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Design a Portable Photovoltaic - Reverse Osmosis Unit for Brackish water As Pathway to Develop Remote Communities

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Abstract: ***In this paper, the operation design of a portable unit for PV RO system for small communities was studied with direct conducting with solar panel and without batters storage system. In this paper the system configurations will be without batteries. In all conditions assessed, the unit showed good performance. The test rig, indicated that the unit comfortably produced at 8.5 l/h with 500 ppm feed salinity, 7.73 l/h with 1000 ppm feed salinity, 5.99 l/h with 1500 ppm feed salinity, 4.69 l/h with 2000 ppm feed salinity, 4.45 l/h with 2500 ppm feed salinity, 4.25 l/h with 3000 ppm feed salinity Sequentially with little work input from an operator. The energy consumed at varies salinity input test as 1.12 Kw.h/m^3 with 500 ppm feed salinity, 1.34 Kw.h/m3 with 1000 ppm feed salinity, 1.71 Kw.h/m^3 with 1500 ppm feed salinity, 2.20 Kw.h/m^3 with 2000 ppm feed salinity, 2.33 Kw.h/m3 with 2500 ppm feed salinity and 2.49 Kw.h/m^3 with 3000 ppm feed salinity Sequentially. The unit is easy and efficient to operate without batteries storage and with little regular maintenance. It is not practical to conduct a continuous monitoring of the system. So it needs to operate using automatic control system. In all the conditions assessed, the unit showed good performance. It is clear that the dissemination of this technique is made easier and improves efficiency to be more common.***

Keywords: About four key words or phrases in alphabetical order, separated by commas.

I. INTRODUCTION

One of the biggest problems in the world is water scarcity. Water supply shortages occur when supply equals demand. High living standards always cause an increase in water consumption. The developing world lacks infrastructure. In the future, climate change will affect water supply everywhere, and this will increase the likelihood that some wet areas will change to dry areas and vice versa, which will affect and increase the salinity of coastal groundwater.

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Laws governing communities affect water consumption, and new supplies can be created; it is known that it takes a long time to reduce the human population. Therefore, it is preferable to develop water infrastructure, which needs a lot of money. All these pressures on man always make him think of practical solutions to the problem of water scarcity.
Desalination of seawater and salt water is one of the most important solutions worldwide. More than 15,000 desalination plants in different parts of the world were operational by 2010 with a production capacity of about 65 million m^3 / day. Desalination is equivalent in volume to about 5% of household use worldwide.

II. MOTIVATION

Reverse osmosis desalination systems require electrical energy. These communities lack electricity sources beyond the main grid. The cost of transporting fuel is also very expensive to run generators. It was found that the use of solar energy provides a suitable source of electricity through solar panels. In this research was studied a small unit working the theory of reverse osmosis solar panels [3, 4, 5]. Previous systems in this area relied on batteries for energy storage. Batteries are very expensive. This paper presents a program for the operation of a reverse osmosis unit with solar panels without storage batteries and works for a specific period of time daily sunrise to sunset [6, 10]. Recent research has focused on the efficiency of the system. All research shows that reverse osmosis technology is technically feasible, easy and inexpensive compared to other methods In this paper, a small solar reverse osmosis system with no storage batteries was introduced for a limited period.

III. OBJECTIVES AND OVERVIEW OF THIS STUDY

Discussing the upgrading of the operational efficiency of reverse osmosis systems with solar panels without batteries can contribute to the growth of communities that depend on this method. There is little research to improve the overall operational performance of reverse osmosis with solar panels without batteries using easy and simple methods of control. One of the biggest problems facing solar power systems is the absence of sunlight for unpredictable periods. This causes the power supply to be cut off to operate the reverse osmosis unit, which forces us to use batteries to store electrical energy. This research deals with the operation of reverse osmosis unit solar panels without batteries for a certain period of time with control of the easiest methods of operation.

Take into account the system not to stop for long periods so as not to cause bacterial dirt of the membranes.

