Comparison between solar panel mechanical tracking systems and fixed system for the photovoltaic power output in Erbil city

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1.Abstract:

In order to harvest the maximum amount of incident solar radiation by photovoltaic solar panels, an idea is immediately crossing the mind that the mechanical photovoltaic solar panel tracker can carry out this process, there is a discussion going around solar panel mechanical tracking which is that the mechanical solar panel tracking requires power for the motors to swing the solar panel in which faces normally to the sun at every moment i.e. providing the optimum tracking angle to the solar panel so as to face normally to the direct radiation of the sunlight.

The overall efficiency of the mechanical photovoltaic solar panel tracking system could be better or could be equal or less as compared to the same solar panel which is fixed that have been tested simultaneously at the meantime and approximately at the same place, the overall efficiency is also depends on the efficiency of the motor that is responsible for the solar panel mechanical tracking.

In our thesis article we are going to explain the effect of mechanical tracking of the solar panel on the overall efficiency of the photovoltaic solar system by tracking, the two cases of both fixed and tracked photovoltaic solar panel is studied and tested by selecting the quite good medium for our experiment which is a place located in Erbil city and at the summer time which is fine weather and direct radiation of the sunlight is % 100 available during the daytime.

Keywords:
Solar irradiation, direct sunlight, mechanical solar panel tracker, photovoltaic, solar tracking angle

List of Symbols

Symbols	Description	Unit
⍰	Mean value	--
A	Azimuth	Degree
FF	Fill Factor	--
H	The Hour Angle Degree	Degree
Hz	Hertz	Hertz
Imp	Current at max power	Ampere
Isc	Short circuit current	Ampere
Pin	Input power	Watt
Pmax	Maximum power	Watt
SE	Standard error	--
V	Voltage	Volts
VBAT	Battery voltage	Volts
VCC	Voltage supply	Volts
Vmp	Voltage at max power	Volts
Voc	Open circuit voltage	Volts
W	Watt	Watt
A	Solar Altitude	Degree
Δ	The Declination Angle	Degree
H	Efficiency	--

Θz	Zenith	Degree
Λ	The Longitude	Degree
Σ	Standard deviation	--
Φ	The Latitude	Degree

2.Acknowledgement:

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I would love to show my full respect to my family especially my Mom, Dad, and my wife they could make me feel safe and strong while I was being outside my country for my study.

To who he could provide equipment and lab. for my lab. works for my thesis, whom happily welcome me to join his lab ,professor Idriss Hamakhan at the university of salahaddin ,faculty of engineering , mechanical and mechatronics engineering department.

4.Introduction:

The source of power, which is used by human, is directly and indirectly gotten from the sun except geothermal and nuclear power and some other rarely used power sources such as tidal power, which is sourced from the attractive force by moon to the oceans, and some other power sources which are under study and have challenges to produce reliable power to be used by people which is free energy, such as perpetual mechanical and magnet use

Solar energy is a renewable and sustainable energy that could provide power in both types of heat and photovoltaic, for heat the solar thermal plants are used while for photovoltaic the solar cells are used to convert sunlight in to electrical power, solar cells are semi conductors which can convert less than half of the sunlight power into electrical power.

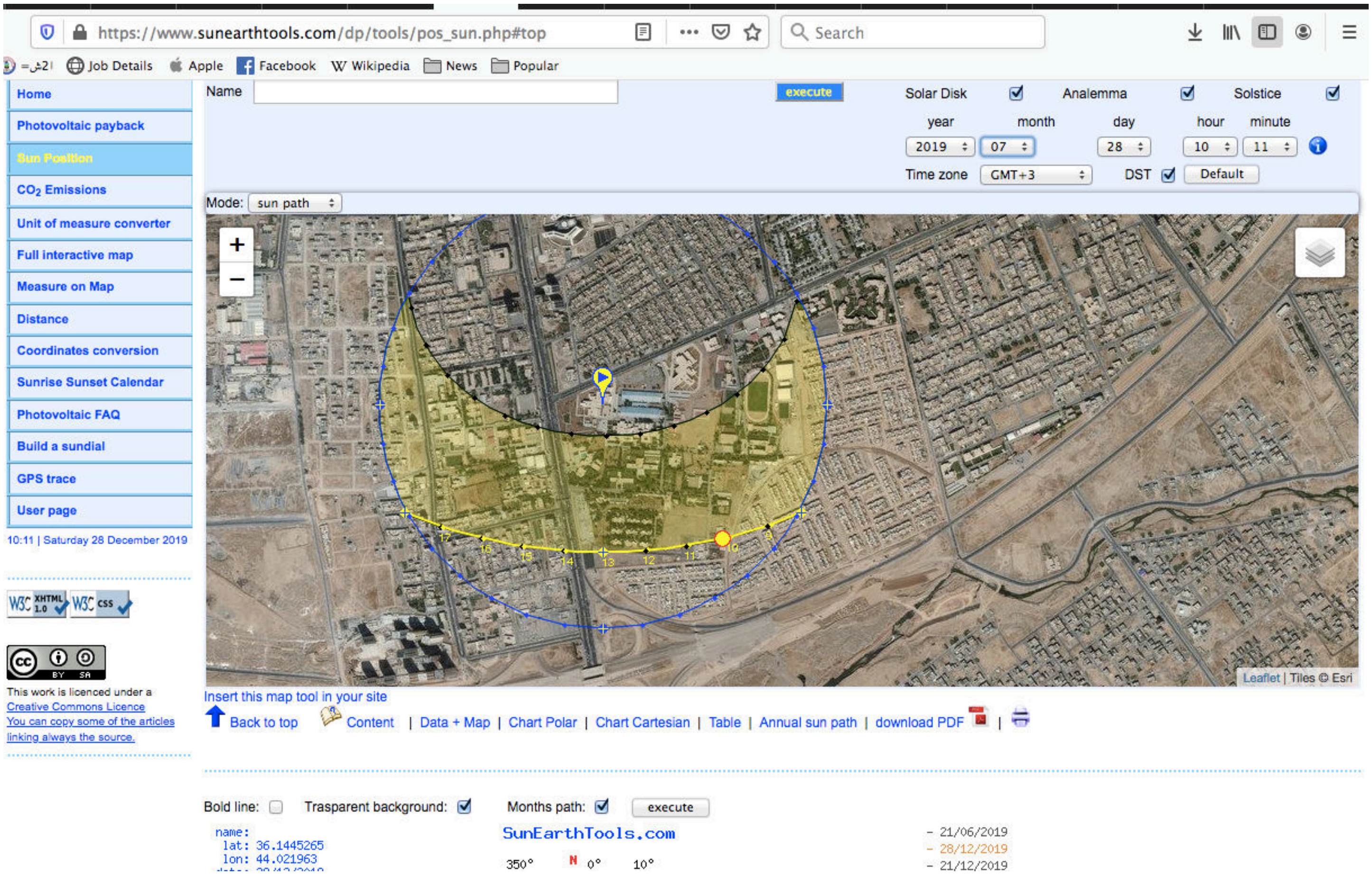
Our works in this thesis article is focused on how to capture the maximum amount of solar radiation by solar panels which is commonly used by people in domestic, industrial and even agricultural, we have used motorized solar panel mechanical tracker to carry out this process.

4.1 An over view of solar power

Before stepping into the solar power generation explanation it's better to explain how much power to be incident on the surface of an earth and the annual changing of solar radiation intensity for this reason we are going to explain the following points one by one:

Sun path:

From dawn the sun rise starts it's path with its intensity increasingly incident on the surface of earth until it get its maximum value at the mid day and decreasing gradually from the mid day downward to the dusk .the figure below shows our test station and solar sun path.



Name:

Solar Disk ☑ Analemma ☑ Solstice ☑

year 2019, month 07, day 28, hour 10, minute 11

Time zone: GMT+3, DST ☑

Mode: sun path

10:11 | Saturday 28 December 2019

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Bold line: ☐ Trasparent background: ☑ Months path: ☑

name:
lat: 36.1445265
lon: 44.021963

- 21/06/2019
- 28/12/2019
- 21/12/2019

Figure (4.1) shows the sun path of our location for our work test in Erbil –university of salahaddin-college of engineering – mechanical and mechatronics department building.

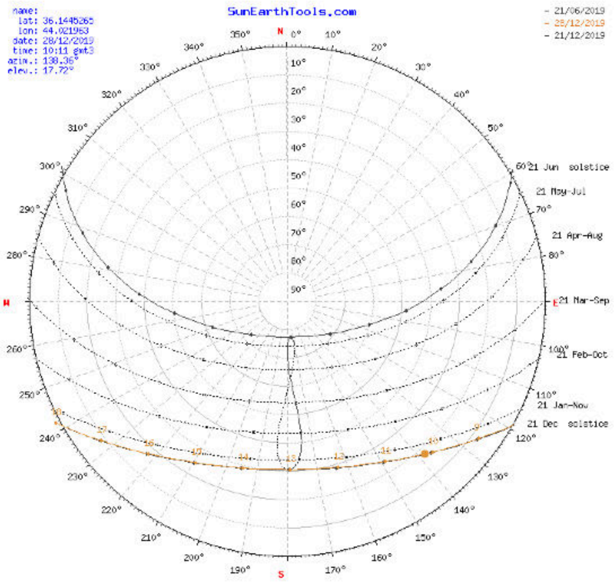


Figure (4.2) sun path diagram

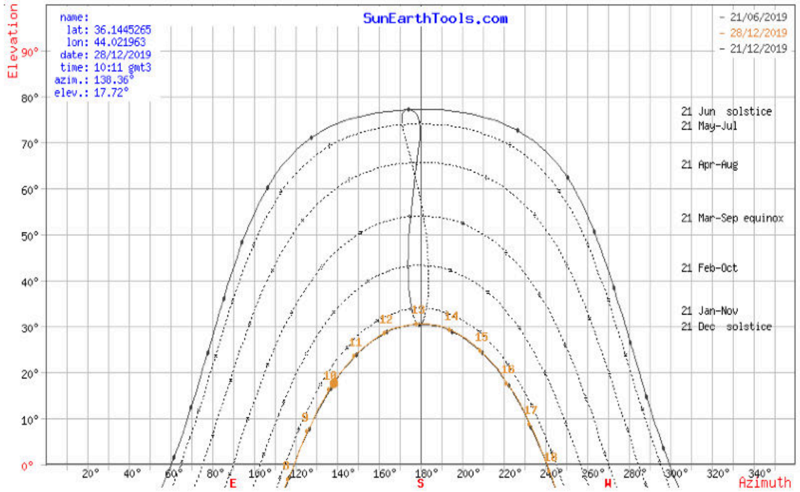
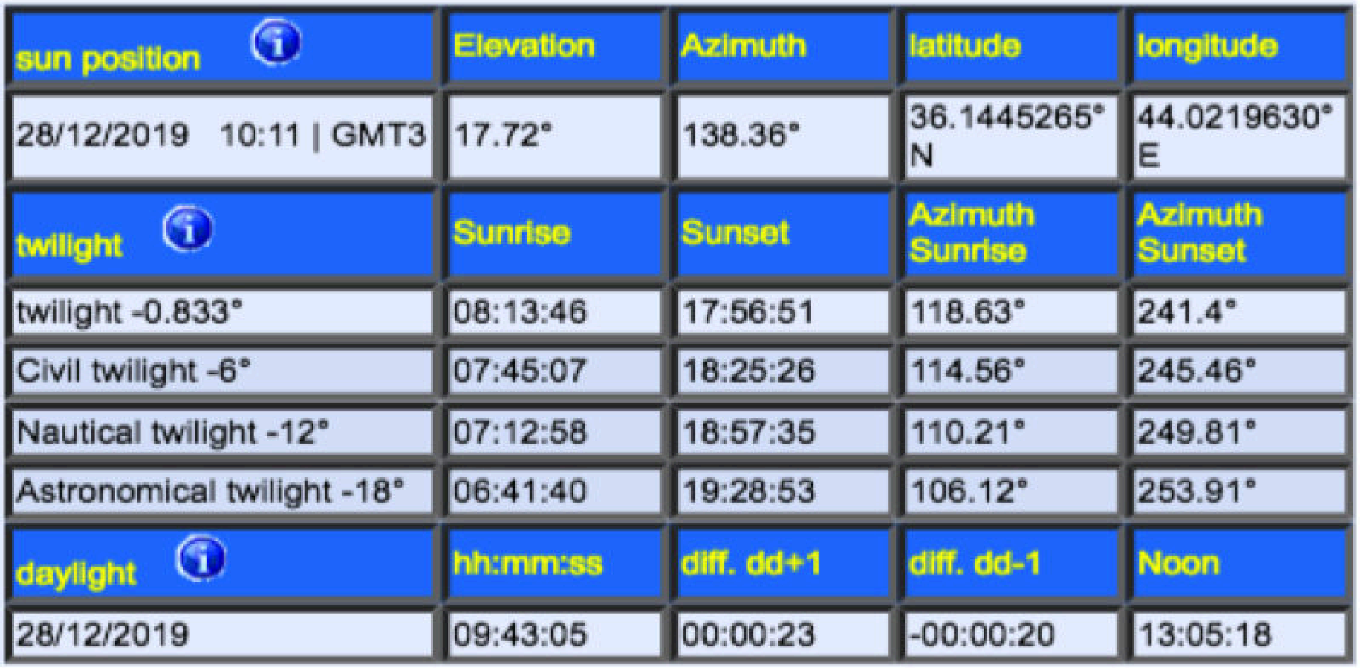


Figure (4.3) sun path diagram



sun position	Elevation	Azimuth	latitude	longitude
28/12/2019 10:11 | GMT3	17.72°	138.36°	36.1445265° N	44.0219630° E
twilight	**Sunrise**	**Sunset**	**Azimuth Sunrise**	**Azimuth Sunset**
twilight -0.833°	08:13:46	17:56:51	118.63°	241.4°
Civil twilight -6°	07:45:07	18:25:26	114.56°	245.46°
Nautical twilight -12°	07:12:58	18:57:35	110.21°	249.81°
Astronomical twilight -18°	06:41:40	19:28:53	106.12°	253.91°
daylight	**hh:mm:ss**	**diff. dd+1**	**diff. dd-1**	**Noon**
28/12/2019	09:43:05	00:00:23	-00:00:20	13:05:18

Figure (4.4) the data’s regarding our location sun position and path.

