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Powering the Drip Irrigation System by Solar Energy

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ABSTRACT

Utilization photovoltaic cells for water pumping is one of the most techniques in solar energy applications. Design and performance analyze of solar energy for pumping water through drip irrigation system are studied the field experiment was conducted during 2017 (from January to December). The experiment was conducted in privet farm located at Madinat Wadi EL Natrun, El Buhayrah, Governorate , Egypt N 30° 32"29. 7859" and E30° 1"41.2169", with average solar radiation between 3.52 and 6.2 kWh/m^2/day considers the ideal location for solar energy harvesting soil tenure is sandy soil for cultivation of olive tree orchard (*europaea olea*) was planted on a 10 faddan. Trees in the orchard had a spacing of 5 × 5 m. Although solar energy and drip irrigation system are highly important technologies in developing countries, they are rarely used together. This paper is concerned to design of direct coupled solar energy water pumping in drip irrigation system without using batteries. The solar pumping system consists of 39 modules of 259.8 watts each and 10.13 kW. AC Submersible water pump. The system was tested for its performance in terms of discharge variation due to change in solar energy. It was examine the various factors contributing to the performance of solar power, such as radiation tracking, hertz and power output, on pump discharge. It was observed during normal climatic conditions the PV array produced power in the range of 9.115 to 10.627 kW from 10:30 am to 3:30 pm during the year. It was observed that reduction in power generation the mean 14.22 % during noon conditions. Photovoltaic (PV) array produced maximum power of 10627.2 watts (12:30 pm) while, voltage, frequency and current of 561 V 49.1HZ and 15.4 A respectively. It is in the morning conditions that pump delivered discharge of 32.8m^3/h as an average from 9.45 am to 1.30 pm of the head of 1.3 bar. It was observed that, in noon conditions pump delivered discharge of 41.82 m3/h (12:30 pm) at the head of 2.1 bar. It was observed that power output from the solar array increases as solar intensity increases. The month with the highest solar radiation was with an average of 6.27, 6.06and 5.97 kW/m^2/month Ac. for months August, July and June respectively. Whereas the three months that average the lowest average solar radiation levels was 3.5, 3.94 and 4.12 kW/m^2/month for months December, January and November respectively.

INTRODUCTION

The issue of the use of new and renewable energy, especially solar energy is one of the strategic options to meet the future needs of energy. It is not depleted because of the continued renewal as long as the universe continues as a safe energy source cannot be monopolized and controlled as fuel as clean and environmentally friendly energy. Preliminary studies suggest that solar radiation in Egypt could have the potential to become a major source of energy in the near future. Because there is a relationship between the availability of solar energy and the water consumption which increase during the hot weather periods when the solar radiation levels are higher and the output of the solar array at a maximum. The water requirement decreases when the weather is cool and the sunlight is less intense Hegazi et al. (2010). They found that pump efficiency decreases as head increases. They came to know that pump efficiency was less than 40% when head is at 4m. Pawan Kumar et al. (2013) noticed that performance analysis of PV based submersible water pump. In their study, they show that maximum discharge was obtained in the noon at 12pm for 2hp DC motor operated by 10 panels of each 225 W and power output 75 to 85 W/m^2. Sahin and Rehman (2012) indicated that Egypt lies in a high solar insulation band, it is blessed with high intensities of solar radiations and longer durations of sunshine hours, it is endowed with abundant solar energy, and good weather conditions most of the year according to Atlas of Egyptian Solar Radiation (1991). The country averages for the solar radiation between 5.4 and more than 7.1 (kWh/m^2) of annual daily direct solar radiation, from north to south. The annual direct normal solar irradiance ranges from 2,000 to 3,200 kWh/m^2, rising from north to south, with a relatively steady daily profile and only small variations in resource. Such conditions are supported by 9–11 hours of sunlight per day, with few cloudy days throughout the year. Abdolzadeh and Ameri (2009) showed that photovoltaic (PV) powered water pumping is one the important typical photovoltaic applications in some developing countries and has the potential to become a main criterion for both of social and economic development. Photovoltaic array are the main part of photovoltaic powered water pumping system so that any changeable in the cell's power will affect the photovoltaic powered water pumping system performance. During spring/summer set PV Module tilt to 25 degree and during Fall/Winter set PV module tilt to 45 degree. ShivLaI et al., 2013 found that solar photovoltaic water pumping system can replace fossil fuels 100%. They mentioned the saving of CO2 emission by 14977.57 kg/year. Abdulkadir and Muhamadu (2012) reported that a plate solar generates vapour and its pressure is enough to pump the water and this flat of plate showed that the pump can lift (0.02m^3) of water per cycle with volumetric flow rate of 0.000333m3/s for 2m discharge head and the pump has an overall efficiency of 53%. Mandal and Naskar, (2012) decided the performance of a solar photovoltaic (PV) pumping system of two 35 watt solar modules. too, calculated the solar radiation over six month (Nov. to Apr.) for covering all the seasonal solar radiation during 6-7h. It can be found that as the discharge pressure proportional efficiency. The efficiency of the system varies from a low value of 1.55% at zero discharge pressure to almost 10% at kg/cm² discharge pressure. The system efficiency increases with system output up to a certain value, then droops with further increase in output.

