ISSN 2277-2685
IJESR/Apr-Jun. 2024/ Vol-14/Issue-2/696-704
Dr. K. Jaghannath *et. al.,* / International Journal of Engineering & Science Research

MODELING AND SIMULATION OF A GEARLESS VARIABLE SPEED WIND TURBINE SYSTEM WITH PSMG

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Abstract: When it comes to wind turbine designs and construction, high-tech technology is at the forefront. Gearless wind turbine designs are necessary because of the extreme stress and climatic conditions under which a wind turbine gearbox must operate. There are a number of advantages to gearless wind turbine technology, including a reduced risk of downtime and repair expenses, which is especially essential when dealing with offshore turbines because of the difficulty of dispatching qualified technicians to the area. This research examines the performance of a wind turbine with a permanent magnet synchronized generator that operates without a gearbox (PMSG). MATLAB/Simulink software is used to model and simulate the gearless variable-speed wind turbine design with PMSG. An electric-power scheme can be sustained by a Wind Turbine, as demonstrated by the results. Model, simulate, and analyses the effects of wind speed and Q-reference variations on the variable speed wind turbine system with a permanent magnet synchronous generator by using this study effort.
Keywords: Electric power grid, gearless wind turbine, variable-speed wind turbine, permanent magnet synchronous generator

I.INTRODUCTION

wind power is one of the fastest-growing sources of renewable energy in the world today. There are currently several wind power renewable producing systems in place around the world as a result of global warming and the exhaustion of fossil fuels. The price of wind renewable power technology is expected to fall over time, allowing for the expansion of existing wind power renewable producing facilities [1] - [4]. With its advantages over fixed-speed wind energy conversion, variable-speed wind energy systems have become the industry standard. These advantages include better energy capture, improved power quality and less mechanical stress. Aside from their inherent reduced mechanical stress and aerodynamic noise pollution [5], they have the potential to capture ideal power. Various technologies have been developed for wind power applications as a result of the increasing use of wind power conversion methods. The multiple advantages of the generation system for permanent-magnet synchronous generators represent an important change in the expansion of wind energy use. The employment of permanent magnets in the rotor creates the excitation field of a permanent magnet synchronous generator. They can be incorporated into the rotor surface, or they can be positioned inside of it. In order to maximise efficiency and reduce manufacturing costs, the space between the stator and rotor is shortened. Static generator systems that use permanent magnets tend to be low-power and low-cost. Compared to the classic wound rotor synchronous generator, the permanent magnet generator has a higher number of poles of 60 or more, making it a more competitive technology for low-speed direct drive wind turbine generator schemes. Only that it does not provide control over the excitation or reactive power of a permanent magnet is a drawback. Because the rotor flux cannot be controlled, one of the main drawbacks of permanent magnet wind turbine synchronous generator systems is that their maximum efficiency can only be achieved at a single predetermined wind speed.

