ISESCO Science and Technology Vision
Volume 2 - Number 1 - August 2006 (49-52)

Viability of Hybrid Wind-Diesel Power Generation in Fossil Fuel Rich Countries : A Case Study of Masirah Island, Sultanate of Oman

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Abstract

Although Sultanate of Oman is blessed with abundance of crude oil and natural gas reserves, there are remote places (e.g. Masirah Island) where it is costly to transport diesel fuel for electricity power generation.

In this study it is proposed to use wind power to augment the existing diesel electric power generators. Detailed wind power resources for the Island is carried out using meteorological wind speed and direction data, in addition to topographical data from satellite maps. The economic analysis show that wind power in hybrid with diesel engines electricity generators can be financially viable in remote locations even in those countries with abundant resources of fossil fuels.

Financing the proposed wind farm is discussed briefly. Involving local population in decision making process is the key to any acceptance of local population and success in any economic enterprise. Therefore, the paper discusses how the local population can be encouraged to be involved.

1. Introduction

The Masirah Island lies between the latitudes of 20∞10' and 20°42' North. The Island is located 15 km offshore the mainland coast of Oman in the Arabian Sea. It is about 65 km long and between 5 and 15 km, wide. It is about 300-km south of the capital of Oman Muscat and can be reached by air or by small ferry, which is able to carry few cars at irregular interval depending on the tides. The island is separated from the mainland by a small strip of shallow sea called the Masirah straits. It is sparsely settled with about ten thousand indigenous inhabitants. The main habitation on the island is at the Royal Air force of Oman air-base in the very north. Close to this is the largest civilian village "Hilf" with a population of approximately 9,000. The local population depends mainly on fishing for their sustenance.

2. The Nature of Current Electric Demand

At present, all electric power demand is met by ten diesel-powered generators located at central power station. The capacity of power rating ranges between 265 and 3136 kW. With total installed power capacity of more than 8,200 kW. About 54 % of the annual total electricity demand (i.e. 1,568 MWh) in 2005 was used in the households. The power is used increasingly to meet air-conditioning load in summer months. About 40% of the annual power demand was consumed equally between the commercial sector and the Government administration, with the remaining 6 % by the industrial sector [1].

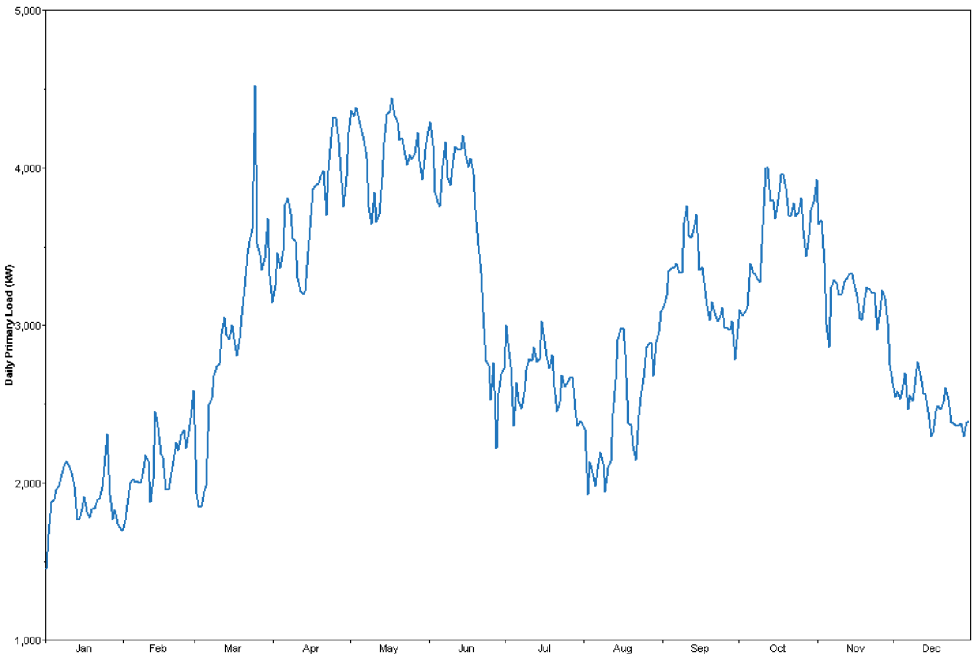

Fig 1. Annual-Daily Power Load for Masirah Island for 2005.

