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COMPARATIVE SIMULATION ANALYSIS OF STATIC, SINGLE AXIS AND DUAL AXIS SOLAR TRACKING SYSTEM FOR BETTER PERFORMANCE EVALUATION

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Abstract: As the energy demand and the environmental problems increasing day by day, the natural energy sources had become a very important as an alternative to the conventional energy sources. The sun is the most abundant source of renewable energy available on the earth Photovoltaic(PV) technology is perhaps the best approach to capitalize the solar energy. Solar energy plays an important role as a primary source of energy, especially for rural area. Solar energy is one of the fastest growing industries among the world. Today more than 500 GW energy is produced by using solar power. Since the solar energy is a renewable energy source, it is a good power source, especially for the developing countries. In this Project, we are going to show you The Comparative Simulation Analysis of Static, Single Axis and Dual Axis Solar Tracking System for Better Performance Evaluation

***Index Terms*–Introduction, Components, Theoretical View, Solar Tracking System.**

1.0 Introduction

As the usage of fuel in vehicles is increasing day by day, along with this, the lack of fossil fuels is also increasing. So there might be a shortage of fossil fuel resources in the upcoming days, so the investigators are focusing more in the area of different type of renewable energy sources for all around the world. Among the different type of renewable energy sources like hydropower, bio-fuel, wind power, tidal power, sun power are the important power sources. Because of the never-ending property of this sources, they are encouraged for the best replacement of fossil fuel sources. Among these energy sources, solar power is one of the most accessible energy sources. Due to the evolution growth In the PV cell, PV cell material with their better execution is improved and cost is also reduced. Therefore nowadays, this energy resource has been widely used for housing purposes and also the demand on electricity and its price is continuously increased over the time. Solar energy has become a preferable alternative to meet the expanding demands of electricity because of its ubiquity, abundance, and sustainability, solar energy is widely available and also completely free of cost. However, it is costly to install but in long term usage it can save more energy and offers more reduction in cost

2.0 Components

2.1 Solar panel:

TheSolar panel is the main part of all kinds of photovoltaic system. A solar panel is a device used to capture the solar radiation. These panels consist of array of solar cells. The solar cells are made up of silicon. They are then connected to complete a photovoltaic(solar) panel. When the sun rays will incident on solar cells, due to this photovoltaic effect, light energy from the sun is converted to electrical energy. We know that most of the energy gets absorbed, when the surface of the panel is perpendicular to the sun. Stationary mounted PV (photo voltaic) panels are only perpendicular to sun only once a day but the challenge for it is to get maximum energy from the source(sun), so for that we use trackers on which the whole system is mounted on it. In tracking system, solar panels will move according to the movement of sun throughout the whole day. Solar panels don't lead to produce any form of pollution and also, they are clean. They also decrease our depend on fossil fuels (which are limited) and traditional power sources. Now-a-days, solar panels are used in wide range of electronic equipment like calculators, which work as long as sunlight is available there. However, the only major drawback of solar panels is that they are quite costly while purchasing. Also, solar panels are installed outdoors as they need sunlight to get charge the battery.

2.2 Diode

Diode is an electrical component that allows the flow of current in one direction only. The most common type of diode used is a p-n junction. In this type of diode, one material (n) in which electrons are charge carriers and in second material (p) in which holes act as charge carriers.

2.3 Resistor

Resistor is a passive two-terminal electrical component that implements electrical resistance into a circuit element. In electronic circuits, resistors are used to reduce the flow of current, adjust signal levels, to divide the voltages, and terminate transmission lines.

OHM'S LAW states that the current through a conductor between two points is directly proportional to the voltage across the two points. Introducing the constant of proportionality, the resistance one arrives at the usual mathematical equation that describes this relationship of it:

Current (I) = Voltage (V) / Resistance (R)

2.4 DC Voltmeter:

DC voltmeter is a voltage measuring instrument, which is used to measure the DC voltage across any two points of the electric circuit. If we place a resistor in series with the Permanent Magnet Moving Coil (PMMC) galvanometer, then the entire combination together acts as DC voltmeter.

Dc voltmeters is a PMMC instruments, MI instruments can measure both the AC and DC voltages, electrodynamometer type, thermal instrument can measure DC and AC voltages as well. Induction meters are not used because of their high initial cost. Rectifier type voltmeter, electrostatic type and also digital voltmeter (DVM) can also measure both AC and DC voltages.

