RECENT DEVELOPMENT OF WIND POWER GENERATION AND DISTRIBUTION

Dr. S.M Ali[1], Shubhra[2]

School of Electrical Engineering ,KIIT UNIVERSITY, Bhubaneswar, Pin-751024,ODISHA,INDIA

Emails- drsma786@gmail.com[1], ,shubhra24srivastava@gmail.com[2]

Abstract- Windmills have been used for many centuries for pumping water and milling grain. The discovery of the internal combustion engine and the development of electrical grids caused many windmills to disappear in the early part of this century. However, in recent years there has been a revival of interest in wind energy and attempts are underway all over the world to introduce cost-effective wind energy conversion systems for this renewable and environmentally benign energy source. In developing countries, wind power can play a useful role for water supply and irrigation (wind pumps) and electrical generation (wind generators). These two variants of windmill technology are discussed. This brief gives a general overview of the resource and of the technology of extracting energy from the wind. This paper mainly includes the technology based generation of wind energy or wind power by using the wind or air and its future requirement.

Index term-- Wind *Energy, Technology, Methodology, Future of Wind Energy.*

Introduction

Wind is simply air in motion. It is caused by the uneven heating of the Earth's surface by radiant energy from the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's energy at different rates. Water usually does not heat or cool as quickly as land because of its physical properties. An ideal situation for the formation of local wind is an area where land and water meet. During the day, the air above the land heats up more quickly than the air above water. The warm air over the land expands, becomes less dense and rises. The heavier, denser, cool air over the water flows in to take its place, creating wind. In the same way, the atmospheric winds that circle the Earth are created because the land near the equator is heated more by the sun than land near the North and South Poles. Today, people use wind energy to make electricity. Wind is called a **renewable** energy source because the wind will blow as long as the sun shines.

Wind Speed:

It is important in many cases to know how fast the wind is blowing. Wind speed can be measured using a wind gauge or **anemometer**. One type of anemometer is a device with three arms that spin on top of a shaft. Each arm has a cup on its end. The cups catch the wind and spin the shaft. The harder the wind blows, the faster the shaft spins. A device inside counts the number of rotations per minute and converts that figure into miles per hour. A display on the anemometer shows the speed of the wind.

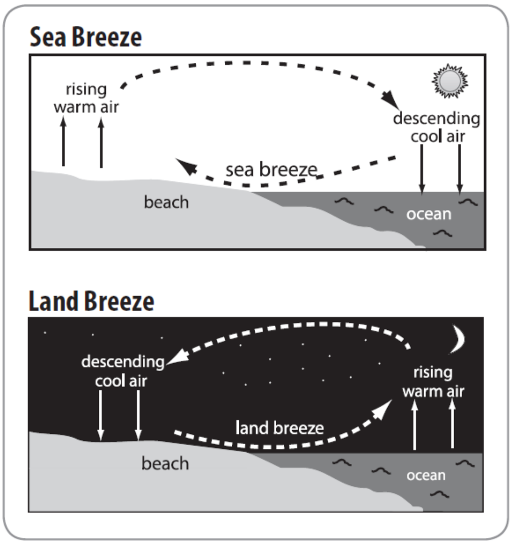

Fig:1

Energy availability in the wind:

The power in the wind is proportional to the cube of wind velocity. The general formula for wind power is:

Power=(density of air x swept area x velocity cubed) / 2

$P = 2.\varrho.A.v^3$

If the velocity (v) is in m/s, then at sea level (where the density of air is 1.2 kg/m3) the power in the wind is: Power = 0.6 x v^3 Watts per m^2 of rotor swept area This means that the power density in the wind will range from $10W/m^2$ at 2.5m/s (a light breeze) to $41{,}000W/m^2$ at 40m/s (a hurricane). This variability of the wind power resource strongly influences virtually all aspects of wind energy conversion systems design, construction, siting, use and economy.