Shivlal et al. (2013) observed the performance of photovoltaic according to types of water pump. Where they found that maximum discharge was obtained it the noon at (12pm) for 2hp DC motor operated by 10 panels of each 225 W and power output ranged 75 to 85 W/m^2. Foster and Cota (2014) found that Photovoltaic are natural choice and symbiotic choice for pumping of water. It is the most economically attractive solar power applications with direct lead Photovoltaic systems which providing decades of reliable service. There is a good match between season of solar resource and seasonal water requirements. Photovoltaic of pumping water systems can meet a wide range of needs and are relatively simple, reliable, cost, and low maintenance. Reca et al. (2016) showed that solar power has a very high potential in Mediterranean zone, as its climate is characterized by a high number of sunlight hours may be up to nine hours per a day. For this reason, the irrigation of many crops in the zone with photovoltaic energy systems is increasingly gaining interest. Nandita et al. (2018) recorded that a solar irrigation pump system type need to take account of the fact that demand for irrigation water will vary throughout the year. Peak demand during the irrigation system seasons is often more than twice the average demand. This means that solar pumps for irrigation are under-utilized for most of the year.

Attention should be paid to the system of irrigation water distribution and application to the crops. The irrigation pump system should minimize water losses, without imposing significant additional head on the irrigation pumping system and be of low cost. Priyanka, et al. (2018) showed that The output power in the range of 7051.40 to 7848.22 watts for corresponding change in temperature range of 29.38 to 33.33 Co. The main of this study was to evaluate solar water pump by measuring solar intensity, output voltage, current and times to study the effect of solar radiation, panel orientation, hertz and power output on pump discharge and computation discharge rate.

MATERIALS AND METHODS

This paper was conducted a to design and evaluation performance of water pump under solar system. The main of this study is to evaluate by measuring solar intensity, output voltage (V), current (A) and operating times (T) the solar radiation, panel orientation, temperature, hertz and power output on pump discharge and computation discharge rate (m^3/h). The solar photovoltaic of total capacity of 10132.2 W (38 panels of 259.8 W each) purchased and installed at the center and were used to generate the power to run motor (AC) submersible water pump. The experiment was conducted in privet farm located at the Madinat Wadi AL Natrun, Al Buhayrah, Egypt N 30^0 32"29. 7859" and E30^0 1"41.2169"

System Components

The whole system of solar pumping includes the panels, support structure with tracking manual, electronic parts for regulation, cables, pipes and the pump itself.

PV Modules

Solar panels are the main components used for drive the solar pump. There are consists of 38 panels divided into two groups each group 19 panels connected to each other in matrices. To producing electricity DC. The specification of solar panels presented in table (1).

Table 1. The specification of solar panels.

Item	Description
Cell Type	Poly crystalline 15.75×15.7cm
Number of cell	60 (6×10)
Dimensions(Module Size mm)	1648 × 990×35
Mass, kg	17.5
Front Glass	3.2 mm Low iron tempered glass
Output Cables	Length 900 mm, 4mm^2
open circuit voltage	37.9V

All these electrical measurements was carried out at standard test condition of 25° C cell temperature, 1.5 Air mass ratio (AM) and 1000 W/m^2 solar intensity.

