International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 5 ǁ May 2023 ǁ PP. 872-885

Investigation of PMSG Based Wind Energy Battery Storage System and Performance Analysis Under Various Fault Conditions

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ABSTRACT *In this paper, the trending demand of renewable energy generation for the future growth of global economy and to save environment from pollution, reducing the risk of global warming. The study of various consequences and demerits of the different part of the power system connected to wind energy conversion system needs more research to develop an updated model and efficient generation of electrical power from new and renewable energy generation system. In this paper study of wind energy system connected to Permanent Magnet Synchronous Generator has taken as an account of research and investigation of different causes which affect the PMSG generation. Because of the height of wind turbines the maintenance, cleaning and supervisory is not easy as compare to solar energy generation system. But due to neat and clean energy, wind energy is more efficient than the other renewable resources. Due to the advantages of high efficiency and reliability, PMSG is mainly used in a WECS hence PMSG based WECS is preferred further for the various case studies. In this paper the performance and analysis of PMSG based wind energy system, the various conditions have been studies and their MATLAB/SIMULINK based prototype simulation and results have been discussed under consideration of faults and battery storage system.*

In this paper analysis of derived model of different cases have done on the generation, load and grid side. The rotor speed fluctuation of the PMSG is also investigated and discussed for all these cases. Simulated MATLAB/SIMULINK model and its generated output result observed the different model for different cases and conditions is simulated and their output result has been analyzed for the PMSG generation side mainly.

INDEX TERMS *PMSG Permanent Magnet Synchronous Machine, WECS Wind Energy Conversion System, TSR Total Speed Ratio, VS Variable Speed, WTGs Wind Turbine Generators, 3-Phase Fault, Battery, GTO Gate Turn Off Thyristor, Grid, PWM Pulse Width Modulation, IGBT Inverter, SOC State of Charge.*

Date of Submission: 18-05-2023 Date of acceptance: 31-05-2023

I. INTRODUCTION

In present scenario wind energy and solar energy are considered the most promising renewable energy sources because of their availability, cost and its efficiency. The renewable energy generation is to be appreciated in present for whole world. The increasing cost of fossil fuels and green house effect, global warming and flood, draught, acid rain and frequently raising epidemics are the another reason to increase the appreciation for renewable energy electricity generation.

As like solar, wind is also available almost every where some time in day and night both and also in cloudy and winter weather. It requires very little area of land to install and operate in comparison of solar energy system. It is also green source of energy and required very less cleaning and maintenance. Main thing is that it can generate 1-phase as well as 3- phase ac power that can use in home as well as industrial load. It can also transmit directly to the distributed grid without using any power electronics converter. That is another beneficial thing as cost reduction for the renewable electricity generation system for generation and distribution of electricity power.

The unpredictable fault conditions and lightning may damage the smooth generation of PMSG. It can damage or shut down of the PMSG wind energy conversion system. The modern power system is focusing upon distributed generation and having energy storage devices for backup supply.

The battery technology is frequently used in storing and supplying back to the power system during unavailability of wind and as well as grid supply. Bidirectional charger and buck-boost converters are being used. It produces switching disturbances and noise; in case of fast charging condition it can damage or shut down the PMSG.

The active and reactive power filters are being used with different controllers and modern power electronics converters. It generates DC-offset and noise switching harmonics. These are the basic technical challenges observed in the study of PMSG based wind energy system with different case studies.

PMSG-based WECS are widely utilized in wind energy generation due to their small structure, high power density, and high torque-inertia ratio. Additionally, the PMSG's internal structure, which incorporates precision gears and brushes, is simplified compared to the doubly-fed induction generator (DFIG). As a result of this development, WECS based on PMSG has become a research hotspot in wind energy generating [1]. However, due to the randomness and unpredictability of wind energy's wind speed, current research on high-power wind generators frequently fails to attain their full output As a result; they decreased the efficiency of wind energy usage and nullified the benefits of high-power wind generators. On the other hand, because wind speeds fluctuate often and wind energy is inherently unstable, the grid connection of large-capacity wind farms may introduce specific shocks into the large-power system, rendering it unstable. To minimize the cost of wind energy generation, the wind farm's wind energy conversion efficiency must be increased. As a result, it becomes more critical to improving the wind energy system's control mechanism. At rated wind speeds, modern WECS frequently use the best characteristic curve as the control mechanism for MPPT. It is capable of varying the mechanical output of the generator in response to the wind turbines input under varying weather conditions. As a result, the WECS maintains an optimal blade Tip Speed Ratio (TSR) to maximize wind energy capture. Wind turbines, on the other hand, capture wind energy based on a variety of parameters. Wind speed, blade pitch angle, and wind wheel rotation speed all affect the amount of wind energy captured. In addition, the randomness of wind variations and energy loss in WECS will affect the WECS's stability [2]. As a result, converting wind energy to electrical energy is not a linear process that often involves significant disturbance and uncertainty. Over the last few decades, numerous control theories and strategies have been proposed in the literature to address the aforementioned PMSG issues [3]. The primary control objectives are to maximize power extraction and regulate reactive power to the desired power factor according to grid needs. Due to the benefits of a simple control algorithm, high reliability, and simplicity of implementation, in reality, the Proportional Integral (PI) control technique is often used to enhance the system reliability of the rotor side converter (RSC) and grid side converter (GSC) of the PMSG wind turbine. The PI controller is used in [4] to optimize the PMSG wind turbines performance in both windy and steady-state circumstances. However, the PI control scheme, which is a linear control approach, is not robust enough to react to the nonlinearity of the PMSG wind turbine system and variations in wind speed and wind turbine parameters. Consequently, several nonlinear control schemes have been developed and applied in wind turbine systems to enhance power quality, including fuzzy control [5-6], back stepping control [7-9], and direct power control (DPC). However, fuzzy control is tough to execute in reality as it demands extensive expert knowledge and human cognition, resulting in a delayed response in exchange for high accuracy. While the DPC gives great transient responsiveness, it needs a high switching frequency to reduce torque/current ripples [10]. Back stepping control has the inherent issue of generating an "explosion of complexity", lowering the controller's performance.

