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EVALUATION OF SOLAR POWERED DRIP IRRIGATION SYSTEM

[148]

Nourhan A. Sadek[1*], Hegazi[2] A., Bedeer[1] O.M. and El-Gindy[1] A.

1- Agric. Engineering Dept., Fac. of Agric., Ain Shams Univ., P.O. Box 68, Hadayek Shoubra 11241, Cairo, Egypt

2- Water and Soils Research Dept., Nuclear Research Center, Atomic Energy Authority, Inshas, Sharkia, Egypt

*Corresponding author: eng.nour393@gmail.com

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ABSTRACT

Egypt's demand for electricity is growing rapidly and the need to develop alternative power resources is becoming ever more urgent. It is estimated that demand is increasing at a rate of 1,500 to 2,000 MW a year as a result of rapid urbanization and economic growth. Egypt is now struggling to meet its own energy needs. Egypt has been suffering severe power shortages and rolling blackouts over the past years, necessitating the requirement to look to alternative energy options.

Energy demand is increasing fastly so as to meet the requirements of growing population in the world. This study aimed to compare between traditional energy and solar generators in terms of energy consumption and cost effectiveness. Pumping systems were used to operate units of drip irrigation for the crop which was planted, so as to determine the best and least expensive energy consumption under this system.

The required hydraulic experiment and measurements were performed on a private farm at Beni Salama, Giza which lies at latitude 30.32°N, 30.80°E during 2016 and 2017. Measurements were done at two days randomly selected in the months of December and March. This study evaluated the average monthly measurements for December 2016 and March 2017 where onions were grown. Maximum and minimum for Pv system DC power output were 6398 and 5755 W, the maximum and minimum for AC current were 5814 and 5548 W, respectively. Maximum and minimum for hydraulic power were 5911 and 3553 W, respectively. Efficiency of both photovoltaic, inverter, pump and overall system were also calculated for these days. Maximum and minimum for module efficiency were 14% and 13.2%, respectively, and maximum and minimum for inverter efficiency were 95%, 89%, respectively. Maximum and minimum for pump efficiency were 64%, 54%, respectively. While for overall efficiency, they were 8**%** and 3**%,** respectively. The results showed that solar pumping system is a reliable system.

Keywords: Photo-irrigation, water pumping, drip irrigation, solar radiation.

INTRODUCTION

Solar energy is the most exuberant source of energy in the world. PV (photovolatic modules) generation is an effective approach for utilization the solar energy. In remote rural areas, whereat electricity is unobtainable, other means are essential to pump water for consuming such as photovoltaic pumping system (PVPS) which has specifications such as: dipped operating cost, dipped maintenance, ease installation and protractive. **(Abu-aligah, 2011)**.

The variations in the solar radiation intensity change the overall efficiency and the pumping flow-rate. Also it has been observed that system performance is maximal around midday and is degraded with the disturbance of the solar radiation and ambient temperature. Further, in spite of the short operating test period compared to the expected lifetime of the system which is between 20 and 25 years, the results generate some optimism regarding the use of PV water pumping systems. The performance analysis will be useful for selecting a suitable motor and load for a water pumping application in remote areas under tropical climatic conditions. **(Belgacem, 2012)**.

Cost effective solar power reply to the answers for all energy needs. Solar power is not solely a respond to today's energy recession, but too an environmental friendly form of energy. PV generation is an effective approach for utilization the solar energy. The cost of solar panels has been permanently diminishing, that encourages its usage in diverse sectors. One of the implementation of this technology is utilized in irrigation systems for cultivation. **(Harishankar et al 2014)**.

PVP'S are a great possibility to large, medium, and small scale applications. Though the installation cost of solar powered pumping system is more than that cost of gas, diesel, and propane powered generator based on pumping system nevertheless it need far less repairs cost. The features of PVP's over the traditional pumping system are illustrated in the **Table (1)**, which is cost effective for long time utilization that is favorable for remote rural areas **(Roy, 2012)**.

Table 1. Comparison between solar and traditional water pump

Attributes	Solar Water Pump	Traditional water Pump
Grid Electricity	No	Yes
Maintenance	Dipped Maintenance and unattended operation Convenient and reliable	Require maintenance and replacement
Fuel	No fuel cost or Spill	Fuel often expensive and supply intermittent
Upfront Cost	Upfront cost higher but last longer	Moderate capital cost
20 years total cost	Lower	Higher

Surendran et al 2015, mention that, the irrigation schedule recommendation to several crops must be location-specific, deeming the soil sorts and agro-ecological prerequisites. The scientific crop water requisites are desired for effective irrigation scheduling, (water balance).

Drip irrigation Method is the best method that has been used in the world among the other irrigation methods because of its good and high uniformity. This method distributes water to the field using the pipe network and transforms it from the pipe network to the plant by emitters **(Alabas, 2013).**

The rates and scheduling of irrigation under the solar system are calculated by one of the normal scheduling methods, but measurements were taken from 8:00 am to 4:00 pm where Sunrise and sunset, like **(Hegazi et al 2010)**.

Evaluation of the performance of a drip irrigation system under a solar energy system for sandy soil at the Atomic and Nuclear Energy Research Institute in Inshas was 96.62%. It classified as "excellent". **(Eldehn et al 2016)**.

(El-Saadawi et al 2019), mention that, the overall system efficiency can be deduced by dividing the system output (hydraulic power) on the system input (solar radiation power), or by multiplying the efficiencies of all system components, (solar panels, inverter, and pumping unit). The overall efficiency of the system is directly affected by solar radiation, but when solar radiation exceeds 900 W/m2 at noon, this is accompanied by an increase in temperature, which negatively affects the efficiency of the solar panels and thus the overall system efficiency. The daily-average overall system efficiency in December, March, and June, reached 7.40%, 8.46%, and 8.51%, respectively.

The objectives of this study are

1. Calculation of cultivated crop water requirement.
2. Irrigation scheduling.
3. Performance evaluation of drip irrigation network in terms of water distribution.
4. Solar pump performance and system efficiencies.
5. Consumed energy measurements to operate the system.

MATERIALS AND METHOD

Experiments were performed on a private farm in, Beni Salama, Giza during 2016 and 2017. Measurements were done for each of the solar irradiance by a Pyranometer every 15 minutes during the two days which have been selected randomly in months of December 2016 and March 2017. Measurements were performed December 2016 and March 2017 where onions were grown. Onion was grown in seedlings from December2016 to April 2017 and was irrigated every two to three days per hour per day at a rate of 60 riyals within 5 months. The productivity rate was half an acre of tons of onion crop and the irrigation system followed was surface drip irrigation that installed to irrigate a plot area of 2100 m^2 which is divided into two plots that was drip irrigated, One of them was (42*25) m^2 and the other was (42*25) with distribution uniformity 88%.

3.1. Main components of PVPS (photovoltaic pumping system)

PV pumping system consisted of:

3.1.1. PV system (Power Source (PV solar module)

PV solar module converts solar energy directly into electricity. There was 36 module each consisted of two electrical strings connected parallelly, each string contains 18, 260W as shown in **Table (2)**, connected to series to generate a DC current. The solar radiation was measured all day. Panel inclination was adjusted according to time of the year (40° for winter, 30° for autumn and spring and 20°for summer).

Table 2. PV module electrical data sheet (polycrystalline 260W)

Module Type	**JKM260P**
Maximum Power (Pmax)	260 W
Maximum Power Voltage (Vmp)	30.5 V
Maximum Power Current (Imp)	8.53 A
Open.circuit Voltage (Voc)	37.6 V
Short.circuit Current (Isc)	8.95 A
Module Efficiency STC (%)	15.89 %
Operating Temperature(℃)	.40℃~+85℃
Maximum system voltage	1000VDC (IEC)
Maximum series fuse rating	15A
Power tolerance	0~+3%
Dimension (L*W*H)	1640*922*40 mm
Weight	19 Kg
Nominal operating cell temperature (NOCT)	45±2℃

STC (Standard Test Condition): Irradiance 1000W/m2 & Cell Temperature 25℃ & Air Mass =1.5

Fig. 1. a) Solar radiation measuring instrument (pyranometer)
b) PV station above a farm building.

