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STUDY OF POWER GENERATION FROM MICRO CUBE WIND TURBINE

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Abstract - *Energy conservation is a process of conquering circulatory waste energy or heat and converting it into usable power which has been continuously attracting more and more researcher interest because of the limitations of traditional power sources. The foremost aim will be to extract usable power which can run various devices having low power requirement such as mobile devices and wireless sensor networks.*

Large Scale Wind Turbines have been extensively examined for decades but very few studies have been conducted on the small scale wind turbines especially for the applications near ground level where wind speed is of order of few meters per second. This study provides the systematic effort towards design and development of small scale wind turbines targeted to operate at low wind speeds (<5 m/s).

A micro cube wind turbine is proposed for power generation. The wind turbine blade consists of 11 airfoils which gives sufficient speed to rotor for generation at low wind speed. The wind turbine is one of the renewable energies has received remarkable attention and rapidly become popular due to low initial-cost and space saving for construction compared to large wind turbine. Wind energy is fastest growing electrical energy in world.

Key words:

Airfoils, Low Wind Speed, Micro Cube, Renewable Energies, Turbine.

1. INTRODUCTION

In the early 1980's, the Department of Non-conventional Energy Sources (DNES) came into existence with the aim to reduce the dependence of primary energy sources like coal, oil etc in view of the Country's energy security. The DNES became Ministry of Non-conventional Energy Sources (MNES) in the year 1992 and now from 2006, the Ministry was renamed as Ministry of New & Renewable Energy (MNRE). The growth of Renewable Energy in India is enormous and Wind Energy proves to be the most effective solution to the problem of depleting fossil fuels, importing of coal, greenhouse gas emission, environmental pollution etc. Wind energy as a renewable, non-polluting and affordable source directly avoids dependency of fuel and transport, can lead to green and clean electricity.

With an installed capacity of 35625.97MW (March 2019) of wind energy, Renewable Energy Sources (excluding large Hydro) currently accounts for 22% of India's overall installed power capacity of 356100.19MW. Wind Energy holds the major portion of 45.5% of total RE capacity (78316.39MW) among renewable and continued as the largest supplier of clean energy.

The Government of India has announced a laudable Renewable Energy target of 175GW by 2022 out of which 60GW will be coming from wind power. The Wind Potential in India was first estimated by National Institute of Wind Energy (NIWE) at 50m hub-height i.e. 49 GW but according to the survey at 80m hub height, the potential grows as much as 102 GW. Further a new study by NIWE at 100m height has estimated a potential 302GW. One of the major advantages of wind energy is its inherent strength to support rural employment and uplift of rural economy. Further, unlike all other sources of power, wind energy does not consume any water-which in itself will become a scarce commodity.

Overall the future of Wind Energy in India is bright as energy security and self-sufficiency is identified as the major driver. The biggest advantage with wind energy is that the fuel is free, and also it doesn't produce CO2 emission. Wind farm can be built reasonably fast, the wind farm land can be used for farming as well thus serving dual purpose, and it is cost-effective as compare to other forms of renewable energy.

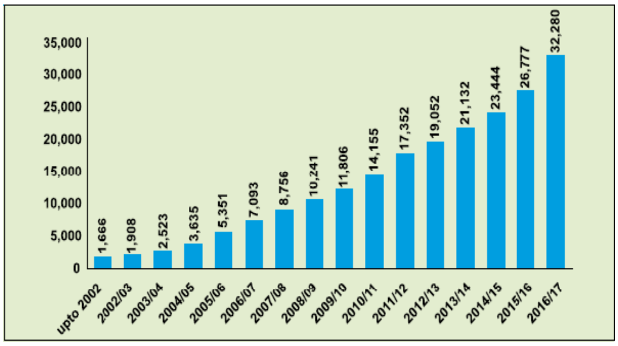

Chart-1:Year-wise Cumulative Wind Power Installed Capacity in India (MW)

A micro cube wind turbine is proposed for power generation. The wind turbine blade consists of 11 airfoils which gives sufficient speed to rotor for generation at low wind speed. The wind turbine is one of the renewable energies has received remarkable attention and rapidly become popular due to low initial-cost and space saving fo construction compared to large wind turbine. Wind energy is fastest growing electrical energy in world.

2. CIRCUIT DESCRICTION OF PROPOSED MODEL

Figure 2.1 shows the schematic representation of proposed wind turbine micro cube system. Power generation from wind turbine gives efficient power by wind turbine system. Micro cube wind turbine consists of 11 airfoils blades, turbine rotor, gear system, generator and grid.

