both solar panel (E_T, E_T) attained the same angle 90^0 at the same time.

In day 1, the bar chart reveals that the tracker based solar panel produced 25% increase in energy (E_T) over stationary solar panel (E_S), while in day 2, 3, 4 and 5, tracker based solar panel (E_T) produced 43%, 45%, 40%, and 42% increase in output energy over stationary solar panel (E_S).

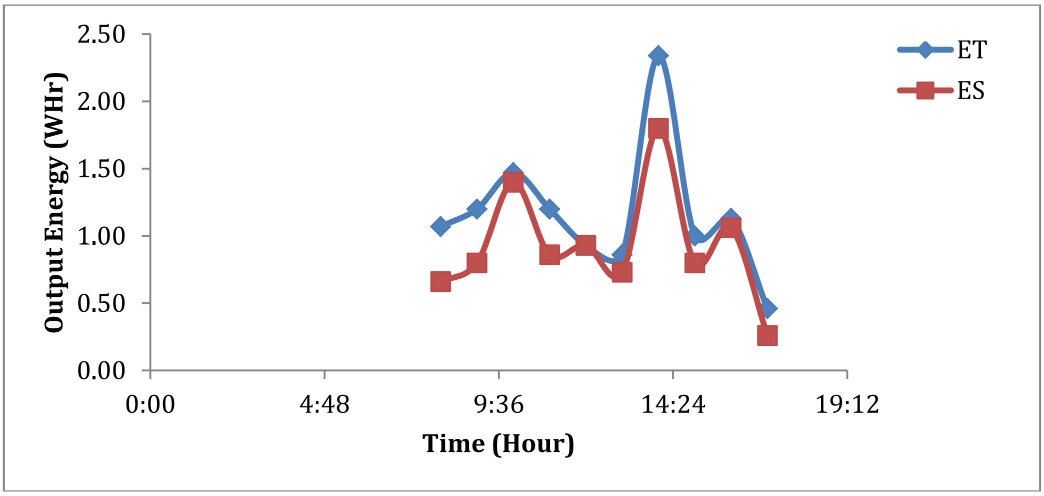