2.5 ICLM317T:

The LM317 device is an adjustable three-terminal positive-voltage regulator which is capable of supplying more than 1.5 A over an output-voltage range of 1.25 V to 37 V. Only two external resistors are required to set the output voltage. This device features a typical line regulation of 0.01% and typical load regulation of 0.1%. It includes current limiting, thermal overload protection also, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected also.

2.6 Light Dependent Resistor (LDR):

A Light Dependent Resistor (LDR) is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are called as light-sensitive devices. They are also called as photoconductors, photoconductive cells or simply photocells. They are made up of semiconductor materials having high resistance value. Photoresistors work is based on the principle of photoconductivity. Photoconductivity is an optical phenomenon in which the material's conductivity gets increased when light absorbed by the material.

When light gets fall on the device, the electrons in the valence band of the semiconductor material are excited to the next band which is conduction band. These photons in the incident light should have energy more than the bandgap of the semiconductor material to make the electrons jump to the conduction band from the valence band.

2.7 Arduino UNO:

The Arduino integrated development environment (IDE) is a cross-platform application(for Windows, mac OS, Linux) which is written in the Java programming language. It is used to write and upload the programs to Arduino compatible boards. The Arduino IDE supports the coding languages like C and C++ using special rules of coding structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures on the board. The User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with the program stub main() into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution.

2.8 Proteus:

The Proteus Design Suite is a proprietary software-based tool suite and used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create the schematic circuits and electronic prints for manufacturing printed circuit boards. The micro-controller simulation in Proteus works by applying either a hex file or a debug file to the micro controller part on the schematic circuit. It is then co-simulated along with any kind of analog and digital electronics connected to it.

2.9 Photovoltaic Cell:

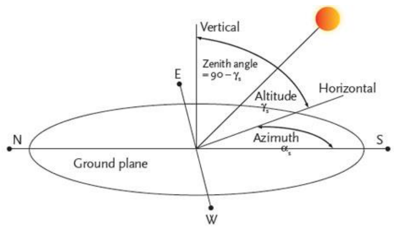
The generating electricity with solar panels all comes down under the photovoltaic effect. the photovoltaic effect can be generally thought of as a characteristic function of semiconductors that allows them to generate an electric current when exposed to the sunlight.

The photovoltaic process works through the following simplified steps:

1. The silicon photovoltaic solar cell absorbs solar radiation from sun
2. When the sun's rays get interact with the silicon cell, electrons begin to move and creating a flow of electric current
3. This direct current (DC) electricity will pass through the wires to a solar inverter to be converted to alternating current (AC).

3.0 Theoretical View:

3.1. Defining Solar Angles and Respective Equations:



3.1.1. Solar Altitude:

Solar altitude refers to the angle of Sun relative to the Earth's horizon. Solar altitude is measured in degrees. The value of the solar altitude varies based on the time of day and the time of year. The latitude on Earth Solar altitude is defined as (α) in figure above,

$$[\alpha = \sin^{-1} (\sin\delta \sin\varphi + \cos\delta \cos\varphi \cos\omega)]$$

3.1.2. Zenith Angle:

The Solar Zenith is the angle between the zenith(vertical) and the center of the sun's disc. It is related to the solar altitude angle, where it is the angle between the sunrays and a horizontal plane. Since these two angles are complementary, the cosine of either one of them equals the sine of the other. where, θz is known as Zenith Angle. The equation of Zenith angle is given below,

$$[\ \theta z = 90° - \alpha]$$

3.1.3. Declination Angle:

The declination angle (δ) varies seasonally (all the time) due to the tilt of the earth on its rotation axis and the rotation of the earth around the sun. If the earth was not tilted on its axis of rotation, the angle of declination would always be 0°. However, the earth is tilted by 23.45° and the declination angle varies plus or minus this value. Only at the spring and fall, the declination angle equal to 0°. Here n means a number of particular days.

$$\alpha = 23.45° \sin[\, 360(n-80)/365\,]$$

3.1.4. Latitude Angle:

Latitude is defined with respect to an equatorial reference plane. This plane passes through the center O of sphere, and also contains the great circle which represents the equator. The latitude of a point P on the surface is defined as the angle that a straight line, passing through both O and P, subtends with respect to the equatorial plane. If P is above the reference plane, the latitude is positive (+) (or northerly); if P is below the reference plane, the latitude is negative (-).