Over the last years, with technological advancement, wind power has grown rapidly and becomes the most competitive form of renewable energy [11-13]. Furthermore, Variable Speed Wind Energy Conversion Systems (VS-WECS) are the dominant technologies in the present wind power industry for the reason that they possess several advantages, over the fixed velocity systems, as the ability to obtain Maximum Power Point Tracking (MPPT) control methodology in order to extract maximum power at different wind, higher overall efficiency, power quality and it can be controlled to reduce aerodynamic noise and mechanical stress on VS-WECS by absorbing the wind-power fluctuations [14-16]. On the other hand, with the increased penetration of VS-WECS into power systems all over the world, Wind Turbines Generators (WTGs) based on Permanent Magnet Synchronous Generators (PMSG) are becoming popular for variable-speed generation system and the use of the PMSG in large WTGs is growing rapidly. It is connected directly to the turbine without gearbox and so it can operate at low speeds [16-18]. Moreover, it can reduce again weight, losses, costs, demands maintenance requirements and, with the advance of power electronic technology, the wind farms are at present required to participate actively in electric network operation by appropriate generation control strategies. In the literature, different controlling types of VS-WECS can be seen [16-20].

This paper is summarized for the performance of the PMSG wind energy system and analyzed under different cases like, Effect of Unpredicted 3-Phase Fault and Battery Storage System. It is observed from the different literatures that a practical power system behaves in an unpredicted way.

In normal conditions, an electrical system operates at nominal current and voltage values. During an electrical fault, the current and voltage level diverges from the nominal range into the abnormal range.

The electrical fault reduces the insulation strength of the conductors causing a short circuit and damaging the equipment and appliances. It can create a short circuit, open circuit, over current, under voltage, over voltage, reverse power and unbalance in the phases. This case study belongs to voltage, current, active and reactive power behavior in PMSG wind energy system at generation, load and grid side of the system.

One of the widely accepted methods to overcome problems like intermittency, instability, unavailability of wind energy is by coupling the wind turbine with the energy storage system.

The most economical way to store the electrical energy generated from wind energy conversion system using Battery Storage System. The most widely used batteries are the Nickel Cadmium, Lithium Ion, Lead Acid batteries. To connect the battery energy storage system with the WECS for charging and when the WECS is not available for discharging. The bidirectional concreter is to be used in power system. This case study belongs to the switching and transient behavior of DC/DC bidirectional converter and batteries connected to grid with PMSG wind energy conversion system.

This paper work discussion is based on the MATLAB/SIMULINK model and its generated output result. The different model for different cases and conditions is simulated and their output result has been analyzed for the PMSG generation side mainly.

1.0 Wind Energy Conversion System

Due to the depletion of fossil fuel reserves and growing worries about CO2 emissions, renewable energy sources, particularly wind energy, are gaining a lot of attention. In order to maximize the use of wind energy, variable speed constant frequency (VSCF) wind energy conversion systems (WECS) have been widely employed since the late 1990s. The most widely used devices for converting wind energy are the doubly-fed induction generator (DFIG) and direct-drive permanent magnet synchronous generator (PMSG). The benefits of high efficiency and dependability of the direct-drive PMSG have garnered more and more interest. Figure-1 depicts the setup of a typical direct-drive WECS with PMSG.

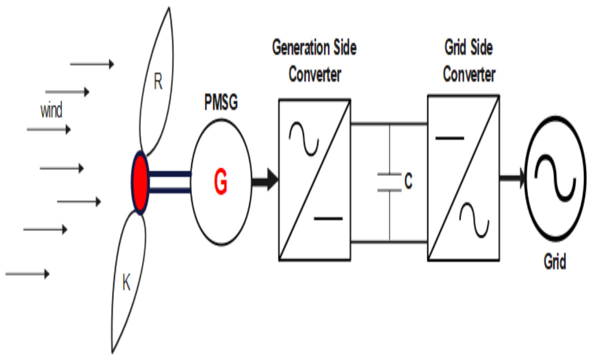

Fig-1 Wind energy conversion system

The wind turbines mechanical energy is transformed by the PMSG into AC electrical energy, which is subsequently supplied to the grid via a power electronic converter. A WECS based on a PMSG is often configured in Figure-1. The wind turbine, generator, rectifier, inverter, battery bank, and grid are the essential elements of a wind energy conversion system.

2.0 Case-1: PMSG and Grid connected unpredicted 3-phase fault.

All areas of the electrical power system, including generation, transmission, distribution, and load systems, are expanding in size and complexity. Short circuit conditions in the power system network are an example of a type of fault that causes significant financial losses and decreases the dependability of the electrical system. An electrical fault is an abnormal state brought on by spinning machinery, human mistake, and environmental factors such as transformer failure. Electric flow interruptions, equipment damage, and even human, bird, and animal deaths are all results of these faults.

When fault occurs it creates a very low impedance path for the current flow. This results in a very high current being drawn from the supply, causing tripping of relays, damaging of insulation and components of the equipments.

In this case study, the 3-phase fault is taken in account for the wind energy system connected to grid. And its simulation model is designed and tested using Matlab and Simulink.

3.1 Block Diagram Model of System

To analyze the performance of the system under faulted condition, two 3-phase faults are applied to the main system as shown in figure-2. Whenever a fault occurs, the load, wind power generating station and grid side cannot meet the voltage and power requirements.

For the above system two three phase faults is applied for duration of 0.10 to 0.15 sec. and 0.15 to 0.20 sec. Then the system performances are analyzed under this faulted condition as shown in the figure.

Analysis and testing of all the simulation results is to be performed with and without fault of the system on generation, load and grid side using Matlab and Simulink model.