Solar pump

Submersible pumps installed inside a well at a depth of 32 meters from the surface of the field and is connected directly to inverter. Its design to meet the watering requirements. The specification of pump motor shown in table (2).

Table 2. The specification of pump motor

Pump type	6SPC46-5
Motor power	10 HP
current	17 A
Voltage AC	380 V
Motor revolution	2850 rpm 26 - 50 Hz

Inverters

The inverters of type ABB it is power 10 Hp it advantages the maximum power point tracking, and used to convert the DC current into AC current using various methods depending on the type of the inverter and the required output waveform.

Support Structure and Tracking Mechanism

Support structure provides stability to the mounted solar array and protects them from theft or natural calamities. To obtain maximum output of water, a manual tracking device was fixed to the support structure. It was made up of two groups each with 19 panels.

Electrical interconnections

A set of cable size 3 in 10 mm and junction boxes, connectors and switches are provided along with the installation.

Soil type and its characteristics

Data presented in Table, (3) presents the soil texture and soil properties. Soil water extract sample as described by Black (1965).

Table 3. Soil physical properties of the experimental site

Soil depth (cm)	Soil physical properties (%)							
	Sand	Slit	Clay	Soil Texture	W.P.	F.C	A.W	B.D (kg /m^3)
0 -30	91.5	4.5	4.0	Sand	5.7	14.6	9.3	1.59
30 -60	93.7	4.0	2.3	Sand	4.8	15.5	13.9	1.39
60 - 90	95.7	3.0	1.3	Sand	4.1	17.9	13.9	1.35

Estimation of Irrigation requirements for olive tree

Most of the effects of the various weather conditions are incorporated into the ETo estimation. Therefore, as ETo represents as index of climatic demand, Kc varies predominately with the specific crop characteristics and only to a limited extent with climate.

This enables for transfer of standard values of Kc between locations and between climates. Also it is primary reason for the global acceptance and usefulness of the crop coefficient approach and the Kc factors developed. ETo is determined by the crop coefficient approach where by the effect of the various weather conditions are incorporated into ETo and the crop characteristics into the Kc coefficient. In the crop coefficient approach the crop evapotranspiration, ETc, is calculated by multiplying the reference crop evapotranspiration, ETo, by a crop coefficient, Kc according to FAO (1979) The same methodology was adopted by many studies(Allen et al., 1998, Gafar, 2009).

$$IR = K_c \times ET_o \times LF \times IE \times R \times A /1000$$

Where: **IR : Irrigation requirement (m^3/feddan).**

K_C : Crop coefficient [0.65-0.75] according to (Allen *et al.*, 1998 and Goldhamer *et al.*, 1994).

ET_o : Reference evapotranspiration (mm/day).

LF : Leaching fraction (assumed 20% of irrigation water).

IE : Irrigation efficiency for the irrigation system, (assumed 90% of the total applied).

R : Reduction factor (60-70 % cover in this study)

A : the irrigated area (Feddan).

1000 :To convert from liter to cubic meter.

Water Productivity (WP)

Water productivity (WP) was calculated based to FAO (1982) as follows: The ratio between the yields (y) and the amount of water where use in the field for the growth season.

$$WP = \frac{Y}{IR}$$

Where: **WP : Water productivity (kg/m^3)**

Y : Crop yield (kg)

IR : The total amount of irrigation water(m^3)

Daily Insolation Levels

The power output from the photovoltaic (PV) array depends upon the insolation and availability of sun per day sunshine hours available on a particular location per day. If water consumption varies round the year then the system design is based on the ratio of water required to the insolation available. The month in which this ratio is largest can determine the optimum PV array size in W/m^2.

Orientation and direction of photovoltaic the array

The photovoltaic array are positioned in such a way that the sunlight is utilized to its maximum that is true south direction. They will be exposed to the sun for the maximum length of time during daylight hours.

Water discharge measurement

Volume of water delivered by pump per unit time (m^3/h). The discharge of the AC submersible water pump used in the flow meter was recorded using stopwatch. The same measurement methods were performed under all conditions.