4.1.1The Sun Solar

the sun solar is dealing with the solar radiation of the sun of the solar system and the earth is one planet of the solar system we are going to start our focus on the solar radiation which is directed to an earth , the two components of the solar radiation is concerning our work and solar power that is utilized by people and those two components are solar angle regarding the solar panel and solar intensity

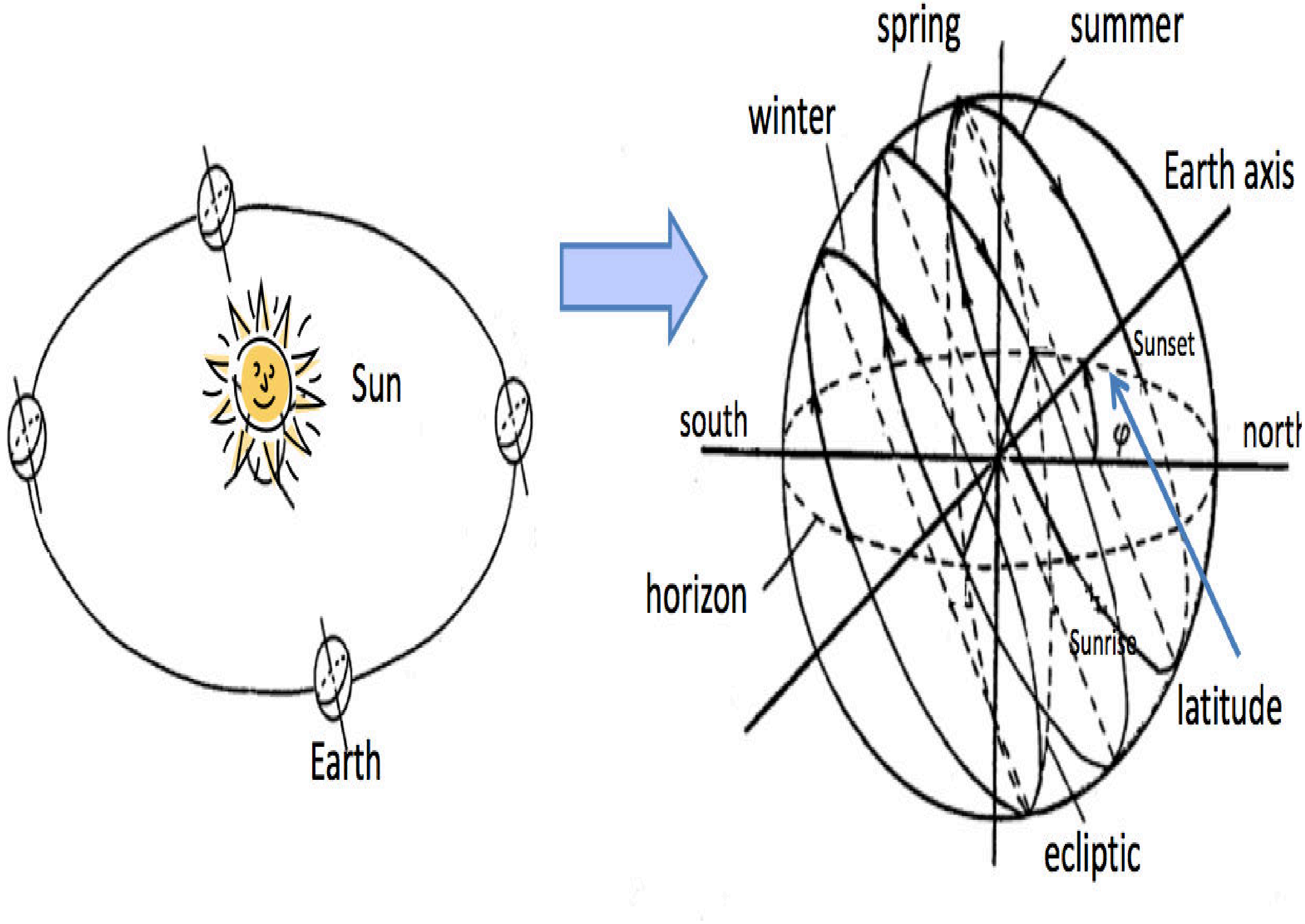


Figure (4.5) earth and the sun ,azimuth inclination and angle with the seasons.

4.1.1.1 solar radiation (solar angle)

in terms of solar angle for the solar power it is important to find the solar angle of the incident sun light ray , a direct radiation, on the ground and find the appropriate angle between the sunlight ray angle and the solar panel in which the sunlight ray should be perpendicular to the solar panel surface as much as possible,

the following is the calculation of an appropriate solar panel angle to be installed .

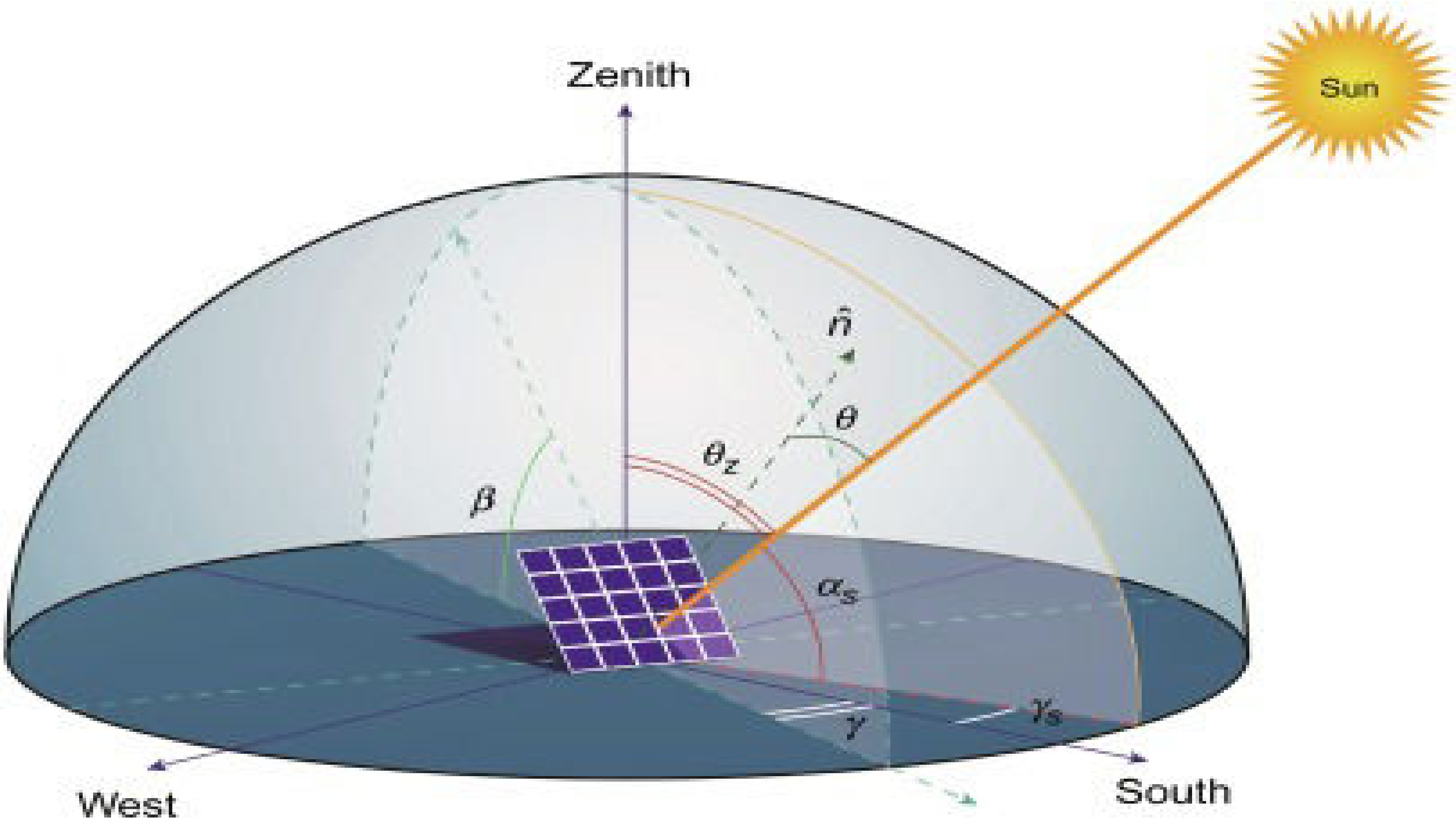


Figure (4.6), Illustrative figure shows sunlight direct radiation with respect to the solar panel

A ($\sin\phi_A \cos\Theta_A$, $\sin\phi_A \sin\Theta_A$, $\cos\phi_A$)

B ($\sin\phi_{\mathbf{B}} \cos\Theta_B$, $\sin\phi_B \sin\Theta_B$, $\cos\phi_B$)

$M^2=(\sin\phi_A \cos\Theta_A-\sin\phi_B\cos\Theta_B)^2+(\sin\phi_A \sin\Theta_A -\sin\phi_B\cos\Theta_B)^2$

$+(\cos\phi -\cos\phi)^2$

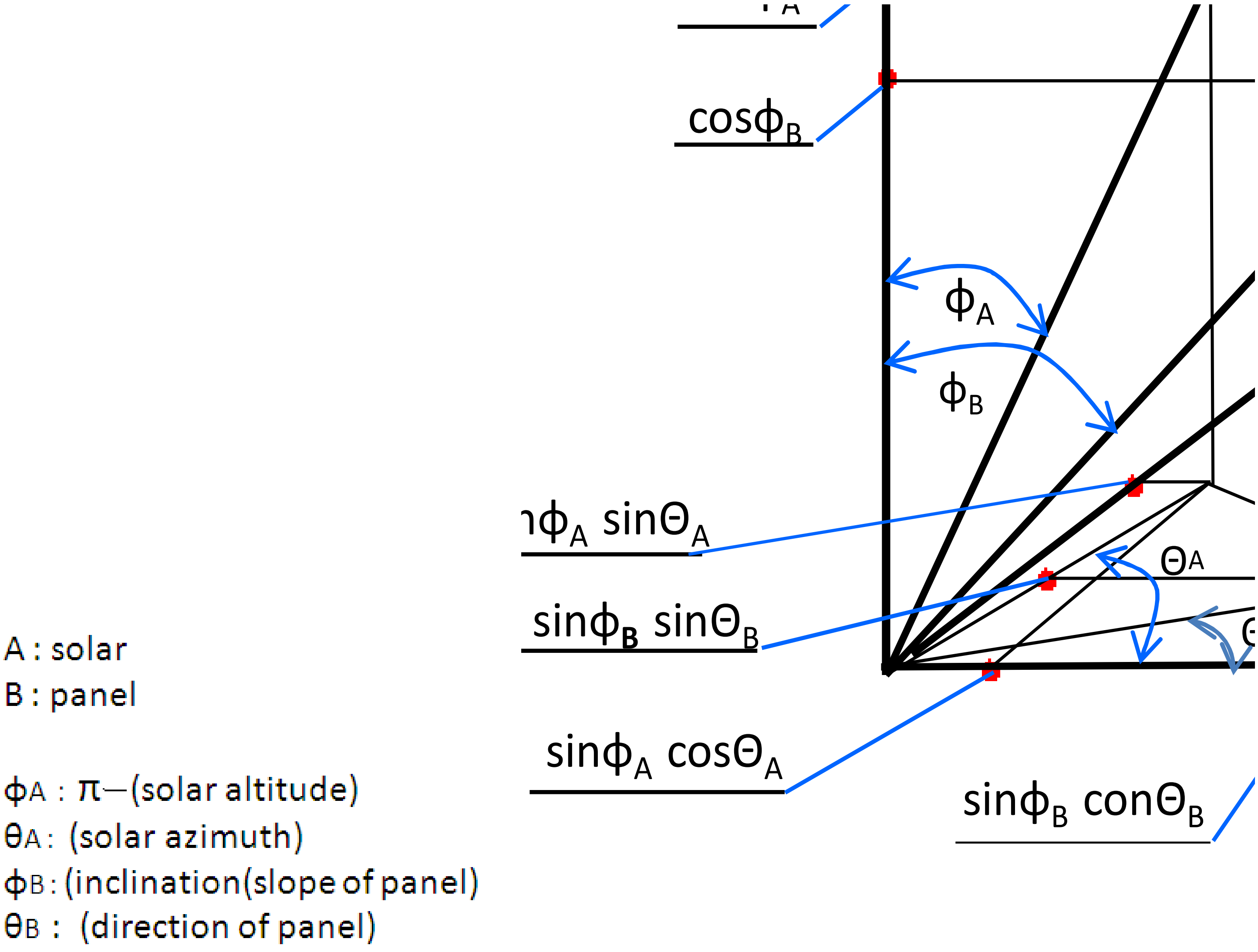


Figure (4.7) solar angle and solar panel

Angle between panel and direct radiation

Figure (4.8), solar panel and direct
Radiation angle

4.1.2.Solar radiation (intensity)

The energy, which has been laying on the different surface of the different objects, have sourced from the sunlight is called ***solar radiation***, the solar intensity at the point directly hits the surface of atmosphere is about 1.4 kw/m2 which is called ***solar constant***, the sun light hits the atmosphere and attenuates its power due to scattering from 1,4 kw/m2 to 1 kw/m2 approximately at the mid day and in a fine weather, however, in the cloudy weather the sunlight hits the cloud and it will refracted to different direction and is called ***diffuse radiation*** the amount of direct radiation hits the ground will be approximately 0.3kw/m2 ,

The collective amount of radiation of both direct and diffuse radiation is called ***Global radiation***

Global radiation = Direct radiation + Diffuse radiation
The figure below illustrates the solar radiation and it's change by weather.

