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Design of a Stand-Alone Power Wind Turbine Optimized for Low Wind Speed in Gaza

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Abstract This paper presents design of a small power wind turbine, considering the low speed wind in the small area Gaza in Palestine. Wind energy is an important type of the renewable energy types, nowadays wind turbine play an important role in power generation. Wind power can be used as a complementary solution for power generation, as Gaza Strip suffers from power outages continually for more than 7 years. Wind speed is the most important parameter in the design and testing of wind energy conversion devices, such stand-alone wind turbines. The energy, which is obtained from wind, is directly proportional with the cubic power of the wind speed. In this paper, an analysis of wind speeds, size, direction and potential availability for Gaza region was present. There is detailed evaluation used in the measurements of the low wind turbine and the manufacturing of its various parts with available techniques and materials in Gaza.

Keywords Renewable Energy, Low Speed Wind Turbine, Gaza Strip

1. Introduction

Renewable energy sources have been important for humans since the beginning of civilization. For centuries and in many ways, biomass has been used for heating, cooking, steam rising, and power generation, hydropower and wind energy, for movement and later for electricity production. Renewable energy sources generally depend on energy flows through the Earth's ecosystem from the isolation of the sun and the geothermal energy of the Earth.

Furthermore, many renewable technologies are suited to small off-grid applications, good for rural, remote areas, where energy is often crucial in human development. At the same time, such small energy systems can contribute to the local economy and create local jobs [1].

Wind is a form of solar energy. The irregular heating of Earth's atmosphere by the Sun causes the air mass to move from regions of high pressure to regions of lower pressure. The kinetic energy of the moving air "wind energy" can be transformed directly into mechanical or electrical energy using wind turbines [2, 3]. The Gaza Strip's needs range between 240 and 280 megawatts (MW), of which at least 49% is purchased from Israel [4].

Therefore, the consideration of use of small alternative energy projects can play an important role, economic, human and of course ecological. Due to the wind poor country like Gaza, a construction of small power wind turbines is advisable, but it must be considered at the constructive design and economic measures. Furthermore, detailed study about the wind and evaluation of wind measurements over the country must be analysed.

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2. Analysis of Wind Data in Gaza Strip

2.1. Location and Data Gathering

The direct costal location of the Gaza Strip on the Mediterranean Sea at 31.3° latitude and 34.3° longitude makes it enjoy a reasonable wind patterns during the whole year as far as small wind-energy systems are concerned. This makes it a good candidate for exploiting wind energy for various applications.

The direct coastal location on the Gaza beach ensures passage-free wind and so the wind turbine harnesses most of the wind energy because of the absence of any obstacles. With such wind speeds, it is feasible to construct a wind-energy system in this geographical location. The number of days-of-autonomy, where the wind speed will be less than the speed limit required for the turbine blades to rotate and turn with them the electric generator, is approximated to 80-days in year 2012according to the wind speed records of Gaza [5].

The Gaza Strip has a pleasantly mild Mediterranean climate with warm and dry summers and mild winters. During the autumn, most rain can be expected, when spring starts temperatures rapidly rise. Table 1 shows the average monthly climate for Gaza Strip.

Table 1. Average monthly climate of the Gaza Strip [6]

Element	Month											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Max. Temp.(℃)	17.5	17.5	19.5	23.0	24.5	27.0	29.0	29.5	27.5	26.5	23.0	19.0
Mean Min. Temp.(℃)	9.4	10.0	11.7	14.5	16.9	19.7	21.8	22.2	21.2	19.4	14.5	11.3
Absolute Max. Temp.(℃)	31.2	34.4	34.8	41.2	43.5	40.0	36.0	32.8	38.8	37.4	35.4	31.6
Absolute Min. Temp.(℃)	2.0	2.6	3.6	7.4	11.4	14.8	18.5	19.2	16.2	12.2	7.5	3.4
Mean Temp.(℃)	13.4	13.7	15.6	18.7	20.7	23.3	25.4	25.8	24.3	22.9	18.7	15.1
Pressure(mbar)	1016	1016	1013	1012	1011	1009	1006	1008	1011	1013	1014	1017
Mean Sunshine Duration(h/day)	5.2	5.9	7.3	8.2	8.9	9.7	10.5	10.4	9.3	8.5	6.5	5.1
Mean RH(%)	67	67	70	70	73	75	76	75	73	69	67	68
Total Rainfall(mm)	105	88	37	9	1	0	0	0	0	36	71	99
Total Evaporation(mm)	68	76	115	142	162	190	193	183	165	132	87	69
Total PET(mm)	53	49	50	72	79	119	96	100	94	96	76	60
Max Monthly Rainfall(mm)	178.0	214.0	132.7	32.0	7.0	2.8	0.0	0.0	0.0	63.8	256.6	237.1

