International Scientific Journal
Environmental Science
http://environment.scientific-journal.com

Promising Areas For The Use Of Wind Power In Egypt

A. A. El-Haroun
Mechanical Power Eng. Dept.
Faculty of Engineering, Menufiya University
Shebin El-Kom, Egypt
E-mail: ah81256@yahoo.com, Fax: 0020482235695

Abstract— **This paper concerns with the most promise applicable fields of wind energy in Egypt. Possible use of wind energy in two main areas in Egypt: First in electricity generation particularly in the coastal areas and secondly in the water pump, especially in agricultural areas.**

It is seen that the chosen rated wind speed, rated and average specific power and annual predicted specific energy having a considerable values for the studied locations in this work. Therefore, it is helpful to construct wind turbines in single case or in wind farms in these locations or along the coastal regions of Mediterranean Sea and Red Sea. It is expected to generate a huge amount of electrical energy from these sites that can cover a part of the increasing energy demand.

The results show also that, it will be a good choice to use simpler and cheaper types of wind turbines, like American multi blades wind turbines, to drive the large number of both manual reciprocating pumps and simple Egyptian water pumps which are distributed over a large area of Egypt. This will save a considerable amount of conventional fuels which used to drive the traditional pumps and will reduce the emission of harmful gases to great extent. It was found also that, a considerable amount of water will be pumped using these wind driven pumps. The pumping rates of water depend on wind regime in location.

Keywords—Wind energy; renewable energy; electricity generation; water pumping; environmental conservation

I. INTRODUCTION

It is evident that the world energy consumption increases more rapidly than the population growth during the last decades. This tendency is expected to be further increasing next years. It should be noted that developing countries contribute now on the energy consumption rate more than industrial countries. The average annual increase of energy consumption in developing countries will be 3.5% versus 0.9% in the industrial countries [1].

Also the measurements taken from all over the world, however, have shown that the global climate is changed and the ozone is depleted. In the last 100 years, the atmosphere has warmed up by about half a degree Celsius [2, 3]. Also, during this time humans have been emitting extra greenhouse gases, which are the result of burning fossil fuels (like coal, oil and gas). These gases include carbon dioxide, methane and nitrous oxide. It is thought that the man-made emissions of greenhouse gases through the increased use of fossil fuels. These gases are responsible for some of the warming of the global climate during the 20th century. If the Earth continues to warm as climate models have predicted, the temperature at the Earth's surface may be 3°C warmer by 2100 than it is today. This rapid change in temperature would be harmful to many ecosystems, and many types of plants and animals [2,3,4].

The burning of conventional sources of fuels in thermal power stations and in driving conventional water pumps is the main reason for present global climate change. Therefore there is a great tendency in the world towards the use of renewable sources of energy [5].

The production and use of renewable energy has grown more quickly in recent years due to oil shortages of the 1970s, higher prices for oil and natural gas and the impact of conventional sources on the environment. Kris et al [6] discussed a methodology to determine accurately the impact of using wind-energy-conversion systems on the operation of the central power system. They found that in all cases considered, the reduction of green house gases emission obtained on a national level is in the range of 350–450 kg CO_2 per MWh of power generated by the wind energy conversion systems. Bueno et al [7] used a general model for the optimum design from the technical and economical point of view of medium sized wind energy/pumped hydro storage systems in the island of El Hierro. The application of the model would allow an increase in renewable-sourced energy penetration of the island grid from the current technically permissible maximum of 30–68.40%. Such a renewable-sourced energy penetration would mean fossil fuel savings as well as a decrease in CO_2 emissions of 20.9 Gg. The use of renewable energy is expected to continue to grow over the next 30 years, although we will still rely on non-renewable fuels to meet most of our energy needs. In the 9th of March 2007, the European council decided a fixing goal of 20% contribution of the renewable energy sources on the total European electric energy production in 2020 [8].