3.1.5. Hour Angle:

The hour angle of a point on the earth surface is the angle through where the earth turns to bring the meridian of the point directly under the sun. The earth is rotating, so this angular displacement represents the time. So, if we observing the sun from earth, the solar hour angle is an expression of time, expressed in angular measurement, usually measured in degrees.

At solar noon, at the observer's longitude on earth, the hour angle is 0.000 degrees with the time before solar noon expressed as negative degrees, and the local time after solar noon expressed as positive (+) degrees. The hour angle is the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15° per hour with morning being negative (-) and afternoon being positive.

$$\theta = (180 * (T - Tsr))/(Tss - Tsr)$$

Here,
T = is the particular time of a day
Tsr = is the sunrise time of a particular day
Tss = is the sun set time of a particular day

3.2 Defining Factors for Finding Solar Energy:

Solar irradiance is the power per unit area received from the sun in the form of electromagnetic radiation. It is measured in the wavelength range of the measuring instrument. The solar irradiance is measured in watts per square meter (W/m2) in SI units. Irradiance may be measured in space or at the earth's surface after atmospheric absorption and scattering. It is measured perpendicular to the incoming sunlight. This Solar Irradiance hits the surface of the earth in two forms, beam(Gb) and diffuse(Gd).

For Fixed Panel:

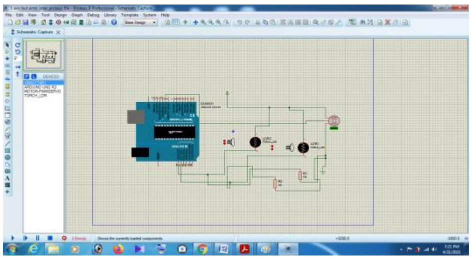
The Solar irradiance value for fixed panel is denoted by I1. The equation of calculating solar irradiance for fixed panel is as follows,

Solar Irradiance ($I1$) = $I0$ * Cos (δ) * Sin ($\boldsymbol{\theta}$)
Here, θ = Hour Angle
δ = Declination Angle

For Single Axis:

The Solar irradiance for single axis sun tracker is denoted by I1. The equation of calculating solar irradiance for single axis is as follows,

Solar Irradiance ($I2$) = Cos (δ) * $I0$
Here, δ = Declination Angle

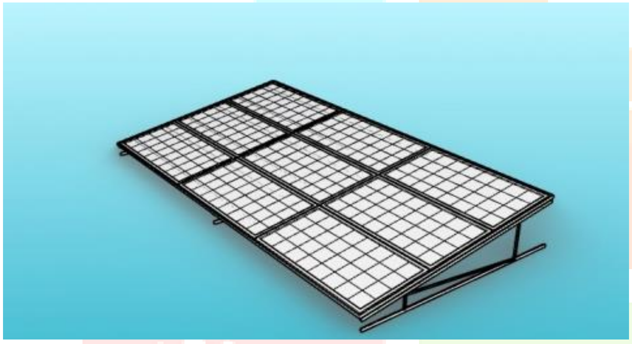


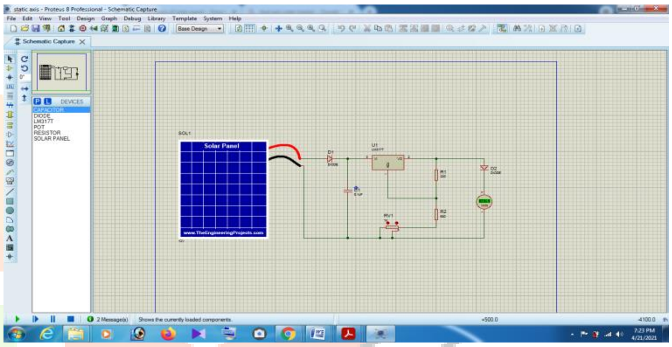
For Dual Axis:
For this project, we have collected some practical data of solar irradiance for dual axis sun tracker. That data contains the solar irradiance value of a particular place from sunset to sunrise which is an hourly basis average data and it is denoted by I0. We have calculated incidental solar radiation by the method of finding slope from this hour basis average data

