ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

LVRT Scheme of Wind Power System using PMSG and Sinusoidal Pulse Width Modulation

E.Rajendran
Assistant Professor,
Dept. of EEE
SKP Engineering College,
Tiruvannamalai,
Tamil Nadu, India

Dr.C.Kumar
Director- Academic,
Dept. of EEE,
SKP Engineering College,
Tiruvannamalai,
Tamil Nadu, India

G.Ponkumar
M.E Power System,
Dept. of EEE
SKP Engineering College,
Tiruvannamalai,
Tamil Nadu, India

Abstract*— This paper offered by the low-voltage ride-through scheme for the permanent magnet synchronous generator (PMSG).Wind power system at the grid voltage sag by using sinusoidal pulse width modulation. The dc-link voltage is controlled by the generator-side converter instead of the grid-side converter (GSC). A dc-link Voltage controller is calculated using a Sinusoidal pulse width modulation technique. Among all, low-voltage ride-through has been enforced in the field, which is one of the leading wind energy conversion system (WECS). It is necessary to design an incorporated controller to protect the converter from over voltage/over current and to support the grid voltage during faults and recoveries. A unified dc-link current control scheme for voltage-source converter-based WECS is proposed. In normal operations, the proposed control scheme can also smooth the real power flow while keeping the fast dynamic presentation of the dc-link current control. The GSC controls, the grid active power is concentrated in the wind energy conversion system. The authority of this control algorithm has been verified by simulations results for a reduced-scale PMSG wind turbine simulator.

Keywords— **DC-link voltage, sinusoidal pulse width modulation, Permanent Magnet Synchronous Generator (PMSG), Low Voltage Ride-Through (LVRT), Wind Power, Wind Energy Conversion System (WECS). Grid Side Converter (GSC).**

I. INTRODUCTION

Among various renewable energy bases, the wind power generation has been concerned as one of the most rapidly growing energy bases. Contrarily from the doubly fed induction generator (DFIG) wind systems, a direct-drive wind energy conversion system based on permanent magnet synchronous generators (PMSGs) has a lot of advantages such as not at all gearbox, extraordinary power density, high accuracy, and modest control method, except initial installation costs [1], [2]. As the scale of wind farms becomes larger and larger, the grid connection condition of the wind turbine is more important. Recently, some countries have issued the dedicated grid codes for connecting the wind turbine system to the electric grid. Also, the micro grid and the smart grid have been researched for the efficient power management. However, in these systems, the grid voltage is much fluctuated in comparison with the conventional one. Therefore, a ride-through control of the wind power generation system is needed for the grid abnormal conditions. The grid codes require the low-voltage ride-through (LVRT) capability of the wind turbine system. For some national grid codes [3], the wind power systems should stay connected to the grid for the grid fault conditions. In the power system where the wind power generation is of a major portion, the grid will experience the power outage if the wind farms trip off. Several solutions have been proposed for the LVRTs in the variable-speed wind turbine systems. For this purpose, a crowbar System (an external resistor) is connected in the rotor side of the DFIG to absorb the active power during the grid fault. The wind turbine continues its operation to produce the active power, whereas the reactive power or the voltage at the point of common coupling (PCC) is controlled by the grid-side converter (GSC). But, in the case of a weak grid and during a grid error, the GSC cannot deliver adequate reactive power or voltage support due to its small power capacity and the risk of voltage instability. Also, a static synchronous compensator (STATCOM) has been used to guarantee the uninterrupted operation of a DFIG wind turbine during the grid faults. The operation of wind force is shown in below figure (1). In this investigation, we are recognized to inspect the maintaining the dc link capacitor at grid side converter is constant by using Sinusoidal pulse width modulation.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

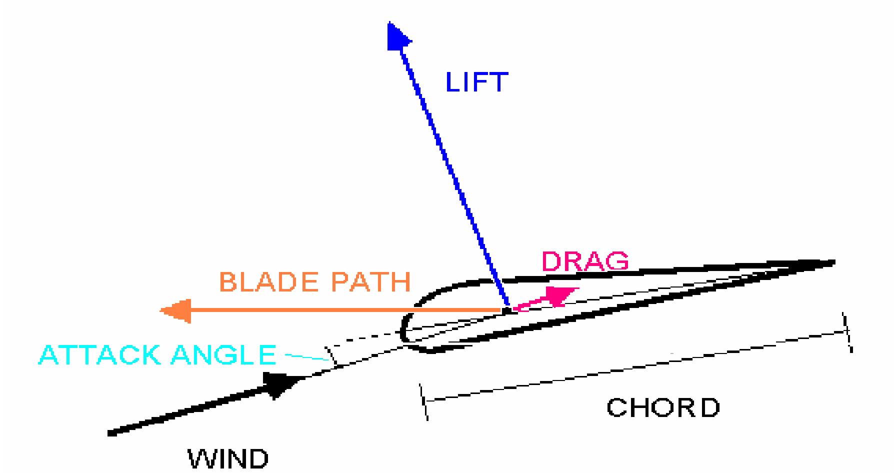


Fig 1.Wind Energy Operation

II. RELATED RESEARCHES: A REVIEW

Some of the recent researches related to power quality improvement for wind energy conversion systems using Sinusoidal pulse width modulation are discussed.

J. Dai *et al*. [2] have suggested an increased penetration of wind power into utility grid brings challenges to power converter design in wind energy conversion systems (WECSs). Among all, low-voltage ride-through has been enforced in the field, which is one of the major challenges for WECS. It is necessary to design an integrated controller to protect the converter from over voltage/over current and to support the grid voltage during faults and recoveries. In this paper, a unified dc-link current control scheme for current-source-converter-based WECS is proposed. The controllers for generator- and grid-side converters are coordinated to provide fault ride-through capability. In normal operations, the proposed control scheme can also smooth the real power flow while keeping the fast dynamic performance of the dc-link current control. Simulation and experimental results are provided to verify the proposed control scheme.

