WIND ENERGY RESEARCH AND DEVELOPMENT IN JORDAN

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ABSTRACT

In recent years, the increase in energy consumption in Jordan has been fast and as the population explosion. With the growing population and greater consciousness about public health and hygiene, environmental pollution control has become very important. Pollution not only creates health hazards and deterioration in the quality of the environment, but also effects the overall production and hence the national economy in the larger perspective. Experience with wind energy in Jordan dates back to 1979. To date, the Renewable Energy Research Center "RERC" at the Royal Scientific Society "RSS" installed several wind energy water pumping and electrification systems in remote desert areas of Jordan. These projects aim to secure the needed water and electricity for people in remote areas; encouraging the use of renewable energy recourses, demonstrate the economic feasibility and technical viability of wind energy systems, and gain experience in addition to applied research and development in the field of wind energy.

INTRODUCTION

The interest in wind energy applications in Jordan began in 1979 at RSS. It purchases and installed a mechanical wind pump for the Aqaba Harbor Authority to pump ground water for its housing complex of about 30m deep. After that, a complete mechanical windmill for water pumping was designed, constructed, and erected in Amman. This wind mill has been in operation for five years and was moved one year ago to El-Mudawara station on the southern border of Jordan and Suadi Arabia. Later, a wind energy converter for electrical generation was designed. The rotor of this converter had 3 blades with a rated power of 1.3kW. In the recent years the RERC Conducted several studies concerning the determination of wind energy application potential in Jordan, investigation of the socio-economic impacts of renewable energy systems in remote areas. The cooperation between the Royal Scientific Society (RSS) and the German Agency for Technical Cooperation (GTZ) on the research and development (R&D) on the use of renewable energy resources in Jordan is an outstanding example of mutual efforts in the area of renewable energy utilization.

RESOURCES FOR POWER SUPPLY

Jordan has only limited oil and gas resources. Annual output of natural gas produced from three wells in the Risha District near the Iraqi border currently amounts to just 5.5 billion cubic feet although new studies suggest reserves could be as much as 1 trillion cubic feet. Depending on the outcome of ongoing exploration activities, a gas pipeline to Egypt might be constructed. The Hamzeh oil field near Azraq yields an average of

600 barrels per day. Exploration is under way in other areas of the country. Efforts have also been taken to exploit Jordan's extensive oil-shale reserves, currently estimated at 40 billion tonnes.

Jordan's oil requirements are almost entirely covered by imports from Iraq. This is allowed under a special arrangement of the "Food-for-Oil Programme" of the United Nations. The Iraqi oil, which is transported by oil transport trucks, has replaced the earlier shipments from Kuwait to Aqaba harbor. The country's only oil refinery is located at Zarqa. The Zarqa plant holds a production concession until 2008.

Wind Projects in Jordan

Prompted by the political commitment to develop renewable energy resources and buttressed by evidence of favourable wind regimes, the Ministry of Energy and Mineral Resources (MEMR), requested private companies to give assistance to a more thorough assessment of the potential for wind energy utilisation and to support investigations of the technical, economic and financial feasibility of wind park projects at pre-selected sites.

A foreign companies planning mission visited Jordan in March 1999 and decided in agreement with the MEMR to more closely examine two potential sites: One in Aqaba and another at Shawbak. For each site, the tentative size of the wind parks considered for detailed investigations was set at 25 MW. The wind speeds measured by MEMR at these two sites are depicted in the table below. The stations of the Meteorological Department are operated since a long time period, but with comparatively simple mechanical equipment. The Ministry of Energy and Mineral Resources performs measurements since ten years now at varying sites, the equipment are data logger based systems. The measurements by Royal Scientific Society were carried out for only one year, but simultaneously at all sites.

