



## Integrated Solar Power System for Greenhouses Irrigation Using Treated Surface Mixed Water, Delta, Egypt



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### Abstract

The present work is representing an integrated solar power system for greenhouses irrigation system using treated surface mixed water, with 75% fresh water and 25% drainage irrigation water in North Delta, Egypt. The agricultural lands in the studied areas are divided into small agricultural blocks each unit is 5 Feddans. The current study includes a full assessment of the current water quality of the source from El-Sheikha canal facing the land area that considers the main irrigation source. A suitable water treatment plant was designed with a complete treatability study has been setup to irrigate the studied area. Based on the results of the chosen parameters of raw water analysis; a complete irrigation system to cover the water demand for irrigating of 46 green houses in the selected area in 5 Feddans has been designed. A convenient design for 46 greenhouses with standard dimensions of 8.0 m (W) x 40.0 m (L) x 4.10 m (H) using multi span is optimized that lead to increase the overall production income of similar areas. The total dynamic head including suction, delivery and friction heads is estimated. Consequently, the irrigation pump power is designed and a solar water pumping system for the selected irrigation systems was designed including the photovoltaic modules' area, number and power. Finally, it is found that the integrated system for the current model is representing the ideal scenario for this type of farm and location. It can be considered as a pilot guide for small farmers and young graduates whom are interesting in agricultural projects in Egypt to optimize the benefits from soil and water units, and to improve quality and maximize the yield products in national and international markets.

**Key Words:** solar power; multi span greenhouses; low quality; water treatment system; irrigation technique; Egypt

### 1. Introduction

Egypt located in the arid and semi geographical location which considered as a harsh environmental with high temperature, solar radiation, climate pollution, low rainfall, sand wind, CO<sub>2</sub> concentration and dust, etc., due that using a low-density polyethylene (LDPE) films as greenhouses cover considered in this study (Babaghayou, M.I. *et al.* 2018, [1]. The global perspective on the integration of water and renewable energy and based on its positive aspects in terms of environmental improvement, it reduces the gaseous emissions and overcoming the depletion of fossil and petroleum fuel. El-Awady *et al.* 2017 [2], investigated that treated effluent offered significant water demand in all areas of activities in rural farm. It

represented the reuse of secondary treated wastewater for irrigating crops; fresh vegetables and feeding fish farm. Results showed that the total heavy metals concentration was less than 0.1 mg/l that exhibited good quality as well as the global perspective of renewable energy has its implications for the need to find effective work programs that depend on developing available assessment systems from renewable energy sources, improving the quality of usable mixed water for irrigation that providing their technologies and developing human resources capable of working with them. Organic agriculture has many benefits for the farmers and the surrounding environment. It represents an important source of hard currency savings through a targeted export program. Greenhouses are widely utilized to replace the conventional open filed agriculture to face the rapid

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Receive Date: 16 July 2020, Revise Date: 08 September 2020, Accept Date: 13 September 2020

DOI: 10.21608/EJCHEM.2020.36073.2747

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population growth, and to improve the quality and quantity of the agricultural products especially for food safety in Egypt. It was also confirmed by El-Gayar *et al.* 2018 [3], that the irrigation water requirements were dramatically reduced with more than 70%. This approach must be implemented due to the sensitive current water scarcity and to make the agriculture products are competing with markets that increase the farmer revenue. Moreover, El-Awady 2014 [4], presented a desalination/plantation/treatment integrated system to provide adequate amount of water for new and remote communities in Egypt. This integrated solar green house was constructed and tested under actual meteorological conditions. The system used a greenhouse to provide a low-cost solution where the fresh water is very limited with enough amount of saline water. It provided self-sufficient fresh water with lowest internal irrigation demand and reduced the contaminated water. Egypt composed as a desert land with low rainfall which makes the agriculture process in open field difficult. So, a modern desalination technology operated by a solar system is preferable to feed the irrigation system and prove that greenhouse is an alternative in water desalination, Hassan El-Banna S. Fath, 2017 [5]. Moreover, selected water decontamination by coagulation-flocculation process, using three different phases of aluminum derivatives, namely; Alum  $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ , Polyaluminum chloride (PAC)  $[\text{Al}_2(\text{OH})_x\text{Cl}_{6-x}]_n$ ; Potassium aluminum sulphate (PAS)  $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ , respectively to remove the suspended solids and colloidal particles were studied. Operating conditions were established to achieve the optimal parameters and to detect the maximum removal efficiency from the River Nile; a main water source as approved by El-Awady *et al.* 2015 [6]. At 2019, El-Awady *et al.* [7] approved that the reduction of sulfate ions using advanced calcium-aluminum precipitation method has been evaluated. It involved the precipitation of sulfate ions as minerals like gypsum and ettringite via calcium/ aluminum compounds. Reduction of sulfate ions via pH,  $\text{Ca}(\text{OH})_2$  and  $\text{NaAlO}_2$  dosages have been investigated, while its optimal experimental conditions were determined. Experimental results indicated sulfate reduction and heavy metals with removal efficiencies up to 99% [6]. The greenhouses are considered as low-rise building based on the American, Canadian and European design codes, besides the wind speed /load force test has been done on the greenhouses to determine the effectiveness of the torsion and shear forces on the greenhouses, Elsharawy M., *et al.* 2013 [8]. Several researches have been conducted to minimize the losses of water irrigation. Drip irrigation is the method that presents the lowest water losses and consequently needs the least amount of water for

