

Use Dual-Axis Tracker to Augmentation Power Production of the Photovoltaic System

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ABSTRACT

This paper proposes an augmentation of power production of a single-phase grid-connected photovoltaic system by a dual-axis tracker by using Solarius PV software to achieve significant energy savings for a building by using sort of renewable energy sources. Therefore, used dual-axis tracker contributed to harvesting the largest amount of incident annual solar radiation that increased the power output with stability by the power supply and harmony between system components. Based on the comparison with a stationary PV system that covered about 69.3% of electricity consumption while PV system tracking could cover 100% of electricity consumed with a surplus energy 9886.55 kWh. Emissions avoided of tracking PV system reaches to (175 016.07 kg CO₂e) for 20 years that proposed as a lifetime of the PV system.

INTRODUCTION

Recently most of the world's electricity is produced through various species of power stations such as nuclear, hydro and thermoelectric, where photovoltaic technology has a significant role in green energy applications, especially with residential, agricultural and industrial applications. On the other hand, it avoided atmospheric emissions due to the adoption of clean energy like PV arrays that has a suitable conversion efficiency to produce power with noticeably lowering the cost of solar arrays [1]. A major issue that facing most of PV systems is reduced energy yield affected by several factors as the amount of solar radiation, partial shading, orientations, tilts type of PV cells and bird droppings. Thus, it is necessary for adopting techniques that could contribute to improving the energy yield of the PV system [2]. However, there is a clear reduction by conversion efficiency of the PV system that could reach 25%, which will greatly affect the power output due to not extracting the total power of the PV panel that leads to lowering the power output of PV system. Thus, adopting tracking for PV panels is one of the solutions that significantly contribute to increasing the efficiency and capacity of PV system generation [3,4]. Lately, many developers have used different types of methods to achieve an effective increase in the efficiency of the system by tracking the maximum power of PV cells with harvest a larger amount of falling radiation that considered an essential element for the work of a PV system. Therefore, use single vertical or dual-axis tracking will contribute to increasing the power output yield that reaches 40%, compared with a static PV system and achieve maximize the power output of the system [5,6], solar-tracking system is one of the proposed solutions used after adding some optimizing for tracker system that works synchronously with sun angle that changes during a day, that would treat the problem of low efficiency for photovoltaic converters [7]. Tracking device works automatically to select the optimal angle of PV panel depending on dedicated sensors that deal with fall of sunlight

intensity where observed that the efficiency of PV panel has a significant increase by the efficiency when using the tracker compared with stationary panel [8], other studies found that adopting the tracking technique of (MPP) with a specific algorithm his work depends on perturbation, observation working on other factors that effects on PV array produce such as variable solar radiation, temperature and low conversion efficiency of PV panel and contribute to maximizing the produced energy of PV system by tracking the peak power of PV panels [9]. Grid-connected photovoltaic (PV) system represents the ideal solution for the consumers who look forward to pollution-free and sustained energy with the ability to store excess energy in batteries to use when the solar energy is intermittent and regular consistency between the grid and the inverter [10].

MATERIALS AND METHODS

Photovoltaic System Configuration

Photovoltaic system installation: The design principle normally used for a photovoltaic system is to maximize the collection of the available annual solar radiation. In most cases, the photovoltaic system must be optimally exposed to sunlight and choosing priority orientation to the south to avoid excess avoiding shading. Therefore, the energy sizing of the PV system was carried out by taking into account not only the financial aspects but the availability of solar energy morphological as well and the environmental factors (shading and albedo). Whatever, effects of shading due to natural elements (trees, buildings), determine the reduction of solar gains, related payback time, the shading coefficient and a function of the site morphology are 1.0 according to the solar energy diagram for Basrah. Following any architectural constraints of the structure upon which the system is installed with different orientations that could adapt as long as they are adequately verified and evaluated. Energy losses due to such phenomena affect the cost of kWh produced and payback time of architectural point of view. In the case of applications on pitched roofs must choose the inclination and orientation into account it is generally advisable to maintain the plane of the modules in parallel or even with the level of the surface itself. Due to not alter the shape of the building and not increase the action of wind forces on the modules with that it is favoured to circulate the air between the rear of the modules and the building surface to limit temperature losses. Modules of PV panels have been installed on a flat roof surface with 117 m for a building with availability of solar energy is verified using the "Meteonorm 7.1" data on the monthly average daily values of solar radiation on a horizontal plane with 20 years as a lifetime of PV system that proposed of Solarius PV software. Basrah location is the place of the building that PV system had installed on it, latitude 30°.5081 N, longitude 47°.7803 E and altitude 4 m., the daily average solar radiation per month on the horizontal plane.

