Modelling & Simulation of Wind Turbine based AC to DC Converter

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Abstract**–***The Wind Turbine MATLAB Simulink model, together with its functional components and simulation modes, are presented in this work. Almost the only ideal option for a stand-alone, consumer-owned, uninterrupted power supply is the wind turbine. These renewable energy converters lower the environmental impact of industry while also lowering fuel prices for locations that rely on gas or diesel. When used in the production of energy in simultaneously. The detailed research of wind power plant flexibility in the interplay between various power system components completes the creation of the simulation model. The model has demonstrated a sufficient energy conversion efficiency, high component accuracy, and consistent simulation modes' dependability.*

Key Words-wind turbine, MATLAB, renewable energy sources, decentralized energy supply

1. INTRODUCTION

Research into maximizing the efficiency of solar energy systems and wind turbines has been spurred by the growing need for renewable energy sources. By including a Simulink model for an AC to DC converter designed especially for wind turbine applications, this study presents a novel methodology.

The finite nature of fossil fuels and the hazards faced with climate-changing are two further elements leading to the development of renewable energy sources[5]. Since wind energy is regarded as one of the most promising alternative energy sources with enormous potential, it is the subject of this study.

Because of the sun's heat and localized variations in air pressure, air masses are heated and wind is produced. Together with the earth's rotation and topography, solar radiation also contributes to the ongoing movement of these air masses, which are unable to attain thermal equilibrium.

Wind energy is the transfer of the wind kinetic power into mechanical power using a turbine. The generator transforms the mechanical power into electricity, which is then fed into the shared grid.

A more thorough method has been suggested actual converter representation with the PWM-averaged model. In this method, the average circuit model takes the place of the switch network, separating the switching elements from the rest of the network and combining them into a switch network that has all of the switching elements.

Nevertheless, the high-frequency effects of the PWM firing method are ignored by the suggested model, making it impossible to calculate DC-link voltage precisely in case of a breakdown.

For both rotor and stator side converters, a switch-by-switch representation of the back-to-back PWM converters and the corresponding modulators has also been suggested. Triangular carrier-based Sinusoidal PWM (SPWM) is utilized in a switch-by-switch paradigm of voltage-fed, current-controlled PWM converters in order to maintain the switching frequency constant..

It is decided to calculate the necessary rotor voltage that needs to be delivered to the generator in order to achieve constant switching frequency. Various methods such as the hysteresis controller, stationary PI controller, and synchronous PI controller have been adopted in order to control the current-regulated induction machine.

The synchronous PI controller is widely regarded as the best of these. The RSC cancels the harmonics fed into the grid and measures the current flowing through a non-linear load attached to the network.

The rotor-side converter feeds the generator with the reactive power needed to sustain the grid and balance harmonic currents. The long-term effects of compensating for reactive and harmonic power using the DFIG are unclear.

1.1 Types of Wind Turbines

The two primary categories of wind turbines are vertical axis and horizontal axis:

1.1.1 Horizontal-Axis Wind Turbines (HAWTs):

a) The blades of a vertical axis wind turbine rotate on an axis perpendicular to the ground,

b) HAWTs function similarly to an airplane propeller in that their blades revolve around a horizontal axis.

These are the most often utilized kind of wind turbine in use today.

c) In order to better capture the wind, the blades are typically positioned upwind of the tower.

d) HAWTs are divided into two primary categories:

e) Onshore turbines: Usually greater in size, these are located on land

f) Offshore turbines: Designed to capitalize on stronger and more reliable winds, these are situated in bodies of water, typically oceans.

