Renewable and Sustainable Energy Reviews 97 (2018) 138–151

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The performance and ranking pattern of PV systems incorporated with solar trackers in the northern hemisphere

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ARTICLE INFO

Keywords:
Solar irradiation
PV system
Solar trackers
Performance ranking
Northern hemisphere

ABSTRACT

Energy produced from a typical PV panel with or without solar tracker is mainly dependent on the available solar irradiance. Interestingly, for some locations on nearly the same latitude in the northern hemisphere, the solar irradiance varies significantly resulting to change in the ranking pattern of solar PV trackers. For this reason, the present study aims to explore the effect of solar irradiation on the technical and economic performance of PV panels incorporated with different solar trackers. Particularly, this paper focuses on locations classified as medium and high latitude countries (20–70°N) in the northern hemisphere. While the considered locations in the northern hemisphere cover the continent of Europe, Africa, Asia, and North America, the studied solar trackers include dual/full/2-axis and single/one-axis (with several tracking orientations namely; East-West, North-South, Inclined East-West, and Vertical–Axis) trackers. The performance metric indicators of the energy gain and levelized cost of electricity (LCOE) are utilized to depict the most preferred solar tracking option for implementation in those regions. Overall, the observed ranking patterns are expected to guide not only solar PV project designers and engineers but also policymakers in the selection and implementation of suitable trackers in the regions.

1. Introduction

The use of solar energy in the generation of electricity is becoming increasingly popular due to global environmental concern associated with the widely utilized non-renewable fossil fuels. Solar renewable technologies have been proven to be technically feasible [1]; however, economic barriers remain the primary impediment to the adoption and widespread deployment of the systems. The capability of solar PV technologies in substituting the fossil fuel utilization is no longer questionable as grid parity is already achieved in some certain countries [2,3]. Available evidence reveal that with the utilization of different solar trackers, the energy gained from PV panels would increase significantly for marginal economic feasibility. In reality, the percentage of energy gain on a PV panel incorporated with solar tracker depends on but not limited to the following; (i) the choice of tracker (single/one or full/dual/2-axis tracker), (ii) the tracking period (summer or winter), (iii) tracking orientations (vertical or horizontal or polar axis), (iv) geographical conditions (latitude of the location) and (v) the required power for tracking. A comprehensive review study of Mousazadeh [4] revealed an energy gain in the range of 10–100% with the use of solar trackers. Several studies have demonstrated the performance of different trackers over certain geographical conditions. Increased energy yield, which ranges from 10% to 45% over fixed panels have been reported by several authors [5–17] with the use of different solar trackers for many locations. Nevertheless, some other authors have commented on the preference of a particular solar tracker over the others by taking into consideration only the technical feasibility [18–28]. Without a detailed economic feasibility assessment, these preferences based on technical performance studies [18–28], which were reported in term of increased energy gain might actually be wrong. Although there is an increasing number of scholarly reports comparing tracking and fixed PV systems from technical performance point of view. There are only a few studies done based on economic feasibility assessment point of view for solar trackers in some parts of the world; including Jordan [29], Italy [30], Iran [31], US [32–34]. Each study had a different conclusion about whether to adopt fixed or tracking system based on the precise conditions of the location. There was no general rule as to which system that should be universally adopted. For this reason, it is important to have papers dedicated to guide global PV solar trackers installation based on both technical and economic performance criteria.

This current study is an extension of the authors previously

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https://doi.org/10.1016/j.rser.2018.08.035
Received 20 April 2018; Received in revised form 27 July 2018; Accepted 23 August 2018

Table 1
Geographical features and solar resources of the study locations.