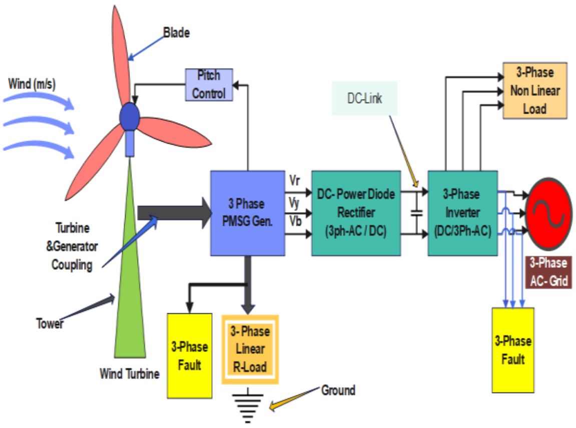

Fig-2 Block diagram of the Testing system

3.2 Simulation Results and Discussion

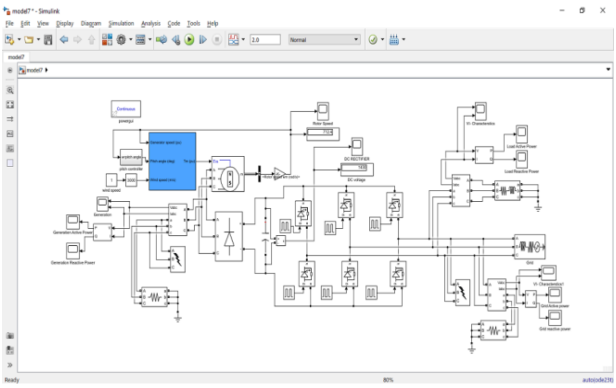

Fig-3 Simulink Model of the System

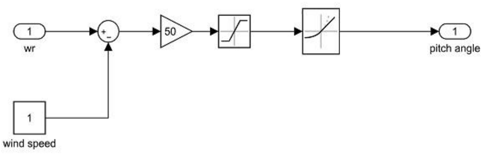

Fig-4 Design of Pitch angle controller for variable speed PMSG

The simulation model of the proposed system shown in figure-3, and basic design of pitch angle controller for variable wind speed PMSG shown in figure-4.

From figure-4, it can be seen that a PMSG wind energy system is connected to 3-phase diode bridge rectifier and GTO bridge inverter both are coupled with dc link capacitor. Two 3-phase fault, one is connected at the PMSG generation side for the duration of 0.10 to 0.15 sec. and other is connected between load and grid of the system for the duration of 0.15 to 0.20 sec.

The Matlab and Simulink model of the system is performed for both situations with 3-phase fault and without 3-phase fault. The performance of the system with their output results have analyzed and discussed further.

4.0 Performance of variable speed PMSG without Fault

To analyze the PMSG wind energy system in faulty condition, the system is first analyzed without fault with variable wind speed as a reference.

4.1 Generation Side

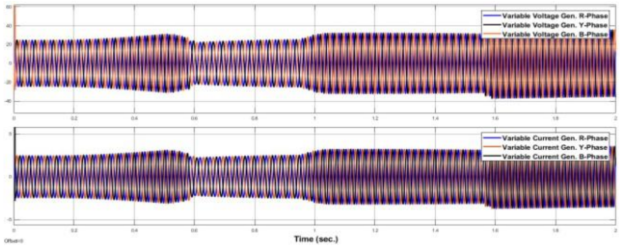

Fig-5 Generation side v-i output characteristics without fault

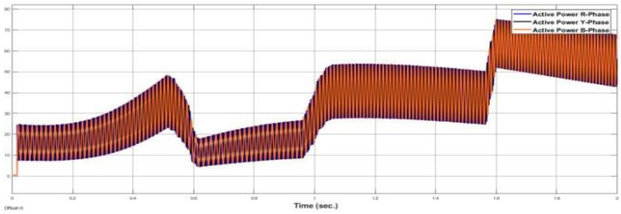

Fig-6 Generation side active power without fault

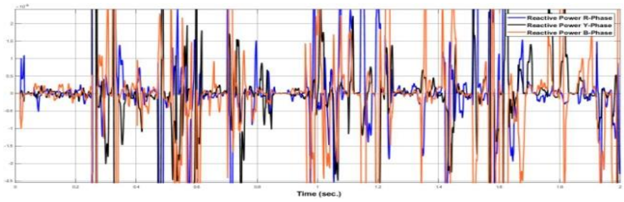

Fig-7 Generation side reactive power without fault

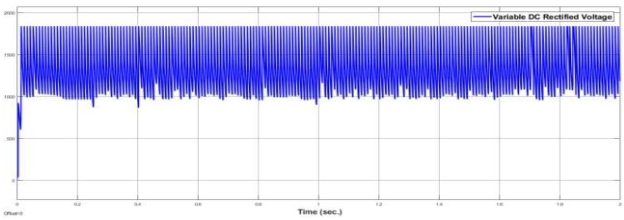

Fig-8 Generation side DC rectified voltage without fault

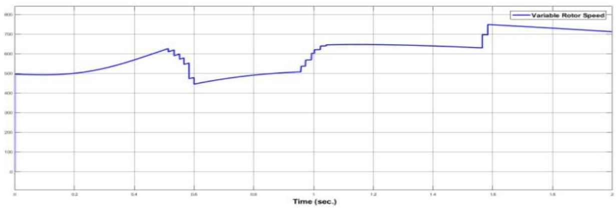

Fig-9 Rotor Variable Speed without fault

The simulation result of variable wind speed PMSG without any fault is shown in figure-5 to figure-9 for generation side of the system. From figure-5, it is observed that 3-phase voltage and current output characteristic is varying as the speed of wind varies. From figure-6 and figure-7, it can be observed that the active and reactive power is also fluctuates as like voltage and current waveform shown in figure-5. It is also observed from figure-8, that DC-rectified voltage fluctuates when; speed of the wind varies at wind turbines blades. Figure-9 shows the fluctuation in PMSG rotor speed with variation in wind speed.

This result would be compared with faulty system to see what happens exactly at the generation side when fault is connected in system.

