Design and study of two axis tracking system

Fareed .M. Mohamed , Awatif .S. Jassim, Yaseen. h. mahmood
Department of physics , collage of science , University of tikrit , tikrit , Iraq
E-mail :-R2amy 5156@yahoo.com

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Abstract:-

In this paper we presents the design, construction and also investigates the experimental study of a two axis (azimuthally and Polar) automatic control solar tracking system to track solar dish according to the direction of beam propagation of solar radiation. The designed tracking system consists of sensor and controller with built operated control circuits to drive motor with control .The designed Sun tracker was operated in the control system, two steeper motors were used to the movement of the system, keeping the sun's beam at the center of the sensor. To investigate the effect of using two-axis sun tracking systems.

The measured variables were compared with the fixed axis, the results indicate that the energy surplus becomes about (20-30%) with atmospheric influences. In case of seasonal, The system is a flexible tracking system with low cost electromechanical set-up, low maintenance requirements and ease of installation and operation.

Keywords: Tracking system , solar tracking system , solar dish tracking , dish tracking system

1- Introduction:-

The efficiency of any solar array can be improved significantly by using sun tracking. Tracking flat plate photovoltaic arrays provide about 33% more power than fixed arrays [1]. Advances in solar cells have resulted in high concentration ratio silicon types with up to 28% efficiency [2]. For concentrating collectors, pyrheliometer data is needed, measured with pyrheliometers mounted on solar trackers.

Three main types of sun trackers exist: passive, microprocessor and electro-optically controlled units, with the Passive systems track the sun without any electronic controls or motors ,these trackers control a fluid, such as Freon, within a frame of pipes, when the array is misaligned the sun heats the Freon on one side of the frame more than the other, this temperature difference causes the heated Freon to evaporate, it may push a piston or may simply flow to the other side of the array and move it by gravity, such as in the zone works system [3]. This tracker is simple but can only provide moderately accurate tracking. Microprocessor controlled sun tracking units use mathematical formulae to predict the sun's location and need not sense the sunlight, to determine position, stepper motors or optical encoders may be used. They are often used in large systems in which one controller controls many arrays [1], many microprocessor controlled trackers use electro-optic sensors for self-calibration [4], it can also be self-calibrated without sensors by using a current maximizing search routine [5] Huld showed that in Northwest and Central Europe the relative gain of two-axis tracking is higher than in the south. The absolute gain of tracking however is still low at 250 kWh per kW_p in the north, were typical yearly gains in Portugal and the Mediterranean region are in the range of 400-600 kWh per kW_p.[6].

2- The theory: -

Aperture Sun Angles; The Angle of Incidence (θ_1) defined the sun's position angles relative to earth-center coordinates $(\emptyset_1\, \delta and\ \omega)$ and then to coordinates at an arbitrary location on the earth's surface (α) and (A) and a functional relationship between these angles are given by the equations.

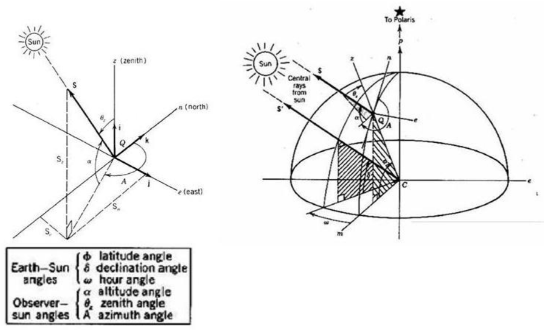


Figure (1) Composite view of showing parallel sun ray vectors S and S' relative to the earth surface and the earth center coordinates. for observer at *Q* showing the solar azimuth

(f$s_z = s'_m cos\emptyset + s'_p sin\varphi$ -------- (1)

$s_e = s'_e$ ---------------------------- (2)

$s_n = s'_p cos\emptyset - s'_m sin\varphi$ --------- (3)

