Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 61 (2014) 2435 – 2438

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Techno-economic analysis of solar tracking systems in South Africa

H.J. Vermaak*

Department of Electrical, Electronics and Computer Engineering, Central University of Technology, Free State Bloemfontein, 9300 South Africa

Abstract

This work presents a techno-economic analysis of the solar tracking system in South Africa. For this purpose, the costs as well as amount of energy produced from 4 different solar tracking configurations have been analysed under three different scenarios (1kWp system, 1MWp system, system mounted on 1hectar of land area). The results reveal that for the single as well as for the two axis system, there is an additional gain of energy of about 33% and 37% respectively compared to the static system. However if 1hectar land area is considered and for the same PV panel size, the single as well as for the two axis system can only produce 15.44% and 22.28% of the amount of power generated the static system; this is due to the specific number of modules that can be erected on the given area.
From the experiment results obtained, it can be concluded that tracking systems are not always cost effective compared to the static system. Therefore the use of each tracking system should be carefully analysed to assess if the acquired gain in energy prevails the general disadvantages of the tracking systems.

Peer-review under responsibility of the Organizing Committee of ICAE2014

Keywords: Photovoltaic systems, Tracking systems, Techno-economic analysis, South Africa

1. Introduction

The conversion efficiency of available solar photovoltaic (PV) panels is around 15-19% [1]. A lot of research is currently being conducted in order to increase even a small percentage in energy conversion efficiency. The energy produced form a fixed amount of installed PV generating capacity can be increased using the solar tracking technology [2]. The following are the most common tracking modes [3]:

- Horizontal axis: In this tracking mode, the panels follow the sun in its elevation; only a simple mechanism and construction is required to drive the PV panels.
- Vertical axis: In this tracking mode, the PV system has a fixed angle relative to the ground whilst it rotates around it vertical axis; follow the sun from East to West (azimuth tracker).
- 2-axis: In this tracking mode, the system can follow the sun from East to West as well as its altitude; this makes the sun's direct radiation always impinge in the optimal angle of 90° onto the panel.

* Corresponding author. Tel.: +0027515073090; fax:+0027515073254.
E-mail address: hvermaak@cut.ac.za.

Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.12.018

However the selection of a specific tracking mode depends on factors such as the size of the PV plant, the electricity rate, the land constraints, the location, the climatic conditions, etc [4]. Therefore, the aim of this paper is to conduct a techno-economic analysis of the use of the different above tracking system in South Africa. The costs as well as amount of energy produced from the PV systems equipped with different tracking configuration will be analyzed under three different scenarios (1kWp system, 1MWp system, system mounted on 1hectar of land area) in order to select the best configuration which is technically and economically profitable in Bloemfontein, which is a South African region well endowed in solar resource.

2. Energy production

2.1. Energy produced from a horizontal orientated and a tilted panel

In order to compare the costs of different mounted PV systems, the electricity production of a horizontal orientated PV system should be analyzed first. The solar panel STP086S-12/Bb by Suntech [5], having 15% efficiency have been selected for this study. Fig.1 (a) shows the energy production of a 1 kWp PV system with a horizontal orientation for a one year period which is 1,800 kWh. Fig.1 (b) shows the electricity production of a 1 kWp PV system with a static angle of 29°. The total electricity production in this scenario is 2,030 kWh which is 230 kWh or 12% more than the electricity produced with the horizontal mounted PV panels.

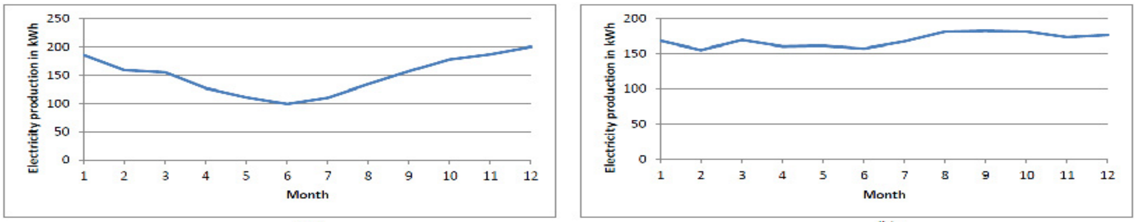

Fig. 1. (a) Energy produced from a tilted panel; (b) Energy produced from a horizontal mounted panel

2.2. Comparison of a static mounted system with different tracking systems

This section analyses how much more electricity tracking systems produce compared to static systems using Bloemfontein weather conditions [6]. The “DEGERenergie” vertical, incline and 2-axis are used in this study; data and prices of these trackers are available from ref. [7]. Fig. 2 (a) shows the energy produced from a 1 kWp using different tracking system over a one year period. The output energy profiles of the different systems have a similar trend with different magnitude all through the year. It can be noticed that the 2-axis tracking system produces more energy over the whole year compared to the single-axis tracking systems. Fig.2 (b) shows the total electricity production of 1 kWp system under different system configuration for a one year period.