M. Chinchilla et al. [1] have proposed wind energy is a prominent area of application of variable-speed generators operating on the constant grid frequency. This paper describes the operation and control of one of these variable-speed wind generators: the direct driven permanent magnet synchronous generator (PMSG). This generator is connected to the power network by means of a fully controlled frequency converter, which consists of a pulse width-modulation (PWM) rectifier, an intermediate dc circuit, and a PWM inverter. The generator is controlled to obtain maximum power from the incident wind with maximum efficiency under different load conditions. Vector control of the grid-side inverter allows power factor regulation of the windmill. This paper shows the dynamic performance of the complete system. Different experimental tests in a 3-kW prototype have been carried out to verify the benefits of the proposed system.

F. K. A. Lima et al. [7] have proposed a a new control strategy for the rotor-side converter (RSC) of wind turbines (WTs) based on doubly fed induction generators (DFIG) that intends to improve its low-voltage ride through capability. The main objective of this work is to design an algorithm that would enable the system to control the initial over currents that appear in the generator during voltage sags, which can damage the RSC, without tripping it. As a difference with classical solutions, based on the installation of crowbar circuits, this operation mode permits to keep the inverter connected to the generator, something that would permit the injection of power to the grid during the fault, as the new grid codes demand. A theoretical study of the dynamical behaviour of the rotor voltage is also developed, in order to show that the voltage at the rotor terminals required for the control strategy implementation remains under controllable limits. In order to validate the proposed control system simulation, results have been collected using PSCAD/EMTDC and experimental tests have been carried out in a scaled prototype.

L. G.Meegahapola et al. [8] has proposes a decoupled fault ride-through strategy for a doubly fed induction generator (DFIG) to enhance network stability during grid disturbances. The decoupled operation proposes that a DFIG operates as an induction generator (IG) with the converter unit acting as a reactive power source during a fault condition. The transition power characteristics of the DFIG have been analysed to derive the capability of the proposed strategy under various system conditions. The optimal crowbar resistance is obtained to exploit the maximum power capability from the DFIG during decoupled operation. The methods have been established to ensure proper coordination between the IG mode and reactive power compensation from the grid-side converter during decoupled operation. The viability and benefits of the proposed strategy are demonstrated using different test network structures and different wind penetration levels. Control performance has been benchmarked against existing grid code standards and commercial wind generator systems, based on the optimal network support required (i.e., voltage or frequency) by the system operator from a wind farm installed at a particular location.

J.-H. Jeon et al.[5] have suggested the ability of the wind power plant to stay connected during grid disturbances is important to avoid a cascading effect due to lack of power. Making it necessary to introduce new code of practice, the grid operators require that wind turbines stay connected to the grid during voltage dips. Low Voltage Ride through (LVRT) has emerged as a new requirement that system operators demand to wind turbines. This paper analyzes the extent to which the LVRT capability of wind farms using squirrel cage generators can be enhanced by the use of a Static Synchronous Compensator STATCOM. The ability of wind farms to stay connected to grid during LVRT is investigated based on E-ON NETZ grid code. A simulation model of 9 MW wind farm interconnected grid is carried out using the MATLAB Sim Power Systems toolbox

III. BLOCK DIAGRAM OF WIND ENERGY CONVERSION SYSTEM

A few research results have been suggested that employ the dc-link voltage control strategies by the generator-side converter instead of the GSC.

