

Power Quality Enhancement in Windfarm by using STATCOM



Babita Nanda, Ranjan Kumar Jena, Bishnu Prasad Muni

Abstract: A FACTS (Flexible AC Transmission) controlled device, STATCOM is the best solution for power compensation in the area of microgrid system. It regulates the reactive power by injecting the reactive current in to the ac/dc hybrid microgrid terminals. The STATCOM is applicable for shunt compensation which has a great role in dynamic performance by controlling its reactive power. The proposed work demonstrated about the enhancement of voltage sag during fault condition. It can improve the wind turbine performance. The main objective for the STATCOM application in windfarm is to improve the system voltage by supplying or absorbing the reactive power into hybrid ac /dc microgrid system. During steady state operation, the fundamental component of the VSC (Voltage source converter) voltage in phase with system voltage, which shows uncontrol action on active power flow. If there is change between these two voltages (lead or lag), then STATCOM can generates (or absorbs) reactive power. This phase shift leads to flow of active power which is responsible for increase or decreases of capacitor voltage. Assumption has been taken by considering the fixed speed of wind turbine. The performance of windfarm with and without STATCOM is examined and analyzed under fault condition by using MATLAB Simulink 2016.

Keywords: STATCOM, SSR, IG, MATLAB 2016, Wind farm

I. INTRODUCTION

A STATCOM (Static synchronous compensator) is a advanced static compensator which damp out the power system oscillation, improve its power factor and works as a controllable current source [1]. The main objective of using STATCOM in microgrid is to increase the transmittable power and its transient stability [2]. It also enhances the overall system stability and diminishes the losses in a power system [3]. The proposed work is designed by installing STATCOM in a windfarm during weak grid condition [3]. The voltage stability is the key challenges for a windfarm during fault condition. Because of the sporadic nature of wind speed, the output of squirrel cage induction generator faces the challenging mode of operation to meet the consumer demand [4]. It can be sorted out with the installation of STATCOM, which is shunt compensator

devices. It resolves the stability problems and takes the vital role during fault condition.

The steady state and dynamic behavior of a windfarm is analyzed by considering the random wind speed. The proportional integral control (PI) lineal and non-linear robust type controller are implemented and compared with STATCOM [5]. They regulate the voltage magnitude at the connected node. A small series dynamic braking resistor (SDBR) and static synchronous compensator (STATCOM) is applied to damp out the torsional oscillation which creates instability in windfarm [6]. The root cause analysis has been done by considering symmetrical and unsymmetrical faults. With the evolution of Power electronics devices, the control of active and reactive power, frequency, voltage sags can be compensated [7]. There are several control approaches have been implemented in the different literature of windfarm. In an isolated and weak grid system [8]. It is a great task for wind turbine to get maximum output from a fixed wind speed. Hill climbing control, fuzzy based control and adaptive controllers are developed to extract maximum power from the induction generator (IG). It has been studied that the failure of turbine generator shaft and its electrical instability causes the oscillation frequency lower than the system frequency. It results sub synchronous resonance (SSR) which damage to the turbine shaft [9]-[10]. During steady state operation, the fundamental component of the VSC (Voltage source converter) voltage is in phase with system voltage. As a result of which there is no control over active power. If there is a change between these two voltages, then STATCOM can generates (or absorbs) reactive power [11]-[13]. The voltage source converter (VSC) voltage lag or lead produces a temporary flow of active power. This is the main cause for increasing or decreasing the capacity voltage [14].

The SCADA Data is best software tool to identify and resolve the power quality problems. The main focus is on voltage control and its stability during fault condition. The pitch control technique is implemented to maintain system voltage stability of FSIG (Fixed speed induction generator). Due to asynchronous nature of FSIG, the system instability caused excessive absorption of reactive power [15]-[16].

Investigation on fixed speed induction generator and the STATCOM are done to analyze the control between the positive and negative sequence of the ac/dc hybrid microgrid.

A huge permeation of wind power generation and power electronics converters creates poor quality and a very poor stability margin in a hybrid microgrid [17]-[18] To resolve this problem so many algorithms are implemented over here. Although the series compensation enhances the transmission capacity, still it faces the sub synchronous problems in proposed microgrid system. Special focus has been given the asymmetrical microgrid on three phase fault condition [19]-[21].

Manuscript published on January 30, 2020.