Efficiency of modules (η_{PV}) was calculated as a ratio of electrric power output (DC) from the modules and solar energy input using the equation (1):

$$\eta_{PV} = \frac{V_{DC} \times I_{DC}}{A_{PV} \times R_S} \times 100 \quad \text{………….. (1)}$$

Where:

A_{PV}: Surface area of solar array, m^{2y}

R_S: Solar radiation, W/m^2

V_{DC}: DC current, A

I_{DC}: DC voltage, V

3.1.2. AC Drive (Inverter)

AC Drive was used to convert DC current to three phase AC current, with minimum input voltage 500 V_{DC} and a maximum of 800 V_{DC}. It converts DC to 15 kW as a maximum output, the output voltage 380 - 440V three phase and output frequency 60 Hz as a maximum. The instantaneous inverter's efficiency ($\eta_{Inverter}$) was calculated as a ratio of the electric power output (AC) from the inverter and the electric power input into the inverter (DC) from the modules input using equation by **(Karami et al 2017)**:

$$\eta_{Inverter} = P_{AC}/P_{DC} \times 100 \quad \text{………….. (2)}$$

Where:

P_{AC}: Electric Power from inverter AC, W

P_{DC}: Electric Power from PV generator DC, W

Electric Power DC (P_{DC}) that was output from the PV, was calculated by using equation (3):

$$P_{DC} = V_{DC} \times I_{DC} \quad \text{………………… (3)}$$

Where:

V_{DC}: The voltage output from the inverter, V

I_{DC}: The current output from the inverter, A

Electric Power AC (P_{AC}) that was output from the inverter, was calculated by using equation (4):

$$P_{AC} = \sqrt{3} \times 380 \cos\emptyset \quad \text{………… (4)}$$

Where:

$\sqrt{3}$: The inverter output 3 phase.

380: The minimum voltage the inverter.

$\cos\emptyset$: Motor power factor, (assumed 0.8).

3.1.3 Pumping System

The pump used was at a Vsp ss 06030/08 submersible centrifugal pump. **Fig. (2)** gives a look on the pump from outside and inside. **Table (3)** illustrates the pump technical data, and the performance curves are shown in **Fig. (3)**.

Submersible Centrifugal Pump at depth of 70 m from the ground surface with 28 – 30 m^3/hr, and operating head 60 m, static level(water level) = 25 m , and the amount of draw down in the surface of the water ~ 5 m, Voltage 415 - 380V (+%6 / %10) and frequency 50 Hz, as shown figure(2). Measurements were made for discharge and pressure every 15 minute at different values of solar radiation, as shown in figure (3). Efficiency of pumping system (η_{PS}) (DC motor and submersible pump) was calculated as a ratio of hydraulic power and electric power consumption (AC power) coming on the inverter using equation (5):

$$\eta_{PS} = HP / AC\ Power \quad \text{………… (5)}$$

Where:

HP: Hydraulic power, W.

Ac power: Alternative current power, W.

3.1.4 Drip irrigation

Drip irrigation was installed to irrigate a plot area of 2100 m^2 which is divided into two plots that was drip irrigated, One of them was (42*25) m^2 and the other was (42*25) in **Fig. (5)**.

Drip irrigation system consisted of

1. The main line which was the feeding line. It was in the middle of the drip lines where water was delivered from the submersible pump to the drip lines. The distance between the lines was 100 cm.
2. Built in drippers with discharge of 4 l/h at 1 bar operating pressure and 30 cm distance between drippers.
3. One manual valve after the pump. Water meter and pressure gauges at output pump.

Hydraulic power (H_P) was calculated by measuring discharge pump and total dynamic head (TDH) using equation:

$$\text{Hydraulic power} = \frac{Q \times TDH \times \rho \times g}{3600} \quad \text{………… (6)}$$

Where:

H_P Hydraulic power

Q Pump discharge, m^3/hr

TDH Total dynamic head, m

ρ Water density, 1000 kg/m^3.

g Gravity acceleration, 9.81 m/s^2.

Table 3. Technical pump data

Pompa Tip	Kad. Sayısı	Motor		Dimensions (mm)					Weight (kg)		Flow rate m^3/hr	Head m
Pump type	**Stages**	**kW**	**HP**	**L**	**LM**	**LP**	**$\emptyset M$**	**$\emptyset P$**	**Motor**	**Pump**	**Q**	**h**
VSP SS 06030/08	**8**	**7.5**	**10**	**1.92**	**748**	**1.17**	**142**	**132**	**53**	**19**	**28 - 30**	**60**

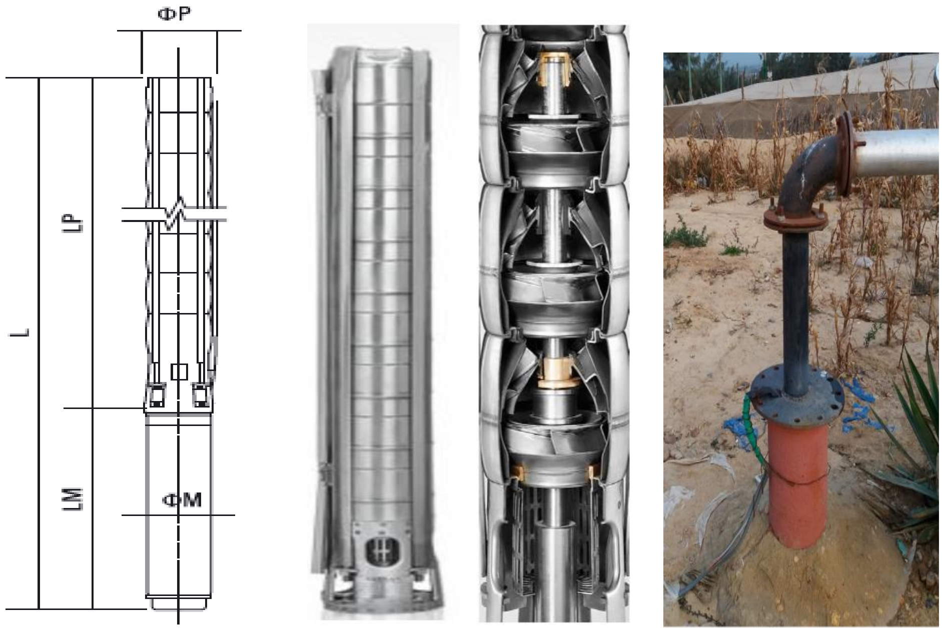

Fig. 2. Vsp ss 06030/08 submersible Centrifugal Pump.

