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FEASIBILITY STUDY OF USING WIND TURBINES WITH DIESEL GENERATORS OPERATING AT ONE OF THE RURAL SITES IN JORDAN

DR ATEF.S. AL-MASHAKBEH
Tafila Technical University
Tafila, Jordan
Electrical Engineering Department
atef_almashakbeh@yahoo.com

ABSTRACT

Jordan is one of the countries, which suffer from energy resources shortage. Therefore, it is entirely dependent on imported oil, form neighboring countries.
The exploitation of green sources is encouraged to reduce the environmental pollution and combat the global warming of the planet. Wind is a natural renewable source energy that has a significant potential in Jordan.
This paper introduces a feasibility study of integrating wind energy with diesel plant for a rural site in a remote southern of Jordan called "Rass Alnaqab". The data concerning the load, the national grid, the price of energy and the average wind speed at that site are calculated. The Weibull distribution technique was then used to analyze the wind data. A simple calculation was done to illustrate the visibility of integrating wind energy with diesel sets. The environmental factors have been calculated.

Keywords: *Feasibility Study, Wind Turbines, Load, Price of Energy, Environmental Factors*

1. INTRODUCTION

Since the beginning of the oil crises in1970s, utilization of renewable energy sources in general and wind in particular has been promoted. Wind energy is non-depletable, non-polluting, and several windy sites are located in each country. Many countries which have sites with average wind speeds in the range of 5 m/s–10 m/s start to exploit the wind energy and put their efforts to minimize their dependence on fossil fuels [1–5]. Although the stand-alone diesel generator sets are considered inexpensive to purchase, but they are expensive to operate and maintain especially at low load levels [6]. Therefore, new power sources from hybrid system (wind ./solar /diesel) have proved to be very promising world-wide [7-11].

2. THE NEED FOR RENEWABLE ENERGY

Today, the exponential population growth, the shortage in natural resources, insufficient and inefficient waste disposal facilities, increasing soil, air, and water pollutions are the matters of concerns to individuals, scientists, engineers, politicians, and to governments. Therefore, renewable energy is considered the only viable alternative to the present sources of energy which can minimize the pollution effect. The development of new renewable energy technologies has advanced steadily over the past few decades, and basic research has been effectively participating in this field.

The total power in the world's atmosphere has been estimated to be about 10^{14}MW, and the potentially recoverable power in the wind is about 10^{6} MW [12]. The generation cost for wind energy is currently comparable to that from the conventional power plants. With the increase in oil prices it is possible to go lower than that from conventional ones.

The cost of consumed energy in 2001 in Jordan, reached about US$ 798 million, or around 9% of Gross Domestic Product [13]. The final energy consumption in 2001 was 3692.4 thousand tons of oil equivalent, of which 14.9% was from the electrical energy sector, 2% from renewable energy [13]. Regarding the protection from the pollution and people health, renewables are important and safe sources of energy.

Generating electricity from fossil fuels has certain negative impacts on the environment. The emissions account for half of the greenhouse effect [14] in the atmosphere. CO2 emission is a major global problem and remedy for its

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reduction is costly. It was estimated that the cost of scrubbing CO2 from coal-fired units is around $1800/kW [15].

3. SITE DESCRIPTION

The selected site (Rass Alnaqab) is located 300 km to the south east of Amman, and its latitude is about 32.1 N, the longitude is 35.5 E, and its altitude is 900 m above sea level. The hourly average annual wind speed of the selected site is 6.5 m/s .The wind speed in this site was measured using a cup anemometer. Figure 3.1 shows the average monthly wind speed of the site

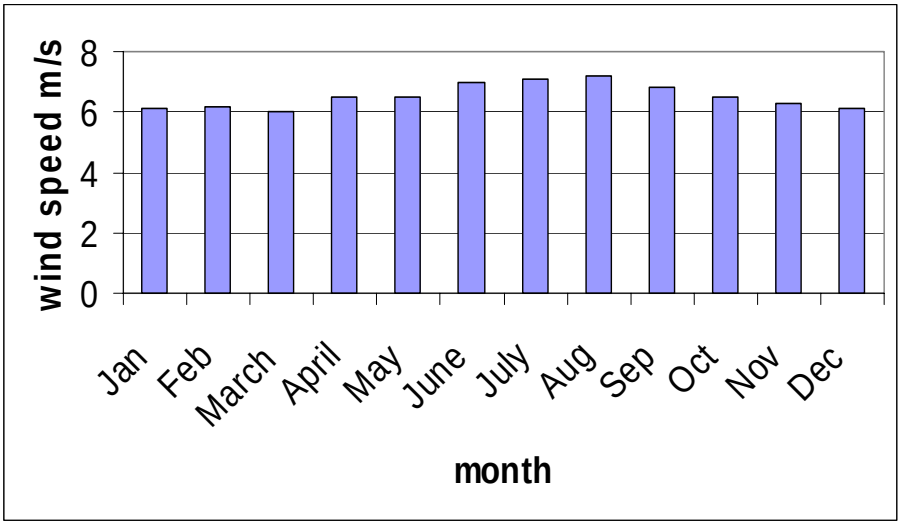

Figure 1: Monthly average wind speed at the selected site

The electrical loads in the site were thoroughly studied. These loads are fed from two sources, diesel generators and the national grid. The diesel generators consist of two Caterpillar machines with a rated power of 250 kW each. The mode of operation is 75% of the time from the grid and 25% from the diesel generators. The cost of kWh from these generators is 0.135JD [16], while from the grid is 0.08JD. Figure 2 and Table1 illustrates the electricity consumption of loads at the site.

