Design of an Energy Efficient Low Power Wind Turbine System

A Project Report
Submitted by

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KUMARAGURU COLLEGE OF TECHNOLOGY
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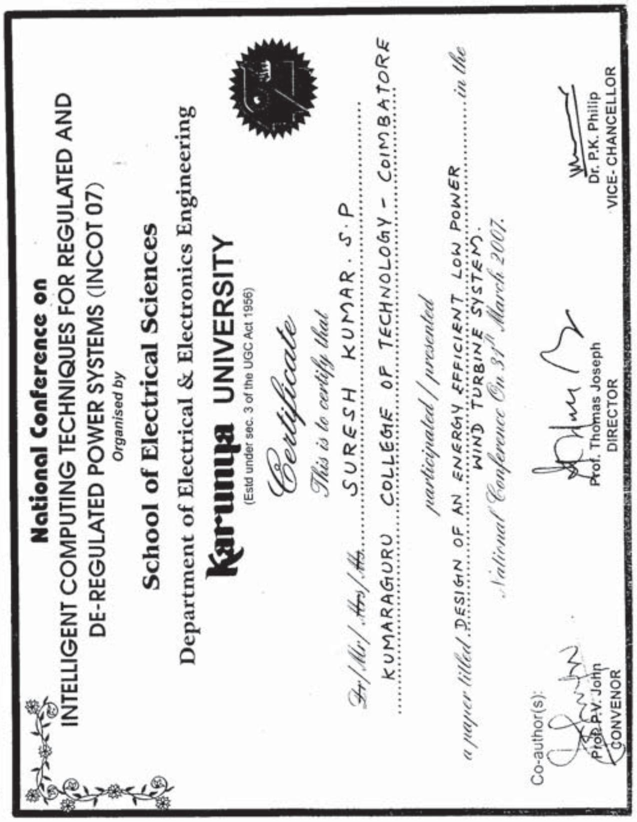

National Conference on
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ABSTRACT

This project proposes the design of turbine blades for a horizontal axis, three-blade wind turbine system, which can produce approximately 500 watts power at a low wind velocity [1-3 m/s] and the simulation of wind turbine system. The world is at present facing a serious crisis for electrical energy. The fossil fuels which are being used now are very much limited and hence it is essential for other alternative sources of energy. Hence the alternative source which is non-conventional energy (i.e. wind energy) has to be utilized greatly in rural areas, where the average wind velocity is low and power requirement is not high. The power generation by wind turbine is not been successful so far, because the production of electricity by wind turbine at a specific site depends on many factors. These factors include the wind speed conditions at the site and system cost, particularly the rated cut in and cut out wind speed parameters; it is desirable to design and select a low cost wind turbine system which is best suited for a particular site in order to obtain the maximum power benefit at a available low wind velocity. According to our personal computer interface based anemometer wind velocity analysis, the proposed specifications are determined for turbine blade design to extract the maximum output from low wind velocity.

ஆய்வு சுருக்கம்

இன்றைய காலகட்டத்தில் மின்சாரத்தின் உபயோகம் அதிகமாக உள்ளதால், மின் உற்பத்தியும் அதிகப்படுத்த வேண்டிய கட்டாயம் உள்ளது. மின் உற்பத்தியை செய்ய ஆக்க ஆற்றல் நிலை மற்றும் மறு ஆக்க ஆற்றல் என இரண்டு நிலைகள் உள்ளன. அவைகளில் மறு ஆக்க ஆற்றல் நிலை தான் சிறந்தது. ஏனெனில் ஆக்க ஆற்றல் நிலையின் எரிபொருள் பற்றாக்குறை, மற்றும் உற்பத்தி செலவு தான் காரணம். எனவே, இந்த ஆய்வுத் திட்டம் மறு ஆக்க ஆற்றல் நிலையின் காற்றாலை மின் உற்பத்தியை பற்றி விரிவாக எடுத்துரைக்கிறது.

இப்போது உள்ள காற்றாலைகளுக்கு மின் உற்பத்தியை தொடங்க குறைந்தது 3 m/s காற்றின் வேகம் தேவைப்படுகிறது. இந்த அளவிலான காற்றின் வேகம் அனைத்து இடங்களிலும் கிடைப்பது இல்லை. ஒரு குறிப்பிட்ட சில இடங்களிலும் மட்டும் தான் கிடைக்கிறது. எடுத்துக்காட்டாக, நம்முடைய கல்லூரி அமைந்துள்ள இடத்தினை சுற்றி காற்றழுத்தத்தை அனிமோமீட்டர் என்னும் காற்றின் வேகத்தை அளவிடும் கருவியை கொண்டு அளவிடும் போது நமக்கு ஆண்டின் சராசரியாக 1 m/s முதல் 5 m/s வரை காற்றழுத்தம் தான் கிடைக்கிறது. இந்த காற்றழுத்தம் தற்போது உள்ள காற்றாலைகளுக்கு பற்றாக்குறையாக உள்ளது. எனவே, இந்த காற்றழுத்த நிலைக்கேற்ப காற்றாலையை வடிவமைக்க வேண்டிய கட்டாயம் ஏற்பட்டுள்ளது. இந்த ஆய்வு திட்டத்தில், குறைந்த காற்றழுத்தத்தில் ஆற்றலை உற்பத்தி செய்யும் காற்றாலையின் இறக்கைகள் (Blades) வடிவமைக்கப்பட்டுள்ளது. இந்த காற்றாலைக்கு குறைந்தது 1.5 m/s காற்றின் வேகமே 500 வாட்ஸ் ஆற்றலை உற்பத்தி செய்யப் போதுமானது.

மேலும் காற்றாலையின் இறக்கை வடிவமைப்பதற்காக M.File Programme எழுதப்பட்டுள்ளது. இந்த Programme-ஐ பயன்படுத்தி இறக்கையின் அகலம், நீளம், கோணம் (Pitch Angle) கண்டுபிடிக்கலாம் மற்றும் காற்றாலையின் மாதிரி சிமுலேசன் (Simulation) மூலம் ஆய்வு செய்யப்பட்டுள்ளது.

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CONTENTS

CHAPTER 1 INTRODUCTION

CHAPTER 2 WIND ENERGY SYSTEM - AN NTRODUCTION

CHAPTER 3 DESIGN CONSIDERATIONS - A STUDY

CHAPTER 4 DESIGN SPECIFICATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS	ABBREVIATIONS
E	Energy (KWh)
M	Mass of moving air
v	Wind speed (m/sec)
ρ	Air density (kg/m2)
F	Force (N-M)
P	Power output (KW)
A	Swept area of wind turbine (m2)
Cp	Power coefficient
r	Radius (m)
ω	Rotational speed of the wind turbine
λ	Tip speed ratio
β	Pitch angle
β_1	Inlet blade angle
β_2	Outlet blade angle
H	Total head in meter
Q	Flow rate in m^3/ sec
Γ	Circulation for single blade
n_s	Specific speed
g	Specific gravity
d bar	Constant value
D_H	Hub diameter
D_O	Outer diameter
K_H	Unit Head
K_Q	Unit Discharge
C_M	Flow velocity
U	Turbine speed
Z	Number of blades
α_r	Absolute velocity

X, X_1, Y, Y_1, and Y_{max}	Blade profile coordinates
W_{ru}	Tangential relative velocity
η_m	Efficiency of wind turbine
η_g	Efficiency of generator
V_{dc}	Dc output voltage
I_{dc}	Dc input voltage
M	Modulation index of PWM inverter
Po	Rectifier output power.
PWM	Pulse Width Modulation
V_t	Terminal voltage
I_a	Armature current
Z_s	Source impedance
R_a	Armature resistance
V_q,V_d	q axis, d axis voltage respectively
R_s	Source resistance
I_q, I_d	q axis, d axis Current respectively
X_q, X_d	Reactance of q axis, d axis respectively
δ	Power angle
θ	Power factor angle
p d/dt	Differential operator
Te	Electromagnetic Torque Produced
T_g	Generator Torque
V_{abc}	Phase voltages
I_{abc}	Phase currents
R_{abc}	Phase Resistances
λ_{abc}	Flux Linkages in abc phases
K_S	Shaft compliance Coefficient

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

People today generally associate wind energy with dense arrays of commercial scale turbines that rise on 200ft or taller towers, so they are often less familiar with wind turbines scaled for personal use on small acreages. Small (or residential) wind energy systems typically generate just enough power to meet the demands of a home, farm, or small business. They range from 400 watts to 1 kW (or) more, and typically consist of a single turbine, while commercial wind farms consist of dozens (or) even hundreds of mw scale turbines. Low power wind generators powered lights, radios and kitchen appliances of modern urban life. In this new century, small wind turbines are an attractive investment for residents in rural areas looking for relief from high-energy costs. Small turbines also contribute a larger public benefit by reducing demand on utility systems now supplied primarily by centralized fossil fuel plants. In recent years this system has left electricity customers vulnerable to power shortage and sharp price increases. The development of large-scale power plants has become riskier in the turbulent energy market, creating the need for new forms of distributed generation sources to make the system more secure and sustainable. Small wind systems can be an important of such energy independence.

The power obtained from wind turbine can be utilized for irrigation and lighting provided there is sufficient wind. A wind power plant is an airscrew, which is used to convert the kinetic energy (i.e. energy of motion) of the wind into mechanical energy that can be utilized to perform useful work or to generate electricity. Most machines for converting wind energy into mechanical energy consist basically of a no blades radiating from a hub or central axis. Renewable power generation systems have been recently getting more and more attention due to the cost competitiveness, and are environment friendly as compared to the fossil fuel and nuclear power generation. Besides the conventional renewable power generation such as hydro and pumping storage, wind power generation has been considered as the most cost effective with developing potential. For wind speed exceeding1.5m/s, the wind turbine can generate power and the rated output power can be obtained for wind speed

above 8m/s. The increase of unit size and enhancement of performance it higher loading factor and reliability have made wind power generation more attractive and its unit generation cost becomes very competitive as compared to traditional fossil generation. According to IWEA estimation, 12% of the power demand of the whole world will be provided by wind generation for year 2020.The utilization of wind energy may be an attractive alternative in places such as rural areas, where fuel is usually expensive and wind regimes are particularly favorable. These conditions are likely to occur in places that are geographically remote and have weak, autonomous power systems. These places are conventionally supplied by diesel power plants, and the installation of wind generators as fuel cost reduction is economically attractive.