Power output

Power output from solar PV panels was recorded in January-December 2017. The output voltage and the current generated from the SPV panel gives energy output in terms of energy.

$$P_{pv} = SR \,.\, A_{pv} .Z_{pv}$$

Where: **P_{pv} = power of PV system, watts**

SR= Solar radiation (W/m^2)

A_{pv}= Area of solar module (m^2)

Z_{pv} = solar module efficacy (for 13 % to 18 %)

The intensity of the radiation was measured by a device (Light Meter) Model: YK-10LX (Table 4)

Table 4. Electrical specifications (23± 5 °C)

Range	Measurement	Resolution	Accuracy
2,000 (Lux)	0 : 1,999 (Lux)	1 (Lux)	± (5% +4d)
20,000(Lux)	2,000 : 19,990(Lux)	10 (Lux)	± (5% +4d)

RESULTS AND DISCUSSION

Water Requirement of the Plant

Maximum water requirements of the olives were calculated in equation (1) and it is tabulated in Table (5). The ET_o values started low at the beginning of the year during January and February (2.7 and 3.0 mm/day respectively) then increased gradually and reached the highest ET_o at mid of the year June and July (6.4 and 7.2 mm/day respectably) and declined again at the end of the year during November and December (3.1 and 2.8 mm/day respectively).

Table 5. Average monthly ETo under current and future climate conditions. (FAO, 1979)

Month	Jan.	Feb.	Mar.	Apri.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	average.
ET_o mm/day	2.7	3.0	3.8	5.7	6.6	6,4	7.2	6.2	5.2	4.5	3.1	2.8	4.8

Data in Table (5) indicated the irrigation requirements olive trees at monthly average irrigation need olive trees resulted from multiplying the average monthly ET_o for each climatic region by crop coefficient of olive trees. According to one feddan of olive needs about 2949 m^3/ year of irrigation. Data in Tables (6) indicated that the highest irrigation requirement was recorded in June and July 405.9, 425.8 m^3/fed. respectively. But the lowest irrigation requirements was recorded in November and December 117.5, 87.4 m^3/month respectively. And also table (7) showed the comparative between the solar water lifting capacity and the water requirements of olive .The results showed that the low solar water produced was more than 2887.5 m^3 in December and the high irrigation water requirement was 425.8 occurred in July. The irrigation water for olive pattern is constant with the solar water pumping capacity. The results also showed that the solar water pumping can meet the demand of olive irrigation.

Table 6. The average crop coefficient values of olive trees (K_c) (FAO, 1998)

$K_{C\,ini}$	$K_{c\,med}$	$K_{c\,end}$
0.65	0.7	0.7

Olives (40:60% ground coverage by canopy)

Variation of pump discharge with respect to solar intensity

The variations of pump discharge with respect to solar intensity presented in Fig. 1 The pump discharge produced in the range 14.8 to 35.7 m^3/h for corresponding change in solar Intensity in the range of 374 to 844 W/m^2. So, it can be deduced that the discharge increases with radiation and also decreases with it following of the same pattern for discharge produced in the range of 7.5, 14.8,20.3,29.5, 35.7,32.5,26.8,17.3 and 8.4 m^3/h for corresponding change in Solar intensity in the range of 78, 374, 610,770, 844, 826, 716,524, and 261W/m^2

Table 7. Average monthly irrigation requirements for mature olive trees

Month	Amount of Water applied		Average daily flow rae m^3/day	Clear sky through the month (day)	Total amount of water produced m^3/month	Total area cultivated in feddan
	(m^3/fed.)	(m^3/tree)				
Jan	84.5	0.503	144.2	22	3172.4	
Feb	85.6	0.509	177.8	21	3733.8	
Mar	178.7	1.06	198.1	26	5150.6	
April	284.4	1.69	214.3	28	6000.3	
May	362.5	2.15	224.7	29	6516.3	
June	405.9	2.42	260.2	30	7806	
July	425.8	2.53	252.6	31	7830	10
August	410.3	2.44	240.8	31	7464	
Sep	295.7	1.76	186.2	30	5586	
Oct	211.5	1.25	161.3	29	4677.7	
Nov	117.5	0.69	135.9	26	3533.4	
Dec	87.4	0.52	115.5	25	2887.5	
Total amount of water applied	2949.8	17.522	2311.6	328	64359.5	

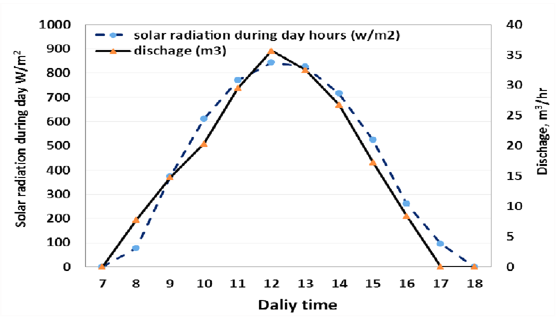

Fig.1. Discharge of pump via solar radiation at different times of a day.

