Renewable Energy Resource: Wind Energy System

ABSTRACT:
Wind power is now a major and growing source of renewable energy. Large wind turbines (with capacities up to 6-8 MW) are widely installed in the power distribution networks. An increasing number of onshore and offshore wind farms, operating as power plants, are directly connected to power transmission networks of hundreds of megawatts. As the level of network penetration began to increase dramatically, wind power began to greatly affect the operation of the modern grid system. Advanced power electronics technologies are being introduced to improve the characteristics of wind turbines and make them more suitable for integration into the power grid. Meanwhile, there are some emerging challenges that still need to be addressed. In this paper, we presented the history and types of wind energy and established an integrated wind power plant with a capacity of (150 MW) to get an idea of the productivity, reliability, cost, and space used to construct a wind power plant, and through the results, we will talk about the most prominent advantages and disadvantages

Keywords: *renewable energy, Wind energy*

1. INTRODUCTION

The key with these energy resources is that they don't harm the environment through factors such as releasing greenhouse gases into the atmosphere. Wind is one of the clean renewable energy. It is a flow of gases and it is caused by the differences in the atmospheric pressure. When a difference in the atmospheric pressure happens, the air moves from higher into lower pressure areas. However, all of these caused by sun effects, because the sun heats the wind unequally around the earth, and 1 to 2 percent of the solar energy which reaches the earth is stocked in wind. [1] The wind can be in general divided into two types, global and local. However, the global wind is the large movements around the world and the local is the movements of wind in a specific part of earth [2]. The wind can be described by two main factors speed and direction, and controlled by a combination of three forces which are: Pressure-gradient force (PGF), Coriolis force, Friction. The wind can be warm or cold because of the earth's surface effects in both friction and pressure of the wind, and the warm wind has less density than the cold. Oceans give a smoother surface more than the land and drastically different certain heat that cause ocean or land breezes through changing of air pressure, In the daytime, the heating is increased more over the oceans, so the air over the land goes up and wind speed goes fast from ocean to land and in the opposite direction at night. [2]

1.1 AIM AND OBJECTIVES OF THIS STUDY

This research was conducted to understand the working principle of the wind energy system and its ability to provide electrical energy per day, month, and year, and to know the cost that the user needs in building a solar plant. Besides, we will discuss the efficiency, output power and losses in the system.

1.2 SOFTWARE TOOLS FOR SYSTEM CONFIGURATIONS:

System Advisor Model (SAM) [3]:

SAM is developed by the National Renewable Energy Laboratory (NREL) with funds from the U.S. Department of Energy.

2. HISTORY OF WIND ENERGY

The idea of using the wind as an energy started by moving the boats along the Nile River in early time by 5000 B.C, while the first simple windmills were used in china in pumping water 200 B.C, however, Persia and the Middle East used the vertical- axis windmills with woven reed sails for grinding the grain. [4] Holland was best known for development in windmills design, by 14th century, which preformed many helpful functions in that time, including timber milling and the most important function was pumping water to drain marshy, low areas and reclaim large lands of Netherlands farming. At the end of 18th century, about 10,000 wind turbines were used in Netherland and Britain as well [4].

By 1990 in Denmark there were about 2500 windmills for mechanical loads which were producing an estimated combined power approximately to 30MW.

The wind turbine technology is one of the attractive renewable energy. The wind power is developed significantly in 1990, where more than 10,000 megawatts of the wind power capacity used around the world [4].

The total amount of the Swedish electricity production in 2003 was 143 terawatt hours, the important part comes from hydropower and nuclear power, which participate about 65 terawatt hours each. 11 terawatt hours come from steam power. The total amount of installed wind power was approximately 400MW at the end of 2003 [4].

The wind power has been the fastest-growing exporter of the renewable energy around the world in the last years, and ability is also progressively expanding in Sweden.