4.0 Solar tracking system:
In solar PV systems, trackers assist to reduce the incidence position between the arriving sun light and the Photovoltaic (PV) panel. Solar Trackers are mainly used to increase the energy output from solar panels and solar receivers. Solar tracker is a device which follows the movement of the sun as it rotates from the east to the west every day along with the sun. Solar Trackers are used to keep solar collectors or solar panels oriented directly towards the sun as it moves through the sky (for Sun) every day. Using solar trackers increases the amount of solar energy which is received by the solar energy collector from sun and improves the energy output of electricity which is generated by the solar panels.

Here We are taking 3 types of solar tracking systems
1. Static Axis Solar Panel
2. Single Axis Solar Tracker
3. Dual Axis Solar Tracker

4.1 Static axis solar panel:
Fixed (Static) Arrays are arrays of Solar Panels placed at a fixed angle which is usually the optimum tilt. To obtain maximum efficiency from the solar panels they need to be pointed in the direction that captures the most part of sun rays. Fixed tilt arrays are being immobile which are simple in construction, easy to design it and maintain it. Since they don't have any moving parts, fixed





systems are salient and it requires very little maintenance. This system won't be optimally aligned. This means it will produce less energy.

4.2 Single axis Solar Tracker:
A 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 the single axis tracking system consists of two LDR's placed on both the sides 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 under the light. The LDR with the maximum intensity of the sun's radiation sends the stronger signal to the controller which in next sends signal to the motor to rotate the panel in the direction in which the sun's maximum intensity is maximum
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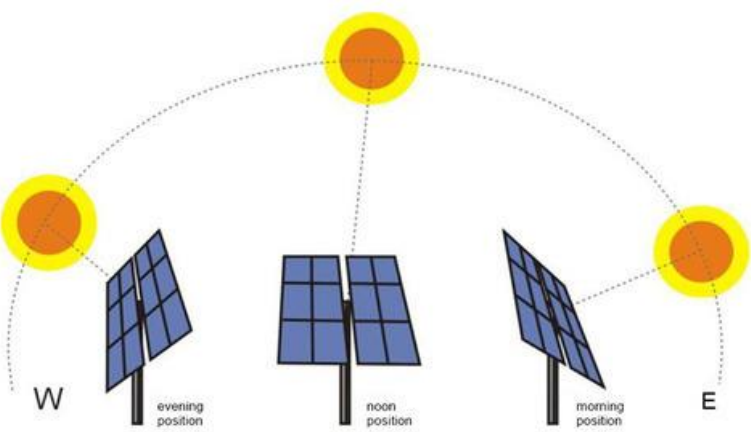
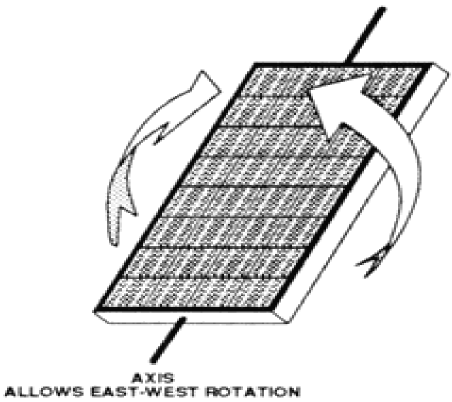
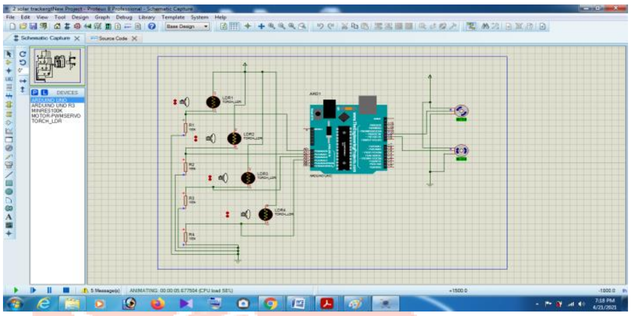




There are many types of single axis solar trackers available these include vertical single axis trackers, vertical tilted single axis trackers, horizontal single axis trackers, horizontal single axis tracker with tilted modules, and polar aligned single axis trackers. The orientation of the module with respect to the tracker axis is important when modeling performance. The horizontal type is mostly used in tropical regions where the sun temperature gets very high at noon but the days are short. On the other hand, the vertical type is used in high latitudes where the sun is not very high(temperature) but summer days can be very long.