Performance of solar pump

Fig. (1) showed that the solar for pump can not lift the water at less than 78 W/m^2 for solar radiation. Discharge also increased by increasing of solar radiation and it reached peak at noon (12:00 m) and then decreased gradually as solar radiation decreased. During the testing period the maximum discharge was found 35.7 m^3/h at 12.30 pm and the total discharge through the day was 193 m^3 at a daily average of 24.2 m^3/h through the day. The results indicates that discharge values increased by increased solar radiation

Variation of solar pump discharge with solar radiation

Fig. (2) represents the Comparing the between discharge of solar pump per months (January, February, March and April.

The results show that the average pump discharge were 144.2, 177.8, 198.1 and 216.3 m^3/day per months, January, February, March and April respectively. Than the highest discharge were found 25.8, 27.2, 28.5 and 29.6 m^3/h of 12.3 Pm per months, January, February, March and April respectively at daily time. And represents the comparing the between discharge of solar pump per months (May, June, July and August).The results show that the average pump discharge were 224.7, 260.5, 252.7 and 240.8 m^3/day per months, May, June, July and August respectively. Than the highest discharge were found 12.30 Pm 30.5, 33.8, 32.9 and 31.5 m^3/h of 12.3 Pm per months, May, June, July and August respectively at daily time. And also represents the Comparing the between discharge of solar pump per months (September, October, November, and December) . The results show that the average pump discharge were 186.2, 161.3, 135.9 and 115.5 m^3/day per months September, October, November, and December respectively. Than the highest discharge were found 12.30 Pm 31, 31.6, 29.5 and 25.7 m^3/h of 12.3 Pm per months, September, October, November, and December respectively at daily time. From previous results shows that maximum discharge values was obtained from per month June and that minimum discharge values was obtained from per month December.

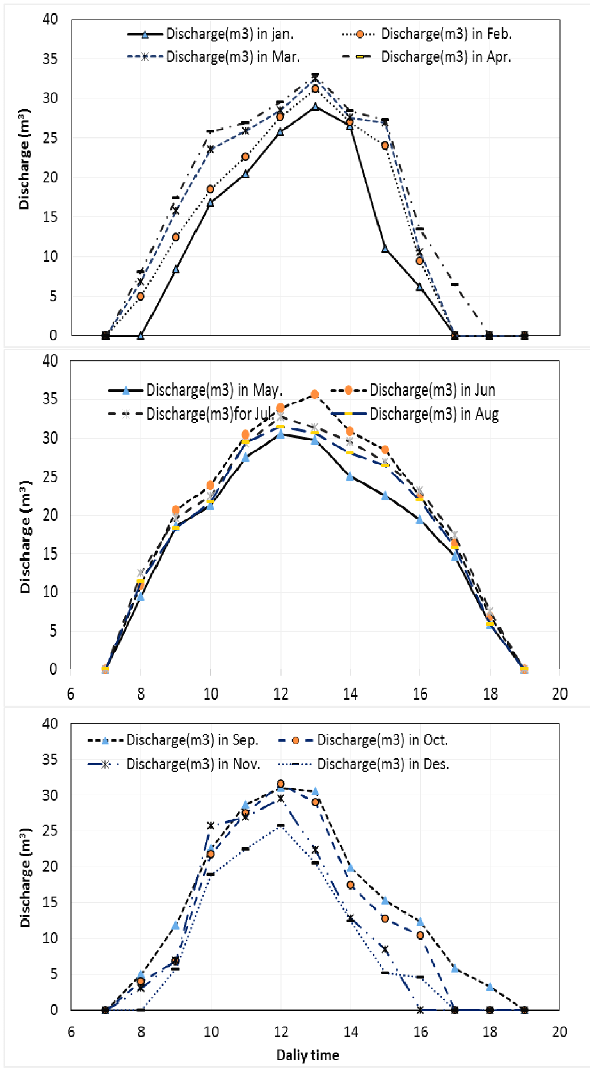

Fig 2. The solar pump discharges per Jan. to Dec.