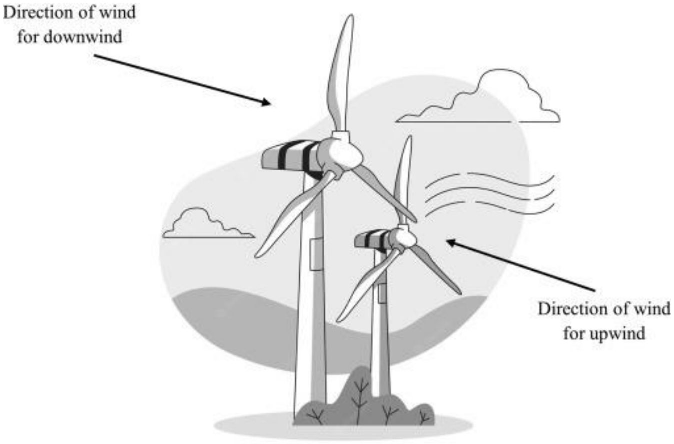

Fig. 1. Horizontal axis wind turbine

2. Vertical-Axis Wind Turbines (VAWTs):

A horizontal axis wind turbine revolve on an axis parallel to the ground.

a) VAWTs resemble large pinwheels or eggbeaters because their blades revolve around a vertical axis. They are appropriate for urban and other restricted locations since they can withstand wind coming from any direction without shifting their position[18].

b) When compared to HAWTs, VAWTs are frequently quieter and may require less maintenance.

c) Comparatively speaking to HAWTs, VAWTs are less frequent in large-scale applications and typically have lower efficiency.

Fig. 2. Vertical Axis Wind Turbine

Every variety has its benefits and drawbacks.

Modern wind turbines have a horizontal axis layout with two or three blades. Multi-blade propellers that revolve around a horizontal axis parallel to the ground are a feature of the horizontal axis wind turbine design. The ground and wind flow are parallel to the blade rotation axis. Certain machines are engineered to function in an upwind mode by positioning their blades upwind of the tower.

Typically, a tail vane is employed in this situation to maintain the blades face the wind. Some designs function in a downwind mode, allowing the wind to travel through the tower and strike the blades first. A wind direction sensor installed on the tower triggers the rotation of some extremely large wind turbines by the use of a motor-driven mechanism.

Wind turbines with a vertical axis are less prevalent than those with a horizontal axis. This is primarily because, in comparison to horizontal axis turbines, they are less able to benefit from the increased wind speeds at higher altitudes above the earth.

Because the shaft is vertical, it is possible to install the generator and transmission at ground level, which makes maintenance simpler and the tower less expensive and heavier. Despite these benefits, the energy efficiency of vertical axis wind turbine designs is inferior to that of horizontal machine designs.

2. Literature Review

Even though these studies offer insightful information, there is still a significant vacuum in the literature when it comes to the precise design and modeling of AC to DC converters intended for wind turbine applications. Research that has already been done frequently looks at solar or wind systems separately, ignoring the combined advantages of a well-integrated converter. Furthermore, a thorough Simulink modeling technique is missing from most research, which is essential for a thorough comprehension of the dynamic interactions inside the hybrid system.

By giving a comprehensive Simulink model for an AC to DC converter based on wind turbines, this work attempts to close this knowledge gap and offer a more sophisticated understanding of the relationships between solar energy generation and wind turbines. Our research adds to the expanding body of knowledge in the field of renewable energy systems integration by filling in these gaps in the literature.

3. Methodology

3.1. Problem Formulation:

The main issue this study attempts to solve is the absence of a complete Simulink model designed specifically for AC to DC converters based on wind turbines. There is a gap in the precise modeling and simulation of the power conversion process within the wind turbine system, despite the fact that previous research examines the integration of wind turbines with different energy systems.

3.2. Component Selection:

The principal obstacle tackled in this study is the absence of an all-inclusive Simulink model specifically designed for AC to DC converters based on wind turbines. Although research has been done on the integration of wind turbines with different energy systems, there is still a lack of precise modeling and simulation of the power conversion process inside the wind turbine system.

The selected parts help the Simulink model accurately depict the behavior of the converter, guaranteeing a trustworthy and useful simulation of the energy conversion process including wind turbines.

3.3. Simulink Model Development:

The suggested wind turbine-based AC to DC converter model was created with MATLAB Simulink. The chosen elements and the associated mathematical formulas were integrated into the model. The converter's performance was optimized through the implementation of control algorithms under various wind situations. Figure 1 depicts a thorough simulation of an AC to DC converter based on a wind turbine.