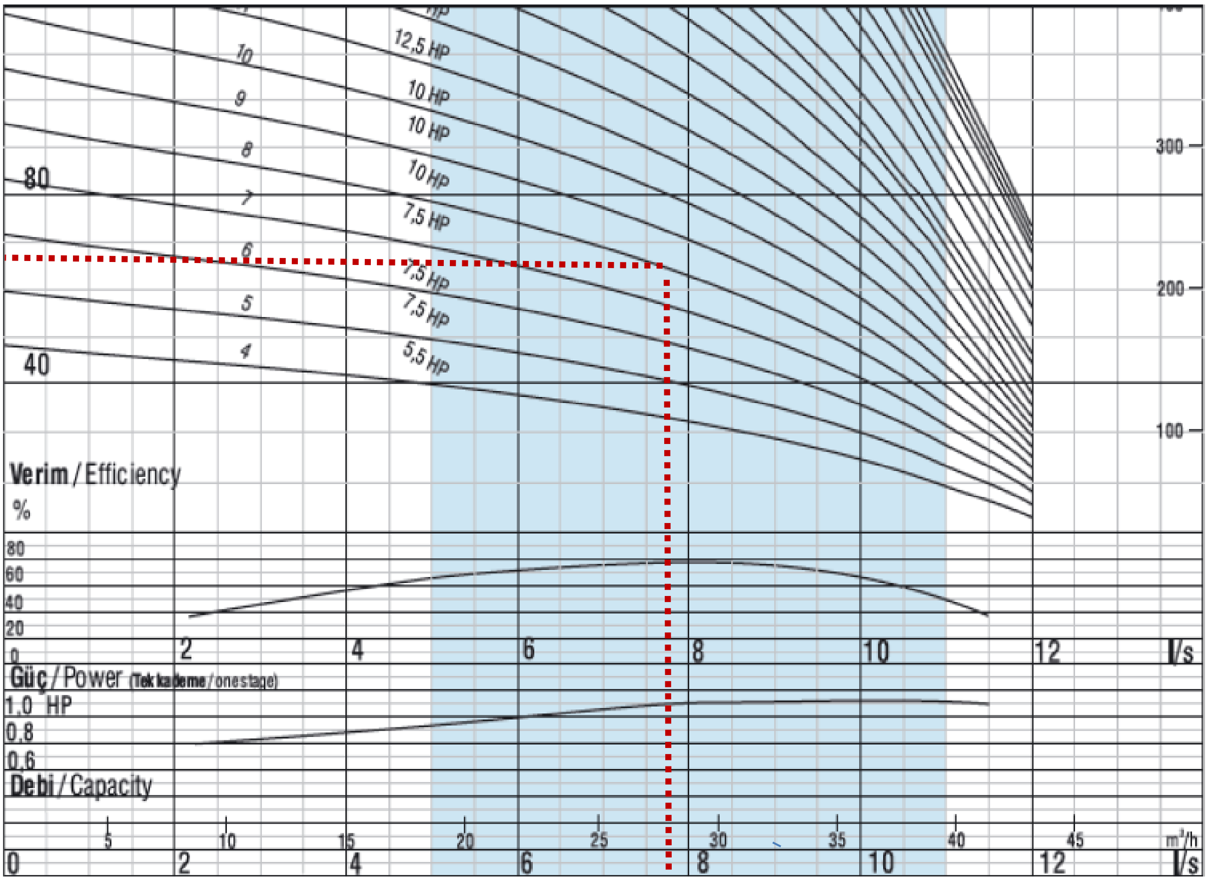

Fig. 3. The submersible pump and its performance curves

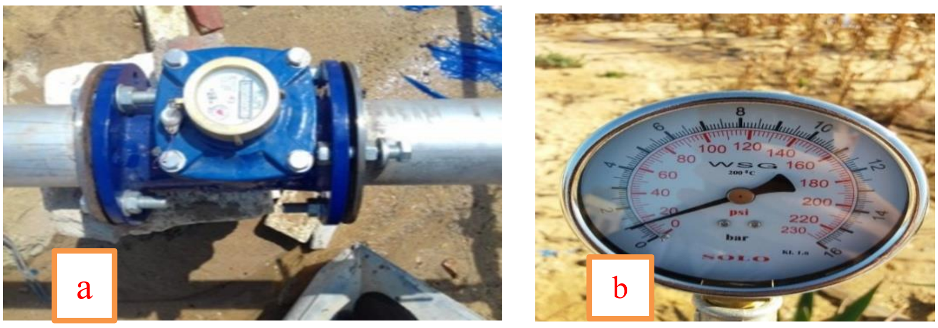

Fig. 4. Measurements tools of pumping system

a) Water meter measuring the output discharge, m^3/hr.
b) Manometer, (bar).

Fig. 5. Drip irrigation system

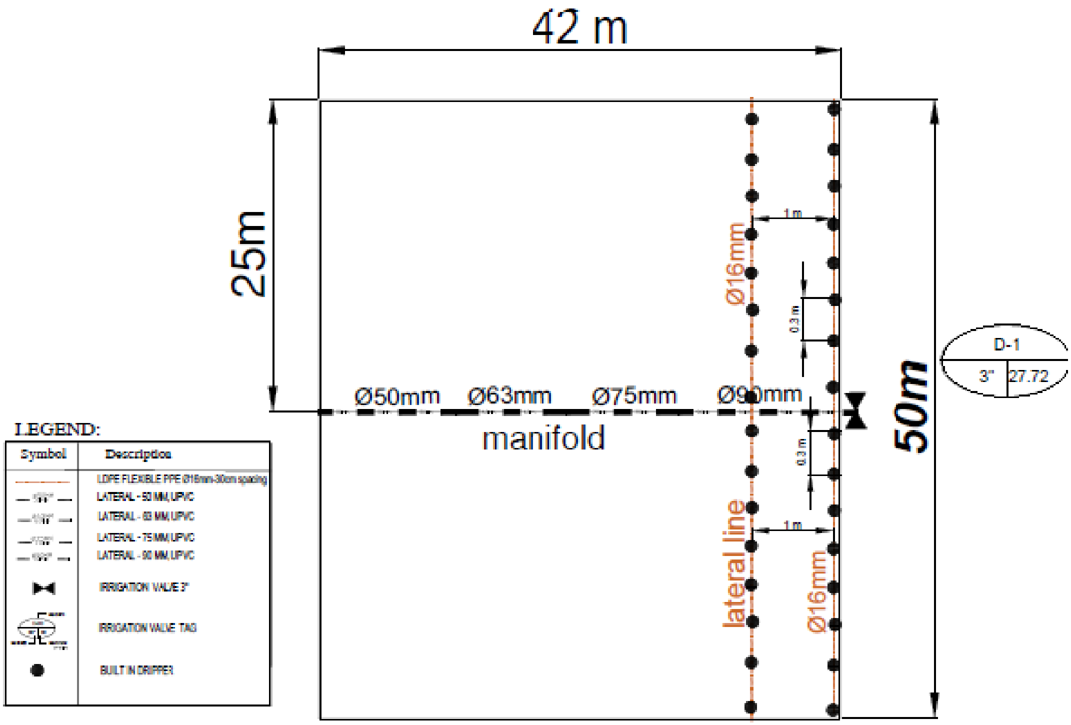

Fig. 6. Layout of Drip irrigation network

Total dynamic head (TDH) was calculated by the sum of both pumping level, vertical level and friction losses (H_f) using equation (7):

TDH =Pumping Level (Static Level + Draw Down) + Vertical Level (Pressure Operating) + Friction **Losses (H_f)** ………………… (7)

TDH = 25 +5 + 20 +10 = 60m

Friction losses (H_f) were calculated using the Hazen William equation:

$$J = 1.21 \times ((10)^{12}) \times ((Q/C)^{1.852}) \times (D^{-4.87}) \quad \text{……………………. (8)}$$

$$h_f = J \times (L/100) \times F \quad \text{……………… (9)}$$

Where:

J Friction loss (percentage) meter/100 meter.
Q The flow rate (L/S)
C William Hazen coefficient (equal to 150 if P.VC pipes and hoses P.E and 120 aluminum pipes)
D Inner diameter of the pipe (mm).

h_f Total Friction loss (meter)
L The length of pipe (meter)
F Correction coefficient depends on the number of exits

3.2 Irrigation scheduling

1. Calculated ET_o was obtained from Central Laboratory for Agricultural Climate, the results were as illustrated in **Table (4)**:

Table 4. The average monthly for the reference evapotranspiration (ET_0) in the planting season according to the Central Laboratory for Agricultural Climate

Month	ET_o mm/day
Dec. 2016	**1.4**
Jan. 2017	**1.6**
Feb. 2017	**2**
Mar. 2017	**2.5**
Apr. 2017	**3.5**

Some analysis has been done in Physics Laboratory in Soils Department, Faculty of Agriculture, Ain Shams University such as: mechanical analysis of Soil, humidity and saturation. The results were as illustrate in **Tables (5 and 6)**.

