Proceedings of GLOGIFT 07
November 15-17, 2007
UP Technical University
Noida, pp. 644-655

OVERVIEW ON WORLDWIDE RECENT DEVELOPMENTS IN WIND POWER TECHNOLOGY

Prashant Baredar*, V.K. Sethi & Mukesh Pandey*****

ABSTRACT

A lot of progress has been made in wind energy technology over the last decade. Today's advanced features offer improved performance, higher reliability, and lower costs. Wind power technology R&D now make use of new technical developments such as advanced airfoils, information from structural blade testing, variable rotor speed operation, and aerodynamic controls. These developments have been implemented into wind turbines that are, or will soon be, commercially available at lowest cost of energy. Further cost reductions are expected as the development and research is going on continuously, technology evolves and moves toward larger scales, and mass production. So an effort is made in this direction. This paper is mainly focusing over the various developments that are occurring worldwide and in India.

Keywords: Power technology, R&D, Rotor Speed Operation, Aerodynamic Controls

Introduction

Wind is the oldest renewable energy sources known to all of us, which has been used for various purposes e.g. to pump water, thresh grain, and propel ships. Like the solar industry, the Wind industry experienced a revival in the seventies and eighties after the energy crisis of the 1970s. For example, from 1981 to 1986, more than 15,000 utilities – scale Wind turbines with a total peak capacity of 1,300 MW were installed only in California. But Nowadays in Europe the installed capacity of Wind turbines increased from 700 MW in 1990 to 4500 MW in 2000. Now we can expect that until 2006 the capacity of Wind turbines will reach approximately 60, 000 MW.

At the end of the eighties, there were various types of different problems, but later growth in the Wind power technology appears rapidly and more approaches of development, replacement of older and obsolete technology by a mature technology that promises to be less expensive than other sources of electricity, fossil and renewable. Manufacturers of small Wind turbines did lot of research and development work that's why they have begun to see substantial growth in sales, mainly to developing countries, where these wind power technology provide a reliable, low – cost alternative to diesel generators for supplying village electrical power. Wind power technology has been developing rapidly due to lot of research and

* Asst. Professor., Laxmi Narain College of Technology, Bhopal
** Professor and Head, School of Energy and Environment Management, RGPV, Bhopal
*** Reader and Dy.Registrar, Rajiv Gandhi Proudyogiki Vishwavidyalaya Bhopal

development work over the last decade.

The experience gained in the wind farms of California is being used to design and develop advanced systems with improved performance, higher reliability, and lower costs. During the past several years, a lot of remarkable gains have been made in wind power technology designs; cost is lowered remarkably at 13 mile-per-hour average annual wind speeds. Further due to continuous and consistent research work as well as technology development is expected to allow the cost of wind-generated electricity to drop below further. Hence, wind power technology is expected to be one of the least expensive forms among the other renewable energy resources of new electric generation in the next few days. Large efforts already underway to reduce energy-related emissions of carbon dioxide, the current availability of this low-cost technology means that the use of wind systems will likely increase worldwide throughout the 1990s for both utility-scale applications and remote, small-village applications. The research and development in technology for both utility-scale wind turbines as well as remote, small-village wind turbines that are currently available or in development stage. The main target for research and development activity is to reduce the weight of nacelle, increasing compactness, increasing output and better control system., the developments for achieving this is going on continuously. And some of them are in process. The total wind capacity in the world is continuously increasing; here the total wind capacity in the different countries as in 2005 and 2006 is given below:

Table 1: Total Windpower Capacity [7]

		Windpower capacity (MW)	
Rank	**Nation**	**2006**	**2005**
01	Germany	18,428	16,629
02	Spain	10,027	8,263
03	USA	9,149	6,752
04	India	4,430	3,000
05	Denmark	3,128	3,124
06	Italy	1,717	1,265
07	United Kingdom	1,353	888
08	China	1,260	764
09	Netherlands	1,219	1,078
10	Japan	1,040	896
11	Portugal	1,022	522
12	Austria	819	606
13	France	757	386
14	Canada	683	444
15	Greece	573	473
16	Australia	572	379
17	Sweden	510	452