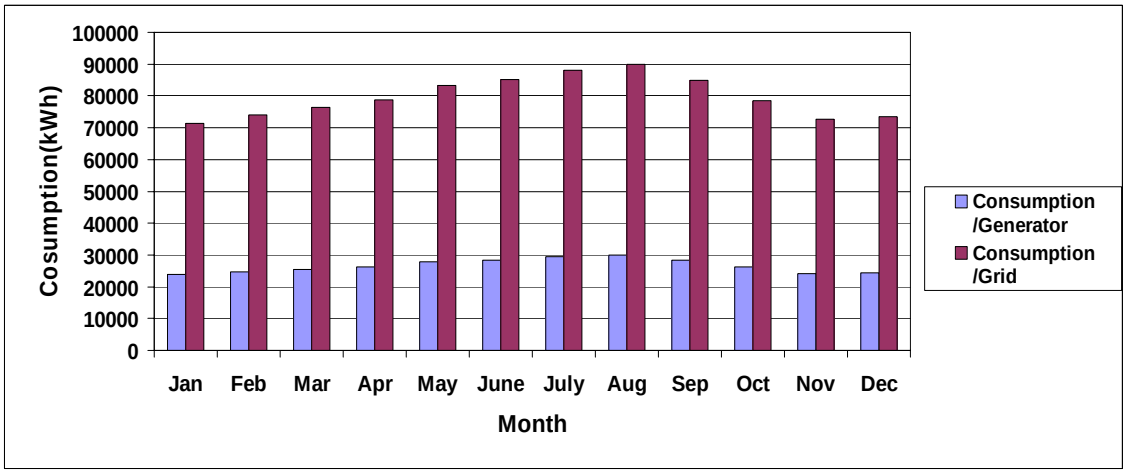

Figure 2: Electricity consumption distribution at the selected site

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Table 1: Consumption and energy cost for loads at Rass Alnaqab

Month	Consumption /Gen (kWh)	Consumption /Grid(kWh)	Total Consumption	Cost(JD)/Gen	Cost (JD)/Grid
Jan	23750	71250	95000	3206.25	5700
Feb	24625	73875	98500	3324.375	5910
Mar	25500	76500	102000	3442.5	6120
Apr	26230	78690	104920	3541.05	6295.2
May	27733	83199	110932	3743.955	6655.92
June	28400	85200	113600	3834	6816
July	29360	88080	117440	3963.6	7046.4
Aug	29950	89850	119800	4043.25	7188
Sep	28250	84750	113000	3813.75	6780
Oct	26210	78630	104840	3538.35	6290.4
Nov	24250	72750	97000	3273.75	5820
Dec	24500	73500	98000	3307.5	5880
Total	**318758**	**956274**	**1275032**	**43032**	**76501**

From the above data, it is easy to note that the average site load is about 147kW, while the maximum is 166kW. A net meter is installed in the site to record the monthly kWh consumption from the grid. The load in summer is more than that in winter. This is attributed to the need for cooling system for some vital equipment in summer at the site which must be operated at a specific temperature, and other military loads operate for longer hours in summer than in winter. The total consumption at the site is about 1275Mwh, which costs 119535JD yearly for RAF (Royal Air Force) to cover this load.

The pollution levels emitted from the diesel fuel used for the generators are shown in Table 2 below [17]:

Table2: pollutants and their percentage emitted from the fuel used in the site generators

Pollutant	Percent of pollution(kg/Litre of fuel)
Carbon dioxide	0.75
Carbon monoxide	0.12
Unburned hydrocarbons	0.015
Particular matter	0.0072
Nitrogen oxide	0.38
Sulphur dioxide	0.04

The fuel consumption of this type of generators is 0.12 L/kWh. From Table 1 above, the generator annual consumption is 38250L of diesel fuel with total price of 8606JD. The emissions based on the above data are shown in Table 4 below.

Table4: The pollutants quantities

Pollutant	Quantity (kg/year)
Carbon dioxide	28690
Carbon monoxide	573
Unburned hydrocarbons	1355
Particular matter	275
Nitrogen oxide	14535
Sulphur dioxide	1530

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These green house gases (GHG) pollute the environment (air, water and soil) which adversely affect the life of human beings. This means that indirect cost is paid for the human health. Finally, it is worth remembering that the diesel power system being used at the site for 25% of the time only adds a total of 46960 kg of pollutants into the local atmosphere of the site every year.