Figure 2: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time for Day 1

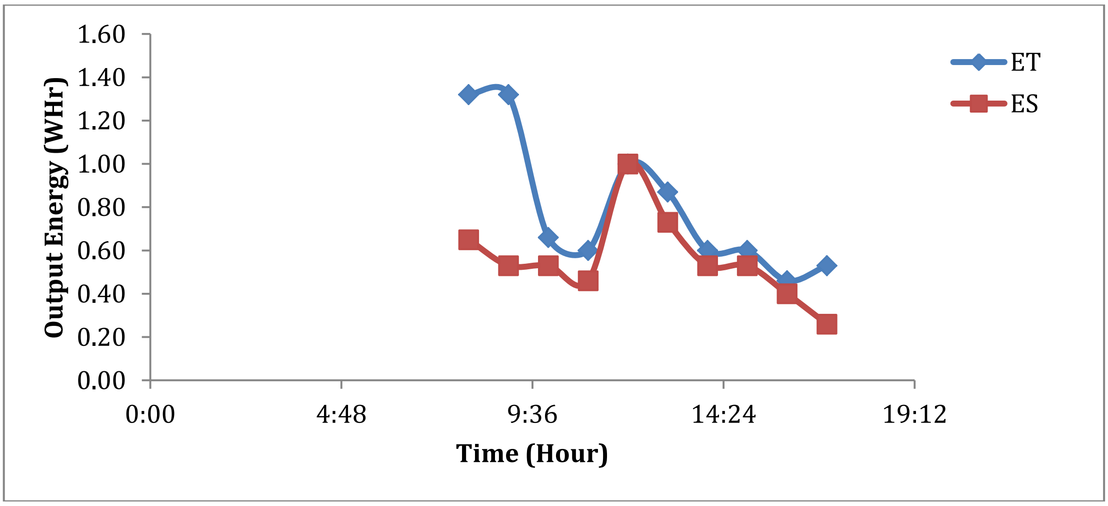

Figure 3: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time for Day 2

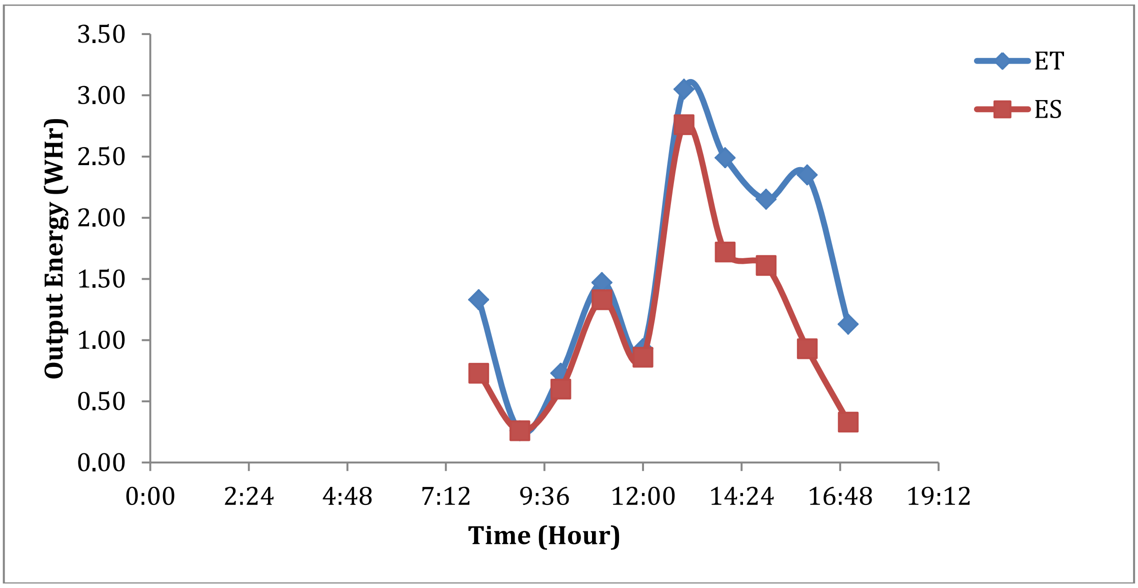

Figure 4: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time for Day 3

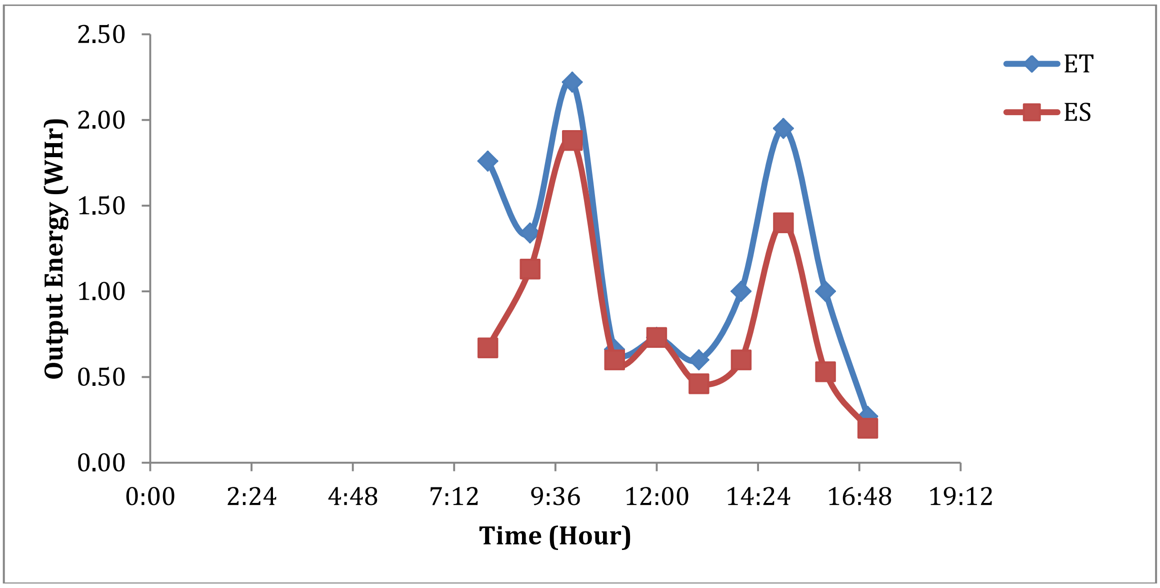

Figure 5: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time for Day 4.