Table 1: Wind speeds at the two proposed wind farm sites, measurements performed by the Ministry of Energy and Mineral Resources

Location	Wind Speed	Measurement height	Measurement period
Aqaba, Wadi Araba	6.1 m/s 6.8 m/s	20 m 40 m	1997 - 98
Shawbak	5.2 m/s	10 m	1992 - 96

The planned activities which will be carried out until the end of 2001 include a comprehensive evaluation of existing wind speed recordings in Aqaba as well as additional measurements and wind data processing at Shawbak. The second main activity focuses on project and feasibility studies for wind parks that could be developed at the selected sites, and a third activity is concerned with arrangements and financing options for such projects. Based on the results of the wind resource appraisal and other relevant inputs, the project-/feasibility studies shall be performed to optimise the technical lay-out of wind park projects at the selected sites to:

a. estimate the costs and benefits of alternative wind park configurations,
b. assess the economic and financial prospects of wind park projects, and to
c. transfer know-how to, and exchange information with Jordanian counterpart experts.

There are a number of regions in Jordan with acceptable wind speed to generate electricity, where the great potential areas are the northern and southern parts. The country is classified into three wind regions according to prevailing wind speed: less than 4 m/s, between 4 and 6 m/s and more than 6 m/s for low, medium and high regions, respectively. But high wind regime is limited to certain districts: most attractive sites are Hofa, in the northwestern corner and Fjeij, near Showbak, and Wadi Araba in the south. Jordan's first wind farm, with a gross capacity of 320 kW in Ibrahimyya close to Hofa, was commissioned in 1988. This pilot project was successful technically and financially: average annual generated electricity is about 650 MWh. The experience gained from this project and the mutual co-operation with the German Government, under the Al-Dorado programme, resulted in a new wind-electric power installation of 1125 kW nominal capacity, in Hofa. The project was connected to the notional grid in 1996 and became fully operational in 1997. At present, the annual rate of power generation from wind-turbines, in Jordan, is 2.9 GWh. Thereby avoiding the need of approximately 800 toe, i.e. 0.044% of the total annual energy consumption in the power sub-sector. The corresponding savings in fuel cost is about 0.15 million US$ annually, at current prevailing prices. More importantly is the sustainable and diversified electricity supplies. On the other hand, wind energy is being utilised to empower several small demonstration projects for water pumping in isolated areas: monitoring and evaluation of these projects is continuing.

There is a growing interest in utilising wind energy and other renewable sources in Jordan. The government has removed the legal obstacles by modernising the General Electricity Law. The environment for non-conventional power sources was changed completely, and for the first time enables independent generators to be established in the country. Although it is not specifically mentioned in the modified Law, the rules governing the operation of renewable power projects are those applicable to conventional generators. All renewable based future electricity generation projects will be valid and open to investors under the Clean Development Mechanism (CDM). Recently, the government, represented by the Ministry of Energy and Mineral Resources, invited the interested native and foreign investors to submit their financial and technical proposals to develop wind parks at the three pre-selected locations in the most promising sites, on Build-Own-Operate (BOO) basis. In each location, windmills will have a total installed capacity of about 25-30 MW along with supporting facilities. The generated power will be supplied directly to the national electrical grid. By 2005, it is predicted that green electricity, from these wind farms, would be available to consumers in Jordan.

Wind Turbine Utilization for Water Pumping in Jordan

This section presents a survey of wind turbine water pumping applications in Jordan, either by direct pumping through mechanical means, or indirectly by generating electric power to drive pumps. Up until now Jordan does not have any proven indigenous traditional energy resources such as coal, gas, or oil. Therefore, we have to look at renewable energy resources with all sincerity and concern to utilize it for multi-purpose functions such as water pumping. We recommend using wind energy to meet the energy requirements for remote villages, settlements, and farms of Jordan.

Wind site selection:

The Royal Scientific Socity (RSS) and Water Authority (WA) worked together to identify the wells, which have a priority to be operated by Wind Energy Pumping Systems .