Table 5. The mechanical analysis of soil

Texture	Clay	Silt	Sand
	<0.002 m micron	**0.05-0.002 m micron**	**0.05 – 2.0 m micron**
Sandy Loam	**1.76**	**19.9**	**78.34**

Table 6. Field capacity, wilt factor and apparent density

Average of the apparent density	Field capacity	Wilt factor
	Average of the Percentage of Volume	**Average of the Percentage of Volume**
1.46 g/cm^3	**20.031 %**	**10.38 %**

Table 7. Deep well water analysis

pH	Salinity	Turbidity
8.4	**223 ppm**	**0.4 NTU**

3. The following equations was used to calculate both the water requirements, irrigation requirements and efficiency of use by using equations (10, 11 and 12) , given by **(Isarelsen et al 1962)**:

$$NWR = A \times Y \times (F.C\ .Wp) \times D \times P/100 \quad \ldots (10)$$
$$IR = NWR / Ea \quad \ldots (11)$$
$$Ea = TR \times EU = KS \times EU \quad \ldots (12)$$

Where:
NWR Net water requirements (Liter)
A Irrigated area (m^2)
Y Percentage of moisture that deplete (%)
F.C Moisture at field capacity (volume) mm/m
Wp moisture at Wilting point (volume) mm/m
D Effective depth of the root zone m
P Percentage of the wetted area from the total area %
IR Irrigation requirements (Liter)
Ea Efficiency of use (%)
TR Ratio of transpiration water quantity in the given amount
KS Efficiency of the soil to store water (sandy lands 0.91 – loam 0.95)
EU The degree of uniformity of distribution of total emitters

4. The following equations were used to calculate the net irrigation water depth, interval time and plant water consumption by using equations (13, 14 and 15), the results were as illustrate in **Table (8):**

$$dn = AW \times \rho \quad \ldots (13)$$
$$F = dn/ET_C \quad \ldots (14)$$
$$ET_C = kc \times ET_0 \quad \ldots (15)$$

Where:
dn Net irrigation water depth (mm)
ρ Depleted moisture, Typically 50% (**The Irrigation Association, August 2001**).
F Interval time (day)
ET_C Plant water consumption (mm / day)
K_C Crop coefficient

3.3. Emission uniformity

Emission uniformity test (EU) was calculated according to the equation (16) given by **Keller and Karmeli, (1974)**.

$$EU = (qn / q_{av}) \times 100 \quad \ldots\ldots\ldots\ldots. (16)$$

Where:

EU Emission uniformity, %

qn Average of the lowest quarter of the emitter flow rate, l/h

q_{av} Average of all emitter flow rates, l/h

3.4. Overall efficiency

Overall efficiency was calculated by using pumping system efficiency (η_{PS}), PV system efficiency (η_{PV}) and inverter efficiency ($\eta_{Inverter}$) or the ratio of hydraulic power and solar energy input using equation (17) given by **(El-Saadawi et al 2019)**:

$$\eta_{Overall} = \eta_{PS} \times \eta_{PV} \times \eta_{Inverter} \;\&\; \eta_{Overall} = \frac{HP}{A_{PV} \times R_S} \times 100 \quad \ldots\ldots\ldots\ldots (17)$$

Where:

$\eta_{Overall}$ Efficiency Overall, %.

η_{PS} Efficiency of pumping system, %.

η_{PV} Efficiency of PV module, %.

$\eta_{Inverter}$ Inverter efficiency, %.

RESULTS AND DISCUSSION

PVP system for irrigation was evaluated for drip irrigation system. Solar radiation was the major factor affecting hydraulic power.

In this study, two days, randomly selected, were evaluated during December 2016 and March 2017.

4.1. Water requirement for cultivated crop

The water requirements, irrigation requirements and efficiency of use have been calculated of onion. Onion crop season results were shown in **Table (8)**.

4.2. Irrigation scheduling

The average of the net irrigation water depth, interval time and plant water consumption have been calculated by compensation in equations (13, 14 and 15), the results was obtained shown in **Table (9)**:

4.3. Emission uniformity

Dippers flow rate increased with increasing pressure, as indicated in **Fig. (8)**

Emission uniformity of the drip irrigation system have been calculated from equation (16) was (88.08%), it was classified as "good".

4.4. Solar radiation intensity measurements

Measurements of solar radiation intensity for two random days during December 2016 and March 2017 by using the pyranometer increased since sunrise and reached its peak at noon while gradually decreased to sunset. Measurements showed the increase of average daily solar radiation for months December 2016 and March 2017 at 7:00 am was as follows: (182, 413 W/m^2.day), respectively. While for average daily solar radiation in the months December 2016 and March 2017 in the afternoon at 12:00 pm, the intensity of solar radiation increased to reach its peak in December 2016 and March 2017 follows: (983 and 1082 W/m^2.day), respectively. The average daily solar radiation for months December 2016 and March 2017 at the sunset at 4:00 pm was as follows: (562 and 595 W/m^2.day), respectively.

4.5. Generated electric power (P_{DC})

The energy generated (P_{DC}) by PV arrays is the result of multiplying both the DC current and the DC voltage that was the output from the PV panels. This is computational for the P_{DC} was depended on the intensity of solar radiation directly and this is illustrated by the **Fig. (10-a) and (10-b)**. So that the P_{DC} from the PV arrays was calculated from the time of passage of the current and increase to reach the peak at noon and reduced to reach the lowest value when there is no current. P_{DC} at 8:00 am for: (4485, 4770 W/15 min.) respectively, and the P_{DC} was increased to reach its peak at noon. The P_{DC} for the two selected days in December 2016 and March 2017 were (7235 and 8060 W/15 min.) respectively and decreased when the solar radiation was less than electricity current. The P_{DC} of the two selected days in December and March were (4216 and 5210 W/15 min.) respectively. Diverseness of solar radiation (RS) caused in diverseness of the P_{DC}, as in **Fig. (11)**. The highest solar radiation intensity was acquired at noon when sunlight is vertical on the PV panel's surface.