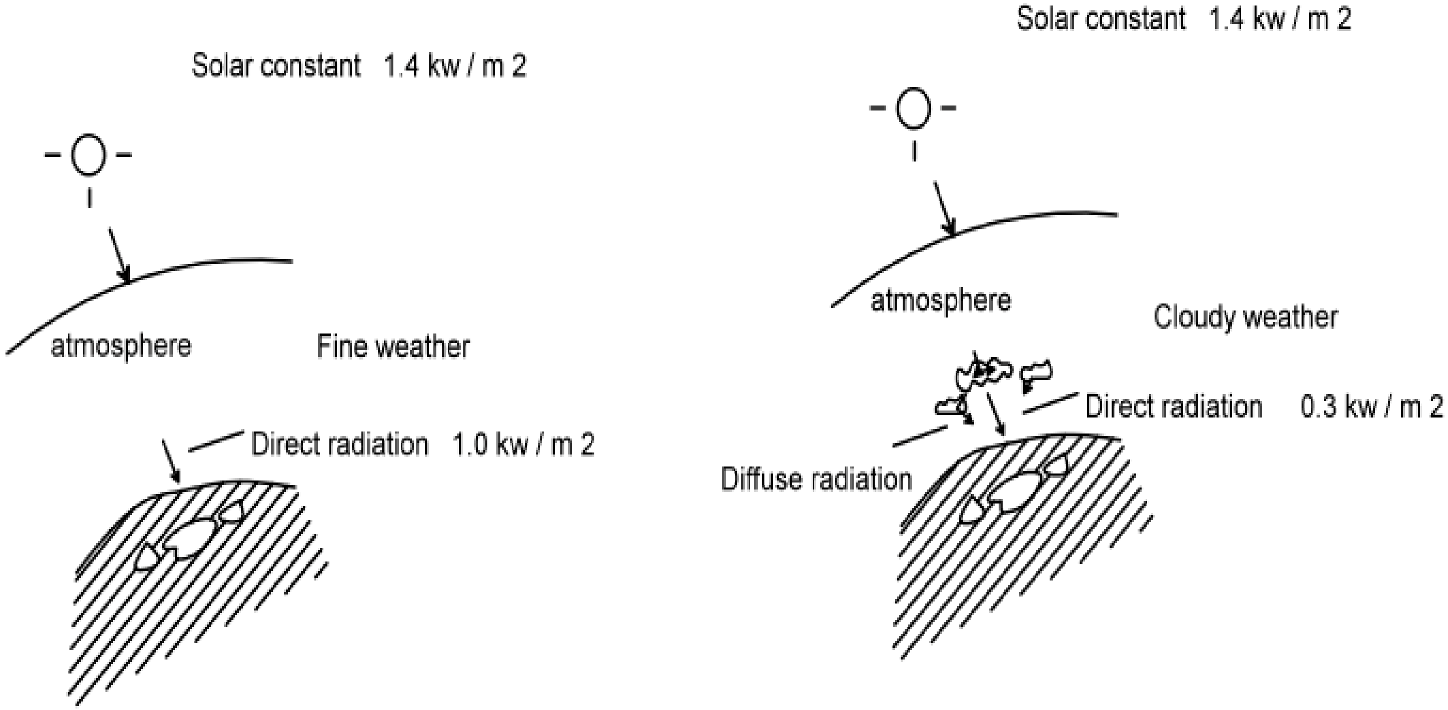


Figure (4.9), Change of solar radiation by weather

Calculation of solar direct radiation

$K_{Tt} \geq K_{Ttc}$

When

$$K_{Dt} = (2.277 - 1.258 \sin h + 0.2396 \sin^2 h) K_{Tt}^3$$

when $K_{Tt} < K_{Ttc}$

$$K_{Ttc} = 0.5163 + 0.333 \sin h + 0.00803 \sin^2 h$$

$K_{Dt} = I_{DH} / I_0 \sin h = I_{DN} / I_0$ $K_{Tt} = I_{TH} / I_0 \sin h$ I_{DN} : [kcal/m^{2}h]

Normal direct radiation

M.Utagawa ; Vol. 256 , journal of AIJ

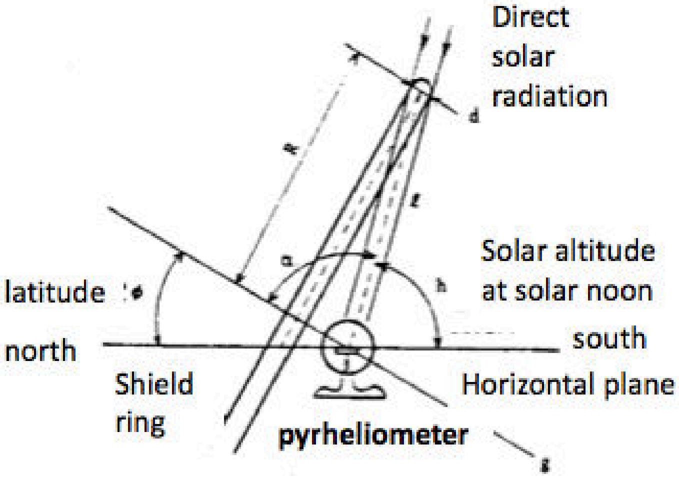
I_{TH} : [kcal/m^{2}h] I_{DH} : : [kcal/m^{2}h] I_0 : [kcal/m^{2}h]

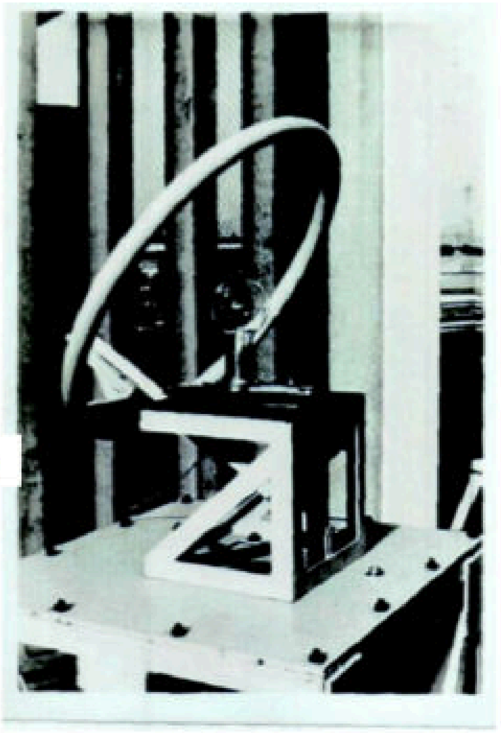
4.2.1.1. The measurement of solar radiation instruments:

the most famous and popular instrument for the global solar radiation measurement is a Pyrheliometer .

Figure(4.10) Pyrheliometer.

For the direct radiation and diffuse radiation the phrheliometer with an additional tracked part which is a shield ring is used , as shown in the following figure.





Figure(4.11) Pyrheliometer with shield ring is used for direct radiation measurement

4.2. The Solar power:

The solar power is the power that is directly taken from the sunlight and this power could be directly converted to electrical power through solar panels or indirectly converted to electrical power such as solar thermal steam power plants.

Solar power is consisting of two parts, one is solar thermal, which is related to heat, and other one is photovoltaic which is related to the solar photon energy

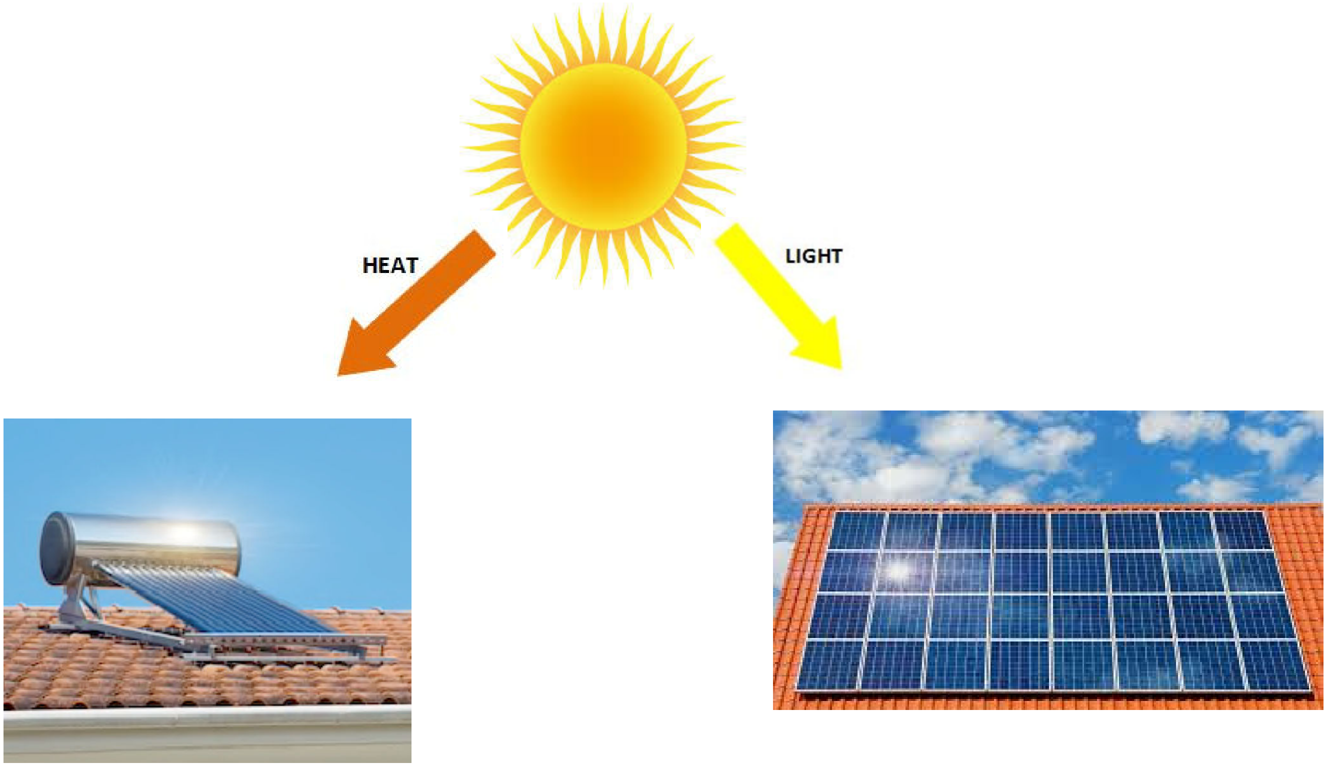


Figure (4.12), sunlight as source of power

Solar thermal power is the power that could directly take from heat of the sun light, plants that are used for this purpose is fallen on to the following types.

4.2.1 solar thermal:

The heat sourced from the sunlight could be collected and trapped by different types of solar thermal plants and the direct radiation sunlight is utilized in solar thermal.

There are most popular types of solar thermal plants which are

4.2.1.1-Solar thermal panels

solar thermal panels trapping heat from the solar radiation by black plates and special types of tubes and by conduction trough the tube walls and convection through the working fluid inside the tubes the heat will be transferred from the outdoor to the indoor of the buildings for heating up the water by using heat exchangers , the solar panels are used to heat up water for the domestic use it is not used for generating electricity and boiling water to generate steam .

4.2.1.2-Heliostats and collecting tower.

in a large scale solar thermal power Heliostats and heating tower is used the heliostats are tracked mirror wise panels are distributed in a concentrated circular arrays and at the center of those arrays the heating tower is installed ,the heliostats reflect direct radiation sunlight to the focus point on the heating tower and at that point the thermal plant starts to generate steam and the steam cycle begins to work and eventually the steam rotates the steam turbine to generate electrical power.

4.2.1.3-fresnel collectors:

Fresnel collectors are the medium scale of the solar thermal plants, which are used to heat up water and generate steam for the steam turbine or to help in generating additional steam for the steam boiler in steam power plants ,

4.2.2 Photovoltaic:

Photovoltaic is the power that is directly trapped from the solar radiation by semi conductors which are called solar cells , solar cells are connected together to for a solar module and mules are connected together to form a solar panel .