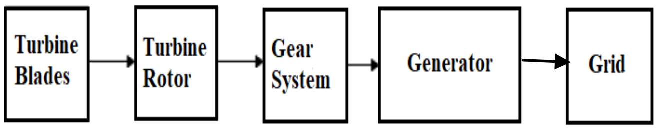

Fig-1: Block Diagram of Micro Cube wind Turbine

2.1: Turbine Blades

The turbine blades are consist of 11 airfoils, the material of blade is GF plastic, CFR polymer, ULTEM, AT2LAS, 316 Stainless Steel, Cupper, Ceramic, Neodymium. Wind turbine works the opposite of a fan instead of using electricity to make wind - like a fan – wind turbines use wind to make electricity. The wind turns the blades, which in turn spins a generator to create electricity.

Fig-2: Turbine Blade

2.2: Turbine Rotor

Turbine rotor or shaft transmits the torque to the output shaft and also redirects the fluid leaving the turbine to the hydraulic systems. The principle behind wind turbines is very simple: the energy in the wind turns the blades around a rotor. The rotor is connected to. The shaft, which spins a generator to create electricity. The voltage drives the electrical current (alternating current power) through power lines for distribution.

2.3: Gear System

A gearbox is typically used in a wind turbine to increase rotational speed from a low-speed rotor to a higher speed electrical generator Torque from the rotor generates power, but the turbine rotor also applies large moments and forces to the wind-turbine drive train. A common ratio is about 90:1, with a rate 16.7 rpm input from the rotor to 1,500 rpm output for the generator. Some multi megawatt wind turbines have dispensed with a gearbox. In these so-called direct-drive machines, the generator rotor turns at the same speed as the turbine rotor. This requires a large and expensive generator. Other wind turbines on the market sit in-between, with gearbox ratios of about 30:1, dispensing with the highest speed stage in a typical gearbox. There is a trade-off between the reliability of gearboxes and gear stages and the cost of slower, higher torque generators.

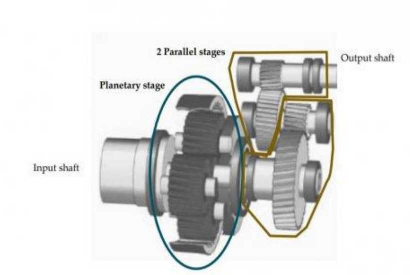

Fig-3: Gear System

2.4: Generator

Wind Turbine Generator which is the electrical machine used to generate the electricity. A low rpm electrical generator is used for converting the mechanical rotational power produced by the winds energy into usable electricity to supply our homes and is at the heart of any wind power system. Generator been squeezed into a device just 3 inches in diameter. The conversion of the rotational mechanical power generated by the rotor blades (known as the prime mover) into useful electrical power for use in domestic power and lighting applications or to charge batteries can be accomplished by any one of the major types of rotational electrical machines commonly used in a wind power generating systems.

Fig-4: Generator

2.5: Grid

Grid is used to give the supply to the appliance for used of electricity created by micro cube wind turbine.

3. WORKING

Wind energy is a form of solar energy. Wind energy describes the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. Mechanical power can also be utilized directly for specific tasks such as pumping water. Wind is caused by the uneven heating of the atmosphere by the sun, variations in the earth's surface, and rotation of the earth. Mountains, bodies of water, and vegetation all influence wind flow patterns. Wind turbines convert the energy in wind to electricity by rotating propeller-like blades around a rotor. The rotor turns the drive shaft, which turns an electric generator. Three key factors affect the amount of energy a turbine can harness from the wind: wind speed, air density, and swept area. Equation for Wind Power:

$$P = \frac{1}{2}\rho A V^3$$

3.1: Wind Speed

The amount of energy in the wind varies with the cube of the wind speed, in other words, if the wind speed doubles, there is eight times more energy in the wind ($2^3 = 2x2x2 = 8$). Small changes in wind speed have a large impact on the amount of power available in the wind.

3.2: Density of Air

The more dense the air, the more energy received by the turbine. Air density varies with elevation and temperature. Air is less dense at higher elevations than at sea level, and warm air is less dense than cold air. All else being equal, turbines will produce more power at lower elevations and in locations with cooler average temperatures.

3.3: Swept Area of the Turbine

The larger the swept area (the size of the area through which the rotor spins), the more power the turbine can capture from the wind. Since swept area is $A = \pi r^2$, where r = radius of the rotor, a small increase in blade length results in a larger increase in the power available to the turbine.

4. ADVANTAGES

i. It generates 1 kW power at low speed.
ii. Having Negligible Safety Risk and Environmental Impact Risk.
iii. Conventional renewable energy systems produce large amounts of power but at the expense of utilizing large amounts of space. This limitation found in conventional system so it can be reduces in micro cube wind turbine.

5. COMPUTATIONAL FLUID DYNAMICS (CFD)

Computational fluid dynamics (CFD) is the use of applied mathematics, physics and computational software to visualize how a gas or liquid flows as well as how the gas or liquid affects objects as it flows past. Computational fluid dynamics is based on the Navier-Stokes equations. The application of CFD is rapidly expanding with the growth in affordability of computational resources. It is becoming essential for CFD solvers to provide validation and verification. Mesh related issues play a very important role on accuracy and convergence. In a CFD analysis, the examination of fluid flow in accordance with its physical properties such as velocity, pressure, temperature, density and viscosity is conducted. A mathematical model of the physical case and a numerical method are used in a software tool to analyze the fluid flow.

