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Proposed Design for Single Axis Photovoltaic Solar Tracker.

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Proposed Design for Single Axis Photovoltaic Solar Tracker

تصميم مقترح لمنظومة تتبع للطاقة الشمسية الكهروضوئية احادية المحور

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KEYWORDS:
Tracking system, Solar energy, microcontroller, PVsyst software

الملخص العربي:- احتياجات البلاد المستقبلية المتزايدة للطاقة الكهربية لتطوير المجتمعات الحالية و بناء المجتمعات الجديدة ادى الى البحث على نظم بديلة لانتاج الطاقة الكهربية .تعتبر الطاقة الشمسية الفوتوفولتية و طاقة الرياح من افضل نظم الطاقات البديلة و النظيفة لانتاج الطاقة الكهربية .يقدم البحث احد افضل الطرق المستخدمة لزيادة انتاجية الطاقة الشمسية من الالواح الشمسية الفوتوفولتية باستخدام المتتبع الشمسى الفوتوفولتى احادى المحور .و قد تم توضيح الجدوى الاقتصادية الجيدة من استخدام المتتبع الشمسى احادى المحور عن استخدام المتتبع الشمسى ثنائى المحور و الاكثر تعقيدا و الادنى اقتصاديا .و قدم البحث دراسة رقمية عن الجدوى الفنية و الاقتصادية عن استخدام المتتبع الشمسى الفوتوفولتى احادى المحور لمحطة فوتوفولتية بقدرة 10كيلو وات و المقام فى محافظة قنا -مصر

Abstract— **our energy needs increase day by day, so the search for a renewable source of energy has become a necessity of life. Photovoltaic solar energy (PVSE) is one of the most important sources in our community because it is clean and renewable. This paper discusses improvement the production energy from this source by using practical design of single axis solar tracking system. The designed solar tracking system used microcontroller Arduino Mega, real time clock (RTC), limit switches and servo motor. The mechanism of the designed solar tracker is applied by moving the solar structure to track the sun on better angle to be perpendicular to the sun to get the most energy from it using the RTC and limit switches. Comparison between solar tracking system and fixed system reveal that the system is more economic and larger power production. This tracking system is designed and tested in real environmental in Qena governorate in Egypt. The 10 kW solar power plants are used as a case study for this system. Comparison between the proposed solar tracking system and the solar fixed system for the same demand is performed using PVsyst software as theoretically. Also, economic viability between the two practical systems is produced.**

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I. INTRODUCTION

NUMEROUS researchers worldwide have increased their attention to the development of renewable energy. Renewable energy sources are friendlier to the environment and more sustainable compared to fossil fuels Renewable energy includes several forms such as solar and wind energy [1-6]. The sun tracking system in different solar energy applications plays an important role where its benefits over the fixed systems not limited to the power and efficiency gains and increase, but also in the large-scale solar energy applications economic analyses [7-13].

The predominant two categories of tracking–single and dual axis tracking–have different features compared to each other. Although the dual-axis tracking is more complicated and has a higher cost, which uses more instruments and equipment [7-13]. Solar tracking systems can be divided into two main types, namely, active and passive solar tracking systems. Active solar tracking systems use gears and motors to control photovoltaic modules, whereas passive tracking systems use a low boiling-point compressed gas fluid that originates from solar heat [1-13]. The sun tracking systems have different based designs and components. The previous studies of the tracker systems can be classified into two main categories; single axis tracker about 42.57% and dual axis tracker about 41.58%. Active tracker recently used in most applications by about 76.42% while the chronological tracker used by about 7.55% as a second impact type. Moreover, the percentages of the other techniques are 16.87% for the Azimuth and altitude tracker, 16.67% for the Horizontal tracker, 10% for the Azimuth tracker and 4.44% for the polar tracker [7-13].

Single-axis tracking systems are nearly the best solution for small photovoltaic modules. The single-axis system is cheaper than other systems, and it can be moved horizontally or vertically depending on the location of the sun and weather [1-6]. There are many tracking techniques have not efficient and not reliable sensors not efficient and not reliable to work in outdoor area such as LDR [14-17] and photoelectric sensor [14-16] and GPS module [14], now we will discuss some of these projects and works. This paper used SCM (Single chip microcontroller), Photoelectric-detection circuit, Global Position System (GPS) module, Voltage/current detection circuit; this system has the advantages of high tracking accuracy, fast response and stable performance [14].

Two light dependent resistors (LDR) are used as a sensor for detecting the sun position. And it found The results of the study showed that the single axis tracker system receives average value of the energy received was 1.35 times greater than the fixed panel system, however the dual axis tracker system receives the average value which is only 1.04 times the received energy of a single axis one. Therefore, as compared to double axis system, single axis system is more useful according results obtained from the installed system in the Qeshm Island, Iran [15].

This designed controller can automatically detect sunlight real-time tracking sun, to improve solar panels' photoelectric conversion efficiency. The controller used DSC (digital single controller) as the control core, real time calculates solar position from data collected by sensors, and then sends a signal to control the motor rotation to achieve automatic tracking sun [16].

Arduino Uno microcontrollers that have open-source prototyping platform are used with dual axis based tracker because of its easy for hardware interrupt and software programming. The solar tracker can automatically be controlled with the Light Dependent Resistor (LDR) sensors or manually using a potentiometer from the experimental results, it is noticed that the generation of the PV system using the solar tracker is increased up to 35.16% when compared to the fixed-axis PV panel [17-22].

