PMSG BASED WIND POWER GENERATION SYSTEM USING MATLAB/SIMULINK

[1] Mrs.Ch.Archana,Assistant professor, EEE Dept. Samskruthi College of Engineering and Technology.
[2] Ms.SK.Gousia Begum, Assistant professor, EEE Dept. Samskruthi College of Engineering and Technology.
[3] Mr. L.Bichu naik,Assistant professor, Assistant professor, EEE Dept. Samskruthi College of Engineering and Technology.

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Abstract- *The simple access to the wind and the fact that it is a clean and sustainable source of energy, wind energy usage for power generation is gaining popularity in electrical power production. In this study, the effects of a mathematical model and its parameters on the electrical output power generated by a wind turbine were investigated. Temperature causes air density to move, causing wind speed to change, and power coefficient as a function of pitch angle and blade tip speed effect wind speed. Modeling and simulation tools will be crucial in the design and research of these wind turbines. In recent years, MATLAB-Simulink has become one of the most popular software applications. It features a graphical user interface that makes accessing, developing, building, and testing mathematical models a breeze. Controlling and testing new ideas and processes is a breeze with these tools. Wind turbine generators are the best illustration of these dynamic systems.*

.**Key Words:** *wind turbine, MATLAB - Simulink, Renewable energy, Power Converters.*

1. INTRODUCTION

A wind turbine is a device that uses wind energy to generate electricity. The most significant component of a wind turbine system is the rotor, which contains the blades that transform wind energy into low-speed rotational energy. The generator is the second portion, and it consists of all control circuits with gearboxes that transform rotating low speed into electric power. Finally, the structure, which comprises the tower and nacelle, is where all of the previous components are stored. The axis along which wind turbines rotate divides them into two groups. Axes are divided into two categories: horizontal and vertical. Because it can gather the most amount of wind energy for the time of day and change the pitch angle of its blades to avoid high windstorms, the horizontal axis is more familiar and common than the vertical axis. Wind energy provided mechanical power for grinding grain and pumping water in a local market until the early 1970s. The windmill of 1850, or even 1950, differed little from the basic devices from which it was developed, with the exception of a few battery chargers and a few unusual trials with larger electricity-producing machinery. Technology, on the other hand, changed dramatically in the second part of the twentieth century. Blades, which were previously made of sail or sheet metal, have developed via wood to complex fibre glass composites. Airfoils are now tested in wind tunnels and designed to be dirt and surface roughness resistant. Thanks to advancements in aero elastic loads and the ability to merge this information into sop, today's machines are more robust than those of a decade ago. The extraction of wind energy demands a good knowledge of wind parameters. Wind speed varies dramatically from place to place, both geometrically and temporally. In addition to seasonal variations in wind speed, there are certain differences on a shorter time scale. These fluctuations are known as synoptic variations, and they last about four days. In addition to the seasonal and synoptic components of wind speed, there is a turbulence component. Turbulence is described as rapid fluctuations in wind speed that last fewer than 10 minutes. With turbinadoes, it's vital to understand mean wind speed, which is influenced by seasonal, synoptic, and diurnal factors and varies over time.
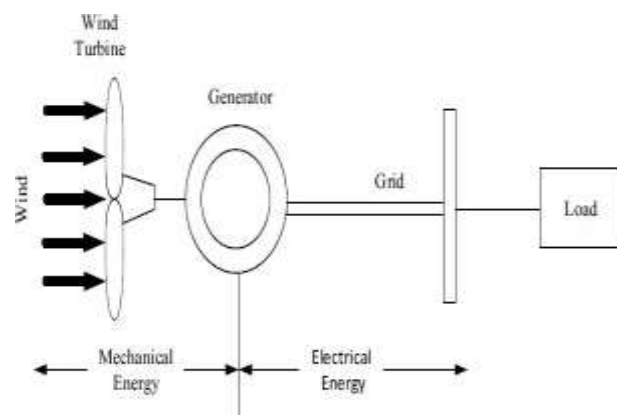