Among renewable energy sources, wind energy has received more attention in many countries in the world because of its competitive and economic. In 2006, wind machines in the United States generated a total of 26.6 billion kWh per year of electricity, enough to serve more than 2.4 million households [9, 10]. This is electricity enough to power a city larger than Los Angeles, but it is only a small fraction of the nation's total electricity production, about 0.4 %. The amount of electricity generated from wind has been growing fast in recent years.

New technologies have decreased the cost of producing electricity from wind. The growth in wind power has been encouraged by tax breaks for renewable energy. Most of the wind power plants in the world are located in Europe and in the United States where government programs have helped and support wind power development. The United States ranks second in the world in wind power capacity, behind Germany and ahead of Spain and India. Denmark ranks number six in the world in wind power capacity but generates 20 percent of its electricity from wind. During the decade following the 1973 oil crisis, more than 10,000 wind machines were installed worldwide, ranging in size from portable units to multi-megawatt turbines. In developing villages small wind turbines recharge batteries and provide essential services [11,12].

Although wind power supplies less than 0.1 percent of the world's electricity, it is one of the fastest growing energy sources. The most ambitious wind energy program is planned for India, which expects to provide enough electrical power to serve 5 million customers. India is expected to be the most rapidly growing market for wind turbines and, if the planned program is successful, wind may supply more energy for India than the country's nuclear program [13].

Interest in wind energy has been driven in part by the declining cost of capturing wind energy—from more than 0.25$ per kilowatt-hour in 1980 to 0.05$ per kilowatt-hour for new turbines in the late 1990s. This makes wind power nearly competitive with gas- and coal-powered plants, even before considering wind's environmental advantages [13]. Encouraged by improved technology, falling costs, and government incentives like tax credits and guaranteed prices, wind power is booming across Europe. Almost no country supports the expansion of nuclear power and, in many areas; wind power is becoming economically viable.

There are two main types of wind turbines used today based on the direction of the rotating shaft: horizontal–axis wind machines and vertical-axis wind turbines, VAWT's. The size of wind machines varies widely. Small turbines used to power a single home or business may have a capacity of less than 100 kilowatts. Some large commercial sized turbines may have a capacity of 5 megawatts. Larger turbines are often grouped together into wind farms that provide power to the electrical grid. Most wind machines being used today are the horizontal-axis type. VAWT's are more suited to commercial applications and are excellent at operating in confused wind areas. They are simpler and very effective at lower wind speeds.

In Egypt the air pollution has reached extreme values. The main reason is the use of conventional sources of fuels in generating mechanical or electrical powers. Conventional sources of fuels are used in wide range in Egypt in lifting water for irrigation purposes.

The coastal regions in Egypt have a relatively high average wind speeds and low population density. These regions are therefore very suitable for using wind turbines in single case or in large wind farms to generate electricity.

A great number of manual reciprocating pumps are distributed over the whole area of Egypt. There are also a large number of simple old Egyptian water pumps that were driven by using animal forces, which is one of the reasons why they are not in use today. There is also other type of pumps with different sizes that are driven by diesel engines.

The aim of this work is to study the possibility of using wind energy for generating electricity in suitable coastal locations and for pumping water by driving these pumps. This will cover a part of the increased demand to energy and will help in the improvement in air pollution situation in Egypt.

II. Fields Of Using Wind Energy

In the following section, two main areas for the use of wind energy in Egypt will be discussed.

A. *Generating Electricity*

Many areas in Egypt are very suitable for the use of wind energy, especially in coastal regions. In order to be the use of wind energy economically in any area, the suitable wind turbine should be selected for the right place. The main important thing which affects the performance of any wind turbine at any location is the selection of the proper rated wind speed. The following empirical equation between the rated wind speed of the wind turbine u_R and shape factor k in Weibull distribution function has been derived according to the data in [14]:

$$k = 7 - 3.833\left(\frac{u_R}{c}\right) + 0.667\left(\frac{u_R}{c}\right)^2 \qquad (1)$$

Where c is the scale parameter in Weibull distribution function. The above equation is derived for start wind speed u_c=0.4 u_R and furling wind speed u_f= 2 u_R. The rated wind speed in the above equation is for maximum power condition.