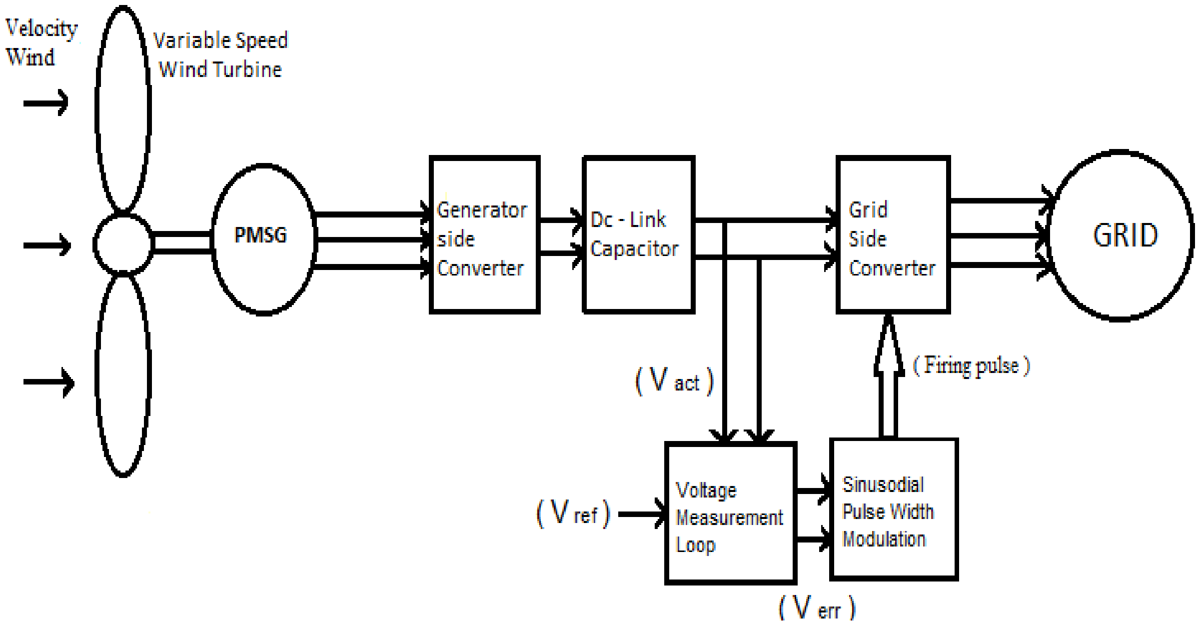


Fig 2.Block Diagram of Wind Energy Conversion System

The exchange of the control roles of the two converters, the dc-link voltage can be controlled to be constant by increasing the generator speed during the grid voltage sag. However, the dc-link voltage response is not so good even though a hybrid adaptive proportional–integral (PI) controller is used based on the power and energy relationship. On the other hand, a Sinusoidal pulse width modulation using an input–output feedback has been applied to various areas such as the dc-link voltage control of PWM converters and the output voltage control of three-phase un interruptible power system (UPS) inverters for the high dynamic responses. This Sinusoidal pulse width modulation technique has been applied to the dc link voltage control for the PMSG wind turbine system. In the first place, a nonlinear relationship between the generator speed and the dc-link voltage is derived, where the dc-link voltage is chosen as output. Then, by applying the Sinusoidal pulse width modulation, a linearized system is obtained and then the dc-link voltage controller can be designed by the classical linear control theory. In the meanwhile, the power of the PMSG is controlled by the GSC. The GSC dual current controllers in the positive and negative-sequence reference frames are employed for grid unbalanced conditions. The validity of the control algorithm has been verified by simulation results for the PMSG wind power system.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

A. Sinusoidal Voltage Controller

The switches in the voltage source inverter below figure (3) can be turned on and off as required. In the Modest method, the topmost switch is turned on if turned on and off only once in both cycle, a square wave waveform effects is achieved. Conversely, if turned on numerous times in a cycle an enhanced harmonic shape may be achieved. In the maximum forthright operation, generation of the desired output voltage is attained. In the maximum forthright application, generation of the anticipated output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave as illustrated. Be contingent on whether the signal voltage is superior or slighter than the carrier waveform, both the positive or negative dc bus voltage is applied at the output. Reminder that over the period of one triangle wave, the typical voltage applied to the load is comparative to the amplitude of the signal (assumed constant) during this period. The resultant chopped square waveform contains an imitation of the desired waveform in its low frequency components, with the complex frequency components being at frequencies of a close to the carrier frequency. Notification that the root mean square value of the ac voltage waveform is still equal to the dc bus voltage, and hereafter the total harmonic distortion is not valuable by the PWM process. The harmonic components are simply shifted into the higher frequency range and are habitually filtered due to inductances in the ac system.

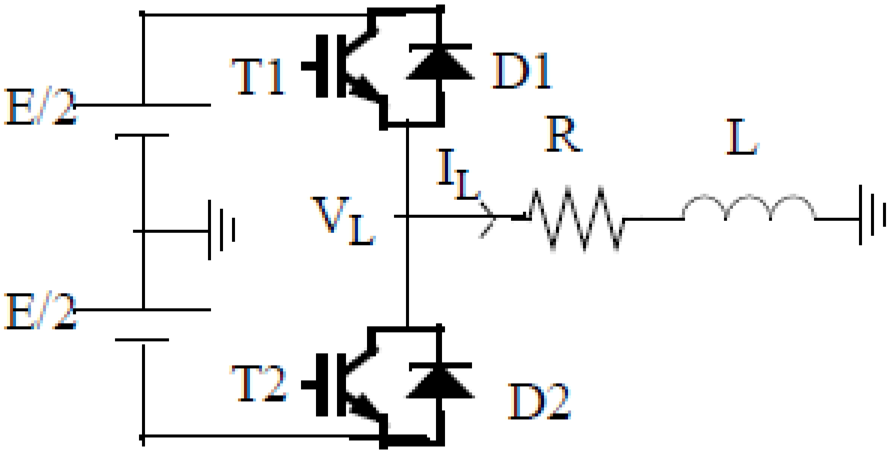


Fig 3. Simple Sinusoidal Voltage Controller

B. Modeling And Controller Design Of Sinusoidal Voltage Controller

In the furthermost forthright implementation, generation of the anticipated output voltage is attained. By matching in the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave are represented in below figure (4). Dependent on whether the signal voltage is superior or lesser than the carrier waveform, whichever the positive or negative dc bus voltage is applied as the output. Explanation in the over period of a unique triangle wave. The average voltage useful to the load is proportional to the amplitude of the signal (assumed constant) during this period. The subsequent chopped square waveform comprises a replica of the desired waveform in its low frequency components, with the higher frequency components presence at frequencies of a close to the carrier frequency. Indication that the root mean square value of the ac voltage waveform is still equal to the dc bus voltage, and henceforth the total harmonic distortion is not affected by the PWM procedure. The harmonic components are just shifted into the higher frequency range and are routinely filtered due to inductances in the ac system. When the modulating signal is a sinusoid of amplitude Remain, and the generosity of the triangular carrier, the ratio m=Am/Ac is known as the modulation index. Annotation that controlling in the Modulation index therefore controls the amplitude of the applied output voltage. The approval waveforms are illustrated in below graphs.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