PV module: Sunlight energy is the main element in the working of the PV system after converted into electrical energy by PV cells. The power output of PV panel influenced by several factors such as solar radiation value, temperature and electrical characteristic of PV module as shown in **Table 1**. In both cases tracking and stationary PV system have used monocrystalline si with peak power (260 W), considering the module minimum and maximum operating temperature points, (-4°C) and (75°C) with a high-quality at operation and available with a competitive price. In the first case, the PV array has connected in two strings each string has 20 arrays with (67 m²) total modules area and fixed with tilt angle (26°) and orientation towards the south to achieve required voltage. Distance between modules has arranged automatically depending on (Solarius PV software) with 1 m from the surface edge and there is no shading could effects PV arrays and PV system had worked with average daily solar radiation per month that reaches (1912.46 kWh/m²). Second case adopted dual-axis tracker techniques (horizontal and vertical) axes that work automatically depending on dedicated sensors that deal with a light intensity of the sun to select the optimal angle of PV panels to harvest the largest amount of falling radiation and achieve the maximum power output of PV system during the irradiation hours and contributing to reducing by system loss. The tracking system could achieve a high of solar radiation and according to the metrological data of (Solarius PV software) had been adopted for average daily solar radiation per month reach 2626.81 kWh/m², as shown in **Figure 1** this value of radiation is larger than annual solar radiation of stationary PV system. Annual load consumption for 4 people is unstable as shown in **Figure 2** due to variations loads of energy consumed for the house throughout the year and according to the data recorded the annual electricity consumption for the building reaches to (17895.88 kWh). May to September is the most energy-consuming month because rising temperatures and increasing refrigeration devices consumption while January and December somewhat less energy consumption compared with the summer season.

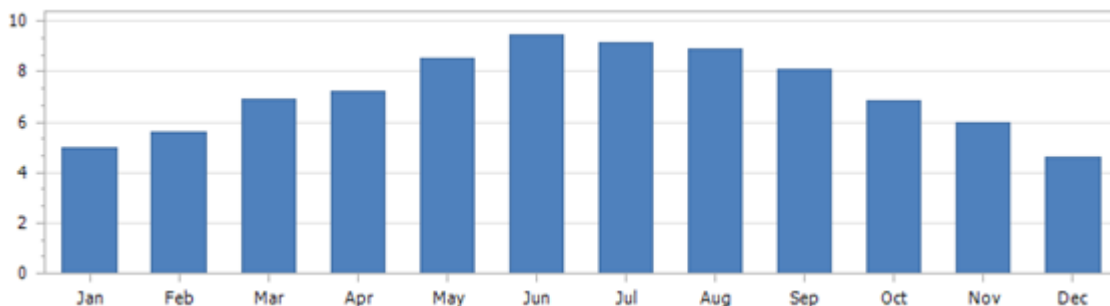


Figure 1. Average daily solar irradiation per month (kWh/m²).

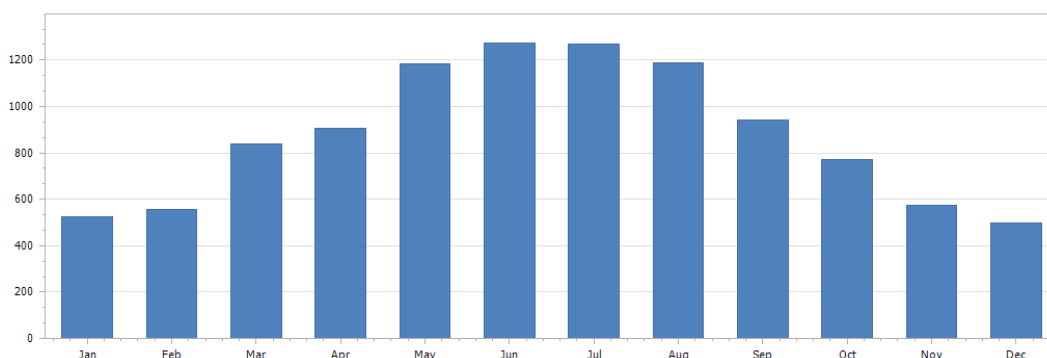


Figure 2. Average monthly electric consumption (kWh).