Technology Based:

Modern Wind Turbines Gearbox:

GE 1.5sl

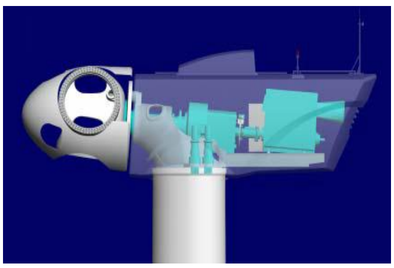

Fig:2

- 1.5 MW
- 77 M Rotor Diameter
- 50-100 M Tower
- 98% Availability
- Speed 10-20 RPM
- Variable Pitch

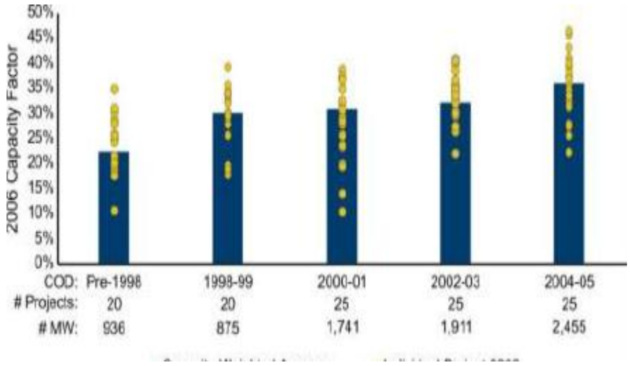

Fig: 2(b)

Capacity Factor = (Annual Yield MWHrs)/(24*365*Power Rating)

Land Based Technology

- 1.5 -3.0 MW upwind configuration
- 80-100m tapered cylindrical steel towers
- 3 stage gearbox
- Distributed component drive train
- Full span pitch control
- 200+MW Wind farms

Wind Energy Convers

Rotor power: $P = 1/2\ c_p\ \varrho A v_w^3$

cp - rotor power coefficient

ϱ - air density

A - rotor swept area

Ideal cp = 0.593 (Betz factor)

where V2 = 1/3 V1 (wind velocity slows by 2/3)

Tip speed ratio: $\lambda = v_t / v_w$

$c_p = f(\lambda)$

Large Offshore Turbines

10 MW Concept

- 180 m rotor diameter
- Downwind 2 blade machine
- Direct drive
- Flexible compliant blades
- Flow control blades
- High rpm/tip velocity > 100 m/s
- Space frame structure
- Multivariable damping controls

• 40 m water depth foundation
• Hurricane ride-thru capability

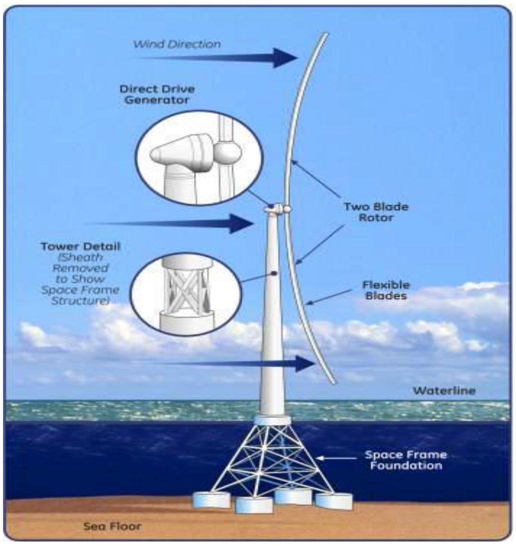

Fig:3 (Large Offshore Turbines)

Wind Turbine Components:

OEMs typically have unique designs for wind turbine nacelles and the leading global OEMs manufacture nacelles in-house. A few companies license wind turbine designs to other companies and several companies contract out nacelle manufacturing. Blades and towers may be produced in-house or by outside suppliers. Nacelles, blades, and towers are shipped directly from the manufacturing plant to the construction site.

Blades: Most wind turbines have three blades, though there are some with two blades. Blades are generally 30 to 50 meters (100 to 165 feet) long, with the most common sizes around 40 meters (130 feet). Longer blades are being designed and tested. Blade weights vary, depending on the design and materials—a 40 meter LM Glasfiber blade for a 1.5 MW turbine weighs 5,780 kg (6.4 tons) and one for a 2.0 MW turbine weighs 6,290 kg (6.9 tons).

Controller: There is a controller in the nacelle and one at the base of the turbine. The controller monitors the condition of the turbine and controls the turbine movement.