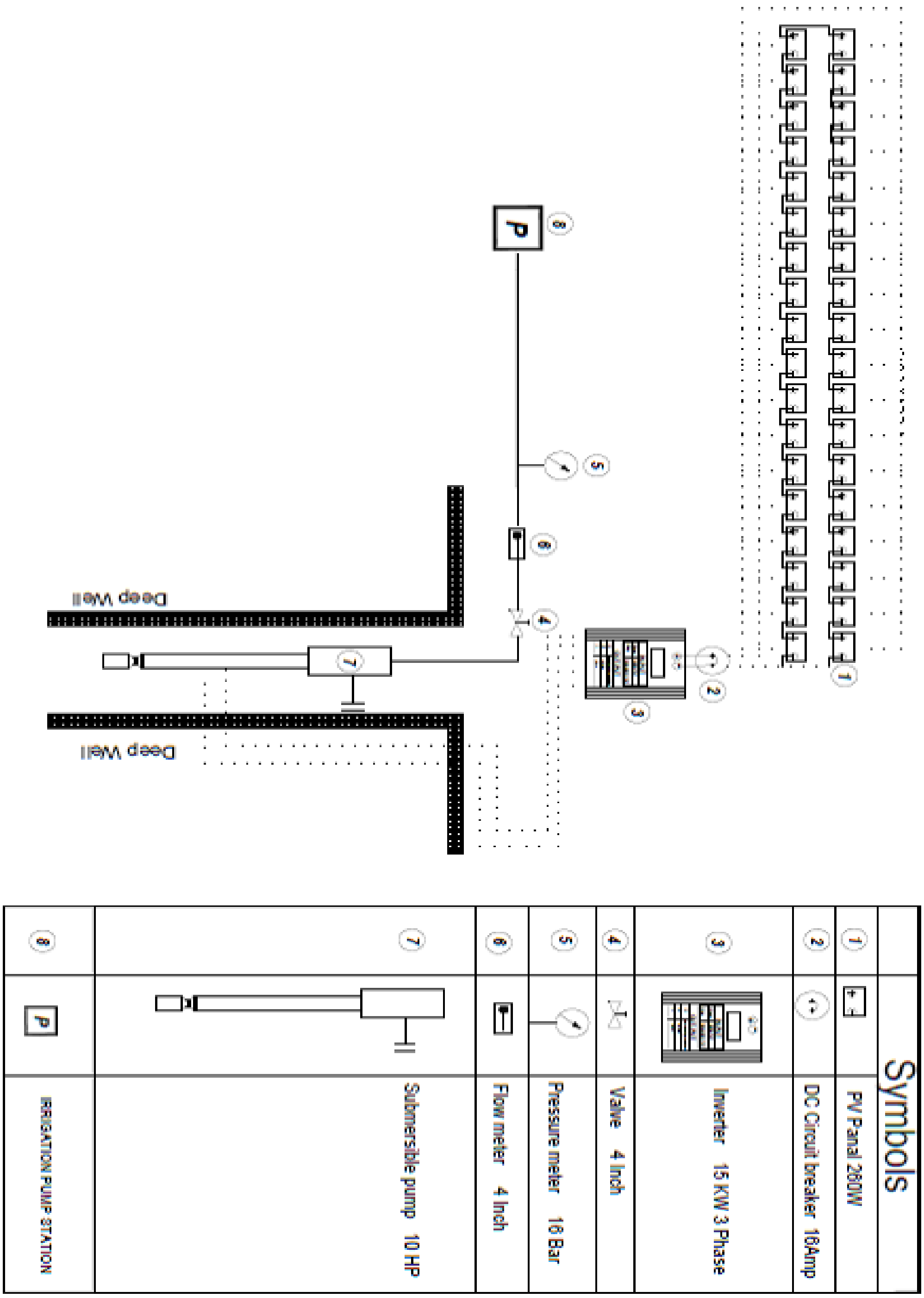

Fig. 7. A schematic drawing of the solar pumping system (PVPS)

Table 8. The water requirements, irrigation requirements and efficiency of use

Onion crop season	NWR	IR	Ea
	0.12 L	0.15 L	80 %

Table 9. The average of the net irrigation water depth, interval time and plant water consumption

ET_o mm/day	AW mm/m	Dn mm	F day	ETC mm/day	Kc	Crop Development stages	Days
1.4	9.8	4.9	2	2.8	0.5	Intial	15 December 2016–30 December 2016
1.5	9.8	4.9	2	2.0	0.75	Crop development	31 December 2016–25 January 2017
1.8	9.8	4.9	3	1.8	1	Mild season	26 January 2017– 20 February 2017
2.25	9.8	4.9	2	2.6	0.85	Late season	21 February 2017 – 26 March 2017
3	9.8	4.9	1	3.8	0.8	At harvest	27 March 2017 - 10 April 2017

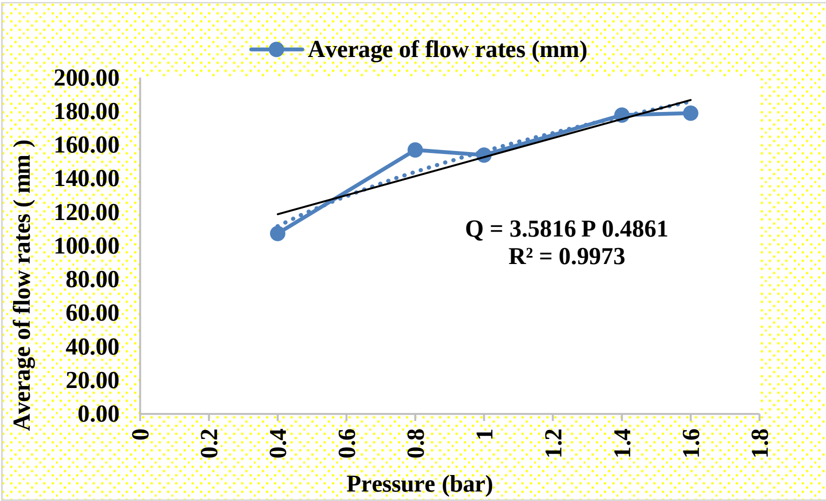

Fig. 8. Relationship between pressure and the average of flow rates

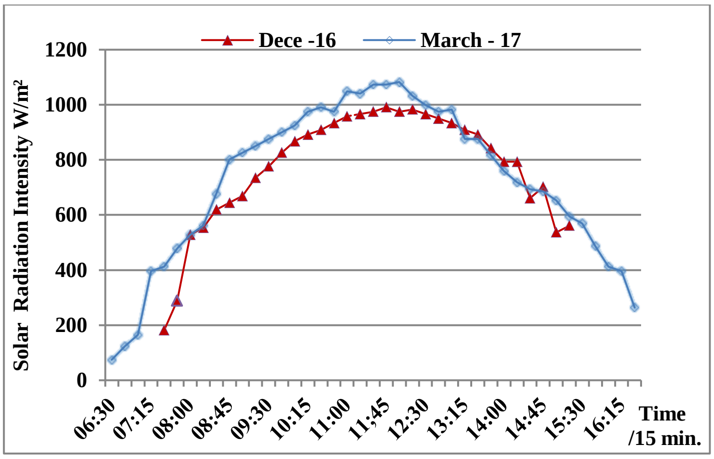

Fig. 9. Shows the intensity of solar radiation every15 minute.

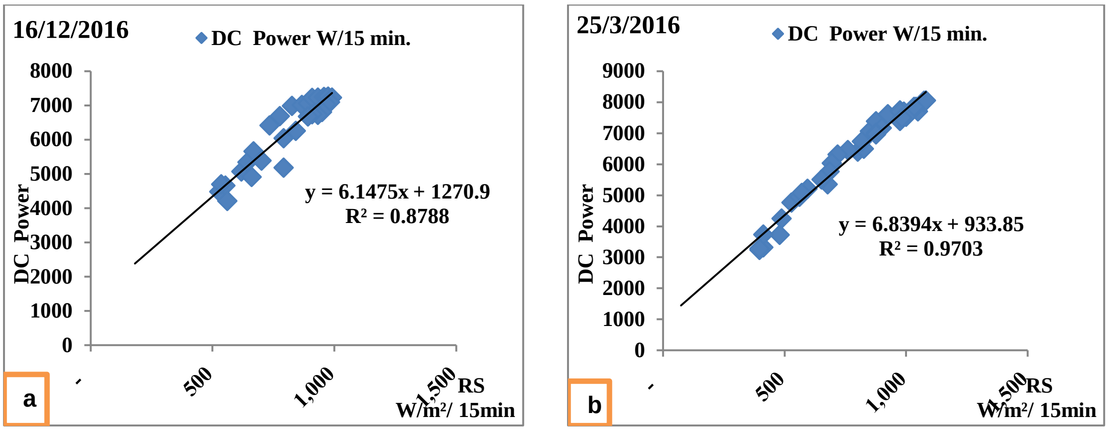

Fig. 10. The ratio between the solar radiation and the DC Power from 8:0 to 4:00 pm every 15 min.

a) 16 December 2016.

b) 25 March 2017.