irrigation [9]. The automated pressurized drip irrigation system that used to control climate condition such as the temperature and the relative humidity inside the greenhouses, and this system can control the applied water amount and fertilization process throughout controlling the root zoon diameter of the wet area. This technique increases the water use efficiency and improve the quality and quantity of products. The current study covers 5 feddans including 6 multi span greenhouses. The solar powered water pumping system increases the efficiency of the used energy and water compared to conventional irrigation methods that in agreement with the result of Onur Devenci *et al.* 2015 [10]. In order to take the advantage of using solar energy as a renewable source in Egypt, a remarkable decrease in the cost of electricity generation systems from photovoltaic systems is considered. Nowadays, an expansion of the use of solar energy is currently taking place in many sectors as energy management along the country, especially in the agricultural sector. The solar power irrigation system in Egypt is an important topic that depends on the availability of solar radiation intensity and the amount of water demands. The solar radiation is abundantly available in Egypt with an average value of  $5.5 \text{ kWh}/(\text{m}^2 \text{ day})$ . Solar pumping systems are environment friendly and require low maintenance with no fuel cost [11]. Keeping in view the shortage of grid electricity in rural and remote areas, PV pumping is one of the most promising applications of solar energy. The technology is similar to any other conventional water pumping system except that the power source is solar energy. PV water pumping is gaining importance in recent years due to non-availability of electricity and increase in diesel prices. The flow rate of pumped water is dependent on incident solar radiation and size of PV array. A properly designed PV system results in significant long-term cost savings as compared to conventional pumping systems. In addition, tanks can be used for water storage in place of requirement of batteries for electricity storage [12]. A PV solar water pumping system consists of a PV array, a DC/AC inverter, surface mounted motor pump set, and electronics. The PV Array is mounted on a suitable structure with a provision of manual or automatic tracking. Water is pumped during day and stored in tanks, for use during day time, night or under cloudy conditions. The water tank acts as storage and generally battery is not used for storage of PV electricity [13]. The capacity of a solar pumping system to pump water is a function of three main variables: pressure, flow, and power to the pump. For design purposes pressure can be regarded as the work done by a pump to lift a certain amount of water up to the storage tank. The total dynamic head including suction, delivery and frictions heads along with the

water demand determined the pump hydraulic power [14]. Several works have dealt with PVWP systems for irrigation, highlighting how solar powered irrigation can be considered an attractive application of renewable energy. Kelley *et al.* [15] analyzed the technical and economic feasibility of PVWP systems for irrigation, concluding that there are no technological barriers for implementation of PVWP systems. The main disadvantage of PVWP systems is still tied to the high price of PV modules. Cuadros *et al.* [16] presented a procedure to design PVWP systems for drip irrigation of an olive tree orchard in Spain, focusing on the assessment of Irrigation Water Network (IWN). Hamidat *et al.* [17] developed a program to test the performance of PVWP systems for irrigation in regions of the Sahara. The study concluded that PVWP systems were suitable for crop irrigation in small-scale applications. Glasnovic and Margeta [18] proposed a new optimization model of PVWP systems for irrigation. The objective function was to minimize PVWP system size, taking into account constraints related to IWN and water availability. There have been many studies comparing different water pumping systems for irrigation, in particular PVWP versus Diesel Water Pumping (DWP) and Wind Pump Water Pumping (WPWP) systems. PVWP systems present several advantages compared to traditional DWP systems used for irrigation in rural areas. The operation of PVWP systems is independent from fossil fuels and so overcomes all related disadvantages: fuel availability, fuel price fluctuations, fuel and oil spills, exhaust gases, and greenhouse gas emissions. Other major advantages of PVWP systems are their high reliability and flexibility, low maintenance and operation costs, and the absence of noise during their operation [19].

## 2 Materials and methods

### 2.1. Materials: Coagulants

Lime; CaO was used as calcium source to adjust pH value, while Alum and FeCl<sub>3</sub> were used as coagulants. Each one is prepared in separate drum and connected to the main water feeding pipe. The raw water is pumped from the canal; selected parameters followed by selected physico-chemical analyses for samples were carried out and tabulated in Table 1, where selected parameters followed by identified physical-chemical analyses for samples were carried out.

### 2.2. Chemical Treatment Plant

Reference to El-Awady *et al.* 2019 [6], the chemical treatment plant has to be constructed. Its total volume is about 1000 m<sup>3</sup> representing three times daily water consumption. The proposed treatment unit is divided into three compartments sequentially connected to each other in series. Each basin is fulfilling its function along the treatment pathway. The coagulants addition is followed by coagulant's aid. Lamella sheets are fixed in the second compartment to encourage the flock's growth formation. The third stage represents the final settling tank where the treated effluent is separated from settled sludge through a PVC baffle. Figure 1 shows the order of treatment stages involves three basins:

#### i- Flash-mixing:

In this basin, the calculated doses 10 mg/l of lime and 20 mg/l alum have been added within 2.0 minutes; the optimum retention time. High-speed flash mixing of chemicals with wastewater in the first basin with about 10 meters' volume is carried out. This process helps the dissolution of the reagents and encourages the undesired suspended solids and soluble ions reduction.

#### ii- Coagulation basin:

In this basin with 90 meters' volume, chemical reaction between fines suspended solids and metal ions in raw water to agglomerates and form bulk particles with coagulants during flocculation process at low-speed mixer.

#### iii- Sedimentation basin:

This basin represents the final settled sludge collected and passed from coagulation basin. It is consisted from some sliding partitions (Lamella) that enhance sedimentation process. The treated water is collected in this basin with 7.0 liters, as final discharging point.