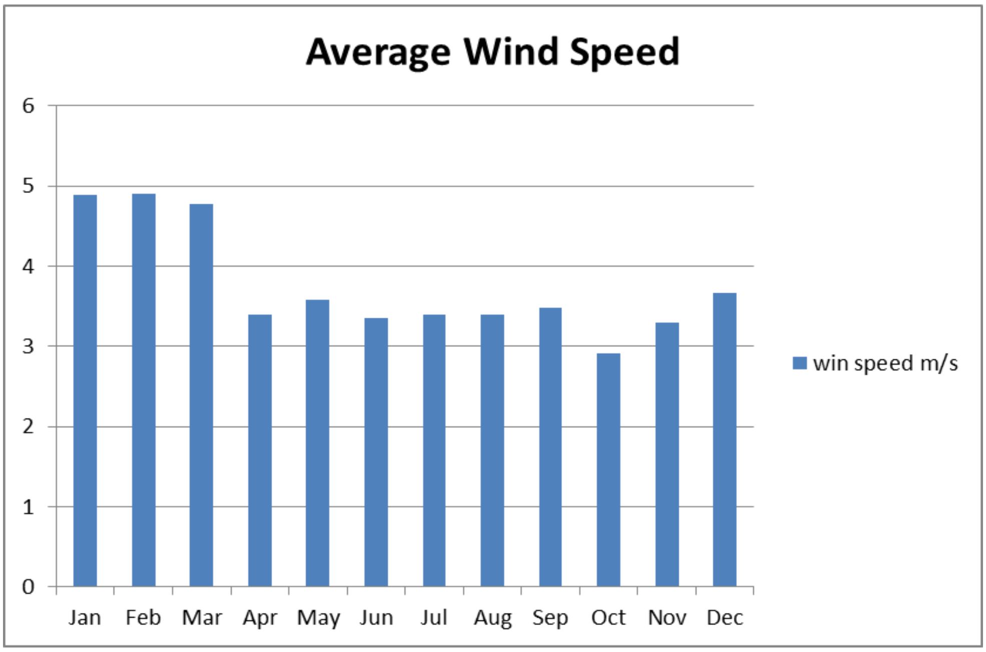

Figure 1. The average wind speed in Gaza Strip for year 2012

Due to the shortage of documented archive of Meteorology within the geographic region, we tend to use the wind speeds and trends of the year 2012 from the meteorological station in Ashkelon. Ashkelon, concerning eleven kilometre from the geographic region, is found on identical outline of the geographical area, and each have similarity of wind actions.

2.2. Wind Speed

Readings recorded for winds throughout the year by 8 readings per day, at difference of 3 hours between each reading. These readings were collected and analyzed for adoption in the design of turbine blades to reach the highest possible efficiency.

Average Wind speeds of year 2012 were divided four sections by seasons of the year. Figure 1 shows the average wind speed throughout the months of the year 2012. The Average wind speed in the spring is equal 3.92 m/s and the maximum average wind speed is equal 4.77 m/s in the March. In the summer, the average wind speed is equal 3.38 m/s and the maximum average wind speed is equal 3.41 m/s in the July. The autumnal wind speed is equal 3.24 m/s and the maximum average wind speed is equal 3.48 m/s in September. In addition, we can summarize on a yearly average wind speeds for year 2012 in the Gaza Strip, it is equal 3.75 m/s.

2.3. Wind Direction

The monthly and annual wind direction in geographical area in year 2012 was common most months of the year, north-west. If we rearrange the wind direction by season, then it will look like this:

Spring: The wind direction is common north-west to west-southwest. In the summer is common north-west to west-north west; in the autumn is common north-northwest to north-west and in the winter is common south-west to west- southwest. Figure 2 shows the wind directions distribution through the year 2012. The average wind direction of year 2012 are west-southwest, WSW = 247.5°.