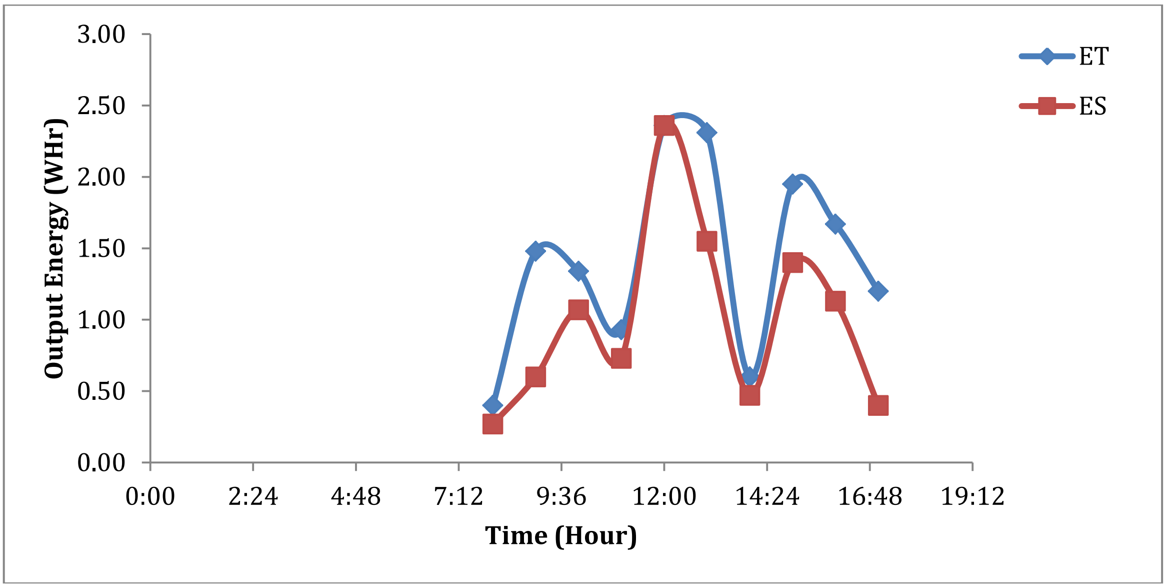

Figure 6: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time for Day 5.