There are some projects used microcontroller and stepper motor. Microcontroller was used to reduce the complexity of the circuit. This system works effectively irrespective of the weather condition or the geographical location [23].

The efficiencies of the open- and closed-loop tracking types are discussed, but we can improve the closed loop tracking by using reliable and simple sensors like limit switches [24]. New technique where those two drawbacks have been addressed. The design uses a microcontroller-based control mechanism to maximize solar energy extraction. This is done by the design of a tracking system known as the PILOT and cells rotating system known as PANEL. First the system is oriented towards the east waiting for sun to rise. When this happens, the PILOT keeps tracking the sun. This is done with the aid of a light to frequency converter (LTF) mounted on a miniature electric motor. This converter always lines the PILOT with the sun. Two identical light dependent resistors (LDR) are mounted, by comparative study, which shows an increase of energy extraction by about 40% over fixed panels [25].

A hybrid algorithm located the sun position automatically using microcontroller by combined mathematical models and sensors so, for all weather conditions it will gain the optimal solar energy. With a large-scale implementation, the proposed hybrid solar tracker can harness optimal solar energy for all weather conditions [26].

Evaluation of the proposed tracking system is performed by comparing several elements with other tracking system. The elements are tracking technique, simplicity of mechanical structure, performance of electrical structure, accuracy, reliability, and percentage of increasing energy. Table 1 explains this comparison. The energy required for the tracking system is small and may be neglected or may be feed from a fixed solar module.

This paper proposed single axis tracking; the collector rotated over a north-south axis. This paper aims to maximize energy produced from PV solar system by using tracking solar system. Tracking system is designed and tested in real environmental in Qena governorate in Egypt. Comparison between the proposed solar tracking system and the fixed system power production and economic aspect is produced. The organization of this paper is as follows; section 1 is introduction, section 2 describe the implementation of hardware tracking system, section 3 show the algorithm applied to microcontroller for tracking system, section 4 produced the algorithm applied to microcontroller for tracking system. Section 5 Energy production comparison between fixed and tracking solar system, Section 6 Economic comparison between fixed and tracking solar system and finally conclusion section.

II. HARDWARE IMPLEMENTATION FOR TRACKING SYSTEM.

The components of solar tracking system are explained in Fig.1. The system contains PV module, battery, servo motor, charge controller, limit switch, micro controller, real time clock, light emitting diode, push button and liquid crystal display.

TABLE 1
COMPARISON BETWEEN THE PROPOSED SYSTEM AND OTHER SYSTEMS

Paper	*Tracking technique*	*Mechanical structure*	*Electrical structure*	*Accuracy*	*Reliability*	*% increasing in energy*
The proposed method	Servo motor	Simple	Very good	Accurate	Very reliable	30.4%
	Limit switches					
	RTC (real time clock)					
Ref [14]	GPS	Not specify	Not specify	Accurate	Not reliable	Not specify
	Photovoltaic sensor					
	Voltage and current detector					
Ref [15]	2 LDR	Complex	Good	Accurate	Not reliable	35%
Ref [16]	DCS & RTC	Complex	Good	Accurate	reliable	14%
	Photovoltaic sensor					
Ref [17]	LDR	Simple	Good	Accurate	Not reliable	36.16%
	Potentiometer					
Ref [23]	Microcontroller	Simple	Good	Accurate	reliable	Not specify
	Stepper motor					

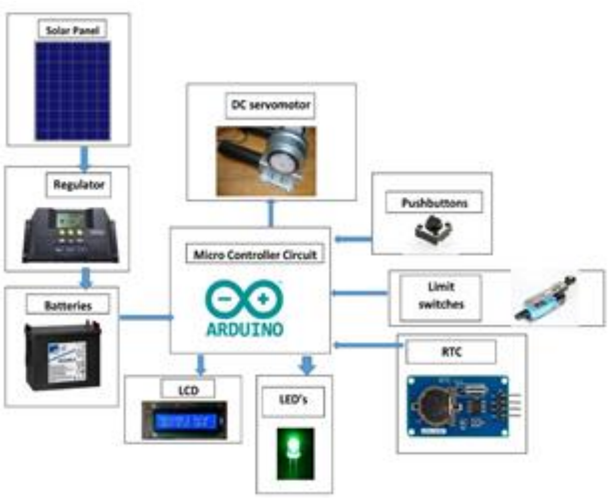

Fig.1 Configuration of system components

A. PV Panel

PV panel used to feed electric power for the batteries by using charger controller this table specifies specification of this solar panel

TABLE 2
THE SPECIFICATION OF THIS SOLAR PANEL

Power	265 W
Rated voltage	30.7 V
Rated current	8.47 A

B. Charger controller

Charger controller used to regulate the voltage and the current to charging the batteries as shown in Fig.2. The electrical specification for the charger controller shows in Table 3.

Fig.2. Charge controller used in the system

TABLE 3
THE ELECTRICAL SPECIFICATION FOR THE CHARGER CONTROLLER

Rated charging current	*30A*
Rated charging voltage	*24 V*

C. Battery

Batteries are used to supply electric power for tracking control systems the system has two batteries' connected in series to get 24 v to each batteries capacity 12V 200Ah, as shown in Fig.3.