18	Ireland	496	339
19	Norway	270	270
20	New Zealand	168	168
21	Belgium	167	95
22	Egypt	145	145
23	South Korea	119	23
24	Taiwan	103	13
25	Finland	82	82
26	Poland	73	63
27	Ukraine	73	69
28	Costa Rica	70	70
29	Luxembourg	35	35
30	Iran	32	25
31	Estonia	30	3
32	Philippines	29	29
33	Brazil	29	24
34	Czech Republic	28	17
35	Argentina	27	26
	World total	**58,982**	**47,671**

Technology developments are being adapted for remote and stand-alone power applications with smaller wind turbines. Hybrid power systems using smaller 1- to 50-kilowatt (kW) wind turbines are being developed for non-grid-connected electrical generation applications. The requirement of electrical power in village is fulfilled by power systems typically using wind energy, photovoltaic (PV), battery storage, and conventional diesel generators to supply power for remote small-village communities. In remote locations, due to transportation costs fuel-powered generating systems becomes extremely expensive. Smaller wind turbines are also used for application as distributed generation sources on utility grids to supply power during periods of peak demand, thereby avoiding costly upgrades in distribution equipment

Future Technological Improvements

The research and development of wind turbine technology is leading to next-generation wind turbines, which promise lot of remarkable improvements in performance, reliability, and cost. In general, each of these competing Wind power technology designs will probably incorporate many of the following advanced features.

Advanced Aerofoil

Structure wise tailored blades made of soft, flexible materials may be possible. Such blades would change shape according to wind conditions, increasing large energy capture and reducing effective loads as wind speed controls blade shape, there should be effective rotor-speed brakes.

Advanced Generators

Using low-speed, direct-drive generators, which could eliminate the need for the gearbox, which are having heavy weight as well as very expensive. This generator is being used in combination with variable-speed operation for taking advantage of the benefits of power electronics for controlling activities. Further research is going on for reducing top head mass.

Advanced Controls Systems

The wind turbine power plant consists of number of wind turbine arrange in array. Advanced, expert control systems capable of controlling entire power plant. Smart systems can detect wind-speed changes and accordingly adjust individual turbines throughout a power plant.

Hybrid System Modeling

NREL has currently developed computer simulation codes to allow modeling of the full range of hybrid power technologies being considered for village power. Building on existing wind/ diesel models, solar-wind model. a new advanced hybrid systems simulation model is being developed which will accommodate a combination of different technologies and system architectures now being considered for hybrid village power systems.

R&D In Wind Turbine Components

Blades

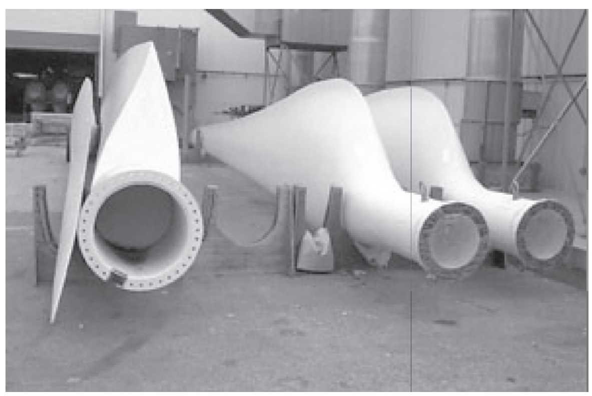

Figure 1 : Blades (Carbon Fibre and Carbon/Glass Hybrid Composites). (2)

Earlier, blades are manufactured using materials fibreglass reinforced technology, which is used in boat-building industry. Over the years, Researchers have developed the knowledge of fibreglass strength and durability to an unprecedented level. The requirement of next generation is of longer, thinner, and equally durable blades. Which will require advanced materials that are lighter, stiffer and stronger. Typical candidate materials include carbon fibre and carbon/ glass hybrid composites. Additional material issues include resins, fibres treatments etc.