$\sin a = sin\delta sin\emptyset + cos\delta \cos\omega cos\emptyset$ --- (4)

cos$a\ sinA = -cos\delta \sin\omega$ ----------------- (5)

In the design of solar energy systems, it is most important to be able to predict the angle between the sun's rays and a vector normal to the aperture or surface of the collector. This angle is called the angle of incidence (Ø). Knowing this angle is of critical importance to the solar designer, since the maximum amount of solar radiation energy that could reach a collector is reduced by the cosine of this angle. The angle of importance the sun's tracking angle. (p). Most types of mid- and high-temperature collectors require a tracking drive system to align at

least one axis and often two axes of a collector aperture normal to the sun's central ray. The tracking angle is the amount of rotation required to do this.
In this section we derive expressions for the angle of incidence for both fixed-axis and single-xis tracking apertures. We also derive equations for the tracking angle for both single-axis
And two-axis tracking apertures. has reviewed a number of sun pointing programs and evaluated their accuracy.
Two-axis Tracking ,Apertures
With two-axis tracking, a collector aperture will always be normal to the sun. Therefore the cosine effect does not come into play and;

$cos\theta_2 = 1.0$------------------(6)

For aiming an aperture toward the sun at all times, rotation about two axis is always required. Two types of tracking mechanism are commonly in use for this purpose: azimuth/elevation tracking systems and *polar* or *equatorial* tracking systems.
Azimuth /Elevation Tracking .
Azimuth / elevation tracking, the collector aperture must be free to rotate about the zenith axis and an axis parallel to the surface of the earth. The tracking angle about the zenith axis is the solar azimuth angle(A), and the tracking angle solar azimuth angle (*A*), and the tracking about the horizontal axis is the solar altitude angle (a) , as defined in Equations,(7,8,9)

$\alpha = sin^{-1}(\sin\delta \sin\emptyset + \cos\delta \cos\omega \cos\emptyset)$-----(7)

$A^{'} = sin^{-1}\left(\frac{-cos\delta sin\omega}{cosa}\right)$---------(8)

Where if: $cos\omega \ge \left(\frac{\tan\delta}{tan\emptyset}\right)$, then A=180°-$A^{'}$---(8- a)

Otherwise: $\cos\omega < \left(\frac{\tan\delta}{\tan\emptyset}\right), and\ A = 360° + A^{'}$---(8-b)

$A^{"} = cos^{-1}\left(\frac{sin\delta cos\emptyset - cos\omega sin\emptyset}{cosa}\right)$----- (9)

Where if: $sin\omega > 0$ then $A = 360° - A^{"}$---(9-a)

$A = A^{'}$---------(9-b)

Otherwise $sin\omega \le 0$ and

Of primary interest to the designer of a two-axis tracking system is the rate at which these angles change called the *slew rate*. For the azimuth / elevation system, the rates of change of both the azimuth and elevation angles are not constant and depend on the location, time of day, and season. An expression for the slew rate about the horizontal axis may be found by taking the derivative of Equation (7) with respect to time. If we neglect the very slow variation in declination angle, the result is

$\frac{da}{dt} = \frac{-cos\emptyset \sin\delta \sin\omega}{cosa} = \left(\frac{d\omega}{dt}\right)$-----(10)

The slew rate about the vertical axis is found similarly from Equation (8) and is

$\frac{dA}{dt} = \frac{cos\delta}{cosAcos^2 a}(cos\delta sin^2\omega \tan acos\emptyset - \cos acos\ \omega)\frac{d\omega}{dt}$--(11)

Figure (1) shows the variation of these slew rates at a specific location. Note the very high azimuth slew rates required near the summer solstice at noon. This must be considered in the design of tracking drive mechanisms and tracking controls.[1]