It can be noticed that with selecting a larger value of U_R for a turbine, the rated power P_{eR} will increase. This is accompanied by a decrease in capacity factor CF. This decrease has economic implications that may force us to select a smaller rated speed than that which produces maximum energy. What we really want is to produce energy with minimum cost, which may yield a different design than the one which strictly maximizes total energy. As we increase P_{eR} for a given turbine, the costs of the necessary generator, transformer, switches, circuit breakers, and distribution lines all increase. However, the decrease in capacity factor means that these items are being used at full load less of the time. The actual economic optimum will be at a rated wind speed slightly below that which yields maximum yearly energy.

So the economic optimum when the entire power network is considered may be at an even lower rated wind speed and higher capacity factor. A reasonable design procedure would be to use the u_R/c ratio to be 90 percent of its value for maximum power [14]. This will yield a total energy production close to the maximum, at a much better capacity factor.

In [15] the scale and shape parameter for some locations in Egypt were determined with different methods. Table 1 shows the average wind speed u_{ave} , Weibull shape parameter k and Weibull scale parameter c for each one of the chosen location in this work.

TABLE I. AVERAGE WIND SPEED U_{AVE}, WEIBULL SHAPE PARAMETER K AND WEIBULL SCALE PARAMETER C FOR EACH ONE OF THE CHOSEN LOCATION [15].

Location	u_{ave} , m/s	k	c, m/s
Mersa Matruh	5.4	1.85	5.961
Hurghada	6.69	1.89	7.412
Ras Benas	6.08	1.49	5.99
Asswan	4.48	2.17	5.03
El-mansoura	2.99	1.56	3.29
Sidi Barrani	5.24	1.98	5.862

Monthly wind speed frequency distribution has been obtained for these locations from the Egyptian meteorological authority. This data was measured for a long period of more than 20 years at 10 m level above ground surface. The wind speed was divided into 8 intervals and the wind speed frequency was measured for each interval.

Once we select U_R/C, we can find the rated electrical power for a turbine with a given rotor area A_t and rated overall efficiency η_o as follows

$$P_{eR} = \frac{1}{2}\rho_a A_t u_R^3 \eta_o \quad (2)$$

where ρ_a is the density of air.

To estimate the yearly energy production from a certain turbine in a certain location, the average electrical power of this wind turbine in this location must be calculated as follows:

$$P_{e,ave} = \int_0^\infty P_e f(u) du \quad (3)$$

where $f(u)$ is the Weibull distribution function.

$$f(u) = \frac{k}{c}\left(\frac{u}{c}\right)^{k-1} \exp\left[-\left(\frac{u}{c}\right)^k\right] \quad (4)$$

k, c are Weibull shape and scale parameter for the location respectively. The integration of equation (3) between start wind speed and furling wind speed yields to

$$P_{e,ave} = P_{eR}(CF) \quad (5)$$

Where CF is the capacity factor, which is expressed mathematically as

$$CF = \frac{\exp\left[-(u_c/c)^k\right] - \exp\left[-(u_R/c)^k\right]}{(u_R/c)^k - (u_c/c)^k} - \exp\left[-\left(\frac{u_F}{c}\right)^k\right] \quad (6)$$

The predicted yearly energy from this wind turbine in the studied location can then be determined as

Energy = average power × time of the year (7)

Once the scale and shape parameters in any location are known, u_R/c ratio for maximum power can be obtained from equation (1). The u_R/c for optimum design is taken as 90% of its value for maximum power. Then from the above equations the expected annual energy from the location can be determined.

B. Water pumping

American multi blade wind turbine which is a low speed wind turbine is chosen to drive the above mentioned types of water pumps. This turbine is very suitable for water pumping because of its high rotation moment, although its low power coefficient. It gives a maximum power coefficient of about 0.18 at optimum tip speed ratio 0.9 [14]. The rated mechanical power of this wind turbine can be expressed as

$$P_R = 0.5\rho_a A_t u_R^3 C_{pm} \quad (8)$$

Where C_{pm} is the maximum power coefficient. The pump uses this power to give its rated discharge according the following relation

$$Q_R = 0.5 C_{pm} \eta_p \rho_a A_t u_R^3 / g h \rho_w \quad (9)$$

Where η_p is the efficiency of the pump, g is the gravitational constant, h is the pumping head of water and ρ_w is the density of water [16, 17].