Passive blade load control has been investigated at SNL to withstand the high frequency loads on Wind turbine blades which could be caused by Wind gusts and turbulence

The Sandia Wind program has developed tools to check and analyse material strength, durability, and reliability. These tools consist of a generalized numerical framework or performing the fatigue analysis of turbine components.

Blades are one of the important Wind turbine component designed and manufactured uniquely for Wind energy applications. The challenge in this respect is to be met to create the scientific knowledge base and engineering tools to help the designers to maximize performance at the lowest possible cost. This task will encourage the Wind industry to stretch rotors to greater swept areas and improve rotor blade designs for increased energy capture, thus getting profitable and effective Wind turbine operation. (2)

The important step toward this target is likely to be blades that are both stiffer and stronger to span greater areas, both lighter and adaptive to reduce system loads, and that, which are having innovative airfoils to increase energy capture or decrease system loads. These improvements require moving to stronger, lighter blade materials created with improved and advanced manufacturing processes and using advanced design analysis tools with validated design techniques and proper evaluation of the design loads. (2)

Latest developments are examining the behavior of composites under spectral loading with compressive loads, the degradation of fatigue properties by environmental factors, the estimation of resin systems for added composite fatigue performance and the performance testing of carbon and carbon/glass hybrid composites. The database regarding this is updated approximately once in a year.

Advanced Tower Solutions For Large Wind Turbines and Extreme Tower Heights

The research and development of Wind turbines during the last two decades has resulted inconsistent and continual growth of the turbine size. Earlier the conventional steel towers were used in installation purpose of wind turbine for onshore Application; Especially for the tower,. Mecal and its partner Hurks Beton have developed a hybrid tower, as an alternative for the tubular steel tower. The conventional steel tower sections, which need a larger diameter than the transportable size of 4,3m, are replaced by prefabricated concrete elements. Because of the segmented construction, the Hybrid tower can be used for a wide range of turbine sizes and hub heights.

The Planetary Gearboxes

The planetary gearboxes are becoming a standard for wind turbines due to a number of reasons. Planetary drive can give 98% efficiency and, it is able to provide extremely low speeds without any loss of efficiency. In the planetary gearboxes High levels of reliability is obtained which is one of the important feature of the planetary design, There is effective distribution of stress among several load-bearing components they are significantly compact and lightweight, and require very little installation space. Planetary gear trains are able to deliver high reduction ratios in small packages; As compared to similarly sized conventional gear units' planetary gearboxes can transmit torque several times. In Wind turbine "Winwind"

The planetary gearboxes are used.

Gearless Permanent Magnet Generators

Gearless permanent magnet generators were selected over conventional technology because at higher megawatt levels the new alternative could provide better reliability and performance than gear-based systems. Seeking to lead the gearless revolution, as the gear is normally the equipment that is most responsible to mechanical damage, Gears are very expensive as well as demand frequent maintenance being a rotatory part. Gearless technology therefore eliminates this particular problem; the above design of generator for wind turbines is based on permanent-magnet technology. Compared with a traditional machine, the new generator offers high output relative to the frame size, making for instance a 3.6MW unit overall frame size smaller. The new generator can be operated in a wide speed range with a maximum output of 3.6MW from

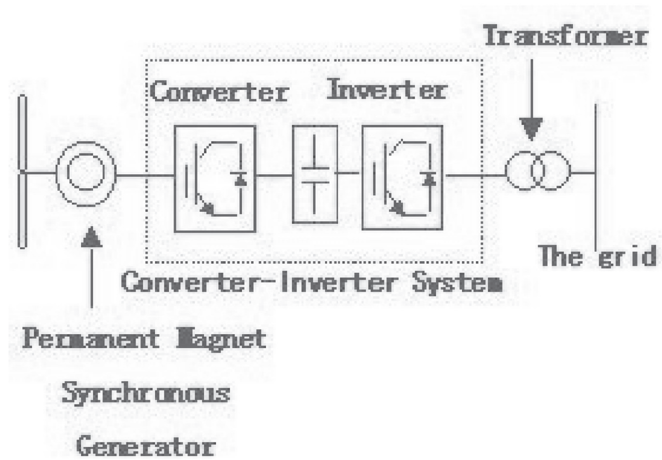

Figure 2 : Permanent Magnet Synchronous Generator (3)