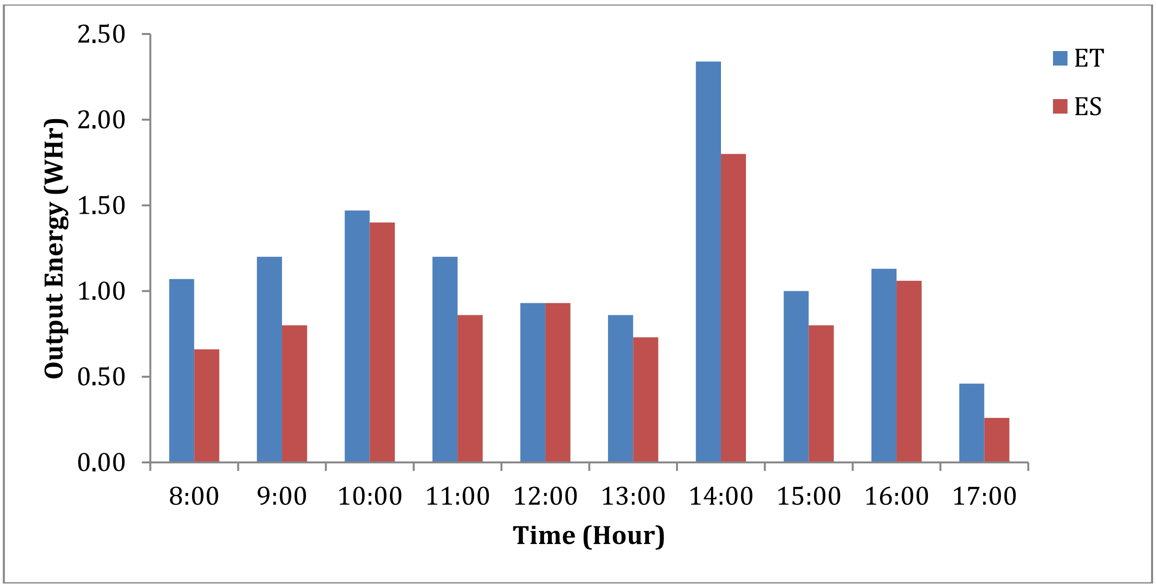

Figure 7: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time for Day 1

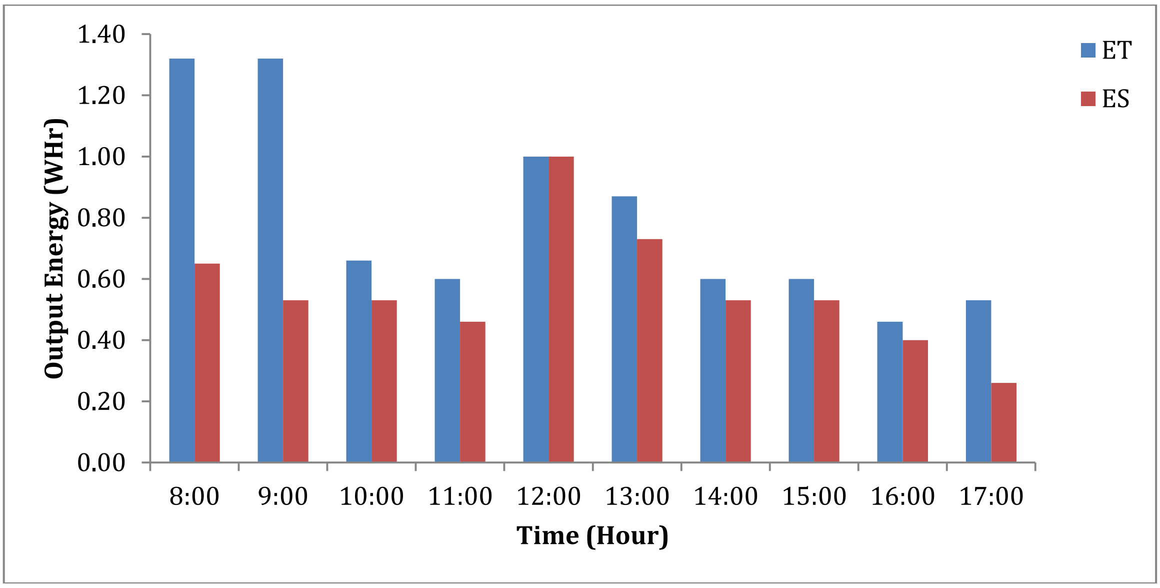

Figure 8: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time for Day 2

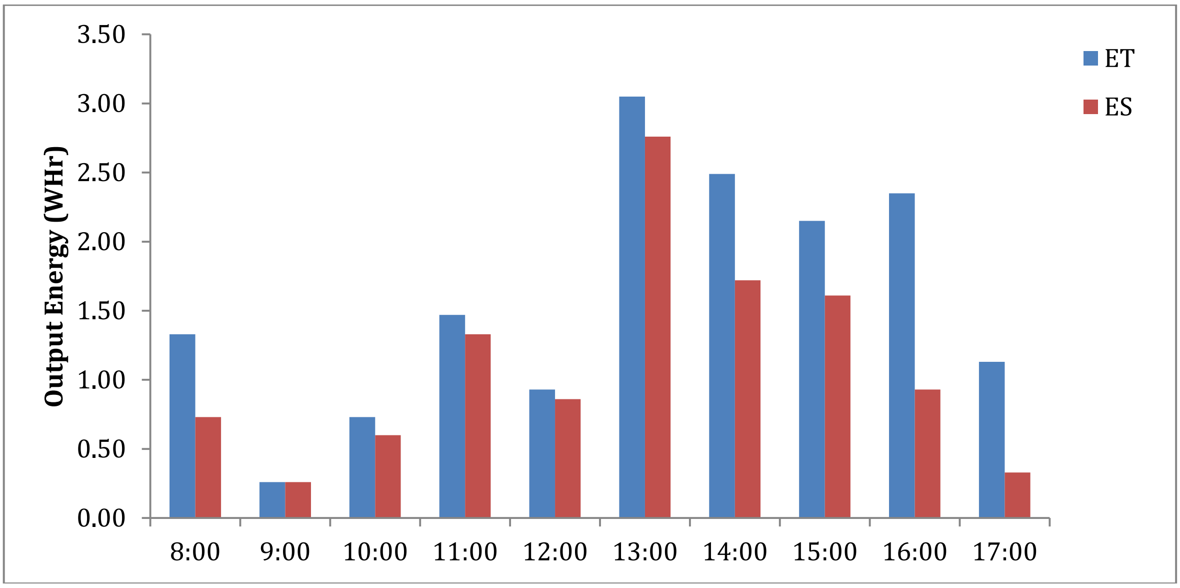

Figure 9: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time for Day 3.

