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Research Article

Design and Analysis of the Performance of Solar Drip Irrigation by using Epanet Program

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Abstract

The process of producing agriculture crops is very dependent on energy. The dependency on fossil fuels causes the cost of producing crops to increase as the prices of fuel increases. Using a renewable energy sources to power and irrigation system is a mean of decreasing the dependency of agriculture crops on the prices of fuel . The research aims to design a drip irrigation system, solar powered for the purpose of watering the plant and operate the system independently from the national grid , which is designed parts thereof according to the mechanism reduce the power required from the system and the preparation of sequential programming to run water pumps , submersible and surface , where the pumps are used enabled solar energy as the rationalization of water consumption is used as a drip irrigation equipment . The computer program is used for the work Epanet hydraulic simulation by selecting the pressure and flow within the pipeline network and access the design optimization.

Keywords*: Renewable energy; Drip irrigation; solar pump.*

Introduction

The solar energy is one of the ever green sources that produce neither green house effect gasses nor hazardous impact through its utilization .Renewable energy sources are being increasing implemented in many applications due to the growing concern of environmental conservation. Photovoltaic (PV) water pumping has become a widely adopted solar energy technology in the last two decades (Z.Firatoglu *et al*, 2004; M.Awady *et al*, 2002).According to a World Bank report , ten thousand PV water pumping systems were installed worldwide up to the year 1993 (R.Barlow *et al*, 1993).This grew over sixty thousand system by 1998 (T.Short *et al*, 2003) .PV water pumping systems have been considered as attractive means of providing water in remote locations since the majority of global rural population live in sunny tropical or sub-tropical areas (William Halcrow *et al*, 1984). Experience of operating PV pumps has shown that due to their simplicity, high reliability and the stand-alone operation thesis systems are appropriate for remote areas (R.Barlow *et al*, 1993).The use of solar power systems for irrigation facilities, there are various possibilities for usage ranging from micro-irrigation systems with as little as 100W up to one KW (E.Hafiner *et al*, 1991).

For the connection between the irrigation system and PV solar powered pumping equipment to be energetically and economically efficient, the following points have to be taken into account.(i) Efficient use must be made of the water resource, i.e., only the amount of water needed for the crop should be raised. The amount should, in turn take into account the soils rainwater retention capacity during the wet season; (ii) this amount of water should be raised to the minimum height above ground level needed to stabilize the pressure at the irrigation heads; and (iii) the most efficient irrigation system for that particular crop should be adopted (F.Francisco *et al*, 2004). 19

The estimation of energy losses due to emitters connection in drip irrigation laterals is very important. Since these losses have a direct effect on drip irrigation system design, the study of these losses will lead to the improvement of system efficiency which will eventually result in conservation of water and energy (S.Ahmed *et al*, 2000).

The emitter discharge is a function of the pressure head and the relationship between them may be expressed as (H.Hathoot *et al*, 1993; I.Wu *et al*, 1993).

$$q=kH^{y} \tag{1}$$

The lateral discharge downstream from the emitter n should be zero and hence; show Fig.(1)

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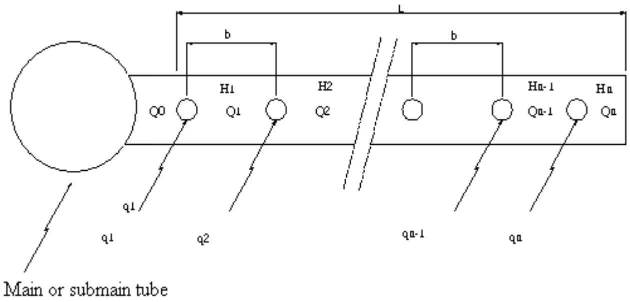