Table 1. Electrical characteristics of PV modules in STC.

VMMP max	VMPP min	No. of cells	Vmax	Isc	Voc	Conversion Efficiency
850 V	250 V	60	1000 V	8.89 A	38 V	16.01%

PV inverter: Inverter is one of the important components of PV system response to the converts current from DC to AC. Both cases tracking and stationary PV system have used one inverter type single-phase model (AEV-50-48) with nominal power reaches to (10000 W) his weight (29 kg). PV arrays have divided for two strings per module each string has 20 PV panels to avoid damaging that could happen for inverter due to overvoltage at the lowest temperature. Electrical output parameters for each string as shown in **Table 2**. A typical sizing factor is between 70% and 120% The inverter sizing factor is the percentage ratio between the nominal power of the inverter and the power of the photovoltaic generator connected to it in the case of MPPT sub-systems, sizing is verified for the MPPT sub-system as a whole. When the inverter selected for the system is higher size, the capital cost of PV system will increase at the same time the produced energy of PV system increase as well. The grid-tied inverter has worked with proportionate efficiency with average daily solar radiation per month reach from 1912.46 to 2626.81 kWh/m², with ability to control on the power output of PV system to meet load consumption by the house when the grid is an interactive system of PV array or battery whether single or three-phases. However, PV inverter has selected to suit the voltage changed of PV array due to variance on radiation and temperature that causing the low output voltage of PV system.

Table 2. Inverter technical specifications.

Nominal Voltage	Phase Type	Max. Efficiency	V max (V)	I max (A)	VMpp max	VMpp min
230 V	Single Phase	91%	900	20	850 V	250 V

Energy storage: Conservation and rationalization of energy are important in the continuity of energy sustainability to meet the shortage of energy consumed for different applications. Providing a storage system capable of storing excess energy is inevitable due to the varying intensity of solar radiation during the day. The storage system should be able to store excess energy for use in inactive hours or low solar radiation and cloudy days. External accumulation system allows the storage of excess energy from the PV production system or generator, to be reused when the generator isn't

producing enough energy. in both cases of PV system (dual-axis tracker and stationary), 20 batteries have used for two string. Batteries that used model (MFV 350-Moura) which has a nominal capacity (425 Ah). State of Charge (SOC) and Depth of Discharge (DOD) has taken into consideration to determine an appropriate operating ratio for regulation to make the battery charged or discharged according to the desired current According to (Solarius PV software) accumulation system of Bidirectional production on AC end have selected to external energy accumulation system. Thus, the external accumulation system allows the storage of excess energy from the PV production system or generator, to be reused when the generator isn't producing enough energy.

RESULT AND DISCUSSION

In both cases, tracking and stationary PV system has connected to the main grid with a "Single-phase in low voltage" and worked under the same conditions where produced energy depends in both cases on:

- Installation that PV system Installation and effect of (latitude, longitude, incident solar radiation, and temperature)
- Exposure of PV modules such as (tilt) angle and (azimuth) angle
- Characteristics of PV modules like power rating, temperature coefficient, decoupling losses or mismatch

In both cases 20 batteries with rated capacity 425 Ah, connected for two strings that regularly charged of PV arrays to meet the shortage of electricity through stored energy when the power is outages for certain periods of the day. Both strings of the PV system had connected with one inverter type single-phase that has nominal power 10,000 W, to converts DC to AC.

First case: According to PV system proposed there is suitable stability of energy produced, where the annual energy production of PV system 15176.54 kWh (equal to 1459.28 kWh/kW), resulting from 40 modules for two strings and **Figure 3** below shows the monthly energy values produced by the PV system. stationary PV system could cover about 84.8% of building electricity consumption and 15.4 covered of the main grid and that considered as a useful indicator to fuel saved when dependence on conventional energy generation. However, variation by the amount of energy produced throughout the year is clear, where January and February there is lowering by energy production due to the fluctuation of solar radiation and frequent clouds. While June, July, and August there is increased by energy-producing due to abundant solar radiation and sun hours. Besides, adopting the photovoltaic system allows a reduction of polluting substances into the atmosphere and avoided emissions that contribute to increasing the greenhouse gases as in **Table 3** shows the percentage of avoiding atmospheric emissions.