Solar cells:

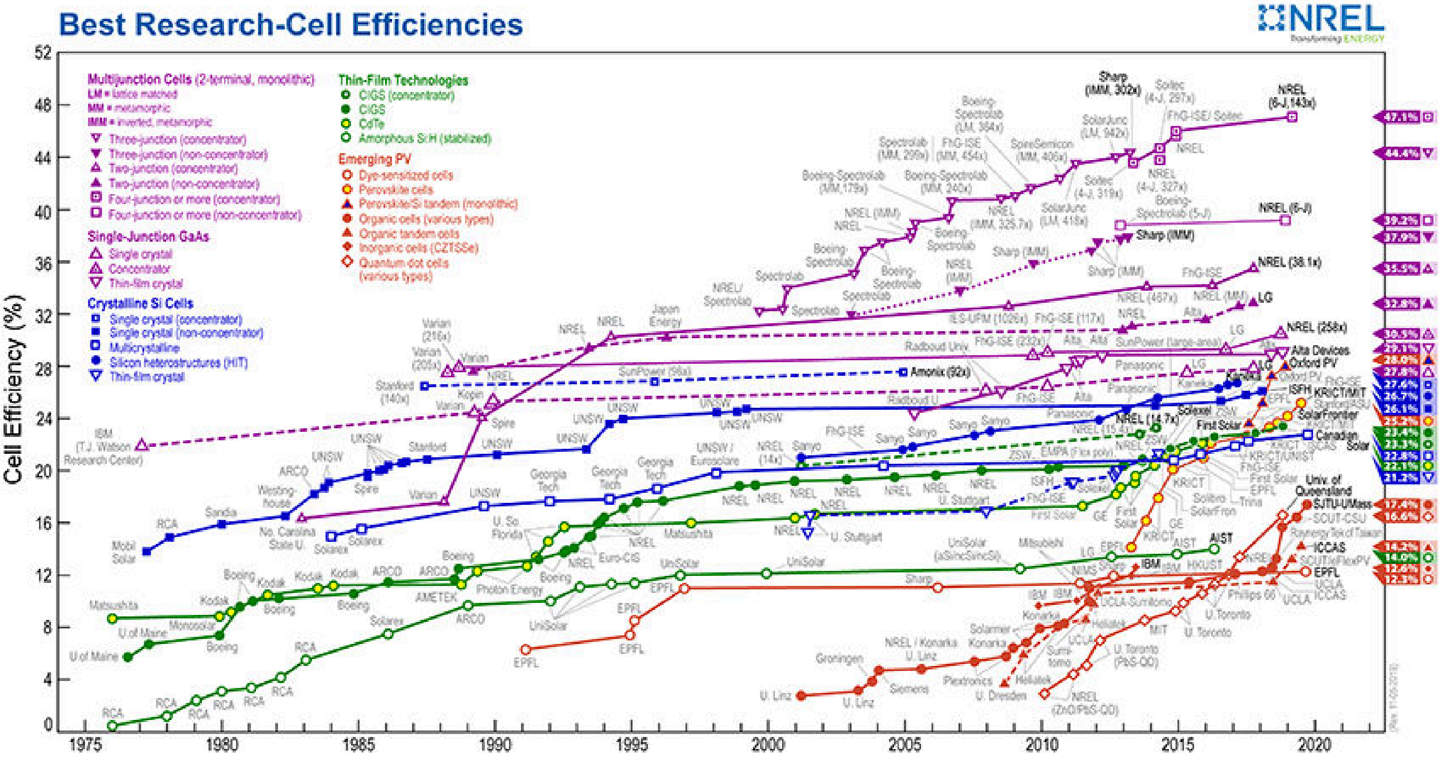


Figure (4.13) the solar cell types and their efficiencies, updated to 2020 by NREL National Renewable Energy Laboratory in USA.

Photovoltaic solar power generation components.

1- Solar cells
2- Power conditioner.
    -DC-DC (Chopper) convertor.
    -DC-AC Invertor.
    -MPPT (Maximum power point tracker)
3-Battery backup.(solar charger potteries)

Solar power types regarding grid

1-Grid tied
2-stand alone
3-microgrid

5. Literature review:-

Prior to get into literature review, which we will focus on mechanical tracking and it is effect on overall efficiency, it is worthy to explain the meaning of tracking and what kind of tracking is used in solar power systems, the term **tracking** in solar power is used in two fields one is MPPT and the other one is mechanical tracking of the solar panel, they are different in meaning.

5.1.: tracking and its meaning, function, position ,regarding solar power:

, The following chart is showing the use of tracking in solar power, however, some of them have extremely different functionality as compared to the others but meaning converging to the same concept which is tracking refers to trap the maximum and optimum value of what is required as an output.

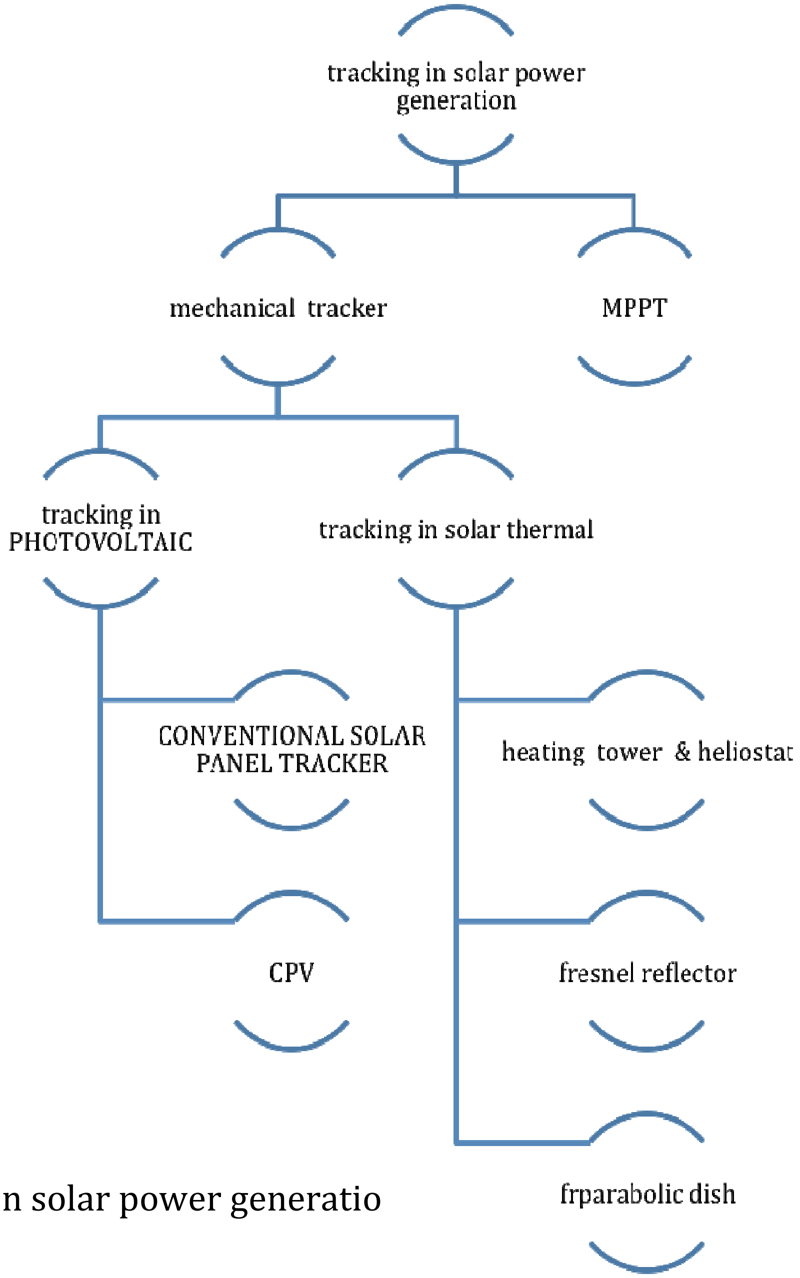


Figure (5.1) tracking in solar power generatio

5.1.1- MPPT

in changing the solar radiation due to changing in weather condition the amount of direct radiation will change also and the solar panels deliver less power or any change in the solar panel out put power the in this case MPPT will deliver the optimum rated value out put power to the demand side then the performance of the photovoltaic system generation circuit will increase as compared to the photovoltaic system generation circuit which has no MPPT.

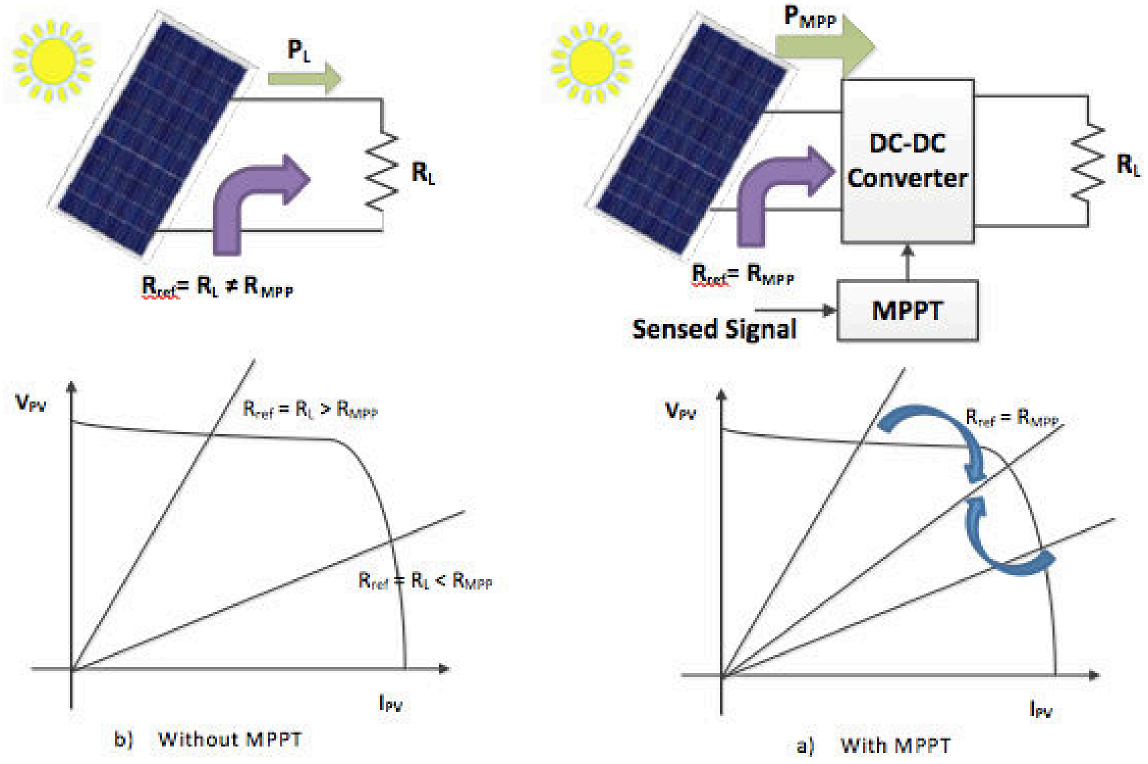


figure (5.2) PV solar power generation without and with MPPT

5.1.2-Mechanical tracker

Mechanical for solar power generation is dealing with direct radiation of the sunlight in both photovoltaic and solar thermal systems, For mechanical tracking there are on two types :

1-Monoaxial trackers
2-Biaxial tracker

5.1.2.1 Mechanical tracking in photovoltaic generation system.

the mechanical tracking in photovoltaic generation system is done by the mounting the stepper motor to the photovoltaic solar panel directly via a proper mechanism from motor to the panel. The two commonly used tracking in photovoltaic are tracking for conventional solar panel like what we have used in our thesis test works and the other one is used CPV (concentrated photovoltaic)

5.1.2.1.1 Mechanical tracking for conventional PV solar panel.

The tracking motor will be mounted to any solar panel to capture a maximum amount of direct radiation of the sunlight through a mechanism to transfer the motor rotation to an angular motion for the solar panel to get the required proper angle in any time .

5.1.2.1.2 Mechanical tracking for CPV Concentrated photovoltaic solar panel.

The same story in item 5.1.2.1.1 mechanical tracking is repeated for conventional PV solar panel, except the solar panel here is designed to be tracked mechanically because if the panel doesn't track mechanically the out put power will be nothing or will be close to nothing

The mechanical tracking is conditional for CPV.

5.1.2.2 Mechanical tracking in solar thermal plants.

Solar thermal mechanical tracking system is conational in what are mentioned in figure

We are not going in the detail of solar thermal because our work was restricted in photovoltaic mechanical tracking. but will briefly describe them .

5.1.2.2.1 Mechanical tracking in heating tower & heliostats

The mechanical tracking is only required for the heliostats to reflect the direct sunlight together simultaneously to the particular point located on the tower which has exactly taken the center location among the heliostats, the focused sunlight lead emerged from each heliostat together lead to heat up the working fluid inside the receiver to energize the steam cycle.

5.1.2.2.2 Mechanical tracking in Fresnel reflector.

Mechanical tracking used in Fresnel reflector is one directional. Like other mechanical tracking and the mechanism is used its tracking system is not much complicated may be simple as compared to some other mechanical tracker mechanisms used in other types of solar PV and solar thermal systems.

5.1.2.2.3. Mechanical tracking in parabola dish.

The mechanical tracking which used in parabola dish for solar thermal is mostly used biaxial or double axis tracking system.

5.2. the literature and what has done regarding mechanical tracking in PV, photovoltaic.

In recent years, there was an increasing amount of literature on solar systems. Numerous attempts have been made to improve the performance of such systems. Several studies focused on solar tracking as a method for performance improvement.

Engin, M. and Engin D. (2013) [12] developed a control algorithm that improves performance and reliability of the two-axis solar tracker, focusing on optimization of the controller board, drive hardware and software. An embedded two-axis solar tracking system and real-time control algorithm was developed for improving photovoltaic panel utilization. The system consists of a microcontroller, two motor-control modules, two DC motors, feedback devices, and other sensors needed for robust operation. The real-time control algorithm enables the solar tracker to be used as a stand-alone system, which can operate automatically without external control. The system combines two different control methods: the open-loop method and the closed-loop method.

Zolkapli et al. (2013) [13] designed and developed high-efficiency dual-axis solar tracking system using Arduino platform. Furthermore, the ultimate objective of this project is to trace the maximum sunlight source to power the solar panel. The project is divided into two stages, which are hardware and software development. In hardware development, five light dependent resistor (LDR) has been used for capturing maximum light source. Two servo motors have been used to move the solar panel at maximum light source location sensing by LDR. Moreover, the code is constructed using C programming language and targeted to Arduino UNO controller. The efficiency of the system has been tested and compared with static solar panel on several time intervals, and it shows the system react the best at the 10-minutes intervals with consistent voltage generated. Therefore, the system is proven to work for capturing the maximum sunlight source for high efficiency solar harvesting applications.