Fig.1 Lateral pipe and emitters

$$Q_n = 0.0 \tag{2}$$

$$Q_{n-1} = q_n \tag{3}$$

The following equation was used to calculate variation of the emitter flow rate:

$$\Delta q = \frac{(q_{\max} - q_{\min})}{q_{avg}} \tag{4}$$

The variation of the pressure is expressed as:

$$\Delta H = \frac{(H_{\max} - H_{\min})}{H_{avg}} \tag{5}$$

In designing drip irrigation laterals it is of practical importance to have a high degree of emission uniformity. In general emission uniformity is defined as the relationship between the minumn (or maximum) emitter discharge and the average emitter discharge within a lateral.The Christiansen uniformity (J.Keller *et al*, 1974) and is given by:

$$UC = 1 - \frac{1}{nq_{avg}} \cdot \sum_{i=1}^{n} \left| q_i - q_{avg} \right| \tag{6}$$

Several researchers suggest a uniformity coefficient of about 97% be equal to an emitter flow variation of 10%, and a uniformity coefficient of about 95% be equal to an emitter flow variation of 20% (V.Demir *et al*, 2007).

The hydraulic head lost by water flowing in a pipe due to friction with the pipe walls can be computed using Hazen-Williams formula (Hazen Williams, http://www.engeneeringtoolbox.com):

$$Pd = \frac{10.67 Q^{1.85}}{C^{1.85} d^{4.87}} \tag{7}$$

A modified Hzen-Wiliams head losses equation:

$$HL = 2.78 \times 10^{-6} \times F \times \frac{L}{D^{4.87}} \times \left(\frac{n \times q}{C} \right)^{1.85} \tag{8}$$

There are three stages in this work (1) determines the irrigation requirements (2) determine the peak photovoltaic power required to irrigation system (3) using Epanet program to hydraulic simulations.

System Design

Atypical scheme of a PV powered drip irrigation system which comprises PV array, Battery , Submersible pump ,Surface pump, controller, Water storage tank, Well and Chemical injector is shown in Fig.(2).The solar panels (monocrystalline) converts sunlight into DC power or electricity to charge the battery .This DC electricity is controlled via a controller PS150.Deep cycle batteries are used in system and provide power for the operation of the other equipment. Submersible pump of DC type 12-24V, model PS150C-SJ5-8 centrifugal pump, ,delivery volume of 60 l/min,delivery head of 12 m,surface pump of DC type of 12-24V model PS150BOOST240, ,delivery volume of 870 l/hr,delivery head of 30m.Storage tank made of PVC with volume of 5 m^3 consist of sensors for level element ,the main components of a drip irrigation system include the mainline, sub-mainline , valve, filter, tubing adapters and fittings, drip tubing, emitters, pressure indicator, flow meter and end caps. Mainline is made of PE to convey water from the source to the sub-mainline, the size of pipe required depends on the flow rate of water in the system. Sub-mainline is made of PE to supply water to the lateral pipes. Lateral pipes are connected to the sub-main pipe at regular intervals. The filter ensures that clean water enters the system, there are different types of filters screen, media and disk. Tubing adapters and fittings are used to watch the drip tubing to the rest of the system. Drip tubing is a polyethylene tube with emitters placed along the plant, the emitters release the water from the drip tubing. Drip tubing and emitters come in various typing and diameters depending on your needs, in this research the drip tubing type of GR tube.

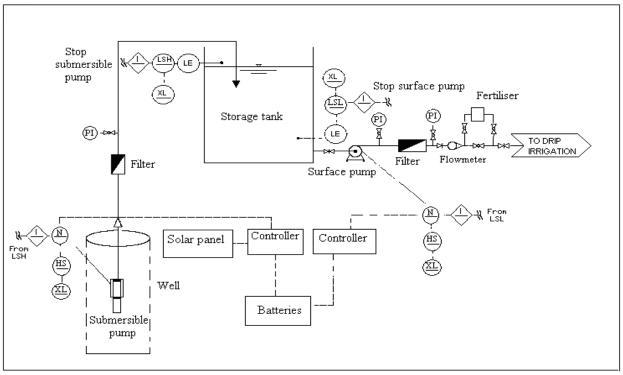

Fig.2 Schematic solar power pumping system (piping & instrumentation)

Drip irrigation requirements

The area to be irrigated is approximately 1200 m^2 ،the rate of consumption of tomato crop water equaled to 4 liter per week. The distance between plant is 50 Cm, and the distance between the drip line is 1.0m ,number of emitter equal to 2400.

