International Journal of Engineering Research and Development (IJERD) ISSN: 2278-067X
Recent trends in Electrical and Electronics & Communication Engineering (Page 59-64)
(RTEECE 08th – 09th April 2016)

Simulation of Low Voltage Ride-Through Effect on 2.5 MW Grid Connected Wind Turbine

Deep Patel[1], Siddharth Joshi[2]
[12]School of Technology, PDPU, Gandhinagar, India

Abstract: *A simulation model of a directly driven wind turbine with permanent magnet synchronous generator (PMSG) is described in this paper. PMSG is connected to grid of 33 kV by full scale back to back power converters and common DC-link. Generator side converter controls the speed of the generator and regulates the working current of the generator. Grid side inverter maintains the DC-link voltage near the reference value. Simulation is carried out for conventional control strategy for inverter. A single line to ground fault is created to observe the effect of low voltage ride-through (LVRT).*

Keywords: *Wind turbine, PMSG, DC-link, Generator side converter, Grid side inverter, Low voltage ride-through (LVRT).*

I. Introduction

The worldwide concern about the environment has led to increasing interest in technologies for generation of renewable energy. Among the all the types of renewable energy sources, wind energy is the world's fastest growing renewable energy source. Compared to doubly fed induction generator wind system a direct-drive PMSG based wind energy conversion system has a more advantages [1]. The PMSG doesn't require gearbox and external excitation source except initial installation cost [1-2]. With the increasing scale of wind power system, the wind power penetration to the grid is increased. So to ensure the overall stability of the system utilities require this system remain connected during the transient fault time [3]. So utilities are looking to ensure that this types of power plant behave like conventional power stations [4].

One of the serious issues for the operation of wind turbine system is LVRT capability through which the wind turbines are expected to comply with the requirements of grid codes. With this wind turbines are required to remain connected to the grid during grid faults [5]. Grid codes cover issues related to voltage operating ranges, reactive power requirement and frequency operating ranges under steady state and transient conditions. Low voltage occurrences are usually associated with grid disturbances like short circuit occurring on the lines connecting the wind farm to main grid [4]. So new sets of grid codes are defined which includes the LVRT requirement for wind turbines to avoid the shutdown of large wind farms [6].

Power electronic converters are an important part of wind turbine generator system for controlling its output current or voltage and its rotor speed. A PMSG with pulse width modulation (PWM) voltage source converters has been widely used for wind turbine generator system [7]. At the time of voltage dip occurs the power injected into the grid is dropped while the power of generator does not change because of the limited current capability of power electronic device [8]. Detailed analysis of the new technologies for enhancement of LVRT capability is carried out in [9].

The paper is dealing with wind energy conversion systems consisting a wind turbine with PMSG and full-scale power converters. Power converters consist the generator side converter (GSC) and grid side inverter (GSI). For interfaces of the pulse width modulation converter with the grid, the AC LCL filter is used. This paper is structured as follows. So as to give a precise description of the control method, a modelling of wind turbine and generator is firstly presented in section 2. In section 3, the control strategy of the system will be submitted. In ection 4, the simulation results are given. Finally, some conclusions are presented in section 5.

II. System Modelling

In this paper 2.5 MW wind turbine [10] and 2 MW permanent magnet synchronous generator is used. PMSG is coupled with the wind turbine directly without gearbox and is connected to the three phase converter which is called generator side converter. Then it is connected to grid side converter through common DC-link. For interfaces between PWM converter and grid the LCL filter and transformer are used.