1.2 OBJECTIVE

Design and fabrication of turbine blades for low wind velocity and low power wind turbine system.

1.3 LITERATURE SURVEY

There were some fixed ideas in our mind before we actually started on this project. The first of them was to try out some new (or) original idea which has never been tried before instead of some tried out ones, because this was going to be our real chance to design something all by ourselves. The other idea was to combat the price hence which is so prevalent these days by making use of proper design and fabrication.

So we first started with analyzing IEEE standard papers, journals, conference proceedings and wind energy based websites. By making use of these resources we found two main things, first thing is minimum number usage of vertical axis wind turbine; though it has more advantages than others especially a TURBY system. TURBY is revolutionary vertical axis wind turbine specially designed foe use in low wind rural areas. So we stared studying about TURBY system but we couldn't continue because high cost of this system.

Second thing is availability of wind; it varies in place to place, day to day time to time. Also in particular area only we can get a good wind velocity for electricity production but that also not available in through out the year. Before erect a wind turbine in particular area we can measure and record the speed of the wind

through out the year by means of anemometer. So we bought one anemometer and that interfaced with pc for analyzing wind velocity. From graphs (the graphs are shown in chapter 5) it is cleared that the average available wind velocity is 1 to 5 m/s through out the year. This is not enough for producing electricity by wind turbine because now days existing system requires minimum 3 m/s wind velocity to start produce the power. So we planned to design and fabricate the low power, low wind velocity and low cost wind turbine system for rural area application. In this my contribution was to design the blades for low power wind turbine system

CHAPTER 2

WIND ENERGY SYSTEM

2.1 FACTS ABOUT WORLD ENERGY CONSUMPTION

In the 20 years from 1970-89 world energy consumption rose by about 53 percent from 2.14x1020 J to 3.28x1020 J. The consumption of fossil fuel energy climbed by 49.2 percent from 2.09x1020 J to 3.12 x1020 J and that of nuclear energy by 22.7 percent from 9.83 x1016 J to 2.33 x1018 J. In the seventies of the 20th century people worried about a coming shortage of energy resources and the direct consequences for the environment e.g. acid rain. From the 1980's, the indirect consequences of high energy consumption e.g. global warming and the ozone hole became a greater concern. The outlook for future energy demand is that it is predicted to rise quite dramatically. From 1998 to 2010 the worldwide yearly electricity demand will rise by about 30 percent to 20,852 TWh and by nearly 50 percent to 27,326 TWh by 2020, with an average annual growth rate of 2 percent. Until 2025, the consumption of the developing countries is estimated to rise on the basis of population growth and increasing industrialization by more than 100 percent. Although the share of fossil fuels used in the production sector will shrink remarkably, the CO2 emissions will increase by about 50 percent due to overall rising consumption. The abovementioned risk to the biosphere and the limit on fossil fuel energy resources will force new solutions. One of the best solutions on the basis of today's technologies consists of a combination of saving energy by different measures and the exploitation of additional sustainable resources of energy such as solar energy (photovoltaic, heat collectors) and wind energy. A nation's development is measured by the growth of agriculture, infrastructure for industrial growth and, importantly, power generation. Electric power is universally required in the production of commodities and services and for their transformation. The growth of the industrial sector has resulted in a phenomenal increase in the demand for power, generation of which could not be stepped up correspondingly due to constraints in the availability of fossil fuels. Hence, the gap between demand and supply of power is increasing.

2.2 HISTORICAL BACKGROUND OF WIND POWER USAGE

Wind machines were used for grinding grain in Persia as early as 200 B.C. This type of machine was introduced into the Roman Empire by 250 A.D. By the 14th century Dutch windmills were in use to drain areas of the Rhine River delta. In Denmark by 1900 there were about 2500 windmills for mechanical loads such as pumps and mills, producing an estimated combined peak power of about 30 MW. Charles F. Brush built the first windmill for electricity production in Cleveland, Ohio in 1888, and in 1908 there were 72 wind-driven electric generators from 5 kW to 25 kW. The largest machines were on 24 m (79 ft) towers with four-bladed 23 m (75 ft) diameter rotors. By the 1930s windmills were mainly used to generate electricity on farms, mostly in the United States where distribution systems had not yet been installed. In this period, high-tensile steel was cheap, and windmills were placed on prefabricated open steel lattice towers.

2.3 GENERATION OF ELECTRICITY FROM WIND TURBINE

Wind power is converted into electricity by a wind turbine. In a typical, modern, large-scale wind turbine, the kinetic energy in the wind (the energy of moving air molecules) is converted to rotational motion by the rotor – typically a three-bladed assembly at the front of the wind turbine. The rotor turns a shaft, which transfers the motion into the nacelle (the large housing at the top of a wind turbine tower). Inside the nacelle; the slowly rotating shaft enters a gearbox that greatly increases the rotational shaft speed. The output (high-speed) shaft is connected to a generator that converts the rotational movement into electricity at medium voltage (a few hundred volts).The electricity flows down heavy electric cables inside the tower to a transformer, which increases the voltage of the electric power to the distribution voltage (a few thousand volts). (Higher voltage electricity flows more easily through electric lines, generating less heat and fewer power losses.) The distribution-voltage power flows through underground lines to a collection point where the power may be combined with other turbines. In many cases, the electricity is sent to nearby farms, residences and towns where it is used. Otherwise, the distribution-voltage power is sent to a substation where the voltage is increased dramatically to transmission-voltage power (a few hundred thousand volts) and sent through very tall transmission lines many miles to distant cities and factories.

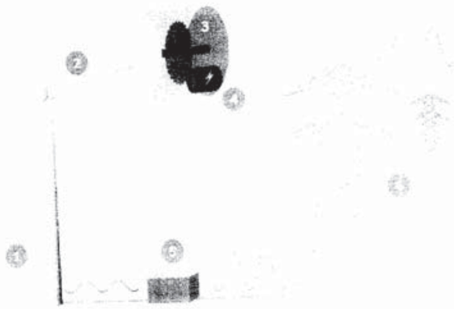

Figure 2.1 Generation of Electricity from Wind Turbine

1. Tower, 2. Shaft inside the Nacelle, 3. Gear Box, 4. Generator, 5. Voltage Regulation, 6. Distribution System.

2.3.1 Types of Wind Turbine

Horizontal axis

Horizontal Axis Wind Turbines (HAWT) has the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Simple wind vane points small turbines, while large turbines generally use a wind sensor coupled with a servomotor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable for generating electricity. Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds.

Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount. Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds, the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Because turbulence leads to fatigue failures and reliability is so important, most HAWTs are upwind machines.

Advantages of horizontal wind turbines

- Blades are to the side of the turbine's center of gravity, helping stability.
- Ability to wing warp, which gives the turbine blades the best angle of attack.
- Ability to fold up the rotor blades in a storm, to minimize damage.
- Tall tower allows access to stronger winds, and can be built offshore away from residential areas. Every ten meters up, the wind speed usually increases by 20% and the power output by 34%.
- Since the rotor blades are shaped like a pinwheel, the airfoils can withstand greater force from the wind. This allows wind turbines to rotate faster.
- Self-starting.
- Cheaper because of higher production volume.

Disadvantages of horizontal wind turbines

- Poor performance at low altitudes, due to lower wind speed.
- Location is determined by latitude and weather. This can prove a problem in low-lying areas.
- Downwind variants suffer from fatigue and structural failure caused by turbulence.
- Horizontal wind turbines in urban areas tend to cause a lot of drag that reduces efficiency in power production

Vertical Axis

Vertical Axis Wind Turbines (or VAWTs) have the main rotor shaft running vertically. The advantages of this arrangement are that the generator and/or gearbox can be placed at the bottom, near the ground, so the tower doesn't need to support it, and that the turbine doesn't need to be pointed into the wind. Drawbacks are usually the pulsating torque produced during each revolution, and the difficulty of mounting vertical axis turbines on towers, meaning they must operate in the slower, more turbulent air flow near the ground, with lower energy extraction efficiency.

Advantages of vertical wind turbines

- Easier to maintain because their generator is located on the ground. This is due to the vertical wind turbine's shape. The airfoils or rotor blades are placed on top of a shaft that is connected to a generator, enabling a safe and easy work environment.
- Due to the turbine's large surface area, very little wind is required to turn the rotor blades to generate power. Vertical wind turbines have two subgroups: Darries and Savonius. Both were invented for the same multipurpose role of generating electricity in a flat open area far inland to create high torque, also creating a high-voltage output that can power residential and commercial applications, such as televisions and lighting.
- Vertical wind turbines have a higher airfoil pitch angle, giving improved aerodynamics while decreasing drag at low and high pressures.
- Being near the ground allows the turbine to collect extra energy from wind that bounces off a forty-five degree slope from the base of the turbine to the ground; when the wind hits the ground and is directed up the slope, around twenty percent more power is added to the wind turbine.

Disadvantages of vertical wind turbines

- The environmental impact upon migratory birds. The large surface area can easily suck birds and other objects into the wind turbine, due to a vortex effect that can be attributed to the vertical position of the rotor blades.
- There is a height limitation to how big a vertical wind turbine can be built.
- Instability due to its main center of gravity being in the airfoil. Strong support at the base is required.
- Must be located in an area with steady prevailing winds.
- Installing a vertical wind turbine is expensive, because they are not as widely used as horizontal wind turbines.

2.4 COST AND GROWTH

The cost of wind-generated electric power has dropped substantially since the first modern turbines were installed in the 1980's. By 2004, according to some sources, the price in the India was lower than the cost of fuel-generated electric power, even without taking externalities into account. At this time, wind energy was reported to cost one-fifth as much as it did in the 1980s, and some expected that downward trend to continue, as larger multi-megawatt turbines are mass-produced. An Indian Wind Energy Association report gives an average generation cost of onshore wind power of around 3.2 rupees per kilowatt-hour. Wind power is growing quickly, at about 38% in 2003, up from 25% growth in 2002. In the India, as of 2003, wind power was the fastest growing form of electricity generation on a percentage basis. For wind and hydropower, fuel costs close to zero and relatively low maintenance costs; in economic terms, wind power has an extremely low marginal cost and a high proportion of up-front costs. The "cost" of wind energy per unit of production is generally based on average cost per unit, which incorporates the cost of construction, borrowed funds, return to investors (including cost of risk), estimated annual production, and other components. Since these costs are averaged over the projected useful life of the equipment, which may be in excess of twenty years, cost estimates per unit of generation are highly dependent on these assumptions. Existing generation capacity represents sunk costs, and the decision to continue production will depend on marginal costs going forward, not estimated average costs at project inception.