Elagib and Osman (2013) [14] described the design and development of a microcontroller based solar tracking system, based on solar maps, which can predict the exact apparent position of the sun, by the latitude's location, it also covers the solar tracking mechanical structure together with the associated electronic circuits. It presented a mean of controlling a sun tracking panel with an embedded microprocessor system. Specifically, it demonstrates working solution for maximizing solar cell output by positioning a solar panel at the point of maximum light intensity.

Paul (2013) [15] offered an implementation and development for prototype of automated two axis solar tracking system and a cost effective system for water heating application. Parabolic dish is constructed around 0.6m2area to capture the sun‟s energy. The assembly programming language is used to interface the PIC microcontroller with two-axis solar tracking system. This auto-tracking system is controlled with two 12V, 18N- m DC gear box motors. Tracking calculation is done by altitude and azimuth angular position of the sun, so that drawback in using light sensor based tracking method can be eliminated. Tracking errors due to weather and environmental factor can be eliminated by this system.

Cheng-Dar, Huang, and Yeh (2013) [16] presented the development of an image-based sun position sensor and the algorithm for how to aim at the sun precisely by using image processing. To verify the performance of the suntracking system including an image-based sun position sensor and a tracking controller with embedded image processing algorithm, a sun image tracking platform is established and the performance testing was conducted in the laboratory; the results show that the proposed sun tracking system has the capability to overcome the problem of unstable tracking in cloudy weather and achieve a tracking accuracy of 0.04°.

Ahmad, Shafie, and Ab Kadir (2012) [17] proposed the design, programming and results of a device that achieved low power consumption. The system has dual-axes tracking controlled by a Programmable Logic Controller (PLC) using a formula which was pre-calculated using the altitude and azimuth of the sun. The designed solar tracker was tested under several weather conditions in tropical climate environments. On a clear and sunny day, the power generated from the tracker is significantly higher than the non-tracking surface unit, whilst the powers consumed by motors and controller were 0.05% and 5.84%, respectively. Overall, the power consumption of the tracker is only 5.89% of the total power generated.

Zhang, Li, and Lu (2012) [18] described the implementation of an intelligent solar tracking system based on embedded microcontroller LPC2131. It can improve the photoelectric conversion efficiency of the solar cell array by tracking the movement of the sun through 2-axis stepping motors' rotation. In order to achieve this goal, a new calculation method for sun position is introduced briefly comparing with two conventional solar tracking methods. Then, the hardware structure of the intelligent solar tracking system based on PhilipsLPC2131 microcontroller is proposed and implemented in detail. Fuzzy control strategy is applied to the control mechanism to ensure its adjustability and fast response time. So that solar tracking system increases the efficiency of solar panels with high accuracy and flexibility.

Kivrak, Gunduzalp, and Dincer (2012) [19] studied an open-loop, two axes movable photovoltaic (PV), solar tracker which was designed and analyzed. Its performance over a fixed tilted (37o) PV system is evaluated theoretically and experimentally for the climatic condition of Denizli, Turkey. Two DC actuator motors are used for the movement of the solar tracker. In addition to the experimental data, a computer program in Visual C#2005 that uses the equations for the solar radiation values of fixed and moving systems is developed. The performance difference of a fixed tilt PV panel and a two-axis moving PV panel was compared for months of May and June and it was found that the energy generation increases nearly 64% for tracking system when it is compared with fixed PV system.

Xie and Zhang (2011) [20] considered a triple-junction solar cell to achieve the highest efficiency. But the systems require concentration and accurate tracking to maintain the focus of the light on the solar cells as the sun moves throughout the day. The tracking system was built with two-axis driven by motor with angle sensor feedback. The two angles were determined by solar positions which are calculated from solar geometric algorithm. The driving system was closed-loop with PID control to reduce errors of the angle output. During the simulation and test, the tracker has been validated by the test data sets. The control system could meet the demand of the Fresnel concentration. With this tracking system could obviously improve the efficiency of the triple-junction solar cell.

Li and Zhou (2011) [21] presented a kind of design method of sun tracker for more transformation efficiency. Using simplified circuit, the tracker can follow the round of sun, which can keep the surface of the solar battery perpendicular to the ray of the sun to obtain the greatest area of light as possible. Also, some parameters, such as local latitude, local time etc. are needed to input by operators. The results of experiment are demonstrated through validation of the sun tracker. This system uses a DC motor and closed-loop control to avoid the angle error in time accumulation, at the same time AVR128 microcontroller is used.

Barsoum (2011) [22] gave a fabrication and installation of a solar panel mount with a dual-axis solar tracking controller. This is done so that the rays from the sun fall perpendicularly onto the solar panels to maximize the capturing of the rays by pointing the solar panels towards the sun and following its path across the sky with dual photo sensors aid to compare the left – right light and up – down light intensity controlled with a PIC16F84A micro controller.

Kassem and Hamad (2011) [23] described a prototype for a microcontrollerbased multi-function solar tracking system, which will keep the solar panels aligned with the sun in order to maximize efficiency. The maximum power point tracking (MPPT) data can be transmitted in real time to other solar systems in need of this data. The control system which is the brain of the proposed system is used to turn a small PV panel in three directions to determine the maximum output current. Three photo-resistors are used every 45 minutes to redirect the PV panel to get the nearest value of the maximum sun.

Farzin et al. (2011) [24] tried to optimize the solar energy in a new way according to the increasing importance of renewable energies and a sample biaxial sun tracker is built. There are three algorithms for tracking the sun: first algorithm, moves the plane in circular coordinates in the small ranges, then finds the point with the best voltage for its field of work and oriented to that and then repeats it again. Second algorithm, finds the slope of the voltage and uses it to find its way. Third algorithm is like second but uses it to find some appropriate points that are distinct in different times. It uses nonlinear multi parameter relation with last mean square method for finding the altitude and predict where the sun will be in the next step. This algorithm, applys this equation to positioning and then verifies second algorithm for confidence. The mechanism for this work is programmed with a digital program that is used in the control system. Position of the sun is calculated and error points will be revealed during routine activities of system.

Seme, Štumberger, and voršič (2011) [25] considered two-axis sun tracking system for a photovoltaic system. The trajectories of the sun tracking system are determined in an optimization procedure. The optimization goal is maximization of an electric energy production in the photovoltaic system considering the tracking system consumption. Determination of the tilt angle and azimuth angle trajectories is described as a nonlinear and bounded optimization problem, where the objective function is not available in the explicit form. A stochastic search algorithm called Differential Evolution is used as an optimization tool. In the optimization procedure, the objective function is evaluated by using the models of available solar radiation, tracking system consumption, and the efficiency of solar cells with the appropriate dc/dc converters. The problem bounds are given in the form of lower and upper bounds for both angles and time and angle quantization. The results presented in the paper show, that the optimal trajectories for the tilt and azimuth angle depend on the available solar radiation, solar cell efficiency, tracking system consumption and the optimization bounds.

Lu and Shih (2010) [26] presented the design of an active solar panel dualaxis sun tracking system with maximum power point tracking fuzzy controller. The tracking system tracks the maximum solar power point and orients the solar panel toward the Sun to enhance the efficiency of the photovoltaic (PV) generation system. The maximum power point of the PV panel is identified in real time and inputted to two fuzzy controllers for dual-axis tracking system. After that, the rotated angles will be got to make the mechanism rotate to the appropriate position. Through the sun tracking method, the PV panel will face the Sun directly. Additionally, four light sensors play a part in tracking the sun position. Through the simulation results, it demonstrates that the appropriate rotation angle of manipulator can be obtained by the two fuzzy controllers to enhance the collected solar radiation.

Abas et al. (2010) [27] designed and presented a new mechanical structure prototype for solar tracker. The structure implements two stepper motors for free rotation on X and Y axis. The rotation is intelligently controlled by a preprogrammed 2K microcontroller device PIC 18F4560 which provides simple programming strategy through C language. The designed algorithm is based on the measurement of intensity of solar radiation which is captured by an ultra violet sensitive device known as Pyranometer.

Nabulsi et al. (2010) [28] presented the design and implementation of a twoaxis standalone rotary sun tracker. The objective is to analyze the effects of introducing both physical sun-tracking and maximum power point tracking (MPPT) on PV systems‟ efficiency in the gulf region. A two-axis rotation mechanism is implemented to track the sun over both the azimuth and elevation angles. The position of the sun is determined using the astronomical method. The sun‟s azimuth and elevation angles are continuously updated throughout the day using a Digital Signal Processor (DSP). The calculated angles are then used as set-points for two closed-loop control systems with PI controllers implemented in the DSP. The panel power is passed through a charger that implements perturb and observe MPPT algorithm to keep the system power operating point at its maximum value.

Pattanasethanon S. (2010) [29] supposed an optimal control on two axes solar tracker which is called altitude and azimuth. The phototransistor with the shade that blocks the screen was employed as a detector of solar beam radiation. The height of the screen determined the sensitivity operation or period of tracking in this solar tracker. The phototransistor is particularly designed to detect solar beam radiation thoroughly through the two axes within the operating time. The mechanism of this solar tracker is that it has a capacity of solar tracking in every 10 min, approximately, which responds in terms of time at about 37° sec−1with an operating point at 0.3 sec. This tracker obtained an average deviation at about 2.5° h−1. In weak sunlight however, the value varies and fluctuates rapidly depending on sky condition. There is only average of 2.5° error in this tracker. The experiment also shows that the error rate diminishes as the solar radiance expands.

Xiaofang and Wencheng (2010) [30] implemented a new tracking system based on Concentrated Photovoltaic (CPV), the tracking accuracy and sensitivity of the solar tracker has a significant influence on the lighting rate and power generation rate of CPV system. The CPV solar tracker based on ARM tracks the sun mainly by using the CMOS sensor. In order to improve the tracking sensitivity, a method of sun spot center orientation based on canny edge operator and ellipse fitting is presented in this tracker. The new method is not demanding for integrity and definition of the sun spot. After being used in the CPV solar tracker, the superiority of accuracy and applicability of the new method is proved by comparison with the traditional methods.

Oo and Hlaing (2010) [31] developed and implemented a prototype of two-axis solar tracking system based on a PIC microcontroller. The parabolic reflector or parabolic dish is constructed around two feed diameter to capture the sun‟s energy. The focus of the parabolic reflector is theoretically calculated down to an infinitesimally small point to get extremely high temperature. This two axis auto-tracking system has also been constructed using PIC 16F84A microcontroller. The assembly programming language is used to interface the PIC with two-axis solar tracking system. The temperature at the focus of the
parabolic reflector is measured with temperature probes. This auto-tracking system is controlled with two 12V, 6W DC gear box motors. The five light sensors (LDR) are used to track the sun and to start the operation (Day/Night operation).Time delays are used for stepping the motor and reaching the original position of the reflector. The two-axis solar tracking system is constructed with both hardware and software implementations.

Dasgupta et al. (2010) [32] described the design and implementation of a novel two axis sun tracking system which utilizes no external light sensors to make PV cell facing in the direction of maximum irradiation to promote system efficiency. The novelty lies in the practical utilization of solar panels as the sensors. The hybrid of the solar cell’s electrical attributes is used to determine insolation parameter. The positioning of the PV cell in the tracking system is driven by two stepper motors which could position the PV cell almost perpendicular to the sun during the day time. Meanwhile, the search algorithm is implemented using step perturbation method. Based on the experimental results, it can be concluded that the novel sun tracking system is not only capable of maintaining optimal tilt angles for the PV cells, but also capable of giving actuator signals for panel protection from excessive heat and logging data with real time performance monitoring.

Jiao et al. (2010) [33] proposed two-axis sun-tracking system that keeps PV panel perpendicular to sunlight by absolute and relative position sensors signal analysis. The photovoltaic (PV) panel produces the maximum power as the incident angle of sunlight is 90 . It is composed of micro-controller, solar illumination sensor, solar position sensors, stepper motors and drivers, two-axis motion mechanism, zero position switches, limit switches and solar system. The tracking range is (-80 , 80) at azimuth and at (10 , 85) altitude. The tracking error is ±0.01 . The system has wide suitability and low cost. It can be applied in all types of solar systems. It could work in the south hemisphere just like in the north hemisphere. Even in equatorial regions, the system just needs exchange east with west semiannually. The innovatively designed two position sensors used visible light sensors to detect the sun in any position quickly. The innovative relative sensor’s orientation increases its measure range. Furthermore, the system improves tracking precision by correcting track.

According to the literature, the dual-axis tracking systems receive more solar radiation and produce more electricity than fixed and single axis tracking system. Dual-axis tracking systems produce about 60% (depends on location and weather condition) more power than fixed systems tilted at latitude angle. The compromise between the energy collected from the sun and that consumed during tracking was important factor to some researches and it not mentioned in others, but it focused on the accuracy of tracking methods. The researches varied in using of light sensing methods between LDR, image-based sun position sensor using image processing, Pyranometer, phototransistor, CMOS, and solar panels as a light sensor.
In each of the above researches, a different control strategy to perform tracking was used; each strategy is chosen to be suitable with its own system capabilities. Control is the way to lead the apparatus in a certain algorithm, every researcher utilizes different control procedure that follows two major paths: closed loop control or open loop control system. For the open-loop tracking system, the tracker will perform calculation to identify the sun‟s position and determine the rotational angles of the two tracking axes using a specific sun-tracking formula in order to drive the solar collector towards the sun. However, this automated system will stay operational even if the weather is cloudy and there is no sun visible to track. The open loop type is simpler and cheaper but it could not compensate for disturbances in the system and has low accuracy.