Data in Table (8) indicated the Average length of day during the months of 2017 the highest length of day was recorded in July and June 13.88, 14.06 hour respectively but the lowest irrigation requirements was recorded in December and November 10.21, 10.63 hour respectively

Table 8. Average length of day during the months of 2017

Month	Average the day length (h)	Solar noon
Jan	10.43	12.06
Feb	11.15	12.15
Mar	11.98	12.05
April	12.91	11.9
May	13.66	11.85
June	14.06	11.91
July	13.88	12.01
August	13.21	11.98
Sep	12.35	11.83
Oct	11.43	11.68
Nov	10.63	11.65
Dec	10.21	11.83

Variation of AC power output with respect to input solar radiation

Fig. 3 shows the variation of AC output power with respect to solar intensity. The AC output power will be in the range of 2106.0 to 10627.2 watts for corresponding change in solar intensity in the range of 195 to 984 W/m^2. The results indicated that output power values increased by increased solar radiation and the maximum value was at 12.30 pm.

Fig. 4 shows the variation of discharge of solar pump with solar radiation during year. The test was conduct on throughout the year from morning to evening. It is observed from the Fig. (4) The month with the highest solar radiation was with an average of 6.27, 6.06and 5.97 kW/m^2/month Ac. for months August, July and June respectively. The three months that average the lowest average solar radiation levels was with an average of 3.5, 3.94 and 4.12 kW/m^2/month Ac. for months December, January and November respectively. That solar pump cannot lift any water at less than 78 W/m^2 of solar radiation. Discharge increased with the increase of solar radiation and it reached peak in the noon (12:00). and then decreased gradually as solar radiation decreased. During the testing period, the maximum discharge was found 35.7 m^3/h at 12.30 pm and the total discharge through the day was 193 m^3 at a daily average of 24.2 m^3/h through the day.

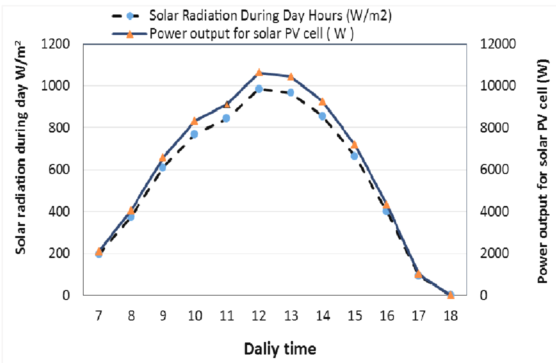

Fig. 3. Variation of power output with respect to input solar radiation at different times of a day.

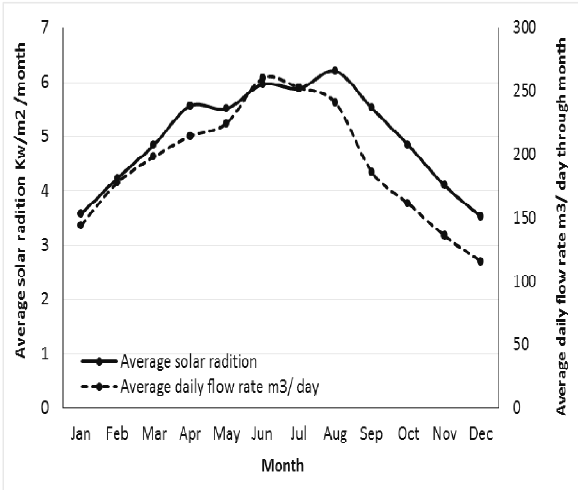

Fig. 4. Variation in the discharge for solar pump with solar radiation during a month.

Variation of discharge with respect to tracking:

Fig. (5) shows the variations of discharge with respect to tracking. Through manual moving (changing the directions of Photovoltaic systems, four times a day to be in front of the sun) Observed results indicated that the output discharge was more than7 % compared with fixed tilted photovoltaic array where it were 196.9 and 211.7 m^3/day for the fixed tilted and manual tracking respectively.