a 500mm frame The efficiency is better than 98%. Gearless permanent magnet generators are used in Enercon E-66 model Wind turbine

Synchronous Generators in Wind Turbine

In synchronous generators Wind turbines, electromagnets are used in the rotor, which are fed by direct current from the electrical grid. Since the grid supplies alternating current, they first have to convert alternating current to direct current before sending it into the coil windings around the electromagnets in the rotor. The rotor electromagnets are connected to the current by using brushes and slip rings on the axle (shaft) of the generator. Synchronous generators are used in Windflow500

Asynchronous - Doubly Fed Induction Generator (DFIG)

A wound rotor circuit is used with the doubly fed induction generator, in which the windings are externally accessible via slip rings. The generator is connected to the turbine through a gearbox. The rotor current is regulated using power electronics, which allows the generator to operate over a relatively large speed range. The DFIG can potentially contribute reactive power, voltage and frequency regulation, and up to a certain extent fault ride-through. Doubly fed induction generator also contributes to the overall power system inertia as the machine stator windings are still grid-connected. An example of this type of generator is the Vestas V90 3 MWWTG proposed by Trust power for Stage III of the Tararua wind farm.

Wind Turbine Control Problem

By implementing the primary technologies in wind turbines, we can help effectively in attaining as well as improving the plants objectives of safe and cost-efficient energy production. As the need to understand the behaviour of various parameters and improve various material properties will continue. Active control can provide the requirements on materials at any stage of the technology. We have discussed here the control requirements for wind turbines, along with the control means and sensors that are employed in modern wind turbines. This will provide background and serve as a focal point for subsequent discussion of the applicability of modern control theory to wind turbines.

The wind turbine control problem has at least three important requirements:

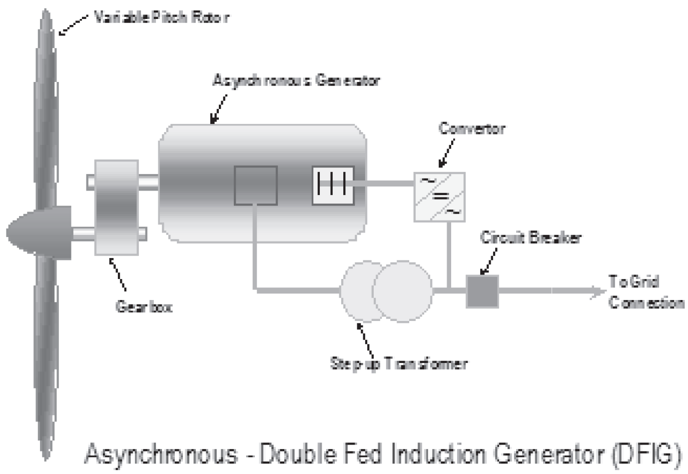

Figure 3

1. Limiting the torque and power experienced by the drive train
2. Minimizing the fatigue life extraction from the rotor drive train and other structural components due to changes in wind direction, speed (including gusts), and turbulence, as well as start-stop cycles of the wind turbine; and
3. Maximizing the energy production.