Since 2000, the Swedish production has grown from 0.5 to 7.1 terawatt hours in 2011, there were approximately 2000 wind turbines in Sweden [4].

3. Types of Wind Turbines

A. The Vertical-Axis Wind Turbine (VAWT)

There are two main types of VAWTs, the Savonius and the Darrieus. The Darrieus uses blades similar to those used on HAWTS, while the Savonius operates like a water wheel using drag forces [14]. The blades rotate around a vertical axis, the turbine is in an optimal position to use this wind. The VAWT has an ingrained inefficiency because one blade is working well the wind, the other blades are effectively pulling in the wrong direction. However, the VAWT resort to be larger than HAWT, also can be not easy to mount them on a tall enough tower to avail of higher and cleaner wind. One of the advantages of VAWT, it does not require a yaw mechanism, since it can harness the wind from any direction [5].

B. The Horizontal –Axis Wind Turbines (HAWT)

The electrical generator and the main rotor shaft are generally placed at the top of a tower for a HAWT. The HAWT has a design which is required that should be faced into the wind to obtain maximum power, this process is called yawing [15]. In general, the turbine is connected to the shaft of the generator through a gearbox which moves the slow rotation of the blades into a faster rotation that is more suitable to drive an electrical generator [6].

4. Calculation of the Wind Energy [7]

The Kinetic energy can be obtained by:

$$E_k = \frac{1}{2} m v^2$$

where v is the speed of wind in meter per second (m/s), and m is the mass of wind in kilogram (kg) and known as the body of air with specific characteristics (temperature, humidity and pressure) and given as:

$$m = 3 * \frac{k * T}{v^2}$$

where k is a constant and equal to $1.38 * 10^-23$ (J/kg) and T is the air temperature of gas in Kelvin.

To obtain the power in the wind, we must have the density of the air ρA in kilogram per cubic meter (kg/m^3) and we can obtain it by:

$$\rho_A = \frac{0.348444 * P_A - (0.00250 * T - 0.0252582) * H_A}{273.15 + T}$$

where k is the air pressure, Ha is the air humidity in percent and T is the absolute temperature in Kelvin.

Then, the wind power is calculated by the formula:

$$P_W = \frac{1}{2} * \rho * A * v^3$$

where A is the projected area which in our case will be the rotor area of a wind turbine and given as:

$$A = \prod r^2$$

where r is the radius of the wind blades.

5. Design wind energy and calculates

I. Site characteristics

The selected location is Tafila which is located in the south with the coordinates 30.76160o N, 35.690096o E. The solar and wind data are shown in the proceeding sections. Figure 10 shows the location of Al Tafila in Jordan, while Figures 4 show the surface altitude and the project exact location respectively.

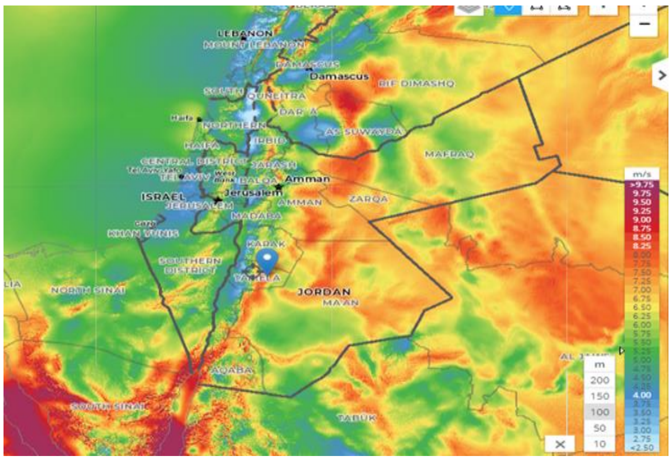

FIGURE 1 LOCATION OF AL TAFILA IN JORDAN [8]