2.5 UTILIZATION

2.5.1 Large scale

Table: 2.1 Total installed wind power capacity (end of year & latest estimates)

		Capacity (MW)		
Rank	Nation	2006	2005	2004
1	Germany	20,622	18,428	16,629
2	Spain	11,615	10,028	8,504
3	USA	11,603	9,149	6,725
4	India	6,270	4,430	3,000
5	Denmark	3,136	3,128	3,124
6	China	2,405	1,260	764
7	Italy	2,123	1,717	1,265
8	United Kingdom	1,963	1,353	888
9	Portugal	1,716	1,022	522
10	France	1,567	757	386
11	Nether land	1,560	1,219	1,078
12	Canada	1,451	683	444
13	Japan	1,394	1,040	896
14	Austria	965	819	606
15	Australia	817	572	379
16	Greece	756	573	473
17	Ireland	745	496	339
18	Sweden	572	510	452
19	Norway	325	270	270
20	Brazil	237	29	240
21	New Zealand	-	168	168
22	Belgium	193	167	95
23	Egypt	-	145	145
24	South Korea	-	119	23
25	Taiwan	-	103	13
26	Finland	86	82	82
27	Poland	152	73	63
28	Ukraine	85	73	69
29	Costa Rica	-	70	70
30	Morocco	-	64	54
31	Luxembourg	35	35	35
32	Iran	-	32	25
33	Estonia	-	30	3
34	Philippines	32	29	29
35	Czech Republic	50	28	17
36	Turkey	50	20	-
37	Lithuania	80	-	
	World total	**73,904 MW**	**58,982**	**47,671**

There are many thousands of wind turbines operating, with a total capacity of 58,982 MW of which Europe accounts for 69% (2005). The average output of one megawatt of wind power is equivalent to the average consumption of about 160 American households. Wind power was the most rapidly growing means of alternative electricity generation at the turn of the century and world wind generation capacity more than quadrupled between 1999 and 2005. 90% of wind power installations are in the US and Europe, but the share of the top five countries in terms of new installations fell from 71% in 2004 to 55% in 2005. By 2010, the World Wind Energy Association expects 120,000 MW to be installed worldwide, implying an anticipated growth rate of about 15% per year. Germany, Spain, the United States, India, and Denmark have made the largest investments in wind-generated electricity. Denmark is prominent in the manufacturing and use of wind turbines, with a commitment made in the 1970s to eventually produce half of the country's power by wind. Denmark generates over 20% of its electricity with wind turbines, the highest percentage of any country and is fifth in the world in total power generation (which can be compared with the fact that Denmark is 56th on the general electricity consumption list). Denmark and Germany are leading exporters of large (0.66 to 5 MW) turbines. Wind accounts for 1% of the total electricity production on a global scale (2005). Germany is the leading producer of wind power with 32% of the total world capacity in 2005 (6% of German electricity); the official target is that by 2010, renewable energy will meet 12.5% of German electricity needs — it can be expected that this target will be reached even earlier. Germany has 16,000 wind turbines, mostly in the north of the country — including three of the biggest in the world, constructed by the companies Enercon (4.5 MW), Multibrid (5 MW) and Repower (5 MW). Germany's Schleswig-Holstein province generates 25% of its power with wind turbines. Spain and the United States are next in terms of installed capacity. In 2005, the government of Spain approved a new national goal for installed wind power capacity of 20,000 MW by 2012. According to trade journal Wind power monthly; however, in 2006 they abruptly halted subsidies and price supports for wind power. According to the American Wind Energy Association, wind generated enough electricity to power 0.4% (1.6 million households) of total electricity in US, up from less than 0.1% in 1999. In 2005, both Germany and Spain have produced more electricity from wind power than from hydropower plants. US Department of Energy studies have concluded wind harvested in just three of the fifty U.S. states could

P-1874

provide enough electricity to power the entire nation, and that offshore wind farms could do the same job. Wind power growth was estimated at up to 50% in the U.S. in 2006, and has reached 11,603 MW of installed capacity for growth of 27% in one year. India ranks 4th in the world with a total wind power capacity of 5,340 MW. Wind power generates 3% of all electricity produced in India. The World Wind Energy Conference in New Delhi in November 2006 will give additional impetus to the Indian wind industry. In December 2003, General Electric installed the world's largest offshore wind turbines in Ireland and plans are being made for more such installations on the west coast, including the possible use of floating turbines. The wind farm near Muppandal, India, provides an impoverished village with energy for work. On August 15, 2005, China announced it would build a 1000-megawatt wind farm in Hebei for completion in 2020. China reportedly has set a generating target of 20,000 MW by 2020 from renewable energy sources — it says indigenous wind power could generate up to 253,000 MW. Following the World Wind Energy Conference in November 2004, organized by the Chinese and the World Wind Energy Association, a Chinese renewable energy law was adopted. In late 2005, the Chinese government increased the official wind energy target for the year 2020 from 20 GW to 30 GW.Another growing market is Brazil, with a wind potential of 143 GW. The federal government has created an incentive program, called Proinfa, to build production capacity of 3300 MW of renewable energy for 2008, of which 1422 MW through wind energy. The program seeks to produce 10% of Brazilian electricity through renewable sources. Brazil produced 320 TWh in 2004. France recently announced a very ambitious target of 12 500 MW installed by 2010.

2.5.2 Small Scale

Wind turbines have been used for household electricity generation in conjunction with battery storage over many decades in remote areas. Household generator units of more than 1 kW are now functioning in several countries. To compensate for the varying power output, grid-connected wind turbines may utilize some sort of grid energy storage. Off-grid systems either adapt to intermittent power or use photovoltaic or diesel systems to supplement the wind turbine. Wind turbines range from small four hundred watt generators for residential use to several megawatt machines for wind farms and offshore. The small ones have direct drive generators,

direct current output, aero elastic blades, and lifetime bearings and use a vane to point into the wind; while the larger ones generally have geared power trains, alternating current output, and flaps and are actively pointed into the wind. Direct drive generators and aero elastic blades for large wind turbines are being researched and direct current generators are sometimes used. In urban locations, where it is difficult to obtain large amounts of wind energy, smaller systems may still be used to run low power equipment. Distributed power from rooftop mounted wind turbines can also alleviate power distribution problems, as well as provide resilience to power failures. A wind turbine that charges a small battery, replacing the need for a connection to the power grid and/or maintaining service despite possible power grid failures, may power equipment such as parking meters or wireless Internet gateways. Small-scale turbines are available that are approximately 7 feet (2 m) in diameter and produce 900 watts. Units are lightweight, e.g. 16 kilograms (35 lbs), allowing rapid response to wind gusts typical of urban settings and easy mounting much like a television antenna. It is claimed that they are inaudible even a few feet under the turbine. [Citation needed] Dynamic braking regulates the speed by dumping excess energy, so that the turbine continues to produce electricity even in high winds. The dynamic braking resistor may be installed inside the building to provide heat (during high winds when more heat is lost by the building, while more heat is also produced by the braking resistor). The proximal location makes low voltage (12 volt, or the like) energy distribution practical. An additional benefit is that owners become more aware of electricity consumption, possibly reducing their consumption down to the average level that the turbine can produce. According to the World Wind Energy Association, it is difficult to assess the total number or capacity of small-scaled wind turbines, but in China alone, there are roughly 300,000 small-scale wind turbines generating electricity. Small wind turbines have a fundamental advantage over large wind turbines: this is the square-cube law. The wind capture or swept area of turbines is proportional to the square of the blade radius, but the volume, and therefore mass, of turbines is (approximately) proportional to the cube of the blade radius. Design and materials improvements have made both large and small turbines lighter for given output. Larger turbines have the advantage of commodity pricing, lower land footprint per output, and lower cost of electronics and minor hardware as a percentage of unit cost. If the price of small turbines can be lowered to near materials cost, with the

barest premium for design and labor, then, with their lower mass per output, they can compete favorably.

2.6 WIND POWER MAJOR ISSUES

2.6.1 Scalability

A key issue debated about wind power is its ability to scale to meet a substantial portion of the world's energy demand. There are significant economic, technical, and ecological issues about the large-scale use of wind power that may limit its ability to replace other forms of energy production. Most forms of electricity production also involve such trade-offs, and many are also not capable of replacing all other types of production for various reasons. A key issue in the application of wind energy to replace substantial amounts of other electrical production is intermittency. At present, it is unclear whether wind energy will eventually be sufficient to replace other forms of electricity production, but this does not mean wind energy cannot be a significant source of clean electrical production on a scale comparable to or greater than other technologies, such as hydropower. A significant part of the debate about the potential for wind energy to substitute for other electric production sources is the level of penetration. With the exception of Denmark, no countries or electrical systems produce more than 10% from wind energy, and most are below 2%. While the feasibility of integrating much higher levels (beyond 25%) is debated, significantly more wind energy could be produced worldwide before these issues become significant.

2.6.2 Theoretical Potential

Wind's long-term theoretical potential is much greater than current world energy consumption. The most comprehensive study to date found the potential of wind power on land and near-shore to be 72 TW, or over five times the world's current energy use and 40 times the current electricity use. The potential takes into account only locations with Class 3 (mean annual wind speeds = 6.9 m/s at 80 m) or better wind regimes, which includes the locations suitable for low-cost wind power generation and is in that sense conservative. It assumes 6 turbines per square km for 77-m diameter, 1.5 MW turbines on roughly 13% of the total global land area (though that land would also be available for other compatible uses such as farming). This

potential assumes a capacity factor of 48% and does not take into account the practicality of reaching the windy sites, of transmission, of competing land uses, of transporting power over large distances, or of switching to wind power. To determine the more realistic technical potential it is essential how large a fraction of this land could be made available to wind power. Although the theoretical potential is vast, the amount of production that could be economically viable depends on a number of exogenous and endogenous factors, including the cost of other sources of electricity and the future cost of wind energy farms. Offshore resources experience mean wind speeds about 90% greater than those on land, so offshore resources could contribute about seven times more energy than land. This number could also increase with higher altitude or airborne wind turbines. To meet energy demands worldwide in the future in a sustainable way, many more turbines will have to be installed. This will affect more people and wildlife habitat.