Similar studies on wind behavior in Palestine territories, West Bank (WB) and Gaza, have also the conclusion; the wind potential in Gaza is not inspiring but definitely not negligible. Therefore, are in the Studies, that the wind speed in the hilly regions of WB can be characterized by the two parameters Weibull probability distribution function. Such a function can be determined from the monthly mean wind speeds. Regions of altitude 850 m and above, such as Ramallah and Jerusalem, have good energy potential. The coastal area of the Gaza Strip has very low wind energy potential, as do the inner hills of the West Bank [7-9].

3. Design of the Wind Turbine

3.1. Evaluating Methods and System Analysis

There are many different types of wind turbines and they can be divided into two groups of turbines depending on the orientation of their axis of rotation, namely horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs). The general public associates wind turbines with HAWTs and are unaware of the several other technologies based on the VAWT. One of the first attempts to generate electricity by using the wind was made in the United States by Charles Brush in 1888. Among the most important early turbines was the turbine developed by Marcellus Jacobs. Jacobs' turbine had three airfoil shaped blades, a battery storage and a wind wane keeping the turbine against the wind. During the 20th century, the HAWTs continued to evolve, which resulted in bigger and more advanced turbines, leading to the modern HAWTs [10].

The great majority of wind turbines in the world are aerodynamically improved versions of the traditional horizontal-axis propeller-type device. Over the past two decades, the Darrieus type vertical-axis wind turbine (VAWT) has undergone considerable research and significant engineering development [11]. Wind turbine blades continue to be the target of technological improvements by the use of better designs, materials, manufacturing, analysis and testing [12]. The selection of turbine model and blade frame depends on various factors, but depends mainly on wind speed and less wind directions.

In order to extract the maximum possible power, it is important that the blades of small wind turbines start rotating at the lowest possible wind speed. Small wind turbines need to be affordable, reliable and almost maintenance free for the average person to consider installing one. This often means a sacrifice of optimal performance for simplicity in design and operation. Thus, rather than using the generator as a motor to start and accelerate the rotor when the wind is strong enough to begin producing power, small wind turbines rely solely on the torque produced by the wind acting on the blades. Furthermore, small wind turbines are often located where the generated power is required, and not necessarily, where the wind resource is best. In these low or unsteady wind conditions, slow starting reduces the total energy generated. In addition, a stationary wind turbine fuels the perception of wind energy as an unreliable energy source [13].