A. Wind Turbine Modelling

The output power of wind turbine is formulated as [2],

$$P_{turbine} = \frac{1}{2}\rho\pi R^2 V_w^3 C_p \quad (1)$$

Where, ρ is the air density (kg/m^3), A is the swept area (m^2), R is the blade radius (m), V_W is wind speed (m/s) and C_p is power coefficient i.e. Aerodynamic efficiency of wind turbine in the conversion of kinetic energy of the wind into mechanical energy. The power coefficient can be written as function of λ and β,

$$C_p(\lambda,\beta) = 0.5\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)e^{-\frac{21}{\lambda_i}} \quad (2)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}$$

Where β is the pitch angle and λ is tip speed ratio is given by;

$$\lambda = \frac{\omega_m R}{V_w} \quad (3)$$

Where W_m is the angular mechanical speed in rad/sec. Maximum power coefficient is achieved for β=0, so from equation (2) we can find the optimum value of λ. After that from equation (3) optimum rotor speed is given by;

$$\omega_{opt} = \frac{\lambda_{opt} V_w}{R} \quad (4)$$

The power conversion coefficient and tip speed ratio depend on the aerodynamic characteristics of the wind turbine. So maximum power is found at a point of λ_{opt} and C_{pmax}.

B. PMSG Modelling

Generally the dq0 or park transformation is applied in PMSG modelling. The steady state model is used for the PMSG as shown in figure (1) is the dq-axis model.

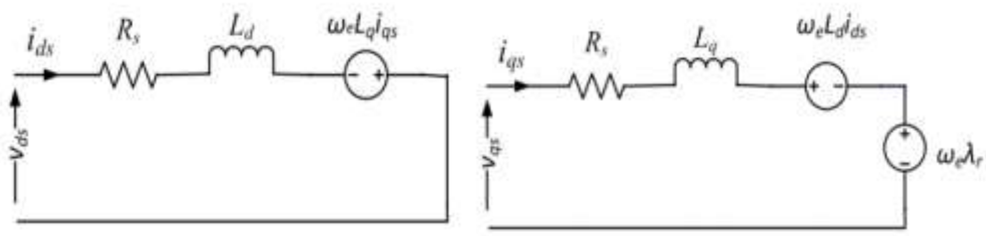


Fig. 1: Equivalent circuit model of PMSG (a) d- axis (b) q- axis

Considering that under balanced conditions the dynamic stator voltage equations of PMSG are described based on dq0 reference frame in which q-axis rotates synchronously with the flux as below.

$$V_{ds} = R_s i_{ds} + L_d \frac{di_d}{dt} - \omega_e L_q i_{qs} \quad (5)$$

$$V_{qs} = R_s i_{qs} + L_q \frac{di_q}{dt} + \omega_e L_d i_{ds} + \omega_e \lambda_r \quad (6)$$

Where V_{ds} and V_{qs} are the instantaneous stator voltages and i_{ds} and i_{qs} are the stator currents in dq reference frame. L_d and L_q are d-axis and q-axis inductance, ω_e is electrical angular speed of rotor and λ is flux linkage of permanent magnet. For surface mounted permanent magnet machine the d-axis and q-axis inductance are equal. So the torque equation is given by;

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right) + \lambda_r i_{qs} \qquad (7)$$

There will be linear relationship between the electric magnet torque and q-axis current so torque can be controlled by regulating q-axis current.

III. Control Strategy

A. Generator Side Converter

At generator side we can say that the wind turbine works at a speed that gives the maximum power by controlling the speed of generator using speed control method and regulating the working current of the generator. Fig.2 shows the schematic control diagram of generator side converter.

In this control scheme, the computational efforts require for PI control and co-ordinate transformation. To controlling the speed of generator, the actual speed of generator which is mounted on the shaft of the rotor is compared to its reference value. This reference value selected in such way that, so the error is mitigated and this error signal is given to the PI controller. So the output of the speed control loop is two reference value of currents Ialpha and Ibeta . To acquire the feedback current signals current sensor senses three phase stator currents and then transformed into the αβ in stationary reference frame according to Clarke's transformation. This gives the two values of current Iappha and Ibeta which is compared with the reference values of the speed control loop and its output is given to the PI controller. Then again αβ-abc transformation is carried out and its output is given to the sinusoidal pulse width modulation block.

In SPWM block, a carrier wave is compared with reference sine wave and when reference wave is higher than the carrier the state of output is a positive value. The outputs of this block are six PWM signals to control the ON/OFF state of the six IGBT switches in the generator side converter.

