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Optimal design of Renewable Energy, Water and sewage Pumping System for a community, Case Study New El-Farafra Oasis, Egypt

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Abstract*- The design and evaluation of a stand-alone hybrid renewable energy system for pumping underground water for a newly proposed community in EL-Farafra-Egypt are presented. Solar radiation, wind speed and environmental conditions for the proposed location are given. Moreover the loads are calculated carefully according to Egyptian codes, the optimal size of the system components is obtained using the simulation tools HOMER based on economic optimization criteria represented in the net present cost and the cost of energy. The compared water pumping systems are; PV only and Wind turbine only. The study was illustrated for climatic conditions of an isolated area in El-new Farafra oasis, Egypt. Water pumping system is simulated for drinking purposes in the proposed site. The results show the NPC and COE are lower in the case of PV only and increased by using a wind turbine system due to the lower wind speed rates in the specified location. The COE was0. 215 $/kWh for PV only and 0.835$/kWh for Wind only.

***Keywords*- PV, Hybrid System, HOMER, Renewable Energy, Water Pumping System. Etc.**

I. INTRODUCTION

Several developed and developing countries are now using solar and wind energy as a clean and sustainable alternative, instead of using polluting materials, but the benefits of renewable energy do not stop there [1, 2]. On the other hand, we find that Egypt is entering the new and renewable energy field with a large project package in different governorates such as implementing the largest solar city in Aswan to generate 1465 MW. Egypt is also taking rapid steps in the field of relying on new and renewable energy to penetrate the field vigorously and become a pioneer, Ministry of Electricity to support projects of solar, wind and hydropower, where renewable sources are expected to contribute 20% of the total electricity produced by 2022.

Egypt is seeking new and renewable energy projects, one of the largest solar cities in the world, specifically in the village of Benaban, Aswan Governorate, so that Aswan will become the second most important source of electricity production for the construction of the High Dam. Many people around the world do not have permanent water so groundwater is used to meet their water needs, and water is pumped from the wells with electric water pumps. Diesel is used to feed its systems. However, these systems are not only costly and require constant and frequent modifications and repairs due to the frequent breakdowns of fuel costs. Here is a major problem, carbon dioxide emitted from this kind of system, which harms nature in general. After years of scientific research and technological developments, solar and wind energy systems proved to be very practical, financial and environmentally friendly. In recent years, the cost of solar technology has dropped too. The price of solar panels in this system decreased by 80% in addition to its life span of up to 25 years and requires only some minor periodic maintenance to ensure its work well during this period [3].These factors have made solar water pumps and wind power the best way to deliver water within countries and communities.

With weather conditions resistant and rainfall or seasonal patterns unreliable. Some governments have chosen to support this type of emerging technology in remote areas. Although solar water pumping is ready for circulation and has begun to spread around the world, its benefits are still largely unknown to local communities, Governments and development institutions. Solar water pumps are used in remote areas and villages to pump and provide water to irrigate crops and land as well as to provide them as a source of drinking for livestock and household use, washing, cooking, drinking, etc.

In this paper renewable energy is used to feed the water pumping system and sewage compact units of the proposed new community in El-Farafra Oasis as a case study. The loads of water pumps and sewage units are calculated carefully according to [4, 5].

II.WATER PUMP

The water pump is a solar-operated submersible pump with maximum flow rate of 7 m^3/h and a maximum head of 140 m. The pump has maintenance-free brushless DC motor, has no electronics in the motor. In determining the horsepower used to pump water, we must know pumping rate in gallons per minute (gpm) and Total Dynamic Head (TDH) in feet [6]. The theoretical power needed for pumping water is called water horsepower (whp) and is calculated by:

$$whp = \frac{\text{pumping rate (gpm)} * \text{TDH (ft)}}{3960} \quad (1)$$

Since no device or machine is 100 percent efficient, the horsepower output of the power unit must be higher than that calculated with equation (2). This horsepower, referred to as brake horsepower (bhp), is calculated by:

$$bhp = \frac{whp}{\text{pumping plant efficiency}} \quad (2)$$

Total Dynamic Head (TDH) may be viewed as the total load on the pumping plant. This load is usually expressed in feet of "head" (1 psi, or pound per square inch = 2.31 feet) [7]. TDH can be calculated withthe equation (3) and fig 1:

TDH = (static head) + (friction loss) + (operating pressure) + (elevation change) (3)

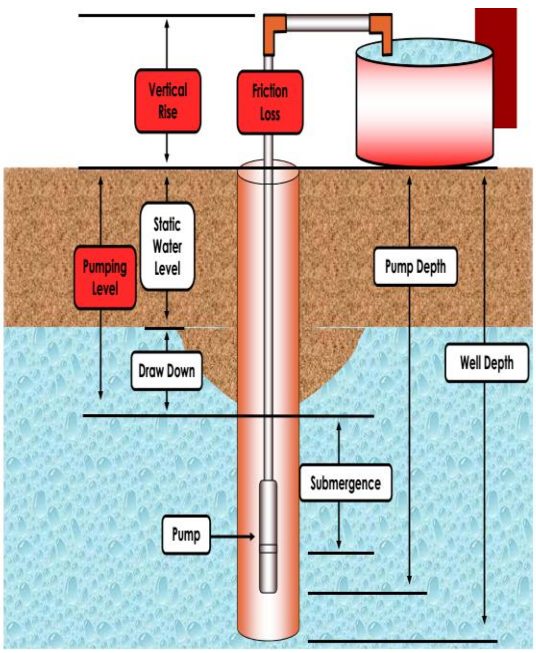

Fig.1 Total dynamic head of water pump.

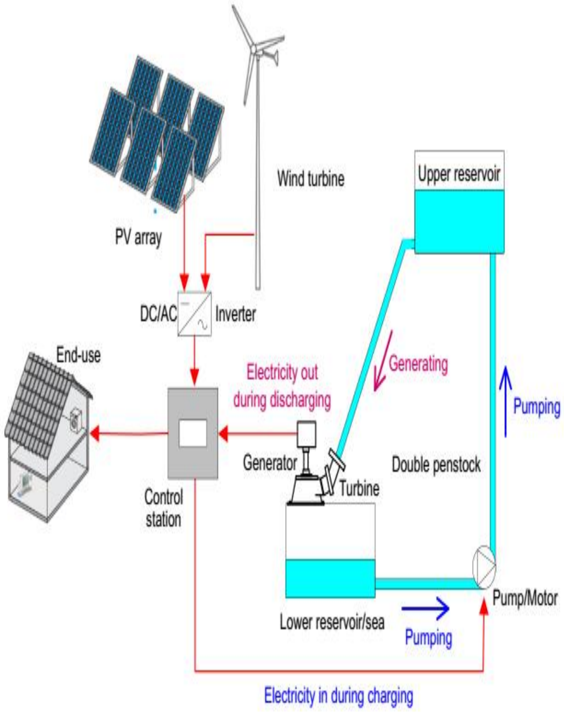

Fig.2 Hybrid water pumping architecture.

III.DATA COLLECTION

Solar energy, wind energy resource, load profile, technical details, and its costs are obtained from reliable sources [8,9,10] and calculated carefully according to Egyptian electrical codes and requirements of Egyptian electricity companies because these data are used as inputs for simulation tool.

1. Solar radiation

Solar radiation for a particular location can be given in several ways, including:

- Typical mean yearly data for a particular location Average daily, monthly or yearly solar insulation for a given location- Global is flux contours either for a full year, a quarter year or particular month- Sunshine hour's data- Solar radiation based on satellite cloud-cover data - Calculations of solar radiation. The clearness index is a measure of the clearness of the atmosphere. It is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the earth. It is defined as the surface radiation divided by the extra-terrestrial radiation [10]. The solar resource used for the hybrid energy system is located in a new Farafra oasis Egypt as Fig. 3

2. Wind speed

The monthly average wind resource data were taken from a NASA resource website based on the longitude and latitude of the community location [11]. The annual average wind speed for the location is 5.45 m/s with the anemometer height of 50 m. The average wind speed of new Farafra Oasis in the western desert of Egypt (selected location) is shown in fig. 4.