Fig-1: conversion of wind energy into electrical energy

1.1 THE DETERMINATION OF WIND TURBINE PROPERTIES AND PERFORMANCE CURVES

Power, torque, and thrust are three indications of a wind turbine's performance that change with wind speed. The

power of the rotor is defined by the amount of energy it catches, the torque of the gearbox is dictated by the gearbox size, and the rotor thrust has a considerable impact on the structural construction of the tower. The energy contained in moving air is converted into electricity by a wind turbine. Air density, power coefficient, air density, and turbine swept area all influence the amount of energy captured.

1.1.1 MODELING OF WIND TURBINE

A wind turbine is an electrical generator that converts wind energy. It consists of an induction generator and other electrical control power requirements. Electrical connections, rotor size, copper and iron losses, wind generator efficiency, and blade design are only a few of the internal and external components that influence wind turbine performance (wind speed, weather parameters, location and height of wind tower). The mechanical power is supplied in the equation.This equation describes the link between input mechanical power, wind speed variation, and other variables (air pressure, air density and temperature). The range of change of these variables is used to account for the effect of the atmosphere on mechanical power. Electrical power (Pe) is around 0.7 times that of mechanical power. The characteristics are measured at the same location where the wind turbines are erected.

$Pw=(1/2)\rho \times A \times V3$
But $P=Cp \times Pw$
Therefore $P=(1/2)\rho \times A \times Cp \times V3$
And $Pe=P-PL$
where: Pw = wind power, P = mechanical power in watts, Pe = electrical output power, PL= power
losses in wind turbine, ρ = air density in kg/m3, A = swept area in m2, Cp =power coefficient of wind
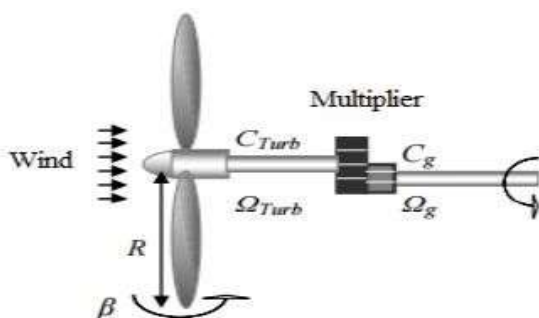turbine, V = wind speed in m/s.

Fig-2: modelling of a wind turbine

A wind turbine's mechanical output is proportional to both wind speed and the swept area of its blades. It's worth noting that the power is proportional to the cube of the wind speed and the square of the rotor blades' radius. When the radius of the rotor blades is doubled, the swept area is quadrupled. When evaluating efficiency, blade size and

shape, number of blades, pitch angle, rotor speed, alternator efficiency, gear losses, and other factors must all be considered. When the wind speed is reduced by half (1/2), the power is reduced to 1/8 of its previous value. As a result, a light wind has little power, thus for the experiments, use a larger table fan. It will produce significantly better results. Albert Betz was a German physicist who pioneered wind turbine technology. We can only harvest 16/27, or 0.593, of the power generated by the wind, he discovered. The Betz coefficient is a mathematical expression that describes the potential maximum efficiency that a wind turbine can attain. Power losses such as mechanical, electrical, and iron losses influence the activity of wind turbines in converting mechanical to electrical power. .

2. WIND SPEED

With the wind speed, mechanical power (P) is harnessed (V). The mechanical power is most affected by the wind speed of air, which is a measure of the wind generator's activity. The dimensional curves of the power coefficient (Cp) as a function of both the tip speed ratio and the blade pitch angle characterise the wind turbine (B).

$Cp=Cp(\lambda,B)$

The value of (λ) should be kept at its maximum value in order to completely use the available wind energy. As a result, the power coefficient associated with that value will reach its maximum value. The tip speed ratio () is the ratio of the wind turbine's angular rotor speed to the linear wind speed at the tip of the blades; in other words, the behaviour of mechanical power effectiveness as a function of wind speed is determined by the power coefficient.$\lambda=\omega t \times r/V$

Where: r = wind turbine rotor radius, V = wind speed, ωt = mechanical angular rotor speed of the wind turbines.