II. wind speed

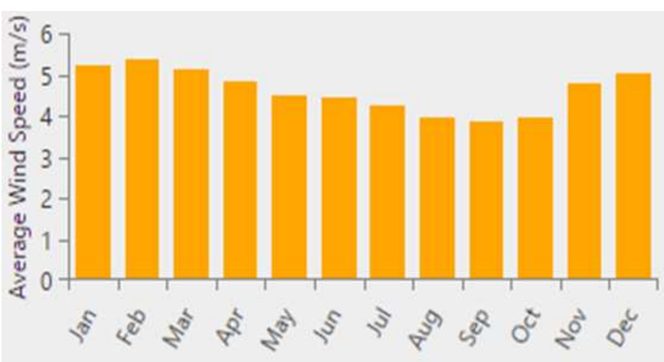

FIGURE 2 MONTHLY AVERAGE VALUES OF WIND SPEED (M/S) FOR THE YEARS (2020) [8]

III. wind turbines

Type of turbine is vestas V112-3 MW

❖ The turbine power curve:

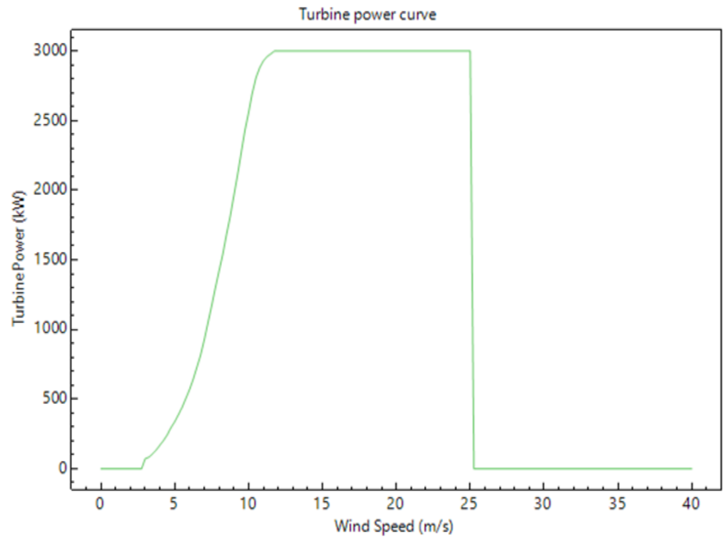

FIGURE 3 TURBINE POWER CURVES [9]

IV. system sizing

Desired faired farm size is 150000 KW

Number of turbines in farm is 50 quantity

System nameplate capacity 150000 KW

V. wake effects

Turbulence coefficient is 0.1 and constant loss is 11.02 %

VI. turbine layout

Turbines per row equal 10, number of rows equal 5

Turbine spacing equal 8 rotor diameters

Row spacing equal 8 rotor diameters

Offset for rows equal 0 rotor diameters

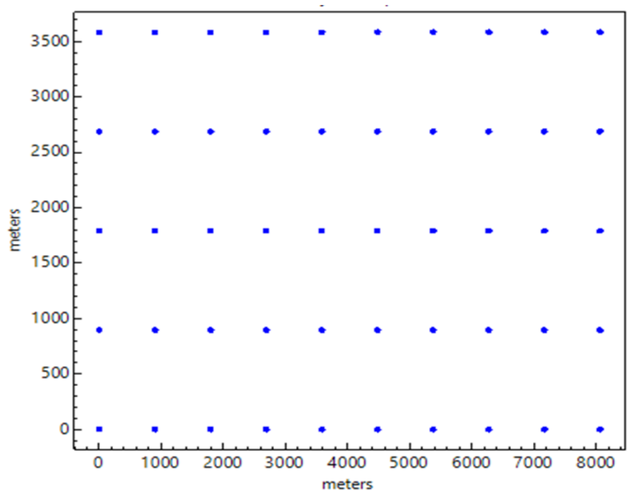

FIGURE 4 TURBINE LAYOUT MAP

VII. losses

A. *Wake Losses*

Internal Wake loss can be set as a constant percent loss on the Wind Farm page, under Wake Effects, by choosing the Constant Loss Wake Model Otherwise Internal Wake Loss will be zero and will be calculated using the given Wake Model

Internal wake = 0.00%

External wake = 1.10%

Future wake = 0.00%

Total wake losses = 1.1 %

B. *Availability Losses*

Energy - based availability is the amount of energy produced as a percentage of the total amount of energy that the wind plant could have captured if turbines were always ready to generate power.