The manual reciprocating pump revolution is calculating from the relation

$$n_p = 4Q_R / \pi d_p^2 l_s \quad (10)$$

Where d_p is manual reciprocating pump diameter, about 0.1 m and l_s is the pump stroke, about 0.15 m [18].

The number of revolution in the case of simple old water pump can be determined from [19]

$$n_p = 60 Q_R / \pi b t z d_i c_q \quad (11)$$

Where b is pump width, t is the height of inlet port; z is number of inlet ports, d_i is the diameter of center of inlet ports and c_q is the discharge coefficient, as shown in Fig. 1.

This is the number of revolution of the system when the turbine is coupled with the pump. The number of revolution of the system when the wind turbine works without load can be estimated by

$$n_t = 60 u_R \lambda_{op} / \pi d_t \quad (12)$$

Where λ_{op} is the optimum tip speed ratio.

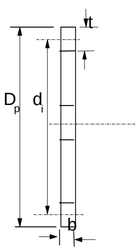

Fig. 1. Main parameters and photo of a simple Egyptian water pump.

The discharge from wind driven pump at any wind speed u can be expressed as

$$Q_u = Q_R \left(\frac{n_{pu}}{n_p} \right) \quad (13)$$

Where n_{pu} is the number of revolution of pump at any wind speed [17, 20].

The discharge from wind driven pump at different values of wind speed, starting from start wind speed u_c to furling wind speed u_f , can be calculated for different locations in Egypt related to wind regime in each location.

To estimate the daily and yearly pumping amount of water for each location, the average discharge in each location must be calculated first as

$$Q_{ave} = \frac{60 Q_R \lambda_{op}}{\pi d_t n_p} \int_{u_c}^{u_R} u\, f(u)\, du + Q_R \int_{u_R}^{u_f} f(u)\, du \quad (14)$$

Where f (u) is the Weibull distribution function

The pumping amount of water Q_{tot} can then be estimated as

$$Q_{tot} = Q_{ave}\ time \quad (15)$$

The diameter of wind turbine used to drive the manual reciprocating pump is taken as 3 m, while the diameter for the turbine used to drive the simple Egyptian water pump is taken as 5 m for operation suitability consideration.

III. Results And Discussion

A. Generating Electricity

There are many coastal areas in Egypt suitable for using wind power to generate electricity. Four were selected from these areas for the application of this research: two on the coast of the Mediterranean Sea; Sidi Barrani and Marsa Matrouh, and two on the coast of the Red Sea, Hurghada and Ras Banas.

Table 2 presents the selected rated wind speed u_R for optimum design, the rated power per unit area of wind turbine rotor, the average power per unit area of wind turbine rotor and the expected annual specific energy from these locations.

TABLE II. Selected Rated Wind Speed U_R , Rated Specific Power, Average Specific Power And Expected Annual Specific Energy For Each One Of The Chosen Locations.

location	u_R, m/s	rated spec. power, W/m^2	Ave. spec. power, W/m^2	energy, W hr/m^2
Mersa Matruh	12.77	562.27	57.89	507112.7
Sidi Barrani	11.84	447.73	51.17	448246.1
Hurghada	15.59	1023.1	108.58	951191.6
Ras Benas	17.2	1373.88	76.22	667670.9

It is seen that the rated wind speed, rated specific power, average specific power and annual specific energy having a considerable values. Therefore, it is helpful to construct wind turbines in single case or in wind farms in these locations or along the coastal regions of Mediterranean Sea and Red Sea. It is expected to generate a huge amount of electrical energy from these sites.

