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USING WIND POWER PLANTS AS ALTERNATIVE ENERGY

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ABSTRACT

In this work we studied wind energy, which is one of the most important types of renewable energies. Also its development and use in generating electricity, pumping water; as well as the turbines design. Then the mechanism of wind energy, factors influencing the production of this great energy

I. INTRODUCTION

Wind is the movement of air from an area of high pressure to an area of low pressure. In fact, wind exists because the sun unevenly heats the surface of the Earth. As hot air rises, cooler air moves in to fill the void. As long as the sun shines, the wind will blow. And wind has long served as a power source to humans. Ancient mariners used sails to capture the wind. Farmers once used windmills to grind their grains and pump water. Today, more and more wind turbines wring electricity from the breeze. Over the past decade, wind turbine use has increased more than 25 percent per year. Still, it only provides a small fraction of the world's energy[1,2].Wind power is the use of air flow through wind turbines to mechanically power generators for electric power. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses little land[3,4].

II. THE USES OF WIND ENERGY

One of the most popular uses of wind energy today is for wind power generation. During this process, a wind turbine is used to harness the energy of the wind. The wind starts to move the turbine blade and generator starts to turn which produces electricity. Wind power has greatly increased in its popularity and efficiency since the first electricity generating turbine was created by Scottish academic James Blyth back in 1887 to provide electricity for the lighting. Today, the technology exists to allow us to build vast wind farms that have a capacity in excess of 1,000 MW[5].

Transportation: Another use of wind energy is in transportation. Civilizations have for many thousands of years used wind energy in transportation in the form of sailing. Researchers believe that sailing has been in existence in some form since as far back as 5000 BC. In more recent times, we have seen both small and large ships capable of sailing under the power of the wind. Some modern shipping companies are beginning to embrace wind energy as a use in transportation. Vessel's including fishing trawlers and even cargo ships have had large kites installed that are capable of helping to reduce fuel consumption on long journey's by as much as 30% under the right conditions[6].

Wind Sports and Activities: A more enjoyable use of wind energy is for sports and activities that rely on the power of the wind[7].Some of the sports that make use of the winds energy**:** Windsurfing , Sailing – This more traditional use of wind Land Sailing, Kite Surfing **,** Kite Boarding**,** Kite Buggying. These sports are classed as "air sports".

***Food Production*:** Wind energy has traditionally been used for food production purposes through the use of windmills. Prior to the industrial revolution, these structures were widely used for milling grain so that it could be then used for producing food such as bread. In more recent times, the introduction of electricity and motors has eliminated our need for such structures and factories can now produce items such as flour much more efficiently [7,8].

Pumping Water: Wind energy can also be used for pumping water through the use of a wind pump. Wind pumps have a similar look to a traditional windmill but instead of milling grain, they can pump water. These structures were historically used for draining land. Similarly to the windmills used in food production, these structures have almost all been replaced due to the introduction of electrical motors. We can use wind energy for enjoyment, or to reduce carbon footprint or to even reduce our dependency on fossil fuels [10].

Advantages of Wind Energy
1. The wind is free and with modern technology, it can be captured efficiently.
2. Once the wind turbine is built the energy it produces does not cause green house gases or other pollutants.
3. Although wind turbines can be very tall each takes up only a small plot of land. This means that the land below can still be used. This is especially the case in agricultural areas as farming can still continue.
4. Many people find wind farms an interesting feature of the landscape.
5. Remote areas that are not connected to the electricity power grid can use wind turbines to produce their own supply.
6. Wind turbines have a role to play in both the developed and third world.
7. Wind turbines are available in a range of sizes which means a vast range of people and businesses can use them. Single households to small towns and villages can make good use of range of wind turbines available today [11].

Disadvantages of Wind Energy
1. The strength of the wind is not constant and it varies from zero to storm force. This means that wind turbines do not produce the same amount of electricity all the time. There will be times when they produce no electricity at all.
2. Many people feel that the countryside should be left untouched, without these large structures being built. The landscape should left in its natural form for everyone to enjoy.
3. Wind turbines are noisy. Each one can generate the same level of noise as a family car travelling at 70 mph.
4. Many people see large wind turbines as unsightly structures and not pleasant or interesting to look at. They disfigure the countryside and are generally ugly.
5. When wind turbines are being manufactured some pollution is produced. Therefore, wind power does produce some pollution.
6. Large wind farms are needed to provide entire communities with enough electricity.
7. Threatening wild life [10].