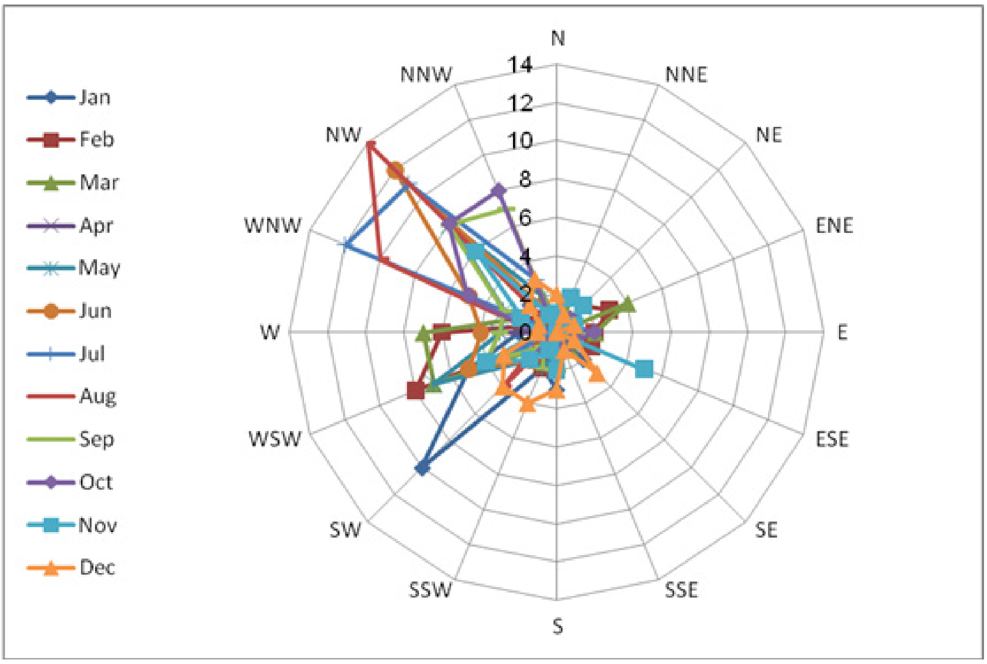

Figure 2. Wind Direction distribution through the Year 2012

3.2. Dimensioning of Blades

In addition, the vertical turbine is selected and therefore further investigated the dimensional of HAWT Blade. HAWT are very sensitive to changes in blade profile and design. This section briefly discusses the major parameters that influence the performance of HAWT blades.

The blades are designed on the shape of an air foil, air foils analyse the wind force into two forces, lift force and drag force, interested is, in increasing the lift force and reducing the drag force to increase the efficiency of the blades. The ideal plan form of a HAWT rotor blade is defined using the BEM method by calculating the chord length according to Betz limit, local air velocities and aerofoil lift. Several theories exist for calculating the optimum chord length which range in complexity, with the simplest theory based on the Betz optimisation. In instances of low tip speeds, high drag aerofoil sections and blade sections around the hub, this method could be considered inaccurate. The Betz method gives the basic shape of the modern wind turbine blade. However, in practice more advanced methods of optimization are often used [14].

The determination of the radius of the blade depends, how much to generate electricity, so at wind speed v = 10 m/s, and 1kW electricity power (Equation1, 2) [15].

$$P = \frac{1}{2}\,\rho A v^3 c_p \text{ (w)} \tag{1}$$

$$r = \sqrt{\frac{P}{0.5*\rho*\pi*v^3*c_p}} \tag{2}$$

The radius may thus be calculate, r = 1.8 m

For optimum chord dimensioning (Equation 3,4) the quantity of blades is considered negligible interms of efficiency. However, in practice when blade losses are considered a 3% loss is incurred for two bladed designs and a 7%–13% loss for one bladed design when compared to three blades [14].

$$Setting\ angle = \tan^{-1}\left(\frac{D}{3*r*TSR}\right) - 4 \tag{3}$$

$$Chord\ width = \frac{1.4*D^2*cos^2(\beta*\frac{180}{\pi})}{r*TSR^2*B*CL} \tag{4}$$

where B is the number of blades, CL lift coefficient.

3.3. Analysed the Module by Using Smart wind Power Software

Efficient design of wind turbine blades requires solving several equations involving the lift coefficient and angle of attack for the airfoil of interest. “Wind turbine blade calculator” software allows specifying the number of blades, required TSR, approximate efficiency of blades, the blade radius and winding speed. A set of blades that meet the specifications will be designed. The software will provide the calculated power output, torque and rotational speed that need to match the generator.

3.4. Electrical Calculation

There is two option for the electric system applied to the wing power one of them is to connect the output of the wind turbine directly to the grid, but this option need a synchronization process that is too dangerous and complicated. The electrical system will consist mainly of a generator, rectifier, and an inverter. In this paper, the usage of a synchronous generator was chosen. Since it, the most common and the most used generator in the present days.

4. Conclusions

Renewable energy inclusive wind energy current states are given year by year for Gaza Strip where electricity generation by wind energy increases in an unprecedented manner in the world. Gaza strip is taken into account of the poor areas of energy with natural resources round the world. This should not prevent to proceed with further research and develop successful test modules for the region. The wind directions are common most months of the year in Gaza. This was north-west, expect months December, January and February, where it was recorded as south-west. The average monthly wind speed was recorded as 3.75 m/s, and the maximum wind speed recorded as 18 m/s.

Regarding to evaluation of several solutions for wind turbines in references, the best solution chosen for poor wind area such Gaza Strip is the Savonius wind turbine. The use of the so-called backup system in this country is useful. The turbine can operate as a stand-alone and thus feed electricity directly to battery charger. A synchronous generator is used here, since it the most common generators and it could be available in Gaza Strip.

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