The control theory here it is given in terms of a pitch-controlled, variable-speed wind turbine. The combination of sensors and control means is thought to span the space of current, practical control techniques. Here it is cleared that stall-controlled and other wind turbines may not require all of the sensors and control means, which are discussed here, upto certain extent this is true. Still, for all wind turbine architectures, research may reveal other analogous techniques for control that are functionally equivalent to the particular techniques e. In any case, there will remain the general requirements for control of the torque and power in the drive train, the minimization of fatigue life extraction, and the maximization of energy production. Pitch control mechanism is used in Enercon 2.3MW and Stall control mechanism is used in Suzlon 350kW

Latest Wind Turbine (Clipper)

Figure 4 : Clipper wind Turbine

In this Clipper wind turbine, advanced generator control technology is used. And wide range variable rotor speed, improving turbine aerodynamic efficiency by adjusting to ever-changing wind velocities. Net benefit of this turbine is more production and extended life. Yaw system consists of 4 electric motors with planetary drives. Also hydraulic brakes are used. High efficiency Mega-Flux generators provide continued operation even with a generator outage as compared to today's turbines with single generator drive train.

Various Software Available For Wind Power Analysis

Windrose Software

Wind Rose is software for analyzing and correlating wind data (speed, direction, turbulence, temperature). Data analysis is related with the requirements guided by the IEC and MEASNET standards. Wind Rose can also calculate the detailed correlation (per wind speed and direction) between two sites and create predicted time-series, based on the existing ones from a reference site, using an advanced MCP technique. All the wind manufacturers i.e.Enercon E-40, NEG-Micon750/48,Vestas V.47 are using this software.

Homer

HOMER is a computer model that clears the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation (DG) applications. HOMER's optimization and sensitivity analysis algorithms tell us to evaluate the economic and technical feasibility of a large number of technology options and to account for variation in technology costs and energy resource availability. HOMER is applicable for both conventional and renewable energy technologies. The analysis can store graphically and numerically into spreadsheets, which can be further used as ordinary Excel files. All the wind manufacturers i.e.Enercon E-40, NEG-Micon750/48,Vestas V.47 are using this software

Wind05

Wind05 Calculates wind pressures per ASCE 7-05 Minimum Design Loads for Buildings and Other Structures for all types of buildings and structures. It can performs Gust calculations for Rigid and flexible structures, with the gust factor for flexible structures based upon the natural frequency and damping of the structure. It also calculates the topographic factors and provides a comprehensive list of all shape factors for the structure and attachments

Windographer

Windographer is a powerful new software tool for analyzing wind data. It reads data from almost any data logger, Further it can produces many great-looking graphs and wind roses, and also advanced statistical processing. All the wind manufacturers i.e.Enercon E-40, NEG-Micon750/48,Vestas V.47 are using this software.

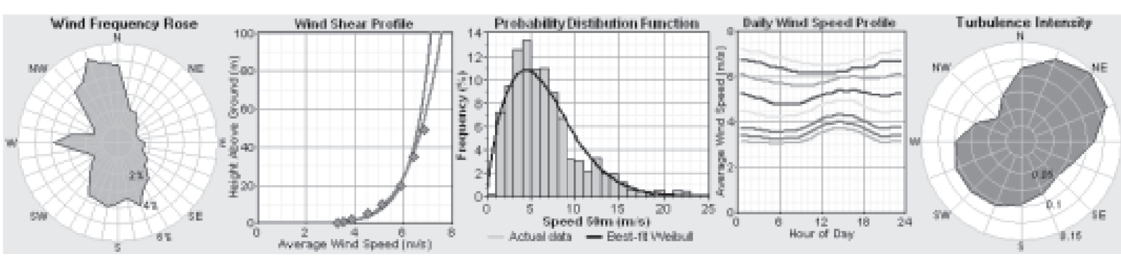

Figure 5: Various Graphs Obtained From Windographer (5)

Indian Scenario

As per future projection of MNES, 10% of the installed capacity of power requirement by the year 2012 i.e.24000MW will come from renewable energy and out of which, 50%i.e.12000MW is likely to come from wind power (4) with the current installed capacity of approximately 4200 MW and the successful demonstration and commercial operation of MW class machines in the recent past, India is the fourth largest wind power producer in the world. India has witnessed remarkable growth in the wind energy sector. During the last year, wind energy capacity increased by more than 35%.

