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ARTICLE

WIND ENERGY CONVERSION SYSTEMS: A REVIEW

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ABSTRACT

Among all the recent technologies, one of the rapid evolving techniques used for the generation of energy is wind power. This is a non-renewable source of energy i.e. it will be continuing useful for the production of power for several coming years. Nowadays, it is becoming a trend to install or establish a system to generate wind power across all over the appropriate places of the world with high or low wind force. The wind energy proves itself as one of the leading components in the electrical power generation sector, and will definitely play a prime role in the renewable energy sector. Every city looking for the development is highly reliant on electricity for their growth. Relative analysis will be very important element for the selection of any renewable energy system. . With the help of life cycle Cost Benefits analysis, unit cost of energy can be calculated .In Wind Energy systems the main component of generation is turbine and generator. Conventional power generation turbines are very much comparable to modern wind turbines as their life span is of about 20-25 years. These turbines are of two types -Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). The inconsistent wind velocity is a major problem, which leads the voltage/frequency fluctuations, in turns the stability in WECS. In this paper, wind energy is reviewed and we have discussed the stochastic structure of wind, Offshore and Onshore wind farms which mainly focuses on Aerodynamics, Mechanical and Electrical aspects.

KEY WORDS
Wind Turbine, Wind Mill, Wind Farm, Onshore, Offshore,

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INTRODUCTION

The useful form of wind energy converted in electrical energy with the help of rotor, sails, and blades. The site selection for Wind Energy Conversion System (WECS) depends upon the availability of the wind [1]. The WECS has many components like wind turbine, control system, generator, interconnection apparatus. There are two types of Wind turbines:

- Horizontal Axis Wind Turbine (HAWT)
- Vertical Axis Wind Turbine (VAWT)

Contemporary wind turbine used HAWT with 2 or 3 blades and activate either downward or upward configuration. The PMSG work with very high torque at low speed with less noise and need no external excitation. DFIG have winding on both stationary and rotating part where major power transfer between shaft and grid. The doubly fed induction generator (DFIG) or PMSG type is the most commonly used generator for wind energy conversion system. Fed Induction Generator (DFIG) or PMSG type [2]. Majority of wind turbine manufacturer make use of DFIG for their WECS as they have advantage in terms of cost, weight and size. This reduction of weight and size is due to the use of multi bridge in the system which includes several components in one housing such as main shaft, shaft bearing, gearbox, etc. The efficiency of generator with multi blades concept is reduced but it becomes cheaper and more reliable than that of the standard one.

Different control strategies like Field Oriented Control (FOC), Direct Torque Control (DTC) [3] are implemented to achieve high efficient energy conversion on these drives. The electrical and mechanical part of wind turbine are mostly linear and there modeling will be easier.

WIND TECHNOLOGIES

Recently the private organizations such as Vestas, Siemens Gamesa are also involve with the wind energy technological office for enhancing the efficiency of next generation wind turbine at low cost. These collaborative research/studies have impact effectively to lowering the cost. Now a day the average cost of wind energy in the UNITED STATE is 3% per KWH, which is 55% in 1980. Though there is a miles to go and several wind industry has been continuously working to ensure the future growth of this technology [4]. Further to improve reliability, increase capacity factor, and cost reduction building should be done on earlier successes. Before 1998, the average capacity factor was 22% for wind turbine which increased to an average of nearly 35% today, up from 30% in 2000 with the help of these collaborative efforts.

WIND ENERGY CONVERSION SYSTEM

Wind energy conversion system consists of following main parts as shown in [Fig. 1]:

1. Wind Turbine
2. Gear system and coupling
3. Generator
4. Controller

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These are mainly the generating unit which converts the wind energy into electrical energy and the generating energy sent to the power grid for electrical loads.

