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Economic Feasibility of 50MW Wind Farm in Shahhat, Libya

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Abstract:- The study reported here was motivated by the growing need for renewable energy when the conventional energy supply is running low. The globe is switching to renewable energy sources for energy generation due to its benefits. In addition, wind energy is being used more and more to generate electricity because of its financial advantages. Wind is one of the many renewable energy sources available in Shahhat, Libya. At 10 and 50 meters, its typical wind speeds range from 4.23 to 5.51 meters per second and 4.95 to 6.45 meters per second, respectively. The analysis of the Techno-economic of wind farms in Shahhat of Libya was studied. These include, load determination, cycle cost, payback period, site selection, life cycle cost and environmental analysis. According to the plant's economic analysis, the wind farm will save $10601708.07 a year, with an investment cost of $65000000. The return on investment was 16.31%, the net present value turned out to be positive, the savings to investment ratio was 3.26, and the simple payback period was determined to be 6 years.

Keywords:- *Component; Economic Analysis; Renewable Energy; Power Generation; Wind Energy.*

I. INTRODUCTION

Wind energy is becoming the resource which is used to generate electricity and it is growing rapidly all over the world because of unstable oil market and the conventional resources are depleting, climate change which is connected to greenhouse gases emission is cause as a result of energy generation using conventional sources. However, to mitigate this emission the world need to improve interest in the use of renewable sources like wind, solar, or biomass [1].

The earth's surface is heated by the sun, which raises the temperature of the air above it. At different regions of the earth's surface, the amount of solar radiation varies. Low pressure is created when hot air rises. High pressure is created at ground level when heated air rises, cools, flows horizontally, and then comes down. The air at ground level is forced to travel from high pressure areas to low pressure areas by these pressure differentials. This air movement is hence wind [2].

With a population of 6 million people spread across 1.7 million square kilometers, Libya is a country in central North Africa with a 2000-kilometer coastline on the Mediterranean Sea [3]. In addition to having the fourth-biggest natural gas reserves in Africa (10 billion BOE), Libya is Africa's largest oil exporter, with an estimated 43 billion BOE of oil equivalent (BOE) and substantial untapped potential [4]. Wind farms are viable in Libya because of the country's average wind speeds of 5.50 m/s and 7.5 m/s at 10 and 50 m, respectively [5].

II. ENERGY POLICY OF LIBYA

Libya electric grid relies just on fossil fuel. It has an installed capacity of 5600 MW with peak demand 3650MW, and the electric grid comprises a high voltage network of about 12,000 km, medium voltage network of around 12,500 km and 7,000 km of low voltage network. Thus, there are many small towns and isolated regions placed far away from these networks. Economically these regions cannot be joined to the grid, because of its small population, and the small amount of energy required. Furthermore, the energy sector is at grave risk due to the unexpected price of this fuel and the rise in global warming caused by thermal plants. In order to supplement this, power must be generated from renewable energy sources [6].

III. BASIC PARAMETERS OF A WIND FARM

A. Wind Turbine Basics

A single wind turbine's power output is dependent upon.

- The wind turbine and generator combination's design and rating,
- The capacity of a control system to maximize wind energy under various conditions
- The presence of wind with the right speed and energy to allow power generation.

The rated output of the turbine/generator combination is typically referred to as the machine's maximum output. The machine's maximum output typically happens at standard air density and rated wind velocity, as well as for all velocities above the specified wind velocity up to the cut-out velocity. The "cut-in" velocity is the lowest wind speed and the "cut-out" velocity is the fastest at which the generator can produce power. Each turbine is only designed to operate within this range of wind speeds. The turbine won't work outside of this range. Kinetic energy (KE) is the type of energy produced by wind. The following equation can be used to determine the amount of energy present in any moving mass traveling at a constant speed (air) [7].

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$$KE = \frac{1}{2} m v^2 \quad (1)$$

Where:

m = air mass (kg),
v = wind speed (m/s)
KE = kinetic energy (Joules)

The power that can be produced in a moving column of air is determined by taking the derivative of energy, as indicated in the equation below, assuming that a cross-sectional area is selected and that the wind velocity is constant.

$$\text{Power} = \frac{dE}{dt} = \frac{1}{2}\frac{dm}{dt}v^2 \quad (2)$$

$\frac{dm}{dt}$ =density × velocity× area=ρ×v×A

Where the resulting power is

$$P = \frac{1}{2}\rho A V^3 \quad (3)$$

Where:
P = power in (W)
ρ = air density = 1.225kg/m2 at 15°C and 1 atmosphere.
v = wind velocity in m/s (1m/s = 2.237mi/hr)
A= Area in (m2).