Fig.3. Battery used in the system

D. Servomotor

Servomotor is a Dc motor with gearbox to reduce the speed of motor as shown in Fig.4; it uses to rotate the panel structure from east to west the general specification for this motor is explained in Table 4. This tracking system has control in six motor start and stop and reverse direction.

TABLE 4
GENERAL SPECIFICATION FOR SERVO MOTOR

Voltage	*24 V*
Rated Current	*4 A*
RPM	*1 RPM*

Fig.4. Servo motor used in the system

E. Limit switch

The limit switch it used to sense the motor position and to limit it is path from east to west or from west to east; as shown in Fig.5. It best chose for this application because it has mechanical switch suitable for outdoor and dusty area.

Fig.5. Limit switch used in the system

F. Microcontroller

The multi things controlled from one place by using Arduino Mega the maximum optimization for use because all pins in Arduino mega used to control in multi things from one place to minimize the cost. The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input / output pins (of which 14 as PWM output available), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button; as shown in Fig.6.

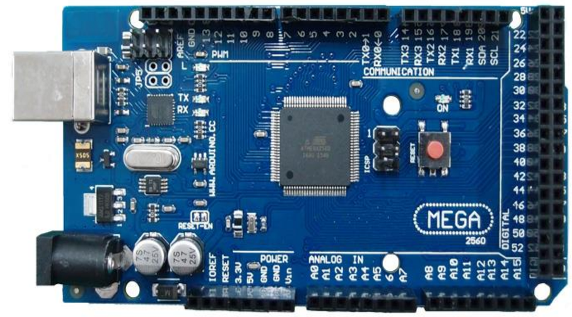

Fig.6. Microcontroller circuit used in the system

G. Real time clock

RTC DS1307 is the module used to send real and accurate time for Arduino mega without any delay time to control in motor position to track the sun in special time clock; as in Fig.7.

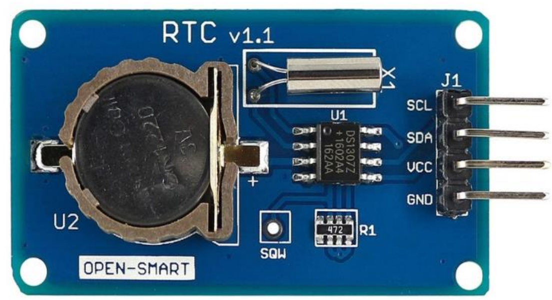

Fig.7. Real time clock circuit used in the system

H. Liquid crystal display

LCD used to display time and position of motor at this time; as shown in Fig.8.

Fig.8. Liquid crystal display used in the system

I. Push buttons

Push buttons used for rotate motors from east to west or from west to east manually to set motor in initial position in our system we have three push buttons the first to rotate motor forward and the second to rotate motor reverse and the third to reset program; as in Fig.9.

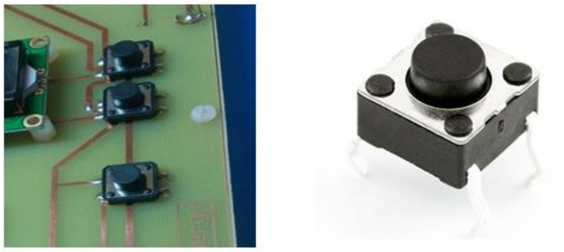

Fig.9. Push button switch used in the system

J. Light emitting diodes

LED's used to indicate the motor steps, the system track the sun with seven steps every step has LED to light up when system reach in this step; as shown in Fig.10.

Fig.10. Light emitting diodes used in the system

III. PRACTICAL MECHANICAL AND ELECTRICAL HARDWARE DESIGN

A. Mechanical hardware design

From sunrise to sunset, the single axis tracking system followed the sun in the sky from the east to the west through the day as shown if Fig. 11. The mechanism rotates only around a single axis in one plane so, it called single axis. The cells can be oriented by the single axis from stand up at a tilt (polar axis) to lie flat (horizontal axis). This single axis technique is less expensive and simple compared by the other methods. The single axis technique is effective method for all locations, even the closer to the equator where the sun's arc is less variable through the day.

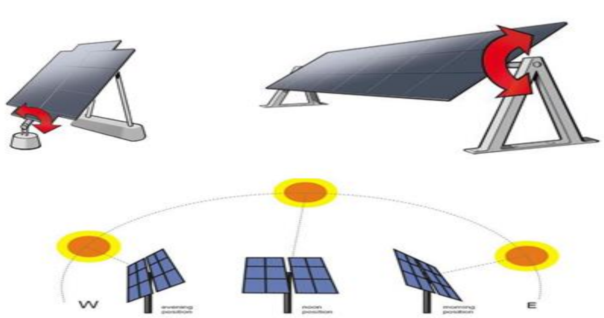

Fig.11. Single axis sun tracker

The Single-pivot horizontal sun trackers are structurally more rigid and stable, and hence it is less likely to be damaged during storms. Moreover, the Single-axis horizontal trackers are also structurally more rigid and stable, and hence less likely to be damaged during storms. In addition to that the properties in normal single-axis are achieved in single-axis horizontal trackers. Fig. 12 and 13 are explained the 3-D and real design for solar tracking system.