III. WIND TURBINES

Is a device that converts the wind's kinetic energy into electrical energy. Wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of intermittent renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels. Wind was shown to have the "lowest relative greenhouse gas emissions, the least water consumption demands and the most favorable social impacts" compared to photovoltaic, hydro, geothermal, coal and gas[11].Most wind turbines in use today are horizontal axis units, or HAWTs, with three blades attached to a central hub Together the blades and the hub form the rotor In many wind turbines the rotor is connected to a shaft that runs horizontal to the ground, hence the name It is connected to an electrical generator. When the winds blow the rotor turns and the generator produces alternating current (AC) electricity. One of the key components of a successful wind generator is the blades; they capture the wind’s kinetic energy and convert it into mechanical energy (rotation). It is then converted into electrical energy by the generator the generators of wind turbines are often protected from the elements by a durable housing made from fiberglass or aluminum. However, in many modern small wind turbines, the generators are exposed to the elements. Most wind turbines in use today have tails that keep them pointed into the wind to ensure maximum production [11].

IV. TURBINE DESIGN

At the heart of any renewable wind power, generation system is the Wind Turbine. Wind turbine designs generally comprise of a rotor, a direct current (DC) generator or an alternating current (AC) alternator which is mounted on a tower high above the ground. A wind turbine is the opposite to a house or desktop fan. The fan uses electricity from the mains grid to rotate and circulate the air,. Wind turbine designs on the other hand use the force of the wind to generate electricity. The winds movement spins or rotates the turbines blades, which captures the kinetic energy of the wind and convert this energy into a rotary motion via a shaft to drive a generator and make electricity as shown [12].

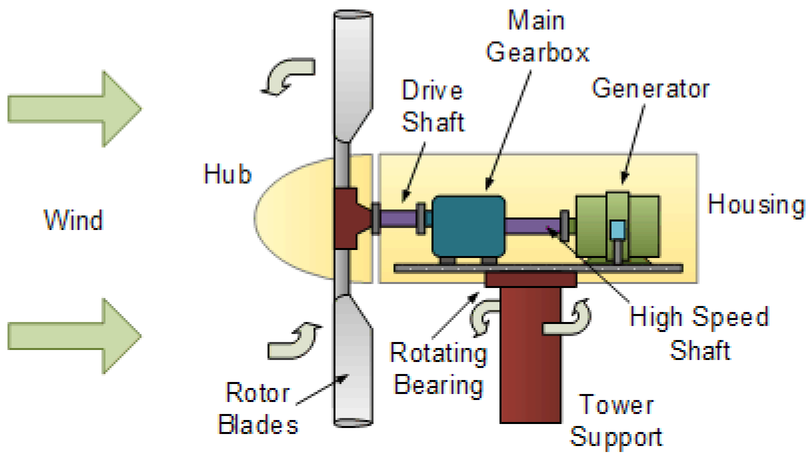

Fig. (1) Typical Wind Turbine Generator Design

V. TYPES OF WIND TURBINE

Horizontal Axis Wind Turbine

It can be further divided into three types: Dutch type grain grinding wind mills, Multi-blade water pumping windmills, and High speed propeller type windmills

Vertical Axis Wind Turbines

It comes in two different designs: The savories rotor, the durries rotor

The most turbine blade has single blade, double blade or three blades [13].

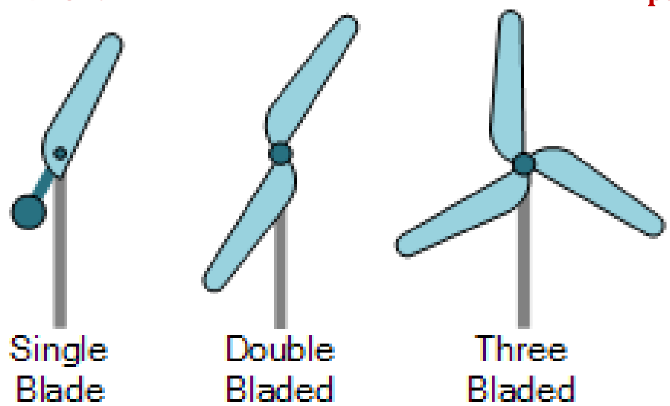

Fig (2) turbine blade

VI. WIND MILL

A windmill is a machine that converts the energy of the Wind into other, more useful forms like mechanical energy. Early windmills were designed to grind grain and pump water. Later on, windmills were designed to generate electricity. Electricity-generating windmills are commonly referred to as wind turbines or wind generators. Water pumping windmills are generally referred to as such or simply as windmills [14].