Turbine = 1.500%

Balance of plant = 3.58%

Grid = 0.50%

Total availability losses = 5.50117%

C. *Electrical Losses*

Electrical losses from a wind farm are the energy losses inherent in energy transmission in collector lines, transformers, and other site equipment and transmission to the point of revenue metering

efficiency = 1.91%

Parasitic consumption = 0.10 %

Total electrical losses = 2.00809%

D. *Turbine Performance Losses*

Turbine performance losses represent the amount of energy that is not produced by a wind turbine at a given wind speed compared to the OEM power curve

Sub - optimal performance = 1.10%

Generic power curve adjustment = 1.70%

High wind hysteresis = 0.40%

Site - specific power adjustment = 0.81%

total turbine performance loss = 3.9545%

E. *environmental losses*

turbine performance les represent the amount of energy that is not produced by a wind turbine at a given wind speed compared to the OEM power curve

Icing = 0.21 %

Degradation 1.80%

Environmental 0.40%

Exposure changes 0.00%

Total environmental loss 2.3952 %

F. *Curtailment / Operational Strategies losses*

The deliberate management of a wind plant to reduce the amount of energy compared to what is possible from the available resource

Lead curtailment = 0.99%

Grid curtailment = 0.84%

Environmental and permit curtailment = 1.00 %

Operational strategies = 0.00 %

Curtailment and strategies operational loss total = 2.80347 %

VIII. <u>System cost</u>

Capital costs

Wind farm capacity = 150MW, Number of turbines = 50

Turbine cost per KW = 1,000.00$ /KW, total cost = 150,000,000.00$

Balance system cost 350.00$/KW, total cost = 52,500,000.00$

Total installed cost = 202,500,000.00$

Total installed cost per KW = 1,350.00/KW

IX. <u>System power generated</u>

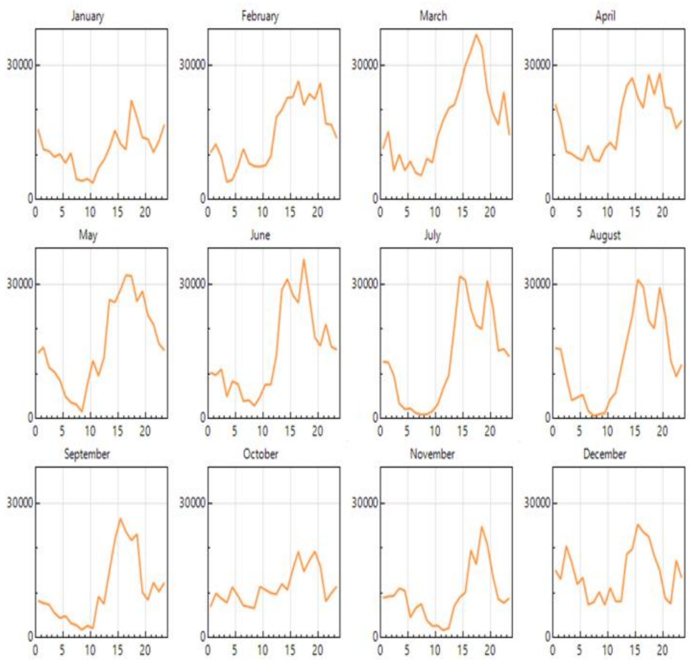

FIGURE 5 SYSTEM POWER GENERATED [KW]

