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Comparison of Performance of Tracked and Fixed Photovoltaic Modules

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Abstract

The main objective of this study work was to compare between tracked and fixed photovoltaic modules. In terms of power output and to investigate the efficiency of tracking. A pyronometer was placed on the tracker to compare the beam radiations readings with the maximum theoretical beam radiation at the location. A 50W photovoltaic module was attached onto both tracked and fixed system. The inclination of the modules was 15.5^0 to facing the south. The tests were conducted at the premises of National Energy Research Center .the tracked modules followed the sun from 9.00am to 5.00pm. The results showed that the average of tracking efficiency was 92% compared with theoretical calculated radiation. The photovoltaic module comparison test showed that the tracker is the most effective in the morning hours from 9.00 to 12.00 hours and in the afternoon from 15.00 to 17.00 hours because the tracker makes solar radiation perpendicular to solar cell.

1- Introduction

The increasing demand for energy, the continuous reduction in existing sources of fossil fuels and the growing concern regarding environment pollution, have pushed mankind to explore new technologies for the production of electrical energy using clean, renewable sources, such as solar energy, wind energy, etc Among the non-conventional, renewable energy sources, solar energy affords great potential for conversion into electric power, able to ensure an important part of the electrical energy needs of the planet.[1]

The conversion of solar light into electrical energy represents one of the most promising and challenging energetic technologies, in continuous development, being clean, silent and reliable, with very low maintenance costs and minimal ecological impact. Solar energy is free, practically inexhaustible, and involves no polluting residues or greenhouse gases emissions.[1]

The conversion principle of solar light into electricity, called Photo-Voltaic or PV conversion, is not very new, but the efficiency improvement of the PV conversion equipment is still one of top priorities for many academic and/or industrial research groups all over the world. Among the proposed solutions for improving the efficiency of PV conversion, we can mention solar tracking, the optimization of solar cell configuration and geometry, new materials and technologies, etc. The global market for PV conversion equipment has shown an exponential increase over the last years, showing a good tendency for the years to come.[2]

Physically, a PV panel consists of a flat surface on which numerous p-n junctions are placed, connected together through electrically conducting strips. The PV panel ensures the conversion of light radiation into electricity and it is characterized by a strong dependence of the output power on the incident light radiation.

As technology has evolved, the conversion efficiency of the PV panels has increased steadily, but still it does not exceed 13% for the common ones. The PV panels exhibits a strongly non-linear I-V (current - voltage) characteristic and a power output that is also non-linearly dependent on the surface insulation. [2]

In the case of solar light conversion into electricity, due to the continuous change in the relative positions of the sun and the earth, the incident radiation on a fixed PV panel is continuously changing, reaching a maximum point when the direction of solar radiation is perpendicular to the panel surface. In this context, for maximal energy efficiency of a PV panel, it is necessary to have it equipped with a solar tracking system.

A solar tracker is a device that orients various payloads toward the sun, that is solar trackers follow the sun’s beam radiation. [3]

Sunlight has two components, the "direct beam" that carries about 90% of the solar energy, and the "diffuse sunlight" that carries the remainder - the diffuse portion is the blue sky on a clear day and increases as a proportion on cloudy days. As the majority of the energy is in the direct beam, maximizing collection requires the sun to be visible to the panels as long as possible. [3]

Perfect tracking is when the beam radiation is continuously perpendicular to the tracking surface i.e. the cosine of the incident beam radiation is equal to 1. The better the solar tracker the smaller the beam radiation angle is to the tracking surface.