The irrigation area was divided into three zones (A,B,C) Fig (3) , to keep the amount of water and power required to a low level.

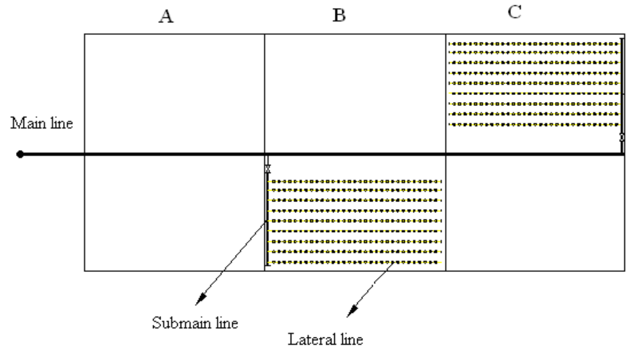

Fig.3 Drip irrigation area layout

The mainline of 50 m long and 50 mm diameter. six sub-mains of 12 m and 25 mm diameter and connected to the mainline through a ball valve .The lateral lines (GR) 16 mm diameter and 16.5 m length with 50 cm spacing between emitters were used and 12 laterals connected to the each sub-main line. the three zone were watered in turn, with one zone per day (i.e. irrigation each zone twice a week in a 3-days cycle) .The quantity of water required per day is estimated to be 1600 liters per irrigation per zone. The submersible pump (300W) pumps water to storage tank with volume 5 m^3 at 1.4 hours and operating two days in week. The surface pump(150W) pumps 1600 liters of water within 2 hours because the time of irrigation is 2 hours and the emitter capacity is 2 liters per hour.

Sizing of solar power system

In order to sizing the solar system, we need to note the power rating of each appliance that will be drawing power from the system. Table (1) represented the stand alone electric load. The total power usage daily equal to 377.143 Watt.hrs, then the power value determine the size and number of panels. The average daily load value will be increase by using load correction factor because the batteries are not 100% efficient and other losses occur in a system. Tow numbers of PV panels are used in the system, and the power output of each panel is 50W, one rechargeable battery having of 100A.hrs are used in the system, the required capacity of the batteries is determined on the basis of the daily power consumption and the minimum number of days for which the system can still be in effective operation under overcast weather. The result shown in table (2).

Table 1: Stand-alone electric load

Load	Qty		Wattage		Use hrs/day		Use Days/week	÷	Watt.hrs
Submersible pump	1	×	300	×	1.4	×	2	7	120
Surface pump	1	×	150	×	2	×	6	7	257.143
DC Average daily load									377.143

Table 2 Sizing of solar panels and batteries

Array sizing										
Average daily load Watt.hrs	×	Safety factor for losses	÷	Peak sun hrs/day	÷	Efficiency (charger, battery)	÷	Peak module watt	=	No. of modules
377.14		1.3		6.45		0.8		50		2
Battery sizing										
Average daily load Watt.hrs	×	Days of autonomy	÷	Discharge limit	÷	Battery voltage	÷	Battery AH capacity	=	No. of battery
377.14		2		0.75		12		100		1