IV. RO MODELING

Several studies on mass transfer of reverse osmosis systems were presented researched and explained [11, 18, 19]. Many of the models that have been explained such as the solution diffusion imperfection model, the solution diffusion model, the finely porous model, models based on irreversible thermodynamics and the diffusion viscous flow model. Several models have been studied in the analysis of reverse osmosis process of different formations and types such as the hollow fiber membranes and spiral wound. The osmosis process is essentially a natural process. The direction of fluid passage can be reversed by pressing it more strongly than osmotic pressure. This process separates the purified liquid water from the salts to pass through the membrane to the other side. The other side is pure water and the other side increases the concentration of the solution by leaving the water cleared and the membrane crossing.

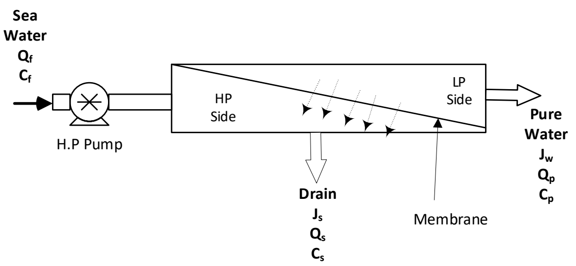

Figure (2) Reverse osmosis membrane module and nomenclature.

Reciprocating pumps are used in reverse osmosis systems to generate the high pressure required to complete the process. The reciprocating pump is powered by an electric motor powered by any suitable electrical source. The osmotic pressure of each solution varies from one solution to another depending on the salt concentration of the solution. Theoretically osmotic pressure of seawater with a concentration of 35,000 ppm is about 25 bars. However, the actual operating pressure required for water passage is practically at least about 55 bar in order to resist the concentrated polarization of the brine, which occurs very close to the membrane in the center of the concentrated solution as a result of leaving pure water to that area.

A. Solution-Diffusion Model

A model was developed by Lonsdale et al. (1965). [12, 18, 19] Where it was assumed that the solvent and solute dissolved in the homogeneous surface layer of the membrane to be penetrated inward by the theory of chemically under-gradient propagation united.

The water flow is referred to as F_{Jw} and represents the amount of water flowing from the surface area unit of the membrane.

The equation F_{Jw} (= Qw / A) and the solute flow F_{JS} it written according to the principles of chemical propagation [13, 17]:

$$F_{Jw} = K(\Delta P - \Delta\pi) \qquad (1)$$

$$F_{JS} = M(C_{wall} - C_p) \qquad (2)$$

Where:-

Across the membrane the applied pressure difference denoted as $\Delta P = P_H - P_L$

The bulk solution at the high pressure side (The subscript b indicates the bulk solution on the high pressure side) denoted as P_H

Is the pressure in permeate (subscript L refers to permeate and subscript wall refers to the membrane surface (on the high pressure side) expressed as P_L

Across the membrane the osmotic pressure difference of the solute expressed as π

The concentration at near of the membrane surface expressed as C_{wall}

Is the permeate side solute concentration and a, b are the solvent (membrane) and the solute (salt) permeability coefficients Expressed as C_p

In any membrane separation process, concentric polarization phenomenon occurs, which causes the concentration of the adjacent membrane solution to be very high than the bulk solution. So the flux of the membrane should be practically measured. This model may not represent one hundred percent in real membranes. The constants in equations (1) and (2) of a particular membrane can be expressed as:

Net driving pressure difference across the membrane is proportional to the rate of water flow through a membrane expressed as K.

The concentration differential across the membrane and is independent of applied pressure is proportional to the rate of salt flow through a membrane expressed as M.

B. Salt Rejection

The solute (salt) rejection, SR, is expressed as [14, 18, 20]:

$$SR = 1 - \frac{C_p}{C_b} \qquad (3)$$

The value of SR is a measure of the salt flow rate with the brine.

C. Osmotic Pressure and Osmotic Coefficient

Kunst, Flemming et al. They expressed the osmotic pressure by turning the concentration of dissolved salts in aqueous solution of sodium chloride salt at a temperature of 50 ° C and the concentration of the solution was concentration (0:49.95 kilograms of salt per cubic meter)[15,19] expressed as.

$$\pi = 0.7949C - 0.0021C^2 + 7.0 \times 10^{-5}C^3 - 6.0 \times 10^{-7}C^4 \qquad (4)$$

Well done. Wijmans et al formulate an equation as follows:

$$\pi = (0.6955 + 0.0025T) \times 10^8 \frac{C}{\rho} \text{(in Pa)} \qquad (5)$$

Where:

Solution temperature denoted by [T] °C

Density of solution denoted by [ρ] kg/m3.