Table 3. Avoiding the greenhouse effect by stationary PV system.

Avoided atmospheric emission	CO ₂	CH ₄	N ₂ O	Total GHG
Specific atmospherical emissions (kgCO ₂ e/kWh)	0.46254	0.00044	0.00236	0.46534
Emissions avoided in one year (kg CO ₂ e)	7019.76	6.68	35.82	7062.25
Emissions avoided in 20 years (kg CO ₂ e)	129015.46	122.73	658.27	129796.46

Second case: used dual-axis tracker has contributed to increasing power output produced through the sensors that used to track the radiation and harvest the largest value of solar radiation that reaches to 2626.81 kW/m² increase by radiation about 37.3% compared with a stationary PV system that contributed significantly to increase the power output produced. Annual energy production that achieved by use dual-axis tracker is 20 406.94 kWh (equal to 1 962.21 kWh/kW), resulting from 40 modules which divided for two string with an increase by output power production reach to 34.4% compared with fixed PV system as shown in the **Figure 4**. PV system with dual-axis tracking could cover the electricity loads consumed of the house with 100%, and achieving a surplus by power output up to 2511.06 kWh that could sell for the main grid. Moreover, maximum power produce was in July and February is less due to increased and reduced irradiation hours throughout the year (**Figure 4**). PV system with dual-axis tracking contributes to a significant reduction of polluting substances that produced conventional stations in **Table 4** a significant difference in the percentages of pollution values that have been reduced compared to the stationary PV system. Dual-axis tracking contributes to increasing avoiding atmospheric emissions by 34.8% comparing with stationary PV system for 20 years.

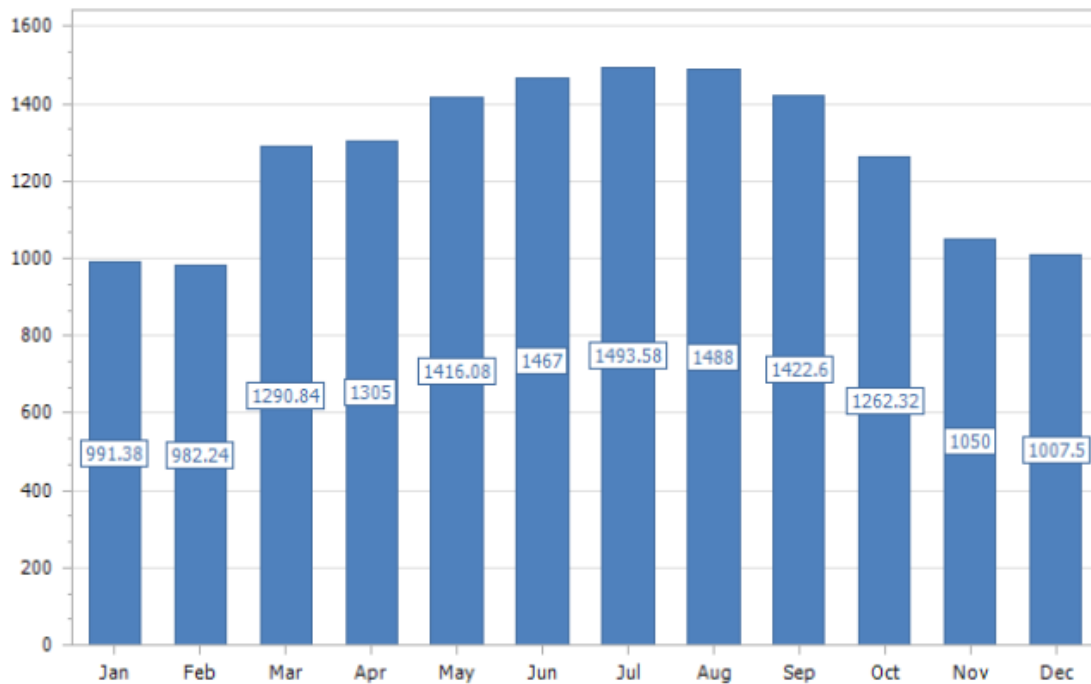


Figure 3. Monthly energy produced by system kWh (first case).