2-Photovoltaic and Photovoltaic Cells:

When sunlight strikes a PV cell, the photons of the absorbed sunlight dislodge the electrons from the atoms of the cell. The free electrons then move through the cell, creating and filling in holes in the cell. It is this movement of electrons and holes that generates electricity. The physical process in which a PV cell converts sunlight into electricity is known as the photovoltaic effect.[1]

One single PV cell produces up to 2 watts of power, too small even for powering pocket calculators or wristwatches. To increase power output, many PV cells are connected together to form modules, which are further assembled into larger units called arrays. This modular nature of

PV enables designers to build PV systems with various power output for different types of applications.[1]

A complete PV system consists not only of PV modules, but also the "balance of system" or BOS - - the support structures, wiring, storage, conversion devices, etc. i.e. everything else in a PV system except the PV modules. Two major types of PV systems are available in the marketplace today: flat plate and concentrators.[1]

As the most prevalent type of PV systems, flat plate systems build the PV modules on a rigid and flat surface to capture sunlight. Concentrator systems use lenses to concentrate sunlight on the PV cells and increase the cell power output. Comparing the two systems, flat plate systems are typically less complicated but employ a larger number of cells while the concentrator systems use smaller areas of cells but require more sophisticated and expensive tracking systems. Unable to focus diffuse sunlight, concentrator systems do not work under cloudy conditions. [1]

3 Solar Tracker Types:

3.1 Single axis tracker:

Single axis tracking system is a method where the solar panel tracks the sun from east to west using a single pivot point to rotate. Under this system there are three types: Horizontal single axis tracking system, Vertical single axis tracking system and Tilted single axis tracking system. In the Horizontal system the axis of rotation is horizontal with respect to the ground, and the face of the module is oriented parallel to the axis of rotation. In the Vertical system the axis of rotation is vertical with respect to the ground and the face of the module is oriented at an angle with respect to the axis of rotation. In the Tilted tracking system the axes of rotation is between horizontal and vertical axes and this also has the face of the module oriented parallel to the axis of rotation, similar to the Horizontal tracking system. The single axis tracking system consists of two LDR's placed on either side of the panel. Depending on the intensity of the sun rays one of the two LDR's will be shadowed and the other will be illuminated.[4]

The LDR with the maximum intensity of the sun's radiation sends stronger signal to the controller which in turn sends signal to the motor to rotate the panel in the direction in which the sun's intensity is maximum.

3.2 Dual axis solar tracking system:

Dual axis tracking system uses the solar panel to track the sun from east to west and north to south using two pivot points to rotate. The dual axis tracking system uses four LDR's, two motors and a controller. The four

LDR's are placed at four different directions. One set of sensors and one motor is used to tilt the tracker in sun's east - west direction and the other set of sensors and the other motor which is fixed at the bottom of the tracker is used to tilt the tracker in the sun's north-south direction. The controller detects the signal from the LDR's and commands the motor to rotate the panel in respective direction.[4]

4. Experimental Set-up

4.1 Introduction:

Everything in nature emits electromagnetic energy, and solar radiation is energy emitted by the sun .The energy of extraterrestrial solar radiation is distributed over a wide continuous spectrum ranging from ultraviolet to infrared rays. In this spectrum, solar radiation in short wavelengths (0.29 to 3.0 m) accounts for about 97 percent of the total energy.

Solar radiation is partly absorbed, scattered and reflected by molecules, aerosols, water vapor and clouds as it passes through the atmosphere. The direct solar beam arriving directly at the earth's surface is called direct solar radiation. The total amount of solar radiation falling on a horizontal surface (i.e. the direct solar beam plus diffuse solar radiation on a horizontal surface) is referred as global solar radiation. Direct solar radiation is observed from sunrise to sunset, while global solar radiation is observed in the twilight before sunrise and after sunset, despite its diminished intensity at these times.[9]

4.2 Instruments Used:

Multi-meter:

It is the instrument used to measure the short circuit current and the open circuit voltage of the photovoltaic modules. To better understand digital multimeters, it's helpful to become clear on the basics of electricity. Electricity passing through a conductor is similar to water flowing through a pipe. Every pipe has force that creates a certain pressure, causing water to flow. In the case of electricity, that force might be a generator, battery, solar panel or some other power supply. The pressure created by that power supply is called voltage. [10]

Model (NB9205L)

Battery R03 Um 4.5V,AAA size

The rang : volt Dc 200 mV – 200V Dc

Current Dc 200mA – 10A

Shown in Figure (4.1)

Figure 4.1 Multi-meter

Pyranometers:

A pyranometer is used to measure global solar radiation falling on a horizontal surface. Its sensor has a horizontal radiation-sensing surface that absorbs solar radiation energy from the whole sky (i.e. a solid angle of 2π sr) and transforms this energy into heat. Global solar radiation can be ascertained by measuring this heat energy. Most pyranometers in general use are now the thermopile type .Factor of measurement 96.7mV@1000W/m^2.Shown in Figure (4.3)

Figure (4.2) Pyronometer

Photovoltaic module:

The photovoltaic module 50W poly Crestline produces the electricity from the solar radiation, shown in Figure (4.3).