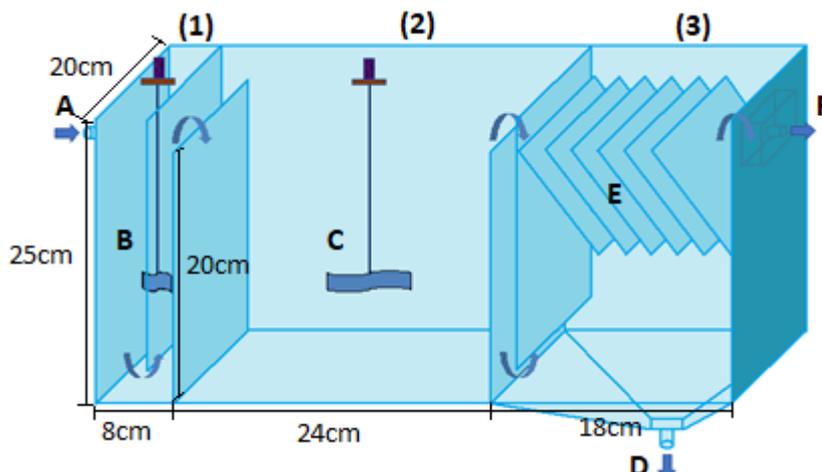


Figure (1): a semi- pilot chemical treatment plant (El-Awady *et al.* 2019)

A. Raw water                      B. Flash-mixing Basin                      C. Coagulation Basin  
 D. Sludge Drainage                      E. Sedimentation Basin                      F. Treated water

### Water source:

The main source of irrigation is El-Sheikha Canal, Baltim, Kafr El-Sheikh governorate, North Delta, Egypt, which is a sub-branch of Rosetta Branch of the Nile River. This canal is feeding its source from Rosetta water mixed with drainage water along the pathway from splitting point of the Nile up to the location of this study. To assess the quality of the feeding water in Sheikha Canal, a series of samples were collected, analyzed and treated along four annual seasons to evaluate the quality of feeding water. According to the results of water analyses; a selected treatment facility was chosen for removing the undesirable impurities. This is to be justified with irrigation pipes, to reach the needed water quality and to the chosen cultivated crops. Table 1 shows the results of four successful analyses of El-Sheikha water samples.

### 2.3 Treatability study:

Different coagulants were chosen like alum, ferric chloride, aluminum sulfate, poly-aluminum chloride, separately or in combination to remove the fine solids and colloidal matters.

## 3 Design of irrigation network and Greenhouses

### 3.1. Irrigation Network

Irrigation network designed to cover water requirements to cultivate six multi span greenhouses (64 m x 40 m) with approximate area 0.61 feddan for each multi span greenhouse except the multi span beside water storage basin (48 m x 40m) without the services roads, with a total area around 5 feddan for all greenhouses. Each multi span greenhouses consists of 8 greenhouses sections (8 m x 40 m). The greenhouses design gave a flexibility to be transported for any other

locations. The irrigation network system elements consist of the following:

- **The Main Pipeline**

The main line designed to cover the water requirements needed for the irrigation network, the main pipeline diameter was 110 mm /140 m, made from Uri Poly Vinyl Chloride (U.P.V.C), with pressure safety limit 6 bar pressure and with 140 m length.

- **The Sub Main Pipeline**

Each greenhouse had fed by one sub main pipeline from the main pipeline with a diameter 90 mm and 37 m length, made from (U.P.V.C) up to 6 bar pressure. The total numbers of the sub main pipelines from the main pipeline are 6 lines distributed as one sub main pipeline for each greenhouse (90 mm / 37 m) as described in Fig. (2).

- **Sub Sub Pipelines**

It is consisting of 63 mm pipelines that fed by water through a group of risers, each riser consists of two valves with 63 mm diameter, each greenhouse fed by one riser built from U.P.V.C and manufactured to work with 6 bar of pressure. The laterals (16 mm diameter) length was 20 m from the both side of Sub Sub Pipelines.