4.2 Load Side

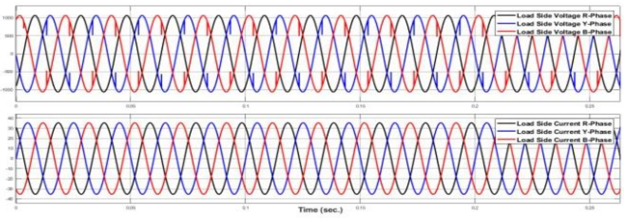

Fig-10 Load side v-I output characteristics without fault

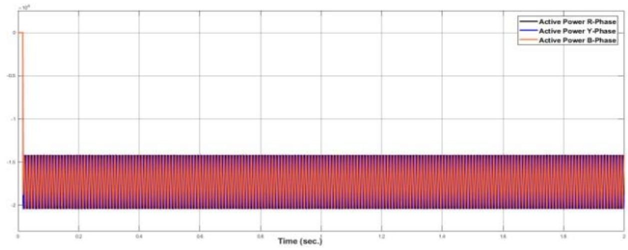

Fig-11 Load side Active power for without fault

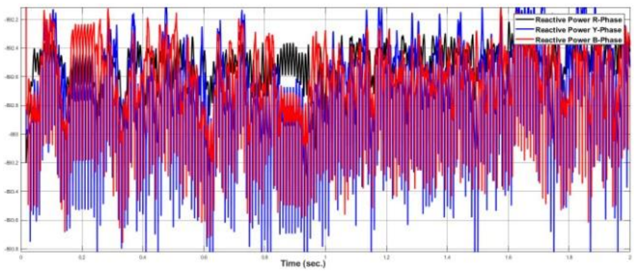

Fig-12 Load side Reactive power for without fault

The simulation results of variable wind speed PMSG without any fault for load side are shown in figure-10 to figure-12. From figure-10, it is observed that the 3-phase voltage and current does not fluctuates at the load side of the system. Because DC link capacitor between diode bridge rectifier and inverter does not allow any fluctuation at the generation side. And grid side is also supply constant 3-phase ac voltage and current that's why it does not fluctuates as like generation side voltage and current shown in figure-5.

From figure-11 and figure-12, it is observed that active power and reactive power also behaves as similar to voltage and current output characteristics.

From figure-10, it is also observed that there is a notching in each phase of the load voltage. This result would be compared with faulty system to see what happens exactly for load side.

4.3 Grid Side

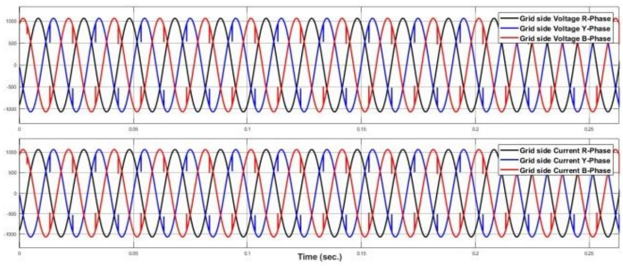

Fig-13 Grid side v-i output characteristics without fault

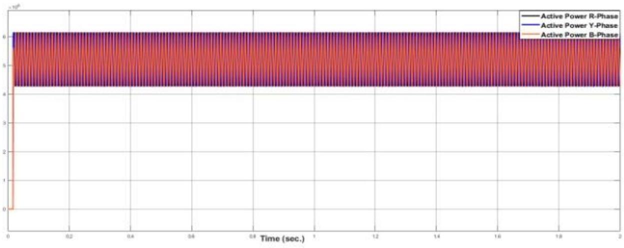

Fig-14 Grid Side Active power without fault

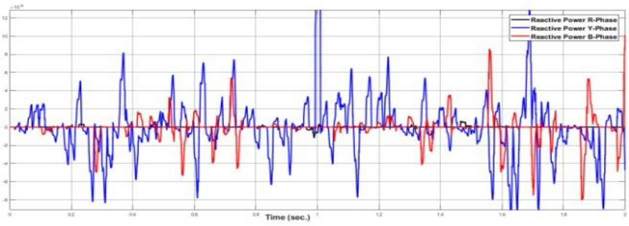

Fig-15 Grid side Reactive power without fault

The simulation result of variable wind speed PMSG without any fault for grid side are shown in figure-13 to figure-15. From figure-13, it is analyzed that the 3-phase voltage and current output characteristics both are in form at the grid side of the system.

From figure-14 and figure-15, it is observed that the active power and reactive power at the grid side is almost similar in waveform as shown in figure-11 and figure-12, but it is less in amount as detected in load side active and reactive power.

This result would be compared with faulty system to see what exactly happens at grid side.

5.0 Performance of variable speed PMSG with 3-Phase Fault

5.1 Generation Side

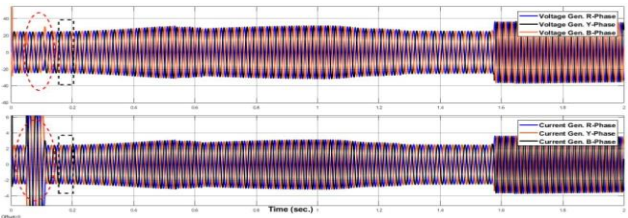

Fig-16 Generation side v-i output characteristics with 3-phase fault

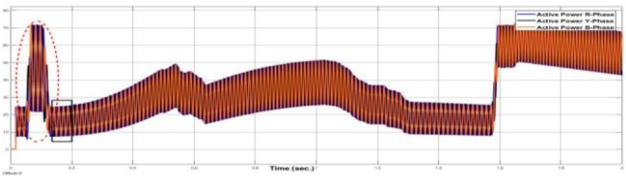

Fig-17 Generation side Active power with 3-Phase fault

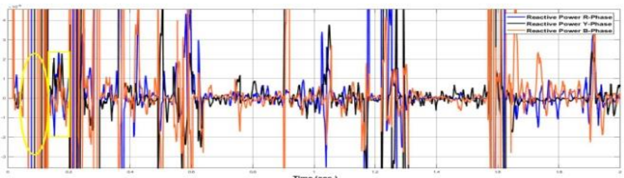

Fig-18 Generation side Reactive power with 3-Phase fault

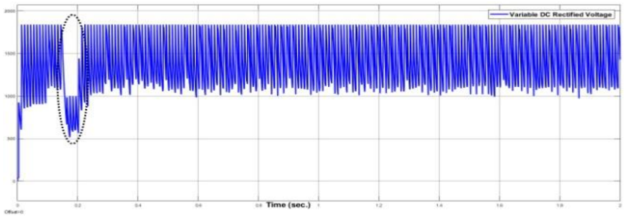

Fig-19 Generation side DC rectified voltage with 3-phase fault

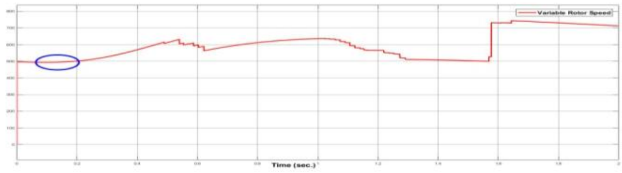

Fig-20 Rotor Variable Speed with 3-phase fault

The simulation result of variable wind speed PMSG connected to 3-phase fault on generation side, load and grid side both for the duration of 0.10 to 0.15 sec. and 0.15 to 0.20 sec are shown in figure-16 to figure-20 for generation side.