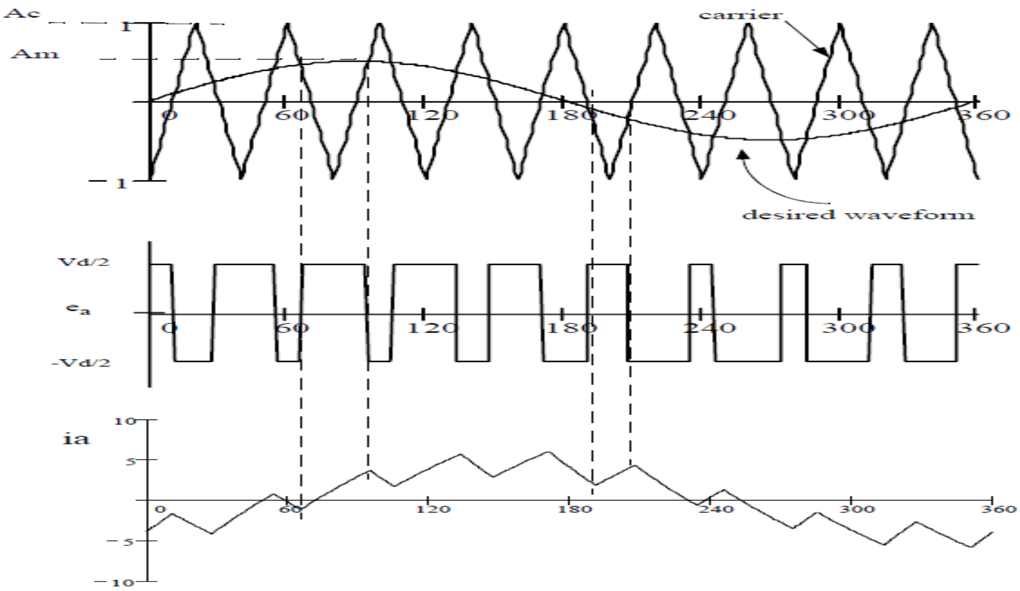
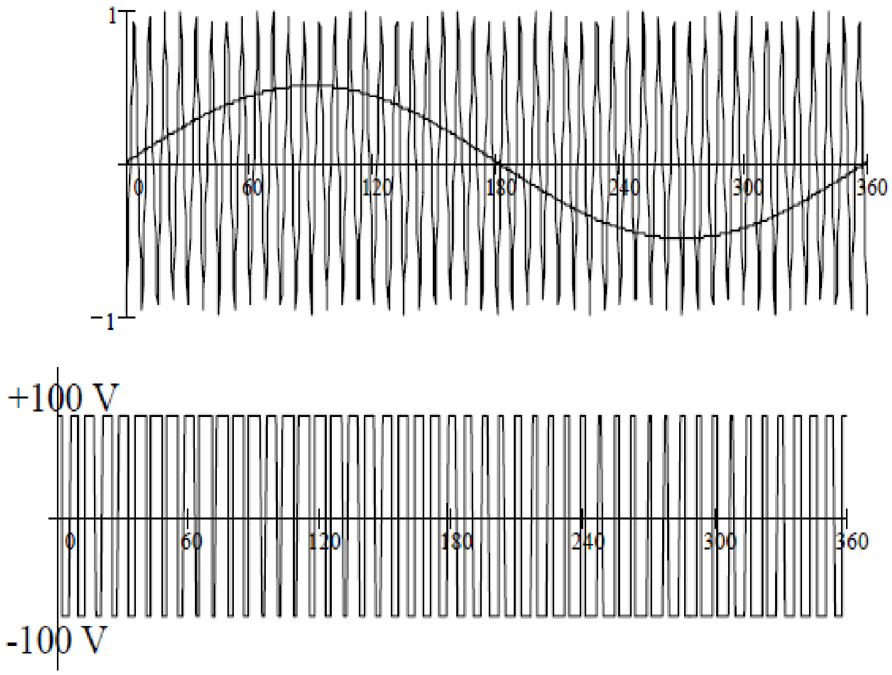


Fig 4.Principle Waveform of Sinusoidal Voltage Controller

C. Structure of Sinusoidal Voltage Controlled

The process works well m is a reduced amount of than 1; there are phases of the triangle wave in which there is no connection of the carrier and the signal as shown in below figure (5). Conversely, a certain amount of this "over modulation" is often permitted in the interest of obtaining a superior ac voltage magnitude even nevertheless the spectral content of the voltage is concentrated slightly poorer. Communication is that with an odd relationship for FC/FM, the waveform is anti-symmetric.



ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

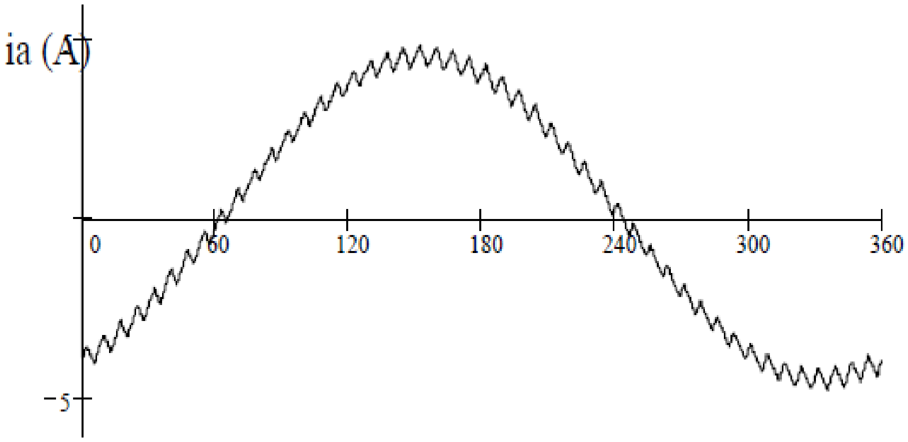


Fig 5.Sinuosidal Voltage Controller

D. DC Link Capacitor

DC link is modeled by relation:

CU dc/dt=idci L

Where

IdC - is DC linkage current and i *L=U dc*

RL - is Resistance load

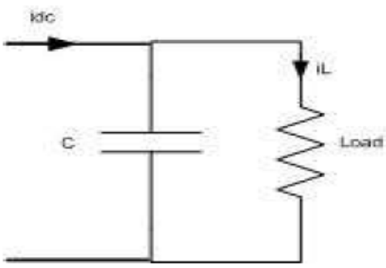


Fig 6.DC Linkage Capacitor

E. Fault Ride through Requirement

The enormous increase in the connected wind capacity in transmission systems forces that wind generation remains in operation in the incident of network disturbances. For this reason grid codes issued throughout the last years invariably demand that wind farms (especially those connected to HV grids) must weather voltage dips to a certain percentage of the nominal voltage (down to 0% in some cases) and for a indicated duration. Such requirements are known as Fault Ride through (FRT) or Low Voltage Ride through (LVRT) and they are described by a voltage vs. time characteristic representing the lowest required protection of the wind power station. The LVRT requirements also comprise fast active and reactive power re-establishment to the pre fault values after the system voltage yields to normal operation levels. Some codes enforce increased reactive power generation by the wind turbines during the disturbance in order to deliver voltage support a requirement that look like the behaviour of conventional synchronous generators in over-excited operation. The necessities depend on the specific characteristics of each power system and the defence employed and they deviate significantly from each other.