B. Water Pumping

Figure 2 shows the relation between flow rate and number of revolution of manual reciprocating pump with wind speed for a location with relative high wind speed, Hurghada. Figure 3 represents the same relation in the case of simple Egyptian water pump. It is shown that, the flow rate and number of revolution of pump increase with the increase in wind speed in location. At the same value of wind speed, the flow rate of water from simple Egyptian water pump is greater than the flow rate from manual reciprocating pump although the smaller value of number of revolution. The reason for that is the different in both geometry and size between the two pumps. The size of simple Egyptian water pump is larger.

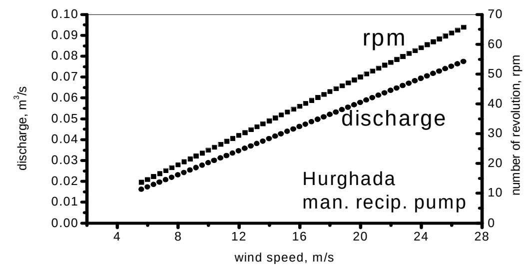

Fig. 2. Relation between flow rate and number of revolution of manual reciprocating pump with wind speed.

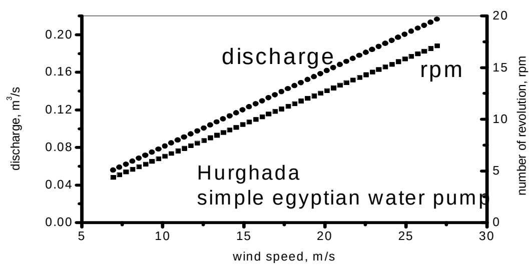

Fig. 3. Relation between flow rate and number of revolution of simple Egyptian water pump with wind speed

Figure 4 illustrates the predicted daily and yearly pumping amount of water by manual reciprocating pump and by simple Egyptian water pump.

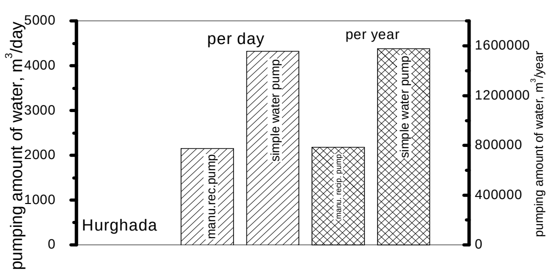

Fig. 4. Predicted daily and yearly pumping amount of water by manual reciprocating pump and by simple Egyptian water pump

Figures 5, 6 and 7 are the corresponding curves for El-mansoura which has a low average wind speed. The curves show the same trend as the above corresponding curves for Hurghada. The above curves illustrate also that sites with good wind regime like Hurghada will have higher values of flow rate

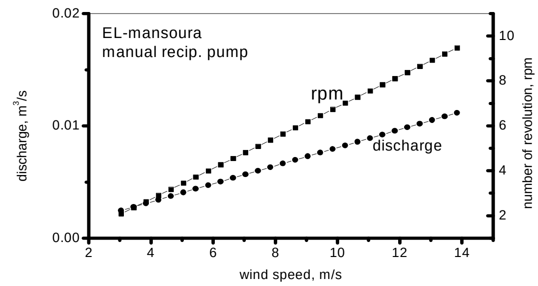

Fig. 5. Relation between flow rate and number of revolution of manual reciprocating pump with wind speed

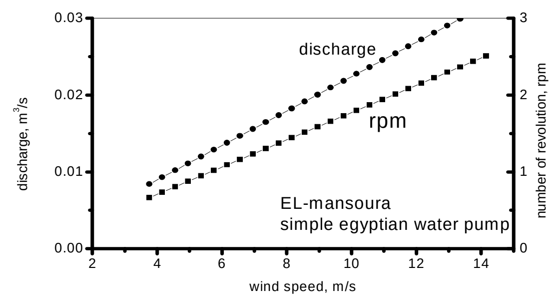

Fig. 6. Relation between flow rate and number of revolution of simple Egyptian water pump with wind speed

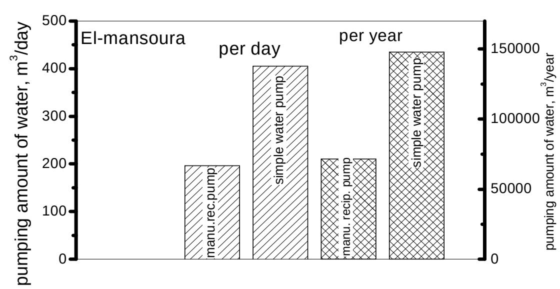

Fig. 7. Predicted daily and yearly pumping amount of water by manual reciprocating pump and by simple Egyptian water pump

, number of revolution as well as pumping amount of water than sites with low wind like El-mansoura.