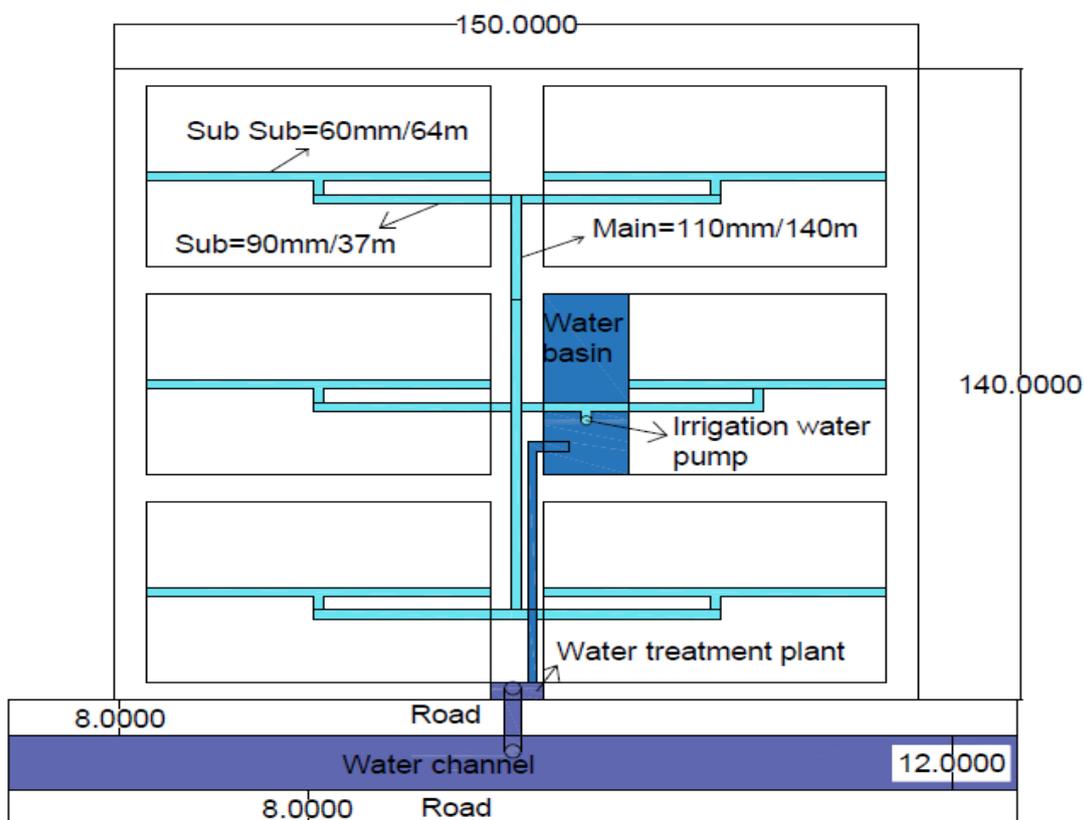
### Emitters (Drippers)

It is drippers with discharge rate 4 L / h distributed along the lateral pipeline with 16 mm diameter, made from black Poly Ethylene (P.E), anti-sun rays. The distance among each dripper

**Table 1:** Analyses of water samples from El-Sheikha Canal, Baltim, Kafr El-Sheikh, North Delta, Egypt\*

Parameter	Unit	Results *						
		1	2	3	4	Min	Max	Ave
pH- value	= =	7.6	7.6	7.6	7.6	7.6	7.6	7.6
TS	mg/l	1560.0	1630.0	1580.0	1590.0	1560.0	1630.0	1590.0
TSS	mg/l	80.0	60.0	70.0	90.0	60.0	90.0	75.0
TDS	mg/l	1480.0	1570.0	1510.0	1500.0	1480.0	1570.0	1515.0
BOD <sub>5</sub>	mgO <sub>2</sub> /l	26.0	34.0	28.0	32.0	26.0	34.0	30.0
COD <sub>t</sub>	mgO <sub>2</sub> /l	125.0	150.0	127.0	138.0	125.0	150.0	135.0
COD <sub>f</sub>	mgO <sub>2</sub> /l	70.0	80.0	77.0	73.0	70.0	80.0	75.0
NH <sub>3</sub>	mg/l	7.10	7.40	7.20	6.90	7.10	7.40	7.15
NO <sub>2</sub> <sup>-</sup>	mg/l	0.10	0.14	0.13	0.11	0.10	0.14	0.12
NO <sub>3</sub> <sup>-</sup>	mg/l	0.18	0.20	0.22	0.20	0.18	0.22	0.20
PO <sub>4</sub> <sup>-3</sup>	mg/l	1.44	1.52	1.48	1.56	1.44	1.56	1.50
H <sub>2</sub> S	mg/l	0.08	0.06	0.02	0.04	0.02	0.08	0.05
SO <sub>4</sub> <sup>-2</sup>	mg/l	88.0	92.0	94.0	90.0	88.0	94.0	91.0
B	mg/l	0.18	0.22	0.26	0.14	0.14	0.26	0.20

\* Results of four successful runs; where: TS = Total solids, TSS = Total suspended solids, TDS = Total dissolved solids, BOD<sub>5</sub> = Biological oxygen demand after 5 days at 20°C, COD<sub>t</sub> = Total chemical oxygen demand, COD<sub>f</sub> = Filtered chemical oxygen demand, NH<sub>3</sub> = Ammonia, NO<sub>2</sub><sup>-</sup> = Nitrites, NO<sub>3</sub><sup>-</sup> = Nitrates, PO<sub>4</sub><sup>-3</sup> = Phosphates, H<sub>2</sub>S = Hydrogensulfide, SO<sub>4</sub><sup>-2</sup> = Sulfates, B = Boron

**Figure (2):** layout of irrigation network design with water treatment plant and water basin

was 30 cm. Each greenhouse section (8 m x 40 m) containing 6 rows with around 135 cm width and 40 m length. Each row covered by two P.E irrigation lines with 60 cm distance between the lines which mean that each line cover 30 cm right and 30 cm left in the cultivated area. The cultivated area of each row contains 4 lines of plants. The average cost of the irrigation network for six multi span greenhouses distributed along 5 feddan was 60,000 LE including the pumps and filters.

- **Water Storage Basin**

It is located in the midpoint of the research area (5 feddan) to store the needed water to irrigate all 6 multi span greenhouses. The basin shape is rectangle with outer area dimension 40 m length, 16 m width and 3 m height with slope 2:1 to the inner area. The inner area dimensions are 28 m length and 4 m width. The basin storage capacity is 1128 m<sup>3</sup> to feed irrigation water through extra pipeline 110 mm/ 60 m. The basin designed to cover multi-purposes such as fish and algal culture. The intensive fish production (150 fish/m<sup>3</sup>) with average production of 50 ton fish/season with average weight 1 kg / 3 fish's, the average price per ton is 20,000 LE and the total productivity for fish only is around 1 million LE. The fixed cost of the pre-production is about 50% of the profit which is 500,000LE / season without algae cultivation which can be used to increase the benefits of the storage basin. The up-take irrigation water from the basin with high fertility used to decrease the addition of fertilizer needed.