Electric power demand increases monthly between the month of January and May and thereafter drops between the month of June and August because of the overcast skies common in the South West monsoon season. Although in some years, the peak demand is reached in the month of May. Due to the influence of the Monsoon with overcast sky, the demand is slowed during this period and starts to climb again in the month of September.

2. The problem

Sultanate of Oman, like most welfare states of the world, is committed to provide the basic necessities of the modern life to all its citizens, wherever they are, in the country. These services are not provided on purely commercial basis. At present, electricity sector is heavily subsidized by the state. The unit electric power is sold to the public at a fifth of the generation and transmission cost. The generating cost itself is not a real reflection of the true cost, taking into account that diesel fuel itself is heavily subsidized by the state.

Can wind power substantially reduce the unit cost of generated electric power in Masirah Island ? This is the question which we are trying to answer in this present work.

3. The Island Wind Regimes

The Island is under Southwest Monsoon region of influence. These winds prevail between June and September. The annual average wind speed for the Island is 5.05 ms^{-1} at 10 m height [2]. Wind speed peaks in summer; for example a monthly mean wind speeds in July is 9.7 ms^{-1} in 2002 and with long term average of 8.33 ms^{-1} [3]. The trend is generally corresponds to the peak demand for electric power.

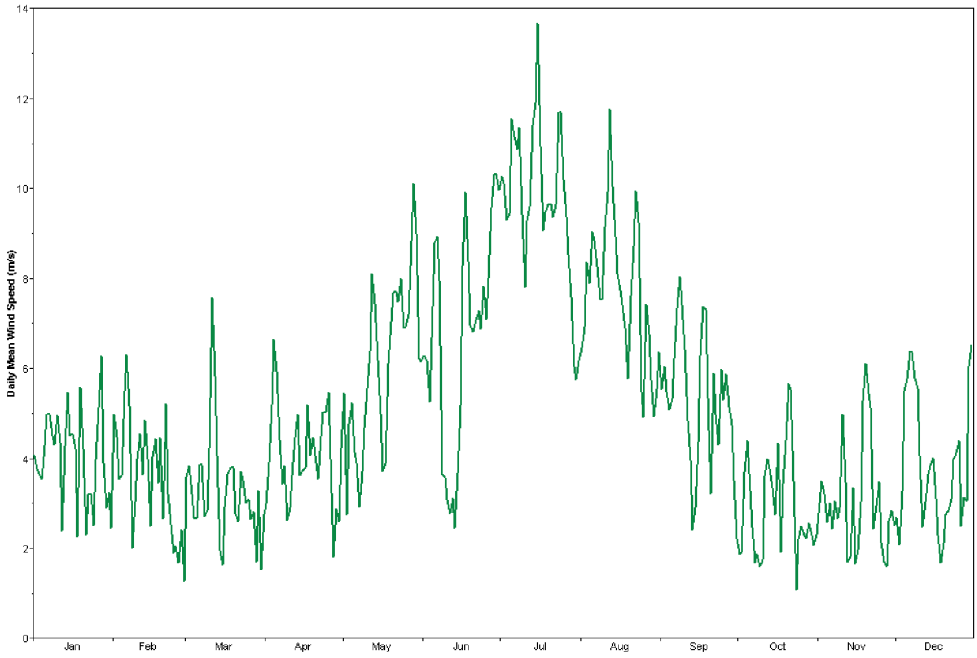

Fig 2. Daily mean wind speed for Masirah Island, 2002.