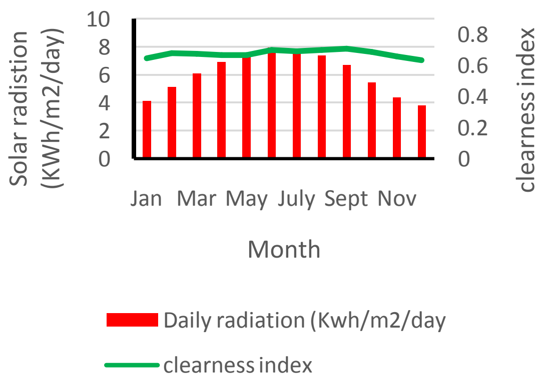

Fig.3 Solar energy profile at the selected location.

3. PV Array

In this case, PV MSX 60 watt is used. The nominal power needed for PV to meet the load demand of water pumps and sewage compact units is 20642 KW, which is produced from the PV array. The area of each Module is 0.55 m^2 (50.2 cm ×110. 5 cm) [12]. The panels are modeled as fixed and tilted at 27 degrees and mounted such that the module is facing south direction. The capital cost of a 1kW PV is taken as $3000. As there is very little maintenance required for PV, only $10/year is taken for O&M costs. The average lifespan for PV is 20 years.

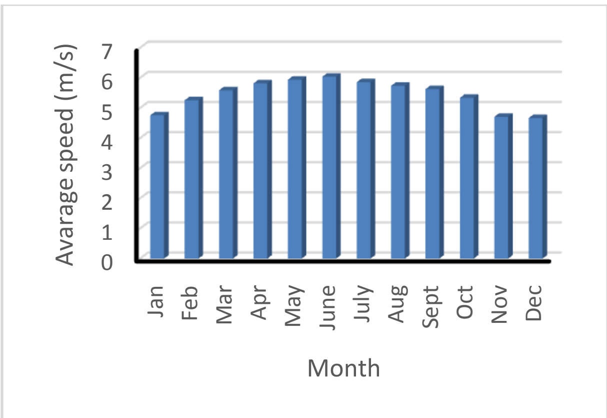

Fig.4 Wind speed profile at the selected location.

4. Load pattern

4.1 Load of water pump

According to the Egyptian Code for the design and implementation of pipelines for drinking water and sewage networks and according to the studies conducted for the cities of Cairo, Alexandria, Port Said and some governorates of Upper Egypt and new cities such as the sixth of October, the average daily consumption of various regions of the Republic in terms of cities or capitals of provinces or centers or rural and average daily consumption represents domestic consumption in addition to general consumption and the consumption of public buildings and small industries. The losses in the networks are neglected. The daily consumption of drinking water in the proposed community can be calculated as the following Average daily consumption = 1.8 * 280 = 504 liters / day / individualAverage consumption hour = 2.5 * 280 + 20 = 700 L / person / day Average monthly consumption = 1.4 * 280 = 392L / person / day Relation between number of populations and water consumptions is calculated from equation (4).

$$y = 0.524 * X \qquad (4)$$

Where: y: the amount of water consumption (m^3/day), x: number of populations and 0.524 is constant. Figure 5, shows the relation between water pump power and its number according to electrical loads of populations. The range of water pumps available from 10 kW to 50 Kw. Figure 6, shows the relation between number of populations and cost of water pumps.

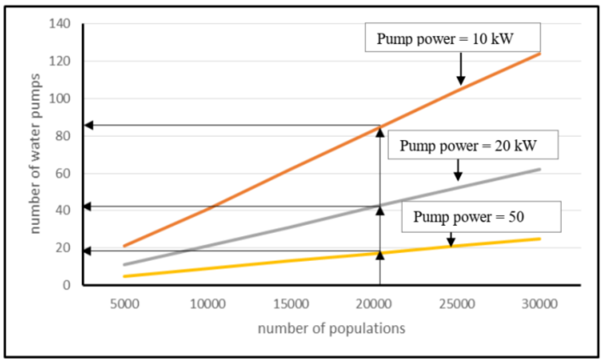

Fig.5 Relation between water pump power and its number.