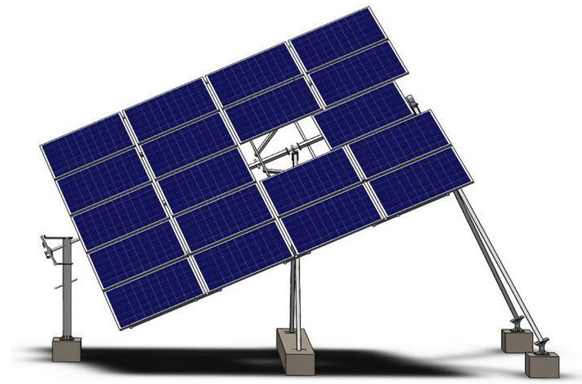

Fig.12. The 3-D solar tracking system

Fig.13. The real solar tracking system

B. Electrical hardware design

1- The initial design

The electrical design starts as prototype to making simulation for the real system, and to find the problems, which the system subjected to it. At the initial design, motor movement and its steps was dependent on the delay time by using timer included in microcontroller, but after a while we noticed that more shift in time occurs and the steps not come on the time, so we turned to use an RTC, Which give real and accurate time for microcontroller. After that problem was solved, another problem appears, there are shifts in motor movement to solve this problem limit switches were used to limit the shift in motor movements. The initial electrical hardware design is appeared in Fig. 14.

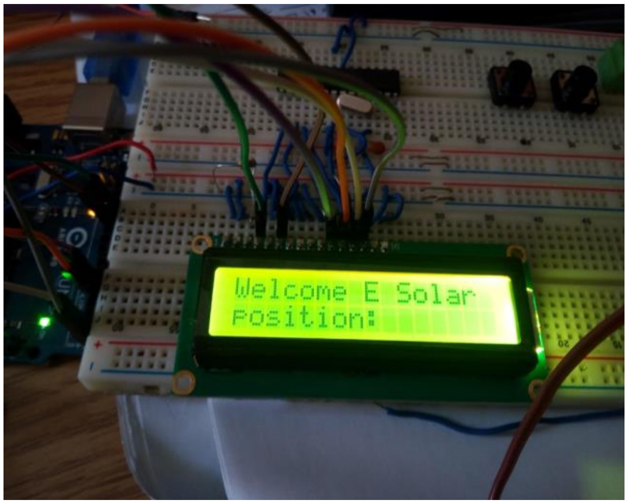

Fig.14. The initial electrical hardware design for the tracking system

2- The final design

The final design has optimization in the control circuit and solve all problems in initial design, the control circuit can control in six motors by using one RTC (real time clock) and twelve limit switches each motor has two limit switches one of them to limit rotation in east direction and the other for the west.

The control circuit has two options for control manual and automatic by using push button's the user can control in the movement of motors manually. This control circuit has seven LED to indicating light at every step and it has LCD to display the real time and the position of the system, these pictures describe the electric circuit design and its components. The final electrical hardware design is appeared in Fig. 15. Arduino mega pin connection is described in Fig. 16.

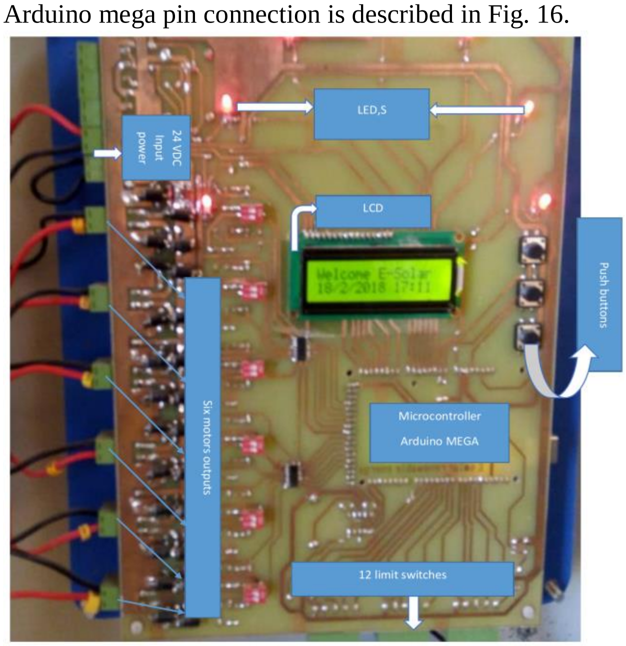

Fig.15. The final electrical hardware design for the tracking system

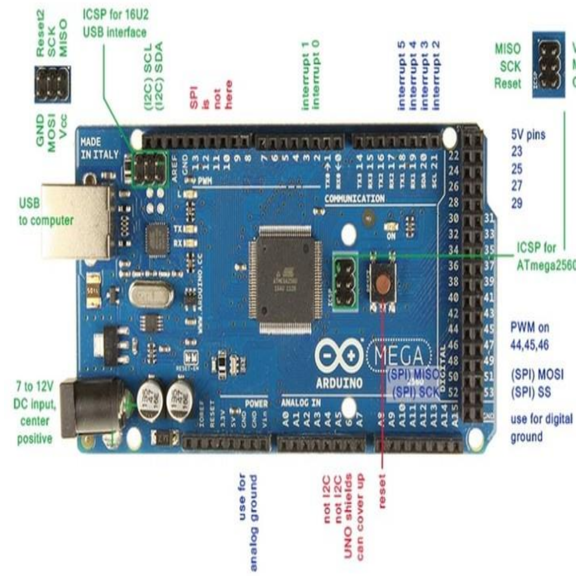

Fig.16. The Arduino mega pin connection used in tracking system

The printed circuit board consisting of:

1. Input and output power

The input voltage for this board 24 V, it has (7805) regulator to regulate 5 V to feed the Arduino control circuit and it has (7812) to regulate the 12 V output to supply power for external fan.