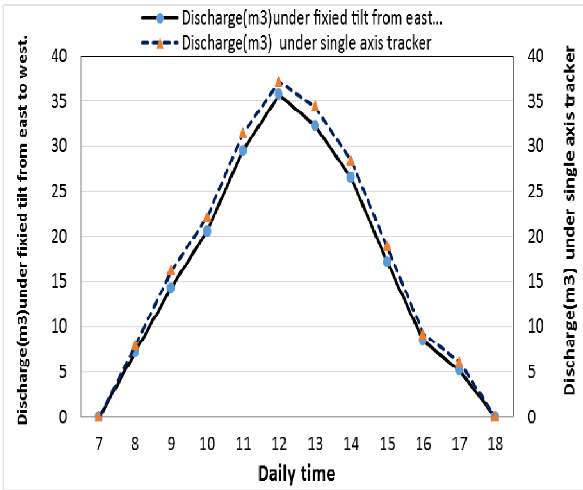

Fig. 5. Variation in the discharge for solar pump with tracking during a day.

Table 7 showed that the solar power systems produced more power in Summer than in Spring, Autumn and Winter which were 23100 ,17667.3, 13797.1 and 9793.7 m^3/season respectively, due to the sun was shine in the sky and the days being longer. From previous results shows that maximum discharge values was obtained from per month June and that minimum discharge values was obtained from per month December.

Water Productivity

The water productivity (Table, 8) (WP) is the ratio of crop yield (y) kg to the total amount of irrigation water (IR) m^3 use in the field for the growth season

$$WP = \frac{Y}{IR}$$

Table 8. The water-yield productivity

Yield kg/feddan	Total area feddan	Total yield kg	Total amount of water produced m^3	Water productivity (WP) kg /m^3
1344	10	13440	64359.5	0.21

CONCLUSION

The data are collected from to January to December 2017. Through these data Photovoltaic energy, input, output, module efficiency, system efficiency. All the variations of radiation, discharge, power and efficiencies with respect to daily times. The conclusions of this study are found as follows.

Most periods of the year. The most productive hours of sunlight are from 9.0 am to 3.0 pm, the solar power might still be produced, but at much lower levels. And the month with the highest solar power output are August, July and June with an average of 585.36, 565.54 and 546.72 kWh Ac respectively. That the three months that average the lowest average solar output levels are December, November and January with an average of 359.47, 396.98 and 405.8 kWh Ac respectively. The water flow (amount of water) of the solar pump changes based on the sunlight. It was high at noon and low in the early morning and evening where it were 14.8, 35.7 and 17.3 m^3/h for the 9.30 Am, 12.30 Pm and 3.30 Pm respectively.

Solar power systems produced higher energy in summer than winter, which were 23100, and 9793.7m^3/season respectively, due to the sun was shine in the sky and the days being longer. Tracking increases the output of water obtained was 7 % more compared to the fixed tilted PV array, where it were 196.9 and 211.7 m^3/day for the fixed tilted and manual tracking respectively by putting the panels in front of the sun. The water consumption of olive pattern was related to the solar water pumping capacity. The results indicated that the solar water pumping also could meet the requirements of olive irrigation.

The system is economically and very important in the area, which in no electricity source, but in the same time the initial cost for this system is high so it is very important sharing and subsidy government for this system to generalization the using of solar energy in agricultural.

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إدارة نظام الري بالتنقيط باستخدام الطاقة الشمسية