- **Basin Digging and Isolation**

The cost of basin digging was 4 LE / m<sup>3</sup> and the total cost was equal 1128 x 4 LE = 4512 LE approximately 5,000 LE. The area of the isolation material used to cover the inside surfaces of the basin was 600 m<sup>2</sup>, the isolation material made from Poly Ethelyn (P.E) with 1mm thickness (1000 micron). The price of m<sup>2</sup> isolation material was 45 LE, with total cost around 27,000 LE approximately 30,000 LE with a total cost for digging and isolation approximately 35,000 LE.

- **Irrigation Pump**

It is a solar pump linked with solar system station, the pump discharge rate 50 m<sup>3</sup>/ h and that to pump the water up to 126 m (including suction, delivery and friction head) through two fixed valves with 110 mm diameter in the medal of main line. The pump utilizes a vertical 2 m suction pipe (110 mm) in the med-point of the basin to avoid suction of any sediment from the bottom of the basin.

### 3.2. Greenhouses Design

The multi span greenhouses designed from the north to south direction and that for better natural aeration and to decrease the relative humidity inside the

greenhouses and that done by opening the doors before sun-set by one hour and decrease the crop diseases, Elsharawy M., *et al.* [8]. Furthermore, side window distributed along the greenhouse sides with 1.5 m height from the ground surface and all windows covered by anti-virous insect nets. All windows opened or closed based on the greenhouse temperature and relative humidity, Hereher, 2017 [20]. The multi span greenhouses designed are flexible to transport from one Governorate to another using arch shape with 2.50 m stand column height. The distance between each stand column is 2.5 m to face the high wind speed that from 70-110 km/h as reported by El-Sharawy M., *et al.* 2013 [8]; this is except the first and the last two columns was 2 m and that to support the entrance and the exit doors with 2 m width and 2.20 height for each greenhouse. The greenhouse height from the med-point of the arc to the soil surface is 4.25 m. Reference to Babaghayou *et al.* 2018 [1], all multi span greenhouses covered by solid plastic sheet or plastic net from treated Polyethylene with thickness 200 micron to fit the climate change during the season as showed in Figs. (3a and 3b). The average cost for one greenhouse is around 260,000 – 300,000 LE.

#### 3.2.1 The Greenhouse Elements (Steel Structure)

- **The Concrete Foundation for the Steel Columns (Earth Support)**

It is a concrete base (foundation) buried under the ground surface. The outside columns concrete base dimension is 50 cm x 50 cm x 75 cm, While the inside columns concrete base dimension is 30 cm x 30 cm x 50 cm and we can adjust the gutter tendencies.

- **Steel Columns (stand columns)**

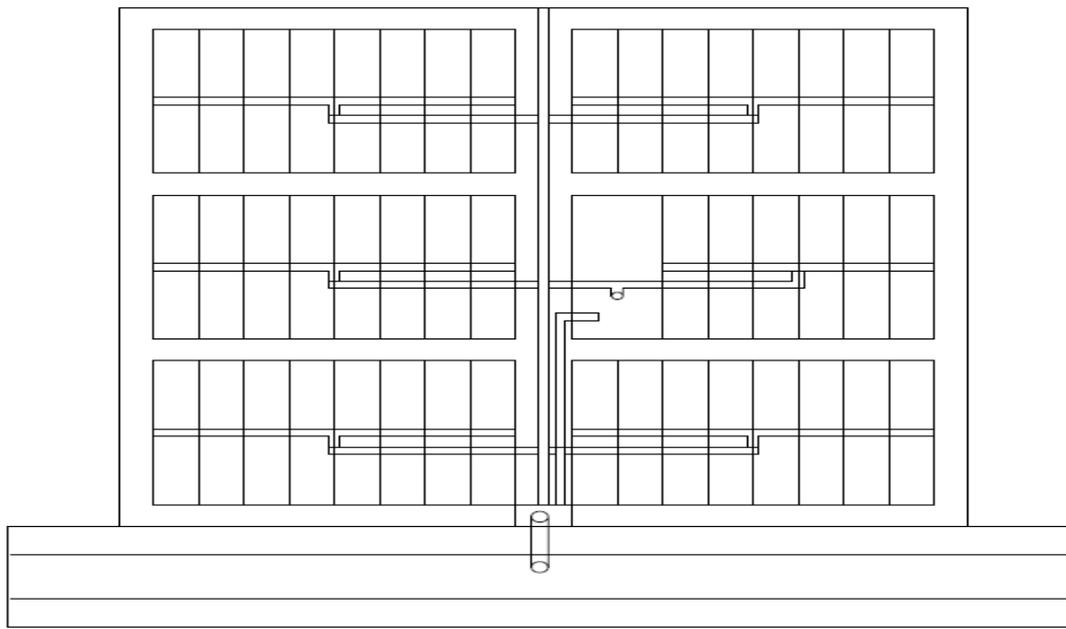
It is hot galvanized steel columns from both internal and external sides with 2 inches' diameter, 2 mm thickness and 2.50 m height. There are 17 columns for each greenhouse from all sides and it can be side stand columns and some of it inside stand columns. The columns designed with 2.5 m in between except the first and last columns designed with 2 m in between shown in Fig. (5).