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To damp out the low frequency oscillation a damping controller is implemented, named as PODC (Lead lag power oscillation damping controller). It improves the stability of the on shore and offshore windfarm under various disturbances condition [22]. A Grid code is a new technique for the reliable operation of the microgrid system. This intrudes an advanced technical solution to the wind in a ac/dc hybrid microgrid. The compliance of grid code resolves the problems and maintain faster response to achieve the steady state condition [23]-[24]. The torque controller is applied to the proposed scheme in order to keep fixed speed for the proposed wind turbine. The power generation from wind is totally dependent on the weather conditions.

II. SYSTEM DESIGN

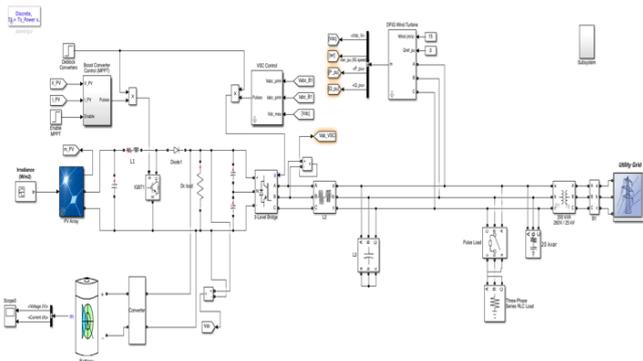


Figure 1. Proposed Hybrid microgrid system

The proposed Hybrid microgrid is designed by taking PV(Photovoltaic) panel, Wind fam and a battery figure 1 shows when it connected to grid, But the simulation work has been done by taking isolated condition of wind farm in fault condition. To damp out the oscillation, a STATCOM is installed in bus bar system which is shunt compensated which is presented in figure 2.

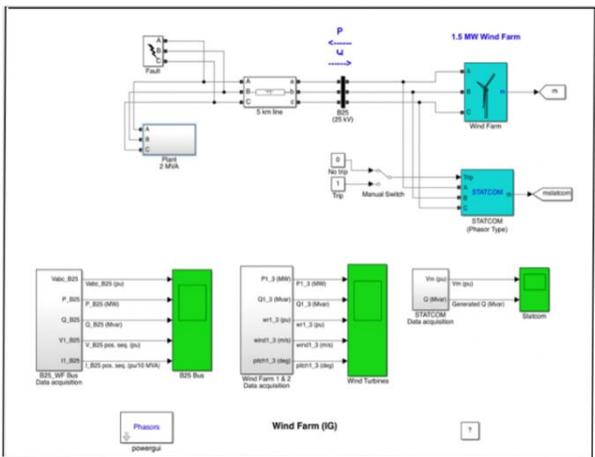


Figure 2. wind farm installed with STATCOM in three phase fault condition.

The mathematical model already available in MATLAB 2016b. So, from MATLAB Simulink, model are taken done in isolated condition, when only wind farm with active in ac/dc hybrid microgrid system. Simulation has been done by taking 1.5 MW of windfarm connected with 3MVar STATCOM with 3% drooping setting. It supplies power to consumer in a weak grid system or isolated system. Literally, STATCOM can represent a source of reactive power which provide active power when it

is attached to the source of power. The main characteristics of the controller is to improve power factor and improvement of voltage regulation. The stator winding of induction generator is connected directly to the 50Hz grid and rotor is connected to a variable pitch wind turbine. The pitch control technique is implemented in order to control output power of generator at its rated value.

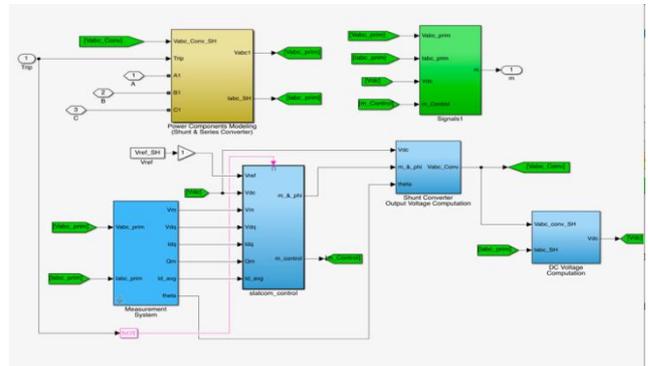


Figure 3. control design of STATCOM controller and its measuring system

Figure 3, represents the STATCOM controller and its measurement system. It is implemented for shunt compensation which absorb and give up reactive power at the point of coupling of bus bar system. So, it maintains the stability of the defined system. The AC Regulator, DC Regulator and Damping controller comprises faster the system response and improve the power quality of the wind farm which is described in figure 4.