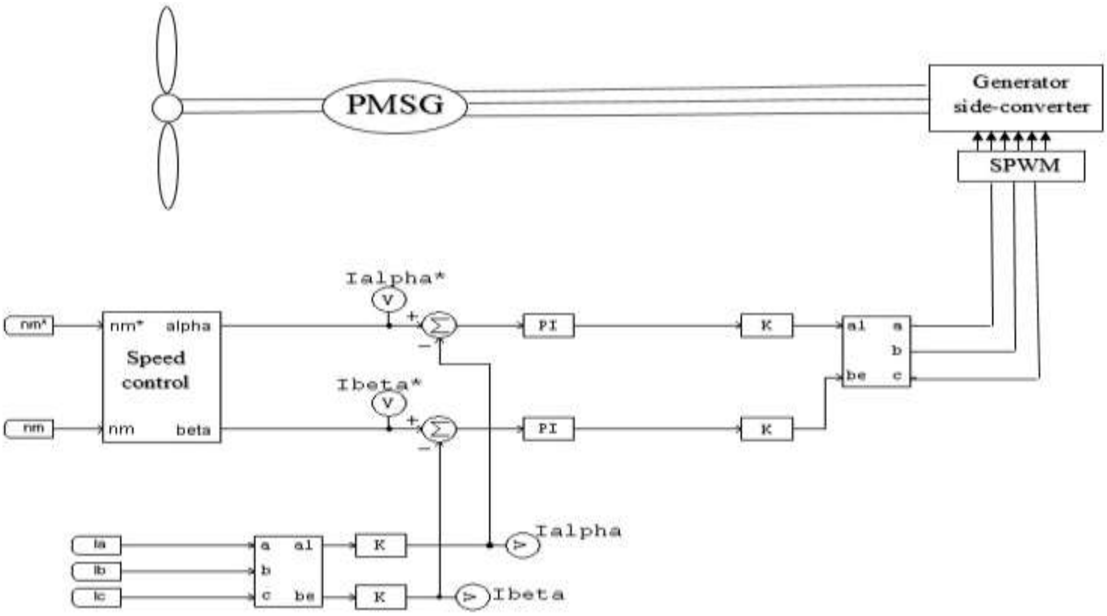


Fig. 2: Schematic of control strategy for generator side converter

B. Grid Side Converter

Fig.3 shows the schematic control diagram of grid side converter. In this control scheme, the output of the generator side converter is sensed by the voltage sensor and compared with its reference value. This reference value is selected in such way that, so the error is mitigated and this error is given to the PI controller. So it maintains the dc link voltage and which gives the reference value of current Iref then it is assigned to the current control block. Then line currents sensed by the current sensor and passes through the low pass filter. Here low pass filter is used because of the high switching frequency of the IGBT. Then abc-αβ transformation is carried out and it gives Ialpha and Ibeta. These values are given to the current control block. Then line voltages

V_{ab} and V_{ca} are compared and is given to the limiter through suitable gain and also through suitable gain V_{bc} is assigned to the current control block.

In current control block firstly output of speed control loop and output of the line voltage is combined and then it is compared with the output of line currents after that through suitable gain it is again compared with the line voltages. Then again αβ-abc transformation is carried out, and its output is given to the sinusoidal pulse width modulation block. The outputs of this block are six PWM signals to control the ON/OFF state of the six IGBT switches in the grid side converter. The output of grid side inverter is given to the grid through filter and transformer.