Figure (4.3) photovoltaic module

Solar tracker:

This type of tracker is a tilted single axis tracker the tilt angle (facing south) is equal to the latitude of the installation. Work by Freon gas to rotate solar cell from east to west is shown in Figure the canisters interconnected with a copper tube. The gas will be driven to one side or the other (by solar heat creating gas pressure) to cause the tracker to move in response to an imbalance. This is a non-precision orientation collector but works fine for common photovoltaic panel types. These will have viscous dampers to prevent excessive motion in response to wind gusts. The shadow plates/reflectors are used to reflect early morning sunlight to the panel and tilt it toward the sun. components of tracker are: frame which Rectangular tubes are used in the frame panel and welded in rectangular shape design to fit the standard solar photo voltage , the gimbal shocks which obtain the track to move at its axis also keep the track at right latitude angle, The pole is a selected pipe to with stand the weight of the track with solar photo voltage and the load of the wind, The pole is a selected pipe to with stand the weight of the track with solar photo voltage and the load of the wind, Two gas tubes is selected in suitable length to the frame and fitted on both frame side to obtain and capture the solar radiation heat ,shading plate. Shown in Figure (4.4).

Figure (4-4) solar tracker

4.3Units of Solar Radiation:

The solar irradiance is expressed in watts per square meter (W/m2) and the total amount in joules per square meter (J/m^2). Conversion between the currently used unit (SI) and the former unit (calories) can be performed using the following formulae:

Solar irradiance: 1 kW/m2 = 1.433 $cal/cm^2/min$

Total amount of solar radiation: 1 MJ/m^2 = 23.89 cal/cm^2 [11]

The experimental was conducted in the energy research institute in Soba region, Khartoum. The Experiments consisted of two parts:

i) Tracking efficiency; by comparing the actual hourly beam radiation to the maximum hourly beam radiation the tracker could attain if tracking is without error.

ii) The percentage increase in a 50Wp photovoltaic module output attached to the tracker to an identical module fixed at a 15.5o inclination facing south.

4.4 Tracking Efficiency Test:

A pyronometer was attached on to the tracker; a second pyronometer was placed nearby in a horizontal position. Hourly readings were taken from both pyronometer forms 9:00 hours to 17:00 local standard time. The readings were the global radiation and diffuse radiation. To acquire the beam radiation, the diffuse radiation was measured by shading the glass globe of the pyronometer this would prevent the beam radiation reaching the instrument sensor; the diffuse radiation was subtracted from the global radiation.

Calculations were done on the horizontal pyronometer readings to obtain the maximum hourly beam radiation the tracker could attain if tracking is without error. The results were then compared with the actual readings of the pyronometer on the tracker.

4.5 Photovoltaic Comparison Test:

A 50 W photovoltaic module was attached to the tracker an identical module was placed nearby with an inclination of 15.5o facing south. The fixed modules had a short circuit current of 3.3 A, an open circuit voltage of 21.1 V and a Fill Factor (FF) of 0.67 the tracking module had a short circuit current of 3.5 A, an open circuit voltage of 21.4 V and a Fill Factor (FF) of 0.67

Both modules were tested under a light intensity of 1000 W/m2 and environment temperature of 25^0 in the photovoltaic encapsulation plant, both have an output power of 50.13Wp

The readings taken from the modules were hourly readings of short circuit current and open circuit voltage with their corresponding global radiation. The results were multiplied by the fill factor to obtain the power output. The output power results of the tracking module were compared with the fixed and the percentage increase recorded.