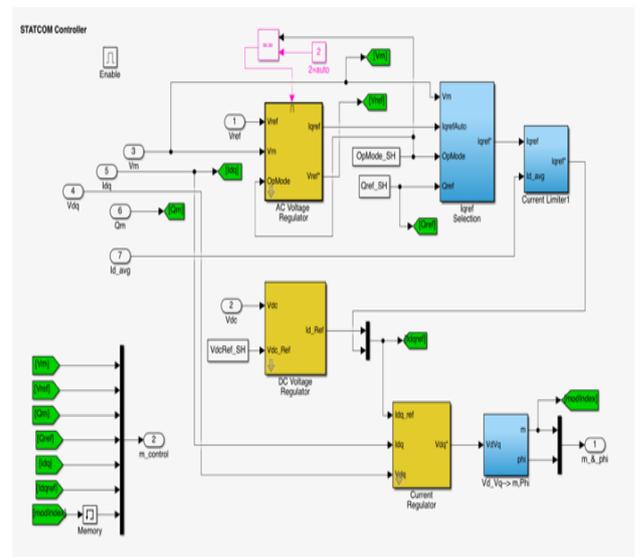


Figure 4. Operating principle of STATCOM controller during three phase fault.

The key role of AC Regulator is to control the generator terminal voltage, DC Regulator maintains the DC capacitor voltage of the STATCOM and the Damping controller can damp out the power fluctuation of the system. The working principle of the above controller follows the lead lag compensator role in the control system of wind farm. The principle of operation can be presented in figure 4.

III. WIND TURBINE MODEL AND ITS CONTROL DESIGN

The mathematical model of wind turbine and its control part is already defined in MATLAB 2016b. This software helps to Simulink the proposed project by considering with STATCOM controller and without of it. It is used for power flow control and damped out the power system oscillation in microgrid during island mode of operation.

In the simulation of wind farm, of 1.5MW wind turbines are considered to design which is presented in figure 4.

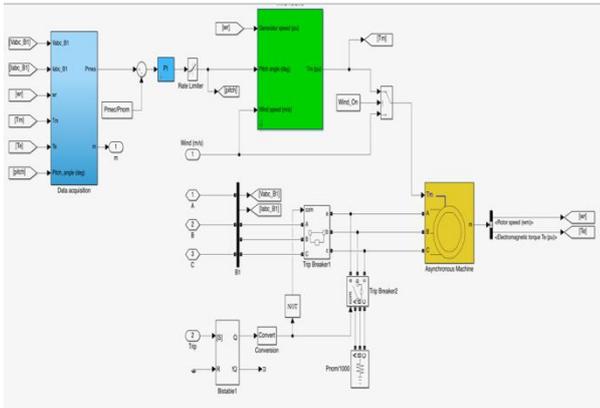


Figure. 5 wind turbine coupled with Asynchronous machine

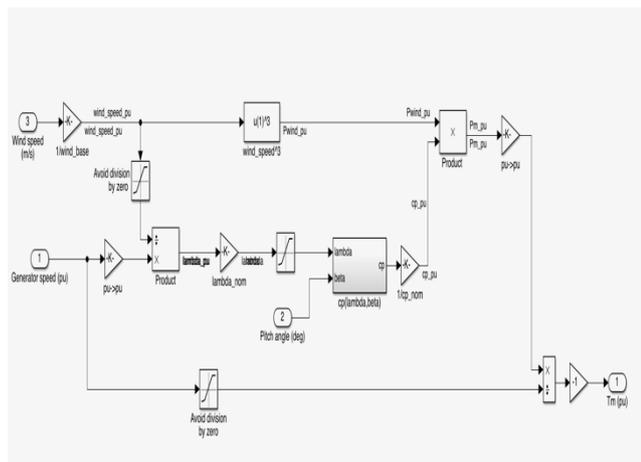


Figure 6 control of generator speed with respect to wind speed.