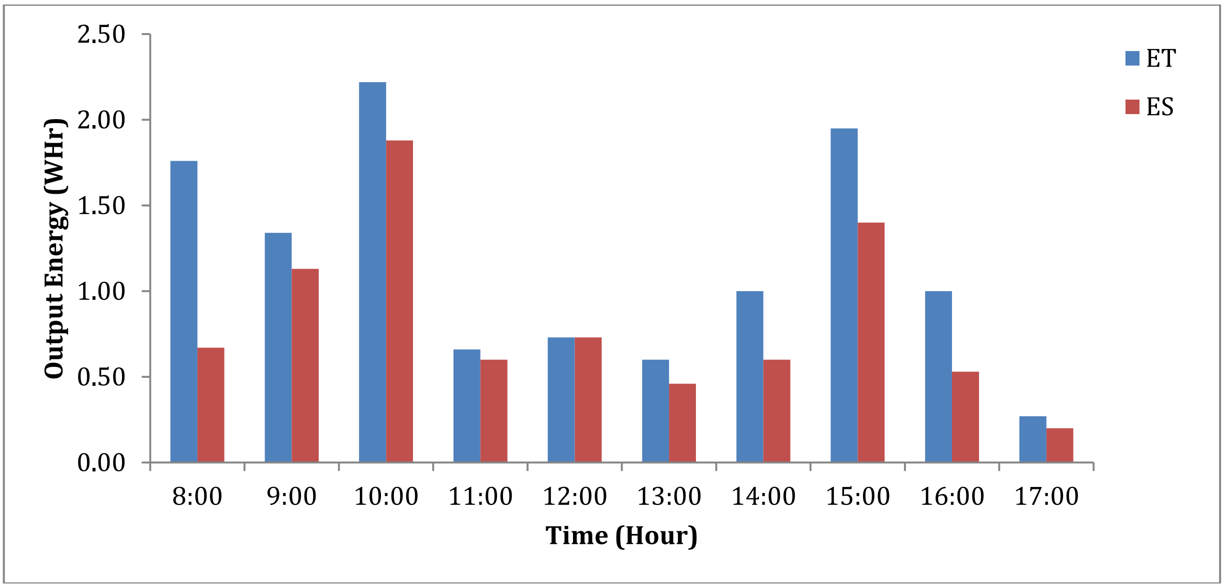

Figure 10: Output Energy of Tracker Based (E_T) and Stationary (E_S) Solar Panel against Time, for Day 4.

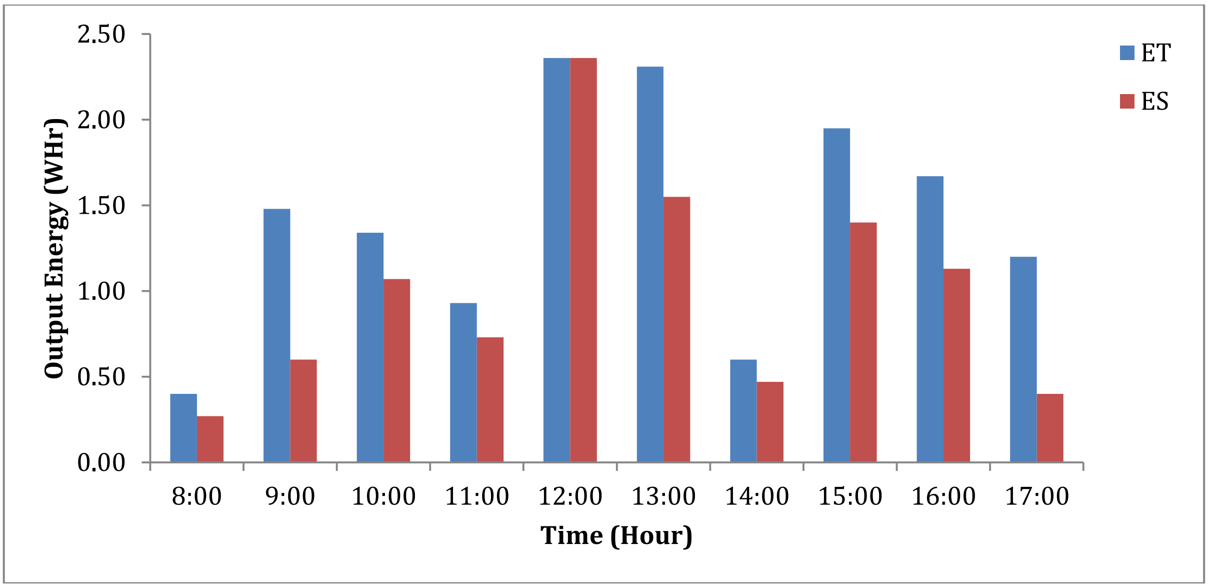

Figure 11: Output Energy of Tracker Based (E_T) and and Stationary (E_S) Solar Panel against Time, for Day 5.