2. Output pins

* The six motors connected at 12 output pins through 12 relays each motor has two relays, one of them for forward (R1) and other for reverse (R2).
* The LCD connected at 6 output pins from A10 to A15.
* The LEDs connected at seven output pins from A2 to A8.

3. Input Pins

* The limit switches connected at 12 input pins each motor has two limit switches to stop motor at end of the forward and reverse steps.
* The Push buttons connected at 2 input pins (A0, A1)
* The RTC connected at 2 input pins (P20, P21)

Table 5 descried the details connections of the pins on the printed circuit board to the microcontroller.

TABLE 5
THE PINS DESCRIPTION ON THE CIRCUIT BOARD

Function	*PIN*	*Comment*	*Function*	*PIN*	*Comment*
SW (Up)	A0	Active High	Limit Switch 6	P7	Active Low
SW (Down)	A1	Active High	Limit Switch 7	P6	Active Low
LED1	A8	Active High	Limit Switch 8	P5	Active Low
LED2	A7	Active High	Limit Switch 9	P4	Active Low
LED3	A6	Active High	Limit Switch 10	P3	Active Low
LED4	A5	Active High	Limit Switch 11	P2	Active Low
LED5	A4	Active High	Limit Switch 12	P1	Active Low
LED6	A3	Active High			
LED7	A2	Active High	Motor 1 Relay 1	P49	Active High
LCD (D4)	A13	-	Motor 1 Relay 2	P47	Active High
LCD (D5)	A12	-	Motor 2 Relay 1	P45	Active High
LCD (D6)	A11	-	Motor 2 Relay 2	P43	Active High
LCD (D7)	A10	-	Motor 3 Relay 1	P41	Active High
LCD (RS)	A15	-	Motor 3 Relay 2	P39	Active High
LCD (EN)	A14	-	Motor 4 Relay 1	P37	Active High
RTC (SDA)	P20	-	Motor 4 Relay 2	P35	Active High
RTC (SCL)	P21	-	Motor 5 Relay 1	P33	Active High
Limit Switch 1	P12	Active Low	Motor 5 Relay 2	P31	Active High
Limit Switch 2	P11	Active Low	Motor 6 Relay 1	P29	Active High
Limit Switch 3	P10	Active Low	Motor 6 Relay 2	P27	Active High
Limit Switch 4	P9	Active Low			
Limit Switch 5	P8	Active Low			

IV. THE ALGORITHM APPLIED TO MICROCONTROLLER FOR TRACKING SYSTEM

Flow chart in Fig. 17 describes the algorithm used in tracking system. The solar tracking control system has two options for control manual and automatic.

A. Manual control

Manual control option is preferred in some cases; case1 is if the users need to select the suitable angle position and preferably in maintenance cases. Manual control option will be active if push buttons which connected on A0 or A1 ports are activated by user, when port A0 is active the tracking system will rotate from east to west and the system will rotate from west to east if port A1 is activated.

B. Automatic control

If the A0 and A1 not activated the system will be tracked the sun from east to west automatically the motor will be rotated forward (from east to west) by six steps and will be rotated reverse (from west to east) in one step.

C. Forward step

At every step forward the microcontroller will check the real time and case of limit switch LS1 (Limit switch 1). If LS1 is not activated the system will be rotated at this duration of time and will be stopped the rotation if the duration of time is end or the limit switch LS1 is activated, the six forward steps will be taken the time according to Table 6.

TABLE 6
THE SIX FORWARD STEPS USED IN MICROCONTROLLER

	Step	*Angel*	*From*	*To*
1	Forward	45 east to 25 east	8:00 AM	8:01 AM
2	Forward	25 east to 15 east	9:00 AM	9:01 AM
3	Forward	15 east to 0	10:00 AM	10:01 AM
4	Forward	0 to 15 west	13:00 PM	13:01 PM
5	Forward	15 west to 25 west	14:00 PM	14:01 PM
6	Forward	25 west to 45 west	15:00 PM	15:01 PM
7	Reverse	45 west to 45 east	18:00 PM	18:06 PM

D. Reverse step

At the end of the day light, the system will be rotated reverse (from west to east) at the specified time (18:00 PM) and the limit switch LS2 is not activated if the duration of time is end at (18:06) or LS2 is activated the system will be stopped at sun set position. This process will repeat every day.