The graphical representation of ride through form is illustrated below figure (7).

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

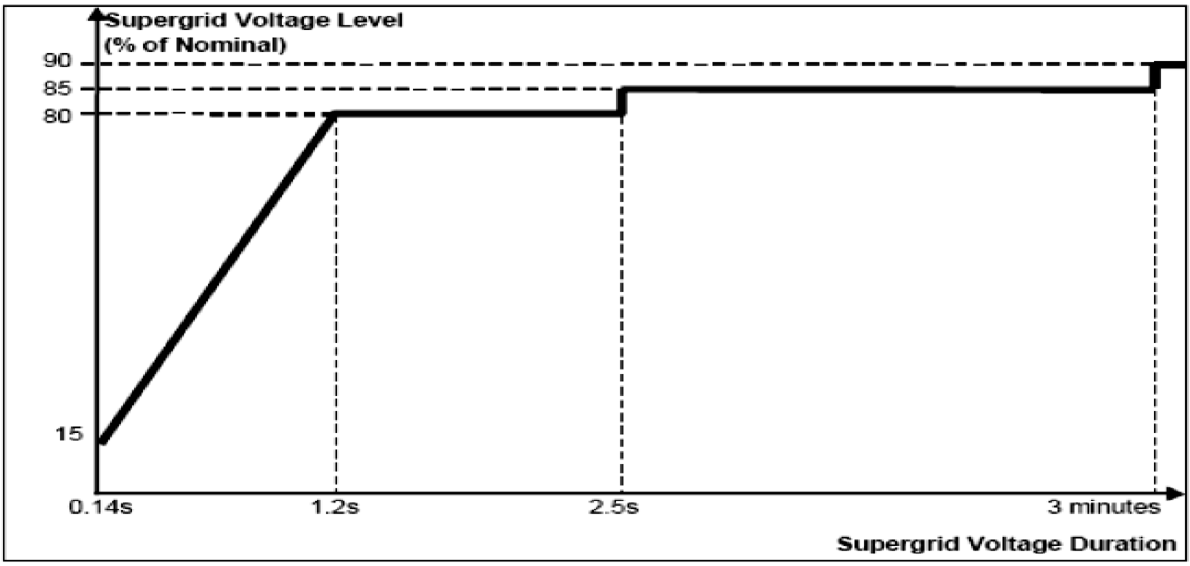


Fig 7. Required ride through capability of wind farms for super grid voltage dips of duration greater than 140ms.

IV. RESULT AND DISCUSSION

The Matlab/simulink model of Grid connected wind energy conversion system using permanent magnet generator and sinusoidal pulse width modulation is shown below.

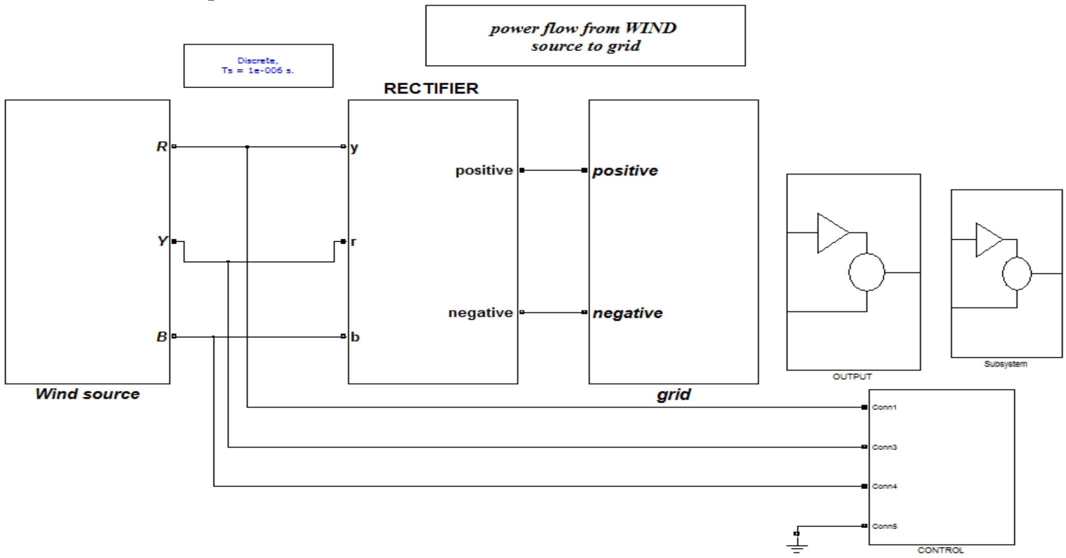


Fig 8. DC Link Voltage Controller in LVRT

In the above figure (8) simulation diagram dc link voltage is controlled by using sinusoidal pulse width modulation is implemented. The dc link voltage controller with low voltage ride through technique builds in subsystem. The grid voltage, and phase current are shown in below figure (10). The below figure (9) simulation diagram is done in matlab by using sinusoidal pulse width modulation. By using this technique, dc link capacitor is maintained constant during grid voltage sag in grid side converter.