X. <u>Final result</u>

Metric	Value
Annual energy (year 1)	117,992,592 kWh
Capacity factor (year 1)	9.0%
p90 Energy (year 1)	99,740,552.0kWh
PPA price (year 1)	33.59 ¢/kWh
PPA price escalation	1.00 %/year
Levelized PPA price (nominal)	36.38 ¢/kWh
Levelized PPA price (real)	28.89 ¢/kWh
Levelized COE (nominal)	32.71 ¢/kWh
Levelized COE (real)	25.97 ¢/kWh
Investor IRR	11.00 %
Year investor IRR acheived	20
Investor IRR at end of project	11.74 %
Investor NPV over project life	$41,563,532
Developer IRR at end of project	13.34 %
Developer NPV over project life	$5,743,116
Sale of property	$212,924,992

FIGURE 6 FINAL RESALT

6. Advantage and Disadvantages of Wind Energy [10]

❖ *<u>Advantages of Wind Energy</u>*

A. Clean & Environment friendly Fuel source:

It doesn’t pollute air like power plant relying on combustion of fossil fuel. It does not produce atmospheric emissions that cause acid rain or greenhouse gases (carbon dioxide (CO_2) or methane (CH_4)). Noise and visual pollution are both environmental factors, but they don’t have a negative effect on the earth, water table or the quality of the air we breathe.

B. Renewable & Sustainable:

Winds are caused by heating of atmosphere by the sun, earth surface irregularities and the rotation of the earth. For as long as the sun shines the wind blows, the energy produced can be harnessed and It will never run out, unlike the Earth’s fossil fuel reserves.

C. Cost Effective:

Wind energy is completely free. There's no market for the demand and supply of wind energy's, it can be used by anyone and is one of the lowest price renewable technologies available today, depending upon the wind resource and the particular project's financing.

D. Industrial and Domestic Installation:

Wind turbines can be built on existing farms or ranches where most of the best wind sites are found. Wind turbines uses only a fraction of the land which causes no trouble in work for the farmers and rancher, providing landowners with additional income paid by the owners of the wind power plants. Many landowners opt to install smaller, less powerful wind turbines in order to provide part of a domestic electricity supply.

E. Job Creation:

Jobs have been created for the manufacture of wind turbines, the installation and maintenance of wind turbines and also in wind energy consulting. According to the Wind Vision Report, wind has the potential to support more than 600,000 jobs in manufacturing, installation, maintenance, and supporting services by 2050.

❖ *Disadvantages of Wind Energy*

A. Fluctuation of Wind and Good wind sites:

Wind energy has a drawback that it is not a constant energy source. Although wind energy is sustainable and will never run out, the wind isn't always blowing. This can cause serious problems for wind turbine developers who will often spend significant time and money investigating whether or not a particular site is suitable for the generation of wind power. For a wind turbine to be efficient, the location where it is built needs to have an adequate supply of wind energy.

B. Noise and aesthetic pollution:

Wind turbines generate noise and visual pollution. A single wind turbine can be heard from hundreds of meters away. Although steps are often taken to site wind turbines away from dwellings. Many people like the look of wind turbines, others do not and see them as a blot on the landscape.

C. Not a profitable use of land:

Alternative uses for the land might be more highly valued than electricity generation.

D. Threat to wildlife:

Birds have been killed by flying into spinning turbine blades. However, it is believed that wind turbines pose less of a threat to wildlife than other manmade structures such as cell phone masts and radio towers. Most of the problems have been resolved or greatly reduced through technological development or by properly siting wind plants.

8.CONCLUSION

The wind energy system is effective and is able to supply energy instead of fossil fuels, but there are problems in supplying energy in the absence of wind, as it needs a storage source for energy.

The cost of one watt of electricity produced by wind energy system was 1,350 $ per watt, with an efficiency of up to 51 percent, and an energy output of 117,992,592 kilowatt-hours.

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