VII. THE MECHANISM OF THE WIND ENERGY

Converting wind energy to kinetic energy. To convert energy form wind to kinetic, wind blades of a wind turbine is used. There are various types of wind blades with different coefficient performance for each. When the wind passes through the wind blades, the blades will rotate. The wind itself contains a high amount of kinetic energy caused by the movement of the wind. Once it passes through the wind blades, the kinetic energy in the wind is reduced significantly. The turbine will rotate and the rotation of the blades will generate its own kinetic energy [15].

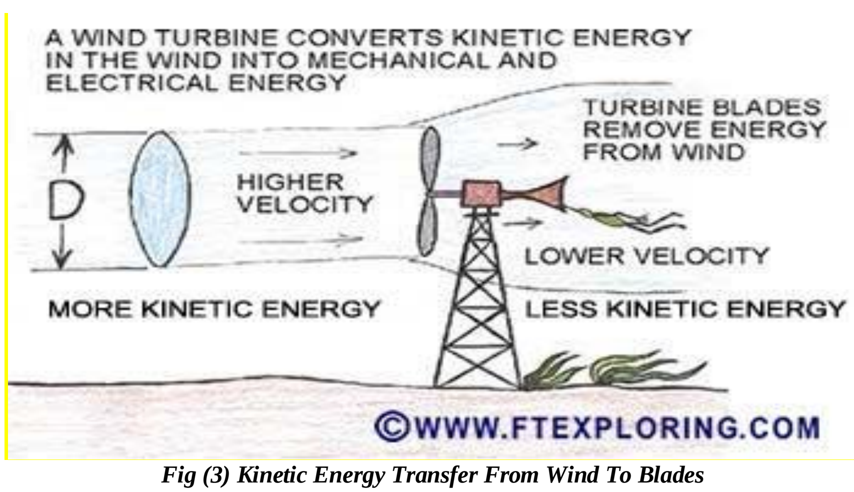

Fig (3) Kinetic Energy Transfer From Wind To Blades

The amount of available energy in the wind can be derived using the kinetic energy equation:

$$E = \frac{1}{2}mv^2 \qquad (1)$$

The mass of air is derived from the flow rate equation for air:

$$m = pvAt \qquad (2)$$

The available energy in wind

$$E = \frac{1}{2} p v^3 t \qquad (3)$$

It is theoretically impossible for a wind turbine to extract 100%. This is because in order for the turbine to actually rotate, there must be a difference in velocity on both sides. The wind velocity will need to be significantly lower after passing through the turbine [16].If there is no wind velocity difference, the turbine will simply not move. This is the basic physics explanation for the wind turbine maximum efficiency. The turbine's blade design is similar to that of an aero plane 'swing. Due to its shape, the curve side will have higher velocity compared to the flat area. Based on Bernoulli's theorem, as the velocity is higher, the pressure is lower. This would mean that the higher pressure will push the blades to rotate, creating a lift force[16].

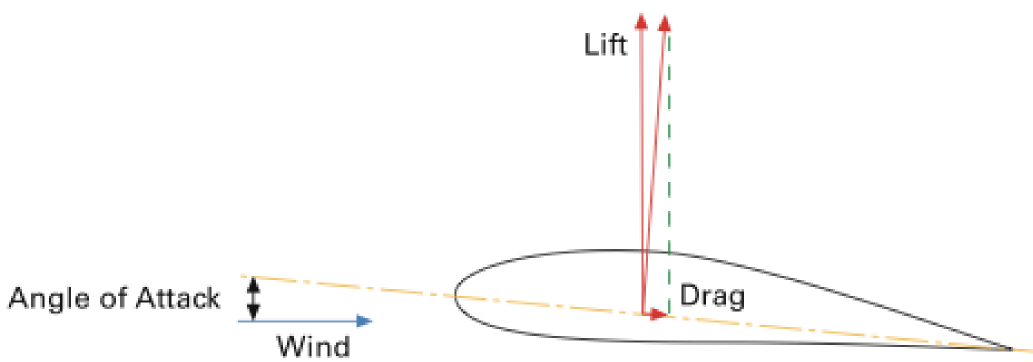

Fig (4) The Lift And Drag Force Acting On A Turbine Blade

The lift force increases as the turbine is turned to higher angle of attack. However when the angle of attack becomes too large, it increases the drag force of the wind. This can cause the wind turbine to stall. A good ratio of lift force over drag force is required for a good turbine[17].