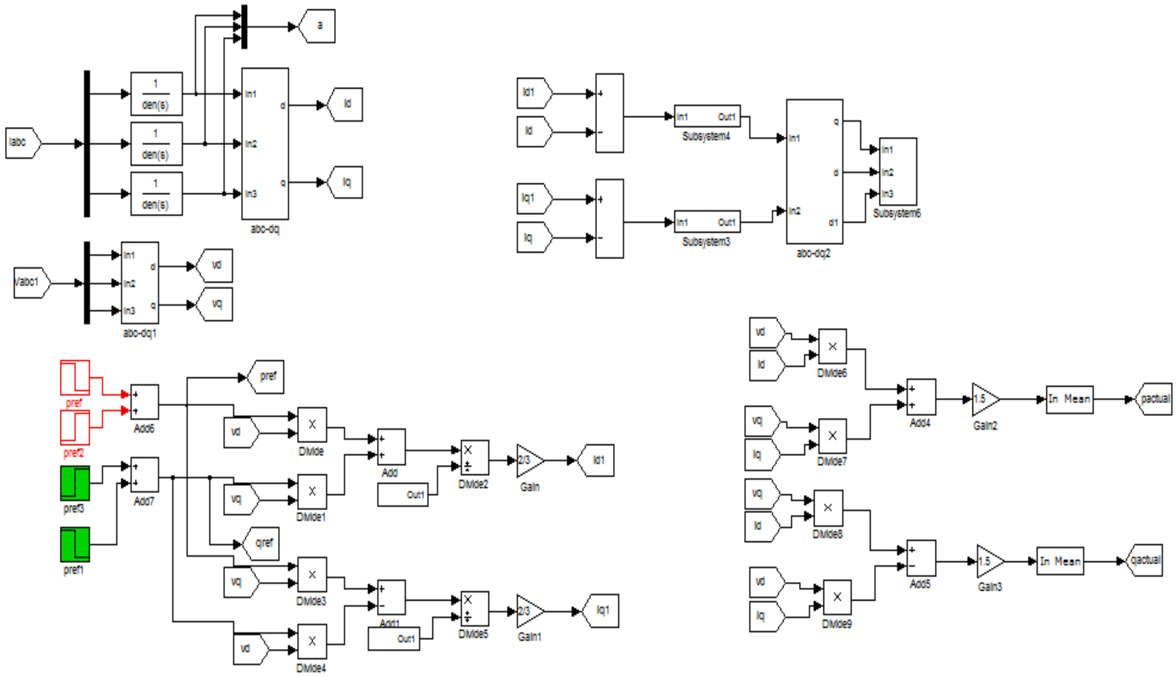


Fig 9. Simulation Diagram of Sinusoidal Pulse Width Modulation

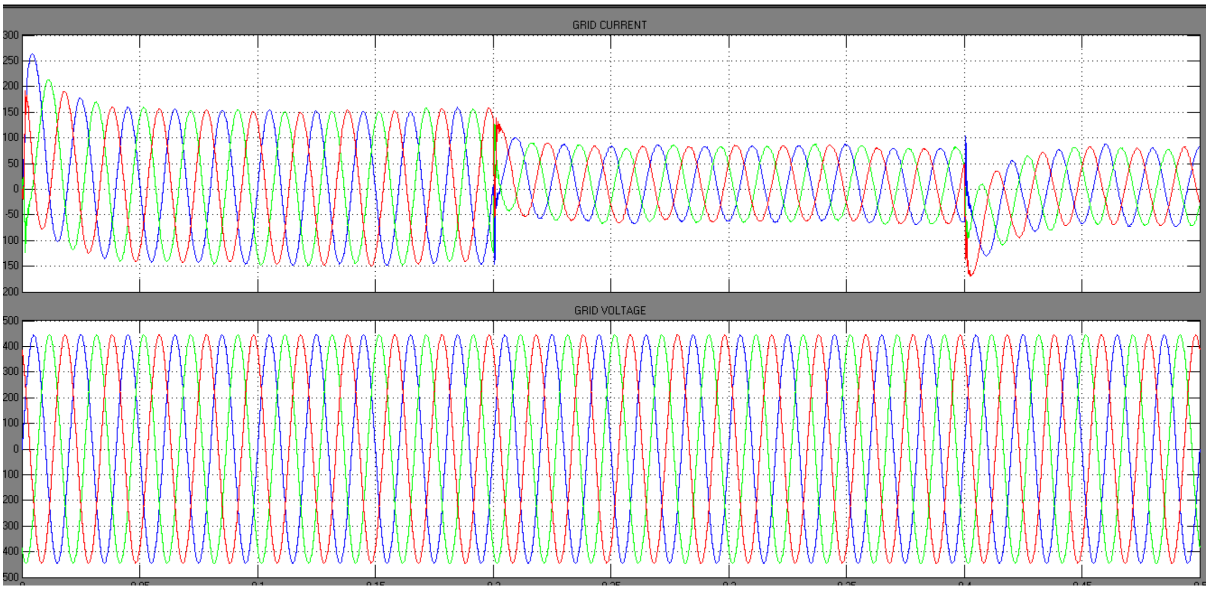


Fig 10.Grid Voltage and Current

The above figure (10) illustrates the grid voltage and current inject to the grid. The inject power is obtained from the wind source. This is attained from above simulation figure (9). The major propose work is to maintain the dc link capacitor is constant in grid side converter by using Sinusoidal pulse width modulation. The below figure (11) illustrate the active power and reactive power injection, during this time certain voltage sag is occurred while injecting to the grid. This should be overcome by Sinusoidal pulse width modulation.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