Wind speed is initially ineffective until it reaches a cut-off speed of 4 m/s, at which point the power begins to initiate and build as the wind speed increases. When the wind speed reaches 14 m/s, the mechanical power remains stable, whereas the decline in mechanical power begins at a cutoff speed of 25 m/s, as illustrated.

3. TURBINE SIZE

Over the previous 20 years, average wind turbine ratings have climbed roughly linearly, with modern commercial machines rated at 1.5 MW. The designers of each wind turbine have said that their machines will be the largest ever built. With each successive generation, however, the size of wind turbines has increased along the linear curve, resulting in decreased life-cycle energy costs. The long-term development of larger turbines is being driven by the need to take advantage of wind shear by putting rotors in higher,

more powerful winds at a higher elevation above ground (wind speed increases with height above the ground). One of the key reasons for the high capacity factor of wind turbines is because of this. The "square-cube law" is the main argument for limiting the size of wind turbines. "As a wind turbine rotor gets bigger, its energy production grows in proportion to the rotor-swept area (the diameter squared), whereas the volume of material, and consequently its mass and cost, climbs in proportion to the diameter cube," it says. In other words, the cost of a larger turbine will eventually outstrip the money earned by the energy output, making scaling a losing investment. Engineers have successfully overcome this restriction by increasing design criteria. The Wind PACT study demonstrates how successive generations of blade design have deviated from the cubic weight growth curve in order to reduce weight. It would be conceivable to continue to innovate around this size constraint if advanced research and development provided even better design methodologies, as well as new materials and manufacturing technologies that allowed the complete turbine to scale as the diameter squared.

4. THE ROTOR

For many land-based commercial installations, wind turbine blades have expanded in size from around 8 metres in 1980 to more than 40 metres nowadays. Thanks to improved blade designs, weight increase has been restricted at a far lower rate than fundamental geometric scaling, as previously mentioned. Today's blade designs are rigorously evaluated utilising the most up-to-date computer analytical tools to decrease excess weight. Designers are also starting to use lighter, stronger carbon fibre in high-stress parts of the blade to stiffen it and improve fatigue resistance while reducing weight. Carbon fibre, on the other hand, must be handled with caution due to its high cost (about ten times that of steel). A turbine will cut-in and start producing power at a wind speed of about 5.4 m/s (12 mph). The pitch control mechanism begins to limit power production at 12.5 m/s to 13.4 m/s (28 to 30 mph) to avoid overloading the generator and motor train. With a speed of approximately 26.8 m/s (60 mph). To avoid overloads and damage to the turbine's components, the control system pitches the blades to cease rotation (known as feathering the blades). The development of custom wind turbine airfoils has made this possible. In fact, turbine manufacturers are now required to have unique airfoil designs for each model. These airfoils are made to maximise low-speed wind efficiency while limiting high-speed wind loads. These new airfoil designs also attempt to prevent blade fouling, which is caused by dirt and bugs collecting on the leading edge and can cause serious damage. The rotor system should catch about 80% of the theoretically Potential energy in the flow stream. The aerodynamic performance of a modern wind turbine has greatly improved during the previous 20 years.
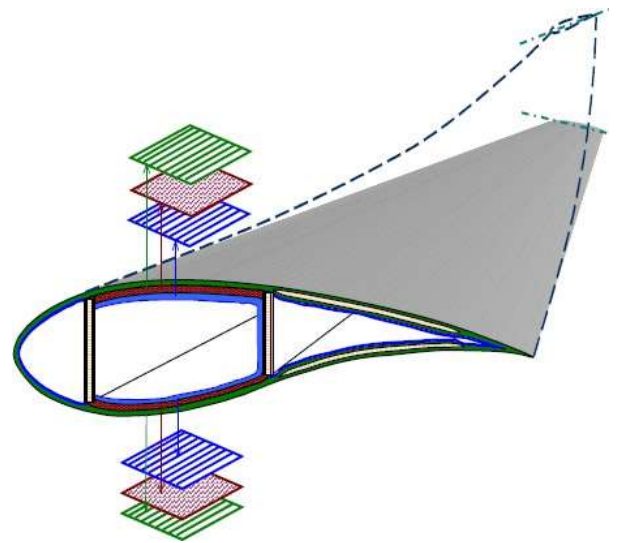