2.6.3 Economics and Feasibility

Wind energy in many jurisdictions receives some financial or other support to encourage its development. A key issue is the comparison to other forms of energy production, and their total cost. Two main points of discussion arise: direct subsidies and externalities for various sources of electricity, including wind. Wind energy benefits from subsidies of various kinds in many jurisdictions, either to increase its attractiveness, or to compensate for subsidies received by other forms of production or which have significant negative externalities. Most forms of energy production create some form of negative externality: costs that are not paid by the producer or consumer of the good. For electric production, the most significant externality is pollution, which imposes costs on society in the form of increased health expenses, reduced agricultural productivity, and other problems. Significantly, carbon dioxide, a greenhouse gas produced when using fossil fuels for electricity production, may impose costs on society in the form of global warming. Few mechanisms currently exist to impose (or internalizes) this external cost in a consistent way between various industries or technologies, and the total cost is highly uncertain. Other significant externalities can include national security expenditures to ensure access to fossil fuels, remediation of polluted sites, destruction of wild habitat, loss of scenery/tourism, etc.

2.6.4 Intermittency and Variability

Electricity generated from wind power can be highly variable at several different timescales: from hour to hour, daily, and seasonally. Annual variation also exists, but is not as significant. This variability can present substantial challenges to incorporating large amounts of wind power into a grid system, since to maintain grid stability; energy supply and demand must remain in balance. While the negative effects of intermittency have to be considered in the economics of power generation, wind is unlikely to suffer momentary failure of large amounts of generation, which may be a concern with some traditional power plants. In this sense, it may be more reliable due to the distributed nature of generation.

2.6.5 Grid Management

Grid operators routinely control the supply of electricity by cycling generating plants on or off at different timescales. Most grids also have some degree of control over demand, through either demand management or load shedding. Management of either supply or demand has economic implications for suppliers, consumers and grid operators but is already widespread. Variability of wind output creates a challenge to integrating high levels of wind into energy grids based on existing operating procedures. Critics of wind energy argue that methods to manage variability increase the total cost of wind energy production substantially at high levels of penetration, while supporters note that tools to manage variable energy sources already exist and are economical, given the other advantages of wind energy. Supporters note that the variability of the grid due to the failure of power stations themselves, or the sudden change of loads, exceeds the likely rate of change of even very large wind power penetrations. There is no generally accepted "maximum" level of wind penetration, and practical limitations will depend on the configuration of existing generating plants, pricing mechanisms, capacity for storage or demand management, and other factors. A number of studies for various locations have indicated that up to 20% (stated as the proportion of wind nameplate capacity to peak energy demand) may be incorporated with minimal difficulty. These studies have generally been for locations with reasonable geographic diversity of wind; suitable generation profile (such as some degree of dispatch able energy and particularly hydropower with storage capacity); existing or contemplated demand management; and interconnection/links into a larger grid area allowing for import and export of electricity when needed. Beyond this level, there are few technical reasons why more wind power could not be incorporated, but the economic implications become more significant and other solutions may be preferred. At present, very few locations have penetration of wind energy above 5%, and only Denmark is in the range of this 20% penetration level.

2.6.6 Energy Storage

One solution currently being piloted on wind farms is the use of rechargeable flow batteries as a rapid-response storage medium. Vanadium redox flow batteries are currently installed at Huxley Hill wind farm (Australia), Tomari Wind Hills at Hokkaido (Japan), as well as in other non-wind farm applications. A further 12 MWh flow battery is to be installed at the Some Hill wind farm (Ireland). The supplier concerned is commissioning a production line to meet other anticipated orders. An alternate solution is to use flywheel energy storage. This type of solution has been implemented by EDA in the Azores on the islands of Graciosa and Flores. This system uses an 18MWs flywheel to improve power quality and thus allow increased renewable energy usage. V2G (Vehicle to Grid) offers another potential solution. In 2006, several companies (Altairnano, A123 Systems, and Electrovaya) announced lithium batteries which could power future EVs (Electric Vehicles) and PHEVs (Plug-in Hybrid Electric Vehicles). A feature of these batteries is a high number of charge/discharge cycles per battery lifetime (Altairnano claim 15,000 cycles). Download (charging) would preferably take place during periods of excess wind (or solar) generation.

2.6.7 Predictability

Related to but essentially different from variability is the short-term (hours - days) predictability of wind plant output. Like the other electricity sources wind energy must be "scheduled" - a challenge because of the nature of the energy source. To this end wind power forecasting utilities or system operators employ methods, which methods are essentially similar to the more general weather forecasting methods used by met offices to date for various reasons the predictability of wind plant output is limited.

2.6.8 CO2 Emissions and Pollution

Wind power consumes no fuel for continuing operation, and has no emissions directly related to electricity production. Wind power stations, however, consume resources in manufacturing and construction, as do most other power production facilities. Wind power may also have an indirect effect on pollution at other production facilities, due to the need for reserve and regulation, and may affect the efficiency profile of plants used to balance demand and supply, particularly if those facilities use fossil fuel sources. Compared to other power sources, however, wind energy's direct emissions are low, and the materials used in construction (concrete, steel, fiberglass, generation components) and transportation are straightforward. Wind power's ability to reduce pollution and greenhouse gas emissions will depend on the amount of wind energy produced, and hence scalability.

- Wind power is a renewable resource, which means using it will not deplete the earth's supply of fossil fuels. It also is a clean energy source, and operation does not produce carbon dioxide, sulfur dioxide, mercury, particulates, or any other type of air pollution, as do conventional fossil fuel power sources.
- Electric power production is only part of a country's energy use, so wind power's ability to mitigate the negative effects of energy use — as with any other clean source of electricity — is limited (except with a potential transition to electric or hydrogen vehicles).
- The desired mitigation goals can be achieved at lower cost and to a greater degree by continued improvements in general efficiency — in building, manufacturing, and transport — than by wind power. During manufacture of the wind turbine, steel, concrete, aluminum and other materials will have to be made and transported using energy-intensive processes, generally using fossil energy sources.
- The energy return on investment (EROI) for wind energy is equal to the cumulative electricity generated divided by the cumulative primary energy required to build and maintain a turbine. The EROI for wind ranges from 5 to 35, with an average of around 18. This places wind energy in a favorable position relative to conventional power generation technologies in terms of EROI.

- The ecological and environmental costs of wind plants are paid by those using the power produced, with no long-term effects on climate or local environment left for future generations.

2.6.9 Ecology

- Because it uses energy already present in the atmosphere, and can displace fossil-fuel generated electricity (with its accompanying carbon dioxide emissions), wind power mitigates global warming. While wind turbines might impact the numbers of some bird species, conventionally fueled power plants could wipe out hundreds or even thousands of the world's species through climate change, acid rain, and pollution.
- Unlike fossil fuel or nuclear power stations, which circulate or evaporate large amounts of water for cooling, wind turbines do not need water to generate electricity.

2.6.10 Ecological Footprint

Large-scale onshore and near-shore wind energy facilities (wind farms) can be controversial due to aesthetic reasons and impact on the local environment. Large-scale offshore wind farms are not visible from land and according to a comprehensive 8-year Danish Offshore Wind study on "Key Environmental Issues" have no discernable effect on aquatic species and no effect on migratory bird patterns or mortality rates. Modern wind farms make use of large towers with impressive blade spans, occupy large areas and may be considered unsightly at onshore and near-shore locations. They usually do not, however, interfere significantly with other uses, such as farming. The impact of onshore and near-shore wind farms on wildlife-particularly migratory birds and bats—is hotly debated, and studies with contradictory conclusions have been published. Two preliminary conclusions for onshore and near-shore wind developments seem to be supported: first, the impact on wildlife is likely low compared to other forms of human and industrial activity; second, negative impacts on certain populations of sensitive species are possible, and efforts to mitigate these effects should be considered in the planning phase.

2.6.11 Land Use

- Clearing of wooded areas is often unnecessary, as the practice of farmers leasing their land out to companies building wind farms is common. Less than 1% of the land would be used for foundations and access roads, the other 99% could still be used for farming. Turbines can be sited on unused land in techniques such as center pivot irrigation.
- The clearing of trees around onshore and near-shore tower bases may be necessary to enable installation.
- Wind turbines should ideally be placed about ten times their diameter apart in the direction of prevailing winds and five times their diameter apart in the perpendicular direction for minimal losses due to wind park effects. As a result, wind turbines require roughly 0.1 square kilometers of unobstructed land per megawatt of nameplate capacity. A wind farm that produces the energy equivalent of a conventional 2 GW power plant might have turbines spread out over an area of approximately 200 square kilometers.
- Areas under onshore and near-shore wind farms can be used for farming, and are protected from further development.
- Although there have been installations of wind turbines in urban areas, buildings may interfere with wind, and the value of land is likely too high if it would interfere with other uses to make urban installations viable. Installations near major cities on unused land, particularly offshore for cities near large bodies of water, may be of more interest.
- Some offshore locations are uniquely located close to ample transmission and high load centers however that is not the norm for most offshore locations. Most offshore locations are at considerable distances from load centers and may face transmission and line loss challenges.

2.6.12 Impact on Wildlife

- Onshore and near-shore studies show that the number of birds killed by wind turbines is negligible compared to the number that die as a result of other human activities such as traffic, hunting, power lines and high-rise buildings and especially the environmental impacts of using non-clean power sources.

- Some onshore and near-shore windmills kill birds, especially birds of prey. More recent sitting generally takes into account known bird flight patterns, but some paths of bird migration, particularly for birds that fly by night, are unknown.
- The numbers of bats killed by existing onshore and near-shore facilities has troubled even industry personnel.