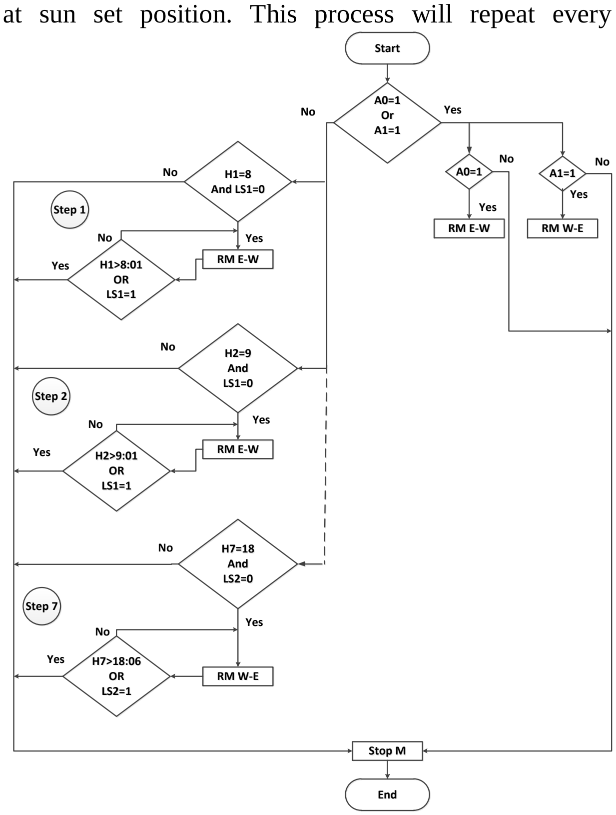

Fig.17. Flow chart for algorithm used in tracking system

V. ENERGY PRODUCTION COMPARISON BETWEEN FIXED AND TRACKING SOLAR SYSTEM

The solar power plant with rate 10 kW is used for comparison between fixed solar system and tracking solar system. The simulation of the two systems is applied by using PVsyst software. Fig.18 explains the screen shoot of orientation parameters for fixed solar system. Fig.19 explains the screen shoot of orientation parameters for tracking solar system.

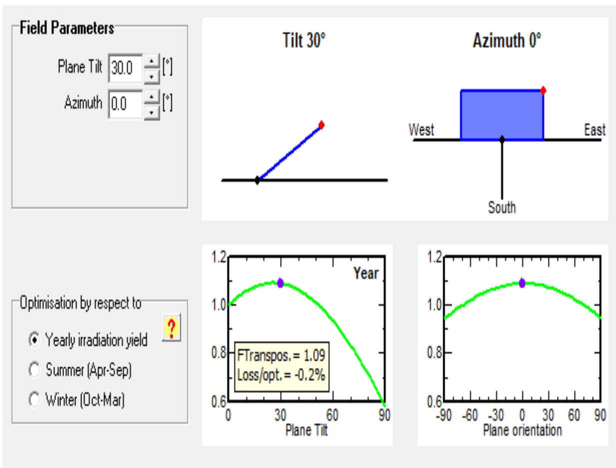

Fig.18. The screen shoots of orientation parameters for fixed solar system

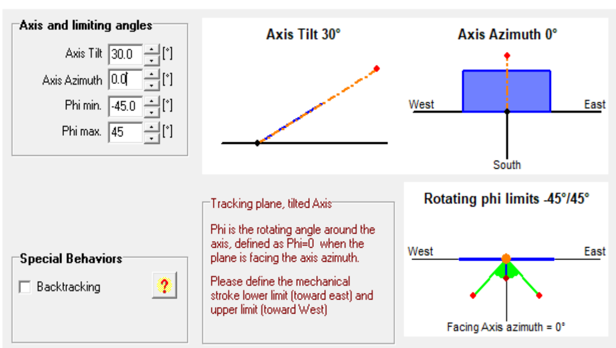

Fig.19. the screen shoots of orientation parameters for tracking solar system

The variation of the yearly Reference Incident Energy in coll. plane (Yr) in kWh/m^2 at day, Normalized Array Production (Lc) in kWh/m^2 at day, Normalized Array Production at peak power (Ya) in kWh/m^2 at day, Normalized System Losses (Ls) in kWh/m^2 at day, Normalized System Production at peak power (Yf) in kWh/m^2 at day, Array Loss / Incident Energy Ratio (Lcr) in kWh/m^2 at day, System Loss / Incident Energy Ratio (Lsr) in kWh/m^2 at day, and Performance Ratio (PR) is described in Table 7 for fixed solar system and in Table 8 for tracking solar system.

The monthly hourly sums production energy for the two systems is described in Table 9 and 10. From these Tables, we observed that; the tracker system increases in productivity as follows; At 5 AM fixed system total output energy 6 kWh, while the tracker system total output energy at the same hour 44 kWh. At 5 PM fixed system total output energy 80 kWh, while the tracker system total output energy at the same hour 559 kWh.

The tracker system increases the number of hours the system works because the total output energy at 6 PM for fixed system is 0 kWh, while the tracker system totals output energy at the same hour 7 kWh.

The monthly energy production for the fixed and tracking solar system is shown in Fig. 20. From this data the total annual Production energy for fixed system is equal to 19.450 MWH. The total annual Production energy for tracking system is equal to 25.378 MWH. From this result, it is noticed that the generation of the PV system using the solar tracker is increased up to 30.4% when compared to the fixed-axis PV panel. That means that the solar tracker with the used algorithm is able to receive more light as compared to the fixed-axis solar panel.