Power available in wind stream is presented in eq 1.

$$P_{air} = (1/2) * \rho * A * V_w^3 \dots\dots\dots (1)$$

Power generation by wind turbine is given in eq.2.

$$P_w = (1/2) * C_p * \lambda * A * V_w^3 \dots\dots\dots (2)$$

Where,

ρ = density of air (kg/m³)

A = Cross sectional area of the stream (m²)

V_w = Speed of wind

A = turbine rotor area

λ = Tip speed ratio = $(W_{rot} * R) / V_w$

C_p = Power coefficient = P_w / P_{air} ,

Maximum value of C_p = 0.593, known as Betz limit.

IV. SIMULATION RESULT AND DISCUSSION

The main aim is to show the performance of STATCOM in a windfarm with fault condition. The STATCOM compensate the reactive power according to voltage fluctuation.

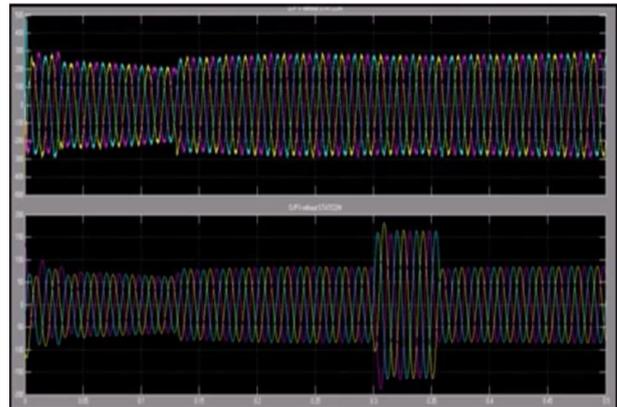


Figure 7. Performance of DFIG without STATCOM

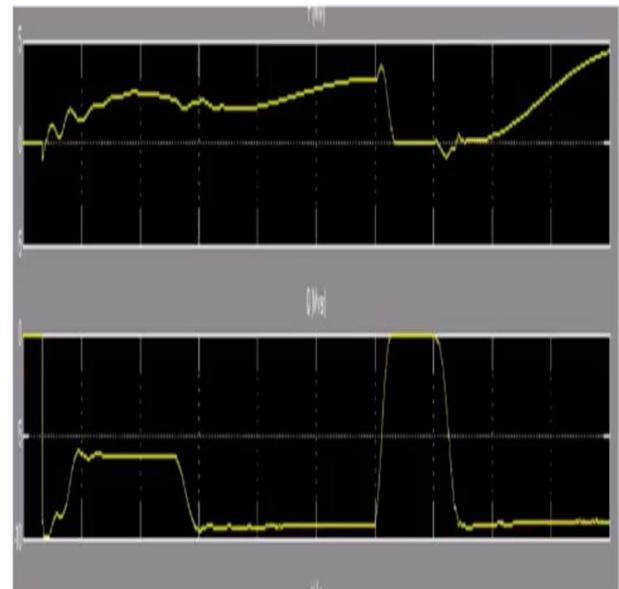


Figure 8. Uncontrolled active and reactive power

Figure 7 and figure 8 shows the output of generator and its uncontrolled power. It has been seen from equation (1) and (2), the turbo generator output is a function of its speed. The ranges of wind speed assumed to be 4m/s to 10m/s. The wind turbine model and STATCOM model allows long simulation times as shown in figure 7 to 8. The minimal wind speed produces the minimal mechanical power (1 pu=3MW) is 9 m/sec. The turbo generator, generated active power starts increasing smoothly to reach its rated value of 3MW approximately in 8 sec. Within that period, the turbine speed changes from 1.0028 pu to 1.0047pu and pitch angle is kept 0°. When the output power surpasses 3MW, the pitch angle increases from 0° to 8° in order to bring output power back to its minimal value.

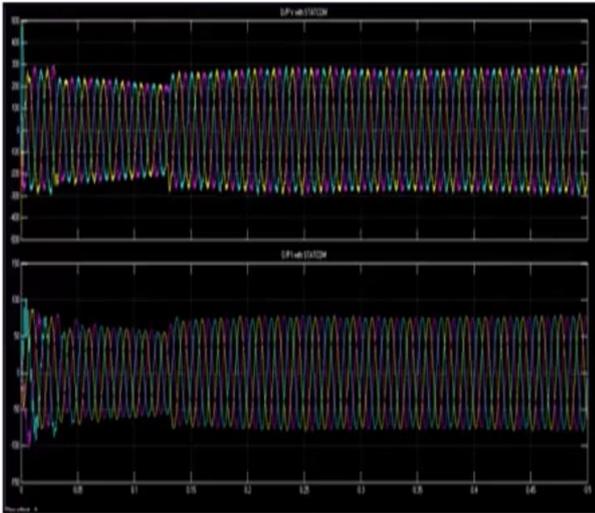


Figure 9 DFIG with STATCOM

Figure 9 represents dynamics performance of the doubly fed induction generator with STATCOM. It provides active power when connected to source of power by exhibiting constant current characteristics. The main performance of installation of STATCOM is to improve power factor and its voltage regulation. In Figure 10, it has shown its symmetrical lead-lag capability.