Fig-3: Rotor Design

It is impossible to extract all of the energy contained in a flowing stream of air; some air must remain in motion after extraction to allow new, more energetic air to enter the device. The flow of air would be stopped at the brick wall, but the free stream of energetic air would simply flow around it. A device that does not slow the air, on the other hand, does not extract energy. Albert Betz, a German physicist, is commonly credited with devising the Betz limit, which is a solution for the optimal obstruction. A device with the same working surface as the gadget may theoretically extract up to 59 percent of the energy in a stream.

5. CONTROLS

Today's controllers take data from dozens of sensors to control rotor speed, blade pitch angle, generator torque, and power conversion voltage and phase. The controller is also in responsible of making critical safety decisions, such as shutting down the turbine in harsh weather. The control system continuously updates the rotor speed and generator loading to maximise output and reduce drive train transient torque loads to achieve maximal efficiency in variable winds. The control system regulates the rotor speed to achieve peak efficiency in fluctuating winds by continuously updating the rotor speed and generator loading to maximise power and reduce drive train transient torque loads. Today, most turbines operate at variable speeds, and the control system regulates the rotor speed to obtain peak efficiency in fluctuating winds by continuously updating the rotor speed and generator loading to maximise power and reduce drive train transient torque loads. Variable speed requires the use of power converters to adapt the generated power to the grid frequency. Turbines can also provide fault ride through protection, voltage management, and dynamic reactive power assistance to the grid thanks to the power converter.
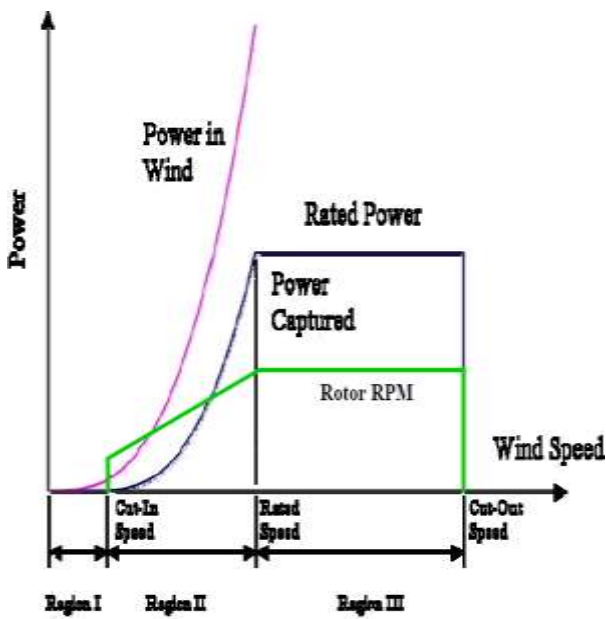
6. Simulation and output waveforms