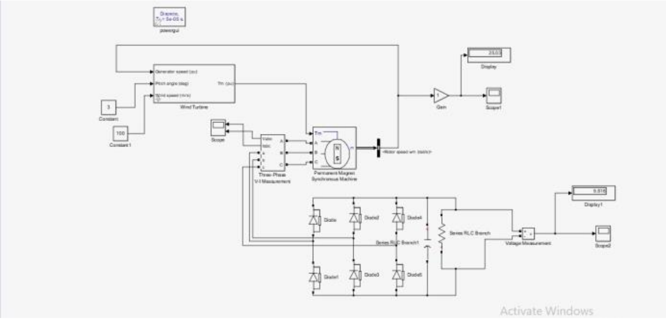

Fig 1. Output from scope ‘S1’

The MATLAB Simulation also entails examining the electrical properties of the converter itself as well as the wind turbine. This entails modeling the behavior of the converter in converting the fluctuating AC output to stable DC power and comprehending the wind turbine's power output at different wind speeds[17]. To fully capture the system's performance and optimize its design for efficiency and reliability, the simulation must also take into account variables like converter efficiency, control algorithms, and grid integration.

4. Sensitive analysis and Optimization

4.1 Sensitivity Analysis:

To investigate how changes in input parameters affect the Simulink model, we have carried out methodical sensitivity analyses. Determine the important variables that affect system performance, such as component qualities, load levels, and wind speed. Analyze the robustness of the model and determine how changes in parameters affect important metrics.

4.2 Optimization:

Iteratively optimize the wind turbine-based AC to DC converter's design parameters based on simulation findings and sensitivity analysis. Optimize the overall system performance by fine-tuning operational methods, control algorithms, and component configurations. The goal of the optimization procedure is to determine the converter's most reliable and efficient design, guaranteeing top performance under a range of operating circumstances.

5. Simulation output

From the scope” s “ we have an AC output obtained from the wind turbine terminals, the fig.2 basically shows the detailed interpretation of the sinusoidal wave describing the nature of an AC wave.

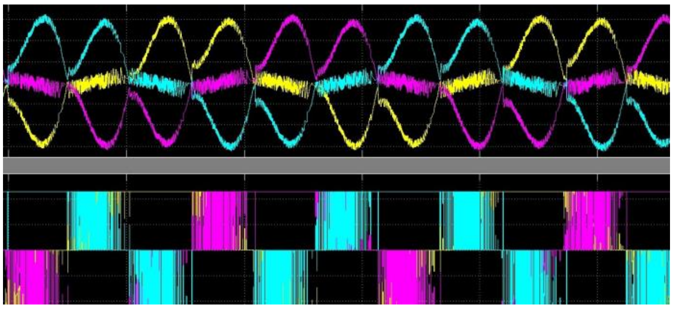

Fig 2. Output from scope S1

Similarly from the scope "S1" we obtained the unrectified DC power

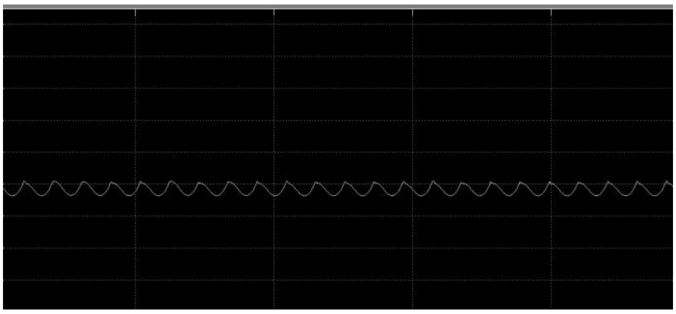

Fig 3. Output from Scope "S1"

And finally the rectified DC output is obtained from the scope "S2" which uses the filter the filter the undesired or extra components on the DC components

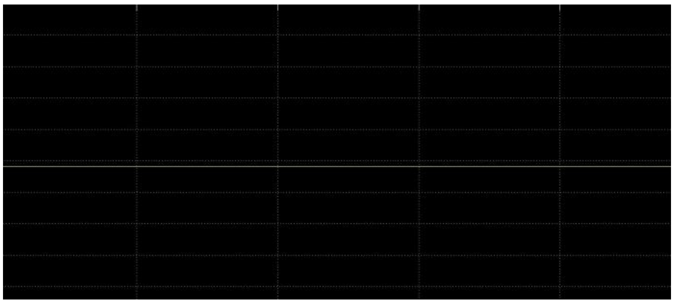

Fig 4. Output from Scope "S2"

6. CONCLUSIONS

Filling the void in the literature, this study provides a thorough Simulink model for an AC to DC converter based on a wind turbine. In addition to optimizing power conversion efficiency and ensuring stability under fluctuating wind speeds and loads, the created model accurately captures dynamic interactions. The model's trustworthiness is increased by validation against experimental evidence and theoretical standards.

