COMPARISON STUDY BETWEEN THE PERFORMANCE OF TRACKING AND STATIONARY SOLAR PHOTOVOLTAIC SYSTEMS IN MALTA

C. Iskander Yousif
Institute for Energy Technology, University of Malta
Triq il-Port Ruman, Marsaxlokk, ZTN 09, Malta
Phone ++(356) 21650675, Fax ++(356) 21650615, E-mail: charles.yousif@um.edu.mt

ABSTRACT: The paper compares the performance of a 1.8 kWp stationary solar photovoltaic grid-tied system and a 360 Wp single-axis tracking system, for the period January to December 2001. Results show that the tracking system had succeeded in maintaining a relatively stable performance ratio, while the stationary system suffered from lower values, throughout summer. Wind gusts of up to 14 m/s were logged during this period but the tracking system, weighed down by concrete blocks, has remained in position on the roof. The tracking mechanism design proved to be rigid and simple to operate however a higher power-rated double-faced pilot solar photovoltaic module had to be used to drive the tracking motor. Analysis of data was carried out according to the guidelines set by the Joint Research Centre - Ispra Establishment.
Keywords: Tracking – 1: Rooftop – 2: Grid-Connected – 3

1. RELEVANCE OF SOLAR TRACKING FOR MALTA

As time passes by, an increasing number of multi-level buildings are replacing the older traditional two-storey terraced houses, due to space limitations, high land cost and greater demand for smaller dwellings. In turn, less roof area per household would be available for installing solar systems. Moreover, the older buildings that may be adjacent to these high-rise constructions would have less effective sunny areas on their roofs due to shading. In such cases, solar tracking may be attractive since it would maximize on the production of energy from solar radiation in a limited space. An added incentive would be the relatively cheap cost of the tracking system, as in this case, when compared to a stationary system that would need more solar modules to produce an equivalent amount of output power.

Solar tracking operates best under clear sky conditions, and this matches the weather conditions in Malta where rainfall is minimal. During 2001, only 324 mm of rainfall were recorded on site.

Figure 1 shows the frequency distribution of 10-minute global horizontal solar radiation data for the year 2001, excluding night readings. Half of the data points have solar radiation greater than 0.4 kW/m² while 30% is actually above 0.6 kW/m².

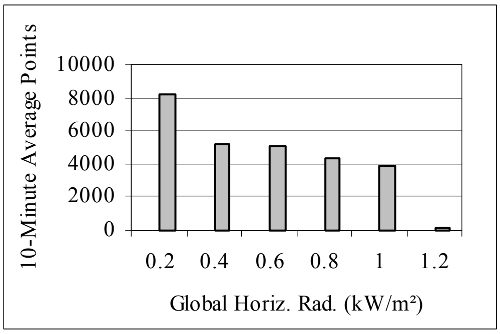

Figure 1: Frequency distribution of 10-minute mean global horizontal solar radiation data for the year 2001, at Marsaxlokk, Malta.

Each bar in Figure 1 represents the number of data points ranging between the following limits: >0-0.2, >0.2-0.4, >0.4-0.6, etc… The data has been gathered using a Kipp and Zonen calibrated CM21 pyranometer at a height of 4 metres above ground level.

2. SYSTEM DESCRIPTION

In order to minimize the differences between the two solar systems, the same types of modules Solarex® MSX60 as well as SMA® inverters were used. The two systems were placed on the same roof close to each other at an angle of 36° to the horizontal.

Figure 2 shows part of the stationary system, which comprises of 30 modules connected together in 5 parallel strings, each comprising of 6 modules in series.

Figure 2: Part of the stationary PV system set up on the roof of the Institute for Energy technology, Marsaxlokk, Malta.

The tracking mechanism consists of a dc motor encapsulated in an aluminum pipe forming part of the structure and being driven by a bi-facial solar photovoltaic module, fixed at an angle of 75° relative to the PV array. In this case, the array was comprised of 6 modules in series and tied on to the aluminium pipe, by means of angle supports, as seen in Figure 3.

When the sun shines on one face of the pilot solar module, a potential difference is created and the motor rotates the tube towards the sun. When the modules face the sun, the bi-facial pilot solar module would be almost perpendicular to the solar beam and the potential difference between the two facades would not be sufficient to further rotate the solar array. As the sun moves in the sky, it will start shining on the other face of the pilot module and as the day goes by, the tracker closely follows the sun along its path. The full span of the tracker is about 120° from East to West [3].