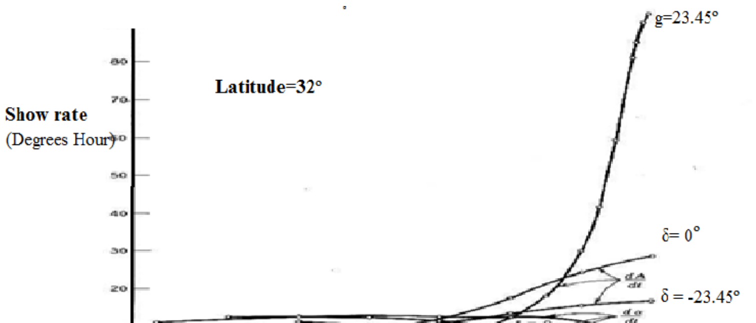


Figure (2) Variation in the rate at which the solar azimuth and altitude angles change for three representative days. The latitude is 32 degrees for this example.

Polar (Equatorial) Tracking
For polar or equatorial tracking systems, one axis of rotation is aligned parallel to the earth's rotational pole, that is, aimed toward the star Polaris, this gives it a tilt from the horizon equal to the local latitude angle. As, the tracking angle about the polar axis is equal to the sun's hour angle (ω).

The other axis of rotation is perpendicular to this polar axis. The tracking angle about this axis is the declination angle (δ).

The slew rate about the polar axis is constant at 15 degrees per hour. The slew rate about the declination axis is very slow, giving rise to the possibility of incremental adjustment. The rate is dependent on the time of year and can be found by taking the derivative of Equation with
respect to time. The result is

$$\sin\delta = 0.39795\cos[0.98563(N-173)] \text{-----}(12)$$

$$\frac{d\,\delta}{dt} = \frac{0.1634}{\cos\delta}\sin[0.98563(N-173)] \text{-----}(13)$$

which adjustment rather than a continuous tracking motion may do this slow rate of tracking. give a maximum tracking rate of 0.0163 degrees per hour (0.28 mrad /h) at the equinoxes. With many types of concentrating collector optics, incremental [7]

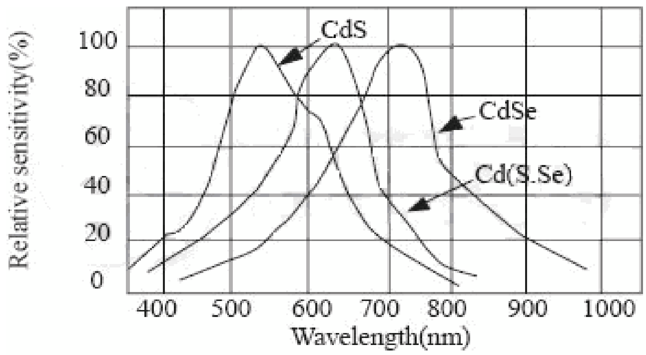
3-Experimental work:-

Tracking Sensor Design:

The tracking sensor is composed of four similar CdS sensors ,CdS is a photo Resistor with high gain at visible light ,One of our key modules is the sensor. Because the sensor tracks the solar light source's orientation, selecting the right tracking sensor is very important. CdS sensors are cheap, reliable, and photo-sensitive. In our design, the CdS sensor provides the following advantages [8.9]:

- Without polarity (ohmic structure), the CdS sensor is easy to use.
- CdS sensors have a photo-variable resistor in which the internal impedance changes with the intensity of light energy.
- When the ambient light brightens, the CdS sensor's internal impedance reduces.
- The CdS sensor's photo sensitivity (spectral characteristics) is 0.4 to 0.8 mm, which is close to the wavelength scope of visible solar light (0.38 to 0/76 mm) , as shown in figure (3).

which are located at the east, west, south, and north to detect the light source intensity in the four orientations. The CdS sensor forms a (45°) angle with the light source. At the CdS sensor positions, brackets isolate the light from other orientations to achieve a wide-angle search and quickly determine the sun's position. The four sensors are divided into two groups, east/west and north/south. In the east/west group, the east and west Figure (3). CdS by using lens with (2.5cm)focal length to focus the Sun ray to origin central of detector a otherwise used widow in front of the lens to decrees the intensity of light reached the four sensor and protected the component of the head Figure (4).