5.1: Engineering Investigations by CFD

CFD analysis of velocity, temperature, and chemical concentration allocation helps engineers in understanding the problem appropriately and offers practical ideas for the best decision about the most flawless and productive designing. Using CFD, you are able to analyze complex problems involving fluid-fluid, fluid-solid or fluid-gas interaction. Engineering fields where CFD analyses are frequently used are for example aerodynamics and hydrodynamics, where quantities such as lift and drag or field properties as pressures and velocities are obtained.

5.2: Simulating the Micro Wind Turbine with CFD

Using the SimScale cloud-based CAE platform, the engineers at American Wind meshed the Micro Cube's CAD model in a way that resembled the live wind tunnel at which it was tested. A square channel was placed before and after the compact Micro Cube. The expected air flow was turbulent, though the range of operational wind speeds indicated that an incompressible model would be sufficient. To incorporate the motion of the fan blades, a multi-reference-frame (MRF) rotation model was used. Although the MRF model simplifies the simulation by "freezing" the rotor, it allows a fast and accurate evaluation of the steady state conditions of the case. The obtained mesh consisted of over 7 mln volumes. It included local area refinements, surface refinements, and turbulent boundary layer mesh. During the analysis, it was assumed that the blades were rotating at a fixed speed dependent on the inflow air velocity, based on experimental data. This is a common approach when testing turbines, which allows the investigation of actual wind flow patterns. The captured data involved all flow field data (pressure, velocity) and extra forces and moments acting on the whole Micro Cube, as well as the forces and moments acting on the blades. During post-processing, the difference in flow rotation before and after the micro wind turbine was calculated.

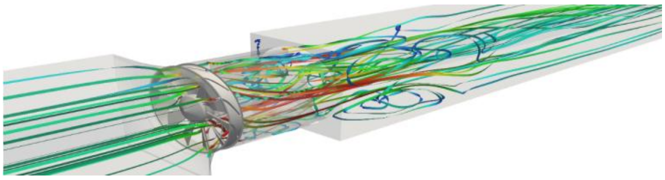

Fig-6: CFD Simulations of the Micro Wind Turbine (Micro Cube)

The two main challenges in the analysis were the preparation of the mesh and obtaining reliable, converged solutions. It took several attempts to obtain a mesh that would be accurate enough and at the same time reasonably big to facilitate the calculation. Fortunately, thanks to the semi-automated manual meshing, the creation of mesh variations was not too challenging.The second main issue was evaluating the results' accuracy. In most cases, it was impossible to tell if the results were good or not until the simulation finished. On the other hand, SimScale allows the calculation of multiple simulations at the same time, which helped the engineers complete the whole analysis 20 times faster than they would have on a single computing unit.

5.3: Simulation Results

In total, 26 operation conditions were analyzed, ranging from extremely low wind speeds up to expected limit conditions. On average, each simulation required 10h of computation time.

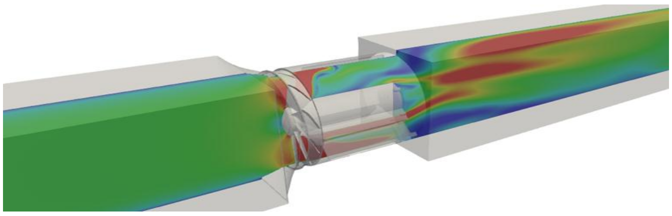

Fig. 4.3: CFD Simulations of the Micro Wind Turbine (Micro Cube)

Four of these simulation runs needed to be repeated with modified numerical conditions and extended convergence times to obtain correct results. Although the residual plots in many cases did not present perfect convergence, this could be attributed to the mesh quality and development of flow features behind the blades. Extending the simulations would most likely not improve the quality of the data since it was most probably limited by the mesh.

An additional interesting result found during the analysis was the occurrence of a wind recirculation region that was discovered attached to the stator arms of the Micro Cube. Awareness of the presence of this flow feature opens up the possibility of optimization of the shape of the stator (generator mount) in a way that will reduce energy losses due to recirculation.

6. CONCLUSIONS

The Micro Cube is small, very small with the cube version of the turbine being slightly smaller than your standard basketball (9 in cubed). But like laptops today, just cause its small doesn't mean it skimps on power. The Micro Cube comes with a 1 Kilowatt generator which is getting big power from a small package. In total, 26 operation conditions were analyzed, ranging from extremely low wind speeds up to expected limit conditions. An additional interesting result found during the analysis was the occurrence of a wind recirculation region that was discovered attached to the stator arms of the Micro Cube. Awareness of the presence of this flow feature opens up the possibility of optimization of the shape of the stator (generator mount) in a way that will reduce energy losses due to recirculation.

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