Gearbox: Many wind turbines have a gearbox that increases the rotational speed of the shaft. A low-speed shaft feeds into the gearbox and a high-speed shaft feeds from the gearbox into the generator. Some turbines use direct drive generators that are capable of producing electricity at a lower rotational speed. These turbines do not require a gearbox.

Generators: Wind turbines typically have a single AC generator that converts the mechanical energy from the wind turbine's rotation into electrical energy. Clipper Windpower uses a different design that features four DC generators.

Nacelles: The nacelle houses the main components of the wind turbine, such as the controller, gearbox, generator, and shafts.

Rotor: The rotor includes both the blades and the hub (the component to which the blades are attached).

Towers: Towers are usually tubular steel towers 60 to 80 meters (about 195 to 260 feet) high that consist of three sections of varying heights. (There are some towers with heights around 100 meters (330 feet)).

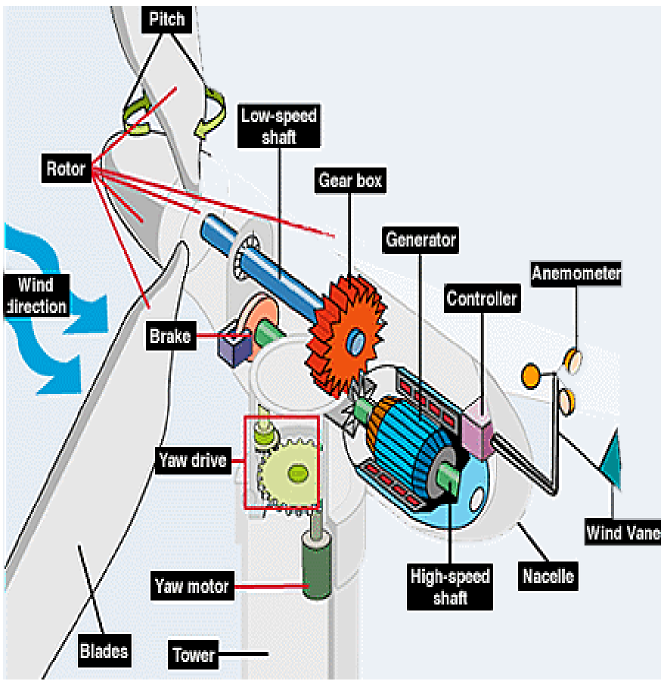

Fig:4

Principles of wind energy conversion:

There are two primary physical principles by which energy can be extracted from the wind; these are through the creation of either drag or lift force (or through a combination of the two). The difference between drag and lift is illustrated (see Figure) by the difference between using a spinnaker sail, which fills like a parachute and pulls a sailing boat with the wind, and a Bermuda rig, the familiar triangular sail which deflects with wind and allows a sailing boat to travel across the wind or slightly into the wind. Drag forces provide the most obvious means of propulsion, these being the forces felt by a person (or object) exposed to the wind. Lift forces are the most efficient means of propulsion but being more subtle than drag forces are not so well understood.

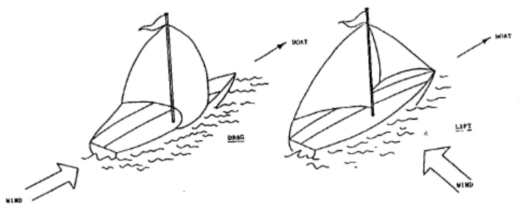

Fig:5 Drag and lift forces

- The basic features that characterise lift and drag are: drag is in the direction of airflow
- lift is perpendicular to the direction of airflow.
- generation of lift always causes a certain amount of drag to be developed.
- with a good aerofoil, the lift produced can be more than thirty times greater than the drag.
- lift devices are generally more efficient than drag devices

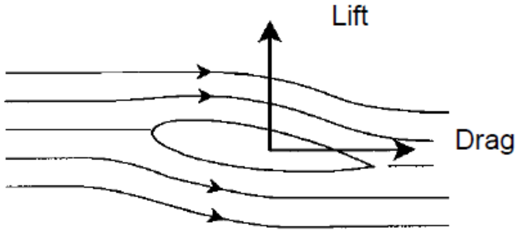

Fig:6 Aerofoil

There are two main families of windmills: vertical axis machines and horizontal axis machines. These can in turn use either lift or drag forces to harness the wind. Of these types the horizontal axis lift device represents the vast majority of successful wind machines, either ancient or modern. In fact other than a few experimental machines virtually all windmills come under this category. There are several technical parameters that are used to characterise windmill rotors. The tip speed ratio is defined as the ratio of the speed of the extremities of a windmill rotor to the speed of the free wind. It is a measure of the 'gearing ratio' of the rotor. Drag devices always have tip-speed ratios less than one and hence turn slowly, whereas lift devices can have high tip-speed ratios and hence turn quickly relative to the wind.