2.6.13 Aesthetics

- Recorded experience that onshore and near-shore wind turbines are noisy and visually intrusive creates resistance to the establishment of land-based wind farms in many places. Moving the turbines far offshore (10 km or more) mitigates the problem, but offshore wind farms may be more expensive and transmission to on-shore locations may present challenges in many but not all cases.
- Some residents near onshore and near-shore windmills complain of "shadow flicker," which is the alternating pattern of sun and shade caused by a rotating windmill casting a shadow over residences
- Large onshore and near-shore wind towers require aircraft warning lights, which create light pollution at night, which bothers humans and can disrupt the local ecosystem.
- Newer wind farms have more widely spaced turbines due to the greater power of the individual wind turbines, and to look less cluttered. The aesthetics of onshore and near-shore wind turbines have been compared favorably to those of pylons from conventional power stations.

CHAPTER 3

DESIGN CONSIDERATIONS

3.1 INTRODUCTION

Utilizing wind energy entails installing a device that converts part of the kinetic energy in then. Atmosphere to, say, mechanically useful energy. This kind of conversion of wind energy into the motion of a body has been in use for a long time. Almost any physical construction that produces an asymmetric force in a wind flow can be made to rotate, translate or oscillate there by generating power.

3.2 POWER OF MOVING AIR MASS

If a body mass 'm'moves with speed 'v' it has the energy $E=1/2\ mv^2$. The mass of air for a given volume with known air density (ρ). Mass $m = \rho V$. The volume streaming through the rotor circle F is per time unit $V=Fv$.

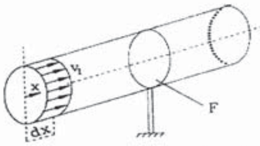

Figure 3.1 Mass flow through a surface

From the above equations the power of the air per unit time results is $P=1/2\ \rho v^3 F$.

3.3 WIND TURBINE POWER

Power from the wind turbine rotor is $P1=Cp1/2\ \rho v^3 F$.where, Cp is called the power coefficient and the Cp is the percentage of power in the wind that is converted into mechanical energy and calculated from following equations. And for the estimation of this maximum the following should be valid: firstly, the air should be regarded as incompressible, which is approximately true for wind speeds below 100m/s. secondly, the converter should not have any aerodynamic (or) mechanical losses.

3.4 AERODYNAMICS OF THE WIND TURBINE

The three bladed rotors is the most important and most visible part of the wind turbine. It is through the rotor that the energy of the wind is transformed into mechanical energy that turns the main shaft of the wind turbine.

3.4.1 Basic Theory

Aerodynamics is the science and study of the physical laws of the behavior of objects in airflow and the forces that are produced by airflows. The front and rear sides of a wind turbine rotor blade have a shape roughly similar to that of a long rectangle, with the edges bounded by the leading edge, the trailing edge, the blade tip and the blade root. The blade root is bolted to the hub. The radius of the blade is the distance from the rotor shaft to the outer edge of the blade tip. Some wind turbine blades have moveable blade tips as air brakes, and one can often see the distinct line separating the blade tip component from the blade itself. If a blade were sawn in half, one would see that the cross section has a streamlined asymmetrical shape, with the flattest side facing the oncoming airflow or wind. This shape is called the blades aerodynamic profile.

3.4.2 The Aerodynamic Profile

The shape of the aerodynamic profile is decisive for blade performance. Even minor alterations in the shape of the profile can greatly alter the power curve and noise level. Therefore a blade designer does not merely sit down and outline the shape when designing a new blade. The shape must be chosen with great care on the basis of past experience. For this reason blade profiles were previously chosen from a widely used catalogue of airfoil profiles developed in wind tunnel research by NACA (The United States National Advisory Committee for Aeronautics) around the time of the Second World War. When the rotor is stationary, as shown in drawing (A) below, the wind has a direction towards the blade, at a right angle to the plane of rotation, which is the area swept by the rotor during the rotation of the blades. The wind pressure is roughly in the same direction as the wind and is also roughly perpendicular to the flat side of the blade profile. The part of the wind pressure blowing in the direction of the rotor shaft attempts to bend the blades and tower, while the smaller part of the wind pressure blowing in the direction of the rotation of the blades produces a torque that attempts to start the wind turbine.

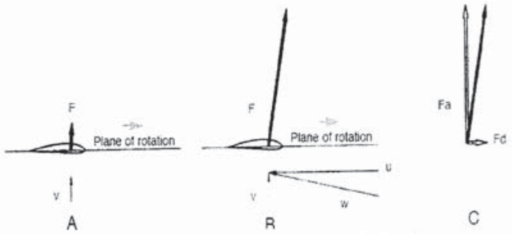

Figure 3.2 Airflow around a blade profile, near the wing tip

Once the turbine is in operation and the rotor is turning, as is shown in the center diagram (B), the blade encounters a head wind from its own forward movement. The strength of head wind at any specific place on the blade depends partly on just how fast the wind turbine blade is rotating, and partly how far out on the blade one is from the shaft. The force will not be in the direction of the resulting wind, but almost at a right angle to the resulting wind. In the drawing on the right (C) the force of the wind pressure is again split up into a component in the direction of rotation and another component at a right angle to this direction. The force at a right angle to the plane of rotation attempts to bend the blade back against the tower, while the force points in the direction of rotation and provides the driving torque. We may notice two very important differences between the forces on the blade. One difference is that the forces on the blade become very large during rotation. If vector arrows illustrating the forces in the diagrams were drawn in a scale that was indicative of the sizes of the different forces, then these vector arrows of a wind turbine in operation would have been 20 times the size of the vector arrows of the same wind turbine at rest. This large difference is due to the resulting wind speed of 51 m/s striking a blade during operation, many times the wind speed of 10 m/s when the wind turbine is at rest. The blade encounters head wind resulting from its own movement; however head wind is of far greater importance on a wind turbine blade.

3.4.3 Lift

Lift is primary due to the physical phenomena known as Bernoulli's Law. This physical law states that when the speed of airflow over a surface is increased the pressure will then drop. This law is counter to what most people experience from walking or cycling in a head wind, where normally one feels that the pressure increases when the wind also increases an air flow blowing directly against a surface, but it is not the case when air is flowing over a surface.

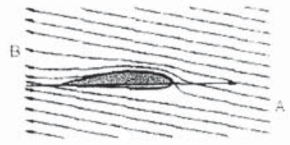

Figure 3.3 Airflow around an aerodynamic profile

The aerodynamic profile is formed with a rear side that is much more curved than the front side facing the wind. Two portions of air molecules side by side in the air flow moving towards the profile at point A will separate and pass around the profile and will once again be side by side at point B after passing the profile's trailing edge. As the rear side is more curved than the front side on a wind turbine blade, this means that the air flowing over the rear side has to travel a longer distance from point A to B than the air flowing over the front side. Therefore this air flow over the rear side must have a higher velocity if these two different portions of air shall be reunited at point B. relater velocity produces a pressure drop on the rear side of the blade, and it is this pressure drop that produces the lift. The highest speed is obtained at the rounded front edge of the blade. The blade is almost sucked forward by the pressure drop resulting from this greater front edge speed. There is also a contribution resulting from a small over-pressure on the front side of the blade. Compared to an idling blade the aerodynamic forces on the blade under operational conditions are very large. The wind turbine will start to rotate very slowly at first, but as it gathers speed it begins to accelerate faster and faster. The change from slow to fast acceleration is a sign that the blade's aerodynamic shape comes into play, and that the lift greatly increases when the blade meets the head wind of its own movement. The fast acceleration, near the wind turbine operational rotational speed places great demands on the electrical cut-in system that must capture and engages the wind turbine without releasing excessive peak electrical loads to the grid.

3.4.4 Change of Forces along the Blade

The drawings previously studied, mainly illustrate the airflow situation near the blade tip. In principle these same conditions apply all over the blade, however the size of the forces and their direction change according to their distance to the tip. The situation near the blade root, we will obtain slightly different results as shown in the drawing below.

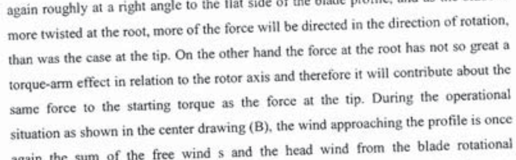

Figure 3.4 Air flow around a blade profile near the blade root

In the stationary situation (A) in the left hand drawing, the force becomes slightly larger than the force at the tip, as the blade is wider at the root. The pressure is once again roughly at a right angle to the flat side of the blade profile, and as the blade is more twisted at the root, more of the force will be directed in the direction of rotation, than was the case at the tip. On the other hand the force at the root has not so great a torque-arm effect in relation to the rotor axis and therefore it will contribute about the same force to the starting torque as the force at the tip. During the operational situation as shown in the center drawing (B), the wind approaching the profile is once again the sum of the free wind s and the head wind from the blade rotational movement through the air. In the drawing on the right (C) force is broken down into wind pressure against the tower, and the blade driving force Fd in the direction of rotation. In comparison with the blade tip the root section produces less aerodynamic forces during operation, however more of these forces are aligned in the correct direction, that is, in the direction of rotation. The change of the size and direction of these forces from the tip in towards the root, determine the form and shape of the blade. Head wind is not so strong at the blade root, so therefore the pressure is likewise not so high and the blade must be made wider in order that the forces should be large enough. The resulting wind has a greater angle in relation to the plane of rotation at the root, so the blade must likewise have a greater angle of twist at the root. It is important that the sections of the blade near the hub are able to resist forces and stresses from the rest of the blade. Therefore the root profile is both thick and wide, partly because the thick broad profile gives a strong and rigid blade and partly because greater width, as previously mentioned, is necessary on account of the resulting lower wind speed across the blade. On the other hand, the aerodynamic behavior of a thick profile is not so effective. Further out along the blade, the profile must be made thinner in order to produce acceptable aerodynamic properties, and therefore the shape of the profile at any given place on the blade is a compromise between the desire for strength (the thick wide profile) and the desire for good aerodynamic properties (the thin profile) with the need to avoid high aerodynamic stresses (the narrow profile). As previously mentioned, the blade is twisted so that it may follow the change in direction of the resulting wind. The angle between the plane of rotation and the profile chord, an imaginary line drawn between the leading edge and the trailing edge, is called the setting angle, sometimes referred to as Pitch.

3.4.5 What happens when the wind speed changes?

In order to understand blade behavior at different wind speeds, it is necessary to understand a little about how lift and drag change with a different angle of attack.