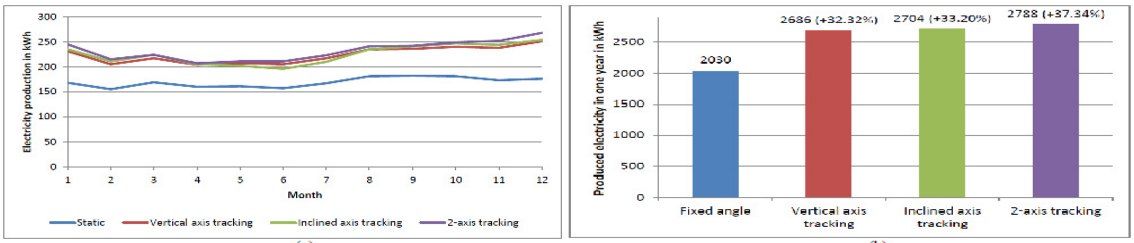

Fig. 2. Yearly energy productions from1 kWp PV with different tracking configurations

3. Economic calculation

Below are the different data and assumptions used in the simulation:

3.1. Small PV system with direct energy usage by the owner

From Fig.3 (a), it can be noticed that the static system has the lowest investment costs and the shortest amortisation time with slightly less than 15 years compared to the other tracking systems. Fig.3 (b) compares the cost of energy produced from the different tracking configurations; the static system has a cost of 0.940 ZAR per kWh which is lower compared to one for the other tracking options.

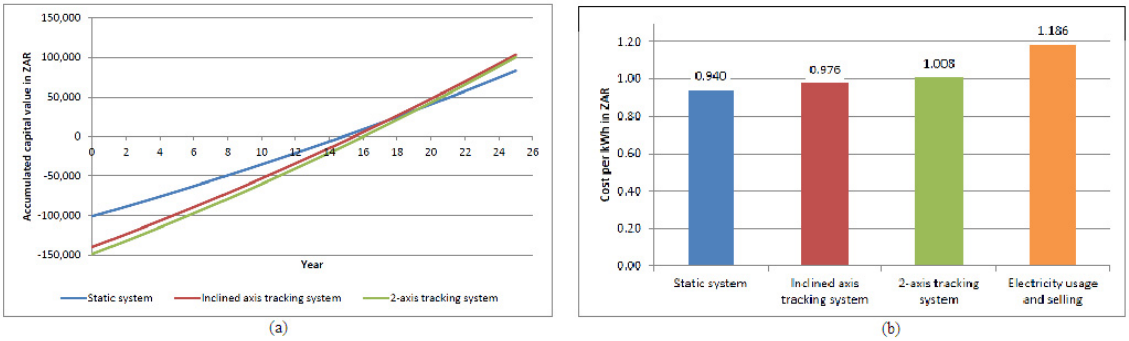

Fig. 3 (a): Amortization time. (b): Cost per kWh from the different systems

3.2. 1 hectare PV power plant

In this section, it is assumed that the PV plants with different tracking systems are built on a 1 ha field. Fig.4 (a) shows that the investment cost of systems with tracker are lower compared to the static system, this is due to the fact that there is lots of space between the trackers and therefore large parts of the area where the tracking systems are built on are empty. The specific costs per kWh are presented in Fig.4 (b). With 0.991 ZAR the static system produces the cheapest energy compared to the other panels equipped with tracking systems.

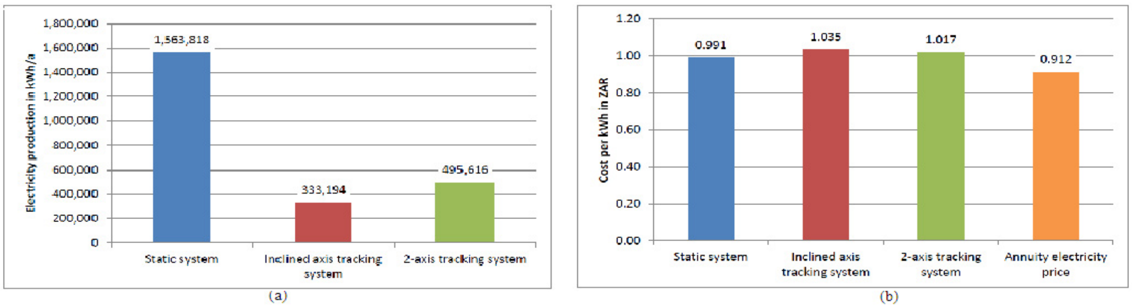

Fig. 4 (a): Investment costs of different systems. (b): Cost per kWh from the different systems