The flow rate from manual reciprocating pump and from simple Egyptian water pump in five locations in Egypt with different wind regime is presented in Fig. 8 and Fig. 9 respectively. The sites with good wind regime like Hurghada, Ras benas and Mersa matruh having higher flow rates from both manual reciprocating pump as well as from simple

Egyptian water pump. While sites with poor wind regime like El-mansoura and Asswan having lower flow rates.

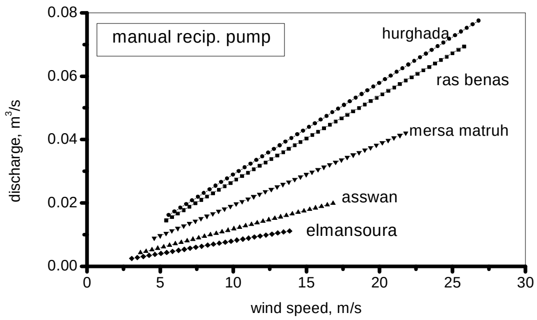

Fig. 8. Relation between flow rate from manual reciprocating pump and wind speed in five locations in Egypt

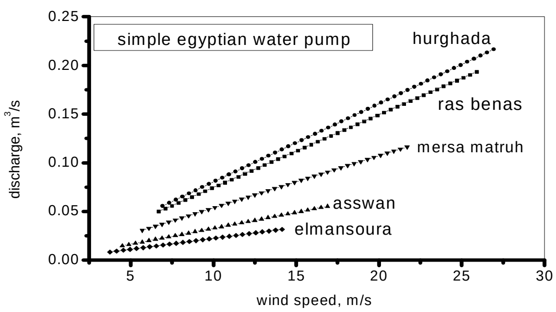

Fig. 9. Relation between flow rates from simple Egyptian water pump and wind speed in five locations in Egypt

The yearly pumping amounts of water from manual reciprocating pump and from simple Egyptian water pump for different locations in Egypt is shown in Figs. 10 and 11 respectively. It is seen that, pumping amount of water by wind driven manual reciprocating pump and by simple Egyptian water pump is very reasonable. Therefore the use of wind driven manual reciprocating pumps as well as simple Egyptian water pumps will be very attractive in these studied locations.

Using wind energy to drive these types of pumps will not only attractive but it saves also a great part of conventional sources of energy which are used till now to drive these pumps. Two main benefits will be achieved from this process, saving in money paid to obtain the conventional sources of energy and reducing of harmful gases emitted from burning of these sources. An improvement in environment in Egypt is consequently achieved.

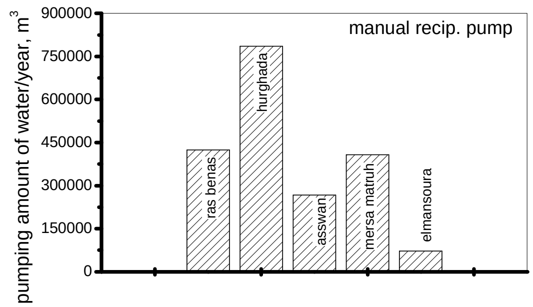

Fig. 10. Predicted yearly pumping amount of water by manual reciprocating pump in five locations in Egypt

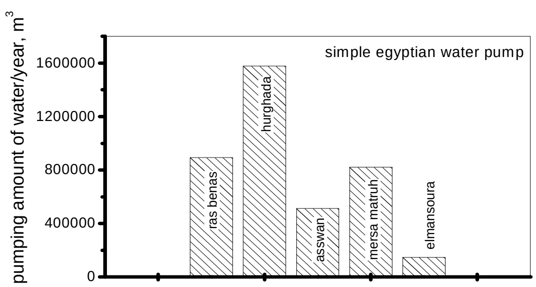

Fig. 11. Predicted yearly pumping amount of water by simple Egyptian water pump in five locations in Egypt

IV. CONCLUSIONS

In this work, the most promising applicable fields for the use of wind power in Egypt were studied, such as generating electricity or pumping water in order to expand the use of wind energy, to reduce dependence on traditional energy and also with the aim of preserving the environment.