Figure(3) The Relative sensitivity CdS , CdSe ,Cd (S.Se)with wave length [10].

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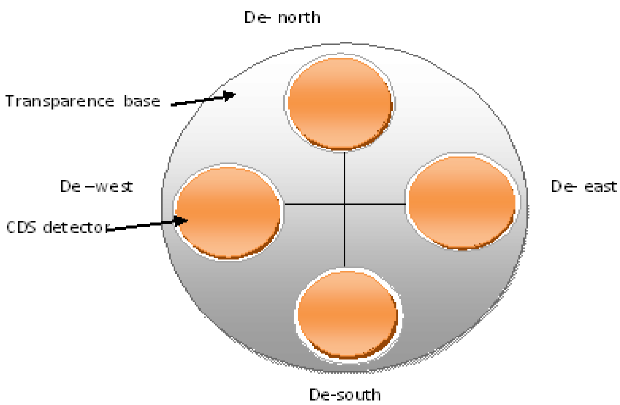

Figure (4) Distribution of CdS detector on a sensor head

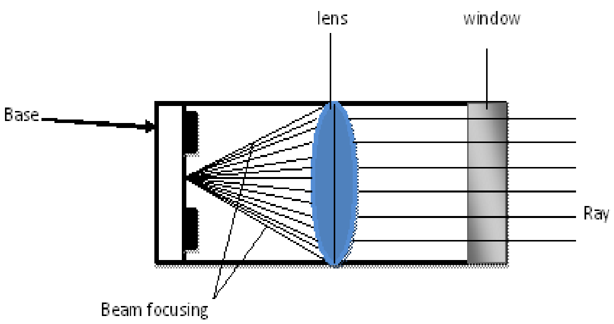

Figure (5) The component of head detector .

Controller of motors and power supply.

The sensors compare the intensity of received light in the east and west. If the light source intensity received by the sensors are different, the system obtains signals from the sensors output voltage in the two orientations. The output voltage go to operation amplifier with inner gain same as and low amplification as a A=1+Ri/Rf here Ri input resistor Rf: feedback resister.

The system then determines which, sensor received more intensive light based on the sensor output voltage value interpreted by voltage go to relay for (left, right) direction.

The system drives the motor towards the orientation of this sensor. If the output values of the two sensors are equal, the output difference is zero and the motor's drive voltage is zero, which means the system has tracked the current position of the sun. Figure (5) The north/south sensors track the position of the sun similarly. The power supply of the circuit and motor center tap transformer (12V) and two diode rectifiers and to similar capacitor to obtains voltage (+12,0,-12) Figure (6) the operating voltage motor (AC 220) from Relay .

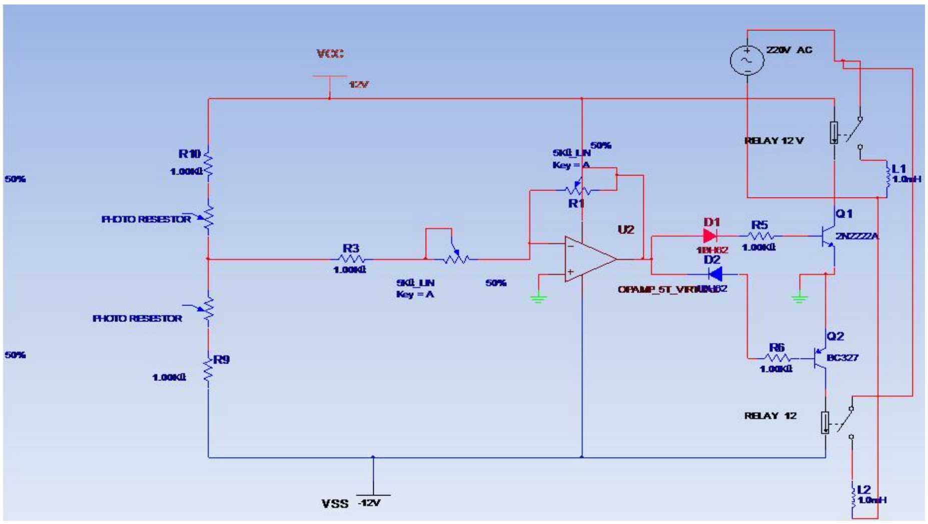

Figure (6) show circuit diagram for tracking system.