On the other hand for the closed-loop tracking system, the sun tracker normally sense the direct solar radiation falling on a light-sensor as a feedback signal to ensure that the solar collector is tracking the sun all the time and keep the solar collector at a right angle to the sun’s rays for getting the maximum solar

6.Methodology and experimental steps and results:

The plan that we have designed for the thesis experimental works have studied in the way that the location for the experiment should be chose to provide the accuracy and validity as well as reliability for the input data's and output results, we have chose Erbil city, university of salahaddin , mechanical and mechatronics engineering building [ ] , and the date of our experimental data acquisition have been designed to be the summer time beginning date from (3-7-2019) to the (18-7-2019) which was expected no cloud will be appeared during this time we can guarantee that the weather at this period is totally sunny and fine.

What we have designed to use inters of equipment and tools for the experiment, is two sets of solar panels one is installed to be unmovable and fixed and other set is motorized solar panel installed to be tracked and they were placed nearby each other on the same roof approximately 3-4 meters away from each other the required parts of the photovoltaic circuit such as power conditioner, including DC-DC convertor and DC-AC invertor as well as MPPT the maximum power point tracker, have been installed in addition a battery backup and a micro controller is connected to gather the data's and monitor the data acquisition process .

6.1.Methodology:

The objective of this work is to trap the maximum amount of solar energy from the incident solar radiation on the solar panels through tracking the solar panel by a motor, and making comparison between what is delivered as a power out put from the fixed solar panel and tracked solar panel,

Mechanical tracker of the solar panel is dealing with the direct radiation, there is no benefit from mechanical tracking of the solar panel for the diffuse radiation, the only parameter that influencing the output power of the solar panel tracking is a direct sunlight it is possible to say that the power output of the tracking solar panel is a function of the direct sunlight

Mechanical tracking of the solar panel power output $= f$(direct sunlight).

Thinking about solar panel tracking for trapping the diffuse radiation is unviable and is incorrect.

6.1.1.Steps of experiment:

First of all we have to list the parts that are using in this experiment and define them and explain their functions and the way of connecting to each other so as to complete the pv circuit

Secondly we have to explain the way of taking data's and gathering the results

6.1.1.1Solar panel

We have used the monocrlystaline solar panels because it is commonly used in the marketplaces and we wanted to make our experiments something applicable in the market places.

Technical Specifications:

6.1.1.2.Sensors.

Sensor is used to guide the tracking of the solar panel directly sends signal to the motor to change the face of the solar panel within a required angle.

The sunlight sensing circuit: With a view to get the optimal tracking efficiency, it is necessary to sense the position of the sun and for that electrooptical sensor is needed. Four LDRs (Light Dependent Resistors) are used in the Wheatstone bridge circuit diagram for the sensor system as illustrated in Figure 4.9. Every one of LDR is connected in series with 1KΩ resistor in order to make a voltage divider on the nodes that are numbered from 1 to 4.

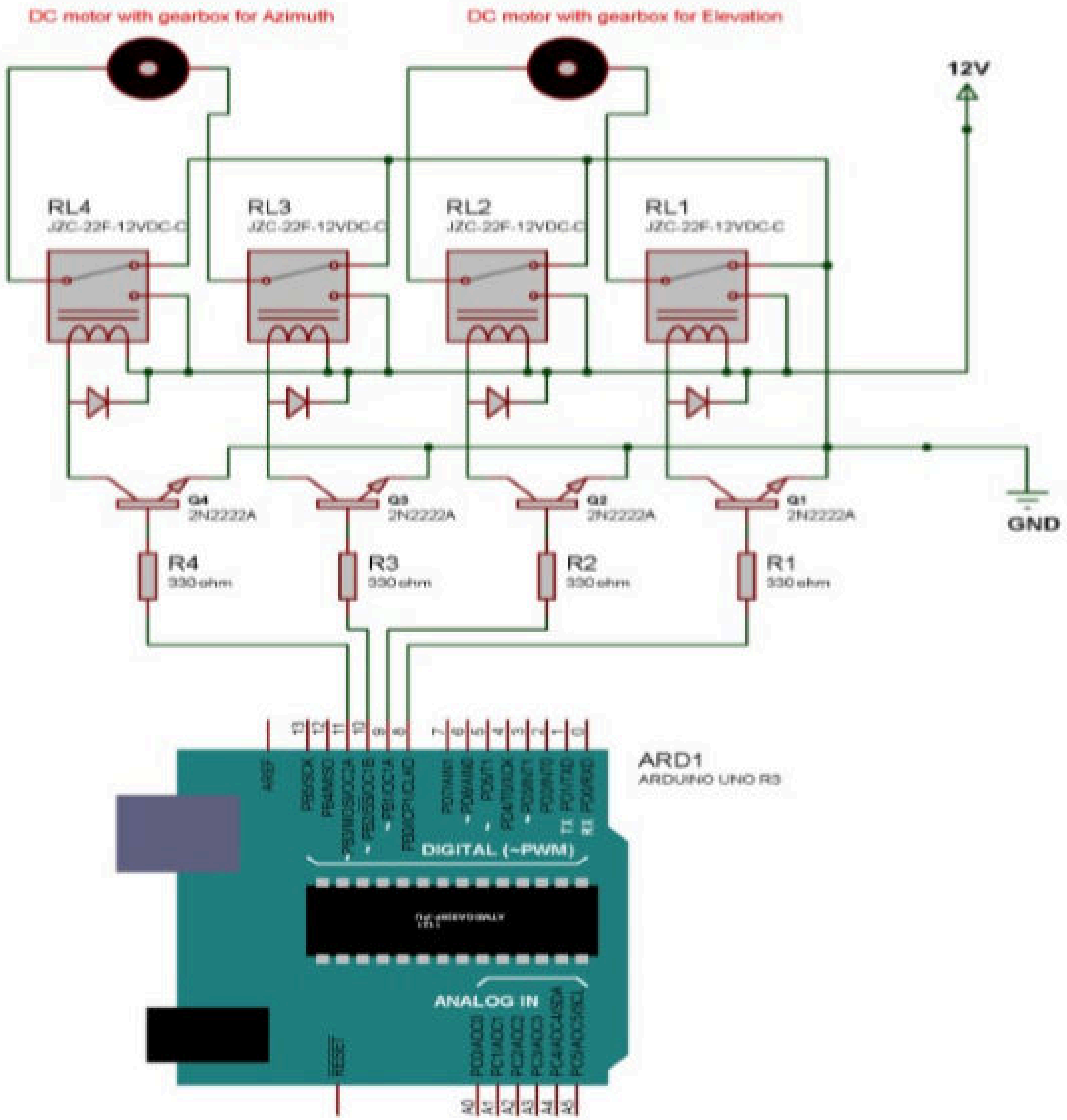


Figure 6.1 Wheatstone bridge circuit of the sensor system

If one of the LDR gets more light intensity than the others, the node voltage difference will be received as an analog signal at the analog input channels on the Arduino platform that are labeled as A0 through A3. Arduino analyzes this data and generates a logic signal to actuate the motor, to move the sensor module to a position where equal light is being illuminated on a pair of LDRs. The Arduino is programmed to generate the logic for azimuth as well as altitude tracking and motor rotation in either clockwise or anticlockwise direction depending on the shadow on LDRs due to perpendicular plastic sheets; these sheets separate LDRs by 90 space rotation as shown in Figure 4.10. Also Figure 4.11 represents the light sensor attached to the solar cell.

If all the four LDRs are equally illuminated by the sun, then the analog voltage signals received at the ADC channel of the microcontroller will have equal values and microcontroller will not generate any logic signal to actuate the motors.

Light Dependent Resistor (LDR)

Light dependent resistor or Cadmium Sulphide cell (Figure 4.12) is a photo resistor whose resistance decreases with increase in light intensity. If light falling on the device is of high frequency, photons absorbed by the semiconductor gives enough energy to bound electrons to jump into the conduction band. The resulting free electron conducts electricity, thereby lowering the resistance.

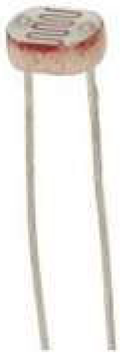


Figure 6.2 Light Dependent Resistor (LDR)

- Technical Specifications of the LDR

Table 4.3 Technical Specification of LDR

Parameter	Value
Diameter	5mm
Dark resistance	1MΩ
Maximum voltage	150V
Maximum power	100mWatt
Operating temperature	-30 C° to +70 C°

Spectrum peak value	540nm

4- The Angle Sensor (Rotary Encoder): A rotary encoder, also called a shaft encoder, is an electro-mechanical device that converts the angular position or motion of a shaft or axle to an analog or digital code. There are two main types: absolute and incremental (relative). The output of absolute encoders indicates the current position of the shaft, making them angle transducers. The output of incremental encoders provides information about the motion of the shaft, which is typically further processed elsewhere into information such as speed, distance, and position.

Absolute and incremental encoders

An "absolute" encoder maintains position information when power is removed from the system. The position of the encoder is available immediately on applying power. The relationship between the encoder value and the physical position of the controlled machinery is set at assembly; the system does not need to return to a calibration point to maintain position accuracy. An "incremental" encoder accurately records changes in position, but does not power up with a fixed relation between encoder state and physical position. Devices controlled by incremental encoders may have to "go home" to a fixed reference point to initialize the position measurement.

Pulse width modulation signal output absolute encoder

Pulse width modulation is a very effective technology using the digital output of the microprocessor to control analog circuits, widely used in measurement, communications, power control and conversion and many other fields. In practical engineering, the rotary encoder as shown in Figure 4.13 outputs a PWM signal corresponding to an absolute angle value, and can use digital processor‟s I / O interfaces and timer to sample directly, which is convenient and rapid for developers, while reducing hardware costs. Absolute encoder‟s regular outlet form is side outlet, 3-wire. Non-standard outlet form can be customized.

Technical Specifications:

6.1.1.3.Tracking motors.

The tracking motor for the solar panel should efficient and have as much as possible low power consume because the power which the motor consumes is getting inside the calculation of the photovoltaic efficiency i.e. the consumed power by the tracking motor is calculated to be on the expenses of the output power of the solar panel

Rolling
Pitching

yawing

Net solar power out put from the tracked panel = power of the tracked solar panel-tracking motor power consuming

6.1.1.4.Power conditioner.

6.1.1.5. Batteries.

6.1.1.6.Load.

6.1.1.7.Micro controller.

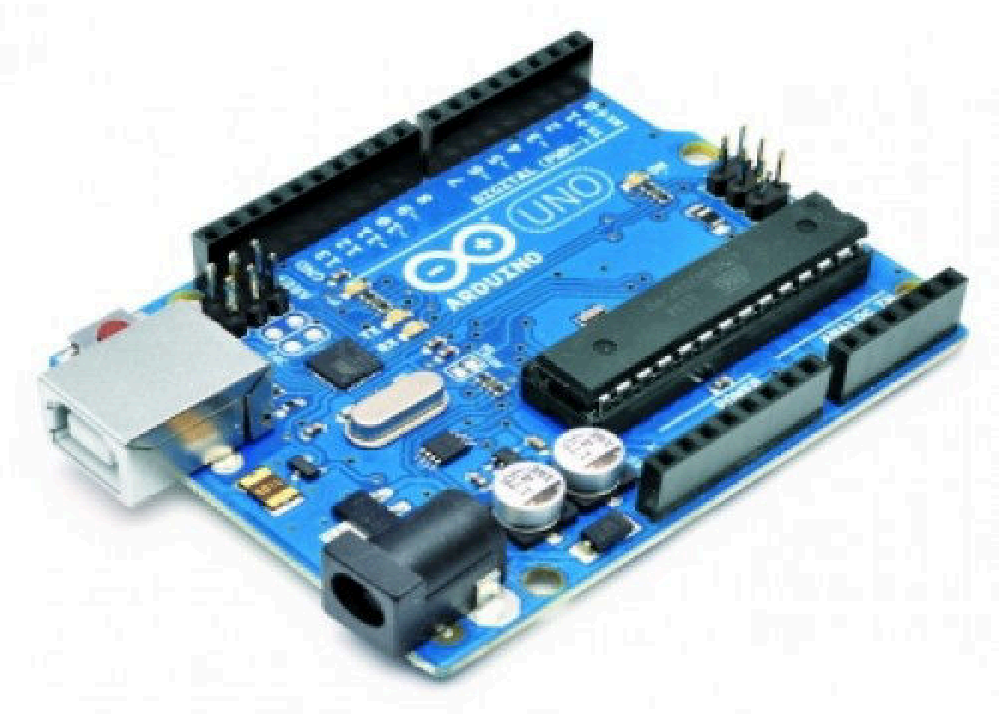


Figure 6.3 Arduino Uno R3

1- Arduino Uno Platform: The Arduino Uno is an open-source microcontroller board based on the Atmel AVR (ATmega328) microcontroller. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; connected simply to the computer with a USB cable or power the board with an AC-to-DC adapter or battery to turn the board on. Arduino Uno Revisio platform is shown in Figure 6.3.

- Board specification :.

Table 4.1 Summary of board specification

Parameters	Value
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage(recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40mA
DC Current for 3.3V Pin	50mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

- Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- **VIN**: The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). Voltage can be supplied through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **- 5V**: This pin outputs a regulated 5V from the regulator on the board.
- **- 3V3**: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **- GND**: Ground pins.
- **- IOREF**: This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V.

- Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

- Input and Output

Each of the 14 digital pins on the Arduino Uno can be used as an input or output, using programming functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial**: pin 0 (RX) and pin 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
-

-**External Interrupts**: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.

-

PWM: pins 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output

- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.

- **SPI** (Serial Peripheral Interface): SPI was developed by MOTOROLA and it is very renowned name in data transmission. It has only three lines (i.e. MISO, MOSI and SCK) for data transmission as well as for handshake unlike UART (which requires 9 pins for full feature operations). In SPI communication, there is only one MASTER controller and one SLAVE controller, and hence the slave addressing is not required. It is a full duplex serial data communication process. The MASTER can read from MISO line while transmitting data on MOSI line. The MASTER controls the complete process of data transmission and also provides synchronization clock on the SCL line. Since the synchronization is done by the MASTER itself, the SLAVE device need not worry about the clock frequency at other end. The data size is not restricted to 8-bit data. The main disadvantage in SPI interfacing is that it can be established only for short distance communication. Though only three pins are required for data transmission, one additional pin (SS) is required in SLAVE device.