Sensitive analysis insights add to a more complex comprehension of system behavior. The enhanced converter design highlights its usefulness in improving the efficiency of wind turbine-based energy systems by showcasing its potential for effective energy conversion.

REFERENCES

[1].M. Nalini Devi , S. Sudharani, "Simulation of Wind Turbine Driven DFIG Using AC-DC-AC Converter", International Journal of Advances in Engineering and Management (IJAEM) Vol. 2,2020.

[2].Evgeny Gordievsky, Alexey Miroshnichenko, Evgeny Solomin," Wind Turbine Matlab Simulation Model", International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM), 2020.

[3]. Kapil Parikh, Ashish Adholiya, "Modelling and Simulation of AC/DC/AC Converter Based Wind Energy Conversion System", Pacific University Journal of Science and Technology Vol. 1, Issue 1,2016.

[4].Olive Ray, Anil Prasad Josyula, Santanu Mishra and Avinash Joshi, "Integrated Dual Output Converter", IEEE transactions on industrial electronics, vol. 62, no. 1, pp. 371-382, Jan. 2015.

[5].Kim Jong-Gyeum, "Analysis for voltage fluctuation and power flow at the grid-connected time of squirrel-cage induction generator", *KIIEE*, vol. 28, no. 6, pp. 45-51, 2014.

[6].M. Godoy Simoes and Felix A. Farret, Renewable Energy Systems-Design and Analysis with Induction Generators, CRC Press, 2004.

[7]. S. C. Kuo and L. Wang, "Analysis of isolated self-excited induction generator feeding a rectifier load", Proc. Inst. Electr. Eng.Generation Transmiss. Distrib., vol. 149, no. 1, pp. 9097, Jan. 2002.

[8].Dynamic Modelling of Ge 1.5 And 3.6 Mw Wind Turbine generators For Stability Simulations Nicholas W. Miller, Juan J. Sanchez-Gasca, William W. Price Robert W.Delmerico.

[9]. A. Kumar, P. Karandikar, and D. Chavan, "Generating and saving energy by installing wind turbines along the railway tracks," IEEE, pp.25–27, 2015.

[10].S. V. Mikhalap, "On the calculation of the wind generator parameters for weak wind areas," Actual questions of energy maisky, pp. 184–189,2018.

[11].K. Anoune, M. Bouya, M. Ghazouani, and A. Astito, "Hybrid renewable energy system to maximize the electrical power production," IEEE, pp. 533–539, 2016

[12]. D. I. Zimnukhova and A. A. Gibadullin, "Problems arising when using wind power engineering," Modern problems of electric power and ways of their solution, no. 3, pp. 120–123, 2018.

[13].A. A. Miroshnichenko, E. M. Gordievsky, A. Z. Kulganatov, and E. A.Sirotkin, "A review of the idea of developing a scalable mobile energy complex based on renewable energy sources," Journal of Western Siberia, vol. 14, no. 4(75), pp. 61–66, 2018.

[14].I. M. Kirpichnikova and E. V. Solomin, Wind power plants. Calculation of the parameters of the components: textbook. Chelyabinsk: Publishing Center SUSU, 2013.

[15].X. Jin, Y. Zhang, X. Dai, and W. Wang, "Study on renewable energy integration with electric thermal storage in demand-side – Part I: Analysis for output characteristics of wind farms and photovoltaic plants," IEEE, pp. 895–899, 2017.

[17].A. O. Troitsky, D. V. Korobatov, S. V. Kozlov, and E. A. Sirotkin, "Classification of control systems for wind power plants," Int. Scientific Journal Alternative Energy and Ecology, no. 13–14 (201–202), pp. 38-45, 2016.