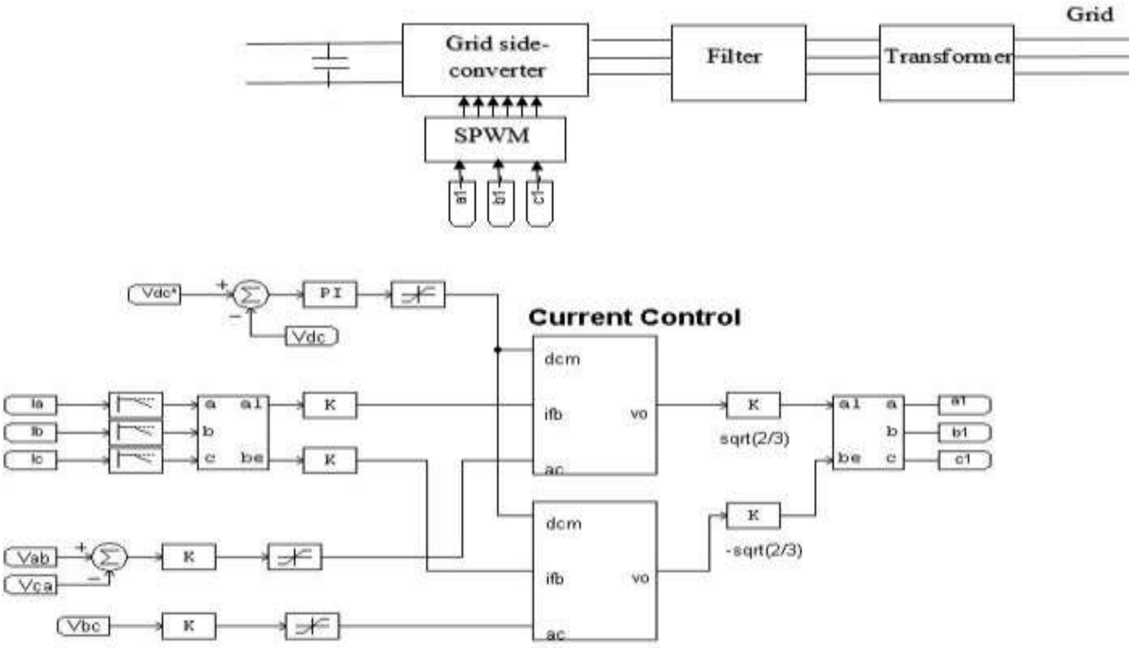


Fig. 3: Schematic of control strategy for generator side converter

IV. Simulation Results

The simulation for 2 MW PMSG wind turbine system has been carried out in PSIM environment. The simulation parameters of the system are given below. PMSG parameters: stator phase resistance = 0.008556 Ω, d-axis and q-axis inductance = 0.00359 H, number of pole pair = 60. In this simulation for the 2.5 MW wind turbine rated speed is 12 m/s and regarding the back to back converters, the rated capacity is 2 MW, DC capacitance is 10000 µf. In simulation 50 km transmission line is used. To observe the LVRT effect single line to ground fault is carried out on phase A as shown in fig.4. Single line to ground fault is created near the grid (33 kV) side.