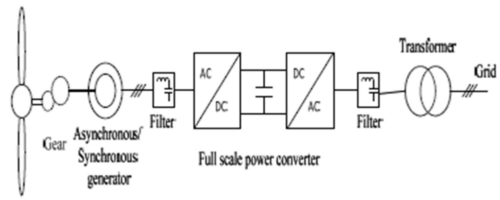

Fig. 1. Full-scale power converter for variable-speed wind turbines

With a full-scale power conversion, a wind turbine generator can be connected to the grid via a power electronics converter, resulting in a variable speed wind turbine generator. This is represented in Figure 1. Reactive power correction and a smooth electrical grid linkage are performed by the frequency converter during the speed variation. There are several types of generators available, such as asynchronous, electrically excited, and permanent magnet excited synchronous machines like the permanent magnet synchronous machine. Asynchronous machines: A full-scale power electronics converter connects the stator windings to the energy grid. One example is the gearless variable speed Wind Turbine Systems (WTSs) depicted in FIG. 1. These conditions necessitate the use of a more powerful, direct-driven multipole generator. Manufacturers of wind turbines prefer to employ systems with a direct drive. To bypass the need for a transformer and link directly to the electricity grid, future full-scale power conversion systems may use voltage levels ranging from low, or less than 1 kV, to medium (or more than 1 kV), or even high voltage (over 1 kV). [14 - 15] Gearbox breakdowns have plagued the contemporary wind industry since its inception because of design flaws and underestimate of operational loads. Wind turbine gearbox performance monitoring is becoming increasingly important among manufacturers as turbines become larger and are deployed in more difficult-to-reach locations, such as offshore. Complications in gearbox repair, high replacement costs, and long downtimes are all factors contributing to wind turbine manufacturers' concerns about gearbox reliability, which can result in revenue losses for utility companies. To increase the speed of the electrical generator from the low-speed rotors, a gearbox is commonly employed in wind turbines. The gearbox design for a wind turbine is challenging because of the loads and climatic conditions in which it must operate. The rotor's torque generates electricity, but the wind turbine's rotor is also subjected to enormous moments and forces. Make certain that the drivetrain clearly isolates the gearbox or ensure that the gearbox is designed to withstand loads in order to avoid catastrophic misalignment of internal gearbox components. This can lead to a buildup of tension and a decrease in productivity.

Fig. 2. An issue with the gearbox in a wind turbine's transmission

Fig. 2 depicts what happens when a wind turbine's gearbox fails, and gear oil is required to withstand the high pressures generated in the wind turbine transmission region.There is a significant amount of transient loading on wind turbine drivetrains during start-ups, shut downs, emergency stops, and grid hookups. Bearings can be damaged by electrical loads that result in torque reversal, as the rollers may be skidding during the abrupt displacement of the loaded area. Seals and lubrication schemes must be able to withstand a wide range of temperatures in order to prevent dirt and moisture from entering the gearbox, and to perform at all rotational speeds. Manufacturing flaws such as grind temper or material inclusions, surface-related issues such as micro-pitting and fretting from minor vibratory motions, such as could occur when a machine is parked, are all potential causes of gearbox failures. Problems with fundamental design such as unproductive interference fits, inefficient lubrication pathways and problems with sealing have plagued a number of wind turbine gearboxes in the past. Wind turbine power generation costs will rise in the future if new gearbox designs are less susceptible to these issues. A gearless wind turbine is therefore required [16].

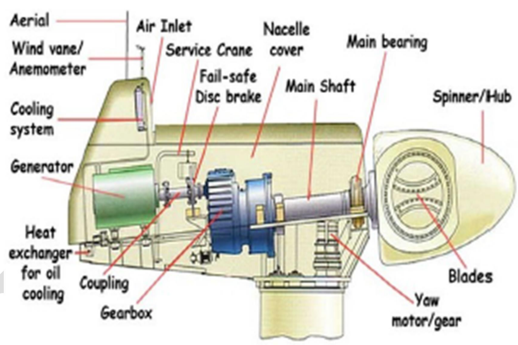

Fig. 3. A wind turbine equipped with a transmission

As depicted in Figure 3, a conventional wind turbine is displayed with its gearbox. A unique gearless generator technology can be utilised as a substitute to gearboxes. An important concern for offshore wind turbine applications is that it is exceedingly expensive to perform maintenance. This makes the turbines more reliable. Taking the gearbox out of the wind turbine removes the wind turbine's most complex component, hence increasing the turbine's overall reliability. The turbine's efficiency increases much more if a permanent magnet is used, as is the case with modern turbine generators. The external excitation power of a gearless wind turbine with a Permanent Magnet Generator (PMG) technology eliminates losses. Low-speed direct drive or gearless wind turbines do away with the necessity for a gearbox from the wind turbine's drive train. Compared to regular wind turbines, the gearless wind turbines are lighter, have fewer maintenance costs, and don't need to repair gearboxes because they are gearless wind turbines. Because of its light weight and great dependability, the permanent magnet generator is the most often used gearless wind turbine generator. Figure 4 depicts a gearless wind turbine.