4. Background

In 1996, Hilal A Al-Ismaily *et al* [3] carried out an extensive studies of wind energy potential in Oman and concluded that the most prospective sites being Thumrait, Masirah and Sur and to a lesser extent Marmul. The Ministry of Water Resources in Oman erected a 10 kW wind turbine for water pumping at Heelat Ar Rakah camp located about 70 km north of Thumrait in December 1996. The turbine was able to meet 30 m^3 water pumping demand for about 80 % of the time [4]. Another wind characteristic study for Oman was carried out by Sulaiman *et al* and published in 2002 [5]. For unknown reason Thumrait is not included in this study. However, Masirah and Sur are commended again as high potential locations for wind power exploitation. In the same year Dorvlo *et al* [6] arrive to the same conclusion noted by previous researchers that the most prospective wind power locations are Thumrait, Masirah, Sur and Marmul. Saudi Arabia is the most, among the GCC countries, to have shown interest in the renewable sources of power. Many academic studies have been carried out assessing the potential of using wind power. Apart from Oman and Saudi Arabia, all other Gulf countries are small and their population's centres are concentrated in few major cities. In a similar study to the present, carried out recently, S. Rehman *et al* [7] concluded that it was not economical, at the time of the study, to use wind power as a hybrid to diesel generators unless the cost of diesel fuel should be more than $0.1 per liter or the annual average wind speed is more than 6 ms^{-1}.

5. Economical Viability of Hybrid Wind-Diesel power Generators

National Renewable Energy Laboratory's software HOMER [8] is used to determine the economical viability of using wind power as a source of electricity in combination with the existing diesel-engine electricity generators. The program may be used to simulate different scenarios of wind-

diesel electric generators mixture. A number of wind speeds regimes, diesel fuel prices, sizes of diesel engines and costs, size of wind turbines and associated costs, operation and maintenance cost can be combined and their related unit output of electricity per kW. For detailed description on how the HOMER parameters are input see references [7 and 9]. For diesel engines power generators, there has been attempt to simulate real life performance of the existing system. There are now four diesel generators sizes being installed at the site. However, the program allows 3 types of generators options only; therefore the 750 kW was not included in the simulation. Amount of annual diesel consumed and its unit cost were provided [1] and used in the simulation.

TABLE 1 - Parameters used to determine the optimum system

Wind Turbine	Range	Provided	Diesel Gen.	Rated	Selected
Enercon E-48			Generator 1	265 kW	5
Hub Height	50-76 m	76	Generator 2	3136	1
Numbers	00-08	8	Generator 3	1000 kW	1
Rated power	800 kW	800 kW	Diesel price	0.4 -0.8$/L	0.48$/L

Options were given to the program to optimize different sizes and numbers of generators and selected 5, 1 and 1 for 265, 3136, and 1000kW, respectively, see ***Table 1***. below.

6. Results

Table 2 below shows the calculated costs for the 8 wind turbines and the selected diesel generators obtained from the HOMER simulation.

TABLE 2 - Annualized cost breakdown of major components

Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
Enercon E-48	4,600,000	359,843	85,010	4,000	0	448,853
Generator 1	682,500	53,390	21,803	33,552	211,013	319,758
Generator 2	940,800	73,596	269,782	357,441	1,400,579	2,101,398
Generator 3	400,000	31,291	42,106	54,260	249,637	377,294
Totals	6,623,300	518,119	418,702	449,253	1,861,229	3,247,302

Energy productions are given in ***Table 3*** and the cost of energy per kWh is found to be $ 0.123 or 12.3 cents. This cost is much competitive compared to that of diesel powered electricity generators (i.e. 26 cents) in remote areas like that of Masirah Island [1].

Table 3 below is divided into parts. The first part provides data for a hybrid wind-diesel system and the second is for diesel with no wind turbines. It shows the amount of power generation which is possible and their percentage contribution to the total power generation.