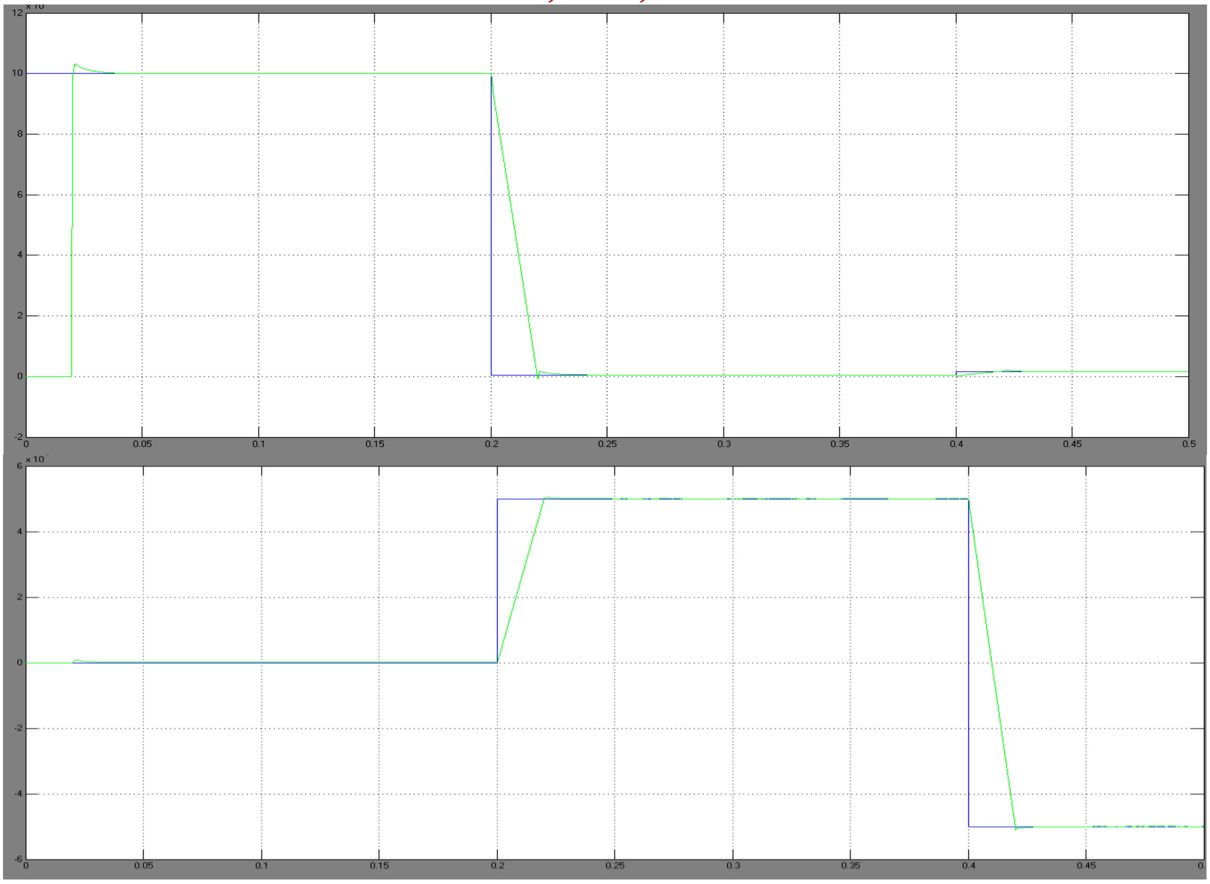


Fig 11.Active and Reactive Power Injection.

The below figure (12) illustrate the dc link capacitor. It should be tuned to adjust, in order to the maintained and achieved quality grid output power by using sinusoidal pulse width modulation.

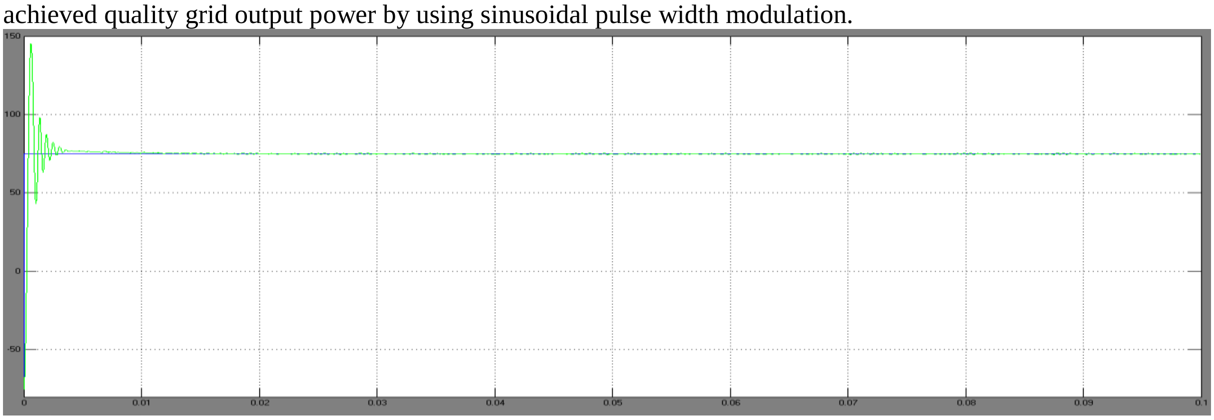


Fig 12.DC Link Capacitor

V.CONCLUSION

In this paper, a PMSG-based WECS with dc link voltage is measured by using Sinusoidal pulse width modulation is suggested. Dc link capacitor is used for maximum power tracking controller and delivering power to the grid, instantaneously. Related to conventional WECS with feedback linearization technique, the amount of switching semiconductors is reduced by one and reliability of system is improved, because there is no requirement for dead time in a low voltage ride though performance. For active power control, two control methods: sinusoidal pulse width modulation method and dc-link voltage control is suggested and compared. It is shown that with feedback linearization method, the validity of the control algorithm has been verified by simulation results for a 2 MW PMSG wind power system. And also, Simulation results is verified for 2.68 kw PMSG wind turbine simulator. The test results have shown a good dc-link voltage constant in Feedback linearization technique. But the proposed sinusoidal pulse width modulation is done for 2.80 kw of dc link voltage constant is increased by 12% related to conventional system. It was also exposed that due to elimination of dead time, the THD of proposed system is similar as conventional system.