Concentration of all constituents in the solution denoted by [C] kg/m^3.

Therefore there are no significant differences in transactions when the constants are standardized for a single operation. So the osmotic pressure coefficient can be obtained directly from the following simple equation:

$$b_\pi = \frac{\pi}{C} \tag{6}$$

D. Characteristics of the Spiral Wound

The general shape of the channel in which the brine is applied largely determines the hydrodynamics that reduces the concentration polarization. Concentric polarization is greatly influenced by the presence of the separating material between the layers of membranes. Kunst and Baker. et al expressed the hydraulic diameter as follows[17,18]:

$$d_h = \frac{4\varepsilon}{\frac{2}{d}+(1-\epsilon)a_{sp}} \tag{7}$$

Where:-

ε void fraction (bulk porosity or void age),

d channel height

a_{sp} specific surface area of the spacer, i.e. the ratio of its surface area to its volume. It is given by:

$$a_{sp} = \frac{8}{d_{sp}} \tag{8}$$

Where:-

d_{sp} spacer thickness. For a flow Q through the spacer filled channel, the velocity is hence defined as:

$$V = \frac{Q}{Bd\epsilon} \tag{9}$$

Important Definitions:

The concentration separator is usually more porous than the porous separator.

The value of d is taken approximately by the thickness of the d_{SP} spacing

The width B is calculated as the width of the entire permeable membrane membranes. All spacers having the same concentration have a thickness of no more than 0.3:0.4 mm. The age void also taken 0.9 mm

V. SYSTEM CONFIGURATION

The main goal is to designing and implementation a compact and portable system. This system is able to supply suitable drinking water for domestic uses from a saline (Brackish) water source. The system is operating on Reverse Osmosis principle powered by a direct photovoltaic Array without batteries storage.

A. Pre-treatment Stage

The pre-treatment stage is consisted of three pre-treatment filters to adjust the quality of influent water to RO stage and avoid the clogging of the RO membrane.

- ❖ Sediment Filter: Active a sieve to deposit dirt, sediment, and other particles and other particulates in water thereby improving water clarity, taste and odor.
- ❖ Anti-bacteria Granular Activated Carbon: Removes organic compounds, chlorine (including Cancer-Causing by-product tri-halo-methane), radon, solvents and hundreds of other chemicals found in influent water.
- ❖ Anti-bacteria Block Carbon: Eliminate any possible residual bad tastes and odors, chlorine, and many organic contaminants; it is also used to reduce items that could foul the reverse osmosis membrane.

B. Booster Pump

The booster pump is mounted before the Reverse osmosis assembly to raise the water pressure at the inlet of the pressure vessel containing the RO membrane to drive the desalination process across the membrane.

Pump Specifications

Booster Pump Type - 2500

Voltage: 24 V/DC

Starting Current: 1.2 Ampere

Flow Rate: 50 GPD (227.3 Litre/day)

80 PSI (5.4 bars) at 0.65 Ampere

C. Reverse Osmosis Membrane

The RO membrane used is a DOW Filmtec BW-60.

Typical Product Performance

Product: BW-60-1812-75

Part number: 11018585

Membrane Type: Polyamide thin-film composite

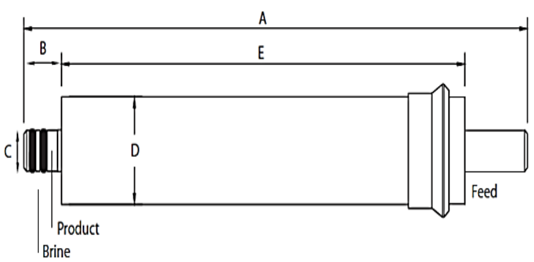

Figure (5) Membrane element and dimensions

Configuration Membrane element:

45 °C is maximum operating temperature.

10 bar is maximum operating pressure.

7.6 lpm is maximum feed flow rate.

5 (SDI) is maximum silt Density index.

< 0.1 ppm is free Chlorine Tolerance.

D: 44.5 mm, C: 17 mm, A: 298 mm, E: 239 mm,

B: 22.2 mm

D. Power Source

The Power source is chosen to be a photovoltaic array due to the availability of the solar energy in Egypt almost all the year.