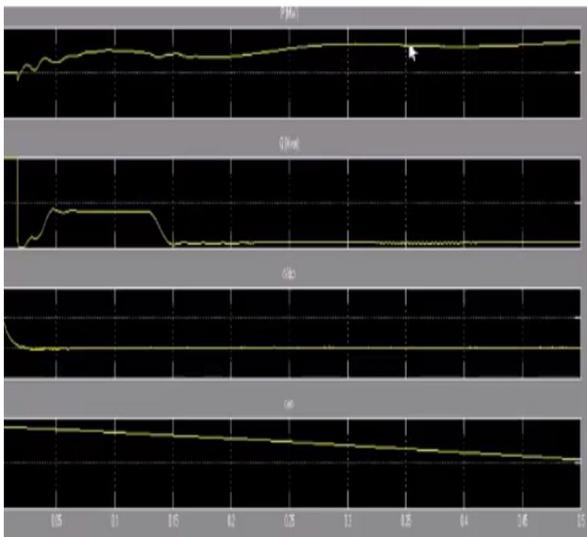


Figure 10. Control of active and reactive power.

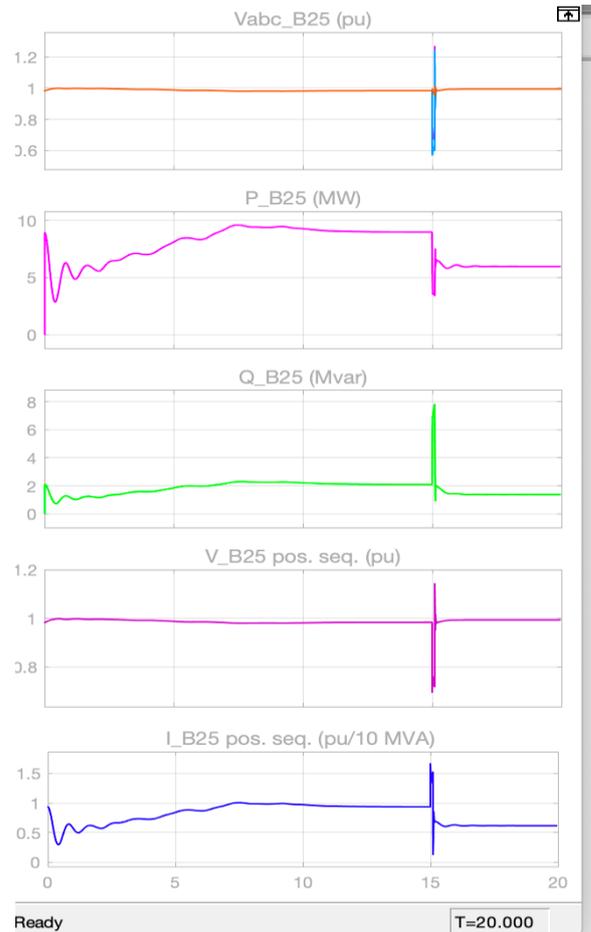
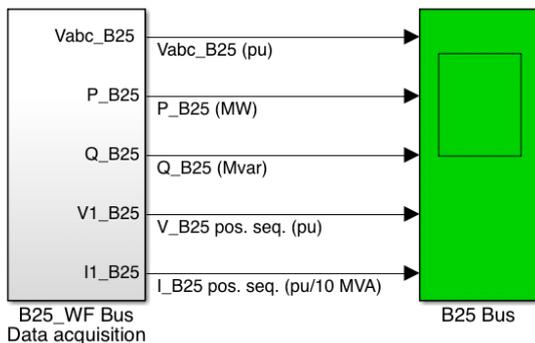
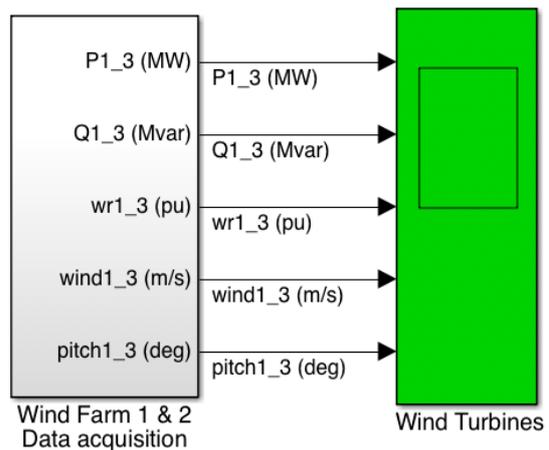