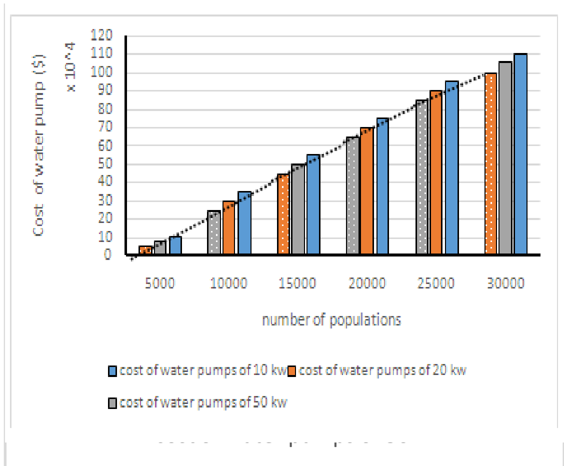

Fig.6 Optimization of water pump (cost) according to number of populations.

- Sewage calculations

The process of designing sewage lines requires the calculation of the maximum and minimum sewage throughout the day to calculate the velocities required for the pipes so that the water flows in the pipes without erosion or sedimentation of the pipes, which affects the efficiency of the sewage network.Sewage of the individual: The sewage of the individual = consumption × (8, - 9), liters per day.

Consumption = (150 - 250) liters per day. By geographical location and by socio-economic status of the population.Average sewage Qav = POP * q *(0.80 - 0.90)Where POP: population, q: water consumption / day.

In this paper, compact unit is used. Compact unit has some advantages such as (Pre-assembled, skid-mounted and factory-tested packaged systems have less requirements for installation and reduced on-site construction costs, Compact designs for easy integration into existing facilities, Completed engineering packages with quick delivery, Comprehensive cleaning capabilities for peak system performance, Simple operation and maintenance requires minimal operator supervision.

5.Pump capacity calculations

$$p = \frac{(\rho\, g\, Q\, H)}{1000 * \text{efficiency}} \qquad (5)$$

Where: ρ: density, g: kg / m^3 gravity wheel, Q: disposition, H: total lift (m)

Figure 7, shows the relation between compact sewage unit power and its number. The range of compact unit power available from 5kW to 60 kW. Figure.8 shows the relation between number of populations and cost of sewage compact units.

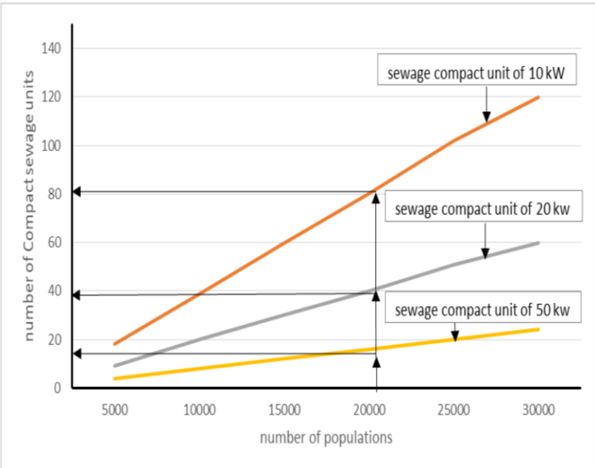

Fig. 7Relation between sewage compact unit powers And its number.

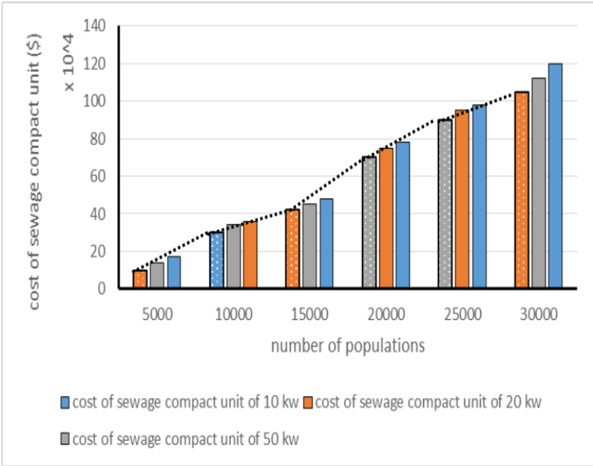

Fig. 8Optimization of sewage compact units (cost) according to number of populations.