-

  - LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off. The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though it is possible to change the upper end of their range using the AREF pin.

- Additionally, some pins have specialized functionality:
  - TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

TWI (Two wire interface as in Figure 6.4): The TWI / I2C (I-two-C) protocol was invented by Philips. In TWI the serial data transmission is done in asynchronous mode. This protocol uses only two wires for communicating between two or more ICs. The two bidirectional open drain lines named SDA (Serial Data) and SCL (Serial Clock) with pull up resistors are used for data transfer between devices. One of the two devices, which controls the whole process, is known as Master and the other which responds to the queries of master is known as Slave device. SCL is the clock line bus used for synchronization and is controlled by the master. SDA is known as the data transfer bus.

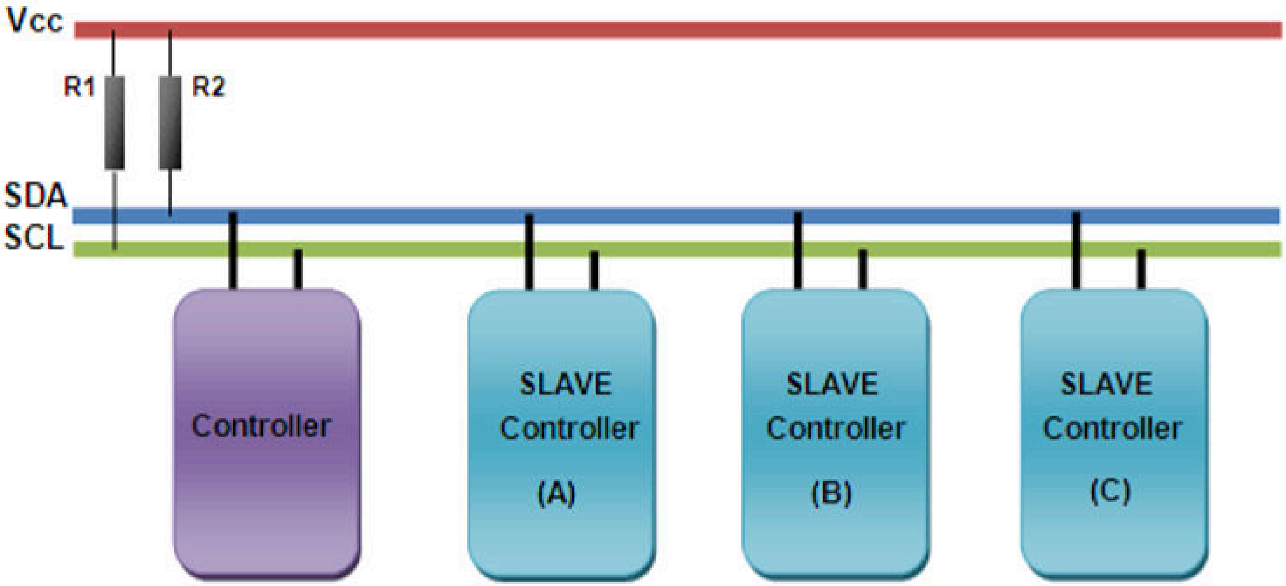


Figure 6.4 TWI Communication

- AREF: Reference voltage for the analog inputs.

- Reset: Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

- ATmega328 Microcontroller ATmega328 chip is the heart of the entire circuit because it controls the terminals with a specific time. The Atmel 8-bit AVR RISC-based microcontroller as shown in Figure 4.5 combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter , programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts. By executing powerful instructions in a single clock cycle, the device achieves throughputs approaching 1 MIPS per MHz, balancing power consumption and processing speed.

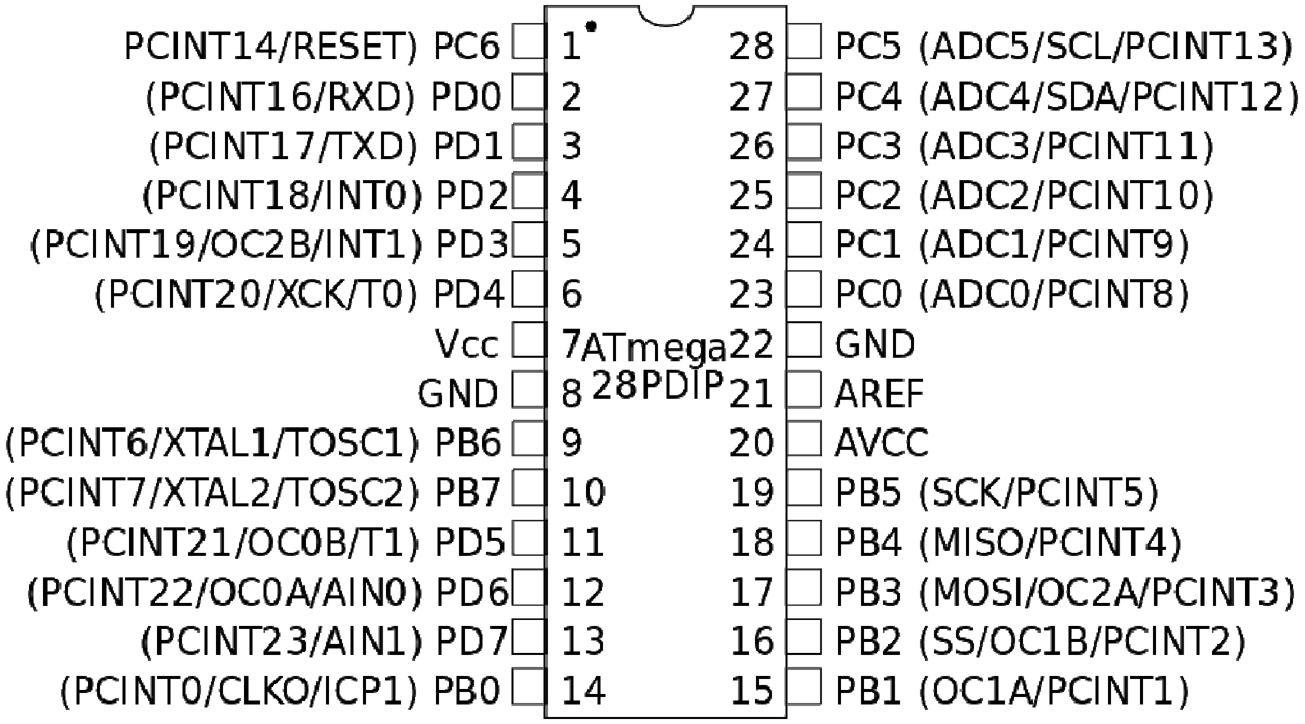


Figure 6.5 ATmega328 Microcontroller [39]

- Key Parameters

➢ Flash	32 Kbytes
➢ RAM	2 Kbytes
➢ SRAM	2 Kbytes
➢ EEPROM	1024 byte

Maximum Operating Frequency	20 MHz
PWM Channels	6
ADC channels	8
ADC Resolution	10 bits
ADC Speed	15 Ksps
SPI	2
TWI (I2C)	1
CPU	8-bit AVR
Maximum I/O Pins	23
Temp. Range	-40 to 85 C°
Operating Voltage (Vcc)	1.8 to 5.5 V
Timers	3

- Communication The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-toserial chip and USB connection to the computer (but not for serial communication on pins 0 and 1). A Software Serial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication.

- USB Overcurrent Protection The Arduino Uno has a resettable poly fuse that protects the computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

- Physical Characteristics The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case [39].

2- The H-Bridge circuit: In robotics applications, the DC motor needs to change its direction. The H- Bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. It is designed to drive a motor clockwise and anticlockwise. To reverse a motor, the supply must be reversed and this is what the H-Bridge does. Microcontroller has a voltage level in the range of 0-5V, so it cannot drive a DC motor with 12V operating voltage. The H- Bridge is used to amplify the voltage level to the level of DC motor, which is 12V. The H- Bridge consists of relays, transistors, resistors and diodes as seen in Figure 6.6.

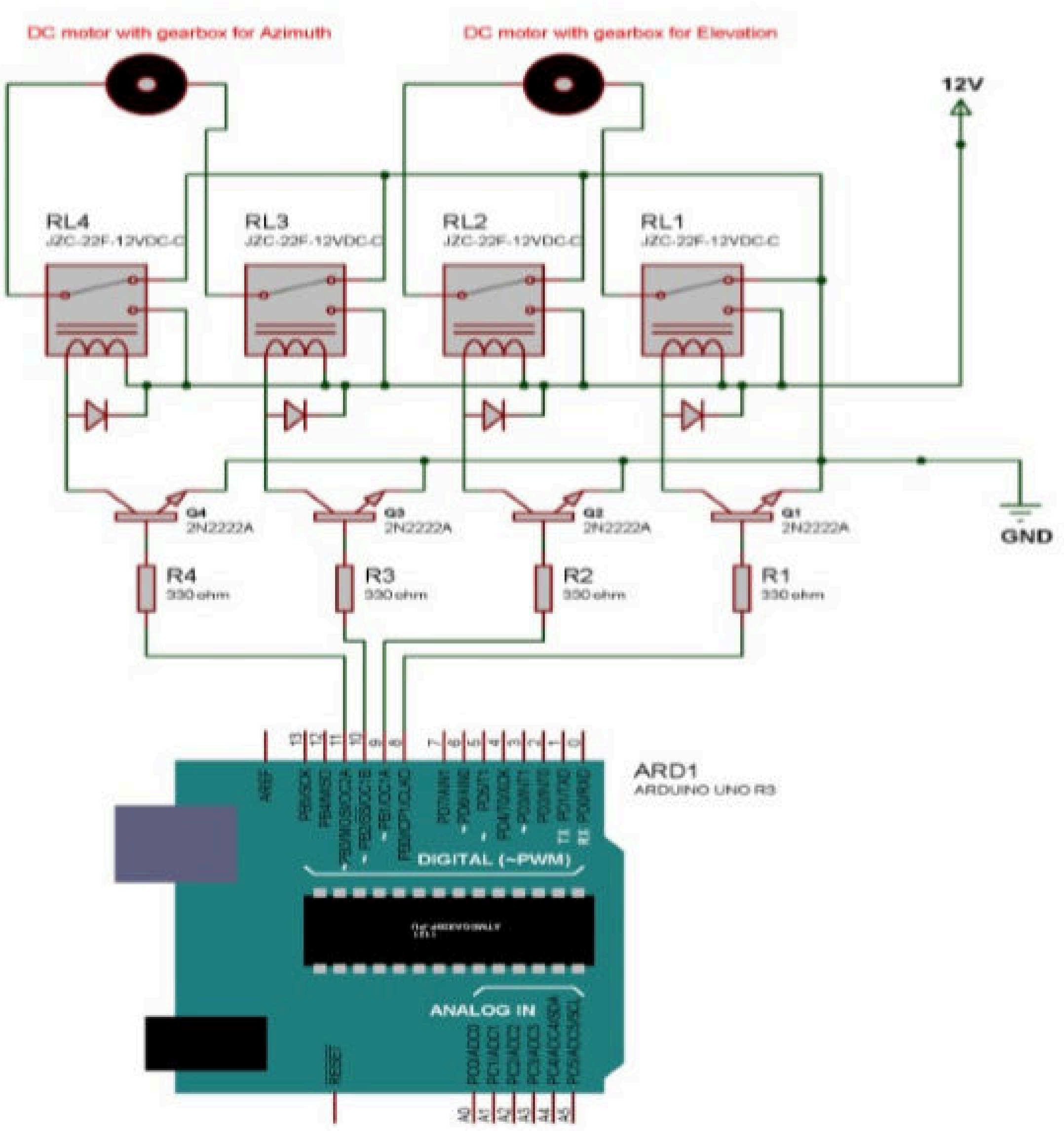


Figure 6.6 The H-Bridge driving two DC motors

H-Bridge operation principles

As illustrated in Figure 6.7 below the motor has two grounded terminals, without any action signal the motor is at standstill. To turn the motor in a clockwise direction, the left terminal is switched from Ā to A and the current will flow as the blue arrow direction. To turn the motor counter clockwise, the left terminal is switched from A to Ā and the right terminal is switched from to B and the current will flow as the red arrow direction. These switches are replaced with relays and transistors in order to actuate the motors in both directions by microcontrollers. Relays are used as a DC motor driver to amplify the voltage level because microcontroller has voltage level in the range of 0-5V. The logic signal generated by the microcontroller causes to energize the driving circuit, for the movement of DC motor after that a gear drive is used to convert low torque to high torque and to achieve the desired speed. Figure 6.8 shows the PCB of the H-Bridge circuit that is mentioned above.

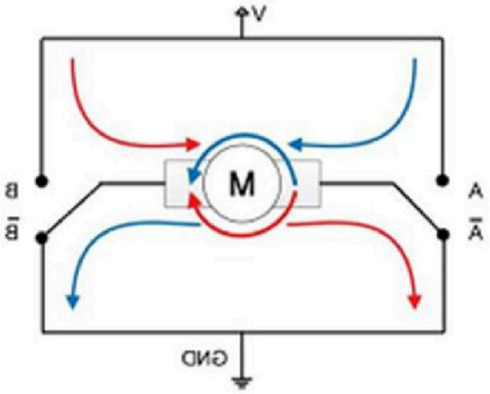


Figure 6.7 The H-Bridge theory

Figure 6.8 The H-Bridge PCB

The PCB components that the H-Bridge circuit is compose of are described briefly in the table 4.2 below.