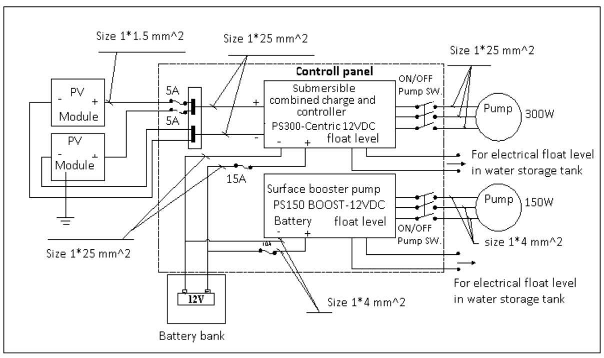

Fig.4 Schematic electric wiring diagram

Analysis of the hydraulic system

Epanet is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. network consists of pipes, nodes (pipe junction) , pumps, valves and storage tank. One typically carries out the following steps when using Epanet to model a drip irrigation system (i) draw a network representation of your distribution system.(ii) select a set of analysis options .(iii) run a hydraulic water quality analysis and view the results of the analysis. When enter the pumps design flow (870 liter/hours) and head 30 meter into this form, Epanet automatically creates a complete pump curve from this single point, show Fig.(5).

The simulation model hydraulic for Epanet calculates head losses for emitters and discharge flow along the laterals , this program distribution of flow on the number of emitters in the network and then calculated the head at all points based on the decreases of this flow through emitters, according to the flow of emitter and pressure, based on the relationship Eq.(1).And after drawing the irrigation network and inserting the required data, the program works to give a simulate the hydraulic pressure and flow at all points. Hazen-Williams Eq.(7) used to calculate the losses in pressure for lateral pipes. In this research insert the first and last of the lateral pipes with length 16.5 m ,diameter 16 mm and number of emitters 33 with spacing 0.5 m , as the result of reading in the table (3) .Fig. (6) and Fig.(8) represented the relationship between the head and length for the first and last of the lateral , and the pressure variation (ΔH <20%) ,Fig. (7) and Fig.(9) represented the relationship between the discharge flow of emitter and length of the first and last of the lateral and the variation flow (Δq<10%) . The correct lateral size can be changed when the (ΔH >20% and Δq>10%).