From figure-16, it is clearly visible in dotted circle and dotted box of the 3-phase voltage waveform that 3-phase voltage generation is unchanged because of any fault. But 3-phase current is increased in dotted circle of the current waveform because of three phase fault connected to the generation side. In dotted box of the current waveform it can be observed that current is unaffected by grid and load side 3-phase fault.

From figure-17, it is observed in dotted circle of the output waveform of active power that the active power is increased due to generation side fault for the duration of 0.10 to 0.15 sec. But for the duration of 0.15 to 0.20 sec as it can be seen the fault of load and grid side does not affect the active power generation.

From figure-18, it is observed that as similar to the active power, reactive power is also increased for the duration of 0.10 to 0.15 sec as shown in yellow circle of the waveform of reactive power from the fault which is connected at the generation side. And from yellow box it can be seen that nothing happens because of load and grid side fault.

From figure-19, it is observed that the DC rectified voltage is reduced for the duration of 0.10 to 0.15 sec because of generation side connected 3-phase fault. And nothing happens for duration of 0.15 to 0.20 sec because of load and grid side fault.

From figure-20, it is observed from blue circle that the PMSG rotor speed is not affected by generation side, load and grid side 3-phase fault.

It is observed from figure-16 to figure-20 that the 3-phase fault at the inverter side does not affect the electrical quantity of the generation side. From above figures it can be said that only generation side fault affect the electrical quantity of the generation side.

5.2 Load Side

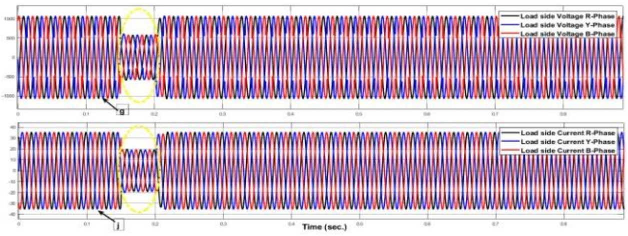

Fig-21 Load side v-i output characteristics with 3-phase fault

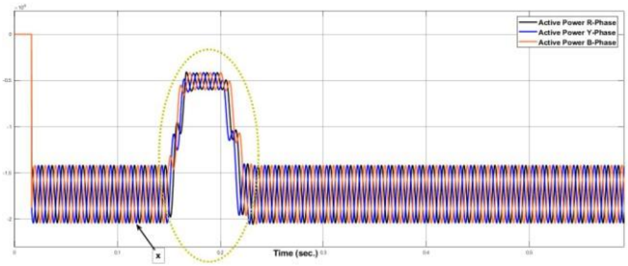

Fig-22 Load side Active power with 3-Phase fault

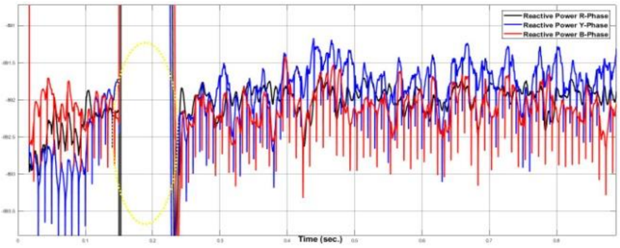

Fig-23 Load side Reactive power with 3-Phase fault

The simulation results of variable wind speed PMSG connected to 3-phase fault on generation side, load and grid side both for duration 0.10 to 0.15 sec and 0.15 to 0.20 sec are shown in figure-21 to figure-23 for load side.

From figure-21, it is observed from yellow circle that the 3-phase load voltage and current is reduced for the period of time 0.15 to 0.20 sec. It can be observed from same figures that there is no effect on 3-phase voltage and current for duration 0.10 to 0.15 sec connected to generation side fault.

From figure-22 and figure-23, it is observed that 3-phase active power and reactive power is increased as shown in yellow circle for the duration of 0.15 to 0.20 sec because of load and grid side fault. It can also be observed that there is no effect of generation side fault applied for duration 0.10 to 0.15 sec.

It is observed from figure-21 to figure-23, that the effect of generation side fault on electrical quantity for duration 0.10 to 0.15 sec is unchanged. But for duration 0.15 to 0.20 sec it increases the active and reactive power and reduces the overall voltage and current for that particular period.