Figure 11. Response at B25 busbar system

Voltage at bus “B25” now drops to 0.91pu. This low voltage condition results in an overload of wind turbine. The pitch angle is regulated in such a way that the mechanical power delivered to the generated power reaches the rated power at some fixed speed.



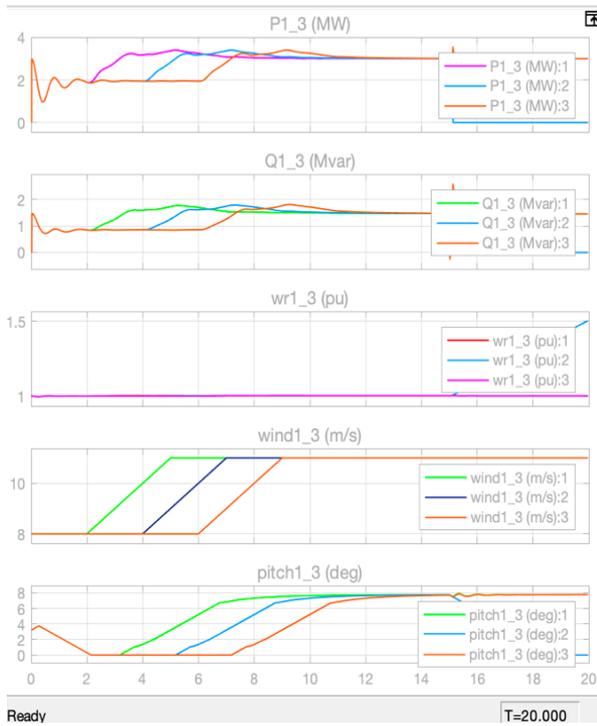


Figure 12.output of wind farm in different pitch angle.

The blade pitch adjustment with the wind speed is presented in figure 12. The software MATLAB 2016 b is basically implemented for the initialization of the all variables during control mechanism. The pitch angle attains its maximum value when wind speed below the rated power of the turbo generator. It has been seen that the response is slow when its output power variation is large. The proposed controller in the windfarm has large response time to excute its stable operation.

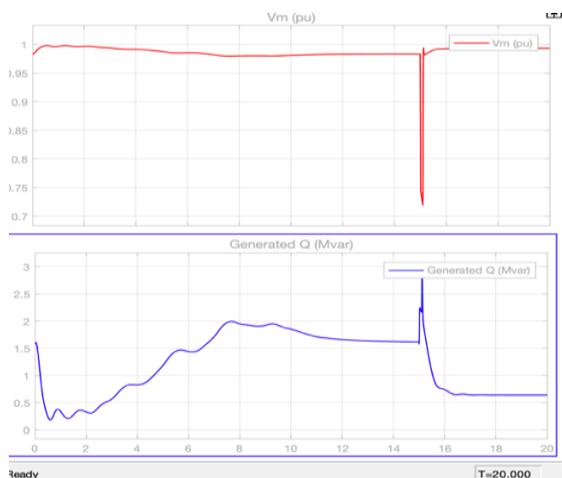
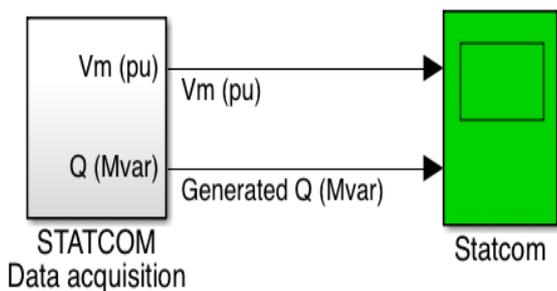


Fig 13. Generate reactive power during three phase faults with STATCOM.