4.3 Dual axis Solar tracker

Dual axis tracking system uses the solar panel to track the sun from east to west and also from north to south using two pivot points to rotate it. 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 directions. The controller detects the signal from the LDR's and commands the motor to rotate the panel in respective of the direction. No matter where the Sun is there in the sky, dual axis trackers are able to angle themselves to be in direct contact with the Sun direction.



Dual Axis Solar Tracker

4.4 Project Overview:

For this project, we have worked on the performance evaluation of the three types of solar power systems which are fixed panel, single-axis and dual-axis solar trackers.

The fixed axis panel solar system is generally mounted on top of the roof or in the open space whether no blockage from trees or buildings is there. As the name suggests, this particular system will be fixed in a certain position and it won't be moving with the course of a day or a year. As in, the changes of solar intensity with respect to the changes of the solar position will have no effect on the positioning of the panel.

The single axis solar panel will possess the capacity to track the sun direction as the sun moves from east to west throughout the day. It should be notable that single axis refers to the change in the position of the tracker to be following the sun's one-dimensional movement. The sun's changing position with respect to seasons, will not be taken into account by the single axis tracker. A single axis solar tracker should be able to generate considerably more energy than what a fixed axis does.

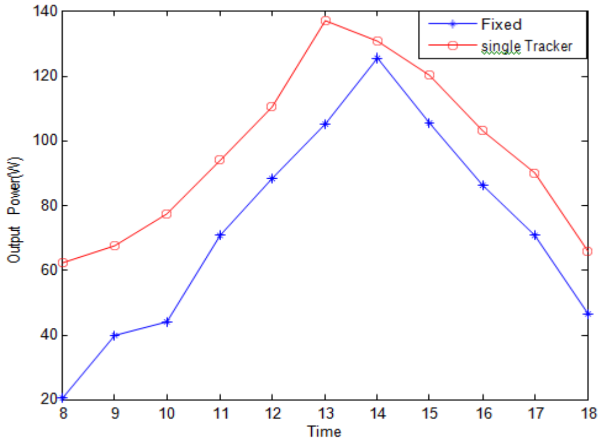
The dual axis sun tracker is essentially able to follow the sun as it changes its position throughout a day as well as a year. As we are all aware of, the sun doesn't only shift from east to west on a daily basis as seasons changes. The sun's position also varies moving from north to south. The dual axis tracker essentially follows the sun's two-dimensional movement to ensure the angle of incidence between the sun ray and the panel is always kept minimum. This way the system is able to absorb maximum sunlight and therefore should be capable of producing more energy than single and fixed axis trackers

The objective of this work is to calculate the output power and cumulative energy for three different systems yield respectively and evaluate as well as to compare the performances of the systems with respect for a particular place and also for a particular time. For our project purpose, we have collected practical hour basis average solar radiation data for only dual axis solar tracker system. We have calculated solar radiation for fixed panel and single axis sun tracker system from that. By following steps, we have calculated the other parameters like output power and cumulative energy. Average solar radiation data of three types of solar panel system for different months are given below.