- **Y Shape Form**

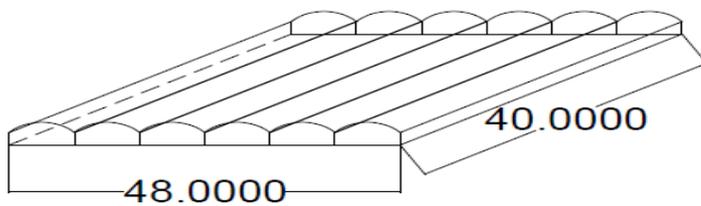
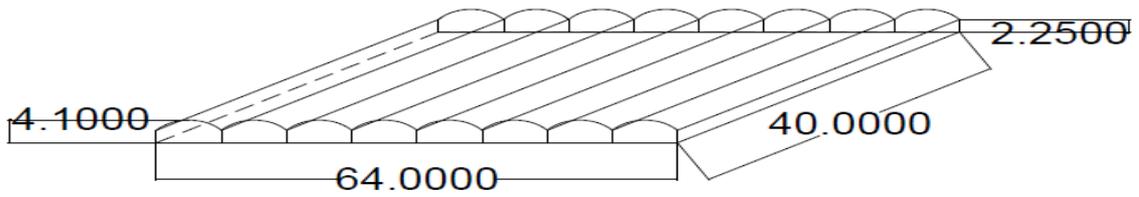
It is used to install and fix the arch from both sides (left and right).

- **The Arch**

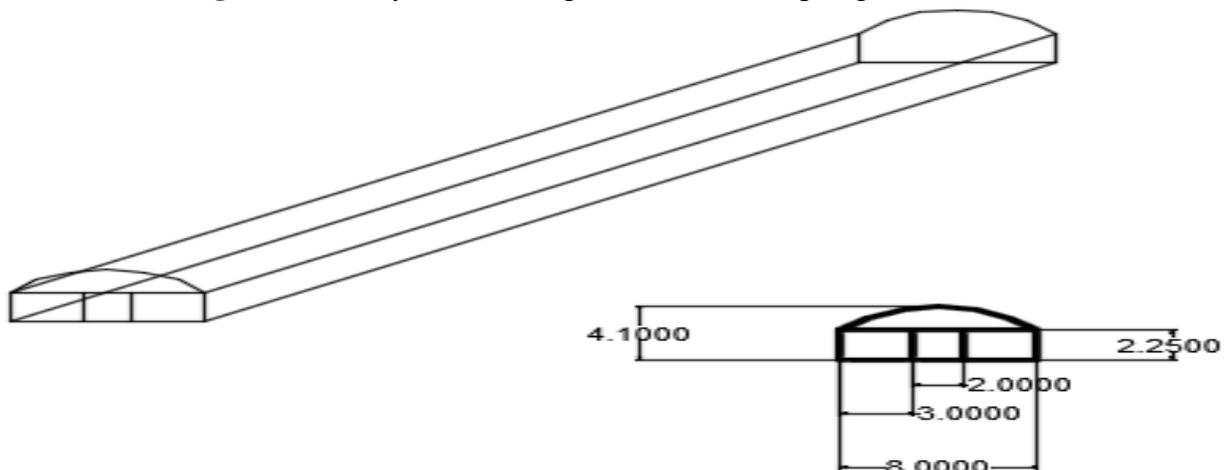
It is made from the galvanized steel with 1.5 inch in diameter and 2 mm thickness and it forms the greenhouse roof, and then it covered by plastic sheets. The arch total height from the mid-point is 4.10 m (1.85 + 2.25 m) as shown in Fig. (4, 5).



**Figure (3a):** Layout of the multi span greenhouses in the 5 Feddans studied area



**Figure (3b):** Layout of the eight and six multi span greenhouses



**Figure (4):** Description of the Greenhouse Design



**Figure (5):** Inside columns structure of the greenhouse

- **Long Support**

It is made from the hot galvanized steel with 3/4 inch in diameter. It is used to fix the arch with each other's and used to fix the plastic sheet. There is one long support in the middle point of the arch and two long supports in each half from left and right of the arch.

- **The Galvanized Steel Clamps**

It is made from the galvanized steel sheets and it is used to fix the plastic sheets with the arch and the long supports.

- **Gutter**

It is made from the galvanized steel sheets with 1.5 mm thickness and it takes a U shape and it has three usages:

- Used to fixing the stand columns with each other It is implemented with inclinations 0.5% it means that the rate is 0.5 cm/m of gutter so that the base of the middle column number (9) higher than the base of the first stand column number (1) and the base of the last stand column number (17) by 10 cm from both sides with inclinations 10 cm in the beginning and ending directions.
- The gutter used to fix the plastic sheets through a plastic profile.
- Used to collect water from the middle and then move it to the beginning and ending sides to drain the water.

- **Crop Support**

It is made from the galvanized steel and used as a horizontal link between the side and inside stand columns, and its location is under the arch so that the distance between the crop support and the mid-point of the arch is 1.85 m and the distance between the crop support and the ground is 2.25 m, and the total height is 4.10 m and this is the optimum height for the greenhouse to maintain the plastic sheet from damage, and the greenhouse optimum ventilation.

- **Hang Crop Support**

It is used to carry the crop and it could be mono or dual hang crop support. The sherry tomato forms the highest loading level that may reach 40 - 50

ton/greenhouse which mean 1:2 to each harvest based on tomato type and the feeding method.