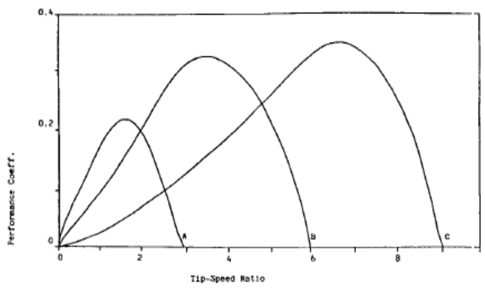

Fig:7 Tip speed ratio and the performance coefficient

Tip speed ratio= Bade Tip Speed / Wind Speed

The proportion of the power in the wind that the rotor can extract is termed the coefficient of performance (or power coefficient or efficiency; symbol Cp) and its variation as a function of tip speed ratio is commonly used to characterise different types of rotor. It is physically impossible to extract all the energy from the wind, without bringing the air behind the rotor to a standstill. Consequently there is a maximum value of Cp of 59.3% (known as the Betz limit), although in practice real wind rotors have maximum Cp values in the range of 25%-45%.

Wind Energy Application Market:
based on the end-use application of the technology. Wind energy projects are common for off-grid applications. However, the largest market potential for wind energy projects is with on- Wind energy markets can be classified grid (or grid-connected) applications.

Off-grid applications: Wind energy was most competitive in remote sites, far from the electric grid and requiring relatively small amounts of power, typically less than 10 kW. In these offgrid applications, wind energy is typically used in the charging of batteries that store the energy captured by the wind turbines and provides the user with electrical energy on demand. Water pumping, where water, rather than energy, can be stored for future use, is also a key historical application of wind energy. The key competitive area for wind energy in remote off-grid power applications is against electric grid extension, primary (disposable) batteries, diesel, gas and thermoelectric generators. Wind energy is also competitive in water pumping applications.

On-grid applications: In on-grid applications the wind energy system feeds electrical energy directly into the electric utility grid. Two on-grid application types can be distinguished.

Fig:8

1. Isolated-grid electricity generation, with wind turbine generation capacity typically ranging from approximately 10 kW to 200 kW.

2. Central-grid electricity generation, with wind turbine generation capacity typically ranging from approximately 200 kW to 2 MW.

Description of Wind Turbines:

Wind turbine technology has reached a mature status during the past 15 years as a result of international commercial competition, mass production and continuing technical success in research and development (R&D). The earlier concerns that wind turbines were expensive and unreliable have largely been allayed. Wind energy project costs have declined and wind turbine technical availability is now consistently above 97%. Wind energy project plant capacity factors have also improved from 15% to over 30% today, for sites with a good wind regime.

Modern wind energy systems operate automatically. The wind turbines depend on the same aerodynamic forces created by the wings of an aeroplane to cause rotation. An anemometer that continuously measures wind speed is part of most wind turbine control systems. When the wind speed is high enough to overcome friction in the wind turbine drivetrain, the controls allow the rotor to rotate, thus producing a very small amount of power. This cut-in wind speed is usually a gentle breeze of about 4 m/s. Power output increases rapidly as the wind speed rises. When output reaches the maximum power the machinery was designed for, the wind turbine controls govern the output to the rated power. The wind speed at which rated power is reached is called the rated wind speed of the turbine, and is usually a strong wind of about 15 m/s. Eventually, if the wind speed increases further, the control system shuts the wind turbine down to prevent damage to the machinery. This cut-out wind speed is usually around 25 m/s.