VIII. CONVERTING KINETIC ENERGY TO MECHANICAL ENERGY

The kinetic energy from the movement of the turbine blades will then be converted to mechanical energy within the turbine

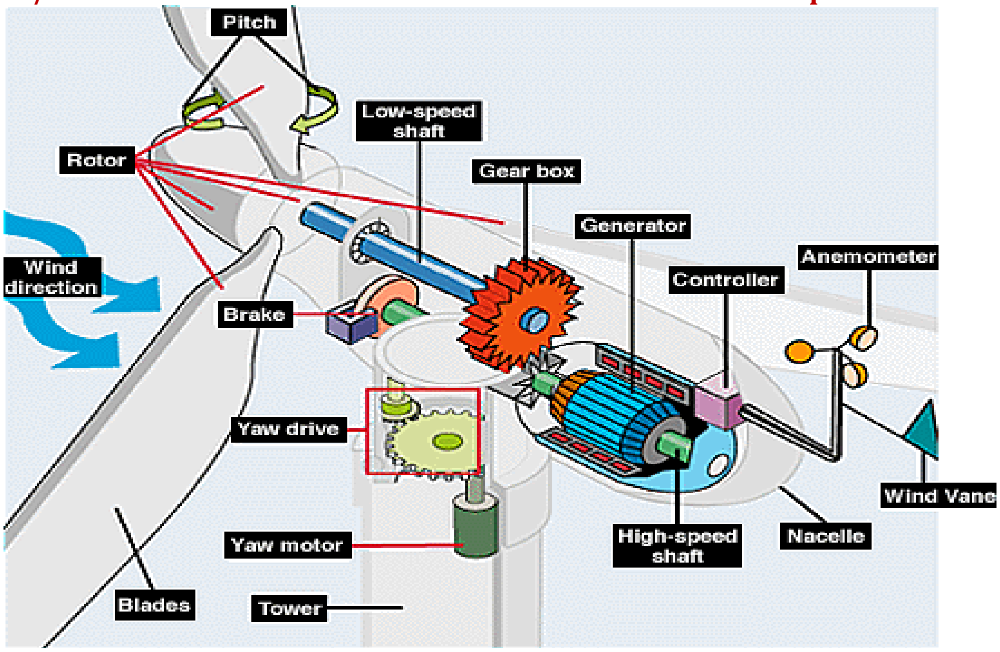

Fig. (5) Mechanical Component In A Wind Turbine

The blades of the wind turbine will be connected to the low-speed shaft. The rotation of the blades will cause the shaft to rotate as well and this produces torque [18].Based on the equation of

$$T = Fr \qquad (4)$$

The large radius will produce large torque but low angular velocity, in order to increase the velocity, a gearbox is used. The gearbox is then connected to a high-speed shaft within a generator. In some wind turbine, a low speed generator is used. This would mean that the low speed shaft can be connected directly to the generator without using gearbox. The final requirement in the mechanical energy is that velocity must be produced by rotation of the shaft.

IX. CONVERTING MECHANICAL ENERGY TO ELECTRICAL ENERGY

The rotation of the shaft is then converted in to electrical energy by using a generator. When mechanical energy is exerted and supplied to rotate the coil inside the generator at uniform angular velocity, a magnetic field is created due to the permanent magnet inside the generator. This creates a sinusoidal electromotive force, which is similar to a voltage. Based on faraday's law [19];

$$E = Bv \qquad (5)$$

E=electromotive force
B=flux density of a constant magnetic field
V=velocity
When a resistance is applied, current is produced.

Ohms law indicates that:

$$V = IR \qquad (6)$$

Since electromotive force acts as a voltage, replacing the equation yield the new equation

$$Bv = IR \qquad (7)$$

$$I = \frac{Bv}{R} \qquad (8)$$

This shows how current and voltage are produced from the various energy conversions that take place in order to harness energy from the wind to produce electricity [20].