4. POWER FROM WIND AND THE WEIBULL DISTRIBUTION

The output power produced by a wind turbine is given by the following equation [18]:

$$P = 0.5\rho A V^3 C_p \quad (1)$$

Where:

P is the power in the wind (Watts),

ρ is the density of air (approx. 1.2 kg/m^3 at sea level),

A is the swept area perpendicular to the wind velocity in m^2 ,

V is the wind speed in m/s,

Cp is the power coefficient of the rotor; its range between 0.2-0.5.

Due to the cubic dependence of power on the wind speed velocity, the twofold increase of wind speed causes an eightfold increase in power.

To describe the distribution of wind speed over a year, the probability density function called Weibull given by the following equation is used [18]:

$$f(v) = (\frac{k}{c})(\frac{v}{c})^{k-1} \exp[-(\frac{v}{c})^k] \quad (2)$$

Where $f(v)$ is the probability of observed wind speed v, k is the dimensionless Weibull shape parameter and c is the Weibull scale parameter.

5. RESULTS AND DISCUSSION

For the studied case, the values for c and k are 6.5 m/s, and 1.8 respectively. Figure 3 lists the estimated number of hours that the wind speed will have.

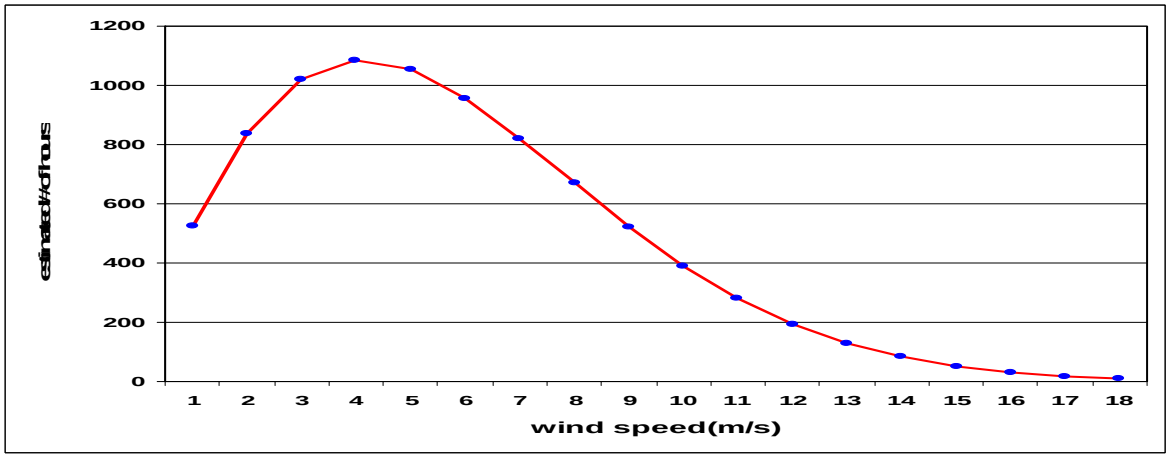

Figure3: Probability distribution function for the wind at Rass Alnaqab

With the estimated hours from the above figure the above values can be converted into energy measured in kWhs, using Eq.(1). Two wind turbines with different ratings were used [19] to show the economical impact of employing wind energy in the present site as shown in Table3.

Table3: Total estimated energy for two turbine ratings.

Wind turbine rating(kW)	Annual estimated energy(kWh)	Rotor area (m^2)	Turbine price(JD)
100	243000	346	103000
60	124000	177	67000

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The estimated energy from these turbines represents 20%, and 9.7% of the annual site load respectively. In generation terms, the above values consist 76%, and 39% respectively of the generator load. It is worth noting that maximum load at the site is 166kW, which is proposed to operate all over the year .The energy which must be supplied from the generators is 363540kWh, costs 49078JD. If it is assumed that this energy is supplied from a 100 and 60 kW wind turbines, the cost of these turbines is 170000JD. Therefore, the payback period is 3.5 years. In this case, the diesel generators are no longer needed except in emergency cases when the grid is interrupted and no enough wind to operate the turbines. The cost of energy, which is incurred from diesel generators operation in this period, is 43000JD yearly. Therefore, the saving in this case can be directed toward buying new turbines to other sites.

Another scenario is to apply wind energy to total load which consumes 1275032kWh. In this case, 5 wind turbines of 100kW and one of 60kW can be used to cover this load with an initial capital cost of 582000JD. The pay back period will be 5 years. The generators in each case can be kept as standby or can be connected to the turbines as a hybrid system to keep the loads especially the vital ones under control.

6. CONCLUSIONS

A simple feasibility study of adding wind turbines to an existing diesel plant was done. The partial or complete replacement of diesel generators is proved to be profitable based on the wind speed at the selected site. The existing diesel generators will be on the standby mode. The payback period of the added wind turbines depends on the intended load coverage. The savings from exploiting wind energy can be used for new similar projects in other sites. Environmentally, the pollution level can be reduced and the health of operators can be kept with good conditions when the wind energy is used.

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