5.Results and Analysis

5.1ResultsTracking Efficiency:

The results of the tracking efficiency are presented graphically in Figures (5.1) to (5.4) below

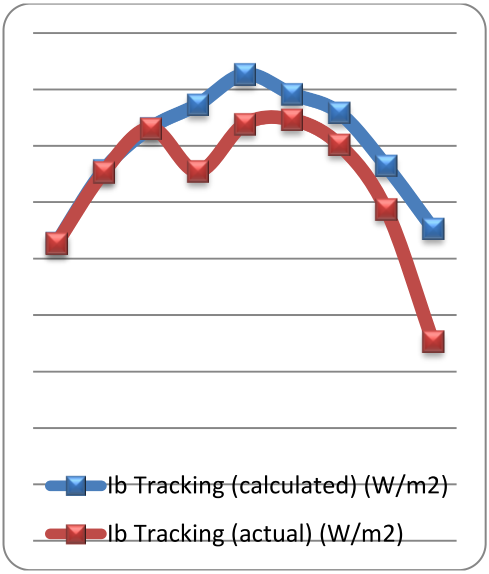

Figure (5.1) solar beam radiation vs time of day 5_th September 2013

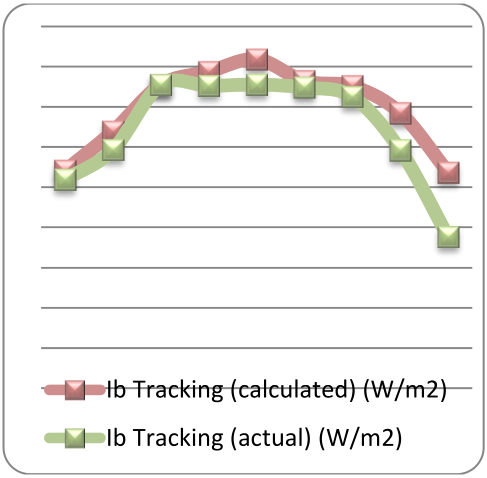

Figure (5.2) solar beam radiation vs time of day 11_th September2019

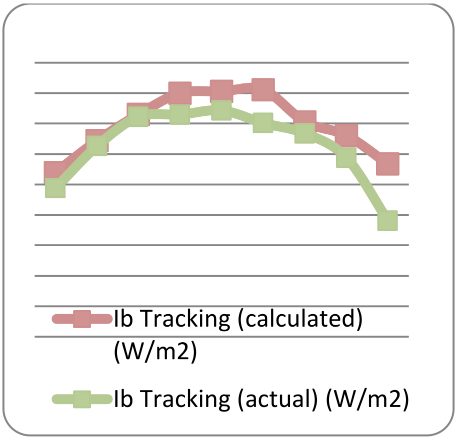

Figure (5.3) solar beam radiation vs time of day 12_th September2019

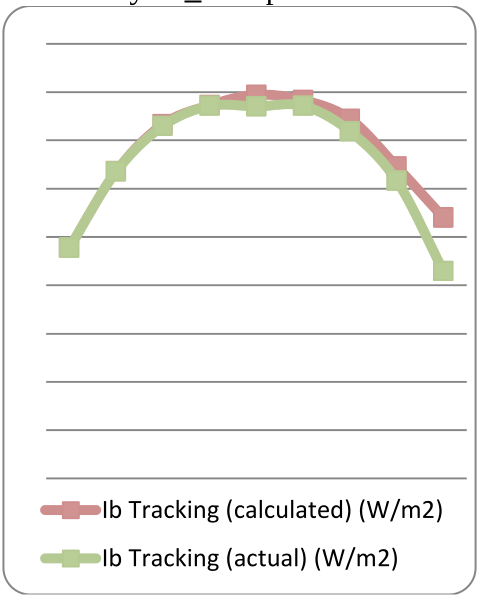

Figure (5.4) solar beam radiation vs time of day 14_th September2019

5-3 Results of Photovoltaic Power Output:

The results of the photovoltaic power output Test are depicted in Figures (5.5) to (5.8)