5.3 Grid Side

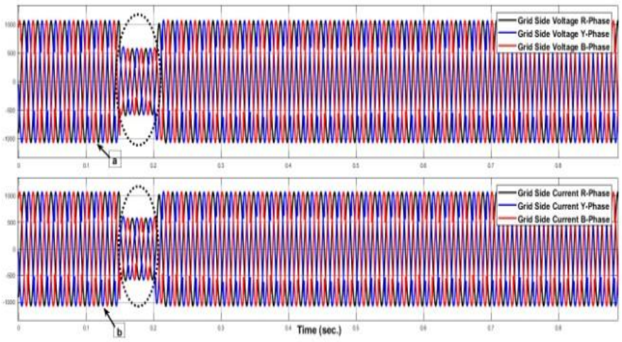

Fig-24 Grid side v-I output characteristics with 3-phase fault

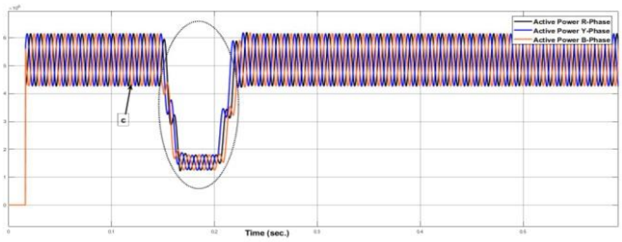

Fig-25 Grid side Active power with 3-Phase fault

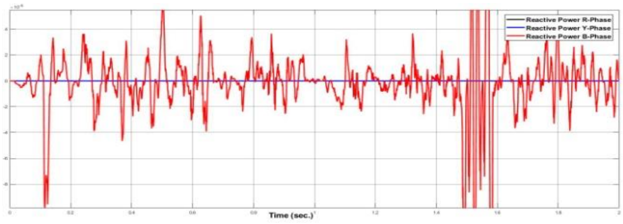

Fig-26 Grid side Reactive power with 3-Phase fault

The simulation results of variable wind speed PMSG connected to 3-phase fault on generation side, load and grid side both for duration 0.10 to 0.15 sec and 0.15 to 0.20 sec are shown in figure-24 to figure-26.

From figure-24, it is observed that grid voltage and current is reduced due to grid side fault for duration 0.15 to 0.20 sec as shown in red dotted circle. It can also be observed that generation side fault does not affect voltage and current for duration 0.10 to 0.15 sec.

From figure-25 and fifure-26, it is observed that 3-phase active and reactive power is reduced for the period of time 0.15 to 0.20 sec. It can also be observed from figure-26 that overall grid reactive power is reduced.

It can be said from figure-24 to figure-16, which the generation side 3-phase fault does not affect grid side electrical quantity. While grid and load side fault affect the electrical quantity at grid side.

6.0 Case-2: PMSG connected to bidirectional DC-DC converter for battery storage system

Since 1996, wind energy has been rapidly increasing as a source of power. Despite its benefits, because to its unpredictable behavior, this energy could never serve as a key source of electric power to be included into the grid, especially in high wind regions like the Great Plains. The grid will experience instability, unreliability, and power quality issues as a result of this intermittent power generation. Connecting a wind turbine to an energy storage system is one of the extensively used solutions to this issue.

The most economical way to store the electrical energy generated from wind energy conversion system using Battery Storage System. The most widely used batteries are the Nickel Cadmium, Lithium Ion, Lead Acid batteries. To connect the battery energy storage system with the WECS for charging and when the WECS is not available for discharging. The bidirectional concreter is to be used in power system. This case study belongs to the switching and transient behavior of DC/DC bidirectional converter and batteries connected to grid with PMSG wind energy conversion system.

The performance and analysis of the result is to be done on the generation side so that the modeling of a real life WECS with battery storage connected to grid would be simple.

6.1 Block Diagram Model of System

A permanent magnet synchronous generator is connected to wind turbine as shown in figure-27. A power diode bridge is used to convert 3- phase AC in to DC form. Capacitor link is provided in between the Diode Bridge and IGBT Inverter Bridge. L-filters and C-filters are also used to make the system stable. 3-phase two binding transformers are connected between the Inverter Bridge and 3-phase load on utility grid for step up and step down the voltage, Pi transmission line is also connected between step up and step down transformers to make a practical environment of the system.

A 12 volt lithium ion battery, rated capacity of 20 AH is connected with a bidirectional DC-DC converter for charging and as well as discharging. The following system is to be performed for the analysis of transients and switching imbalance of the PMSG generation side using Matlab and Simulink.

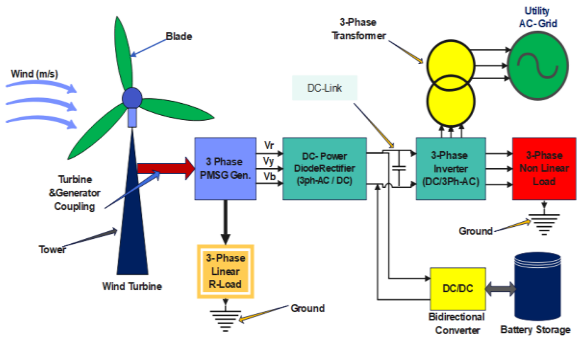

Fig-27 Block diagram of the Testing system

6.2 Simulation Results and Discussion

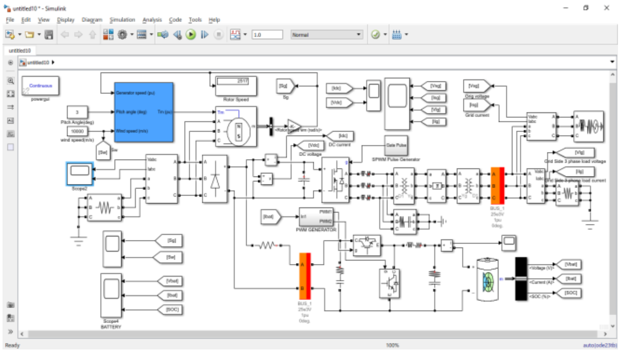

Fig-28 Simulink Model of the System

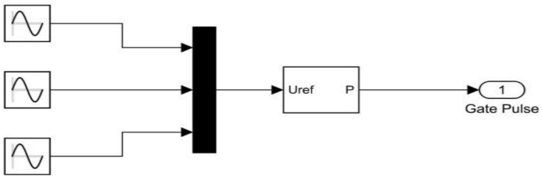

Fig-29 SPWM Gate Pulse Generator for IGBT Inverter Bridge

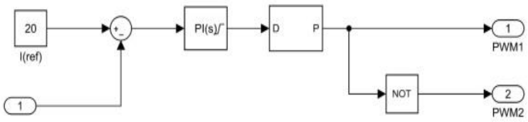

Fig-30 PWM Gate Pulse Generator of DC-DC Bidirectional Converter for Charging and Discharging Battery Storage System

The simulation model of the proposed system is shown in figure-28; it can be seen from the figure that a PMSG with variable wind speed to a 3-phase IGBT inverter bridge. Two transformers are connected with transmission line and a bus is provided to distribute the energy between load and grid.

LC and RC filters are also connected between IGBT inverter bridge step up transformer of the system.

From figure-29, it can be seen that a SPWM controller is connected to the IGBT inverter bridge for gate pulse generation.