PV Array Specifications:

Mono-Crystalline PV cell
Efficiency: 18% – 20%
50 Watt (25 Volts, 2 Amperes)

A main goal in configuring the PV array is to be foldable to minimize the size of the array so it consists of 3 panels each of 8 Volts and 2 Amperes and 30 cm* 30 cm dimensions connected in series. The three panels is fixed on a piece of cloth to be folded after the end of operation.so that the space needed for the storage of the system is minimized.

The system is operating directly on the power out from the PV array without using batteries to eliminate the high cost of batteries. Therefore, the system is set to be in a continuous operation as soon as the sun is shining and the product water is stored for usage instead of storing electric energy.

E. Measurement tools

Ammeter: To measure the current out of the Photovoltaic Array.

Voltmeter: To measure the Voltage out of the Photovoltaic Array.

Pyranometer: To measure the Solar irradiance on the PV Array.

Stop watch.

Graduated Container.

Conductivity Meter:

EZODO type (COND5021)

Specifications:

Range: 10-9990 µS/cm 10-9990 ppm , Accuracy: ± 1% FS , Environment: 0-50 oC , Battery: 9 V/DC

Curves are plotted between time on X-axis and Solar Irradiance, PV power, Pumping Power, Permeate salinity, Reject salinity, permeate flow rate and Reject flow rate on Y-axis for each experiment.

Curves are also plotted between Feed water salinity on X-axis, permeate salinity, Reject salinity, Permeate flow rate, Reject flow rate, Recovery rate and Salt rejection on Y-axis for all the six experiments to estimate the behavior of the system upon changing the feed salinities. The following is a schematic diagram for the system.

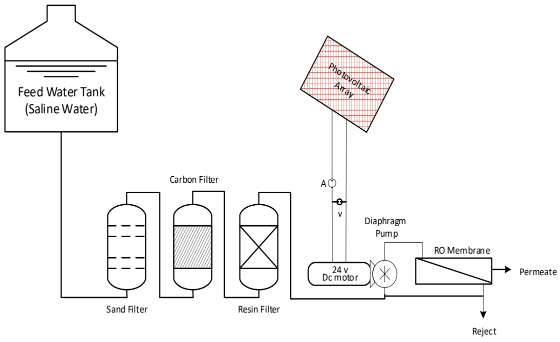

Figure (6) Schematic Diagram for the System

Figure (7) Pinch Test Rig for the RO-PV Portable Unit.

VI. RESULTS AND DISCUSSION

The results of experiments are plotted between different parameters affecting the system performance and curves for each experiment and the six experiments carried over are shown in this section.