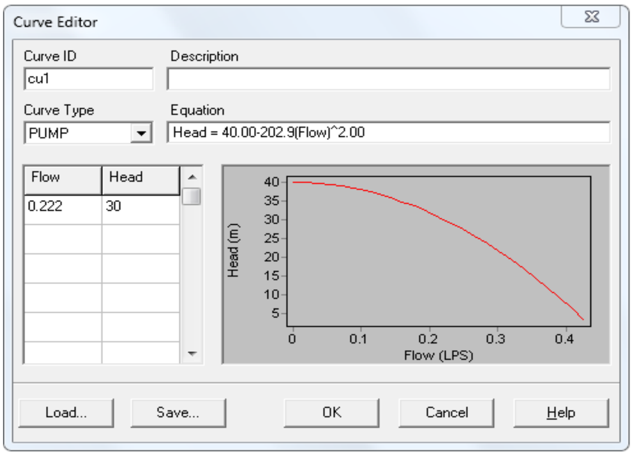

Fig.5 Epanet pump curve

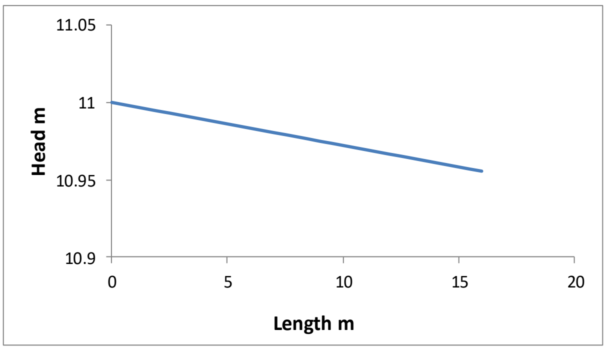

Fig.6 Head of emitter in first lateral pipe

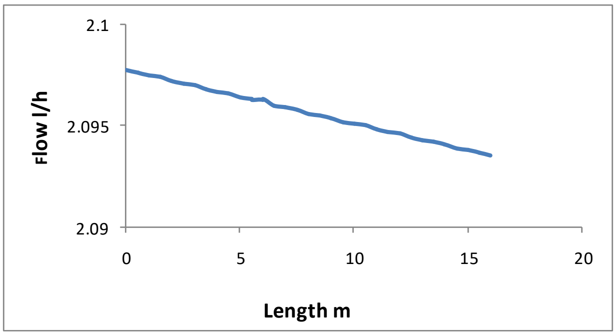

Fig.7 Discharge flow of emitter in first lateral pipe

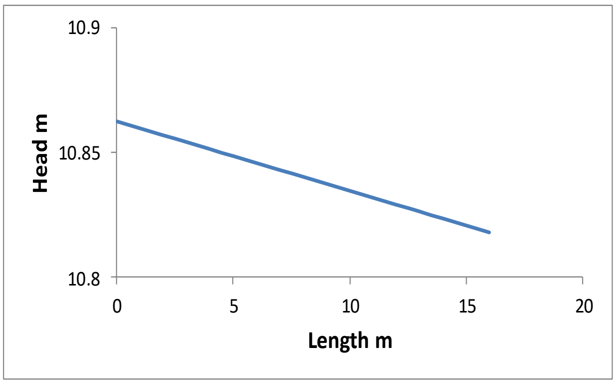

Fig.8 Head of emitter in last lateral pipe

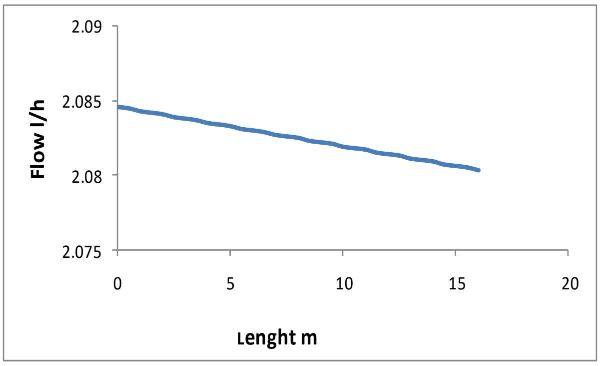

Fig.9 Discharge flow of emitter in last lateral pipe

Table 3 Head and flow for emitters No.

Emitter No. first lateral pipe	Head m First lateral pipe	Flow l/hr First lateral pipe	Emitter No. last lateral pipe	Head m last lateral pipe	Flow l/hr Last lateral pipe
1	11.0000	2.0978	368	10.8625	2.0846
2	10.9986	2.0976	369	10.8611	2.0845
3	10.9972	2.0975	370	10.8597	2.0843
4	10.9958	2.0974	371	10.8583	2.0842
5	10.9944	2.0972	372	10.8569	2.0841
6	10.9931	2.0971	373	10.8556	2.0839
7	10.9917	2.0970	374	10.8542	2.0838
8	10.9903	2.0968	375	10.8528	2.0837
9	10.9889	2.0967	376	10.8514	2.0835
10	10.9875	2.0966	377	10.8499	2.0834
11	10.9861	2.0964	378	10.8486	2.0833
12	10.9847	2.0963	379	10.8472	2.0831
13	10.9833	2.0963	380	10.8458	2.0830
14	10.9819	2.0960	381	10.8444	2.0829
15	10.9805	2.0959	382	10.8430	2.0827

16	10.9792	2.0958	383	10.8417	2.0826
17	10.9778	2.0956	384	10.8403	2.0825
18	10.9764	2.0955	385	10.8389	2.0823
19	10.9749	2.0954	386	10.8375	2.0822
20	10.9736	2.0952	387	10.8361	2.0821
21	10.9722	2.0951	388	10.8347	2.0819
22	10.9708	2.0950	389	10.8333	2.0818
23	10.9694	2.0948	390	10.8319	2.0817
24	10.9680	2.0947	391	10.8305	2.0815
25	10.9666	2.0946	392	10.8291	2.0814
26	10.9653	2.0944	393	10.8278	2.0813
27	10.9639	2.0943	394	10.8264	2.0811
28	10.9625	2.0942	395	10.8249	2.0810
29	10.9611	2.0941	396	10.8236	2.0809
30	10.9597	2.0939	397	10.8222	2.0807
31	10.9583	2.0938	398	10.8208	2.0806
32	10.9569	2.0937	399	10.8194	2.0805
33	10.9556	2.0935	400	10.8180	2.0803