TABLE 3 - Annual calculated electric energy production

Component	Production (kWh/yr)	Fraction %	Production (kWh/yr)	Fraction %
Wind turbines	21,327,072	62	No Wind	0
Generator 1	626,589	2	332,328	1
Generator 2	11,306,724	33,	23,197,920	88
Generator 3	972,582	3	2,836,237	11
Total	34,232,968	100	26,366,484	100

7. Conclusions

From this preliminary study, using real measured data of load demands and wind speed, we can conclude that wind power has come to an age in even in the fossil fuel rich countries of the Middle-East. Electricity generation in remote areas of the region still depends on diesel fuel. Economically viable production of electricity in areas of high wind speeds and high cost of diesel and its transportation can be realized.

Masirah Island with low power demand but reasonably high wind speeds, its remoteness and not connected to the national grid and still using diesel generators has made it a natural choice to start experimental wind power farms in Oman.

Recommendations

There has been tremendous change in the energy sector in Oman and around the globe. Crude oil prices have sky rocketed in recent months reaching over $70 per barrel. This increase has made renewable sources even more attractive and in particular the wind power. Electricity sector has also been liberated from the daily run by the Government, with private sector plays now an important role.

We recommend that those in a position of authority take keen interest in the renewable energy technologies and in particular those that are economically viable and also those which are on their way to becoming so; by initiating wind atlas for the country as the first step. The second step would be to subsidize renewable power technologies in similar terms to traditional power generation methods. The third step would be providing a legal framework through which the electricity regula-

tor in the country encourages the companies operating in high potential wind areas to generate electricity through wind power technology. This can be specified as a ratio to the total electricity generation. The fourth step would be to open up the market to interested investors to erect wind turbines and guarantee the purchase at competitive rate for a specified period of time.

The participation of the local population is vital to make any venture a success. Unless the locals see the advantage of wind turbines in their midst, there will be some resentments. We strongly recommend that the locals are included in any future investment in wind farms. There inclusion should be in the form of ownership by issuing shares to local population if they wish to participate in the ownership. There is high likelihood that the locals would tolerate foreign artifacts if they have stake in the ownership of the wind farms.

Acknowledgement

We sincerely thank Mr. Hamoud Al-Busaidi, the General Manager of Rural Areas Electricity Company for his co operation with this project. His readily available assistance by providing us with valuable data for the Masirah Island made the difference.

References

[1] Rural Areas Electricity Company

PO Box 1166, PC 133, Al-Khuwair, Sultanate of Oman.

[2] Ministry of Transport and communication, 2002 Weather data for Masirah Island, Directorate General of Civil Aviation and Metrology, Department of Metrology, Sultanate of Oman

[3] Hilal A. Al-Ismaily et al, Prospects for harnessing wind-power economically in the Sultanate of Oman, *Applied Energy*, Volume 55, Issue 2, October 1996, Pages 85-130.

[4] Zaher Al Suleimani et al, Wind-powered electric water-pumping system installed in a remote location, *Applied Energy*, Volume 65, Issues 1-4, April 2000, Pages 339-347.

[5] M. Yusof Sulaiman, et al., Wind characteristics of Oman, *Energy*, Volume 27, Issue 1, January 2002, Pages 35-4.

[6] A. S. S. Dorvlo, et al, Wind energy potential for Oman, *Renewable Energy*, Volume 26, Issue 3, July 2002, Pages 333-338.

[7] S. Rehman et al, Feasibility study of hybrid retrofits to an isolated off-grid diesel power plant, *Renewable and Sustainable Energy Reviews*, In Press, Corrected Proof, Available online 5 July 2005,

[8] NERL, Hybrid Optimisation Model for Electric Renewables (HOMER), available freely online to download at http://www.nrel.gov/homer/

[9] M.J. Khan and M.T. Iqbal, Pre-feasibility study of stand-alone hybrid energy systems for applications in Newfoundland, *Renewable Energy*, Volume 30, Issue 6, May 2005, Pages 835-854.