REFERENCES

[1] 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 Trans. Energy Convers., vol. 21 , no.130– 135, Mar. 2009.

[2] H. Polinder, F. F.Avan der Pijl, and P. Tavner, "Comparison of direct-drive and geared generator concepts for wind turbines," IEEE Trans. Energy Convers., vol. 21, no. 3, pp. 543–550, Sep. 2006.

[3] F. Iov, A. D. Hansen, P. Sørensen, and N. A. Cutululis, "Mapping of grid faults and grid codes," Risø Nat Lab., Tech. Univ. Denmark, Roskilde, Denmark, Tech. Rep. Risø-R-1617(EN), Jul. 2007.

[4] C. Saniter and J. Janning, "Test bench for grid code simulations for multi- MW wind turbines, design and control," IEEE Trans. Power Electron., vol. 23, no. 4, pp. 1707–1715, Jul. 2008.

[5] J.-H. Jeon, S.-K. Kim, C.-H.Cho, J.-B.Ahn, and E.-S. Kim, "Development of simulator system for micro-grids with renewable energy sources," J. Electr. Eng. Technol., vol. 1, no. 4, pp. 409–413, Feb. 2006.

[6] R. Pollin, H. G. Peltier, and H. Scharber, "Green recovery: A new program to create good jobs and start building a low-carbon economy," Center for American Progress, Washington, DC, Sep. 2008.

[7] F. K. A. Lima, A. Luna, P. Rodriguez, E. H. Watanabe, and F. Blaabjerg, "Rotor voltage dynamics in the doubly fed induction generator during grid faults," IEEE Trans. Power Electron., vol. 25, no. 1, pp. 118–130, Jan.2010.

[8] L. G.Meegahapola, T. Littler, and D. Flynn, "Decoupled-DFIG fault ride through strategy for enhanced stability performance during grid faults," IEEE Trans. Sustainable Energy, no. 3, pp. 152–162, Oct. 2010.

[9] Q. Song and W. Liu, "Control of a cascade STATCOM with star configuration under unbalanced Conditions," IEEE Trans. Power Electron., vol. 24, no. 1, pp. 45–58, Jan. 2009.

[10] W. H. Zhang, S.-J. Lee, and.-S. Choi, "Setting considerations of distance relay for transmission line with STATCOM," J. Electr. Eng. Technol., vol. 5, no. 4, pp. 522–529, Jul. 2010.

[11] H. M. Pirouzy and M. T. Bina, "Modular multilevel converter based STATCOM topology suitable for Medium-voltage unbalanced systems," J. Power Electron., vol. 10, no. 5, pp. 572–578, Sep. 2010.

[12] G. Brando, A. Coccia, and R. Rizzo, "Control method of a braking chopper to reduce voltage unbalance in a 3-level chopper," in Proc. IEEE Int. Conf. Ind. Technol., 2004, vol. 2, pp. 975–978.

[13] J. F. Conroy and R.Watson, "Low-voltage ride-through of a full converter wind turbine with permanent magnet generator," IET Renewable Power. Generation, vol. 1, no. 3, pp. 182–189, Sep. 2007.

[14] W. Li, C. Abbey, and G. Joos, "Control and performance of wind turbine generators based on permanent magnet synchronous machines feeding a diode rectifier," in Proc. IEEE Power Electron. Spec. Conf., Jun., 2006.

[15] B. Singh, R. Saha, A. Chandra, and K. Al-Haddad, "Static synchronous compensators (STATCOM): Are view," IET Power Electron., vol. 2, no. 4, pp. 297–324, 2009.

AUTHOR BIOGRAPHY

E.Rajendran received the B.E. Degree in Electrical and Electronics Engineering from Anna University, Chennai, India in 2005 and the M.Tech. Degree in Power Electronics and Drives from VIT University, Vellore, Tamil Nadu, India in 2007. He is currently pursuing his Ph.D., Degree in Electrical Engineering faculty from Anna University, Chennai, Tamil Nadu, India. He is working as an Assistant Professor of Electrical and Electronics Engineering Department at S K P Engineering College, Tiruvannamalai, Tamil Nadu, and India. His research areas of interest are Power Quality Analysis, Renewable Energy Systems, Z-Source Inverter and Various Controlled Techniques of Inverter and Rectifier, Power Electronics, Control Systems, Special Electrical Machines Microprocessor and Microcontroller.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

Dr.C.Kumar received his B.E and M.Sc (Engg) degree in Electrical and Electronics Engineering from Alagappa Chettiar College of Engineering and Technology Karaikkudi and Thiagarajar College of Engineering Madurai. Tamil Nadu, India in 1975 and 1979 respectively and the Ph.D. Degree from Madurai Kamaraj University, Madurai, Tamil Nadu, India in the year 2001.He has totally 48 years of teaching experience and at present he is the Director Academic at S K P Engineering College, Tiruvannamalai, Tamil Nadu, India. To his credit he has published & presented more than 54 research papers. Dr. C. Kumar is currently senior member of IEEE, fellow of IE (India), and fellow of IETE (India).

G.Ponkumar has completed his Bachelor"s degree in Electrical and Electronics Engineering from VRS college of engineering and technology in 2011. He is currently doing the Post graduation in Power System Engineering at S K P Engineering College. He is interested to do the research in the area of power system operation optimization.