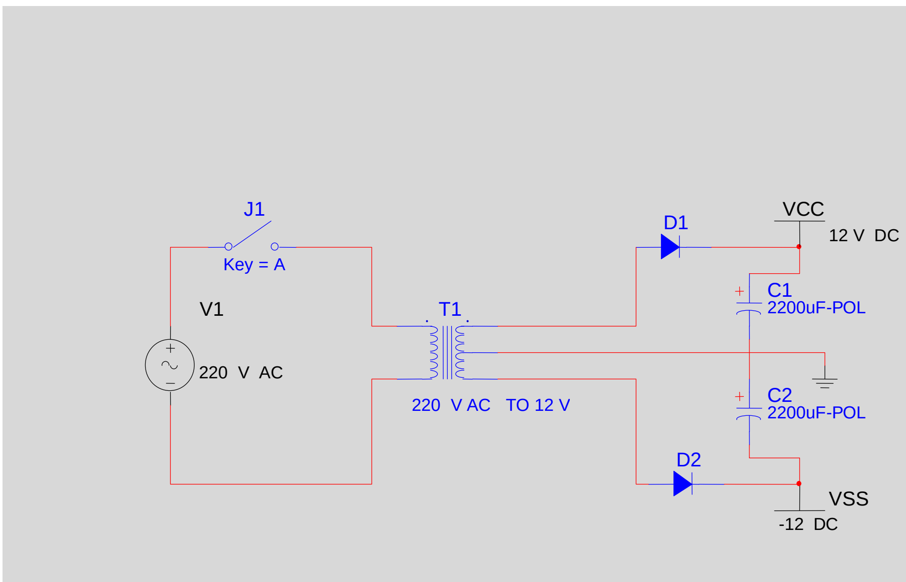

Figure (7) show power supply for trakcing circuit.

The head sensor insulation on the dish concentration ,to direction of the Sun .and parallel to Sun ray with head sensor. The motor for cctv camera is suitable to pan tilt drive with specification.

ST8322 series 220V pan/tilt controller

TECHNOLOGHY SPECIFICATION

1- Input Voltage :AC 220 V
2- Output Voltage :AC 220 V
3- Operating current 960 mA .
4- Turn angle pan : 0° to 350 $^\circ$,Tilt: 35.
5- Speed pan:9°/ sec, Tilt1° /sec
6- Limit stop externally adjustable
7- Load level :25Kg plump: 12Kg
8- Linker 1.Auto ,2.left,3. Right,4.up,5.down,6.com
9- Working temperature Current:- 10°C to+55°C Heat: -$35^\circ$to+55°
10- Weight 3.7Kg(301) 3.4Kg(303)
11- Dimensions 190mm. 275mm (301) 200mm. 255 (h) (303)

3- Result and discussion :-

The study was devoted to solar radiation in Iraq-Tikret latitude angle is (34 .59°) and longitude angle is (43.68°) ,1n (20-5-2011) the solar tracking were designed by using (AC motor) for CCTV camera solar tracing because it has slowly movement to any direction and easy to connected with circuit drive. the electronic circuit with power supply Figure (5) and (6). Are very easy but high precision. No need mechanical component to install the solar dish or panel solar cell. on concentration dish, without tracing and with tracking shown an increasing of the solar radiation and it is maximum at time (11 to 13) h, also an increase of the solar radiation with tracking about (15°-25°) with time day ,as seen in Figure(8) otherwise increase solar radiation by incoming solar reflection from earth and atmosphere.