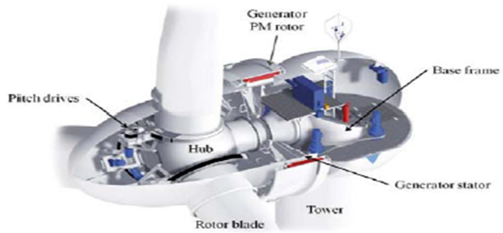

Fig. 4. A gearless wind turbine

II.LITERATURE SURVEY

[1] M. Abdel-Akher, M. M. Aly, Z. Ziadi, H. El-kishky, and M. A. AbdelWarth, "Voltage Stability Modeling and Analysis of Unbalanced Distribution Systems with Wind Turbine Energy Systems", In: IEEE International Conference on Industrial Technology (ICIT), Busan, South Korea. Feb. 26 - Mar. 1, 2014.

Unbalanced distribution systems with wind turbine generation systems are being assessed for voltage stability using a new method presented in this research (WTGSs). Lagrange linear and quadratic interpolations have been used to forecast voltage magnitudes and phase angles during the voltage tracing procedure. Unbalanced three-phase forward/backward power flow solver is used to correct the anticipated solutions. The problem-solving procedure continues until the system's maximum loading conditions are met. The primary benefit of this approach is that it does not require the traditional Newton-Raphson method's huge augmented three-phase Jacobian matrix. Models of direct-connected WTGSs have been developed with sufficient detail to account for distribution system imbalances and slip fluctuations. Voltage regulation is also taken into account when substation transformer taps are placed. Unbalanced systems with multiple unbalanced radial feeders are explored for voltage collapse scenarios. Voltage stability in power distribution networks can be maintained using the proposed continuous flow of power method. When it comes to voltage stability, WTGS with synchronous generators outperform those with induction generators, according to the results of this study.

[2] J. Tamura, "Calculation Method of Losses and Efficiency of Wind Generators," S. M. Muyeen (ed.), Wind Energy Conversion Systems, Green Energy and Technology, Springer-Verlag, London, 2012.

In this study, a steady state analysis-based method is presented for representing various losses in wind generators as a function of wind speed. We can easily calculate wind turbine power and generated power as well as copper and iron leakage and stray load loss, as well as mechanical losses and energy efficiency by applying the proposed approach. One year of wind data was used to calculate the capacity factor and total efficiency of a wind farm using Probability Density Functions. Final results show that a wind farm design and construction plan can be improved by using the proposed approach for calculating wind generators' power output.

[3] G. Fandi, F. O. Igbinovia, Z. Müller, J. Švec, and J. Tlustý, "Using renewable wind energy resource to supply reactive power in medium voltage distribution network", In: IEEE 16th International Scientific Conference on Electric Power Engineering (EPE); Kouty nad Desnou, Czech Republic: IEEE. pp. 169 – 173, 20 - 22 May 2015.

Wind energy can be used to optimise reactive power in a distribution network by controlling the reactive power at a wind farm, and the increase in power factor is used as a new method for reducing power losses. Matlab/Simulink is used to show the results of the analysis.

[4] G. Fandi, F. O. Igbinovia, J. Švec, Z. Müller, and J. Tlustý, "Advantageous positioning of wind turbine generating system in MV distribution network", In: IEEE 17th International Scientific Conference on Electric Power Engineering (EPE), Prague, Czech Republic. 16– 18 May 2016

Renewable wind turbine generation systems (WTGS) deployed in various locations on an MV distribution system can now be used to stabilise voltage and reduce power losses. Low voltage (LV) feeder with an active power (P) of 8 MW and a negative volt-ampere (Qc) of 0.5MV AR are part of the proposed network. A 20 kV MV feeder with a negative VAR (Qc) of 1.5 MV AR and an active power (P) of 22 MW is also included in the system. There are variable positive VAR values of 2, 2.25, 2.5, 6, 6.5, and 7 MVARs for the 0.4 kV and 20 kV feeders, respectively. Third, all of the feeders are connected to the distribution network, which is coupled to a 20kV substation, in data 1, 2, and 3. A 20 kV MV renewable WTGS energy source with IGBT converters is then connected into the network for effective compensation of reactive power. In the first scenario, the planned power system network was examined without any WTGS connected to the network, in other words when the WTGS was turned off (this is designated as Case 1). Third is when the wind energy source is moved to the beginning of the 20 kV MV power line terminal (point 2, which is designated as Case 3). Matlab/Simulink software is used for the simulation of the system model. A comparison of simulation results for each case study shows that research findings for Case 2 are more effective in improving voltage stability and reducing power losses in the medium voltage electric power distribution network.