It has been observed that the generated active power increases when the absorbed reactive power increases. At nominal power, each pair of wind turbine absorbs 1.47 MVar. For 11m/sec wind speed, the total exported power measured at B25 bus is 1.5 MW. STATCOM maintains voltage at 0.984 pu by generating 1.62 MVar.

V.CONCLUSION

The ac/dc hybrid microgrid with wind farms performance can be improved by using FACTS controlled devices such as STATCOM. The dynamic model of the studied windfarm with and without STATCOM is simulated using MATLAB Simulink 2016.To validate the effect of the STATCOM controller of windfarm operation,the system is subjected to different disturbances such as faults and power operating conditions. Simulation results show that the STATCOM deviced.

REFERENCES

- Li Shengqing, "Wind farm Grid Voltage Stability Reseaching Based on cascade STATCOM," Third International conference on intelligent system design and Engineering application.
- Sukriti Solanki, " Study of 6MW wind farm with and without STATCOM using MATLAB/SIMULINK," International conference on information ,communication, instrumentation and control (ICICIC), 2017,IEEE Conference.
- Keping Zhu, " Cascade STATCOM application in voltage stability of grid connected windfarm,"International conference on Electronics, communications and control(ICECC),2011,IEEE conference.
- Nestor D Galan, "Application of PI and Super twisting drivers to voltage regulations of wind farm via statcom,"vol.13,issue 2,IEEE Latin America transactions year -2015.
- S.M.Muveen, " A combined approach of using an SDBR and a STATCOM to enhance the stability of a windfarm,"vol.9,issue.3,IEEE system journal -2015.
- A Moharana, " SSR alleviation by STATCOM in induction generator based windfarm connected to series compensated line," vol 5 ,issue 3 ,IEEE transaction on sustainable energy -2014.
- Chong Han, "STATCOM impact study on the integration of a large wind farm into a weak loop power system,"vol.23,issue 1,IEEE transaction on energy conversion-2008.
- Rita M M Pereira, "comparative study of STATCOM and SVC performance on dynamic voltage collapse of an electric power system with wind generation,"vol .12,issue 2, IEEE Latin American transaction -2014.
- Rajiv k verma, "Nighttime application of PV solar farm as STATCOM to regulate grid voltage," vol.24,issue 4,IEEE transaction on energy conversion -2009.
- Hua Geng, "Synchronization and reactive current support of PMSG -Based windfarm during sever grid fault," vol.9,issue 4,IEEE transaction on sustainable energy -2018.
- C. Wessels, "Statcom control at wind farms with fixed-speed induction generator under asymmetrical grid faults," vol.60,issue 7,IEEE transactions on industrial electronics-2013.
- Li Wang ,C.T.Hsiung, "Dynamic stability improvement of an integrated grid connected offshore wind farm and marine current farm using statcom," vol.26,issue 2 ,IEEE Transaction .2011
- A. Arulampalam , "Power quality and stability improvement of a windfarm using STATCOM supported with hybrid battery energy storage ,"vol 153,issue 6,IEEE proceedings -Generation ,Transmission and Distribution -2006.
- Wei Oiao, " Real time implementation of a STATCOM on a windfarm equipped with doubly fed induction generator ,vol 45,issue 1,ieec transaction on industry application -2009.
- Jun Yao, "Capacity configuration and coordinated operation of a hybrid wind farm during grid fault,"vol.32,issue 3,IEEE transaction on energy conversion -2017.
- M.Reza Nasiri , "Model predictive control of a multilevel CHB STATCOM in wind farm application using Diophantine equation ,"IEEE transaction on industrial electronics-2019.

17. B.Gao, Y.Hu, "Sub-synchronous resonance mitigation by a STATCOM in doubly fed induction generator based wind farm connected to a series-compensated transmission network ,"vol 2019,issue 16, The journal of Engineering -2019.
18. Wei Oiao,"Coordinated reactive power control of a large wind farm and a STATCOM using Heuristic Dynamic Programming,"vol.24,issue 2, IEEE Transaction on energy conversion -2019.

AUTHORS PROFILE



Babita Nanda, is working as an Associate Professor in JSPM's BSIOTR Engineering College, Wagholi, Pune. She has [17] years' experience in teaching and industries. Thoroughly understands the learning process and works hard to adapt methods and use various teaching styles.

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