Fig-4: Power Output Versus Wind Speed Curve

Fig-5: Offshore Wind Technology Developement
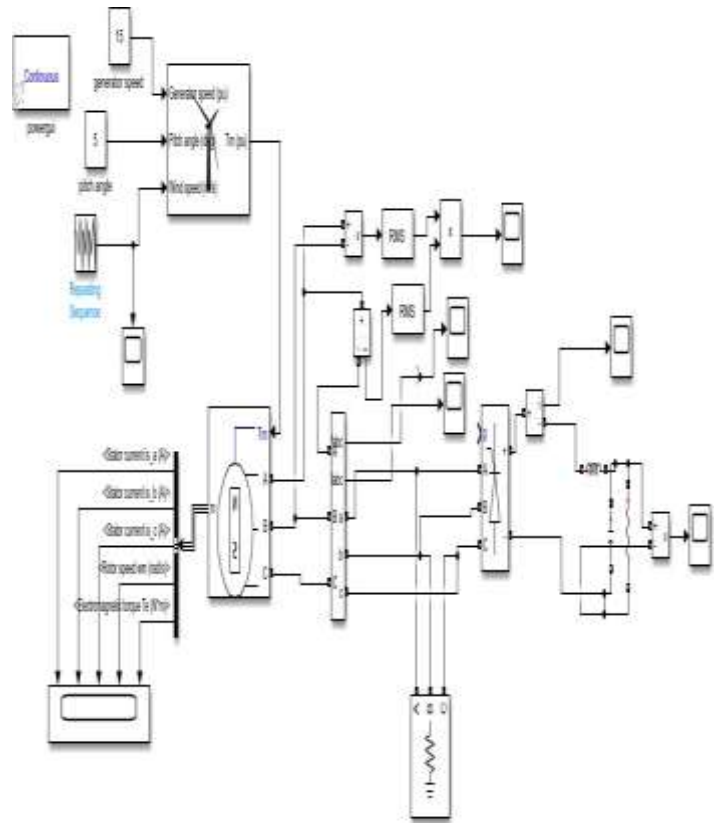

Fig-6: Modelling of Simulink Circuit of Wind Turbine Connected PMSG

Fig-7: Applied Wind Speed Curve
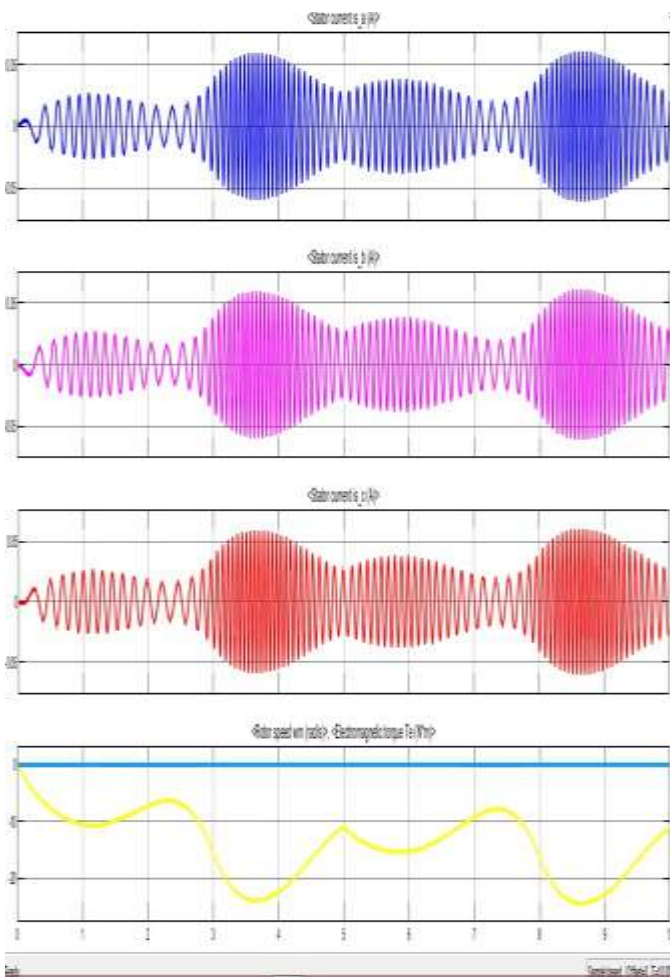
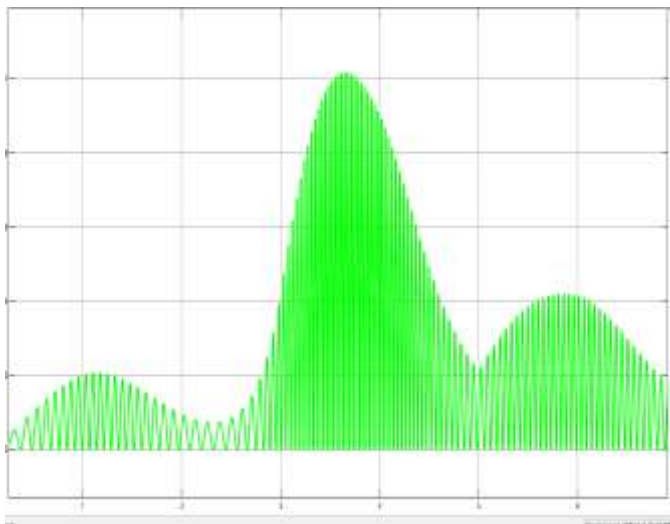**Fig-8:** PMSG Currents, Torque, and Speed Waveform
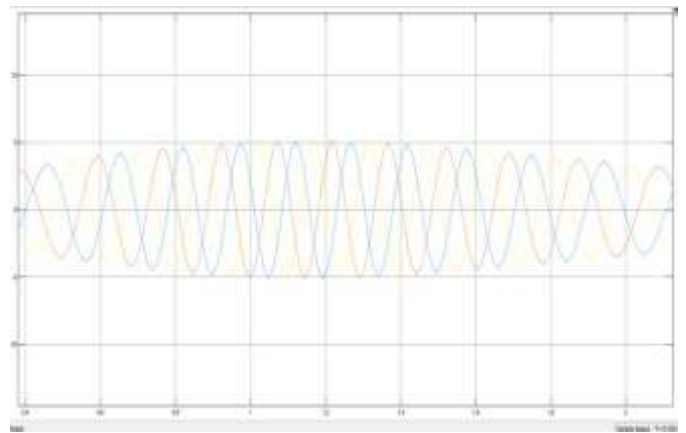