III. PROPOSED ACTIVE AND REACTIVE POWER CONTROL IN WIND TURBINE SYSTEMS

Doubly-Fed Induction Generator (DFIG) wind turbine systems can be operated at variable speeds, resulting in lower costs for power electronics converters and reduced power losses compared to fixed-speed wind turbine generators. By virtue of their greater efficiency in capturing more wind energy and their capacity to provide higher power quality, variable speed wind turbine systems are more effective. Wind turbine systems with variable speed can lessen the stress on the turbine construction, including the blades and tower, by controlling the turbine output power at a lower speed. Higher power efficiency, longer life span, and increased power quality result from this, making wind turbines more inexpensive in the market, despite their high starting costs. Since 27 through 32. It is becoming increasingly common for wind turbines to be equipped with power electronics converters in order to better regulate and link them to the electrical grid. When it comes to power schemes that can regulate both active and reactive power at all operating points, partial-scale and full-scale power electronics converters are now the focus [14]. Fig. 5 illustrates a different control system for a full-scale converter-based wind turbine. For example, the DC-link can do some control decoupling between this wind turbine and the electric grid. It will also allow the wind turbines to be linked with energy storage units that can better control the active power flow into the electricity grid network, which will further enhance the electricity grid supporting capabilities of the wind turbine systems. It is the generator side converter that controls the wind turbine system's generated active power, whilst the electrical grid side converter controls the reactive power generated by the turbines themselves. It is common to use a DC chopper as a means of preventing DC-link overvoltage when there is a sudden reduction in the energy grid voltage.

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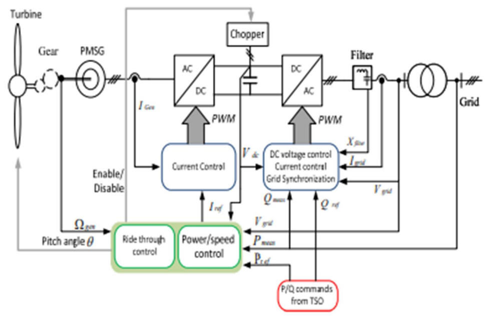

Fig. 5. Using a multipole PMSG for wind turbine active and reactive power control

IV.METHODOLOGY

As shown in Fig. 6, the typical working or permissible power of the wind turbines generator is 10/0.9=11.11 MVA, which was used in this study to power 5 wind turbines, each with a rating of 2 MW. The Q-reference input parameter is used to govern reactive power generation, which is created in proportion to the nominal power. Three different wind speed measurements are taken, each at a different value between 5 and 15 m/s. From 0.0 to 1 p.u. are the Q-reference values The Type-4 wind turbine was chosen for this project because of its high degree of design and operational adaptability.

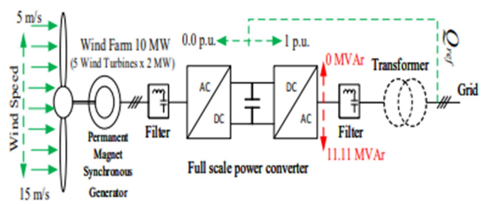

Fig. 6. Schematic diagram of the PMSG gearless variable speed wind turbine system

V.SIMULATION RESULTS

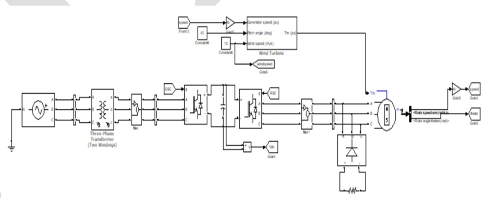

Fig.7 MATLAB/SIMULINK circuit diagram of the proposed system

For a system with 15 m/s wind speed, the proposed wind turbine scheme's reactive and active power are shown in Fig. 8(a) and (b), respectively, given that there were sudden changes in current, but the time to reach steady state and stable regulation of the scheme is extremely short, which is T = 0.25 seconds. This implies that the system is genuine and confirms that the scheme is operating properly. Figs. 9 and 10 demonstrate the current and voltage waveforms of the system, which are both symmetrical and sinusoidal, bolstering the system's validity. Because of this, the scheme is suitable for use on a grid.