The optimum rated speed for wind turbines in some locations in Egypt was chosen to achieve best economy. The predicted annual specific electrical energy from each location was calculated. The use of wind energy to drive some types of old traditional water pumps was studied.

The results of this work show that, the use of wind energy to generate electricity especially in costal regions will be very attractive. The selected rated wind speeds as well as the predicted annual specific energy in these locations have considerable values. The wind turbine can be constructed in single or in large wind farms along the coastal regions and will produce a huge amount of energy.

The results show also that, the use of wind energy to drive the great number of both manual reciprocating pumps and simple Egyptian water pumps which distributed over a large area of Egypt will be a very good choice. This will save a considerable amount of fossil fuels that used to drive the traditional pumps and will reduce the emission of harmful gases to great extent. Simpler in construction and cheaper types of wind turbines, like American multi blade wind turbines can be used to drive these pumps. It is seen that, a reasonable pumping rate of water is obtained through using this turbine to drive manual reciprocating pump and simple Egyptian water pump. This pumping rate is related to the wind regime in the location. In locations having good wind regime, like Hurghada, the daily and yearly pumping amounts of water by manual reciprocating pump are about 2100 and 785000 m^3 respectively. The daily and yearly pumping amounts of water by simple Egyptian water pump in this location were found to be about 4300 and 1.6×10^6 m^3 respectively.

It is concluded that the use of wind energy in Egypt either for electricity generation or for pumping water will be a very good choice. This can cover a part of energy demand, save a fraction of traditional fuel used for these purposes and help in conservation of environment.

REFERENCES

[1] O. P. Dimitriev, "*Global energy consumption rates: Where is the limit?,*" Sustainable Energy, vol. 1, pp. 1-6, 2013.

[2] M. O. Abdeen, "*Green energies and the environment,*" Renewable and Sustainable Energy Reviews, vol 12, pp. 1789–1821, 2008.

[3] I. Dincer and M. A. Rosen, "*Energy, environment and sustainable Development,*" Applied Energy, vol. 64, pp. 427-440, 1999.

[4] I. Dincer, "*Energy and environmental impacts: present and future perspectives,*" Energy Sources, vol. 20, pp. 427-453, 1998.

[5] R. E. H. Sims, " *Renewable energy: a response to climate change,*" Solar Energy, vol. 76, pp. 9-17, 2004.

[6] K. Voorspools and W. D'haeseleer, "*Impact assessment of using wind power,*" Solar Energy, vol. 80, pp. 1165–1178, 2006.

[7] C. Bueno, J. A. Carta, "*Technical–economic analysis of wind-powered pumped hydrostorage systems. Part II: model application to the island of El Hierro,*" Solar Energy, vol. 78, pp. 396–405, 2005.

[8] A. Campoccia, L. Dusonchet, E. Telaretti and G. Zizzo, "*Comparative analysis of different supporting measures for the production of electrical energy by solar PV and Wind systems: Four representative European cases,*" Solar Energy, vol. 83, pp. 287–297, 2009.

[9] L. Duenas-Osorio and B. Basu, "*Unavailability of wind turbines due to wind-induced accelerations,*" Engineering Structures, vol. 30, pp. 885–893, 2008.

[10] G. M. Joselin Herbert, S. Iniyan, E. Sreevalsan, and S. Rajapandian, "*A review of wind energy technologies,*" Renewable and Sustainable Energy Reviews, vol. 11, pp. 1117–1145, 2007.

