FEASIBILITY STUDY OF WIND POWER IN THE KINGDOM OF BAHRAIN

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Abstract

The geographical distribution of wind power for the Kingdom of Bahrain (a wind atlas) is presented for the first time. It is shown that several locations in the less-populated central and southern regions of Bahrain Island have a good potential for wind farm development. The mean wind power is up to 450 W/m² with capacity factor of 29%. Two sites have been proposed for wind farms with total capacity of 200 MW, amounting to a penetration level that can reach more than 35%. Demand-side management utilizing two reverse osmosis desalination plants have been considered as a means to ease the integration of wind power into the island power supply system.

KEYWORDS: wind power, load flow, demand side management, desalination

I. Introduction

The Kingdom of Bahrain consists of 36 islands and coral reefs with a total area of 700 km², located on the southern shores of the Arabian Gulf, between latitudes 25°32' and 26°20' N, and longitudes 50°20' and 50°50' E. In the last few years, the government of Bahrain has become interested in wind energy. As a result, public and private sectors have started to look for potential sites. An innovative early project has been the construction of the first large scale wind integrated office building in the world, the Bahrain World Trade Centre. These developments emphasise the need for a comprehensive study of the wind resource in Bahrain.

Some preliminary studies of Bahrain’s wind potential were conducted during the early 1990s. These studies include monthly and annual mean wind speeds, and calculations of the corresponding available wind power [1-3].

In addition, The potential and economic feasibility of wind power generation were assessed [4]. It has been concluded that wind energy in Bahrain would be most appropriate using relatively small wind plants for water pumping and electrical generation.

However, the aforementioned studies depended on limited data and were restricted to just a few sites. No assessment of the geographical distribution of wind has been undertaken.

Further investigation of the islands’ wind geographical distribution is required to support possible future wind power developments. For this reasons, this study examined the wind characteristics and geographical distribution across the country (with the exclusion of the Hawar Islands). In addition the relation between the wind power and the demand will be investigated.

II. Wind resource assessment:

The data used for the wind assessment was recorded by the Meteorological Directorate at a weather station situated at Bahrain International Airport, on an hourly basis for a period of ten years. These data indicate a wind speed of 4.8 m/s at 10 m height and mean Weibull scale and shape parameters C and K of 4.8 m/s and 1.74 respectively, which shows that the wind potential is high and of good quality (strong enough winds of long duration).

Using Bahrain’s contour map and hourly wind speed, a ten and sixty-meter-height wind power atlas was presented using WAP software. The calculations were performed with corrections for the topography, obstacle, roughness and terrain effects.

Six islands were included in the calculations namely, Bahrain (main island), Muharraq (weather station site), Um Al Nassan, Sitra, Al Nabih Salih and Jedah. Of these, Um Al Nassan and Jedah are unpopulated.

A resolution of 100 x 100 metres was used in the calculations. At 60 metres, the annual mean wind speed for the region is predicted to be 6.93 m/s with annual mean power density of 440 w/m² and capacity factor of 29%.

Significantly the north, west and the central rim of the main island have the highest wind power density. However, the north part is highly populated whereas several locations in the central and southern parts of Bahrain are unpopulated, hence it will be favourable for wind energy production, the
result are presented in Fig 1 and Fig 2 for both 10 and 60 metres height.

![Figure 1](image1.png)

Figure 1 the Wind Power geographical distribution at 10 metres height.

Figure 2 the Wind Power geographical distribution at 60 metres height.

III. Power Electricity production and consumption:

The electricity production, transmission and distribution in Bahrain are the responsibility of Ministry of Electricity and water, which operates five stations with total installed capacity of 2.9 GW, supplying a load demand of about 1.9 GW.

Figure 3 shows the trend for the annual energy consumption. The continuous growth mostly due to the increase of population and industrialization. The total consumption has risen from 1.4 GW in 2000 to 1.850 GW in the year 2006. The growth in consumption begins around mid-April and reaches a peak in August and subsequently decreases sharply until mid-January (around 0.450 GW) and then stabilizes at a more or less constant level of consumption until next April.

![Figure 3](image2.png)

Figure 3 the forecasted annual mean power consumption between the years of 2003 and 2019 (data provided by Ministry of Water & Electricity.

The Power Demand and Wind power

Figure 4 shows the mean diurnal pattern for both wind speed and power demand, it is clearly shown that, although, the Wind atlas showed that several locations in the central and southern areas of the main island, which are less to non populated, can quite reasonably be considered favourable for the production of wind energy. The maximum wind occurs during the low power demand during the day.

![Figure 4](image3.png)
Figure 4 the diurnal pattern for the power demand and wind speed.

The mismatch between the demand and wind power can also be observed between the monthly means, Figure 5.

Figure 5 the monthly mean power demand and wind speed.

In order to investigate the level of wind power penetration into the electric power, figure 6 compares the hourly variation of 15th January 2005. The wind power are calculated for two proposed wind farms, the first (Al Zalaq) located to the central west of the main island and the second located to the south (Ras AlBar). The total installed capacity of the two wind farms is 200 MW.

This month characterized with high wind speed and low power demand reaching a minimum of 460 MW during the early morning. Consequently the instantaneous penetration level of wind power exceeds 35%.

For wind energy to be widely employed for electricity production, careful step-by-step planning must be considered in order that the operation of the conventional power plant does not suffer from fluctuations in demand and to avoid wind curtailment and, hence, storage arrangement or load management will be crucial.

The load in Bahrain can be categorised into four main sectors, industrial, domestic, commercial and desalination. The highest of all are the domestic sector due to the high demand on air-conditioning specially during the summer months which covers the period between April to November. The next, is sea and brackish water desalination. The current summer water demand is nearly 446,200 m3/day. Desalination corresponds to more than 70% of the water demand and it is expected to rise. Bahrain’s installed desalination capacity is supplied from four plants; two are thermal stations and two Reverse Osmosis plants (RO).

The RO desalination plants with their need for high energy provide an excellent case for installing and operating not only single wind turbine generator, but also a number of large wind farms. On the other hand, the current installed RO plant represent only 29% of the total desalination with total power consumption of 28 MW. However, to be able to accommodate the proposed wind farms, a new RO plants will need to be installed. The size and the operation strategies of the RO will need to be investigated as a next stage of this study, using a comprehensive analysis of the power transmission.
system of the country, keeping in consideration the technical limits, fuel saving, and the capacity of the current RO plants. Also the current water storage capacity should be considered in the study which can be divided into Ground Tanks and Elevate Tanks, with a capacity of 165,600 m³/day and 32,200 m³/day respectively.

**Conclusion:**

Although, the wind resources are attractive, the size of the grid, makes a penetration of a 200 MW wind farms a challenge during winter days.

On the other hand, Bahrain already relies heavily on the desalination of sea and brackish water using thermal and RO technologies. The possibility of using the RO plants as controllable loads (demand-side management) to help accommodate variable wind power production is considered and further study is recommended to measure the impact of the RO in the total power system operation with the high wind penetration.

**Reference:**