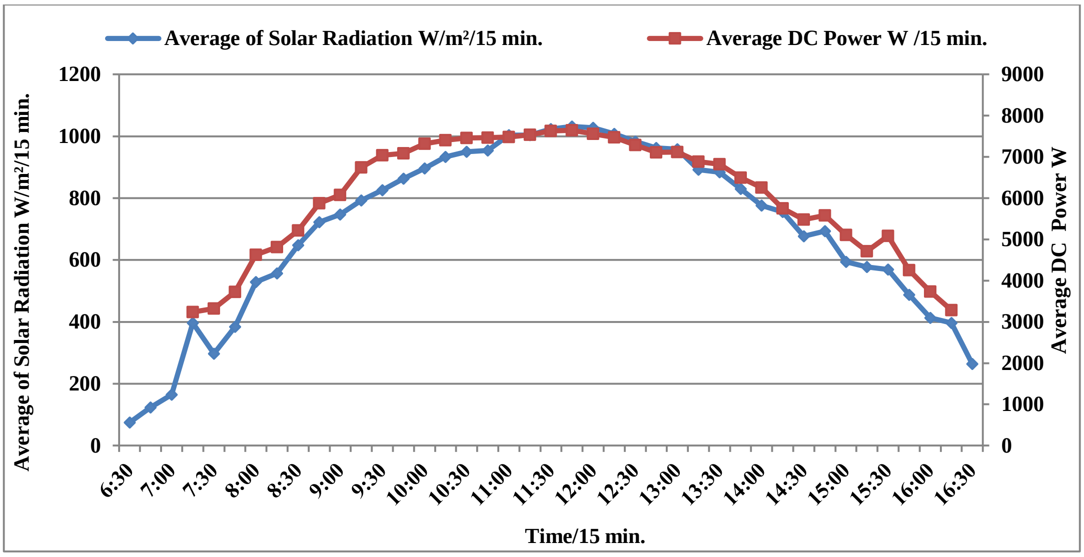

Fig. 11. Diverseness of solar radiation (RS) caused in diverseness of the P_{DC}

4.6. Generated electric power (P_{AC})

The power generated (P_{AC}) by the inverter is the result of multiplying both 3 roots, motor power factor, AC current and AC voltage that were the output of the inverter. This is computation for the P_{AC} was depended on the intensity of solar radiation directly and this is illustrated by the **Figs. (12-a) and (12-b)**. So, the P_{AC} from the inverter was calculated from the time of passage of the current, is increase to reach the peak at noon and its decrease to reach the lowest value when there is no current. Average daily P_{AC} for months December 2016 and March 2017 at 8:00 am were (3528 and 4581 W/15 min.), respectively, and the average daily P_{AC} for months December 2016 and March 2017 increased to reach its peak at noon. (6371 and 8060 W/15 min.), respectively and decreased in the average daily P_{AC} for months December 2016 and March 2017 in the sunset at 4:00 pm as follows: (3159 and 4897 W/m^2.day), respectively, where the solar radiation was less than electricity current. It showed the correlation between AC power and solar radiation, which indicates the adoption of AC power on solar radiation (the value of AC power changes with solar radiation).

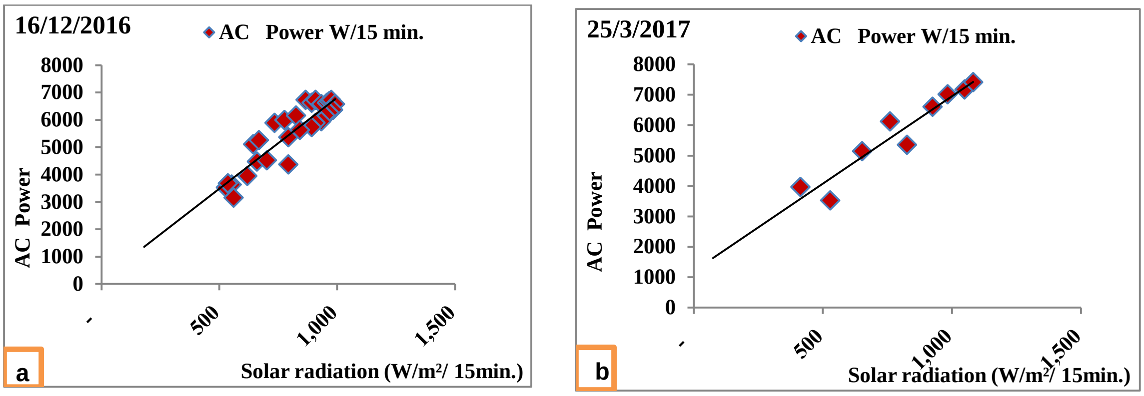

Fig. 12. The ratio between the solar radiation and the AC Power from 8:0 to 4:00 pm every 15 min.

a) 16 December 2016.
b) 25 March 2017.

4.7. Pump performance

4.7.1 Discharge

Discharge depend on the intensity of solar radiation. Its values begin when a constant current passes where the values were low, then peaked at noon at the highest value of solar radiation, and then decreased to the lowest values when there was no current. Average daily P_{AC} for months December 2016 and March 2017 for P_{AC} at 8:00 am was 3528 and 4581 W/15 min., respectively. It increased to reach its peak at noon (6371, 8060 W/15 min.), respectively. It decreased in the average daily P_{AC} for months December 2016 and March 2017 in the sunset at 4:00 pm as follows: (3159 and 3686 W/m^2.day), respectively. As **Fig. (13-a) and (13-b)** show the ratio between average daily discharge for months December 2016 and March 2017 for the discharge and the average daily solar radiation every hour for the two selected days for the month of December 2016 and March 2017, respectively. **Fig. (14-a) and (14-b)** show the ratio between the discharge and pressure for the time every hour for the two selected days for the month of December and March, respectively.

4.7.2. Hydraulic Power (HP)

Hydraulic power was calculated for the PVP system. **Fig. (15-a) and (15-b)** show the ratio between HP and solar radiation intensity.

In March 2016, HP values were higher compared to December 2017 ones. That meant higher irrigation water delivery in spring time than winter. **Fig. (16-a) and (16-b)** show the ratio HP between DC and AC power for both days. It shows the correlation between hydraulic power and solar radiation, indicating the adoption of hydraulic power on solar radiation (the value of hydraulic power changes with solar radiation)

4.8. Electric Power Consumption (AC)

The average energy consumption for the two months of December 2016 and March 2017 were calculated for the three systems (solar energy, electric power and diesel). The average monthly consumption of solar energy for December and March were 40.00 and 48.80 kW. The average monthly electricity consumption for December 2016 and March 2017 were 50.00 and 61.00 KVA. The monthly average power consumption for diesel in December 2016 and March 2017 were 3.60 and 4.40 Liter, as shown **Table (10).**

Month	Average Electric Power Consumption KW	Average Electric Power Consumption KVA	Average Energy consumed from diesel (L)
December 2016	40.00	50.00	3.60
March 2017	48.80	61.00	4.40

4.9. Overall Efficiency ($\eta_{Overall}$)

The overall efficiency of the system was less than the other competencies because the total efficiency is divided among the efficiency of the inverter, efficiency of the pump and the efficiency of the module. Module efficiency and the inverter efficiency indicates the appropriate choice for both the inverter and the module, as shown **Fig. (17)**. **Fig. (18-a) and (18-b)** show overall efficiencies, solar radiation and both relationships. Efficiency of system was higher in winter than in spring due to low module temperature. Values were 3%, 7%, 8%, 5% for December and 3%, 6%, 8%, 5%. These values are consistent with **(El-Saadawi et al 2019)**.

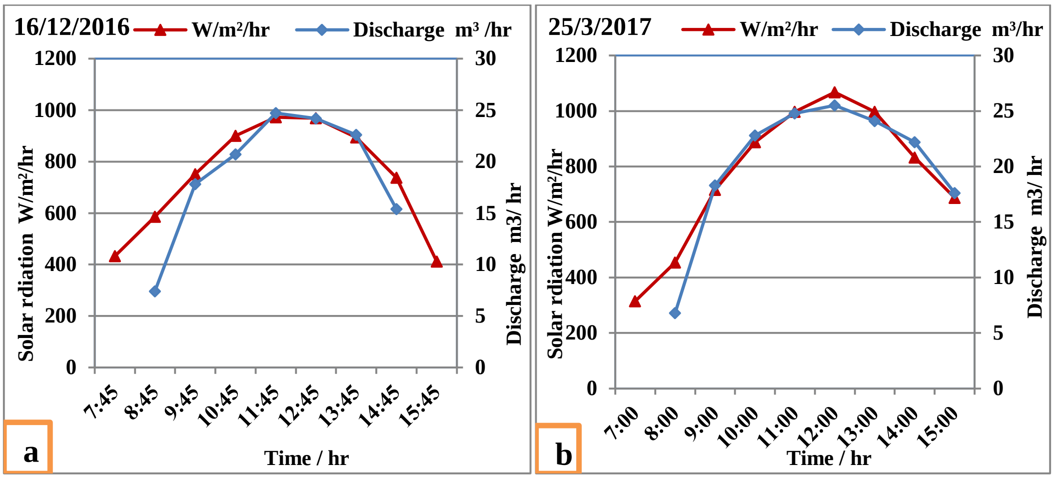

Fig. 13. The ratio between time every hour and discharge from 8:0 to 4:00 pm for:

a)16 December 2016.
b)25 March 2017.