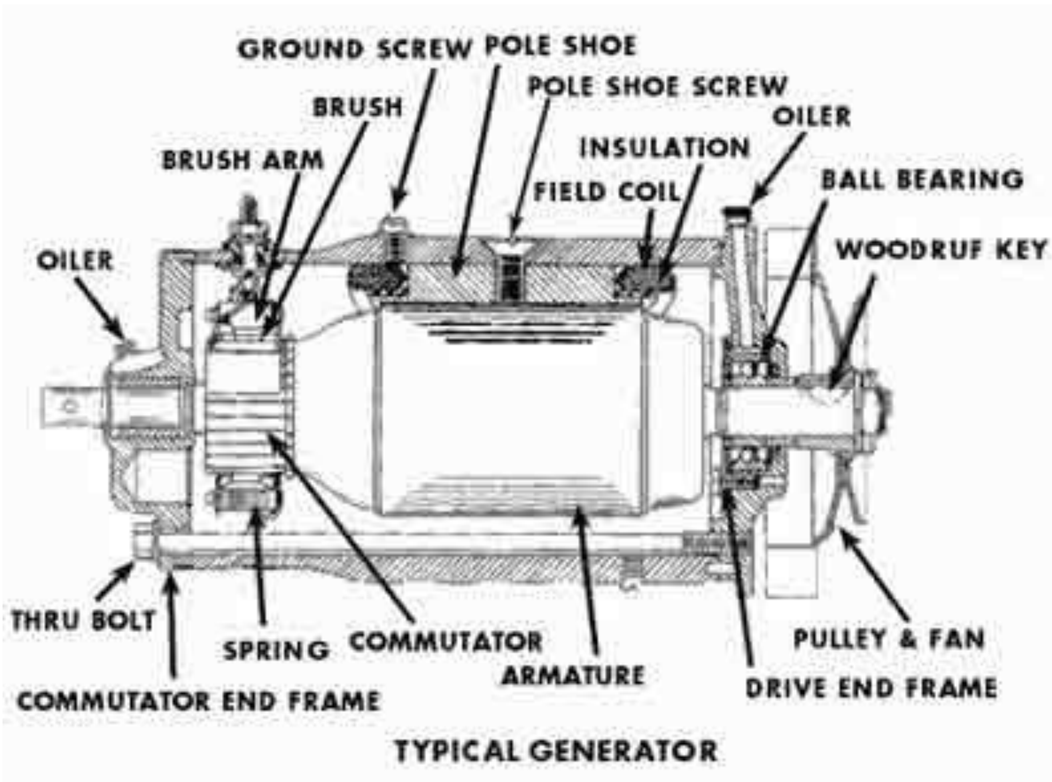

Fig (6) Atypical Generator Design

X. FACTORS AFFECTING WIND ENERGY PRODUCTION

The most important factor when it comes to efficiency of a wind energy system is the availability of wind. This can be associated with the geographical location of the wind farm [21].

Rated Wind Speed: It is common misconception that the faster the wind is, the more power the turbine can produce. However, each specific turbine has rated power output based on the turbine's design [22].
Wind Sweep Area: Based on the theoretical power equation;

$$\mathrm{Pt} = \frac{1}{2}\mathrm{pAv}^3 \qquad (9)$$

The wind sweep area, A, influences the amount of power that a wind turbine may harness. The wind sweep area for the wind turbine is the area of the circle that the turbine blades rotate

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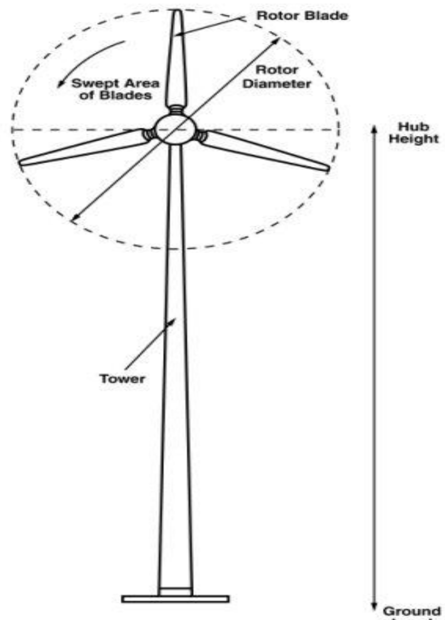

Fig (7) Wind Sweep Area

The larger the area, the more power it can generate. However, a large turbine would also be very heavy, and would require a strong tower structure and will also create a large unwanted drag force due to its large mass. The appropriate size of the wind turbine considering all the variable such as weight, cost and efficiency need to be factored in before decided on the size of the wind sweep area [23].