An ideal site for a wind pump is an open, exposed area, where the wind blows freely. Sheltered locations (in woods or valleys) are generally unsuitable. Also the correct evaluation of wind resources is essential to determine the economic viability of using wind energy for water pumping, and the cost of water from a wind pump is very sensitive to monthly average wind speed. The amount of wind available at a site is influenced by overall wind patterns, by the general topography of land surrounding the site, and by whether a site is open or has obstacles such as trees or buildings, Meel and Smulders (1989), Blake (1978). Many researchers, Stevens (1979), Ta'ani and Al-Mulki (1985), and Anani and Wakileh. (1992) have found that the monthly wind-speed data for various sites follow the weibull distribution; consequently, the daily, hourly and ten-minute interval values should also be weibull-distributed. Ta'ani and Al-Mulki (1985) found that the weibull function gave the same power output as found by using the measured wind speed distribution. They concluded that the weibull distribution is dependent on two parameters: the shape parameter k and the scale parameter c (m/s).

From the monthly average, one can calculate the wind-speed distribution and the cumulative distribution for each wind-speed interval. Based on the average monthly wind speed, the average monthly demand and the selected components, a procedure for the selection of the optimal WEPS and the optimal storage tank can be developed.

Accurate measuring instruments were installed, to determine the wind energy resources of different sites which were selected. RSS has installed 14 data acquisition systems for measuring wind speed and direction at a 10-meter height in various geographical locations throughout the country. The following set of criteria was considered for the selection of sites:

-The sites should have different topographical characteristics

-The sites should be located in different parts of Jordan

-The sites should be the most likely for the installation of a WEC.

A recent socio-economic study was performed for different sites in Jordan by RSS researchers, they concluded that the use of wind turbines for pumping water is acceptable to people in remote areas.

CLASSIFICATIONS OF WATER PUMPING SYSTEMS

There are many systems used for water pumping which utilize wind power. The power supplied to a pumping system can be obtained from either a horizontal or a vertical WEC. Almost all the horizontal WECS are of the lift type. This is inherent from the configuration of the horizontal axis machine where the blades rotate in a plane perpendicular to the wind stream. From the two main categories of WECS, the vertical-axis will be excluded, because they are not in use in Jordan, and the choice will only be among the horizontal axis lift-type machines. From this category, there are two types of systems for pumping water using wind energy, mechanical wind pumps, and electrical wind energy conversion systems. Most mechanical windmill systems (tip speed ratio little better than 1) are essentially drag devices (tip speed ratio less than or equal to 1). Wind-electric systems (tip speed ratio usually around 5 to 7) are definitely lift devices. For higher power demands wind electric pumping systems (WEPS) can be applied, incorporating a wind generator (available in larger diameter) driving an electric motor-pump combination through an electrical transmission.

This system consists of a multi-blade rotor that is connected to a piston pump through the crank and another vertical shaft, a rotor, a nacelle, a tower, a water storage tank, and a piping system. The flow rate of this MWPS will depend upon the consumption rate and the wind regime at the site. The MWPS's were installed at six different locations in Jordan, RSS (1994):