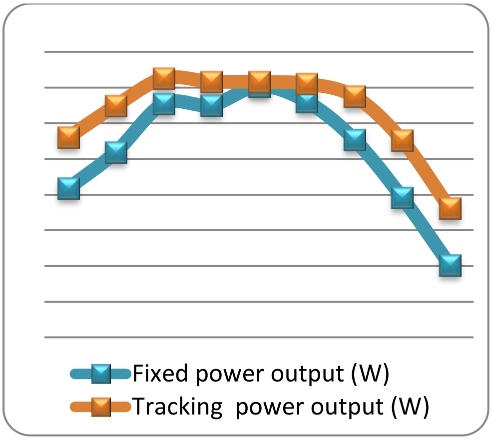

Figure (5.5) tracking power output vs fixed power output 5_th September2019

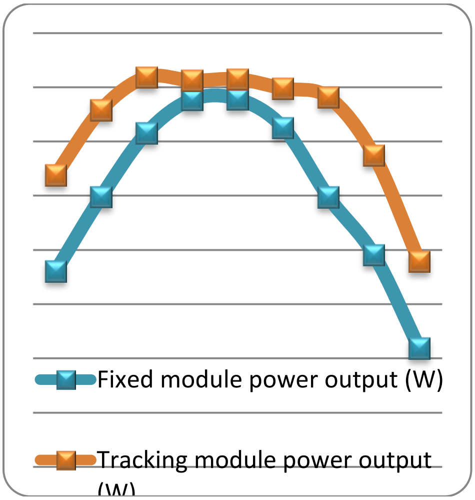

Figure (5.6) tracking power output vs fixed power output 11_th September 2019

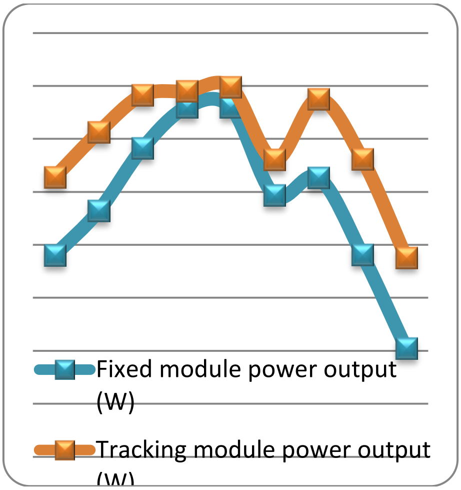

Figure (5.7) tracking power output vs fixed power output 12_th September 2019

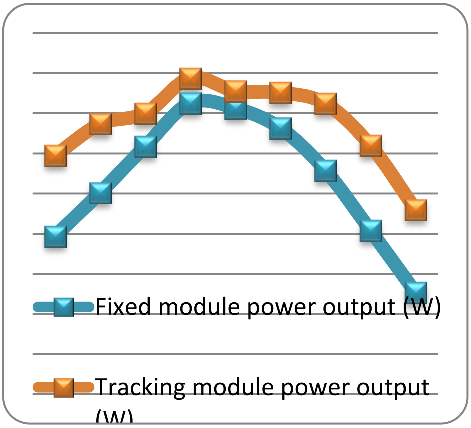

Figure (5.8) tracking power output vs fixed power output 14_th September 2019

6- Conclusion:-

In Figure (5.1) to (5.4) the results show that the average tracking efficiency 92%. Efficiency less than this average occur; it is due to the wind that can cause forces on the tracker to the point of misalignments from the beam radiation.

In Figure (5.5) to (5.8) the results show that the percentage increase in power output of the tracking module is from 10.91% to 50.96% at 9:00 to 11.00 hours in the morning.

At 15:00 and 17:00 hours the percentage increase of the tracking module was in the range of 21.97% to 81.81%. At 12:00 to 14:00 hours the percentage increase of the tracking module ranges from 1.76% to 13.61%.

At solar noon the power output of the tracking module was near as the fixed module this is due to position of both is the same.

Obliviously this experiments show that an increase of performance of solar cells by using solar tracker.

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