Figure 3: A solar array of 6 modules attached to a tracking mechanism, which is being driven by an inbuilt dc motor operated by a bi-facial solar module.

3. DATA ANALYSIS

Three parameters were used here to compare the performance of the two systems namely, the Performance Ratio (PR), the System Efficiency (η) and the Final Yield (Y_f). The description of these parameters may be found in references [1] or [2].

Between January and April 2001, the tracking mechanism was not operating properly since the original 7 W bi-facial module could not drive the dc motor. This occurred due to the increase of resistance at the brushes as they get slightly humid in winter. It took time to discover the reason and to order a larger 12 W module to drive the system. The solar pyranometer developed a fault in November 2001 and therefore the data could not be utilized for the last two months of the year. Hence, the available data between May and October would be used for the comparison of the two systems.

Figure 4 shows the mean daily global and diffuse solar radiation on the horizontal plane, global radiation on the inclined stationary surface of the solar modules at 36° to the horizontal and facing South and the solar radiation on the plane of the tracking PV array, for the period May to October 2001. All pyranometers were of the same type, namely, calibrated Kipp and Zonen CM21 instruments.

It is clearly shown that the diffuse radiation is always around a mean of less than 2 kWh/m²/day, which implies that cloudiness is not common in Malta.

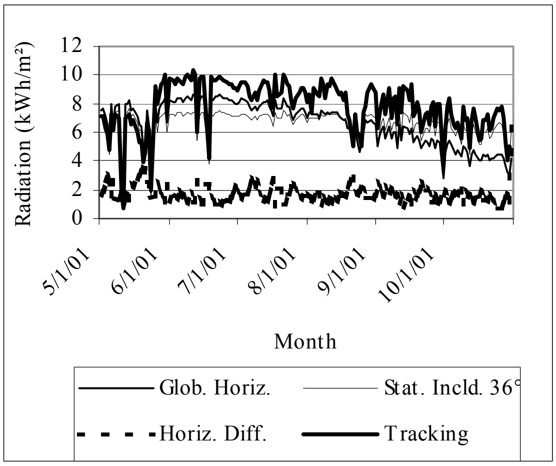

Figure 4: Mean daily solar radiation on different planes for the period May – October 2001.

4. SYSTEM PERFORMANCE

The following results compare the performance characteristics of both systems, however some data was lost for the tracking system between 29 July and 19th August 2001. Hence, results for these two months are restricted to the available dates for both systems, to enable correct comparison between them.

Table 1 shows a summary of the monthly mean values of the solar radiation incident on both surfaces of the modules, the final yields, performance ratios and system efficiency for the months May – October 2001, with the bold rows representing the results of the tracking systems.

Table 1: Monthly performance characteristics for a tracking and stationary PV system. (Bold rows refer to data of the tracking system).

Month 2001	Rad. kWh/m²/day	Y_f kWh/kWp/day	PR	η %
May	**6.38**	**4.37**	**0.69**	**6.9**
	6.17	3.01	0.49	4.9
June	**9.32**	**6.12**	**0.65**	**6.6**
	7.08	2.89	0.41	4.1
July	**8.91**	**5.63**	**0.63**	**6.3**
	7.08	2.63	0.37	3.7
Aug.	**8.16**	**4.62**	**0.64**	**6.4**
	6.75	2.77	0.44	4.0
Sep.	**7.6**	**5.16**	**0.68**	**6.8**
	6.35	3.6	0.57	5.7
Oct.	**6.65**	**4.49**	**0.68**	**6.8**
	5.86	3.23	0.55	5.5

For the year 2001, solar radiation incident on the tracking system reached a maximum mean monthly value of 9.32 kWh/m²/day, compared to 7.08 for the stationary system during June. On the other hand, the final yield and likewise, the performance ratio and efficiency for the tracking system peaked in May, when the ambient temperature was lower than the summer months. From the results, one concludes that temperature still affects the output of the tracking system but not as much as that of the stationary system. In other words, the increased solar radiation intensity on the tracking solar array counterbalanced the negative effect of temperature and yielded a relatively stable performance ratio for this period, as seen in Figure 5. Lost data for end of July and part of August has left a gap in the graph of the tracking system.