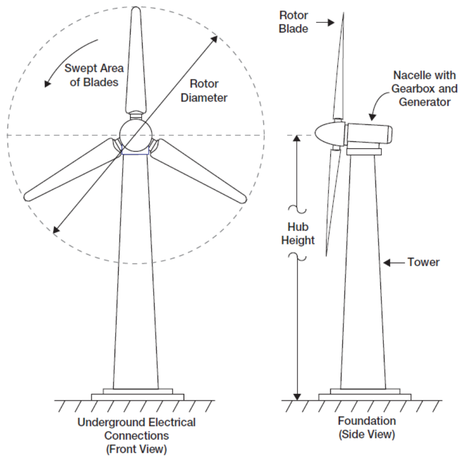

Fig:10 Wind Turbine

Large OEMs usually develop proprietary wind turbine designs and assemble the nacelles. A few smaller OEMs contract out nacelle assembly. Blades and towers are

manufactured in-house or by outside suppliers. Many OEMs have a combination of in-house production and outside suppliers for blades and towers.

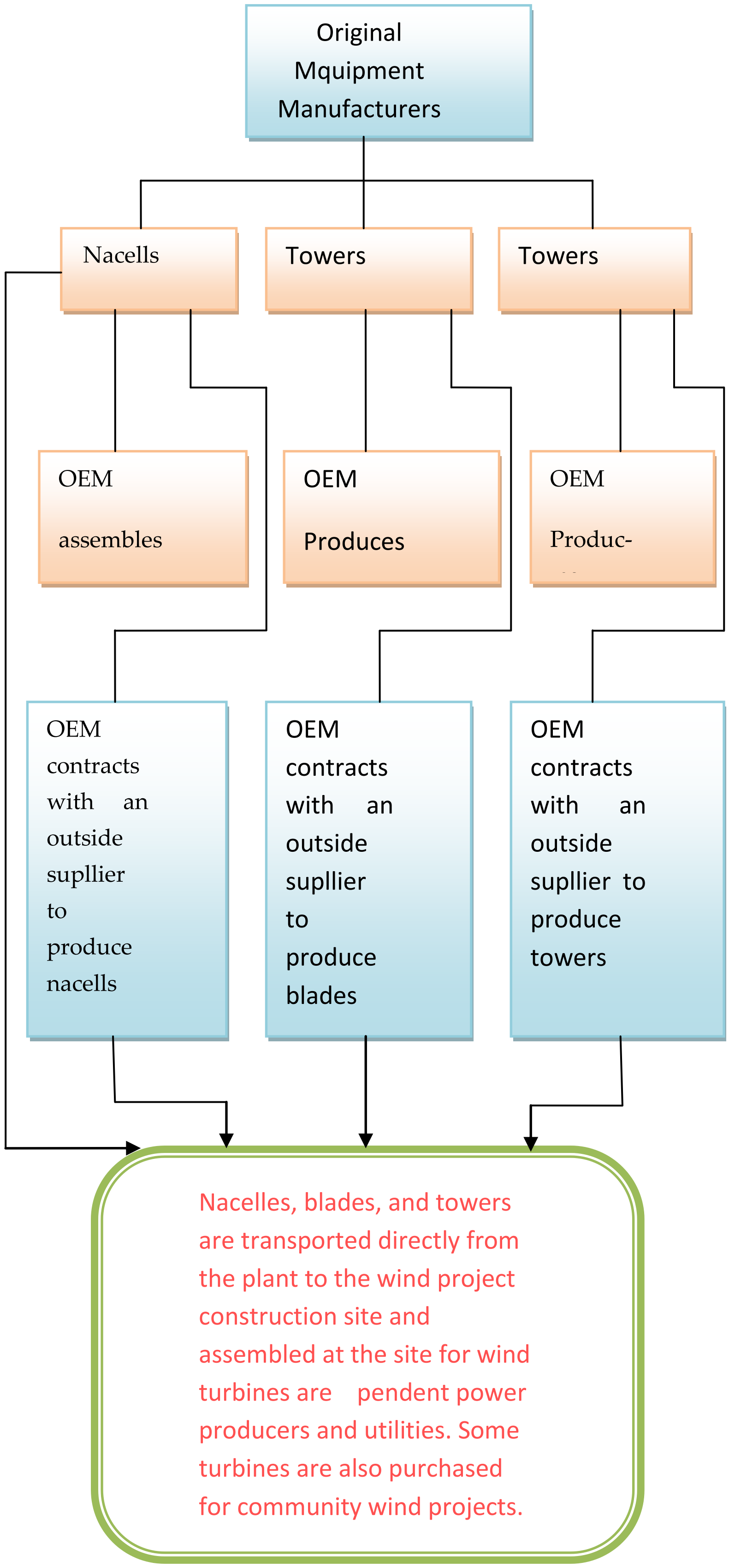

Fig:11 **Original Equipment Manufacturers (OEM)**

The rapid growth in global demand in the last few years strained the wind turbine supply chain. In response, some OEMs expanded and diversified their supply chain while others enhanced in-house production capabilities through investments in new manufacturing facilities or purchases of major component suppliers. Different business models have led to different degrees of vertical integration by company and by component. Suzlon, for example, has pursued a strategy of in-house production and vertical integration for most major components. GE is less vertically integrated than Suzlon, leveraging its experience and competitive advantage in supply chain management to build its wind turbine supply chain. Siemens falls in the middle. Unless all production is in-house, companies usually have at least two suppliers for key components.

WIND CHARACTERISTICS

The earth's atmosphere can be modelled as a gigantic heat engine. It extracts energy from one reservoir (the sun) and delivers heat to another reservoir at a lower temperature (space). In the process, work is done on the gases in the atmosphere and upon the earth-atmosphere boundary. There will be regions where the air pressure is temporarily higher or lower than average. This difference in air pressure causes atmospheric gases or wind to flow from the region of higher pressure to that of lower pressure. These regions are typically hundreds of kilometres in diameter. Solar radiation, evaporation of water, cloud cover, and surface roughness all play important roles in determining the conditions of the atmosphere.

METEOROLOGY OF WIND