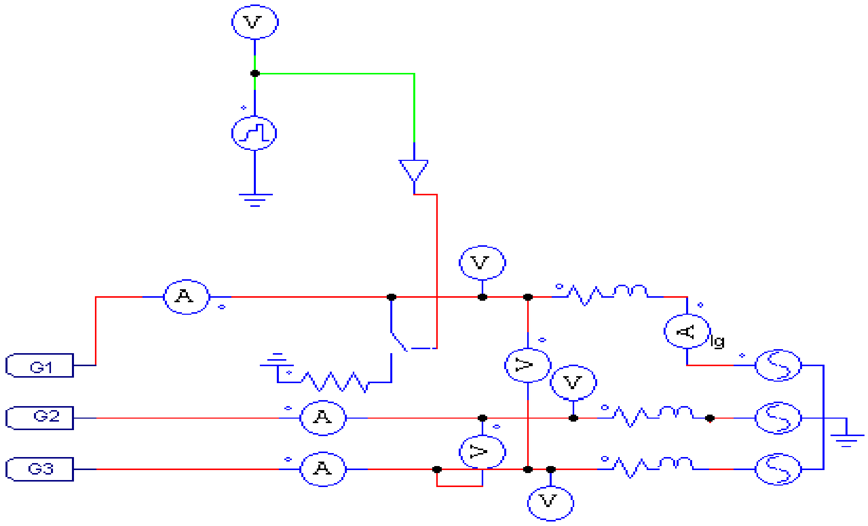
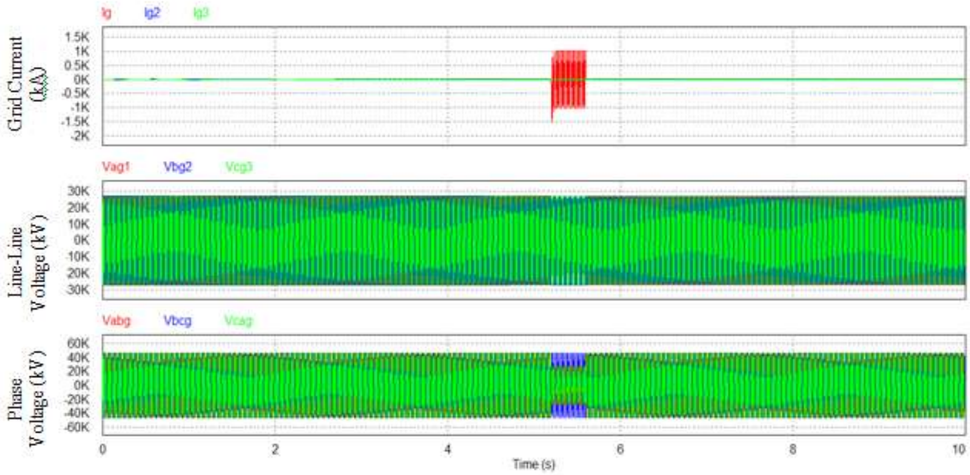
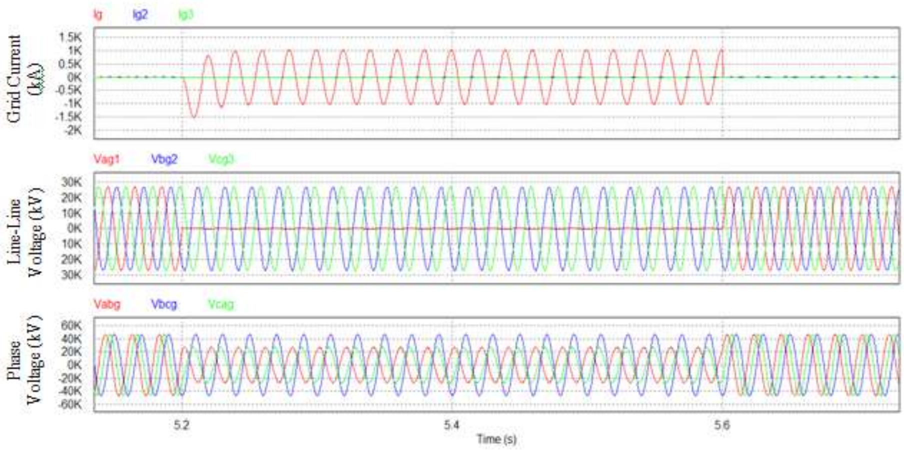