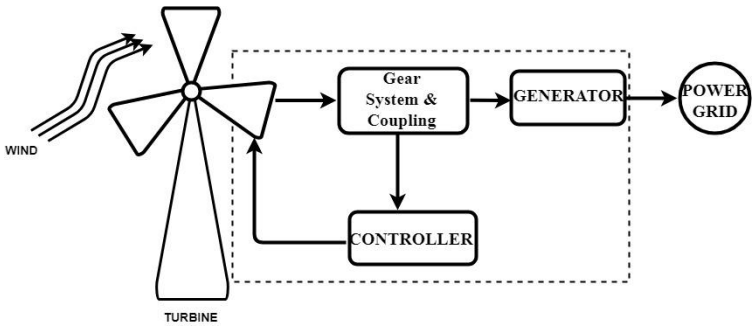

Fig. 1: Block diagram of wind energy conversion system [5].

WIND TURBINE

This device is used to produce the electrical energy from kinetic energy of wind. In the present trends the wind mill are also known as wind turbine. The maximum 6MW power can be generated by the largest wind turbine [6]. As compare to fossil fuel, it generates quite less power. The fossil fuel power plant can be produce in the range of 500MW to 1300MW. But it also have major drawback like limited and when fossil fuel burns, it produce harmful pollutants which directly affect the nature. So that's why the WECS now in more trend because it is a renewable source of energy and cannot affect the nature.
They are of two types: Vertical and Horizontal.

HORIZONTAL AXIS WIND TURBINE (HAWT)

In this type of wind turbine, the electrical generator along with the main rotor shaft is placed at the top of the tower. The blades of the turbine are arranged in such a manner so that the wind can exert maximum of its force to rotate the turbine. This rotational energy is used to drive an electrical generator to produce the current. There are two types of HAWT- with gear and gear less [7].

In geared wind turbine a gearbox is attached in between the turbine and electrical generator. This gearbox is used to speed up the rotation of the blade. This high speed rotation is appropriate to drive an electric generator. The slow rotation of the blade is transformed to a faster rotation by the gear box which is more suitable to drive an electric generator. In gearless turbines a permanent magnetic generator is used which is directly drive by the blades. As downwind machines do not require an additional mechanism for keeping them in line with the wind [8] so they have been built. For day time visibility by aircraft the blades are generally colored white and its range is from 20-80 meters.

VERTICAL AXIS WIND TURBINE (VAWT)

They have main rotor shaft which is arranged vertically. It is inherently less steerable so it becomes an advantage when the turbine is integrated into a building. The major drawback of VAWT is that less energy is produced by their design averaged over time, which is. The buildings often redirect wind over the roof which cans double the speed of the wind turbine when the turbine is mounted on a rooftop. When wind speed within the built environment is much lower than at exposed rural site, the concern subtypes of the VAWT may be noise [9].

NEW OFFSHORE TECHNOLOGY TO GROW WIND TURBINE

According to DOE (Department of Energy) the united states has significant offshore wind resources. Offshore wind could provide almost twice the total electricity generation that US needed in 2025. Development of these resources is also on the rise, largely financed by the private sector. The first planned offshore wind project in the US was THE CAPE WIND PROJECT, a 131 turbines offshore wind farm to be located in the Nantucket sound.

BENEFITS

The most significant benefits of offshore wind are of course they cleaner energy and overall improvement in environmental impact. Other benefits may depend on projects and sites; include lower cost of energy and economic benefits for the area.

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LIMITATIONS

Underwater noise and electro-magnetic fields

An environmental impact of great concern that come with the installation and operation of an offshore wind facility is increased noise. Installing turbines requires pile-driving, drilling and dredging, all very loud operations. In addition, the turbines will continue to generate disruptive underwater noise and vibrations once they are functioning and will emit EM waves.

VESSEL TRAFFIC

During the exploratory stages of the project and when the turbines and the cables are being installed, heavy boat traffic is expected in a concentrated area. This is expected to decrease as a result of shipping routes being altered to avoid the turbines. A decrease in boat traffic is not the only long term benefits that wind farm may bring to marine wild life.