Boyle's law, which
states that the product of pressure and volume of a gas at a constant temperature must be a constant, or

$$p1V1 = p2V2 \qquad \text{(i)}$$

Another law is Charles' law, which states that, for constant pressure, the volume of a gas varies directly with absolute temperature.

$$V1 \div T1 = V2 \div T2 \qquad \text{(ii)}$$

If a graph of volume versus temperature is made from measurements, it will be noticed
that a zero volume state is predicted at −273.15oC or 0 K.
The laws of Charles and Boyle can be combined into the *ideal gas la*

$$pV=nRT \qquad \text{(iii)}$$

In this equation, R is the universal gas constant, T is the temperature in kelvins, V is the volume of gas in m_3, n is the number of kilomoles of gas, and p is the pressure in pascals (N/m^2). At standard conditions, 0^0C and one atmosphere, one kilomole of gas occupies 22.414 m^3 and the universal gas constant is 8314.5 J/(kmol·K) where J represents a joule or a Newton meter of energy. The pressure of one atmosphere at 0^oC is then

$$\frac{(8314.5 J/(kmol \cdot K))(273.15\ K)}{22.414\ m^3}$$

$$=101{,}325 Pa$$

One kilomole is the amount of substance containing the same number of molecules as there are atoms in 12 kg of the pure carbon nuclide 12C. In dry air, 78.09 % of the molecules are nitrogen, 20.95 % are oxygen, 0.93 % are argon, and the other 0.03 % are a mixture of CO2, Ne, Kr, Xe, He, and H2. This composition gives an average molecular mass of 28.97, so the mass of one kilomole of dry air is 28.97 kg. For all ordinary purposes, dry air behaves like an ideal gas.
One kilomole is the amount of substance containing the same number of molecules as there are atoms in 12 kg of the pure carbon nuclide 12C. In dry air, 78.09 % of the molecules are nitrogen, 20.95 % are oxygen, 0.93 % are argon, and the other 0.03 % are a mixture of CO2, Ne, Kr, Xe, He, and H2. This composition gives an average molecular mass of 28.97, so the mass of one kilomole of dry air is 28.97 kg. For all ordinary purposes, dry air behaves like an ideal gas.