XI. TYPES OF TURBINES

Different types of turbines have different coefficient of performance. Wind turbines have much lower efficiency than that and it is heavily dependent on the type of the turbine and the design of the turbine itself. The higher the coefficient of performance, better the potential to generate higher electricity [24].

Lift and Drag Ratio*:* When wind passes through a turbine's blade, it causes the turbine blade to experience both lift force and drag force. By optimizing the lift /drag force ratio, the optimum angle of attack can obtained [25]

Fig (8) various angle of attack

A low angle of attack will have low drag force, but also low lift force .in order to increase the lift force, a higher angle of attack is introduced. If the angle of attack goes too high, the drag force increases and the lift force reduces drastically. Therefore, it is very important to optimize the angle of attack to get the maximum lift force.

Optimal Tip Speed Ratio: Tip speed ratio is defined as the ratio of the speed of the rotor tip to the free stream wind. This is very important in determining the efficiency of a wind energy system. If the TSR is too low, it show the rotor is spinning too slowly. This would allow much wind to pass through undisturbed; hence the turbine does not extract as much energy as it is capable of. However, if the turbine rotates too quickly and a high value of TSR exists, this would just create a large drag force and prevent air from passing through [26]. The TSR value is determine by: Turbine blade design, Number of blades, Type of wind turbine.

XII. MECHANICAL EFFICIENCY

There would be an energy lost when the conversion from kinetic energy to mechanical energy takes place. This is mostly due to the bearing and the generator that is used [27]

XIII. CHALLENGES

Despite the economic and ecological advantages, so far even good wind resources in developing and emerging countries have not been used to the desirable extent. The essential reasons for this are based in the lack of knowledge in the developing and emerging countries. From the view of international wind energy companies, beside the difficulties of raising of capital and risk covering, the barriers for private investment are especially [28]:

- Lack of information on foreign markets
- Lack of knowledge of the energy-sector framework conditions and support mechanisms
- Insufficient wind energy legal framework (technical and economical conditions for feeding wind-generated electricity into power grids, permit procedure, ...)
- Lack of qualified staff, especially in the field of service/maintenance . Technicians and buyers are often unfamiliar with wind technology, and in remote locations installments often break down because of a lack of servicing, spare parts, or trained manpower to administer them. In reality, wind pumps are less maintenance intensive than diesel pumps. However, the wind pump technology is "strange" to many people and there is a need to train maintenance staff where pumps are installed.
- Infrastructure to support the installation, commissioning and maintenance of wind generators is not developed. Users and technicians are generally unaccustomed to the technology.
- Investment Cost. Although the lifetime cost of wind is often less than diesel or petrol-powered pumps, the investment cost of purchasing a wind pump is usually higher than that of diesel pumps. Groups purchasing water supplies often have limited funds and cannot take a long-term view toward the technology.
- Wind energy does not have as consistent an output as fuel-fired power plants. Small-scale wind generators require battery storage to allow usage in periods of low or no wind. For grid connected systems, a stable grid is required to act as the storage. Wind pumps require water storage.
- Wind generators are designed to work over a given range of wind speeds, usually 4– 12m/s. This means that the technology can only be used in areas with sufficient winds

XIV. CONCLUSION

- The wind energy is available.
- Wind energy is also a renewable source.
- We do not need to wait for formation wind energy.
- The wind energy does not contribute to the exhaust of deadly pollutant.
- Use of an indigenous resource without producing greenhouse gases or other pollution.
- Wind energy contributes to the power supply diversification,

- Wind energy projects can develop local resources in terms of labor, capital and materials.
- Wind projects reinforce the cooperation with different donors including Germany, enhancing local capacities and technological know-how.
- Wind projects attract new capital and can be included in the new approach of Independent Power Production (IPP).