6. Case study for a community 20000 population

To reach optimal system configurations, alternative configurations supplying the estimated daily load pattern are used to simulate the system performance. The optimum system fulfills the load requirements within the acceptable percentage of the unmet load which is one of the decision variables. Optimality condition is based on the objective minimum cost which is defined by two criteria; the first is the minimum net present cost (NPC) and the second is the cost of energy (COE) generated from the system.

The daily quantity of water required for drinking water supplies for a new community is about 10480m^3. The submerged pump is installed at a distance 41 m from ground level, assuming that the tank is at 2 m above the ground, and then the total elevating head is 43 m. The total KW required for the water suppliers and sewage loads is 20642 KW. For economic comparison purposes, of the PV only and WT only pumps systems, 2 cases of the different investigated system configurations are simulated and analyzed using software HOMER. The proposed systems are as follows;

- PV system
- Wind turbine.

IV.RESULTS AND DISCUSSION

1. Case 1: PV only

In this case, the system used the PV arrays only to drive the loads. The Cost of Electricity (COE) resulted from system simulation is 0.215$/kWh.

Table 1System architecture

PV	Generic flat plate PV	1746kw
Dispatch	Homer combined dispatch	

The energy summary is shown in Fig. 9

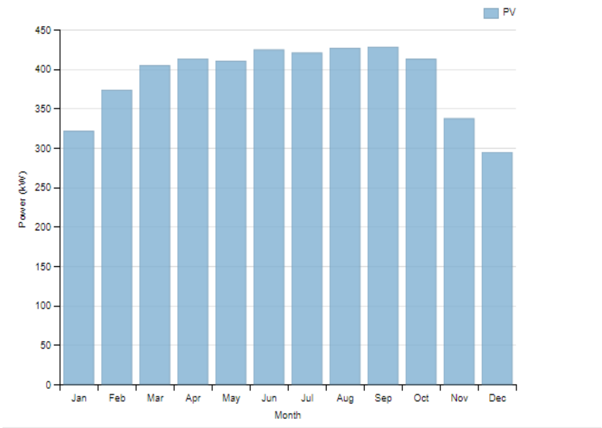

Fig.9 Energy summary of PV pumping system.

2. Case 2: Wind turbine only

In this case, the system used the wind turbine XANT M-21 [100kw for one turbine] only to drive the pump loads. The COE resulted from system simulation is 0.835$/kWh.

Table 2 System architecture.

Wind	XANT M-21 [100kw]	2100kw
Dispatch	Homer combined dispatch	

The energy summary is shown in Fig. 10.

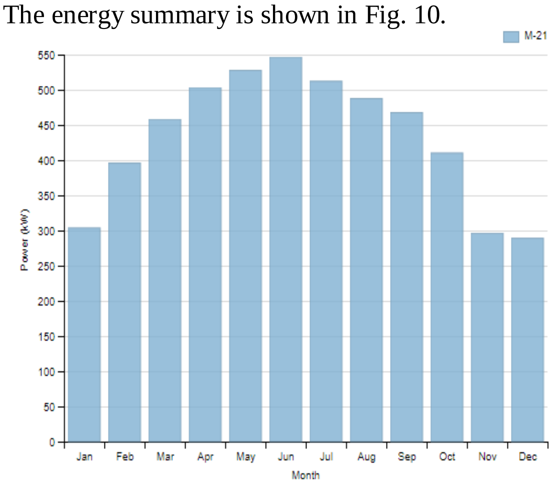

Fig.10 Energy summary of wind pumping system.

V.CONCLUSION

This paper illustrated the specifications of an installed water pumping system for water drinking supply purposes in EL-Farafra Oasis, Egypt. For economic comparison, the paper theoretically analyzed different renewable energy, water pumping systems using commercial software. The systems using PV only and wind turbine only are investigated. The economic analysis was carried out based on the NPC and COE. The result of the analysis showed the following conclusions, the COE is lower in case of PV only andincreased by using WT due to the lowerwind speed rates in the specified location. The COE was0.215$/kWh for PV only, 0.835$/kWh for Wind only. Monthly average wind speeds on the location are muchlower than the turbine rated wind speed which leads to non-optimal operation of the WT. This leads to higher NPCand COE values for wind only. The optimal system was PV only system.

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