WIND BELT- LOW COST ENERGY PRODUCTION USING FLUTTERING WIND BELT

It is a device which works on the theory of aero elastic flutter and on mutual induction method between the magnet and the coil. The magnet is arranged on the ribbon in this device which on passing wind, start fluttering on the based on aero elastic flutter theory [10]. As a result of fluttering, the magnet between the two coils which are arranged one above the other and having little space for the magnet between them also to reciprocate. Mutual induction takes place due to this movement of magnet between the coils by the flutter which leads to the induction of current and the voltage. The voltage produce is increased when the speed of the wind increases.

MAGNETIC PROPERTIES OF WIND BELT

The magnets used in this device are permanent magnet or rear earth magnet which has high magnetic field intensity as compared to the ferrite magnet. The magnetic field of these magnets never weakens and they also have high resistance towards the corrosion.

COIL PROPERTIES OF WIND BELT

The copper is used for making the coil of wind belt. Therefore the current induced in the coil largely depends on the rating of copper wire used. The copper turn and the total weight of the coil directly affect the output.

LIMITATION OF WIND BELT

The diameter of the magnet used is 1mm, which restricts the fluttering of ribbon, in order to avoid this; we use the similar magnet of smaller size. These magnets are lightly weighted, same magnetic strength, better result and output voltage due to its low weight and area. As compared to the others devices of this range at low to medium wind velocity this device is very cheap and gives better output.

ECONOMICAL TRENDS OF WIND ENERGY

Past trends

The average capital cost of the electricity produced by wind energy has decline noticeably from the 1980's to the early 2000. This historical cost reduction is attributed to the dramatic enhancement in the performance of the turbine which resulted due to the advancement in turbine components. In the duration of year 2004 to 2009, the cost of the wind turbine increases due to the capital cost raise in the market. This cost raise is dedicated to various factors (in terms of wind turbine) such as turbine up scaling, raised in material prices, energy prices, manufacturer profitability, and labor cost [11].

Present trends

After 2009, the cost of the wind turbine was started to declined but it is still little bit higher and hadn't touch the same rate of 1980's .However, the performance is continuously improving at the same pace [12].

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Future trends

On the basis of various observations and studies, it is predicted that the LCOE of wind energy will fall and continuing the same trend for the near future [13]. As per the data available this fall is now under lying in between the range of 20% to 80% and it is predicted that this range will become in between 20% to 30% with the reduction in LCOE. The estimated per year initial cost reduction ranges from 1% to 6%.

Operators of future wind energy cost reduction

The major factors which effect the cost reduction are availability of better material, and real time control capability. These factors are also responsible for the enhancement of the reliability if wind turbine. Cost is expected to decline in the future- similar to those, which is observed in between 2004-2009. Manufacturing improvement and innovation in logistic challenge are also expected in reducing the cost of wind energy. Among manufacturers there is an increasing competition which drives down the LCOE of onshore wind energy to a greater extent than otherwise envisioned.

CLASSIFICATIONS OF GENERATORS FOR WIND TURBINE

Permanent magnet synchronous generator (PMSG)

This generator is used to enhance the reliability of variable speed wind turbine [14, 15]. It has self excitation property due to which it offers enhance efficiency and power factor. It is also helpful to extract the maximum power from the wind turbine in the condition of fluctuating wind [16].

Induction generator as wind power generator

This generator is used for the efficient control on power and speed up of the turbine [17]. In turbine system this motor is directly attached to the grid. This motor controls the power with the help of hydraulic pitch system and starting current limiting circuitry. The entire system is simple and having robustness.

CONTROL STRATEGY OF WECS

Pitch adjustment

This is mainly the adjustment of angle of turbine blade in order to give maximum output. The blade can be adjusted through tilt angle (angle of attack). If the blade is tilted in such a manner that its flat side faces the force of wind then the angle of attack is increased. The decreasing situation of the angle of attack opens the edge of the blade to face the wind. Through of manner of generate the maximum power output.

Yaw adjustment

In case of yaw adjustment tower/pole the entire wind turbine is rotated on its horizontal axis in order to give the maximum output.