Technology Trends in India

During 90s most of the machines installed were of small capacity in the range of 200/250kW, either pitch controlled or stalled regulated design. After that the next higher sizes say, 500/600kW machines were introduced.

In the twenty-first century, the introduction of MW class machines in Indian market occurs. This recent trend of higher size machine has brought in taller towers, advanced electronic controls and also variable speed

The challenge for the transportation of major parts to the remote sites and the installation and commissioning of the WEGs was very big task, as the infrastructure facilities in the villages are not so developed as in the western countries. But these have been overcome and 2 MW wind turbine power plant have already been developed and installed in Tamilnadu.The advanced features of the MW class design are implemented and the developers are confident about the growth of the wind power sector with these higher capacity turbine.

Table 2: Estimated Wind Power Potential in India

Sl. No.	State	Gross Potential (MW)
1	Andhra Pradesh	8275
2	Gujarat	9675
3	Karnataka	6620
4	Kerala	875
5	Madhya Pradesh	5500
6	Maharashtra	3650
7	Orissa	1700
8	Rajasthan	5400
9	Tamil Nadu	3050
10	West Bengal	450
Total		**45195**

Overview on R & D Projects by C-wet India

C-WET stands for center for wind energy technology, the R & D unit of C-WET is focusing the innovations in development of components as well as sub-systems of wind turbines in association with other R&D Institutions and Industry in India.

The Research and Development activities of C-WET are classified into four generic areas:

- Improvement in performance of existing Wind Turbine Installations.
- Research support for Wind resource Assessment.
- Manpower Training and HRD
- Technology support to Wind Power Industry.

The R&D department conducts research for achieving improvement in performance of existing wind turbine installations as well as research in advanced wind turbine technology.

The R&D team has carried out number of projects in various fields like grid related investigations of wind farms, optimum blade angle for energy maximization and failure analysis of gearboxes of wind turbines aimed at the existing wind turbine installations

The Ongoing Projects in the Department

- Development and validation of design methodologies and design tools for low and moderate wind regimes
- Modelling of Interconnection of Wind Turbines with the grid.
- Parameterisation of flow distortion around the wind turbine nacelle
- Installation of Renewable energy Devices
- Study of acoustic emissions of wind turbines
- Failure Analysis of gearboxes of wind turbines

The department is also working for establishing a wind farm that will serve as a Wind Power System performance evaluation facility as well as for Technology Demonstration

Ongoing Projects

1. *Development & Validation of Design Methodologies & Design Tools for Low & Moderate Wind Regimes*

This project will help in generating an indigenous design data bank for the development of indigenous, low cost, robust, technologically advanced wind turbine blades / rotors optimised for low/ moderate wind regimes prevailing in India. This is keeping in view the importance of the rotor in contributing to the turbine cost, energy production of the turbine and loads on the machine. Hence a joint project with National Aerospace Laboratories (NAL), Bangalore has been started. The main objective of this project is to conduct a survey of existing blade profiles and existing modelling strategies for wind turbine aerodynamics, introducing new modelling strategies supporting in-house computational projects, carrying out blade / rotor performance studies as well as wind tunnel and water tunnel studies.

2. *Modelling of Interconnection of the Wind Turbines with the Grid*

The objective of this study is to develop a simple tool to study the grid interaction of wind turbines, to determine the role of the Wind turbine in governing the behaviour of the grid and to study the planning & control strategies which are involved in the implementation of a wind farm. The methodology of the study is to develop a simple tool in MATLAB to study the grid interaction of wind turbines and to check the feasibility of the model through real-time measurements in field.

3. Parameterisation of Flow Distortion Around Wind Turbine Nacelle

The objective of this study is to observe the dynamics of wind flow around the nacelle body and to determine the position of free stream wind near the nacelle body through a wind tunnel experiment. It is basically for positioning the anemometer on the top of the nacelle for site calibration experiments in the future for power performance testing. This will also help in correcting the measured power curve for site effects with very less uncertainties in complex terrains. The fabrication of the model has been completed and experimentation will be conducted through a wind tunnel experiment.