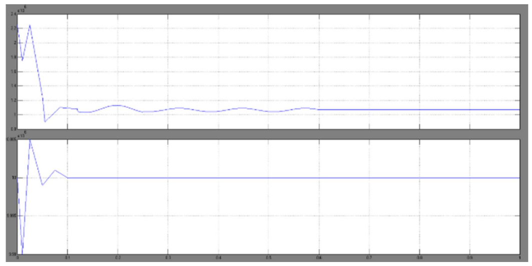

Fig.8 (a) A 15 m/s rate of supply of reactive power to the grid network & (b) At the operational speed of 15 m/s, the grid network receives active power.

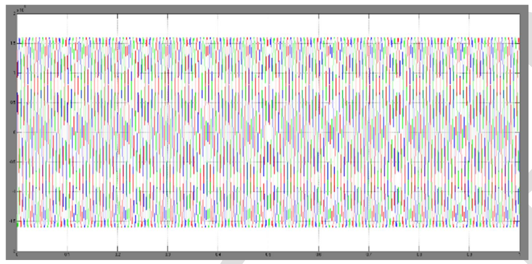

Fig. 9. The voltage waveform of the system is symmetrical and sinusoidal

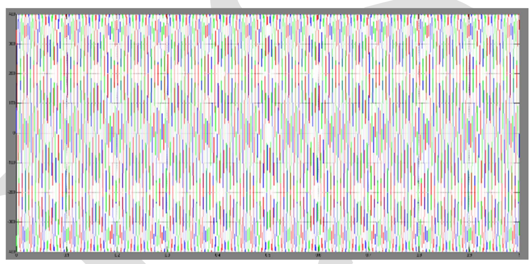

Fig. 10. The scheme's symmetrical and sinusoidal current waveforms

CONCLUSION

Wind turbine designs have a wide range of viable technology options. Gearless or direct drive wind turbines are preferred by some manufacturers. No gearbox means that there are fewer moving parts and tooth difficulties, as well as a reduced risk of fire hazard and environmental spillage due to the oil cooling system. Efficiencies of the gearless wind turbine technology can be demonstrated using the available information. No gearing is required for a gearless variable-speed wind turbine, and the proposed system provides for the independent regulation of active and reactive power at variable wind speeds. MATLAB/Simulink simulations have proven that this system is a valid model. Gearless wind turbines are feasible because they can generate power at a variety of speeds while maintaining stability during the course of varied operational wind speed values studied.

REFERENCES

[1] M. Abdel-Akher, M. M. Aly, Z. Ziadi, H. El-kishky, and M. A. AbdelWarth, “Voltage Stability Modeling and Analysis of Unbalanced Distribution Systems with Wind Turbine Energy Systems”, In: IEEE International Conference on Industrial Technology (ICIT), Busan, South Korea. Feb. 26 - Mar. 1, 2014.

[2] J. Tamura, "Calculation Method of Losses and Efficiency of Wind Generators," S. M. Muyeen (ed.), Wind Energy Conversion Systems, Green Energy and Technology, Springer-Verlag, London, 2012.

[3] G. Fandi, F. O. Igbinovia, Z. Müller, J. Švec, and J. Tlustý, "Using renewable wind energy resource to supply reactive power in medium voltage distribution network", In: IEEE 16th International Scientific Conference on Electric Power Engineering (EPE); Kouty nad Desnou, Czech Republic: IEEE. pp. 169 – 173, 20 - 22 May 2015.

[4] G. Fandi, F. O. Igbinovia, J. Švec, Z. Müller, and J. Tlustý, "Advantageous positioning of wind turbine generating system in MV distribution network", In: IEEE 17th International Scientific Conference on Electric Power Engineering (EPE), Prague, Czech Republic. 16– 18 May 2016

[5] J. S. Thongam, P. Bouchard, R. Beguenane, A. F. Okou, and A. Merabet, "Control of variable speed wind energy conversion system using a wind speed sensorless optimum speed MPPT control method," In: 37th Annual Conference on IEEE Industrial Electronics Society (IECON) , pp. 855-860, 7–10 Nov. 2011.