APPLICATIONS OF WIND ENERGY

The wind energy is used to produce electricity. The large turbine blade is rotated due to the power of wind [8]. This rotated motion of the turbine is then converted into the electrical current with the help of electrical generator. Some of the prominent applications which use wind energy are:

- Wind electric
- Wind pump
- Wind energy-water desalination
- Wind mill
- Wind turbine

WIND FARMS

Arrangement of large wind turbines are known as wind farms. It is of two types:

- Offshore wind farms
- Onshore wind farms

On the basis of the location of the turbines which is on the land or in the sea. They are known as Onshore and Offshore respectively.

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OFFSHORE WIND FARMS

The wind farms which are situated in the sea and the height of the turbine is high and the transmission cables are used to transmit energy from generating stations to substations [18]. The undersea cables are used for the transmission of the power from turbine to grid.

Advantages:

- The size and the height of the wind mill installed in this category are large, which allow collecting more energy.
- Again, due to its position in the sea (far from the seashore), hence it doesn't interfere with the land available at the seashore which can be used in any other valuable purpose.
- Generally the wind flow out at the sea with large wind force as compare to the other. Due to this huge wind force, the higher amount of energy is produce in much higher in volume.
- As the wind farm impact negatively to the environment. Therefore it is prefer to build these farms in remote areas or where the environment condition is not too delicate.
- The wind flow can not to effect by the physical restriction such as building or hills, etc.

Disadvantages:

- Cost is the biggest disadvantage oh the offshore wind farm. These farms are highly expensive as compare to the fossil fuel generator and the nuclear plant. This is reported 91% and 51% respectively, while these are built for the support only. Also, the cables used for them are costlier, as they need to cover a long distance to reach to onshore battery [15].
- Further the cable runs more power is lost due to voltage drop in long cable.

ONSHORE WIND FARMS

It is situated on the land area so it is known as onshore wind farms. The height of the wind turbine is 20 meter and distance between two turbines is 200 meter [3].

Advantages:

- Onshore wind farm is used as mass firms due to its cost effectiveness.
- As the distance between the end consumer and the wind mill is less which in term effectively reduces the amount of voltage drop.
- The installations of these wind mills are easy and it consumes less time to install.

Disadvantages:

- The major drawbacks of these farms are that they seem to be obstacle to observe the beauty of the landscape/ nature.
- These farms are not capable to produce the energy all over the year due to the physical hurdles/obstacle such as buildings or hills and especially due to the lower speed of wind.
- The noise produce by these farms are huge that it affects the nearby community as noise pollution.

GEOGRAPHICAL WIND ENERGY PRODUCTION

According to the Global wind energy council; China is the largest wind energy generating country producing 19660 MW in 2017 which makes up the 37% of world wide wind energy production. India has the 5th rank in the wind electricity generation producing 4148 MW of energy, which is 8% of the world wide generation [19].

In India, top most wind energy generating states are Tamil Nadu, Maharshtra, Gujrat, Rajasthan and Karnataka. These states together, generate 93% of total wind energy produced in India. The table 1 shown below represents the percentage of wind energy production in India.

Table 1: State wise wind energy production in India [20]

Sl. No.	State	% Generation
1	Tamil Nadu	33
2	Maharshtra	19
3	Gujrat	16
4	Rajasthan	14
5	Karnataka	11
6	Others	7

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CONCLUSION AND FUTURE WORKS

It is concluded in this paper that wind farm power generation individually has high capital cost, but the clean energy source may be used in Hybrid power generation. The LCOE of wind energy will continue to fall on a long term international basis and in fixed wind resource classes this is suggested by variety of factors. The most complicated cost modeling along with more advanced component, turbine, project level design and cost tools give greater power inside into possible future cost which is based on changes in material used and design architecture. The capital cost reduction and performance improvement has led to decrease in the cost of wind energy appreciably .Together all these efforts are enhance to be able to understand future cost, prioritize and the impact of incentives is understood in future.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None.

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