4. 45 KW Wind-Solar-Pungham Integrated Generation System

A wind-solar-pungham integrated generation system will be installed in C-WET premises to meet the load demand partially and also to undertake R&D studies on the system. The proposed system will consist of 10 kW small wind turbine generating system

5. Study of Acoustic Emissions of Wind Turbines

The objective of the study is to measure acoustic emission of wind turbines as per IEC 61400-11. And then a comparative study of the emissions by different turbines will be carried out.

6. Failure Analysis of Gearboxes of Wind Turbines

The objective of this project was analysis on failure of gearboxes of wind turbines.

Based on the project, two areas have been identified for further study and improvement; one is with respect to the design specification of the gearbox and the other with respect to the lubricant used. Efforts are now underway. Some parameters that are responsible for failure were analysed and studied.

R & D in Indian Industries

Enercon had developed a new turbine modelE-82. Which has 39 m long rotor blades. New E-82 wind turbine has a swept area of 5.281m2 which guarantees at least 35 per cent more energy output at mean wind speeds

Suzlon has commissioned large wind park of 201 MW in India. The Vankusawade Wind Park is located on a high mountain plateau at 1150 m, running north to south above the Koyna Reservoir in the Satara District of Maharashtra State. It is approximately 40 km from the town of Satara (200 km south - southeast of Mumbai), and approximately 80 km from India's west coast. Further a lot of research and development work is going on by wind turbine manufacturers

Future Direction to Research Work

For innovation work, sky is the limit. There is lot of scope for research and development. Basically wind power technology I must say that it is a multidisciplinary approach. So contribution from various discipline i.e.Mechanical, Civil, Electrical, Electronics and computer is needed. Due to time constraint I have not covered all the aspect and various elements that have active role in wind power Technology. I have discussed only few of them.

Conclusion

We find that the energy future is in wind power technology. Wind energy currently has a small percentage of shares in our total energy generation but due to lot of benefit it is becoming important part of energy mix. Wind power technology R&D now make use of new technical developments such as advanced airfoils, information from structural blade testing, variable rotor speed operation, and aerodynamic controls. These developments have been implemented into wind turbines that will soon be, commercially available at lowest cost of energy. Hence the whole world is taking keen interest in wind power technology. A lot of research and development work is done and also going on continuously in each and every part of wind power technology i.e. nacelle, gearbox, wind blade tower, generator etc. here I have tried to sum up some of these developments which are innovated recently. Above trends indicate that due to R&D work the cost of wind power decrease rapidly and also the performance of wind turbine improved tremendously.

There is vast potential for Europe-India cooperation for technological up gradation of wind turbines and for developing regulatory framework and pricing mechanism. The collaborative approach would also be beneficial for progress of wind power technology in the Indian context.

Rererences

1. www.suzlon.com
2. www.vestos.com
3. www.Enercon.de
4. http://www.sandia.gov/Wind/search.htm
5. Snel, H.;'Dynamic Stall Modelling: Some Results'. 11-th IEA Symposium on the Aerodynamics of Turbines, ECN Petten, 1997
6. Thresher, R.; Hock, S.; Loose, R.; Cadogan, J. (1994). *The National Wind Technology Center.* Presented at the Windpower '94 Conference, Minneapolis, MN, 9-13 May.
8. http://www.windpower.org/en/tour/wtrb/syncgen.htm
9 Eize de Vries, *Renewable Energy World*, January-February 2006).
10. http://www.sandia.gov/wind/links.htm
11. http://www.mhi.co.jp/nsmw/mwt/en/gearless.html
12. Robert W. Thresher Wind Technology Development: Large and Small Turbines (Presented at the POWER-GEN AMERICAS '94 Conference, Orland, Florida, December 7-9, 1994)
13. http://www.mistaya.ca/products/windographer.htm