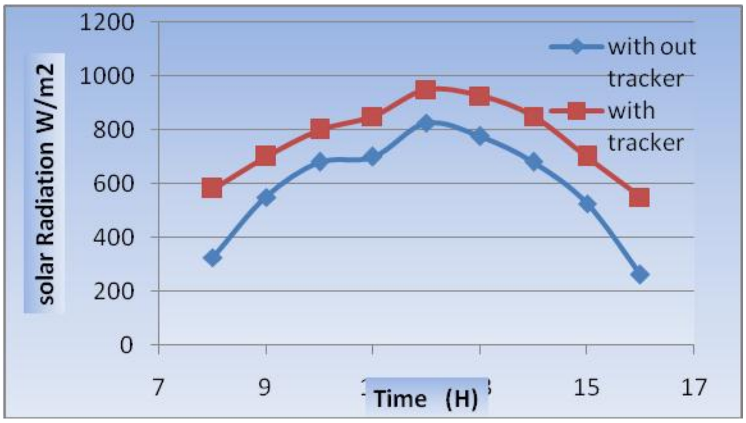

Figure (8) Relation between solar radiation with time.

In Figure (9) we have drawn the measured incident radiation with time ,it shows a maximum Solar radiation at midday .

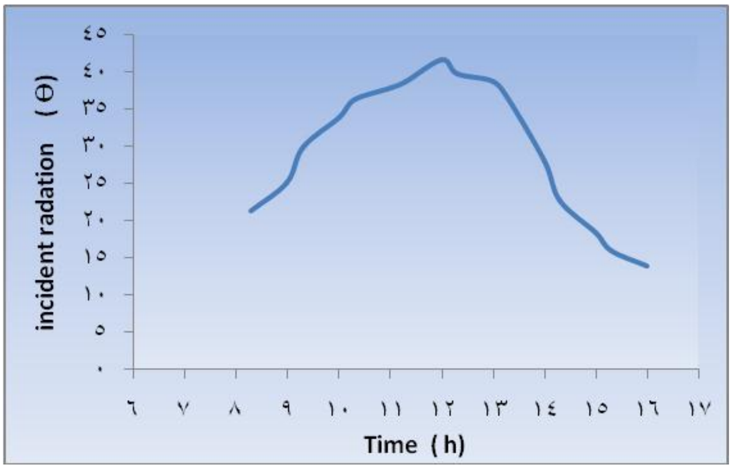

Figure (9) Relation between time and experimental incident radiation.

While Figure (10) the air mass was increased with increasing time gets maximum between .

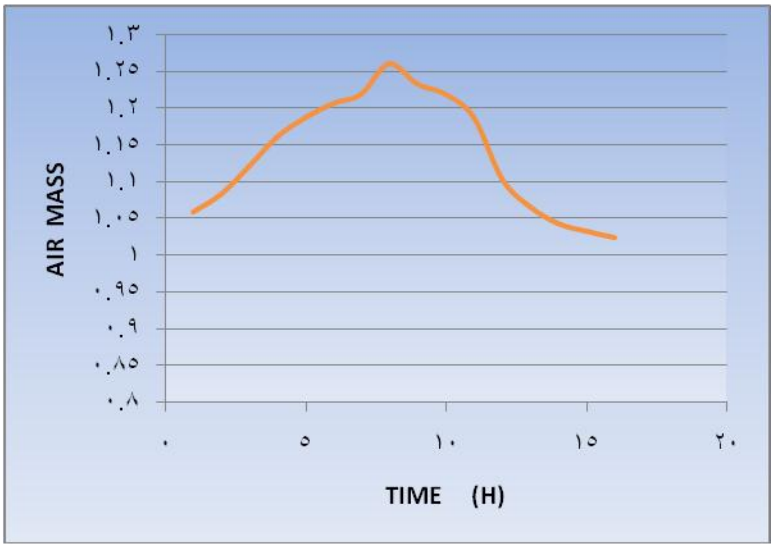

Figure (10) Relation of air mass with time.