1) Mudawara mechanical wind energy water pumping station. This is the first wind energy water pumping station built by RSS in 1983, and was installed at a southern water well in Jordan, at the Jordan-Saudi Arabia border, as a substitute for a diesel engine driven vertical shaft pump. The pump has been in operation since then, with only minor maintenance routines and is pumping a sufficient quantity of drinking water to the border check point, and the local Bedouins. The system configuration is as follows. The high solidity 4.2-meter diameter rotor is made of galvanized sheet metal, a 3:1 gearbox ratio is used, and the pump is a single acting piston pump with an internal cylinder diameter of 120 mm (4.7") and stroke of 180 mm (7"), the maximum water head is 30 m (Table2).
2) Jurf El-Daraweesh mechanical wind energy water pumping system. This system installed in February 1992 and similar to the system used in Kharana. The maximum water head is 56m. The system configuration is as follows. The 24 blade rotor has a diameter of 7.5 m and is made of a steel structure with galvanized sheets. In this design, the gears were avoided, and a crank linkage mechanism was introduced for power transmission. The tail is inclined relative to the vertical in order to limit rotational speed. The pump is single-acting, with an inside cylinder diameter of 104 mm made of brass and the 3 leathers on the piston for sealing. Test laboratories for the determination of the performance of mechanical wind converters were installed in Al-Kharana and Jurf El-Daraweesh.
3) Kharana mechanical wind energy water pumping system. This system was installed in February 1992 and can pump $4m^3$ /h from a total head of 96m. This system is similar to the Jurf El-Daraweesh MWPS which is described above.
4) Twana mechanical wind energy water pumping station. It is situated in the Tafileh Mountains south of Jordan. The area is characterized by rugged mountainous terrain and inhabited only by Bedouins who live on raising sheep. It is located approximately 25 km north east of Elaka. The wind pump at this station is the Kenyan made Kijito wind pump. It was installed at Twaneh as a replacement for the diesel system. This wind pump has been in operation and pumping water from a total head of 40 m since 1987 with only the necessary routine maintenance. The high solidity 7.2 m diameter rotor has 24 blades. The pump is a single acting piston with an internal diameter of 95 mm and stroke of 320 mm. An economical study by Samara and Wakileh (1992) proved that, the chosen MWPS provided the necessary water supply at this station without the aid of a back-up unit. The Bedouins of that area never complained of the lack of

water all the year round. Also the high reliability, simplicity and low maintenance requirements of the system made it even more suitable for this particular location.

5) Elaka mechanical wind energy water pumping station. Elaka station is situated in the Tafileh Mountains south of Jordan. The wind pump installed at this site is the smallest size of RSS MWP type-B with 4-meter rotor diameter and a 9 meter height tower. It was installed in March 1993 and pumps 4.2m^3/h from a total head of 40 m.
6) Tal-Hassan mechanical wind energy water pumping station. This system is similar to the Jurf El-Daraweesh and Kharana MWPS, which they are described above. But in this system the pump with a cylinder diameter of 200mm and a stroke length of 310 mm is used. The rated output of this system is 30m^3/h. This system is utilized to pump water in the drip irrigation system at the station. The system has been working since 1991 without any problems. The technical specifications of the MWPS at different sites are shown in table 2.

Table 2. Technical specification of the MWPS at different stations.

	Tal-Hassan	Jurf El-Daraweesh	Twana	Mudawara	Elaka	Kharana
Manufacturer	RSS	RSS	KIJITO	RSS	RSS	RSS
Rotor diameter (m)	7.5	7.5	7.2	4.2	4	7.5
No. of blades	24	24	24	24	18	24
Tower height (m)	12	12	9	12	9	12
Tip speed ratio	1	1	1.1	1.1	1	1
Rotational speed (rpm)	30	50	35	45	35	50
Solidity ratio %	54	54	53	55	53	54
Pump cylinder diameter (mm)	200	104	95	120	93	93
Pumping stroke length (mm)	310	350	320	180	350	310
Power transmission	Crank shaft	Crank shaft	Crank shaft	Gear 3:1	Crank shaft	Crank shaft
Rated wind speed (m/s)	8	8	8	7	7.5	8
Cut-in wind speed	3.5	3.5	3	2.5	2.8	2
Location relative to Amman	125 km east	170 km south	205km south	340km south	190km south	70 km east

CONCLUSIONS

Jordan has little indigenous energy sources and is almost fully dependent on cured oil imported from neighboring Arab oil-Producing countries. The national scene should adequately set for energy conservation and for rapid development and utilization of alternative sources of energy. As a result of topography and terrain of Jordan, wind energy is a promising resource of energy. The Arab countries are called upon to establish centers of excellence for wind energy research and development, to include the development of this resource in their national energy plans, also to establish the necessary social and economic incentive for its utilization, and to open further avenues for cooperation with developed and developing countries.