"A" is the Area where the turbine blades sweep in a normal horizontal axis turbine. Equation (4) below can be used to determine this given the blade diameter.

$$A = \frac{\pi}{4} D^2 \quad (4)$$

Where:
D = Blade diameter in meters
A = Area swept by the blade in m^2

The power density provided in (W/m2) for some reference temperature, blade height, and altitude is defined by:

$$\text{Power density } \frac{P}{A} = \frac{1}{2}\rho V^3 \quad (5)$$

At a potential wind farm location, wind speed is measured for a predetermined amount of time at a predetermined elevation above the ground, often between 10 and 50 meters, and then adjusted for the tower and turbine heights that will be erected. As height increases, so does velocity. The wind velocity is adjusted for height above the ground using the semi-empirical equation below [7].

The following equation is used to determine the actual power that a wind turbine can produce.

$$P = \frac{1}{2}\rho A V^3 C_p \quad (6)$$

IV. METHODOLOGY

High wind speeds are a characteristic of Shahhat, which is situated in the northeastern region of Libya. The average yearly wind speeds in this area are appropriate for producing electricity. The following factors are taken into account in the analysis done for this research.

A. Site Selection

Wind resource maps use the projected wind power density (W/m2) to classify wind sites. A wind farm's potential power output at a specific site is estimated on the map. Because the maps only measure the mean yearly wind speed at a site and then compute power density from this measurement and the projected probability distribution, these numbers must be adjusted for altitude and height above the ground [7]. This paper's main goal is to evaluate a region of Libya's feasibility for producing wind power. The available wind velocity statistics from the NASA database and the Libya Meteorological Office are used to determine the potential power available from this location.

B. Metrological Data Collection

The Libya Meteorological Office provided the data measurements at 10 and 50 meters above sea level.

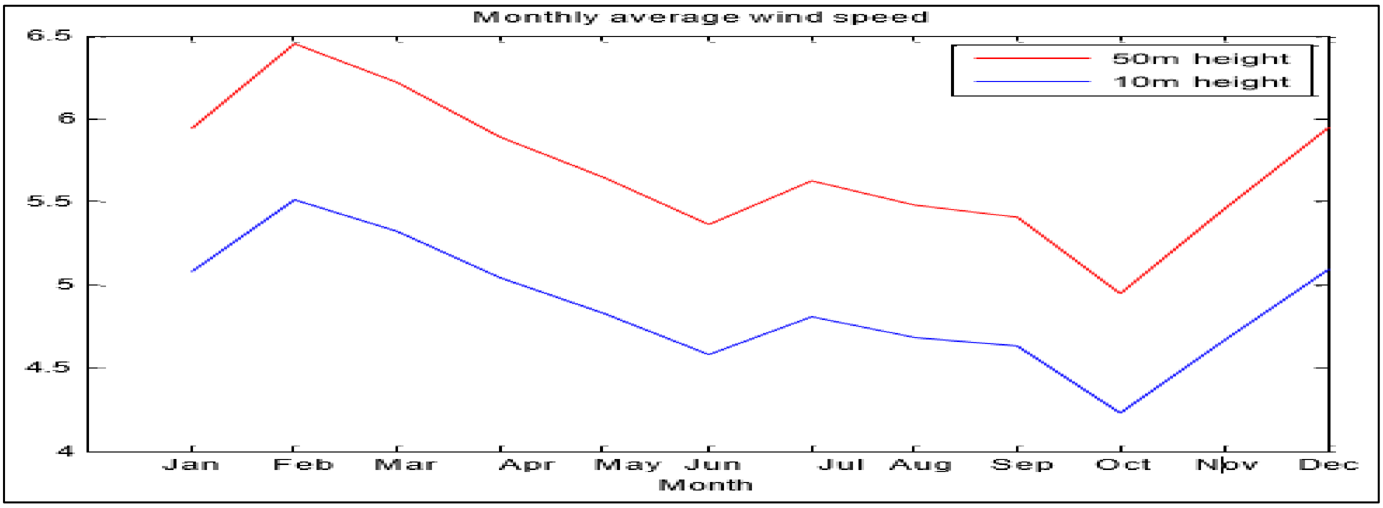

Fig 1: Monthly Average Wind Speed at Shahhat- Libya

C. Wind Turbine Description

There are many wind turbines on the market with varying capacity and features. The DIRECTWIND 52/54-500KW wind turbine was chosen after a thorough evaluation of the features of the various wind turbines because of the specifications shown in the table below.