Now from figure-28, it can further seen that a DC to DC bidirectional converter is connected with DC of power Diode Bridge for charging and discharging of a lithium ion battery capacity 12 volt and 20AH. From figure-30, it can be seen that a PWM controller is connected to bidirectional DC to DC converter for gate pulse generation. The Matlab and Simulink model of the system is performed and their output results have analyzed and discussed further.

7. Performance of PMSG connected to Grid, DC to DC-Bidirectional Converter & Battery

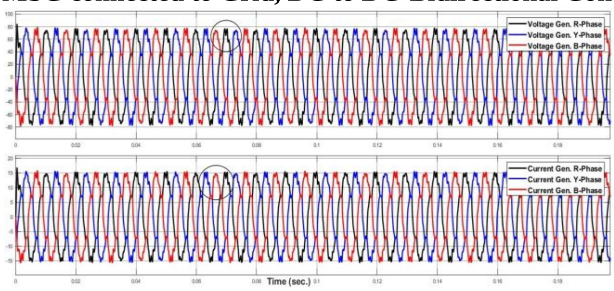

Fig-31 Generation Side v-i output characteristics for battery storage

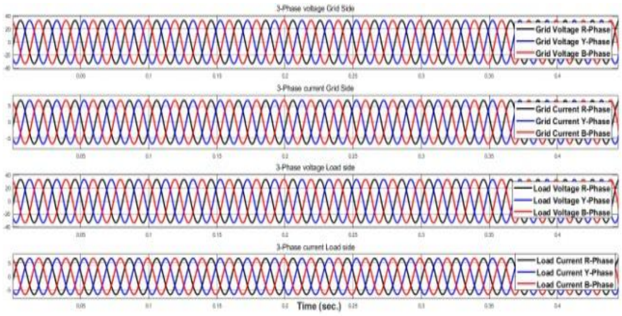

Fig-32 Grid and Load side v-i output characteristics for battery storage

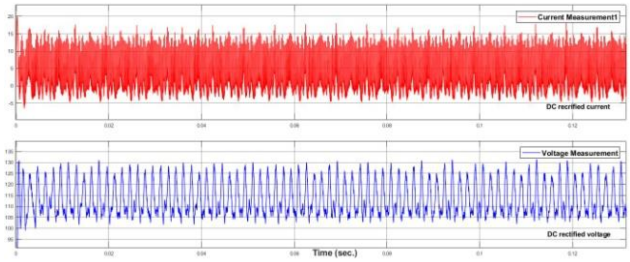

Fig-33 Diode Bridge DC rectified output characteristics for battery storage

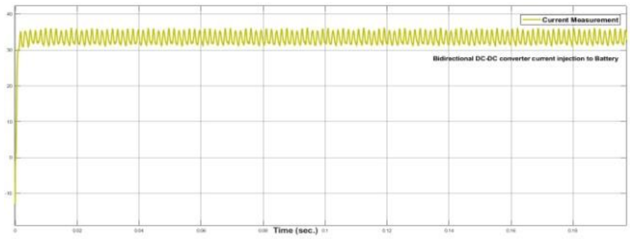

Fig-34 Bidirectional DC-DC converter current injected to battery

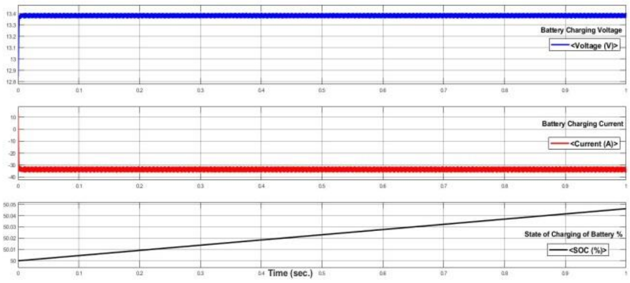

Fig-35 Battery side output characteristics

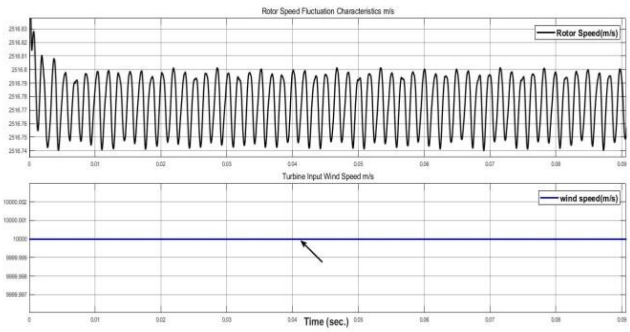

Fig-36 PMSG Rotor speed characteristics

The simulation of case study-02 is performed and the generated results have collected in here. The analyses of the results are done from figure-31 to figure-36; it is observed that when a PMSG wind energy system is connected with transformers, transmission lines and grid with battery storage system through dc to dc bidirectional chargers.

The battery capacity 12 volt and rated capacity is 20 ampere hours is considered, the battery initially is 50 % charged. Two transformers one is step up and other is step down connected with transmission line and grid with 3-phase IGBT Inverter Bridge.

From figure-31, it is observed that generated 3-phase ac voltage and current fluctuates as shown in red circle of the generated 3-phase v-i output characteristics.

From figure-32, it is observed that the load and grid side voltage and current have not any fluctuation because of DC link capacitor between diode bridge rectifier and inverter.

From figure-33, it is observed that the DC rectified current has frequent fluctuation as shown in red waveform. And DC rectified voltage has very less distortion as shown in blue waveform.

Figure-34 shows the current waveform which is injected to bidirectional DC-DC converter.

Figure-35 shows the actual output behavior of the battery storage such as charging voltage, current and state of charging of the battery.

From figure-36, it is observed that a constant wind speed (m/s) is injected to the wind turbine as shown pointed by arrow with blue line shown in figure as a reference without any fluctuation to see what happens exactly to the rotor speed of the PMSG wind energy system.

From the upper black colored waveform in figure-36 rotor speed fluctuation is clearly visible. So it can be said that the charging of battery, connection of electrical devices and equipment in power system such as bidirectional converter, transmission line, transformers, filters and other power electronics converter with different load condition also generate distortion and fluctuation in rotor speed of the PMSG wind energy system.