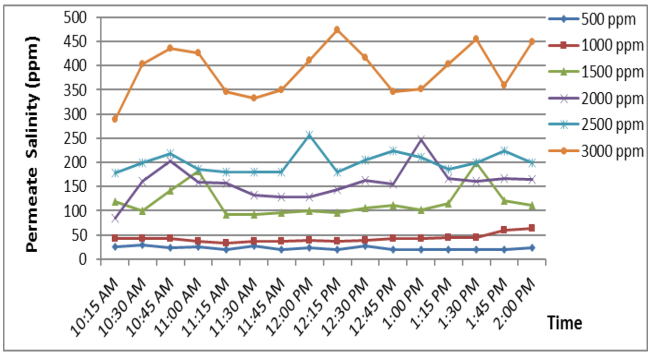

Figure (8) Permeate Salinity. And Time

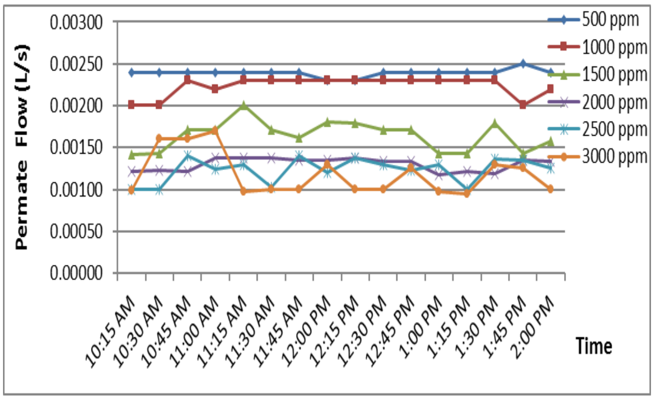

Figure (9) Permeate Flow (l/s). And Time

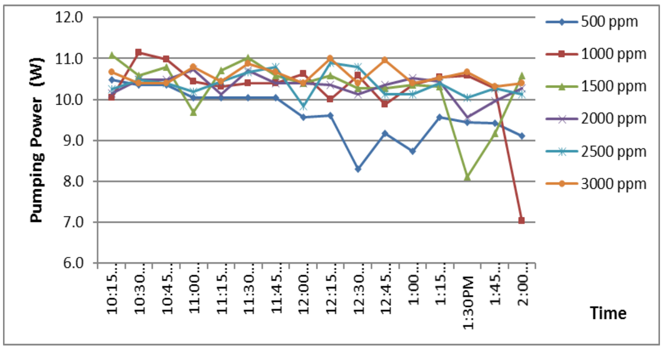

Figure (10) Pumping Power (w). And Time

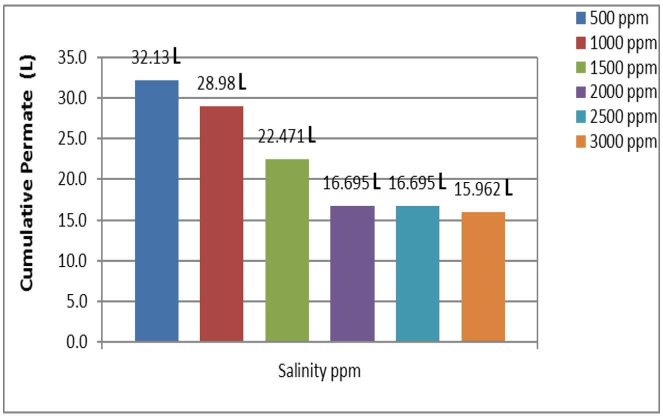

Figure (11) Cumulative Permeate. (L) And Salinity (ppm)

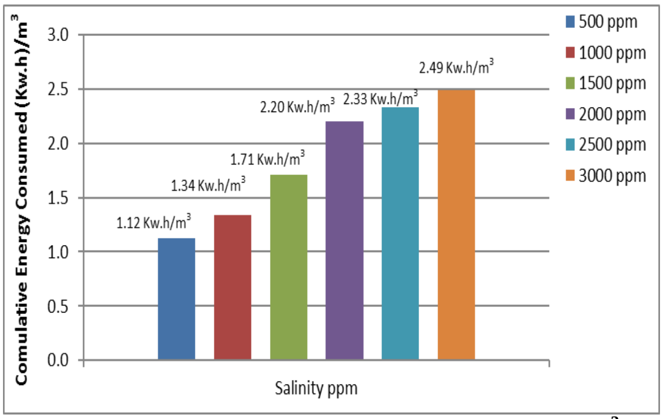

Figure (11) Cumulative Energy Consumed (Kw.h/m^3). And Salinity (ppm)

VII. CONCLUSION

Solar energy is an increasingly important and cheap energy source for driving desalination processes. There is increasing interest in developing solar-driven desalination process with a target niche of small community installations for brackish water desalination. The unit consumed approximately at a feed water of 3000 ppm concentration.

It's also easy to operate and durable. It is high performance with little periodic maintenance. Experiments showed satisfactory results in terms of quantity and quality of water. Experiments showed satisfactory results in terms of quantity and quality of water.

The test rig indicated that the unit comfortably produced at least 75 l/day. This is sufficient to supply a full water service for one Remote community's family or meet the drinking water requirements for 5: 7 people from a Remote community .

The test rig proving that small units of an integrated reverse osmosis system powered by solar panels can be moved and carried easily. This system can be a practical solution to solve the problem of small remote communities spread throughout the desert and on the seas and oceans. This is the best solution that can get clean drinking water anywhere under any emergency conditions and is better than carrying drinking water of relatively heavy weight.

We recommend developing and intensifying studies to discover small desalination systems. And develop methods for high pressure on water without the use of mechanical systems. Certainly, we need to develop the primary treatment of the small reverse osmosis system using solar panels to reduce the operation and maintenance costs and maintain a longer membrane life.

With the development and deployment of such systems, the key to the development of many remote areas of the world could be areas of population attraction.

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