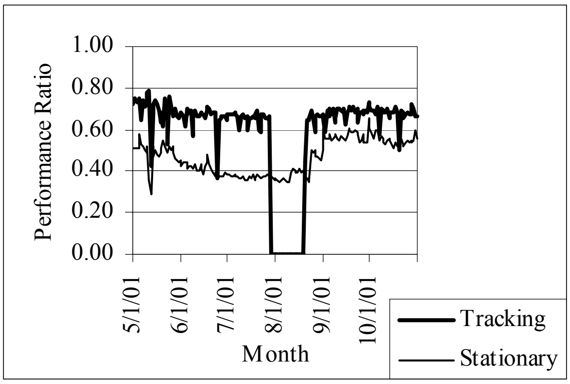

Figure 5: Performance ratio for the tracking and stationary solar PV systems between May and October 2001.

5. BENEFITS AND ECONOMIC ANALYSIS

The overall result for the six-months period considered here concluded that for a 20% increase in incident solar radiation, the tracking system had 67% higher final yield than that of a stationary system and an overall 40% greater performance ratio and efficiency. This implies that in order to produce a certain amount of electric energy, up to 40% less roof area would be needed for a tracking system.

The cost of the tracking system amounted to € 11.5/Wp, while the stationary system price was € 8/Wp. Keeping in mind that the tracking system would have 1.66 times as much final yield as a stationary system, one can easily conclude that for two systems with equal annual energy outputs, the total capital investment would be lower for the tracking system.

Within the confinements of the limited data available to date, it can be concluded that a 1.8 kWp stationary system operating in Malta would be equivalent to a 1.1 kWp tracking system. The capital investment would be lower by 20% for the tracking system, and the system would occupy 35% less roof area. However, more data would be needed to confirm these results.

Another advantage of tracking systems is that since only few solar modules are installed on one tracker, a system of trackers can be easily distributed in the sunny areas on the roof, thus eliminating any possibility of cross-shading one another.

6. SIMULATION PROGRAMME ANALYSIS

A simulation software known as the "PVF Chart" was used to compare the actual solar radiation and final yields of the two systems to that predicted by the software. This would be an indication whether the actual data is within the expected range. Comparison data for the stationary system may be found in reference [2], whereby the 5-year percentage difference between the actual and predicted values of solar radiation and final yield were 0.168% and –15%, respectively.

Table 2 shows the results obtained for the tracking system with the percentage deviation of the data from the predicted values.

Table 2: Comparison of long-term predicted PVF-Chart results and actual data for the year 2001.

	Solar Rad. kWh/m²/day			Final Yield kWh/kWp		
Month	PV F-Chart	Actual	Diff. %	PV F-Chart	Actual	Diff. %
May	8.98	6.38	-29	5.99	4.37	-27
June	9.42	9.32	-1	6.17	6.12	-1
July	9.79	8.91	-9	6.33	5.62	-11
Aug.	9.49	8.15	-14	6.10	4.63	-24
Sep.	7.90	7.60	-3	5.13	5.16	+1
Oct.	6.71	6.64	-1	4.46	4.49	+1

Low values for July and August are attributed to loss of data, while that for May could be due to imperfect tracking of the Sun caused by cloudiness. The PV F-Chart assumes perfect tracking throughout the day. Otherwise the tracker seemed to have performed well within the expected values.

7. PROBLEMS ENCOUNTERED

The solar tracker has not functioned well during the previous year 2000 and early 2001 due to the fact that the bi-facial pilot solar module that drove the tracking d.c. motor could not produce enough power to rotate the tracker. This was due to an increase in the contact resistance between the motor's brushes and the commutator caused by condensed humidity.

According to the manufacturer [4], this problem could be remedied by using a 12 W (V_{oc} = 21 V, I_{sc} = 0.8 A), mono-crystalline bi-facial module instead of the original 7 W module. New trackers are now equipped with copper-graphite brushes instead of carbon brushes to avoid this problem.

8. REFERENCES

[1] *Guidelines for the Assessment of Photovoltaic Plants, Document B,* Issue 2, June 1990, Commission of the European Communities, Joint Research Centre - Ispra Establishment.

[2] Iskander Yousif, C and Scerri, E., A Five-Year Report on a Solar Photovoltaic Grid-Tied System Operating Under a Typical Mediterranean Climate, *Proceedings of the 17th European Photovoltaic Solar Energy Conference and Exhibition, Munich, Germany, 22nd-26th October, 2001,* pp. 720-723.

[3] Website: http://www.traxle.cz

[4] Private communication with the manufacturer by e-mail dated 29th May 2002.