Fig. 4: Single line to ground fault

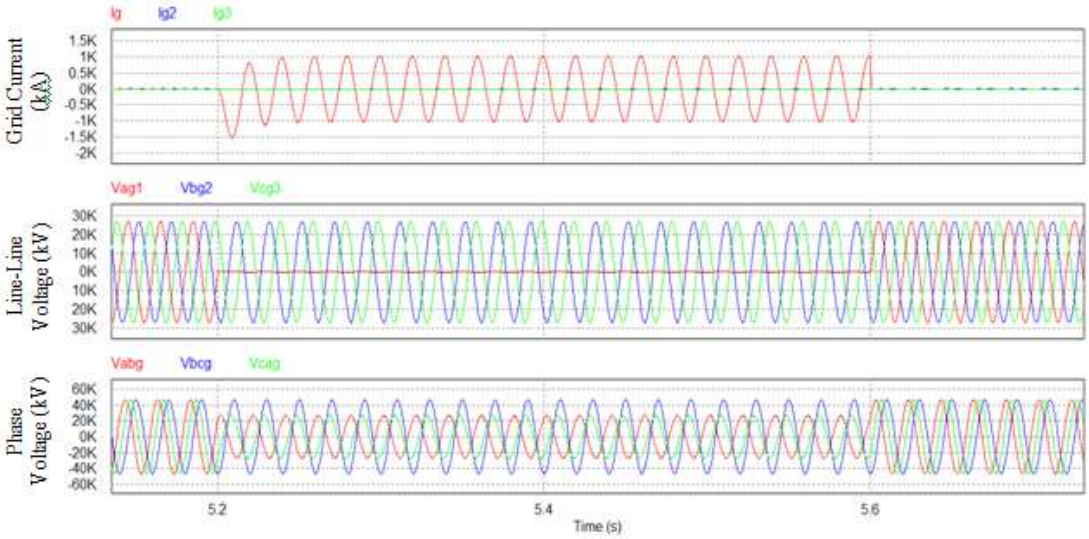
Due to the line to ground fault on the phase, voltage dip occurs on the grid voltage and current is increased as shown in fig.5(b). The effect of fault has been observed at every junction of the system.i.e due to fault voltage dip and momentry current ripple has been observed in the inverter current and inverter voltage.



(a) Grid current and voltage during fault (5.2-5.6)



(b) Grid current and voltage during fault (Zoomed)



(c) Inverter current and voltage during grid fault
Fig. 5: Simulation waveforms during grid fault

V. Conclusion

This paper presents a control strategy of back to back converters for grid connected wind energy conversion system. Through the control strategy of generator side converter control the speed control is achieved and DC link voltage is kept constant as reference value. The value of DC link voltage is enough to operate an inverter. Simulation has been carried out for observing the LVRT effect. From the simulation results, we can say that the effect of grid fault not only seen on the grid side but also has been seen in the inverter voltage and current.

References

[1]. Ki-Hong Kim, et al. "LVRT scheme of PMSG wind power systems based on feedback linearization." *Power Electronics, IEEE Transactions on* 27.5 (2012): 2376-2384.
[2]. Youssef Errami, Mohamed Maaroufi, and Mohammed Ouassaid. "Variable Structure Direct Torque Control and grid connected for wind energy conversion system based on the PMSG." *Complex Systems (ICCS), 2012 International Conference on*. IEEE, 2012.
[3]. Keqing Qu, Jinbin Zhao, and Yuehong Xing. "A LVRT control strategy based on DC-link voltage limit for PMSG wind generation system." Power Electronics and Motion Control Conference (IPEMC), 2012 7th International. Vol. 2. IEEE, 2012.
[4]. G Joos, "Wind turbine generator low voltage ride through requirements and solutions." Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE.
[5]. Thanh Hai Nguyen, and Dong-Choon Lee. "Advanced fault ride-through technique for PMSG wind turbine systems using line-side converter as STATCOM." *Industrial Electronics, IEEE Transactions on* 60.7 (2013): 2842-2850.
[6]. S. M. Muyeen., et al. "A variable speed wind turbine control strategy to meet wind farm grid code requirements." Power Systems, IEEE Transactions on25.1 (2010): 331-340.
[7]. Mohhamad Reza Abedi, and Khuan Y. Lee. "Modeling, operation and control of wind turbine with direct drive PMSG connected to power grid." *PES General Meeting| Conference & Exposition, 2014 IEEE*. IEEE, 2014.
[8]. Yang Xiao-ping, et al. "Low voltage ride through of directly driven wind turbine with permanent magnet synchronous generator." Power and Energy Engineering Conference, 2009. APPEEC 2009. Asia-Pacific. IEEE, 2009.
[9]. R.A Ibrahim, et al. "A review on recent low voltage ride-through solutions for PMSG wind turbine." Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), 2012 International Symposium on, IEEE, 2012.
[10]. Gold Wind 2.5 MW PMSG Wind Turbine, Product Broucher, Pdf.