3.3. 1 MW power plant

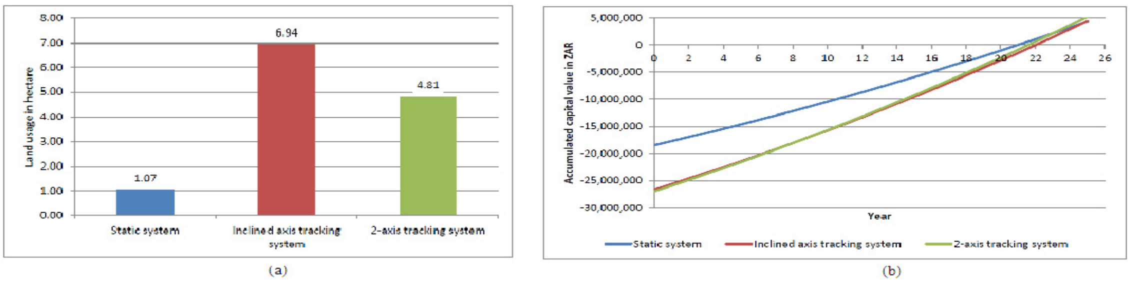

Fig. 5 (a): Land used to build different systems (b): Amortization time.

Fig.5 (a) shows the size of land required by the different tracking system to achieve a maximum output power of 1 MWp. A plant equipped with static PV panels requires an area of 1.07 ha, while the inclined tracking system requires 6.94 (550%) ha and the 2-axis tracking system requires 4.81 ha (almost 350% more). From Fig.5 (b), it can be noticed that the static system has the lowest investment costs and the shortest amortization time of 21 years which is slightly lower compared to the other tracking systems.

4. Conclusion

In this paper, the static PV system is compared with the single as well as to the 2-axis tracking systems for the specific case of Bloemfontein in South Africa. The main results of this study are summarized below:

- For a 1 kWp PV system, the additional energy produced from the single axis tracking systems is about 33% and the one from a 2-axis tracking system is about 37% higher compared to the static system.
- For mall PV system with direct energy usage by the owner, the static system has the lowest cost of energy produced as well as shortest amortization time compared to the PV with tracking systems.
- For PV plant built on 1 hectare land space, the static system has the lowest cost of energy produced.
- If a 1 MW plant is considered, using static system will require less land used compared to tracking systems.

Even if tracking systems can bring additional gain of energy, there are several challenges linked to factors such as land used, resources, electricity rates, etc. Therefore the use of each tracking configuration for a specific application should be carefully analyzed to find out if the acquired surplus of energy prevails on the techno-economical disadvantages of the tracking systems.

References

[1] Singh G.K. "Solar power generation by PV (Photovoltaic) technolohy: A review" Energy, Vol. 53, 2013, 1-13.
[2] Huang B.J., Huang H, Chen G., Hsu P., Li K. "Improving solar PV system efficiency using One-axis 3-positions sun tracking" Energy Procedia, Vol. 33, 2013, 280-287.
[3] Baker L., Neber M., Lee H. "Design of a low-profile two-axis solar tracker" Solar Energy, Vol. 97, 2013, 569-576.
[4] Koussa M., Haddadi M., Saheb D., Malek A., Hadji S. "Sun tracker systems effects on flat plate photovoltaic PV systems performance for different sky states: A case of arid and hot climate" Energy procedia, Vol. 18, 2012, 839-850.
[5] Suntech Power Holdings Co., Ltd. Suntech STP085S-12Bb. Solar power - solar panels and systems for home and business - Energy Matters. Available from: http://www.energymatters.com.au/images/suntech/STP085S-12Bb.pdf [accessed 17.12.2013].
[6] Clean Energy Decision Support Center. RETScreen software. Available from: www.retscreen.net [accessed 17.12.2013].
[7] DEGERenergie solar tracking system "The Specialist for Tracking Systems". Availabble from: http://www.degerenergie.de [accessed 17.12.2013].

Biography

Prof. H.J. Vermaak (PhD) is the HOD of the Electrical, Electronics and Computer Engineering Department at the Central University of Technology, Free State. His research interests are Evolvable Manufacturing and Renewable Energy Technologies.