REFERENCES

1. "GWEC, Global Wind Report Annual Market Update 2011" (PDF). Gwec.net. Retrieved 14 May 2011.
2. Fthenakis, V.; Kim, H. C. (2009). "Land use and electricity generation: A life-cycle analysis". Renewable and Sustainable Energy Reviews. 13 (6–7): 1465. doi:10.1016/j.rser.2008.09.017.
3. "Wind power is cheapest energy, EU analysis finds". the guardian. Retrieved 15 October 2014.
4. Walwyn, David Richard; Brent, Alan Colin (2015). "Renewable energy gathers steam in South Africa". Renewable and Sustainable Energy Reviews. 41: 390. doi:10.1016/j.rser.2014.08.049.
5. Gasch, Robert and Twele, Jochen (ed.) (2013) Windkraftanlagen. Grundlagen, Entwurf, Planung und Betrieb. Springer, Wiesbaden 2013, p. 569 (German).
6. Gipe, Paul (1993). "The Wind Industry's Experience with Aesthetic Criticism". Leonardo. 26 (3): 243–248. doi:10.2307/1575818. JSTOR 1575818.
7. Holttinen, Hannele; et al. (September 2006). "Design and Operation of Power Systems with Large Amounts of Wind Power" (PDF). IEA Wind Summary Paper, Global Wind Power Conference 18–21 September 2006, Adelaide, Australia. Archived from the original (PDF) on 25 August 2011.
8. Abbess, Jo (28 August 2009). "Wind Energy Variability and Intermittency in the UK". Claverton-energy.com. Archived from the original on 25 August 2011.
9. "Impact of Wind Power Generation in Ireland on the Operation of Conventional Plant and the Economic Implications" (PDF). eirgrid.com. February 2004. Archived from the original (PDF) on 25 August 2011. Retrieved 22 November 2010.
10. Armaroli, Nicola; Balzani, Vincenzo (2011). "Towards an electricity-powered world". Energy & Environmental Science. 4 (9): 3193. doi:10.1039/c1ee01249e.
11. Platt, Reg (21 January 2013) Wind power delivers too much to ignore, New Scientist.
12. Platt, Reg; Fitch-Roy, Oscar and Gardner, Paul (August 2012) Beyond the Bluster why Wind Power is an Effective Technology Archived 12 August 2013 at the Wayback Machine.. Institute for Public Policy Research.
13. Huang, Junling; Lu, Xi; McElroy, Michael B. (2014). "Meteorologically defined limits to reduction in the variability of outputs from a coupled wind farm system in the Central US" (PDF). Renewable Energy. 62: 331–340. doi:10.1016/j.renene.2013.07.022.
14. Denmark breaks its own world record in wind energy. Euractiv.com (15 January 2016). Retrieved on 20 July 2016.
15. New record-breaking year for Danish wind power Archived 25 January 2016 at the Wayback Machine.. Energinet.dk (15 January 2016). Retrieved on 20 July 2016.
16. REN21 (2011). "Renewables 2011: Global Status Report" (PDF). p. 11.
17. "GWEC Global Wind Statistics 2014" (PDF). GWEC. 10 February 2015.
18. The World Wind Energy Association (2014). 2014 Half-year Report. WWEA. pp. 1–8.
19. Wind in power: 2015 European statistics. (PDF) . EWEA.
20. Price, Trevor J (3 May 2005). "James Blyth – Britain's First Modern Wind Power Engineer". Wind Engineering. 29 (3): 191–200. doi:10.1260/030952405774354921.
21. Shackleton, Jonathan. "World First for Scotland Gives Engineering Student a History Lesson". The Robert Gordon University. Archived from the original on 17 December 2008. Retrieved 20 November 2008.
22. Anon. Mr. Brush's Windmill Dynamo, Scientific American, Vol. 63 No. 25, 20 December 1890, p. 54.
23. A Wind Energy Pioneer: Charles F. Brush Archived 8 September 2008 at the Wayback Machine., Danish Wind Industry Association. Accessed 2 May 2007.
24. History of Wind Energy in Cutler J. Cleveland,(ed) Encyclopedia of Energy Vol.6, Elsevier, ISBN 978-1-60119-433-6, 2007, pp. 421–422

25. *Watts, Jonathan & Huang, Cecily. Winds Of Change Blow Through China As Spending On Renewable Energy Soars, The Guardian, 19 March 2012, revised on 20 March 2012. Retrieved 4 January 2012.*
26. *Xinhua: Jiuquan Wind Power Base Completes First Stage, Xinhua News Agency, 4 November 2010. Retrieved from ChinaDaily.com.cn website 3 January 2013.*
27. *"Muppandal (India)". thewindpower.net.*
28. *Terra-Gen Press Release Archived 10 May 2012 at the Wayback Machine., 17 April 2012*
29. *Started in August 2001, the Jaisalmer based facility crossed 1,000 MW capacities to achieve this milestone. Business-standard.com (11 May 2012). Retrieved on 20 July 2016.*