Fig-10: Phase Output Voltage Waveform at Load

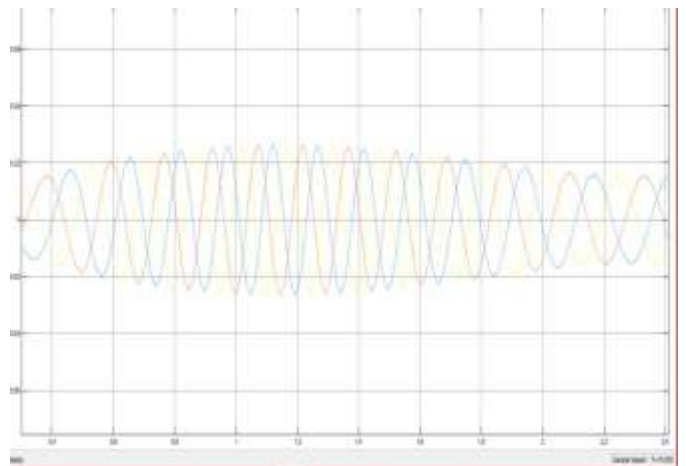**Fig-11:** Phase Output Current Waveform at Load

Fig-9: Output Power Waveform at the Load

7. CONCLUSIONS

The electrical market is very interested in wind energy studies for power generating. Wind energy can be used to improve renewable power generation capacities, raise capacity factor, and engage in cost-effective electricity generation. Many factors, such as air density, wind speed, and power coefficient as a function of pitch angle and blade tip, are taken into account during the production or installation of wind turbines. The modelling and simulation of a wind turbine generator using Matlab/Simulink were demonstrated in this study. The model developed in this study is simple to comprehend. The work presented the integration of the designed wind turbine model with the public electricity grid. The model was used to verify its utility once it was built; a study of its behaviour when incorporated into the entire power system was required. Many wind speed levels were considered, including low with an average of 8 m/s, medium with an average of 10-12 m/s, and high with an average of 14 m/s.

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