Table 1: Wind Turbine Specification

Type	**3 blades, horizontal axis**
Cut -in speed	3 m/s
Cut-out speed	25 m/s
Survival wind speed	59.5 m/s
Rated power output	500 KW
Swept area	2291.2 m2
Blade diameter	54 m

Although there are many various types of wind turbines on the market, the DIRECTWIND 52/54-500KW wind turbine was chosen for this study; the specifications are listed in the table above.

V. ANALYSIS OF THE WIND FARM

Table 2: Power Output from a Single Turbine

Month	Power delivered by the wind turbine in watts at 50m, Cp=0.4(KW)	Power delivered by the wind turbine (KWh)
January	235.29	175055.76
February	301.257	202444.70
March	270.165	201002.76
April	229.406	165172.32
May	202.49	150652.52
June	172.883	124475.76
July	200.347	149058.17
August	184.757	137459.21
September	177.766	127991.52
October	136.1678	101308.84
November	98.932	71231.04
December	236.488	175947.072
Total		1781799.675

According to the given result, a single wind turbine can produce 1781799.675 KWh of net energy. Therefore, 100 wind turbines are required for a 50 MW wind farm.

➢ *Land Requirement for Wind Farm:*

This farm's projected land area needs are as follows: Power output = 100× 1781799.675×0.85 = 151452972.4 KWh/year

$$\frac{p_{av}}{m^2} = \frac{power\ density}{320} = \frac{70.06}{320} = 0.2189\ {}^{W}/_{m^2}$$

0.2189×8760 = 1.918 KWh/m^2/year

Land requirement for 50MW wind plant

$$= \frac{151452972.4}{1.918} = 78964010.64\ m^2$$

VI. ECONOMIC ANALYSIS

The size of the turbine and other project-related expenses affect the wind farm's investment cost. Installing a wind turbine is expected to cost between $1300 and $1450 USD/KW [8]. The analysis in this study used 1300 $/KW. However, since an onshore wind farm's generation cost per KWh ranges from 14 to 18 cents per KWh [8], a 5 cent per KWh generation cost is assumed. For this project, a 15% discount rate and a 20-year project lifetime are considered

The project's estimated total investment cost is $65000000, and the annual generation cost is $7572648.62. Nevertheless, the 50 MW wind farm's yearly energy state is 151452972.4×0.12=18174356.69.

Thus, the yearly savings amount to 10601708.07.

A. Simple Payback Period (SPP)

It measures the period it takes to recover the investment cost in years.

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$$SPP = \frac{Investment}{Saving} = \frac{65000000}{10601708.07} = 6\ years$$

B. Present Value

It can be estimated the project after 20 years because the turbine has a 25-year lifespan.

P=A× [P/A, I, N],

Where:
A= Annual savings,
P= Present value,
I=Discount rate,
N=Number of year
P= 10601708.07 [6.2593] =66359271.32

C. Net Present Value (NPV)

NPV=A× [P/A, I, N] - present value cost

NPV= 66359271.32- 65000000= 1359271.32

D. Saving to Investment Ratio (SIR)

This calculates the present worth of all benefits then calculates worth of all costs and takes the ratio of the two sums.

$$\mathbf{SIR} = \frac{\text{Lifetime savings}}{\text{Investment cost}}$$

$$\text{SIR} = \frac{10601708.07 \times 20}{65000000} = 3.26$$

E. Return on Investment (ROI)

It is the simple payback reciprocal, shown as a percentage. It indicates the portion of the investment cost that will be returned each year through savings.

$$\frac{\text{savings}}{\text{Investment}} \times 100 = \frac{10601708.07}{65000000} \times 100 = 16.31\%$$

VII. ENVIRONMENTAL ANALYSIS

People living near the wind farm may be disturbed by the noise produced by the wind turbine's rotating propellers. Additionally, birds that might fly around could be killed by the propeller. However, the power facility will cut down on carbon emissions from thermal plants.

VIII. CONCLUSION

A 50 MW wind farm in Shahhat is described in this paper. According to the economic analysis, the wind farm will save $10601708.07 a year, with an investment cost of $65000000. The return on investment was 16.31%, the net present value turned out to be positive, the savings to investment ratio was 3.26, and the simple payback period was determined to be 6 years.

From the results gathered, it can be mentioned that wind farm is possible in Shahhat with considerable annual savings and payback period. Additionally, it was demonstrated that the plant will lower greenhouse gas emissions.

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