The density of ϱ a gas is the mass m of one kilomole divided by the volume V of that kilomole.

$$\rho = m/v \qquad (v)$$

The volume of one kilomole varies with pressure and temperature as specified by Eq. (iii) When we insert Eq.(iii) into Eq. (v), the density is given by

$$\rho = m\rho/RT = 3.484\rho/T \quad kg/m^3 \qquad (vi)$$

where p is in kPa and T is in kelvins. This expression yields a density for dry air at standard conditions of 1.293 kg/m^3. The common unit of pressure used in the past for meteorological work has been the bar (100 kPa) and the millibar (100 Pa). In this notation a standard atmosphere was referred to as 1.01325 bar or 1013.25 millibar.

Atmospheric pressure has also been given by the height of mercury in an evacuated tube. This height is 29.92 inches or 760 millimeters of mercury for a standard atmosphere. These numbers may be useful in using instruments or reading literature of the pre-SI era. It may be worth noting here that several definitions of standard conditions are in use. The chemist uses 0^oC as standard temperature while engineers have often used 68oF (20^oC) or 77oF (25^oC) as standard temperature. We shall not debate the respective merits of the various choices, but note that some physical constants depend on the definition chosen, so that one must exercise care in looking for numbers in published tables. In this text, standard conditions will always be 0^oC and 101.3 kPa. Within the atmosphere, there will be large regions of alternately high and low pressure.

Factors Affecting Wind Turbine Demand

- Government Mandates
- Electricity Prices Financing
- Transmission Capacity
- Intermittence
- Policy Stability
- Transportation and Permitting
- Siting

Merits And Demerits Of Wind Energy

Merits

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.

Demerits:

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.

Environmental Effect:

Compared to the environmental impact of traditional energy sources, the environmental impact of wind power is relatively minor. Wind power consumes no fuel, and emits no air pollution, unlike fossil fuel power sources. The

energy consumed to manufacture and transport the materials used to build a wind power plant is equal to the new energy produced by the plant within a few months. While a wind farm may cover a large area of land, many land uses such as agriculture are compatible, with only small areas of turbine foundations and infrastructure made unavailable for use. There are reports of bird and bat mortality at wind turbines as there are around other artificial structures. The scale of the ecological impact may or may not be significant, depending on specific circumstances. Prevention and mitigation of wildlife fatalities, and protection of peat bogs affect the siting and operation of wind turbines.
There are anecdotal reports of negative effects from noise on people who live very close to wind turbines. Peer-reviewed research has generally not supported these statements.

Wind Power over Fossil Fuels

1. Wind is Free - Everyone knows that moving air (wind) is costs nothing. Converting the wind to energy is the challenge. Although not free, the initial investment in a wind to electricity type system will be needed. Going back 80-90 years, we had to invest in the infrastructure to drill and refine Oil and this will be no different.

2. The Wind does not Smell - If you have ever been near a refinery, you know the stench that can permeate the air is foul and undesirable.

3. The Wind is environmentally sound. The recent anniversary of the tanker that ran aground in Alaska reminds us all of the devastation fossil fuels have caused to our environment. The wind will never be a negative contributor to the planet.

4. The Wind is everywhere - Our dependency on fossil fuels has caused some nations to look the other way to ideas and principles that would otherwise be considered barbaric and inhumane. Since the wind is available to anyone who can take advantage of it, removing those dependencies will allow us to be more critical of our neighbours in the global community.

5. Wind is Forever and easy to Find- Even though wind is unpredictable, it will always be available at some time in every location. Although, there are locations that generate more wind, those places are easy to find. With fossil fuels, we spend billions of dollars searching for new sources of crude oil to pump from the ground and they will eventually become less productive.

Future Of Wind Energy

In the near future, wind energy will be the most cost effective source of electrical power. In fact, a good case can be made for saying that it already has achieved this status. The actual life cycle cost of fossil fuels (from mining and extraction to transport to use technology to environmental impact to political costs and impacts, etc.) is not really known, but it is certainly far more than the current wholesale rates. The eventual depletion of these energy sources will entail rapid escalations in price which -- averaged over the brief period of their use -- will result in postponed actual costs that would be unacceptable by present standards. And this doesn't even consider the environmental and political costs of fossil fuels use that are silently and not-so-silently mounting every day.