4.5 Comparison:Comparison of Static Over Single Axis And Dual Axis

4.5.1Efficiency of Single-Axis Tracking System over Static panel

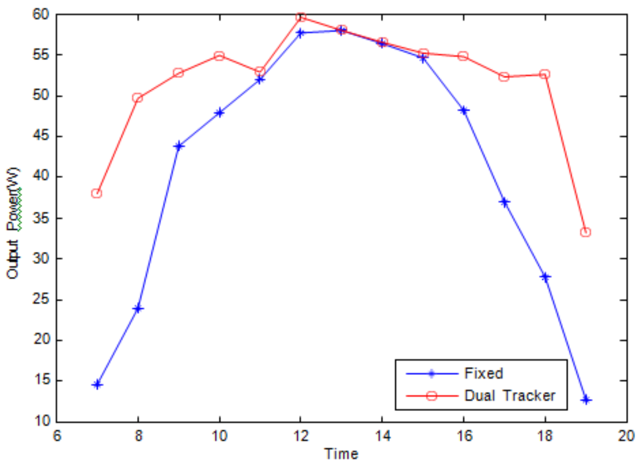
HOUR	POWER FORFIXEDMOUNT(W)	POWERFOR SINGLE-AXIS(W)
08:00	20.664	62.403
09:00	39.780	67.473
10:00	44.176	77.212
11:00	70.616	93.772
12:00	88.110	110.430
13:00	104.960	137.160
14:00	125.334	130.754
15:00	105.342	120.335
16:00	86.172	103.096
17:00	70.620	89.910
18:00	46.494	65.625



Static vs Single AxisSimulation Result for Comparison of Fixed mount and Single-Axis Tracker System

4.5.2 Efficiency of Dual-Axis Tracking System over Static

HOUR	POWER FORFIXED MOUNT(W)	POWER FORDUAL-AXIS(W)
07:00	14.575	38
08:00	23.987	49.728
09:00	43.876	52.701
10:00	47.94	54.9519
11:00	52	52.974
12:00	57.6666	59.6156
13:00	57.96	58.0488
14:00	56.412	56.5687
15:00	54.6883	55.3151
16:00	48.174	54.8562
17:00	36.96	52.3698
18:00	27.72	52.668
19:00	12.69	33.22

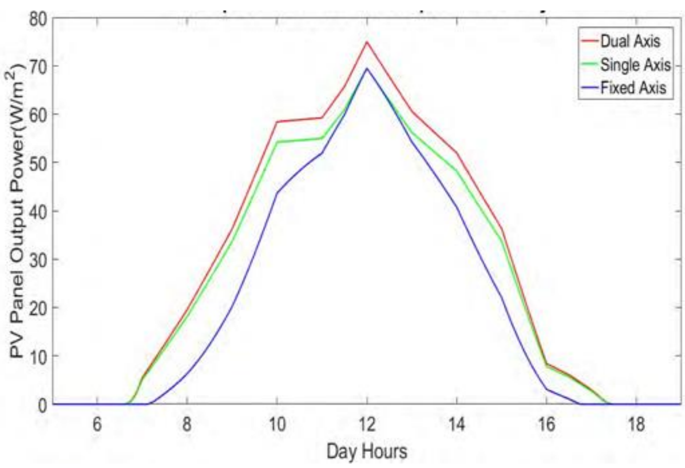


Fixed vs Dual AxisSimulation Result for Comparison of Fixed Mount and Dual Axis Tracker System

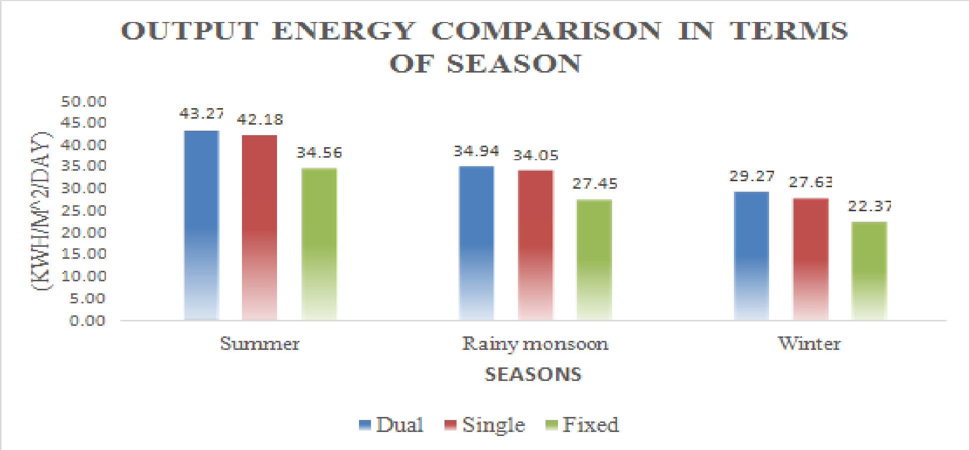
5.0 Result and 0bservational

In this chapter, we are going to evaluate the outputs of fixed panel, single-axis and dual-axis solar panel systems. According that, we will calculate total energy throughout a year and also for different months individually. By following that, we will also compare the output power and total energy for different systems.