Country	City	Location		Diffuse to the Global ratio	Beam to the Global ratio	Global Horizontal (kWh m^{-2})
		Latitude (N°)	Longitude (E°)			
Saudi Arabia	Mecca	21.48	39.83	0.32	1.01	2231.6
Vietnam	Hanoi	21.01	105.8	0.64	0.52	1390.6
Egypt	Luxor	25.67	32.70	0.24	1.10	2244.8
China	Hechi	24.70	108.05	0.67	0.45	1107.7
Egypt	Cairo	30.13	31.40	0.35	0.96	1911.9
China	Chongqing	29.51	106.48	0.76	0.34	886.2
Cyprus	Larnaca	34.88	33.63	0.33	1.00	1872.5
USA	Daggett/CA	34.86	− 116.78	0.22	1.30	2137.9
USA	Winnemucca/NV	40.90	− 117.8	0.32	1.19	1719.3
Italy	Rome	41.80	12.23	0.49	0.75	1278.7
USA	Billings/MT	45.80	− 108.53	0.37	1.16	1508.7
Italy	Milan	45.43	9.28	0.55	0.67	1070.6
Germany	Frankfurt	50.05	8.60	0.59	0.69	1035.0
Russia	Chita	52.01	113.33	0.39	1.33	1323.8
Denmark	Copenhagen	55.63	12.67	0.61	0.71	980.3
Canada	Edmonton/AB	53.53	− 114.1	0.43	1.19	1252.8
Sweden	Stockholm	59.65	17.95	0.56	0.84	921.8
USA	Yakutat/AK	59.51	− 139.67	0.64	0.83	853.2
Sweden	Kiruna	67.82	20.33	0.66	0.73	747.8
USA	Bettles/AK	66.91	− 151.51	0.49	1.26	897.0

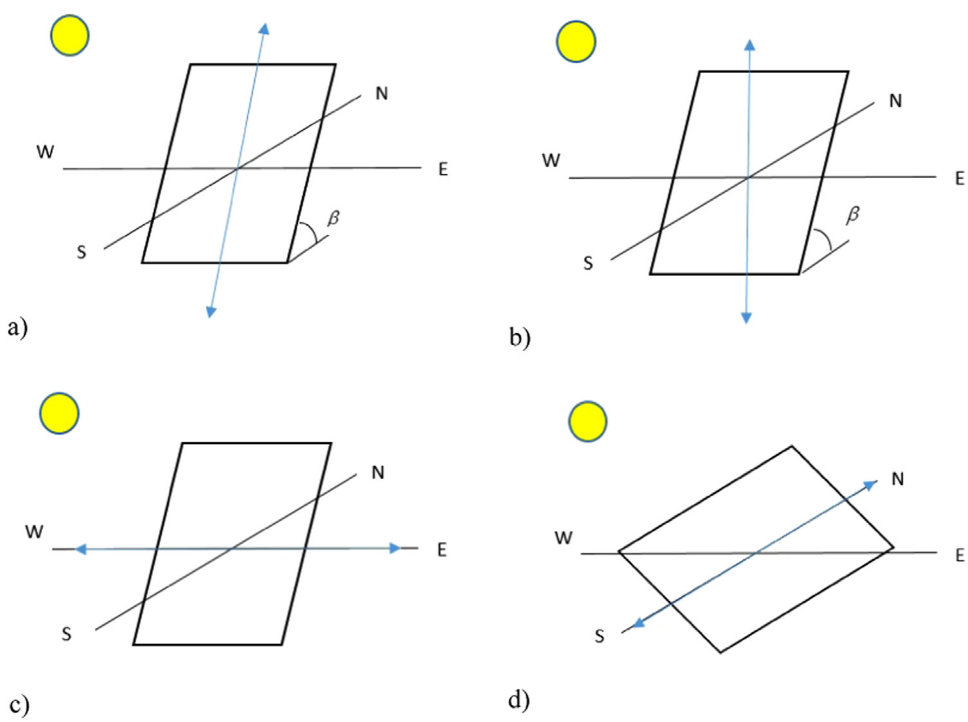

Fig. 1. Implemented one-axis tracking orientations (a) Inclined East-West (IEW), (b) Vertical-axis (V), (c) North-South (NS), (d) East-West (EW) [25].

published paper in [35]. In Bahrami et al. [35], the actual performance of solar PV panels in terms of energy gain and levelized cost of energy (LCOE) were presented and compared. However, the analysis in [35] was dedicated to locations defined as low latitude countries (0–15°N) with limited access to electricity in three continents such as those around the Gulf of Guinea in Africa, the Gulf of Thailand in Asia, and the Caribbean Sea in America. However, for locations in the northern hemisphere on nearly the same latitude, the ratios of diffuse/beam to the global solar irradiation can vary extensively. This variation in the available solar irradiation has a tremendous effect on the ranking of the solar PV panels incorporated with solar trackers. For instance, the ratio of diffuse to the global irradiance of Cairo in Egypt (latitude 30.13°N)