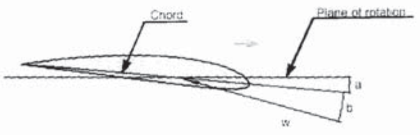

Figure 3.5 Angles of the profile

This is the angle between the resulting wind and the profile chord. In the drawing below the angle of attack is called setting angle. The setting angle has a fixed value at any one given place on the blade, but the angle of attack will grow as the wind speed increases. The aerodynamic properties of the profile will change when the angle of attack changes. These changes of lift and drag with increasing angles of attack are illustrated in the diagram above used to calculate the strength of these two forces, the lift coefficient and the drag coefficient. Lift will always be at a right angle to the resulting wind, while drag will always follow in the direction of the resulting wind.

3.4.6 The Stall Phenomena

The above diagrams showing the components of lift and drag illustrate the result of stall. Lift diminishes and drag increases at angles of attack over 15 degrees. A stall is understood as a situation during which an angle of attack becomes so large that the air flow no can longer flow smoothly, or laminar, across the profile. Air looses contact with the rear side of the blade, and strong turbulence occurs. This separation of air masses normally commences progressively from the trailing edge, so the profile gradually becomes semi-stalled at a certain angle of attack, but a full stall is first achieved at a somewhat higher angle. From the diagram showing the lift and drag components, one can estimate that the separation at the trailing edge starts at about 12 degrees, where the curve illustrating lifts starts to fall. The profile is fully stalled, and the airflow is separated all over the rear side of the blade at about 20 degrees. These figures can greatly vary from profile to profile and also between different thicknesses of the same profile. When the stall phenomenon is used to restrict power output, it is important that blades are trimmed correctly. With the steep lift curve, the angle of attack cannot be altered very much, before maximum output also changes, therefore it is essential that the angle of the blade is set at the correct value. One cannot alter the different angles on the blade itself, once the form, shape and blade molding has been decided upon and fabricated. So we normally talk about calibrating the tip angle. Not because the blade tip has any special magical properties, but we can place a template at the tip, which allows us to make measurements using a theologize. Adjusting of the tip angle can therefore be understood as an example of how the angle of the total blade is adjusted. Importance for power output limitation is also the fact that in practice lift and drag normally behaves exactly as would be

expected from the theoretical calculations. However this is not always the case. Separation can often occur before expected, for instance due to dirt on the leading edges, or it can be delayed if the air flow over the profile for some reason or other, is smoother than usual. When separation occurs before expected, the maximum obtainable lift is not as high as otherwise expected and therefore maximum output is lower. On the other hand, delayed separation can cause continuous excessive power production output. Accordingly profile types chosen for our blades have stable stall characteristics with little tendency to unforeseen changes. From time to time, however, it is sometimes necessary to actively alter the stall process. This is normally done by alteration to the leading edge, so that a small well-defined extra turbulence across the profile is induced. This extra turbulence gives a smoother stall process. An area of rougher blade surface, or a triangular strip, fixed on the leading edge, can create turbulence. This stall strip acts as a trigger for the stall so that separation occurs simultaneously all over the rear side. On a wind turbine blade, different air flows over the different profile shapes interact with each other out along the blade and therefore, as a rule, it is only necessary to alter the leading edge on a small section of the blade. This altered section will then produce a stall over the greater part of the blade.

3.5 TRANSMISSION SYSTEM

Hub - The blades on all wind turbines are bolded to the hub. The hub is cast in a special type of strong iron alloy called 'SG cost iron'. Because of the complicated hub shape which is difficult to make in any other way. It is convenient to use cast iron.

Main shaft - The main shaft of a wind turbine is usually forged from hardened and tempered steel. Hardening and tempering is result of forgoing the axle after it has been heated until it is white hot at about 1000degrees centigrade. By hammering (or) rolling the blank is formed with an integral flange, to which the hub is later bolter.

Main bearings - All modern wind turbines have spherical roller bearings as main bearings. The term spherical means that the inside of the bearings outer ring is shaped like across section of a ball. This has the advantage of allowing the bearings inner and outer ring to be slightly slanted and out of track inner and outer ring to be slightly slanted and out of track in relation to each other without damaging the bearing while running. The spherical bearing has two sets of rollers. Allowing both absorption of

radial loads from the weight of the rotor, shaft, etc and the large axial forces resulting from the wind pressure on the rotor.

Clamping unit - By the means of a clamping unit the main shaft of the wind turbine is coupled to the gearbox. The gear has a hollow shaft that fits over the rear end of the main shaft torque between the two component is transferred by friction between the two. Transferred torque is dependent upon friction between the main shaft and the hollow shaft.

Gearbox - Placed between the main shaft and the generator, its task is to increase the slow rotational speed of the rotor blades to the generator rotation speed of 1000 (or) 1500 rpm. Here gearbox has always a constant and a speed-increasing ratio. So that if a wind turbine can operate at different operational speeds.

3.6 GENERATOR

The generator is what converts the turning motion of a wind turbine's blades into electricity. Inside this component, coils of wire are rotated in a magnetic field to produce electricity. Different generator designs produce either alternating current (or) direct current and they are available from low range to large range of output power rating. The generator's rating or size is dependent on the length of the wind turbines blades because longer blades capture more energy.

3.7 CONTROL/BRAKING SYSTEM

The system working basic principles of centrifugal action of balls it is controllers the rotor rpm through governors. The rotor can be stopped under most wind conditions using the manual braking for low power wind turbine systems and electromagnetic brake for large systems. But frequent use of mechanical braking function is not advisable because of the heat stress it puts on the alternator, particularly when the winds are strong. In this case we have one more option by electrical braking system, where the controller circuit controls the rotor rpm.

Electrical storage - Batteries are the most common from of electrical storage, where heat, rather than electricity is the desired end product of a wind turbine application hot water is the usual storage medium; Batteries can store and deliver only dc power. Unless an inverter is used to convert dc to ac, only dc appliances can be operated from the stored power.

3.8 TOWER

The smooth flow the wind over the land is interrupted by obstructions and the land is interrupted by obstructions and topographical variations. These interruptions bring about two important phenomena: wind shear and turbulence wind shear describes the fact that close to the ground the wind is slowed down by friction and influence of obstacles. This, wind speed is low close to the ground and increase with increasing height above the ground. Wind shear is more pronounced over rough terrain and less pronounced over smooth terrain. Turbulence is essentially rough air caused by the wind passing over obstructions such as trees, buildings (or) terrain features. Turbulent air reduces energy output and puts greater strain on the wind turbine. The effects of both wind shear and turbulences diminish with height and can be largely over come simply by putting the machine sufficiently high above the ground. Taller towers usually will provide better economics because the power in the wind increase as the cube of the wind speed will result in a large increase in long-term energy output.

Tail assembly - The tail assembly, composed of a tail boom and the tail fin, keeps the power head at perpendicular of the wind direction. Where, the fiberglass material is used.

3.9 SITE SELECTION

Site selection may have a significant effect on annual energy production. It is typically worth the additional time and effort to locate the proper size to maximize energy production and maintain the wind turbine expected life. The following sitting factors should be considered. Wind resources characteristics, annual average wind speed must be 4.5m/s, prevailing wind direction, turbulence, peak wind speed, height and location of obstructions, local restrictions relative to height, proximity to boundaries, tower height, site accessibility and its effect on construction and maintenance costs.

CHAPTER 4

DESIGN SPECIFICATIONS

The specifications for the proposed wind turbine are given below:

4.1 SYSTEM : 500watts

[i] Type : Stand alone system

4.2 PERFORMANCE PARAMETERS

[i] Rated electrical power : 500 watts
[ii] Rated wind speed : 1-5m/s
[iii] Cut in wind speed : 1-1.5m/s
[iv] Cut out wind speed : 20-25m/s

4.3 ROTOR

[i] Type of hub : Fixed pitch
[ii] Rotor diameter : 2.1m
[iii] Number of blades : Three
[iv] Rotor speed at rat.win.speed : 100- 150rpm
[v] Location relative to tower : Up wind

4.4 BLADE

[i] Length : 0.8 m
[ii] Material : Glass fiber
[iii] Root chord : 30mm
[iv] Maximum chord : 120mm
[v] Tip chord : 45mm
[vi] Blade trailing edge : Parabolic

4.5 GENERATOR

[i] Type : AC generator
[ii] Watts at rated wind speed : 500w
[iii] Speed in rpm : 1000rpm

4.6 TRANSMISSION

[i] Type : Gear system
[ii] Rotor to generator speed ratio: 1:10
[iii] Lubrication : oil

4.7 YAW SYSTEM

[i] Normal : By tail vane rotates 360 deg
[ii] Structural : Yaw bearing mounted on tower tip

4.8 TOWER

[i] Type : Lattice tower
[ii] Tower height : 10m

CHAPTER 5

DESIGN METHODOLOGY

5.1 INTRODUCTION

Wind energy systems as other energy systems have to be planned carefully to achieve reliability and low cost. They are by their nature very sensitive to meteorological phenomena because these do not only influence normal operation (by the given wind conditions) but can disrupt the service, augment demands or require consideration for environmental reasons. From the system analysis and investigation, the design steps are fixed for low power wind turbine system. The steps start with wind velocity analysis, turbine blade design, nacelle design and tower design. This chapter discussed wind velocity analysis and turbine blade design only.

5.2 WIND VELOCITY ANALYSIS

Meteorological information for wind energy use should contain high resolution spatial maps of regional wind climatology's derived by special algorithms. As a prerequisite, models for transforming measured wind data into objective scale representative values must be used, because measured meteorological data very often are unrepresentative. Furthermore short term forecasts of wind speed (24-48 hours) for scheduling and dispatching may be a favorable method to optimize wind energy buying and selling by the wind farm operators. These forecasts have to be highly accurate local forecasts with an uncertainty of less than 15 percent and should be based on a numerical weather prediction. Basically, for sitting and yield estimation the following data and information must be finding from measuring devices and representative ness of data. Measurements/observations are time series of wind speed and wind direction (hourly or 10-minute averages), Maximum winds or gustiness and Lightning frequencies.

Site selection is typically worth the additional time and effort to locate the proper size to maximize energy production and maintain the wind turbine expected life. Site selection may have a significant effect on annual energy production. For the site selection wind velocity should have to analyze in installing area. Before the wind turbine erection in a particular area, we have to measure and record the speed of wind by using anemometer. So first we started with analyzing wind velocity in our area by using our PC interfaced record able anemometer. The velocity of the wind is analyzed and found to be varying with seasons, days and hours. As we know the maximum required wind velocity to generate the power in the existing system is around 3 m/s. But in our case we got only 1.0-5.0 m/s wind velocity even in the windy season itself. So to over come this situation we decided to design a low power wind turbine to generate electric power satisfactorily with the available low wind velocity (1.5 m/s).