Table 4. Avoiding the greenhouse effect by tracking PV system.

Avoided atmospheric emission	CO ₂	CH ₄	N ₂ O	Total GHG
Specific atmospherical emissions (kg CO ₂ e/kWh)	0.46254	0.00044	0.00236	0.46534
Emissions avoided in one year (kg CO ₂ e)	9439.03	8.98	84.16	9496.17
Emissions avoided in 20 years (kg CO ₂ e)	173962.08	165.49	887.60	175016.07

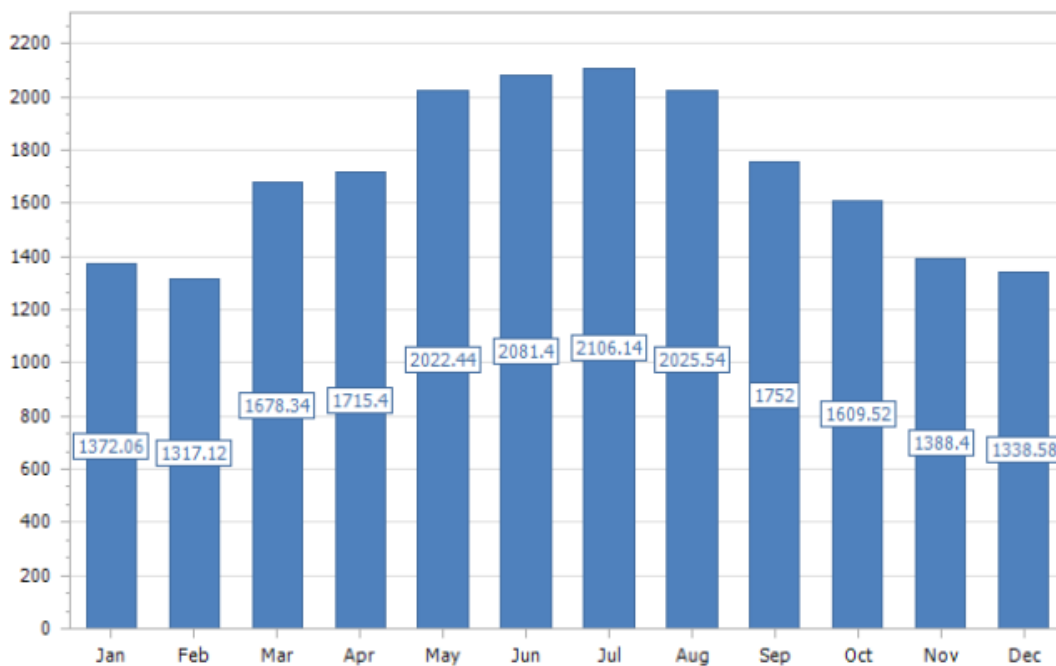


Figure 4. Monthly energy produced by the system.

CONCLUSION

Dual-axis tracking PV system has adopted to provide stable energy to covering for building electrical consumption with a lifetime which is set of the tracking PV system is 20 years. However, a comparison had conducted between stationary and tracking PV system to find out the power production for both cases, where tracking PV system could harvest 2626.81 kW/m² with an increase by radiation about 37.3% compared with a stationary PV system due to use tracking technologies that work automatically depending on dedicated sensors that deal with an intensity of radiation. Power production of a tracking PV system is variable during the year, where July has the biggest producer of power due to an abundance of solar radiation while February is less due to reduced irradiation hours. Annual power production that achieved of the tracking PV system by using a dual-axis tracker is 20 406.94 kWh, that could cover 100% of electricity consumption with 2511.06 kWh surplus, while stationary PV system covered 84.8% of electricity consumption with annual power production of PV system reaches 15 176.54 kWh. Thus, a tracking PV system with a dual-axis tracker could achieve stability by energy provide with an increase of energy production reach to 34.4% compared stationary PV system. Using a tracking PV system is a very useful indicator to measure the amount of fuel saved when using a renewable energy source. On another hand, using dual-axis tracking could avoid atmospheric emissions (Greenhouse gases) reaches 175 016.07 (kg CO₂e) of emissions in 20 years which represents the lifetime of PV system.

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