The major technology developments enabling wind power commercialization have already been made. There will be infinite refinements and improvements, of course. One can guess (based on experience with other technologies) that the eventual push to full commercialization and deployment of the technology will happen in a manner that no one can imagine today. There will be a "weather change" in the marketplace, or a "killer application" somewhere that will put several key companies or financial organizations in a position to profit. They will take advantage of public interest, the political and economic climate, and emotional or marketing factors to position wind energy technology (developed in a long lineage from the Chinese and the Persians to the present wind energy researchers and developers) for its next round of development.

Conclusion

Wind energy will be a main contributor to the implementation of the EU objectives on renewable energy production. However, the current R&D efforts for wind energy are insufficient – at all levels - to respond to the energy challenges faced by the EU. The risk is therefore of failure in reaching the EU objectives for energy production from renewable sources (and therefore on reduction of CO_2 emissions), and in implementing the European strategy for growth and jobs.

A critical component is the contribution of the EU, which, in order to achieve the objectives of the Lisbon Strategy, should lead by example. A strong and clear signal from the EU would act as catalyst at Member State level in strongly supporting renewables and wind in particular.

Refrences

1. P. Fraenkel, R. Barlow, F. Crick, A. Derrick and V. Bokalders: Windpumps – A guide for development workers. ITDG Publishing, 2012.
2. E. H. Lysen: Introduction to Wind Energy, basic and advanced introduction to wind energy with emphasis on water pumping windmills. SWD, Netherlands, 2012.
3. E. W. Golding: The Generation of Electricity by Wind Power Redwood Burn Limited, Trowbridge, 2012.
4. T. Anderson, A. Doig, D. Rees and S. Khennas: Rural Energy Services - A handbook for sustainable energy development. ITDG Publishing, 2012.
5. S. Lancashire, J. Kenna and P. Fraenkel: Windpumping Handbook I T Publications, London, 2012.
6. German Wind Energy Association, “Wind Energy ‘Made in Germany’ is an Export Hit,” 2012
7. Magee, Joshua T. “Wind Turbine Supply Chain Trends and Component Tiers.” Presentation at AWEA windpower supply chain workshop, Cleveland, OH,2012
8. Clipper Windpower. “Clipper Leads on Technology and Size as it Develops the Britannia Offshore Wind Turbine.” News release,2012.
9. Hugh Piggott: It’s A Breeze, A Guide to Choosing Windpower. Centre for Alternative Technology,2012.
10. Conover, K., ***Wind Energy Financial Due Diligence***, R. Lynette & Associates, Seminar on Opportunities for Finance and Investment in Wind Energy,2012.
11. Leng, G., Dignard-Bailey, L., Bragagnolo, J., Tamizhmani, G. and Usher, E., ***Overview of the Worldwide Photovoltaic Industry***, Report no. 96-41-A1 (TR), CANMET Energy Diversifi cation Research Laboratory, Natural Resources Canada, Varennes, QC, Canada, J3X 1S6.2012.
12. Vesterdal, J., ***The Potential of Wind Farms***, ELSAM,2012.

BIOGRAPHY

Dr S M Ali is Associate Professor in Electrical Engineering of KIIT University Bhubaneswar. He received his DSc & Ph.D. in Electrical Engineering from International university, California, USA in 2008 & 2006 respectively. He had done M.Tech from Calcutta University. His area of research in the field of Renewable Energy both Solar & Wind Energy. He had also guided five nos. of Ph. D students in his research area. He has also presented more than 50 papers in different National & International conferences in the field of Renewable Energy apart from around 20 nos of paper also published in National and International journals. He has conducted several nos. of Seminar, Workshop and short term training program for the Faculty members Engineering College, Polytechnic in collaboration with AICTE, ISTE, MHRD DST, & Ministry of Industries, Govt. of India. He is Vice President of Solar Energy Society of India and Secretary of Institution of Engineers (India) , Odisha state centre. Ph.+91-9437032351.

Shubhra: Had received her B.Tech in Electrical and Electronics Engineering from S.I.T.M, Lucknow, Gauttam Buddha Technical University, Uttar Pradesh, India in 2011. Presently pursuing M.Tech in Power and Energy System from KIIT-University, Bhubaneswar, Odisha, India. She is the life member of Solar Energy Society of India. Ph.+91-8658216994.