The below graph [Figure. No 5.1] shows the July, August, September, and October 2006 wind velocity in m/s. From the graphs it is cleared that the maximum wind velocity available in July 5m/s, August 5.5 m/s, September 2.75 m/s and October 1.5 m/s. Even though these months are windy season, our area wind velocity is very low. And the graph [Figure. No 5.1] shows maximum wind velocity in December 06 1.5 m/s, in January 2007 1.7 m/s. in February 2007 1.75 m/s and in March 2007 1.5 m/s. this is very low wind for energy production. So to over come this situation and make use of this low wind for through out year production we planned to design the blades as per the aero dynamic principles.

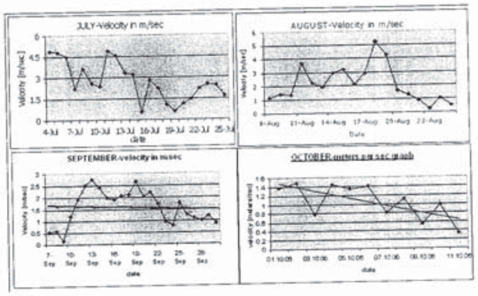

Figure 5.1 wind velocity analysis graphs

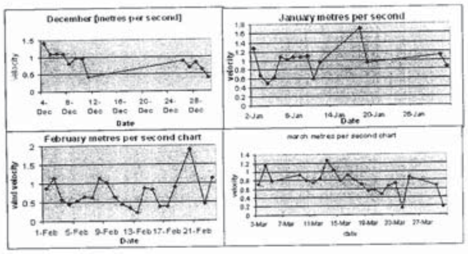

Figure 5.2 wind velocity analysis graphs

5.3 Turbine Blade Design

The wind turbine blade is designed as per the aerodynamic principles to obtain the maximum power available in the wind. Blades are one of the most critical and visible. Components of wind turbine rotor blades can be made from almost any material. Fiber glass has grown increasingly popular. It is strong, relatively inexpensive and has good fatigue characteristics.

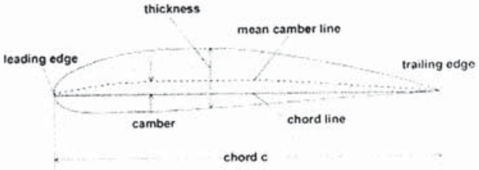

Figure 5.3 Aerodynamics of blade

Airfoils are a family of shapes which are characterized by a blunt nose and a finely tapering tail. They can be either symmetrical or not. Their property is that a flow can follow their curved surfaces with out separation. The effect is that they can develop a lift many times. Where the important calculating factors are pitch angle, mean camber line, absolute angle and blade profile values.

The following steps are used to calculate the mean camber line:

Step 1: $H = V^2/2g$
$= (1.5)^2/(2*9.81)$
$= 0.1146$ m

Step 2: $P = HQ\Gamma$
$Q = 250/(0.1146*9.81*1.1)$
$= 202.2$ m3/sec

Step 3: $A = Q/V$
$= 202.2/1.5$
$= 134.8$ m2

Step 4: $n_s = n(N)^{1/2}/(H)^{5/4}$
$= 150/0.0666$
$= 2252.25$ rpm

Step 5: d bar = 0.1 and $C_m = 1.75$

Step 6: $D_o = (Q/(\pi(1-(d\ bar)\ 2)\ C_m))^{1/2}$
$= 6.1$ m

Step 7: $D_H = d\ bar * D_o$
$= 0.61$ m

Step 8: (i) $r_1 = ((D_o/2) + (0.02*D))$
$= 0.43$ m
(ii) $r_2 = ((D_o/2) + (0.02*D))$
$= 2.92$ m
(iii) $r_3 = (r1 + r5)/2$
$= 1.65$ m
(iv) $r_4 = (r_3 + r_5)/2$
$= 2.3$ m
(v) $r_2 = (r_1 + r_5)/2$
$= 1.08$ m

Step 9: $K_H = (H/((n/60)^2(D^2)))$
$= 1.23*10-4$

Step 10: $K_Q = (Q/((n/60)(D^3)))$
$= 0.1781$

Table 5.1 Mean chord line design formulas

Radius (m)	0.43	1.05	1.68	2.30	2.92
$U = (2\pi rn/60)$ [m/s] n = 300 rpm	13.50	32.97	52.75	72.22	91.68
$C_m = C_o$ [m/s]	1.75	1.75	1.75	1.75	175
$\beta_1 = \tan^{-1}(C_m/U)$ [deg]	7.38	3.03	1.9	1.38	1.09
$C_{U2} = (gH/U)$ [m/s]	0.083	0.034	0.023	0.015	0.012
$\beta_2 = \tan^{-1}(C_m/(U-C_{U2})$	7.43	3.04	1.9	1.38	1.09
$\Delta\beta = \beta_1 - \beta_2$	0.05	0.01	0	0	0
l/t	0.5	0.4	0.28	0.16	0.03
$t = 2\pi r/Z$ [m] Z = 3	0.96	2.19	3.51	4.81	6.11
Blade length l_1 (m)	0.48	0.88	0.98	0.78	0.18
$\Gamma_1 = \Gamma/Z = ((60gH)/(nZ))$	0.09	0.09	0.09	0.09	0.09
$W_{\infty u} = U-((\Gamma_1)/(4\pi r))$	13.48	32.96	52.74	72.21	91.67
$\alpha_\infty = \tan^{-1}(C_m/W_{\infty u})$	7.39	3.03	1.9	1.38	1.09
$W_\infty = (Cm/\sin\alpha_\infty)$	13.6	33.10	52.78	72.66	91.99
$J_1 = \Gamma_1/(W_o l\beta)$	0.0132	0.0038	0.0017	0.0015	0.0054
Final pitch angle $\beta = \beta_2$ + sharp angle(5o) [deg]	12	8	7	6.5	6

From the above steps and table [Table No.5.1] we can calculate the blade rated speed, energy coefficient, radius, length thickness, pitch angle by giving the inputs like wind velocity and required output power. The angle of attack is the smallest angle which makes with the surface of rotors. The force which the surface experiences, perpendicular to the stream is the lift and that which is parallel to it is drag. The shape of the tips of the blades is determined according to their duties they perform. The aerodynamic blades of a wind turbine extract more power from the surroundings at their tips than they do near the hub. This is expressed as tip speed ratio.

Table 5.2 Blade profile value design formulas

SL .NO	$X_1 = X/l$	$Y_1 = Y/Y_{max}$
1	0	0
2	0.0025	0.1468
3	0.005	0.1958
4	0.0075	0.2290
5	0.01	0.2650
6	0.0125	0.2938
7	0.025	0.4050
8	0.05	0.5160
9	0.075	0.6000
10	0.10	0.6620
11	0.15	0.7630
12	0.20	0.8400
13	0.25	0.9040
14	0.30	0.9490
15	0.35	0.9810
16	0.40	0.9980
17	0.45	1.0000
18	0.50	0.9820
19	0.60	0.8950
20	0.70	0.7420
21	0.80	0.5280
22	0.85	0.4080
23	0.90	0.2770
24	0.95	0.1410
25	0.97	0.0832
26	0.99	0.0254
27	1.00	0

Wind turbine design entirely depends on lift and drag coefficients. The lift co efficient must be minimum. This implies that air foil must be at angle of attack consistent with high lift but not very high that the blade starts stalling. The air foil must be set at a blade angle relative to its direction of motion in order to adjust angle of attack. When once the machine is running, too many blades may interfere with each others air flow and thus limits the speed and hence reduces the power developed so the three blade system is more efficient than others. From the above design steps, the blade is designed as shown in the below figure [Figure No 5.4].

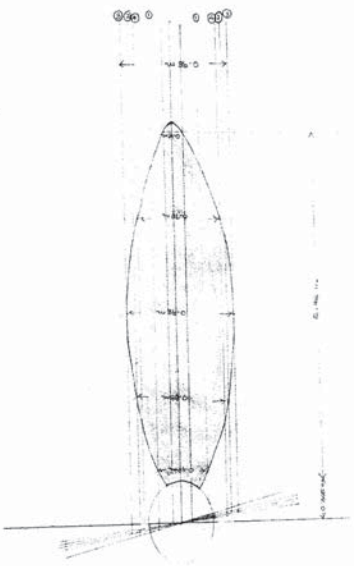

Figure 5.4 proposed blade design

CHAPTER 6

SIMULATED MODEL OF WIND TURBINE SYSTEM

6.1 SIMULATION MODEL DIAGRAM

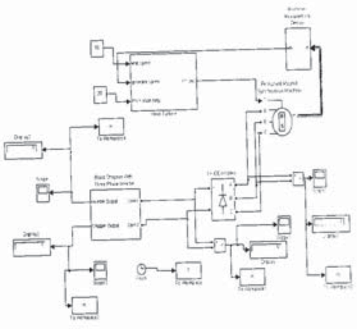

Figure 6.1 Overall Simulation model of Wind Electric System.