8. CONCLUSION

System is performed and analyzed with various different cases and condition. The overall system is considered to verify the stability of wind energy system. First, the faulty conditions are analyzed and second the effect of power system equipment and devices with battery storage is performed and analyzed.

It can be said that power system connected to wind energy system has very sensitive consequences with the both two cases such as rotor speed fluctuation, rising in fault current and fall in fault voltage and many other problem.

So we can say that for both cases wind energy system is unstable and it will demand frequent maintenance due to frequent damage in PMSG rotor.

REFERENCES

[1]. Benamor, A.; Benchouia, M.T.; Srairi, K.; Benbouzid, M.E.H. A novel rooted tree optimization apply in the high order sliding mode control using super-twisting algorithm based on DTC scheme for DFIG. Int. J. Electr. Power Energy Syst. 2019, 108, 293–302.

[2]. Pan, C.; Shao, L. Wind energy conversion systems analysis of PMSG on offshore wind turbine using improved SMC and Extended State Observer. Renew. Energy 2020, 161, 149–161.

[3]. Bounar, N.; Labdai, S.; Boulkroune, A. PSO–GSA based fuzzy sliding mode controller for DFIG-based wind turbine. ISA Trans. 2019, 85, 177–188.

[4]. Liu, J.; Zhou, F.; Zhao, C.; Wang, Z.; Aguirre-Hernandez, B. A PI-type sliding mode controller design for PMSG-based wind turbine. Complexity 2019, 2019, 2538206.

[5]. Soliman, M.A.; Hasanien, H.M.; Azazi, H.Z.; El-Kholy, E.E.; Mahmoud, S.A. An adaptive fuzzy logic control strategy for performance enhancement of a grid-connected PMSG-Based wind turbine. IEEE Trans. Ind. Inform. 2019, 15, 3163–3173.

[6]. Beddar, A.; Bouzekri, H.; Babes, B.; Afghoul, H. Experimental enhancement of fuzzy fractional order PI+I controller of grid connected variable speed wind energy conversion system. Energy Convers. Manag. 2016, 123, 569–580.

[7]. Aounallah, T.; Essounbouli, N.; Hamzaoui, A.; Bouchafaa, F. Algorithm on fuzzy adaptive backstepping control of fractional order for doubly-fed induction generators. IET Renew. Power Gener. 2018, 12, 962–967.

[8]. Yin, W.; Wu, X.; Rui, X. Adaptive robust backstepping control of the speed regulating differential mechanism for wind turbines. IEEE Trans. Sustain. Energy 2019, 10, 1311–1318.

[9]. Beniysa, M.; Idrissi, A.E.J.E.; Bouajaj, A.; Britel, M.R.; Ariwa, E. Neural network adaptive backstepping control via uncertainty compensation for PMSG-based variable-speed wind turbine: Controller design and stability analysis. Wind Eng. 2021.

[10]. Matraji, I.; Al-Durra, A.; Errouissi, R. Design and experimental validation of enhanced adaptive second-order SMC for PMSGbased wind energy conversion system. Int. J. Electric. Power Energy Syst. 2018, 103, 21–30.

[11]. Y Xia, K.H Ahmed, B.W. Williams, A New Maximum Power Point Tracking Technique for Permanent Magnet Synchronous Generator Based Wind Energy Conversion System, IEEE Transactions on Power Electronics, Vol. 26, No 12, pp. 3609 – 3620, December 2011.

[12]. Shao Zhang, King-Jet Tseng, D. Mahinda Vilathgamuwa, Trong Duy Nguyen and Xiao-Yu Wang, Design of a Robust Grid Interface System for PMSG-Based Wind Turbine Generators, IEEE Transactions On Industrial Electronics, Vol. 58, No 1, pp.316-328 , January 2011.

[13]. Jiacheng Wang, Dewei (David) Xu, BinWu, Zhenhan Luo,A Low-Cost Rectifier Topology for Variable-Speed High-Power PMSG Wind Turbines, IEEE Transactions On Power Electronics, Vol. 26, No. 8, August 2011.

[14]. S. M. Muyeen, Rion Takahashi, Toshiaki Murata and Junji Tamura, A Variable Speed Wind Turbine Control Strategyto Meet Wind Farm Grid Code Requirements,IEEE Transactions on power systems, Vol. 25, No. 1, February 2010, pp. 331 – 340.

[15]. Y. Errami, M. Ouassaid, M. Maaroufi and M. Charkaoui, Direct Torque Control and MPPT Strategy of PMSG Used for Variable Speed Wind Energy Conversion System, IEEE-International Conference On Systems and Control (ICSC), June 2012.

[16]. Zhe Chen, Josep M. Guerrero and Frede Blaabjerg, A Review of the State of the Art of Power Electronics for Wind Turbines, IEEE Transactions on power electronics, Vol. 24, No. 8, August 2009, pp. 1859 - 1875.
[17]. S. M. Muyeen, Rion Takahashi and Junji Tamura, Operation and Control of HVDC-Connected Offshore Wind Farm, IEEE Transactions On Sustainable Energy, Vol. 1, No. 1, April 2010, pp. 30 - 37.
[18]. A. Mesemanolis, C. Mademlis and I. Kioskeridis, Maximum Efficiency of a Wind Energy Conversion System with a PM Synchronous Generator, IEEE-MedPower 2010, Power Generation, Transmission, Distribution and Energy Conversion, Proceedings of 7th Mediterranean Conference and Exhibition on, pp. 1-9, November 2010.
[19]. F. Blaabjerg, F. Iov, Z. Chen, K. Ma, Power Electronics and Controls for Wind Turbine Systems, Energy Conference and Exhibition (Energy Con), IEEE Conferences, pp. 333–344, December 2010.
[20]. M.A. Abdullah, A.H.M. Yatim and Chee Wei Tan, A Study of Maximum Power Point Tracking Algorithms for Wind Energy System, IEEE First Conference on Clean Energy and Technology (CET), pp. 321 - 326, June 2011.
[21]. www.Wikipedia.com
[22]. www.Researchgate.com
[23]. www.Google.com
[24]. www.Sciencedirectia.com
[25]. www.seciencedirectia.com