### 3.2.2 Services Roads

The service roads were used in transportation inside the studied area showed in Fig. (2) as follow:

- Main horizontal middle way with 10 m width and 140 m length.
- Left and right horizontal sideways with 6 m width and 140 m length.
- Two main vertical ways with 6 m width and 150 m length.
- North and south vertical side-ways with 4 m width and 150 m length

### 4 PV water pumping system

It is essential to calculate the adequate power rating for a photovoltaic system to meet the total required electricity load. Before designing the system, the daily average sun hour, amount of daily solar radiation falling on the horizontal surface, and the ambient temperature should be defined. The SWPS consists of the following components [21]:

- PV module which converts solar energy into electricity to drive the pumps.
- Inverter to convert DC power generated from the PV panel to AC to meet the load of the pumps.
- Battery bank to drive the pumps shortage of solar radiation and charger controller to regulate and adapt battery charging (in case of using storage system).
- Variable speed pump to be operated according to the variable solar energy input (in case of not use storage system).

#### 4.1 Design of solar water pumping system

Some basic information should be known to develop the complete design process of the solar water pumping system as follows:

1. The amount of solar energy falling on the horizontal surface.
2. The water demands.
3. The Total Dynamic Head (TDH).
4. Selecting a pump that will cover the water demand and the desired pressure.
5. Sizing the PV capacity (kW) to power the required pump electric load.
6. Estimating the system land requirements.
7. Estimating the SWPS cost.

The design sequence will be preceded as shown in Figure 6.

**4.2 Calculation of the water demand**

Calculating the water demand based on the total greenhouses water requirements that developed by the design section of the water irrigation network.

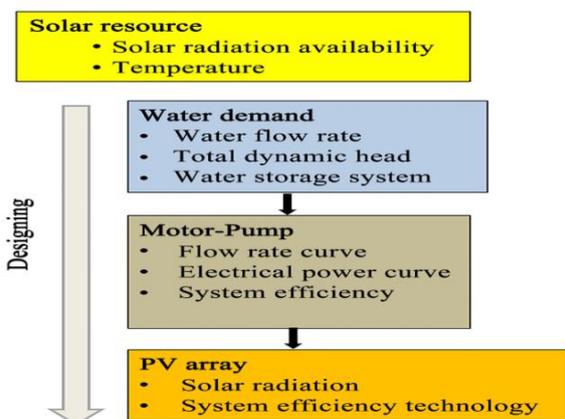
**4.3 Calculating the total dynamic head**

The Total Dynamic Head (TDH) is the sum of the total suction head, the friction head losses and the total delivery head. It is estimated from the design of the water irrigation network layout.

**4.4 Pump Selection**

Pump sizing can be calculated based on these factors:

- Pump flow rate (m<sup>3</sup> / day).
- Pumping head (m).
- Type of operation (centrifugal or positive displacement)
- Water source (surface or submersible).
- Different manufacturer’s available manuals.



**Figure (6):** Design sequence of the solar water pumping system [21]

**4.5 Hydraulic Power**

The hydraulic Power, P<sub>h</sub>, required to lift a volume of water over a total head, TDH is

$$P_h = \rho_w g TDH \tag{1}$$

Where

$\rho_w$  = Density of water (1000 kg/m<sup>3</sup>),

$g$  = Acceleration due to gravity (9.81 m/s<sup>2</sup>), and

$Q$  = Flow rate or volume of water lifted per second in m<sup>3</sup>/s.

**4.6 Estimating the system land requirements**

The size of the PV system in W<sub>p</sub> for the peak load can be defined as [21]

$$APV = \frac{EL}{H \times \eta_{pv} \times \eta_{inv} \times \eta_B \times \eta_{cc} \times T_c} \tag{2}$$

Where

$A_{pv}$  = total area of photovoltaic requirement (m<sup>2</sup>),

$E_L$  = Peak daily required electrical energy for the SWPS (Wh/day)

$H$  = daily global irradiation (Wh/m<sup>2</sup>/d),

$\eta_{pv}, \eta_{inv}, \eta_B, \eta_{cc}$  = efficiencies for photovoltaic, inverter, battery and charge controller, respectively, and

$T_c$  = Temperature correction factor of the PV module.

**4.7 Sizing the PV capacity (kW)**

The required photovoltaic modules power P<sub>pv</sub> (W), to meet the electric load demand can be estimated as follows

$$P_{pv} = A_{pv} \times H_{sc} \times \eta_{pv} \tag{3}$$

Where

$H_{sc}$  =Standard solar irradiation, 1,000 W/m<sup>2</sup>.

**5. Results and discussion**

Table 1 represents the water quality of El-Sheikha Canal, Baltim; Kafr El-Sheikh; North Delta; Egypt which considered the main water irrigation source. Results showed that the water contains pollutants in the form of organic matters and detectable amounts of suspended solids. These are the main cause of restricted water flow as a result of nozzles blocking in the water droppers. Consequently, in order to keep continuous and regular water flow, a treatment stage has to be carried out for the raw feeding water prior distribution step.