Table 4.2 H-Bridge Components

NO.	Component	Type
1	Relay	JZC-22F-12VDC-C
2	NPN Bipolar Transistor	2N2222A
3	Diode	General purpose
4	Resistor	Carbon Film Resistors 330 Ω 0.25 watts

6.2. Test results.

As shown in the appendix all of result data's have been shown and out of those result data's we have a new data table by reduction the half -hourly based taken result data's to a monthly-based result data's for both fixed and tracked PV system of our experimental work. the reduction of half-hourly based result dates to a monthly data's have done by taking average of former to get the latter

overall data for tracking								
			Battery			Solar		
Time	Winds(Km/h)	Temp©	Voltage	Ampere	watt	Voltage	Ah	Wh
9:00	7w	36.67	25.64	3.60	95.02	13.29	0.00	23.73
9:20	7w	36.67	25.69	3.78	97.09	13.33		52.72
9:40	7w	36.67	25.78	3.79	97.56	13.37		82.04
10:00	9w	39.00	25.79	3.89	100.05	13.53		105.60
10:20	9w	39.00	25.82	3.89	100.32	13.56		137.52
10:40	9w	39.00	25.84	3.84	99.11	13.50		172.00
11:00	13wsw	40.50	25.91	3.85	99.69	13.52		185.83
11:20	13wsw	40.50	25.97	3.88	100.50	13.61		236.57
11:40	13wsw	40.50	26.06	3.75	99.30	13.72		270.18
12:00	13wsw	41.50	26.24	3.78	98.80	13.51		301.85
12:20	13wsw	41.50	26.24	3.79	99.32	13.58		333.52
12:40	13wsw	41.50	25.95	3.84	99.54	13.54		369.07
13:00	15wsw	42.00	26.05	3.87	98.53	13.47		393.19
13:20	15wsw	41.92	26.14	3.79	99.04	13.55		428.23
13:40	15wsw	41.92	26.09	3.73	97.26	13.49		457.89
14:00	15wsw	42.08	26.05	3.72	96.83	13.51		485.19
14:20	15wsw	42.00	25.83	3.68	94.93	13.38		513.68
14:40	15wsw	42.00	25.95	3.62	93.82	13.35		543.07
15:00	17wsw	41.08	25.82	3.55	91.12	13.30		569.28

overall data for fixed panel								
			Battery			Solar		
Time	Winds(Km/h)	Temp©	Voltage	Ampere	watt	Voltage	Ah	Wh
9:00	7w	36.67	24.49	1.78	44.93	16.35	0.00	14.48
9:20	7w	36.67	24.45	2.06	52.26	16.19	0.00	26.00
9:40	7w	36.67	24.54	2.27	57.46	16.32	0.00	43.82
10:00	9w	39.00	24.61	2.60	66.33	15.98	0.00	63.69
10:20	9w	39.00	24.67	2.88	73.44	15.59	0.00	86.72
10:40	9w	39.00	24.69	2.91	74.31	15.89	0.00	112.63
11:00	13wsw	40.50	24.70	3.08	79.00	15.64	0.00	136.28
11:20	13wsw	40.50	25.07	3.39	87.66	15.29	0.00	156.76
11:40	13wsw	40.50	25.14	3.25	84.04	15.74	0.00	193.01
12:00	13wsw	41.50	25.35	3.38	87.74	15.35	0.00	212.57
12:20	13wsw	41.50	25.47	3.38	88.06	15.28	0.00	240.67
12:40	13wsw	41.50	25.24	3.56	92.15	15.16	0.00	278.86
13:00	15wsw	42.00	25.30	3.50	91.00	15.35	0.00	303.08
13:20	15wsw	41.92	25.36	3.52	91.61	15.00	0.00	335.40
13:40	15wsw	41.92	25.27	3.48	90.23	15.23	0.00	371.13
14:00	15wsw	42.08	25.25	3.43	88.95	15.25	0.00	401.17
14:20	15wsw	42.00	25.15	3.37	86.82	15.36	0.00	429.92
14:40	15wsw	42.00	25.08	3.30	84.83	15.23	0.00	455.55
15:00	17wsw	41.08	24.91	2.98	79.97	15.71	0.00	477.81

As showen in the chart relation between the time for the x axis and out put power for the y- axis we are clearly see the difference between an out put result for both fixed and tracked PV panels of our experimental work as illustrated in the figure (6.9)

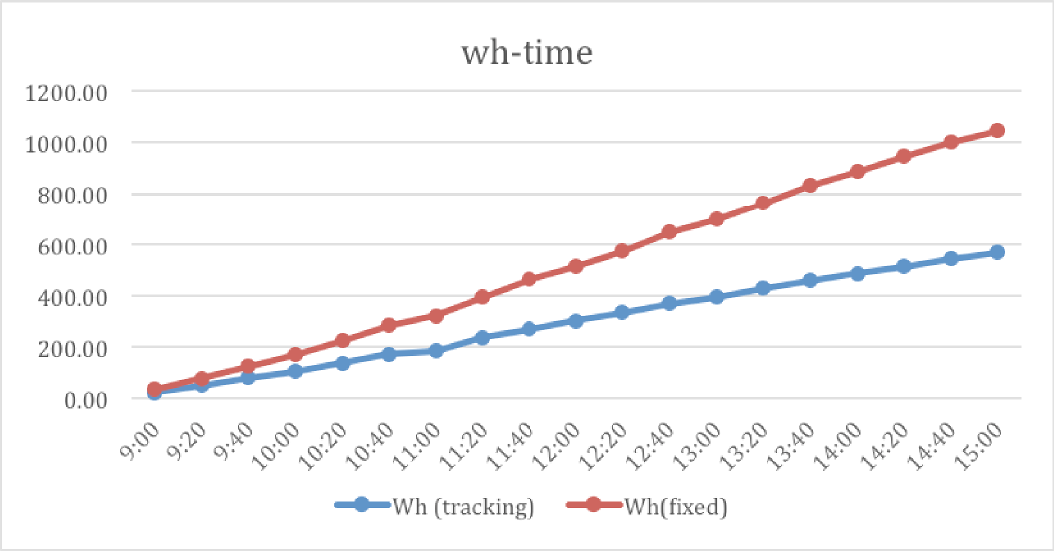


Figure (6.9) the chart relationship between time and output power for both fixed and tracked pv system of our experimental work, motor power is not calculated

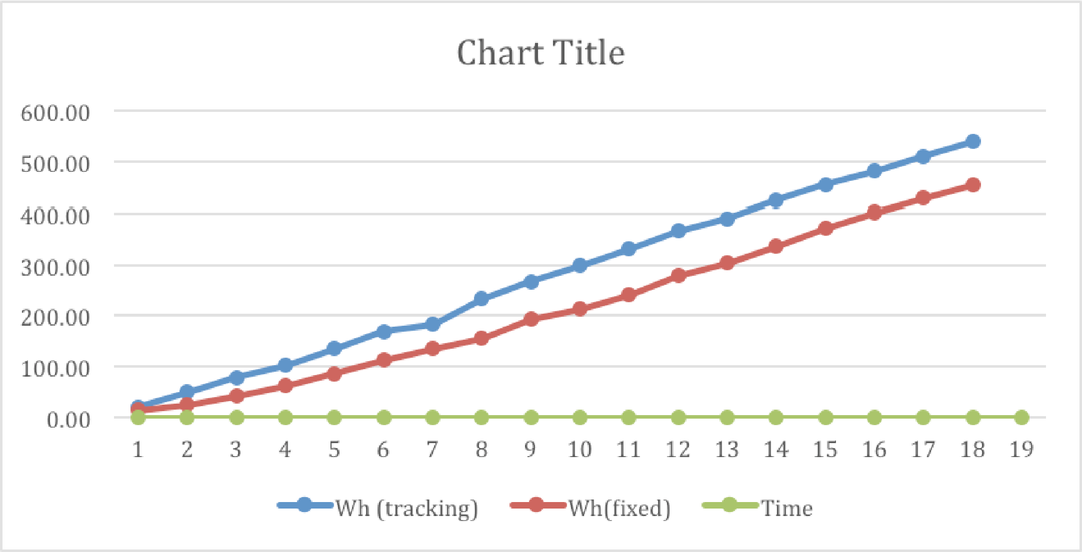
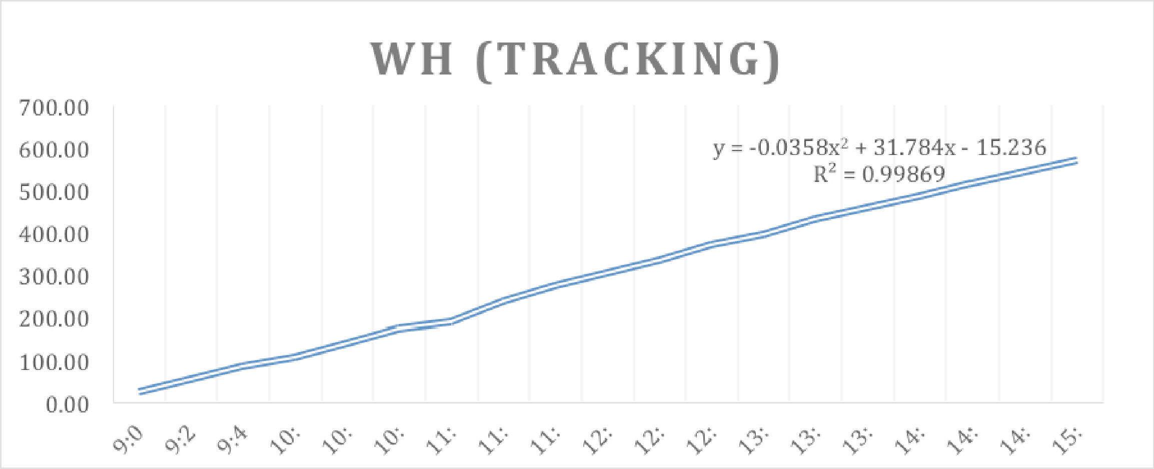
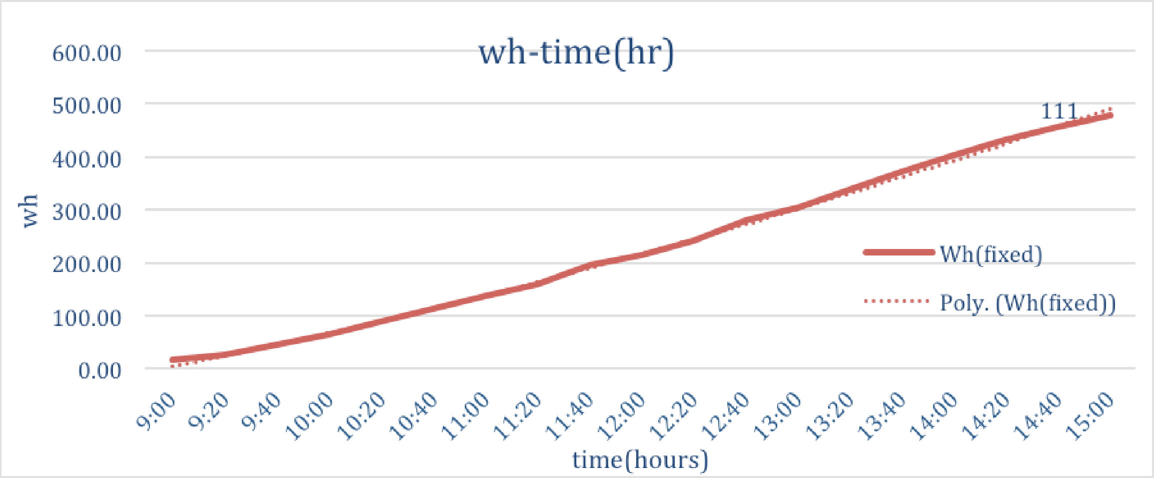


Figure (6.10) the chart relationship between time and output power for both fixed and tracked PV system of our experimental work, motor power is calculated .

The motor power is assumed to be unchanged and used 3.0 W as its rated power.





7. Conclusion.

Once we gazing at our experimental result data's and charts we will figure out that the mechanical tracking system is helping the PV solar panel obviously trap the greater amount of direct solar radiation as compared to the fixed PV panel
There are some points to be explained and discussed and also some points need to be suggested, hence, we are going to give some details in discussion and future works

7.1. Discussion.

During our experimental works some issues came to be decided and fixed to make our work comes closer to the reality as much as possible, here are the points explained as below

1- the effect of wind on the performance of mechanical tracking sometimes the wind force which has subjected to the panel supporting the motor for tracking and some others is standing against the solar panel tracking direction and tackling the movement of the motor and made the motor uses additional power to its rated power and eventually will adversely affecting on the overall efficiency of the PV output and vise versa. During our experimental test we have some hours that the wind speed is very low as shown below.

2-temeperature and wind, in terms of the PV solar panel the ambient temperature rise will increase the temperature of the PV solar panel while wind speed may affect of decreasing the temperature of the surfaces of the PV panel the overall efficiency will has another value if we involve both of temperature and wind speed.to the an overall efficiency.

3- so as to decrease the error and make our experimental results more viable and more reliable we decided to use one PV system components for both fixed and tracked PV solar panel and also two micro controllers, one for the fixed PV panel and tracked PV panel, are used separately for data acquisition and monitoring of the whole PV system.

4- it was designed to install the fixed PV solar panel and tracked PV solar panel to be not much far from each other and the distance between them was approximately 3m, which could help the experimental results to be more accurate.

7.2 Future works

As we mentioned before the mechanical tracking in CPV concentrated photovoltaic is %100 conditional and the CPV for the summer season in our region and especially in the middle and south of Iraq which the fine weather period is annually is long , it is expected that the CPV is beneficial and applicable , for the sunny day the CPV has a good efficiency in one hand and low cost on the other , the same technic of our experiment at the same location for tracking could be applied for CPV .

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