Conclusions

From the above results the following conclusions are derived:

- The average daily load for operating submersible pump and surface pump equal to 377.14 Watt.hrs.
- The size of solar power is 2 panels with 50 watt for each panel and 1 battery with capacity of 100 A.H, using the solar irradiation in Iraq equal to 6.45KW.hr/m^2.day.
- The variation in pressure head is less than 20% and the variation in discharge flow is less than 10% in the drip irrigation system.

Nomenclature

C Friction coefficient (140 for polyethylene,130 for PVC pipes)
d Inside diameter of the pipe (m)
H Pressure head (m)
k Emitter constant contained in Eq.1
n Number of emitters
P_d Head losses in meter of water per Meter of pipe
Q Flow rate in pipe (m^3/sec)
Q_n Lateral discharge downstream From the last downstream emitter
q_n Discharge from the last downstream emitter
q Emitter discharge (liter/sec)
q_{max} Maximum emitter discharge
q_{min} Minimum emitter discharge
q_{av} Average emitter discharge
q_i Discharge from emitter
U_C Christiansen uniformity Coefficient
y Constant depend on the size of emitter barb
ΔH Lateral pressure head variation
Δq Lateral emitter discharge variation

References

Firatoglu,Z. and B. Yesilata (2004) New approaches on the optimization of directly coupled PV pumping system , *Solar Energy*,77:81-93

Awady,M.N.; M.F.A. Sallam and A.M. Hegazi (2002) Performance of solar-powered drip irrigation system,*Misr J.Ag.Eng*.,19(2):297-312

Barlow, R.; b. Mcneils and A. Derrick)Solar pumping: an introduction and update on the technology,performance, costs,and economics, World Bank Technical Paper No.168.*Intermediate Technology Publications and the World Bank,Washington*,DC,USA.

Short,T.and R.oldach. (2003)Solar powered water pumps: the past, the present-and the future,*j.Solar Energy ENG*.,125(1):76-82

William Halcrow & partners (1984)Handbook on Solar water pumping.

Hafiner, E. and G, Marotz.(1991), Irrigation using solar energy, combination of drip irrigation and photovoltaic pump system, *Natural Resources and Development ,a biannual collection of recent German contributions concerning the exploration of natural resources*,34

Francisco.,F.L.Rodriguez,A.Marcos and J.Coello (2004)Procedure to size solar powered irrigation schemes *solar energy* 76

Ahmed S.al-Misned, Ahmed i.AL-Amoud and Helmi M.Hathoot Effect of Energy Loss due to Emitters on the Desin of Tricle Irrigation Laterals,*J.King Sannd Univ*.,Vol.12,Agric.Sci.(2),pp,107-120[2000].

Hathoot,H.M.,AlAmoud,A.I and Mohammed, F.S. (1993) Analysis and design of Trickle irrigation laterals,J.Irrig.AndDrain.Div.ASAE,119,No.5,paper No 3937

Wu.I.and Yue,R. (1993)Drip lateral design using energy gradient line approach,*Trans.of the ASAE*,36,No.2

Keller.J. and Kameli,D. (1974)Tricle Irrigation Design Parameter*Trans. of the ASAE*, paper No.73-234

V. Demir, H.Yurdem, A. Degirmencioglu (2007) Development of prediction models of friction loses in drip irrigation laterals equipped with integrated in line and on line emitters using dimensional analysis *Biosystem Engineering* 69(4)

Hazen-Williams equation of pressure drop Available at *http://www.engeneeringtoolbox.com*].