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ظهرت على الساحة العالمية والمحلية انتشار استخدام الطاقة الجديدة والمتجددة وخاصة الطاقة الشمسية حيث انها لا تنضب بسبب استمرار تجددها مادام الكون مستمر كما انها طاقة مأمونة المصدر لا يمكن احتكارها والسيطرة عليها كالوقود بالإضافة انها طاقة نظيفة وصديقة للبيئة , وتشير الدراسات الأولية الى ان الاشعاع الشمسي في مصر يمكن ان يكون له القدرة على ان يصبح مصدرا رئيسا من مصادر الطاقة حيث يتراوح بين ٢٠٠٠ كيلو وات ساعة في الشمال حتى ٢٦٠٠ كيلو وات /ساعة (متر مربع /سنة) في الجنوب لذلك يهدف هذا البحث الى استخدام الطاقة الشمسية لضخ المياه في نظام الري بالتنقيط . وتم اجراء التجربة في مزرعة خاصة بمنطقة وادى النطرون التابعة لمحافظة البحيرة باستخدام منظومة طاقة شمسية مكونة من ٣٩ لوح قدرة اللوح ٢٥٩.٨ وات وقدرة الوحدة ١٠١٣٢.٢ وات تعمل بالنظام المتحرك من الشرق الى الغرب تعمل لتشغيل طلمبة ٩.٥ حصان لري مساحة ١٠ افدنة مزروعة بأشجار الزيتون (صنف تفاحي و وعجيزي) على ابعاد ٥ متر * ٥ متر عمر ٥ سنوات وتم دراسة العوامل المؤثرة على تصرف الطلمبة مثل الاشعاع الشمسي ودرجة حرارة الجو وحركة اتجاه الالواح والتردد والطاقة الناتجة خلال عام ٢٠١٧ من(يناير حتى ديسمبر) من حيث تأثير الاشعاع الشمسي على التصرف وجد انه بزيادة الاشعاع الشمسي يزداد تصرف الطلمبة وتكون ساعات الشمس اكثر إنتاجية من التاسعة صباحا حتى الثلاثة مساء وخارج هذا النطاق يمكن انتاج الطاقة الشمسية ولكن بمستويات اقل بكثير وتصل ذروتها الساعة الثانية عشر ونصف ظهرا حيث بدأ الاشعاع الشمسي ٧٨ وات عند الساعة الثامنة صباحا وكان التصرف ٧.٥ متر مكعب /ساعة وظل يزداد حتى وصل ذروته الى ٨٤٤ وات عند الساعة الثانية عشر وعندها التصرف اصبح اعلى ما يمكن ٣٥.٧ متر مكعب /ساعة وبدأ في التناقص مرة أخرى حتى وصل ٢٦١ الساعة الرابعة مساء حيث انخفض التصرف الى ٨.٤ متر مكعب /ساعة .اما بالنسبة لتأثير درجة الحرارة على التصرف فانة بزيادة درجة الحرار ة يزداد التصرف مع وجود الاشعاع الشمسي حيث كان التصرف ١١.٢ , ١٧.٨, ٢٥.٨ و٣٣.٨ متر مكعب عند درجات حرارة ٩.١, ١٣.٥, ١٧.٥, ٢٣ درجة مئوية بالترتيب وايضا بزيادة الطاقة الخارجة يزداد التصرف حيث بزيادة القدرة الناتجة من ٣٢٦٥.٠٢, ٣٥٢٥.٣, ٦٧٢٢.١, ٧٣٦٨.١٢ وات اصبح التصرف ٧.٥, ١٤.٨, ٢٠.٣, ٣٥.٧ متر مكعب /ساعة بالنسبة لتأثير توجيه الالواح فان تتبع الالواح مع اتجاه الشمس تزيد التصرف بنسبة ٧ % عنة في حالة ثبات الالواح حيث كان التصرف في حالة ثبات الالواح طوال اليوم ١٩٦.٩ متر مكعب و٢١١.٧ متر مكعب في حالة تتبع الالواح مع اتجاه الشمس وأيضا زيادة التردد يزداد معه التصرف فزيادة التردد من ٣٢.٦ و ٣٧.٥ و ٤٠.٤ و٤٥.٤ و٤٧.٥ و٤٨.٩ هيرتز أعطت تصرفات ٣.٦ و ١٣.٤ و ١٧.٦ و٣٠و٣٢.٤ و ٣٧.٢ على الترتيب وتبين ان اعلى متوسط شهري للإشعاع الشمسي هو أغسطس يليه يوليو ثم يونيو ٦.٢٧ و٦.٠٦ و٥.٩٧ على الترتيب وان اقل متوسط شهري للإشعاع الشمسي ٣.٥ و٣.٩٤ و٤.١٢ لأشهر ديسمبر يليه يناير ثم نوفمبر على الترتيب وان اعلى متوسط شهري لإنتاج المياه كان لأشهر يونية ويوليو ٧٨٠٦ و ٧٨٣٠ متر مكعب على الرتيب واقل اشهر ديسمبر ويناير ٢٨٨٧.٥ و ٣١٧٢.٤ متر مكعب على الترتيب.