6. CONCLUSIONS

The performance of automated time dependent solar tracker in Calabar has been carried out. The system has been able to track efficiently for ten hours (8:00 to 17:00) GMT and return to its initial position at sun rise. The overall results and comparative analysis shows that there is a strong relationship between solar radiation and solar panel output power as tracker based solar panel yields more than 40% increase over a stationary solar panel. In this wise, if an automated time dependent solar tracker is introduced or installed in Calabar, it can optimize all the solar street lights and other solar powered systems.

6. RECOMMENDATION

Since the system is not ideal, its design and concept should be improved in terms of system compatibility, compactness, efficiency and advance use of dual purpose solar tracking system (i.e thermal/photovoltaic tracker) for solar street lighting systems and solar farms.

REFERENCES

Anusha, K. and Chandra, M. R. S. (2013). Design and development of Real Time Clock Based Efficient Solar Tracking System. *International Journal of Engineering Research and Applications*, 3(1), 1219-1223

Bhupendra, G., Neha S., Brahman S. B. and Pankaj E. J. (2013). Design, Construction and Effectiveness Analysis of Hybrid automatic Solar Tracking System for Amorphous and Crystalline Solar Cells. *American Journal of Engineering Research*, 2, 221-228.

I. CLIFFORD M. J AND EASTWOOD D. (2004). DESIGN OF A NOVEL PASSIVE SOLAR TRACKER. ELSEVIER. 22-28.

Deepthi S., Ponni A., Ranjitha R. and Dhanabal R. (2013).), Comparison of Efficiencies of Single Axis Tracking System and Dual Axis Tracking System with Fixed Mount. *International Journal of Engineering Science and Innovative Technology.* 2(2), 425-430

Demirel, Y. (2012). Energy and energy Types. Green Energy and Technology, Springer-Verlag London Limited. Available at www.springer.com Retrieved: 09/12/2015

Ettah, E. B., Udoimuk, A. B., Obiefuna, J. N. and Opara, E. E. (2012). Effect of Relative Humidity on the efficiency of solar Panels in Calabar, Nigeria. *Universal Journal of Management and Solar Sciences*, 2(3), 8-11

Harriet, K. (2018). Energy from the Sun. The NEED Project. Available at www.NEED.org. Retrieved: 26/01/2021

John, S. (2011). Passive Solar Design. Zonbak Inc. Available at www.zonbak.com Retrieved: 12/08/2015

Mark, R. (2012). Sunflowers Inspire More Efficient Solar Power System. Available at www.phys.org/news/2012-08-sunflowers-efficient-solar-power.html Retrieved: 09/07/2015.

Mehling, H. (2017). What is energy, and why is it conserved. Avalible at https://www.researchgate.net/publication/312071321_What_is_energy_and_why_is_it_conserved_A_review_analysis_and_suggested_explanation_and_definition.

Mekhilef, S., Saidur, R. and Kmalisarvestani, M. (2012). Effect of dust, humidity and air velocity on efficiency of photovoltaic cells. *Science Direct*, 16, 2920-2925.

Narendrasinh J. P., Ankit .N. P. and Vinod S. G. (2015). Passive Solar Tracking System. *International Journal of Emerging Technology and Advanced Engineering*. 5(1) 138-145.

Okan, B., Ahmet, A. and Yusuf, O. (2005). Microcontroller Based Solar-Tracking System and its Implementation. *Journal of engineering Science*, 234-248.

Qi-Xun Zhang, Hai-Ye Yu, Qiu-Yuan Zhang, Zhong-Yuan Zhang, Cheng-Hui Shao and Di Yang (2015). Solar Automatic Tracking System that Generates Power for Lighting Greenhouses. Energies. 8, 7367-7380

Sobuj, K. R., Abu,l B. M., Maruf, A. and Fahad, B. S. (2012). Two Ways of Rotating Freedom Solar Tracker Using ADC of Microcontroller. *Global Journal of Researches in Engineering.* 12, 29-34.