6.1.1 Wind Turbine Model

The basic wind energy conversion device is the wind turbine. A wind turbine is a machine used for converting the kinetic energy into the mechanical energy. There are two types of wind turbine namely vertical axis and horizontal axis. Horizontal axis wind turbine due to the advantage of ease in design and cheaper in cost for higher power ratings. The power captured by the wind turbine is

$$P = \tfrac{1}{2} \pi \rho R^3 V^2 C_p \qquad (6.1)$$

The power coefficient C_p is a nonlinear function of wind velocity and blade pitch angle and is highly dependent on the constructive characteristics of the turbine. It is represented as a function of tip speed ratio

$$\lambda = R\, \omega_t / V \qquad (6.2)$$

It is important to remark the aerodynamic efficiency is maximum at an optimum tip speed ratio. The turbine torque is obtained by dividing turbine power by turbine speed.

$$T_t(V, \omega_t) = \tfrac{1}{2} \pi \rho R^2 V^3 C_t(\lambda) \qquad (6.3)$$

Where C_t (P) is the torque co-efficient of the turbine and is given by

$$C_t(\lambda) = C_p(\lambda) / \lambda \qquad (6.4)$$

The power co efficient C_p is given by

$$C_p(\lambda) = (116/\lambda_1 - (0.4 * \beta) - 5)\, 0.5\, e\, (-165/\lambda_1) \qquad (6.5)$$

Where, $\lambda_1 = 1/((1/(\lambda + 0.089\, \beta)) - (0.035/\beta_3 + 1)$ (6.6)

The pitch angle can be calculated from the following M-file programme.

```
Close all;
Clc;
Clear all:
H=input ('enter the total head-H'):
Q=input ('enter the flow rate-Q');
n=input ('enter the speed-n'):
ns=3.65*n*sqrt (Q)/power (H, 3/4):
kbar=input ('enter the constant kbar'):
Co=kbar*power ((Q*power (n, 2)), 1/3);
dbar=input ('enter the constant dbar');
Do=sqrt (Q/ (pi*(1-power (dbar, 2))*Co)):
dn1=dbar*Do;
Kh=H/ (power (n/60, 2)*power (Do, 2)):
Kq=Q/ ((n/60)*power (Do, 3)):
r1= (dn1/2) +0.02*Do:
r5= (Do/2)-(0.02*Do);
r3= (r1+r5)/2;
r2= (r1+r3)/2;
r4= (r3+r5)/2;
r=input ('enter the radius "r" in mm'):
D=2*r/1000;
Cm=Co;
u=pi*D*n/60;
```

```
beta1= (atan (Cm/u))*180/pi:
g=9.8;
eh=1-(0.42/power ((log10 (Do)-0.172),2));
Cu2=g*H/(eh*u);
s1=u-Cu2;
beta2= (atan (Cm/s1))*180/pi;
delbeta=beta2-beta1:
lbyt=input ('enter the l/t ratio'):
z=input ('enter the number of blades');
ev=1/(1+0.68*power (ns,-2/3)):
t=2*pi*r/z;
l1=lbyt*t
disp ('LENGTH');
gamma=60*g*H/ (eh*n);
gamma1=gamma/z;
Cm1=Co/ev;
wiu=u-(gamma1/(4*pi*r)):
alphai=atan (Cm/wiu)*180/pi;
wi= (Cm/sin (alphai*pi/180));
j1= (gamma1/(wi*l1)):
j2=input ('enter the value of (gamma1/(wi*l*beta)) from figure'):
beta3= (j1*1000/j2)*180/pi;
disp ('PITCH ANGLE'):
delalphai=input ('enter the value of delalphai from figure'):
alphafinal=delalphai+alphai:
k1=l1*cos (alphai*pi/180):
k2=l1*sin (alphai*pi/180);
alpha2= (atan (Cm1/Cu2))*180/pi:
delm=input ('enter the value of delm');
delmbar=delm/l1:
fbar= (tan ((beta3/2)*pi/180))/2;
k3=input ('enter the value of (dalfbar/delmbar)');
delfbar=k3*delmbar;
fbarimp=fbar+delfbar:
```

```
betaimp=2*atan(2*fbarimp)*180/pi;
R=l1/(2*sin(betaimp*pi/180))
disp('RADIUS');
theata=betaimp*2;
disp ('INCLUDED ANGLE');
disp (theata);
```

From the following steps we ca calculate the co-ordinates of profiles for blades. It varies in near hub and at the tip of the blade.

```
% Co-ordinates of profiles for blades
x=input ('enter the value of "x"')
l=input ('enter the value of "l"')
y=input ('enter the value of "y"')'
ymax=input ('enter the value of "ymax"')
xbar=x/l;
ybar=y/ymax;
```

6.1.2Permanent Magnet Synchronous Generator

Permanent magnet synchronous generators provide an optimal solution for variable-speed wind turbines, using either a gearless or single-stage gear configuration. This eliminates the need for separate base frames, gearboxes, couplings, shaft lines, and reassembly of the nacelle. The output of a permanent magnet synchronous generator can be fed to the power grid via power converters. This provides a high overall level of efficiency, while keeping the mechanical structure of the turbine simple .In PM machines, the excitation or field winding is replaced by a permanent magnet and, of course, no external source of electrical energy is required

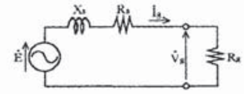

Fig 6.2 Equivalent circuit per one phase of synchronous Generator

Generated emf / phase $E=V_t + I_a Z_s$ (6.7)

Where, $Z_s= (R_{a2}+X_{s2})$ ½ (6.8)

The rotor reference frames of the voltages are

$$V_q= - (R_s+L_{qp})\, I_q - \omega_r\, L_d\, I_d + \omega_r\, /m \tag{6.9}$$

$$V_d= - (R_s+L_{dp})\, I_d + \omega_r\, L_q I_q \tag{6.10}$$

The expression for the electromagnetic (EM) torque in the rotor is the relationship between the angular frequency of the stator voltage (r) and the mechanical angular velocity of the rotor (m) may be expressed as

$$T_e= (3/2)\, (P_n/\, 2)\, ((L_q-L_d)\, I_q I_d - \lambda_m I_q) \tag{6.11}$$

$$\omega_r= P_n/2\ \omega_m G \tag{6.12}$$

$$P\, \omega_r = (P_n/2I_g)\, (T_m-T_g) \tag{6.13}$$

$$P_\theta=\omega_r \tag{6.14}$$

Torque developed by the turbine Tt and the input to the generator Tm is expressed as

$$T_m=T_t/G \tag{6.15}$$

6.1.3 Rectifier

A three-phase diode bridge rectifier converts the AC output voltage from the generator terminal, which is variable in magnitude and also in frequency, in to DC. The average output voltage of the three-phase diode rectifier is

$$V_{dc}= (3*V_m)/\, \pi \tag{6.16}$$

The average load current of the three-phase diode rectifier is

$$I_{dc}=V_{dc}/R_L \tag{6.17}$$

The Rms value of load current of the three-phase diode rectifier is

$$I_{rms}=V_{rms}/R_L \tag{6.18}$$

6.1.4 Boost Chopper

The conversion of fixed DC voltage to an adjustable DC output voltage, through the use of semiconductor devices, can be carried out by the use of DC – DC converters or chopper circuits.

The output voltage for Chopper

$$V_o = V_s\, (T/\, (T-T_{on})) \tag{6.19}$$

$$V_o = (V_s\, /\, (1-k)) \tag{6.20}$$

Where, K =Duty ratio of the chop

6.1.4 PWM Inverter

The converter that changes a dc voltage to an alternating voltage is called an inverter. For providing adjustable frequency power to industrial applications, three phase inverters are more common than single-phase inverters. Gating signals for PWM Inverter switches are generated by Sinusoidal Pulse Width Modulation Technique (SPWM). In this SPWM comparing a Sinusoidal reference signal with a triangular carrier wave of frequency f_C generates gating signals. The frequency of reference signal f_r determines the inverter output frequency f_O and its peak amplitude controls the modulation index and then in turn the rms output voltage.

6.2 SIMULATION RESULTS

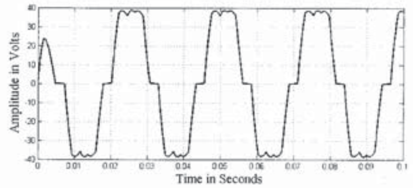

Figure 6.3 PMSG output voltage curve

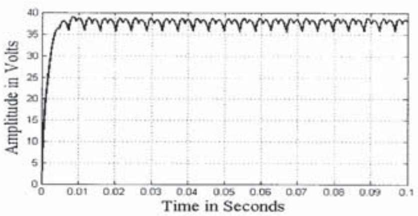

Figure 6.4 Rectifier output voltage

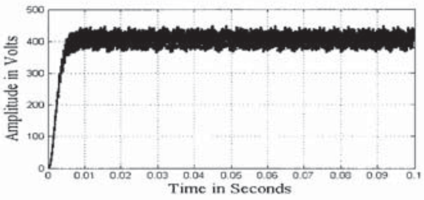

Figure 6.5 Boost chopper output voltage curve

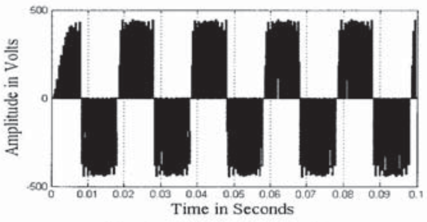

Figure 6.6 PWM inverter output voltage

CHAPTER 7

FUTURE ENHANCEMENTS

Future work will include the design of the generator and tower and the fabrication for low power wind turbine system. This entire small wind turbine is 'rated' to operate at just 1.5m/s wind velocity instead of the usual 3m/s rating of other turbines. All of this means that this turbine will capture more energy over a range of different wind speeds that are realistic on most sites. On top of this, this turbine will 'cut-in' at a much lower speed, which means that the wind turbine spends more time generating energy instead of 'freewheeling' in low wind speeds. It is possible to mount a turbine on a house or building (often called a roof-mount). However this should be considered as a last resort as the turbine will be less efficient due to the turbulence caused by the building itself. This will result in less power production and will increase the stresses on the turbine due to turbulence. A specially designed anti-vibration system should be employed to help prevent vibrations from the turbine from being transmitted to the building. It is recommended to mount the turbine as high as possible away from obstructions such as buildings and trees. This will greatly improve the power production of the turbine.

Apart from this, the turbine can also be designed for vertical axis, which can be more suitable in high tower buildings like flats and multistory buildings. The design consideration can also be extended to the control system of the turbine blades which will give better performance.

CHAPTER 8

CONCLUSION

In this project, a novel technique has been proposed for the design and fabrication of blades that can be used for low power aero generators, where the turbine blades are designed as per the aerodynamic principles to produce the maximum power at an available low wind. From the wind velocity analysis, the power production will be based on the various factors like wind velocity, area and time. And M-FILE programme has been written for blade design. By using this programme, we can calculate blade design parameters such as length, pitchangle, absolute angle by giving the input parameters like availability of wind and requirement of power. The simulation results show the possibility of producing efficient power with various wind velocity and pitch angle. The advantage of this approach is that the system can run at low wind speed, producing sufficient power at low cost for rural areas.

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