5.1 Comparing outputs of all 3 types of solar tracker:

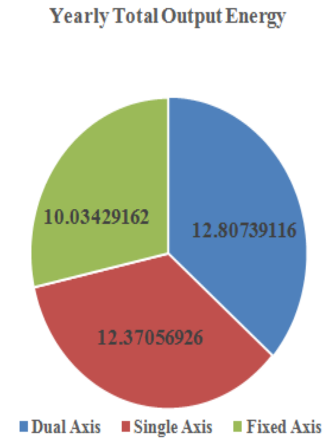


5.2 Season-wise Comparison:



Comparison of output energy for three different PV Panel systems (Fixed, single and dual axis) in terms of season.

5.3Comparison of Yearly Energy with Respect to Fixed Panel:



6.0 Discussion:
Throughout the project, we have discussed about output power and total energy for three different systems which are fixed panel, single-axis and dual-axis solar tracking solar panel system By comparing three different systems in different types of criteria, we have found that dual-axis solar tracking solar panel system is more efficient in terms of output power and generating total energy. The difference between single-axis sun tracking system and dual-axis sun tracking system is very close. Moreover, the output power for these two different systems are almost equal. There is another most concerning fact which is cost effectiveness. In terms of this fact, single-axis sun tracker is more preferable. Dual-axis sun tracking system is most expensive than the single-axis sun tracking system. Since the precision and efficiency between these two is slight, so we can consider single-axis tracking system over dual-axis tracking system. In short, though dual-axis solar tracker is most efficient but in terms of cost effectiveness single-axis is more preferable.

6.1 Factors that Affect Solar Power:
There are several factors that can affect the efficiency of different solar panel systems. Some ofthesefactorshavebeenstudiedtoeither increase ordecreasethepowerproductionfromthethree types of solar panel system such as sun intensity, cloud cover, relative humidity, and heat buildup. When the sun is in its peak, during mid-day, the most solar energy is collected; therefore, there is an increase in the power output. Cloudy days contribute to the decrease in sun light collection effectiveness since clouds reflect some of the sun's rays and limit the amount of sun absorption by the panels. Solar energy output is also affected by weather and seasonal variations. The angle of the sun to the solar panel changes with the time of day andseasonal variations. During summer days when the temperature is at its highest and heat is built up quickly, the solar power output is reduced by 10% to 25% for the reason that too much heat Increases the conductivity of semiconductor making the charges balance and reducing the magnitude of the electric field. In addition, if humidity enters into the solar panel frame, this can reduce the panel's performance producing less amount of power and worse can permanently weaken the performance of the modules.

6.2 Future Work:
Commercially, dual-axis sun tracking system is still rare even in countries where a significant part of electricity is being generated by solar energy as they claim that single-axis sun tracking system is doing the job. But dual-axis sun tracking system can

significantly increase the efficiency. So, there is a scope to improve the performance of single-axis sun tracking system from different aspects which will be more cost effective. In this project, we have worked on different sun angles and mainly the solar radiation for different systems. We have ignored different factors like humidity, sun intensity etc. So, here is a scope to improve it more and make it more accurate. The other most important fact is practical data of solar radiation what we have collected. Because a few numbers of data were missing in there. If we are able to collect more accurate data, the result would be more accurate.

6.3 Conclusion:

In conclusion, it can be said that the systems have no significant difference in between them while considering all the factors what affect the output power of solar panel. According to comparison, the electrical output is quite little of single-axis sun tracking solar panel system and has no significance over dual-axis sun tracking solar panel system's electrical output. In terms of cost effectiveness, single-axis sun tracking solar panel system is more preferable over dual-axis sun tracking solar panel system. The values would have diverged more between dual and single axis if the location is different. Considering all the factors performance of three different systems are very close to each other though it varies In different regions. According to all the calculations, dual-axis sun tracking system is ahead of other systems but as a whole the performance of three different systems do not vary that much. In this contribution we have tried to explain the comparison between three different solar panel systems in different criteria. Our contribution is not criticism of the previous works but merely a clarification. We wish to carry on our work from here and onwards.

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