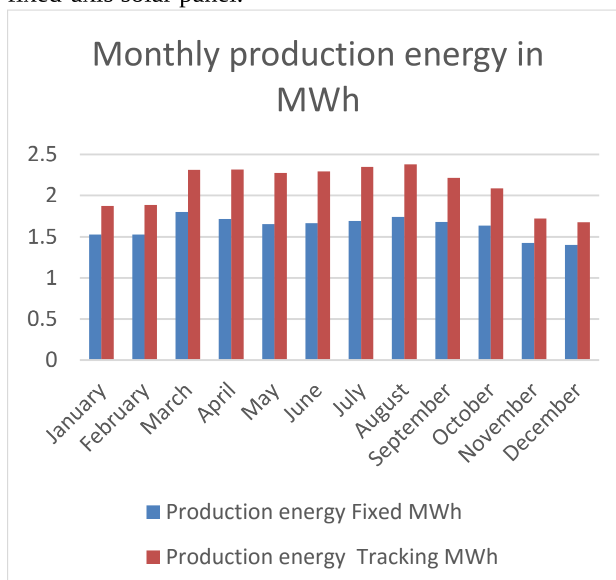

Fig.20. The monthly energy production for the fixed and tracking solar system.

VI. ECONOMIC COMPARISON BETWEEN FIXED AND TRACKING SOLAR SYSTEM

The cost of the solar fixed system and solar tracking system is analyzed in this section. The elements used in the solar fixed system are photovoltaic modules, inverter, mounting structure, cables, cables trays and protection box. Elements used in the solar tracking system are photovoltaic modules, inverter, mounting structure, cables, cables trays, protection box, servo motor, batteries, charger, control box and limit switches. Table 11 and Table 12 explain the cost of the elements of the two systems in addition to installation cost and transportation cost. The power station mentioned in this study contains 38 solar energy panels in the case of the fixed system while the tracking system contains 39 solar panels; 38 of them is designed as solar tracking system that is compared with fixed system and one of these panels is set separately fixed to feed the control circuit of the solar tracking. The cost of the energy required for the solar tracking control system and its component are described in table 11 as explain in items (7:12).

TABLE 7
THE ENVIRONMENTAL DATA FOR FIXED SOLAR SYSTEM

	Yr kWh/m²	Lc kWh/m²	Ya kWh/m² at peak power	Ls kWh/m²	Yf kWh/m² at peak power	Lcr kWh/m²	Lsr kWh/m²	PR ratio
Jan	5.60	0.57	5.03	0.14	4.89	0.101	0.024	0.874
Feb	6.29	0.72	5.57	0.15	5.42	0.114	0.025	0.861
Mar	6.86	0.92	5.94	0.17	5.77	0.135	0.025	0.840
Apr	6.92	1.09	5.83	0.16	5.67	0.157	0.024	0.819
May	6.52	1.08	5.44	0.15	5.29	0.165	0.024	0.811
Jun	6.89	1.22	5.67	0.17	5.50	0.177	0.024	0.799
Jul	6.80	1.23	5.57	0.16	5.41	0.180	0.023	0.796
Aug	7.01	1.28	5.73	0.16	5.57	0.182	0.023	0.795
Sep	6.92	1.2	5.72	0.16	5.56	0.174	0.023	0.803
Oct	6.36	0.98	5.38	0.14	5.24	0.153	0.023	0.824
Nov	5.56	0.71	4.85	0.13	4.72	0.126	0.025	0.849
Dec	5.15	0.54	4.61	0.12	4.49	0.104	0.025	0.871
Year	6.41	0.9617	5.44	0.1508	5.29	0.150	0.024	0.826

TABLE 8
THE ENVIRONMENTAL DATA FOR TRACKING SOLAR SYSTEM

	Yr kWh/m²	Lc kWh/m²	Ya kWh/m² at peak power	Ls kWh/m²	Yf kWh/m² at peak power	Lcr kWh/m²	Lsr kWh/m²	PR ratio
Jan	6.89	0.73	6.16	0.16	6.00	0.105	0.024	0.871
Feb	7.82	0.94	6.88	0.2	6.68	0.120	0.025	0.855
Mar	8.86	1.24	7.62	0.21	7.41	0.140	0.024	0.836
Apr	9.36	1.47	7.89	0.22	7.67	0.157	0.023	0.820
May	8.94	1.46	7.48	0.2	7.28	0.163	0.023	0.814
Jun	9.48	1.68	7.80	0.21	7.59	0.177	0.023	0.801
July	9.41	1.68	7.73	0.21	7.52	0.179	0.023	0.798
Aug	9.59	1.76	7.83	0.21	7.62	0.183	0.022	0.795
Sep	9.16	1.62	7.54	0.21	7.33	0.177	0.023	0.800
Oct	8.14	1.27	6.87	0.18	6.69	0.156	0.023	0.822
Nov	6.75	0.89	5.86	0.16	5.70	0.132	0.024	0.844
Dec	6.18	0.66	5.52	0.15	5.37	0.107	0.025	0.868
Year	8.38	1.283	7.10	0.1933	6.90	0.153	0.023	0.824

TABLE 11
COST OF ELEMENTS USED IN SOLAR TRACKING SYSTEM

No	Components	price (EGP)	Quantity	total
1	PV modules (1kW)	6000	10	60000
2	mounting structure	2000	10	20000
3	Inverter	30000	1	30000
4	Cables	60	15	900
5	cable trays	20	20	400
6	protection box	1000	1	1000
7	servo motor	2000	1	2000
8	PCB+ control box	2500	1	2500
9	Batteries	1750	2	3500
10	Charger	750	1	750
11	limit switches	70	2	140
12	solar panel(for tracking system)	2300	1	2300
13	installation cost	10000	1	10000
14	transportation cost	3000	1	3000
	Total			136490