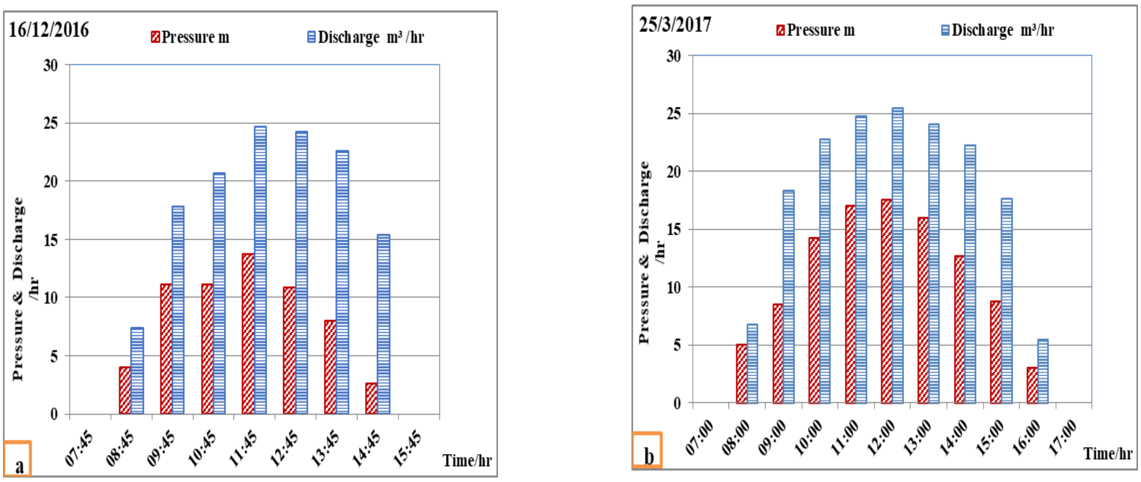

Fig. 14. Pumping system head and discharge for two days from 8:0 to 4:00 pm every hour

a) 16 December 2016.
b) 25 March 2017.

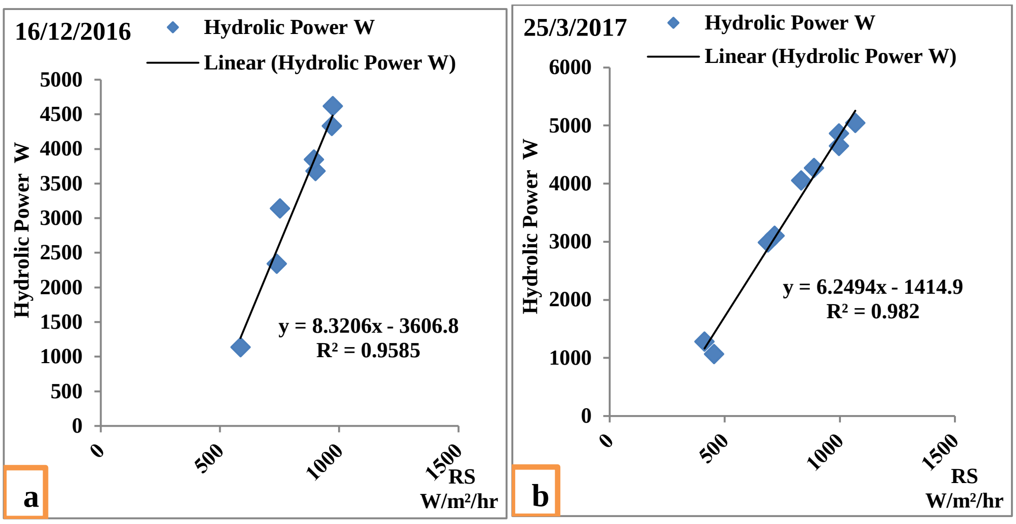

Fig. 15. The ratio between average daily of the solar radiation and the average daily of the hydraulic power from 8:0 to 4:00 pm:

a) 16 December 2016.
b) 25 March 2017.

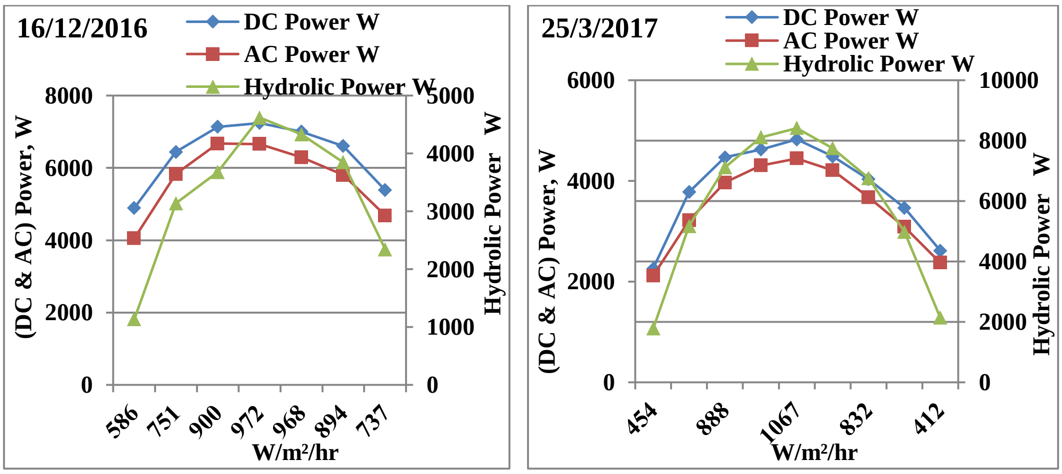

Fig. 16. DC and AC power, W, for two days December 2016 and March 2017 respectively

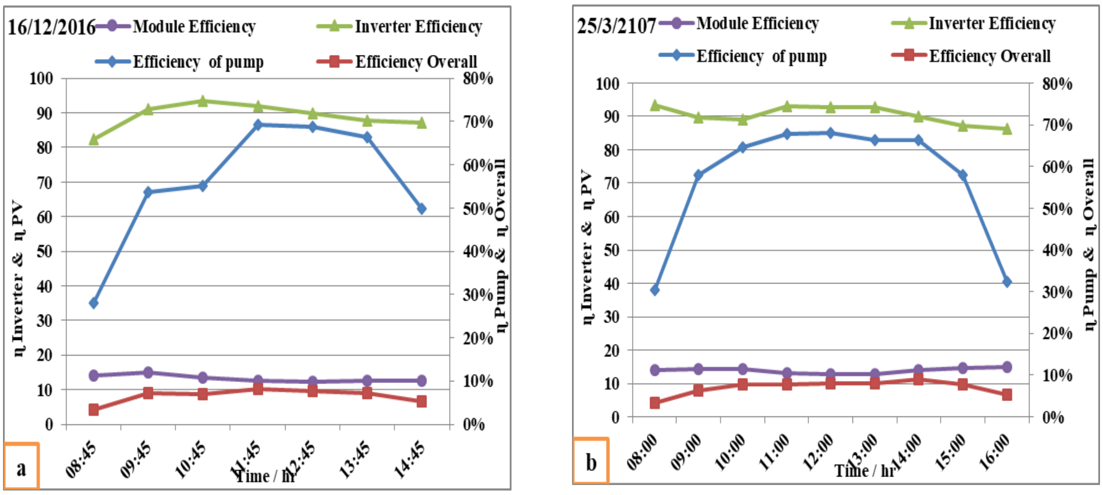

Fig. 17. System efficiencies, module, inverter, pump and overall efficiencies for two selected days from 8:0 to 4:00 pm

a) 16 December 2016.
b) 25 March 2017.