[11] J. P. Molly, " *Windenergie: Theorie – Anwendung - Messung,*" Mueller, Karlsruhe, Germany, 1990.

[12] M. Kleemann and M. Meliss, "*Regenerative Energiequellen,*" Springer-Verlag, Berlin, 1988.

[13] D. S. Ahmet, "*Progress and recent trends in wind energy,*" Progress in Energy and Combustion Science, vol. 30, pp. 501–543, 2004.

[14] G. L. Johnson, "*Wind energy systems,*" Printice-Hall, Inc., Englewood Cliffs, New jersey, 1985.

[15] A. A. El-Haroun, "*Estimation of Wind Energy in some Locations in Egypt using Weibull and Rayleigh Distribution Functions,*" in Proc. of 4th Conference of Egyptian Rural Development, Shebin El-Kom, Egypt, 15-17 Sept. 2003.

[16] M. M. Alam and J. D. Burton, "*The coupling of wind turbines to centrifugal pumps,*" Wind Engineering, vol. 22, pp. 223-234, 1998.

[17] S. Mathew and K. P. Pandey, "*Modeling the integrated output of mechanical wind pumps,*" Solar Energy Engineering, Transactions of the American Society of Mechanical Engineers, vol. 122, pp. 223-226, 2000.

[18] A. A. El-Haroun, "*Performance Study of Wind Driven Manual Reciprocating Pumps in some Locations in Egypt,*" in Proc. 9th International Conference for Mechanical Power Engineering (ICMPE-9), Shebin El-Kom, Egypt, 21-23 December 1996.

[19] A. A. El-Haroun, "*The Performance Study of Wind Driven Simple Egyptian Water Pumps,*" in Proc. Sharjah Solar Energy Conference, Sharjah, United Arab Emarates, 19-22 Feb. 2001.

[20] J. D. Burton, "*The mechanical coupling of wind turbines to low lift rotodynamic water pumps,*" Solar and Wind Technology, vol. 5, pp. 207–214, 1988.

NOMENCLATURE

A_t	rotation area of wind turbine, m^2
b	simple pump width, m
C	Weibull scale parameter, m/s
CF	capacity factor, ----
C_{pm}	the maximum power coefficient, ----
c_q	discharge coefficient, ----
d_i	diameter of center of simple pump inlet ports, m
d_p	manual reciprocating pump diameter, m
f (v)	Weibull distribution function
g	gravitational constant
h	pumping head of water, m
l_s	pump stroke, m
n_p	pump revolution, rpm
n_{pv}	number of revolution of pump at any wind speed, rpm
n_t	number of revolution of the system without load, rpm
P_{eR}	rated electrical power of wind turbine, W
P_R	rated mechanical power of wind turbine, W
Q_{av}	average discharge in each location, m^3/s
Q_R	rated discharge from wind driven pump, m^3/s
Q_{tot}	total pumping amount of water, m^3
Q_v	discharge from wind driven pump at any wind speed v, m^3/s
t	height of simple pump inlet port, m
u	wind speed, m/s
u_c	start wind speed, m/s
u_f	stop wind speed, m/s
u_R	rated wind speed, m/s
z	number of inlet ports, ----
ρ_a	air density, kg/m^3
ρ_w	density of water, kg/m^3
η_p	efficiency of the pump,----
λ_{op}	optimum tip speed ratio, ----

Filename: Paper template.doc
Directory: E:\prffile\papers\p4ENVIRON CONSERV\pap4modified\conference
باريس
Template: C:\Users\ahmed\AppData\Roaming\Microsoft\Templates\Normal.dot
Title: Paper Title (use style: paper title)
Subject:
Author: IEEE
Keywords:
Comments:
Creation Date: 03-Apr-14 5:07:00 PM
Change Number: 32
Last Saved On: 07-Apr-14 5:54:00 PM
Last Saved By: ahmed
Total Editing Time: 371 Minutes
Last Printed On: 08-Apr-14 11:46:00 AM
As of Last Complete Printing
Number of Pages: 7
Number of Words: 4,118 (approx.)
Number of Characters: 23,474 (approx.)