TABLE 12
COST OF ELEMENTS USED IN SOLAR FIXED SYSTEM

No	Components	price (EGP)	Quantity	total
1	PV modules (1kW)	6000	10	60000
2	mounting structure	1300	10	13000
3	Inverter	30000	1	30000
4	Cables	60	15	900
5	cable trays	20	20	400
6	protection box	1000	1	1000
7	installation cost	5000	1	5000
8	transportation cost	3000	1	3000
	Total			113300

From the results in section 5; the annual plant production for the solar fixed system is 19456 kWh. The annual plant production for the solar tracking system is 25380 kWh. The price of the slide 10 kW in Egypt country is calculated with 1.10 EGP for each one kWh. From the results in table 11 and 12, the price of each one kWh is calculated for the solar fixed and tracking system; the price of each one kWh is 0.233 EGP for the solar fixed system. The price of each one kWh is 0.215 EGP for the solar tracking system. The percentage of increasing annual energy production for the solar tracking system is 30.488% more than the solar fixed system. Percentage of decreasing the price of each one kWh for the solar tracking system is 7.725% less than the solar fixed system.

VII. Conclusion

This study worked on the sun-single axis tracking system in a large system size unlike other systems makes single axis tracking on small system size. The Energy production comparison between fixed and tracking solar system show that the total annual Production energy for fixed system is equal to 19.450 MWH while The total annual Production energy for tracking system is equal to 25.378 MWH, so the percentage of increasing annual energy production for the solar tracking system is 30.488% more than the solar fixed system. Economic comparison between fixed and tracking solar system show that the price of the slide 10 kW in Egypt country is calculated with 1.10 EGP for each one kWh, the price of each one kWh is 0.233 EGP for the solar fixed system while the price of each one kWh is 0.215 EGP for the solar tracking system, so the Percentage of decreasing the price of each one kWh for the solar tracking system is 7.725% less than the solar fixed system. The mechanical design is simple and uncomplicated as it did not contain Chains or hydraulic presses containing only Servo motor with gearbox. The electrical design is very good as the control circuit is small multiple tasks, it can control six motors from one place where the circuit is designed on the PCB (printed circuit board) and put with them the protectors, capacitors and fans needed for long periods in industrial environments or high temperatures conditions. The cost of this system is low because it does not require any photoelectric sensor and it does not contain any hydraulic presses.

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TABLE 9
THE MONTHLY HOURLY SUMS PRODUCTION ENERGY FOR FIXED SOLAR SYSTEM

	5H	*6H*	*7H*	*8H*	*9H*	*10H*	*11H*	*12H*	*13H*	*14H*	*15H*	*16H*	*17H*	*18H*
January	0	0	59	124	172	205	217	216	201	166	115	52	0	0
February	0	0	55	121	169	202	213	214	197	170	124	61	1	0
March	0	10	78	148	200	231	244	243	227	195	144	75	6	0
April	0	25	88	149	193	218	229	227	208	175	125	64	10	0
May	1	31	90	147	187	211	219	215	197	165	118	58	11	0
June	4	31	88	144	185	208	218	215	199	169	122	64	17	0
July	1	27	83	142	185	211	222	220	205	176	130	70	19	0
August	0	26	87	149	193	219	230	228	211	181	132	70	14	0
September	0	28	92	152	193	216	226	220	204	169	120	56	3	0
October	0	30	95	158	198	223	225	219	193	155	101	38	0	0
November	0	5	77	142	169	194	208	202	185	143	85	14	0	0
December	0	1	68	135	174	200	211	198	176	139	84	13	0	0
Year	6	214	962	1711	2220	2538	2662	2616	2404	2003	1400	635	80	0

TABLE 10
THE MONTHLY HOURLY SUMS PRODUCTION ENERGY FOR TRACKING SOLAR SYSTEM

	5H	*6H*	*7H*	*8H*	*9H*	*10H*	*11H*	*12H*	*13H*	*14H*	*15H*	*16H*	*17H*	*18H*
January	0	0	130	182	204	217	218	217	214	200	172	117	1	0
February	0	5	121	183	204	215	215	215	208	201	183	125	9	0
March	0	56	165	220	240	245	245	244	242	236	218	163	38	0
April	3	108	179	215	227	229	230	230	226	218	199	160	93	0
May	15	123	181	211	220	221	220	219	216	209	193	154	89	1
June	11	124	186	212	219	220	219	218	216	213	199	164	93	1
July	10	119	185	214	222	224	223	222	221	218	206	175	104	4
August	4	112	187	219	229	232	231	230	228	223	209	172	100	1
September	1	115	181	213	223	225	226	224	222	213	195	143	32	0
October	0	107	172	212	224	230	225	224	213	199	170	111	1	0
November	0	19	136	189	190	200	208	206	204	185	142	44	0	0
December	0	6	131	189	201	209	211	200	191	172	132	34	0	0
Year	44	893	1954	2459	2604	2666	2671	2650	2602	2489	2219	1561	559	7