[6] E. Spooner and A. C. Williamson, "Direct coupled permanent magnet generators for wind turbine applications," IEE Proceedings - Electric Power Applications, vol. 143, no. 1, pp. 1-8, Jan. 1996.

[7] N. Yamamura, M. Ishida, and T. Hori, "A simple wind power generating system with permanent magnet type synchronous generator," In: IEEE Proceedings of the International Conference on Power Electronics and Drive Systems (PEDS), vol. 2, pp. 849-854, 27-29 July 1999.

[8] S. H. Song, S. Kang, and N. K. Hahm, "Implementation and control of grid connected AC–DC–AC power converter for variable speed wind energy conversion system," In: Eighteenth Annual IEEE Applied Power Electronics Conference and Exposition (APEC), vol. 1, pp. 154-158, 9 Feb. 2003.

[9] A. M. Knight and G. E. Peters, "Simple wind energy controller for an expanded operating range," IEEE Transactions on Energy Conversion, vol. 20, no. 2, pp. 459-466, Jun. 2005.

[10] T. Tafticht, K. Agbossou, A. Cheriti, and M. L. Doumbia, "Output power maximization of a permanent magnet synchronous generator based standalone wind turbine," In: IEEE International Symposium on Industrial Electronics (ISIE), Montreal, Quebec, Canada, vol. 3, pp. 2412–2416. 9-12 Jul. 2006.

[11] Mr. Mohd Amaan Ali Sayeed, Mr. Mohammed Ghayaasuddin, Mr. Syed Imran, Mr. M.A.Mubeen, An Enhanced Elderly Person Health Parameters Monitoring System With Medicine Prescription, International Journal of Multidisciplinary Engineering in Current Research - IJMEC Volume 8, Issue 7, July-2023, http://ijmec.com/, ISSN: 2456-4265.

[12] Mr. Shaik Ibrahim Ahmed, Mr. Syed Musharraf Ali, Mr. Mohammed Affan , Automatic Image Caption Generation, International Journal of Multidisciplinary Engineering in Current Research - IJMEC Volume 8, Issue 7, July-2023, http://ijmec.com/, ISSN: 2456-4265.

[13] Mr. Abdul Mutallib Bin Abood Bin Sawad, Mr. Abrar Ahmed Khan, Mr. Mohammed Nasiruddin, Mr. Mohammed Hannan Qureshi, Mr. Mohammed Saad Afzal, Environmental Parameters Monitoring And Device Controlling Using Iot, International Journal of Multidisciplinary Engineering in Current Research - IJMEC Volume 8, Issue 7, July-2023, http://ijmec.com/, ISSN: 2456-4265.

[14] M. Chinchilla, S. Arnaltes, and J. C. Burgos, "Control of permanent magnet generators applied to variable-speed wind-energy systems connected to the grid," IEEE Transactions on energy conversion, vol. 21, no. 1, pp. 130–135, Mar. 2006.

[15] S. M. Dehghan, M. Mohamadian, and A. Y. Varjani, "A New VariableSpeed Wind Energy Conversion System Using Permanent-Magnet Synchronous Generator and Z-Source Inverter," IEEE Transactions on Energy Conversion, vol. 24, no. 3, pp. 714 – 724, Sep. 2009.

[16] Synchronous Generator, [Online]. Available from: http://www.alternative-energy-tutorials.com

[17] F. Blaabjerg, M. Liserre, and K. Ma, "Power electronics converters for wind turbine systems," IEEE Transactions on Industry Applications, vol. 48, no. 2, pp. 708–719, Mar./Apr. 2012.

[18] C. H. Ng, M. A. Parker, L. Ran, P. J. Tavner, J. R. Bumby, and E. Spooner, "A multilevel modular converter for a large, light weight wind turbine generator," IEEE Transactions on Power Electronics, vol. 23, no. 3, pp. 1062–1074, May 2008.

[19] W. Musial, S. Butterfield, and B. McNiff, "Improving Wind Turbine Gearbox Reliability", European Wind Energy Association (EWEC), Milan, Italy, 7–10 May 2007

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