**5.1 Canal water treatment**

Treatment of raw water including three pillars: chemical treatment, contamination control, and water pumping station. The first scenario; chemical treatment includes two stages; coarse suspended solids removal followed by fine and colloidal matters removal. In this stage and due to the presence of coarse suspended solids from agricultural waste, dead animals, plastic bags and other materials; a pre-treatment including multistage screen has to be used to remove this type of suspended solids. In the second stage and due to the presence of fine and colloidal matters that form bio-film and block the irrigation nozzles; these types of pollutants have to be removed via chemical treatment process. So, a treatability study was carried out using different coagulants like lime, ferric chloride, aluminium sulphate, poly-aluminium chloride, separately or in combination. Filtration step; the chemically treated water has to go through settling tank combined with lamella unit in order to get rid of the chemically formed sludge that is frequently discharged according to its level and quantity. The drained sludge has to be dried by natural drying bed or via simple solar drier. Disinfection of the chemically treated water is being exposed to Ultraviolet cell (UV) with calculated retention time to destruct any residual microbial contaminants. Feeding reservoir; the finally treated water is being stored in a concrete tank with capacity ~ 600 m<sup>3</sup>. It is relevant to the water quantity needed to be used directly via the solar pumping system for about 2 days. The second scenario is water treatment and bacterial contamination control including water disinfection using chlorine water. It

consists of dosing pump to be installed on the main feeding line of raw mixed water. The pre-chlorination dose has been adjusted via chlorine sensor. The chlorine is being stopped and operated according to the water flow rate and chlorine dose is to be calibrated with reference to organic and microbial loads. The chemical dosing unit consists of water feeding tank supported with chemicals dosing pump to feed and mix with the chosen coagulants at their optimal operating conditions. The flash mixing time is about 2 minutes. Water clarifier; the chemically treated water has to be left for about 30 minutes as flocculating and settling time. Final collecting tank including lamella unit is used as buffer tank for treated water as a final stage. Pumping station will provide treated water for irrigation. The third scenario is surface water pumping station with 300 m<sup>3</sup>/h flow rate to feed the irrigation system with the required water. Booster Pump station that transfer the water from buffer tank to the sand filter, and it will run automatically through a programmable logic controller (PLC). Sand filter with 300 m<sup>3</sup>/h flow rate is operated to remove any residual impurities from the water. Activated carbon unit with 30 m<sup>3</sup>/h as final stage was setup to remove residual chlorine, color, and organics from the water to be used for organic farming. Reverse osmosis (RO) unit with 180 m<sup>3</sup>/h in 3 Skids x 60 m<sup>3</sup>/h as final product which include Micron Filter 3 units' X 96 m<sup>3</sup>/h, and cartridge filter unit to remove fine impurities from water before RO membranes to increase life time of membranes. Chemical dosing unit for anti-scaling, and de-chlorination before RO unit to protect the membranes, and increase the life time of RO membranes. It includes 2 housing X 3 units = 6 housing high pressure pump unit 220 m<sup>3</sup>/h to feed the RO membranes with the required flow, which include 9 Pumps (3 pumps for each RO skid). A complete control system was setup including pressure transducer and to keep the operation pressure at the required value to control startup & stop of the pumps. Also, frequency inverter control, is working to keep constant pressure for the plant. It includes manual butterfly valves before and after each pump Stop Valves. Install Check valves at outlet of every pump. Operation: fully automated pressure gauge for outlet by PLC, Pressure gauges. All pipes and fittings for inlet and outlet of piping network are designed to be stainless steel 316L.

### 5.2 solar water pumping system

After estimating the total area of PV panels (m<sup>2</sup>), the number of total modules (N<sub>m</sub>) can be determined based on the commercially available area of a single PV panel. The number of modules can be defined as follows

$$N_m = \frac{PPV}{P_m} \quad (4)$$

Where

P<sub>m</sub> is the power of the single module (W).

Based on the water demand of the irrigation system network for the 46 greenhouses and the total dynamic head, it is found that hydraulic system needs two pumps (one in duty and one standby) of 20 kW each and for the water treatment plant, the hydraulic system needs two pumps to pump the water from the treatment plant to the water basin storage tank (one in duty and one standby) of 15 kW each. Using equations 4 and 5 to calculate the PV modules area and peak power in kW. If the commercially available PV module power is 300 W, it is found that the PV system needs a power of 36 kW with 205 m<sup>2</sup> PV modules area and 120 PV modules for the irrigation network and a power of 27 kW with 150 m<sup>2</sup> PV modules area and 90 PV modules for the water treatment plant respectively.

### 6. Conclusions

The study recommended that a new organization should be established such as Egyptian Greenhouse Horticulture Association (EGHA) or National Greenhouse Manufacturers Association (NGMA) for Legislation, operation and management of the greenhouses in Egypt through ministry of agricultures. The studied model provides irrigation technique that leads to decrease the irrigation water amount used in cultivation by 20-25% and significant energy saving in greenhouses systems, it also contributed to support the food security, and improved the quality and quantity of the products to compete in national and international markets which increase the total revenue for farmers from 5-8 times. From the current comprehensive study, some concluded remarks can be listed below:

- 1-A complete irrigation system to cover the water demand for irrigating of 46 greenhouses in the selected area in 5 Feddans is considered as a pilot guide for small farmers and young graduates whom are interesting in agricultural projects in Egypt to optimize the benefits from soil and water units, and to improve the product quality.
- 2-Producing a full assessment of the raw water to treat the mixed water through the water treatment plant that provided a model to utilize the treated water for irrigation to save water.
- 3-Using solar energy for water irrigation has a positive impact in the environment and save fuel as it considered a clean source of energy.
- 4- The solar PV system can be installed above the water basin storage tank to minimize the land requirement of the PV system and minimize the rate of evaporation from the water basin storage tank.

- 5- It is concluded that the integrated system for the current model is representing the ideal scenario for greenhouse plantation using treated surface mixed water and utilizing solar energy for power generation

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