And by using container of water at focal length of meter diameter dish and measuring the temperature of water with and without tracing. Figure (11).

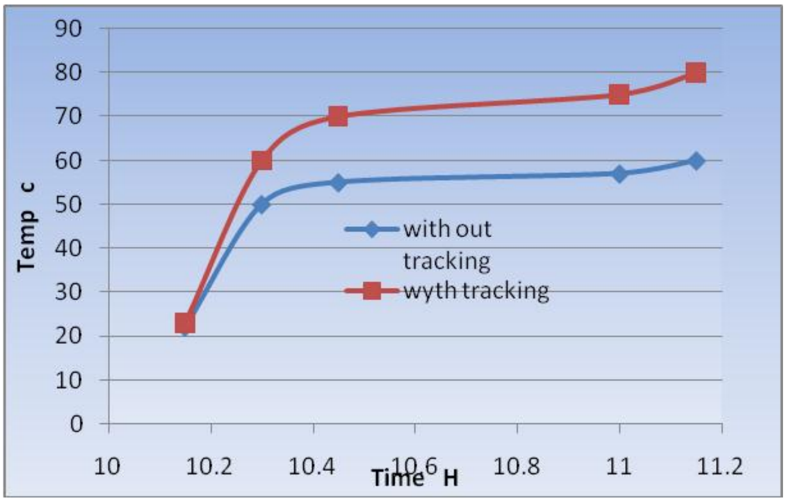

Figure (11) Relation between time and temperature with and without Tracking

Shown the increasing temperature between time (10.25) to (11.25) with, and without tracking [10] but the efficiency increased with about (10-25)% with the same time .

Reference :-

[1] Gay CF, Yerkes JW, Wilson JH. Performance advantages of two-axis tracking for large flat-plate photovoltaic energy system. In: Proceedings of 16th IEEE Photovoltaic Specialists Conference, 1982. p. 1368–71.
[2] Boes EC, Maish AB. Advances in concentrator technology. In: Proceedings of 19th IEEE Photovoltaic Specialists Conference, 1987. p. 985–91.
[3] Zomeworks Corporation, Passive solar track rack. Albuquerque, NM, US Pat. No. 4275712.
[4] Edwards BP. Computer based sun following system. Solar Energy 1978;21(6):491–8.
[5] Maish AB. A self-aligning photovoltaic array tracking controller. In: Proceedings of the 20th IEEE Photovoltaic
[6] T. Huld, M. Suri, E. Dunlop; Prog. Photovoltaic's R&A, 2007 Vol 16, p47; http://re.jrc.ec.europa.eu/pvgis
[7] willium B. Stin and Michael Geyer" power from the sun",(2001).42.
[8] Zhang Xinhong, Wu Zongxian, Yu Zhengda," Intelligent Solar Tracking Control System Implemented on an FPGA" (2007).
[9] R.K ansal، "PIC Baced Automatic solar Radiation Tracker" , M. Sc. Thesis, Electronics Instrumentation & Control Engineering ,University of Thapar, june (2008) .
[10] John Dascomb "Low cost concentration for solar steam generator" University of Florda, MSC. Thesis, 2009.

تصميم ودراسة منظومة تتبع شمسي بمحورين

فريد مجيد محمد ، عواطف صابر جاسم ، ياسين حميد محمود

قسم الفيزياء ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

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الملخص

في هذا البحث تم تصميم وتركيب منظومة للتتبع الشمسي باتجاهين العمودي والأفقي ليستمر بتتبع الشمس تم استخدام ماطور خاص يستخدم في كاميرات المراقبة يتحرك باتجاهين عمودي وافقي وتم عمل دائرة الكترونية للسيطرة لهذا الغرض باستخدام كاشف بصري كادميوم سلفايد. ومن خلال المنظومة تم دراسة الاشعاع الشمسي لمدينة تكريت الساقط على المركز الشمس ولوحظ زيادة الكفاءة بحدود (30−20)% وكان النظام رخيص وكفوء في عملية التتبع .