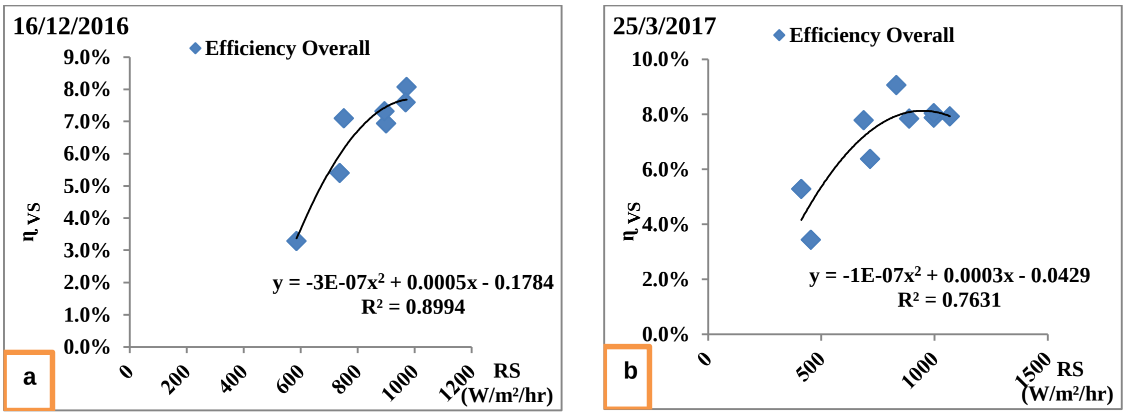

Fig. 18. System overall efficiencies (VS), solar radiation (RS) from 8:0 to 4:00 pm for:

a) 16 December 2016.
b) 25 March 2017.

This study showed that this kind of solar energy utilizing pumping system is very suitable for the remote areas in the desert and luxurious areas.

CONCLUSION

This study showed that this kind of solar energy utilizing pumping system is very suitable for the remote areas in the desert and luxurious areas.

REFERENCES

Abu-Aligah M. 2011. Design of PV water pumping system and compare it with diesel powered pump. **Jordan J. of Mechanical & Industrial Engineering, 5(3), 273-280.**

Alabas M.A.A.A. 2013. Evaluation the hydraulic performance of drip Irrigation system with multi cases. **Global J. of Research in Engineering, 13(2), 1-7.**

Belgacem B.G. 2012. Performance of submersible PV water pumping systems in Tunisia. **Energy for Sustainable Development, 16(4), 415-420.**

Eldehn F.I., Hegazi A.M., Mostafa M.M. and El-Nono M.A., 2016. Performance evaluation of solar powered pump based on a drip irrigation system for small scale areas using nuclear techniques. **Fac. of Agric. Ain Shams Univ., Cairo, Egypt, 38 p.**

El-Saadawi F.Y., Hegazi A.M., El-Laithy A.M. and Tayel S.A. 2019. Evaluation of solar energy system for agricultural application. **Fac. of Agric., Cairo, Al-Azhar Univ., Cairo, Egypt, pp. 65-96.**

Harishankar S., Kumar R.S., Sudharsan K.P., Vignesh U. and Viveknath T. 2014. Solar powered smart irrigation system. **Advance in Electronic and Electric Eng., 4, 341-346.**

Hegazi A., Awady M.N., Hegazi M.M. and El-gindy R.W. 2010. Performance evaluation of locally assembled solar powered irrigation pump. **Misr J. of Agric. Eng., 27(1), 141-150.**

Karami E., Rafi M., Haibaoui A., Ridah A. and Hartiti B. 2017. Performance analysis and comparison of different photovoltaic modules technologies under different climatic conditions in casablanca. **J. Fundam Renewable Energy Appl., 7(231), 2-8.**

Keller J. and Karmeli D. 1974. Trickle irrigation design parameters. **Transactions of the American Society of Agric. and Biological Eng., 17(4), 678-684.**

Roy R.B. 2012. Design and performance analysis of the solar PV DC water pumping system. **Canadian J. on Electrical and Electronics Eng., 3(7), 403-412.**

Surendran U., Sushanth C.M., Mammen G. and Joseph E.J. 2015. Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad district of humid tropical Kerala, **India. Aquatic Procedia, 4, 1211-1219.**

مجلة اتحاد الجامعات العربية للعلوم الزراعية ، جامعة عين شمس ، القاهرة ، مصر
مجلد(27)، عدد(3)، 1853-1870، 2019
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[148]

تقييم نظام الري بالتنقيط يعمل بالطاقة الشمسية

نورهان أنور صادق[1*]– أحمد حجازي[2] – أسامه محمد بدير[1] – عبد الغني الجندي[1]
1- قسم الهندسة الزراعية – كلية الزراعة- جامعة عين شمس- ص.ب 68- حدائق شبرا 11241- القاهرة –مصر
2- قسم بحوث الأراضي والمياه – مركز البحوث النووية – هيئة طاقة الذرية – انشاص – الشرقية – مصر
*Corresponding author: eng.nour393@gmail.com

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الموجـــــــز

يتزايد الطلب على الطاقة الكهربائية بسرعة في مصر ، وأصبحت الحاجة ملحة إلى تطوير موارد بديلة للطاقة أكثر من أي وقت مضى. وتشير التقديرات إلى أن الطلب يتزايد بمعدل 1,500 إلى 2000 ميجا واط سنوياً، نتيجة للتوسع الحضري السريع والنمو الاقتصادي. تكافح مصر الآن لتلبية احتياجاتها من الطاقة، وتعاني أيضا من نقص شديد في الطاقة وانقطاع الكهرباء على مدى السنوات الماضية، ونظرا لزيادة أسعار الوقود والكهرباء وعدم توافرها في العقود الماضية الأخيرة في مصر، والزيادة السكانية مما يتطلب توفير في الطاقة وعدم اهدارها واستغلالها الاستغلال الامثل لذا تم استخدام الطاقة الشمسية (طاقة متجددة نظيفة) في نظام الري المتبع (الري بالتنقيط).

ولذلك يتزايد الطلب على الطاقة بسرعة فيما يتعلق بالوفاء بمتطلبات النمو السكاني في العالم. تهدف هذه الدراسة إلى مقارنة بين الطاقة التقليدية ومولدات الطاقة الشمسية من حيث التكلفة واستهلاك الطاقة. استخدمت نظم الضخ لتشغيل وحدات للري بالتنقيط للمحصول الذي يزرع من أجل تحديد استهلاك الطاقة أفضل وأقل تكلفة بموجب هذا النظام.

أجريت التجربة الهيدروليكية المطلوبة والقياسات في مزرعة في قرية خاصة "بني سلامة"، الجيزة التي تقع على خط عرض 30.32 درجة شمالا وخط طول 30.80 درجة شرقا خلال الأشهر من سبتمبر 2016 حتي يونيه عام 2017.

القياسات التجريبية لكل من الإشعاع الشمسي و التيار المتردد الثابت والفولت DC و درجة حرارة الخلية ومعدل التدفق والضغط كل 15 دقيقة خلال الأيام الأربعة التي اختيرت عشوائياً في الأشهر (سبتمبر- ديسمبر – مارس – يونيه). القياسات الشهرية خلال فترة نمو البصل من ديسمبر 2016 إلي مارس 2017.

من خلال قياسات الأيام المختارة عشوائيا في الأشهر (ديسمبر، مارس) لعامي 2016 -2017، كان الحد الأقصي والحد الأدني للقدرة الكهربائية للتيار المستمر هى (6398، 5575) وات، وكان الحد الأقصي والحد الأدني للقدرة الكهربائية للتيار المتردد هى (5814، 5548) وات، وكان الحد الأقصي والحد الأدني للقدرة الهيدروليكية للمضخة هى (5911، 3553) وات.

ومن هذه القياسات أيضا تم حساب كفاءة كلا من الخلايا والأنفرتير والمضخة والكفاة الكلية للنظام لتلك الأيام. فكان الحد الأقصي والحدالأدني لكفاءة الخلايا هي (13%، 14%)، وكان الحد الأقصي والحدالأدني لكفاءة الإنفرتيرهي (89%، 95%)، وكان الحد الأقصي والحدالأدني لكفاءة المضخة هي (54%، 64%)، وكان الحد الأقصي والحد الأدني لكفاءة الكلية للنظام هي (3% ، 8%). وتبين النتائج أن نظام ضخ الطاقة الشمسية هو نظام جيد وذو ثقة.

الكلمات الدالة: نظام الري بالخلايا الفلوتوضوئية، ضخ المياه، الرى بالتنقيط، الإشعاع الشمسي

تحكيم: ا.د عصام عبد المنعم لواصف
ا.د محمود محمد حجازي