Sliding Mode Controller based Permanent Magnet Synchronous Generator with Z-Source Inverter for Variable Speed Wind Energy Translation Structure using Power Quality Enhancement

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ABSTRACT
Small scale stand alone wind generators are a significant different source of electrical energy. Unluckily, most of these systems do not capture more power at every wind speed. Particularly, at low wind speeds which are provide low power. To address this problem, this paper has been proposed a permanent magnet synchronous generator (PMSG) and Z-source inverter. This generator is connected to the power network by means of a Z-source inverter. Permanent-magnet synchronous generators are having some amazing characteristics such as with a reduction of burden and level, advanced performance, minimized size of gear box and no need of external power in permanent magnet excitation. The PMSG defeat the all other generators, marvelous performances without absorb the grid power.This paper presents a Z-source inverter that can be proposed as an option power conversion concept for variable speed wind turbines. It consist both buck and boost capabilities as they permit the inverter to perform the shoot through state. It utilizes a special Z-source network (L-C network) to DC-link in between inverter and the DC source. By controlling the shoot-through duty cycle of IGBTs in inverter system, we can diminish the line harmonics, develop power factor, and enlarge output voltage range.

Keywords
Permanent Magnet Synchronous Generator (PMSG), Wind Energy Conversion System (WECS) and Z-Source Inverter (ZSI).

1. INTRODUCTION
In recent years, a bunch of work has been prepared in improvement of Power Quality using variable generators and power electronic devices. Here fresh permanent magnet synchronous generator (PMSG) technology offers elevated efficiency power conversion from mechanical into electrical power. Additionally, it allows for special machine design with very low speed e.g. in gearless wind and hydro application and at very soaring speed for micro gas turbines, which is of interest for several regenerative or co-generative power conversion technologies. A survey of already realized prototypes or in use PM generator systems is presented for that purpose.

Among all other generators which are used in wind turbines the PMSG's have the highest advantages because they are stable and secure during normal operation and they do not need an additional DC supply for the excitation circuit (winding). Initially used only for small and medium powers the PMSG's are now used also for higher power. Traditional Voltage source inverter (VSI) and current source inverter (CSI) are Provides either a buck or a boost Operation and not a buck-boost Performance. i.e. their accessible output voltage range is restricted to either larger or lesser than the input voltage. Z-source inverter (ZSI) was projected as an alternative power conversion concept as it can have both voltage buck and boost qualifications. Moreover it has the following advantages: resistant to EMI noise and mis-triggering, little or no in-rush current compared to the voltage source inverter (VSI) and Very small common mode noise.

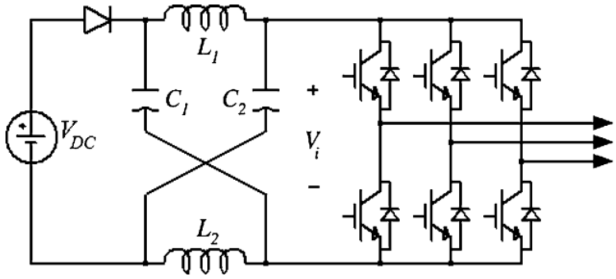

Figure 1:Z Source Inverter

Figure (1) Shows in the major circuit diagram of the Z-source inverter. It employs a matchless impedance network preset between the power source and the circuit for converter which consist a split-inductors (L1 and L_2) and capacitors (C_1 and $C_{2)}$ fixed parallel. The Z–Source network merges the inverter to a V_{DC} (DC voltage source). The DC voltage source will be a battery or a wind generator. This distinctive impedance network allows the Z-source inverter to buck or boost its output voltage, and also donate it with distinctive features that cannot be obtained in traditional power inverters.

The Sliding mode controller is presented in [8], [10]. The Sliding mode controller is appropriate for an exact class of nonlinear systems. This is presented in the presence of modelling imprecision, parameter dissimilarity and turbulences, given that the higher bounds of their supreme values are known. Modelling incorrectness may come from certain indecision about the plant that is unknown plant parameters or from the selection of a simplified demonstration of the system dynamic. Sliding mode controller design gives a methodical approach to the problem of keep up stability and acceptable performance in presence of modelling deficiency.

In this paper, a new Permanent Magnet Synchronous Generator (PMSG) based Wind Energy Conversion System (WECS) with *Z*-source inverter is proposed. The projected topology is shown in Fig. 2. In this topology, instead of simple PWM control Based Z-source inverter, We have executed sliding Mode Based Z-source inverter,. Moreover, reliability of the system is very much improved. Why because the short circuit across any phase leg of inverter is authorized. Also, in this configuration, inverter output power distortion is reduced, since there is no need to phase leg dead time. At long last, simulation results are offered to verify the performance of the proposed system.Nowadays the permanent magnet synchronous generators are utilized for distribution system to develop the moment of power in the power system and also to moderate the losses of power in the system. Furthermore it has some features such as small weight and volume, soaring performance, reduce the gear box size, and no need of external power supply for permanent magnet excitation With several advantages, permanent-magnet synchronous generator (PMSG) generation system symbolize an important tendency in development of wind power applications. Here a new variable-speed WECS with a PMSG sliding mode controller based Z-source inverter is proposed. The main Characteristics of *Z*-source inverter are maximum power point tracking control and delivering power to the grid, simultaneously. The two main objectives of PMSG are extracting highest power from wind and feeding the grid with high-quality electricity. Characteristics of Z-source inverter are used for maximum power point tracking control and deliver the quality power to the grid, concurrently. The Z-source converter utilize a unique impedance network to combine the converter main circuit to the power source, hence providing distinctive features that cannot be achieved in the traditional voltage-source and current-source converters respectively.

2. POWER QUALITY ENHANCEMENT FOR WECS USING PMSG WITH Z-SOURCE INVERTER

2.1. Variable Speed Wind Energy Translation Structure

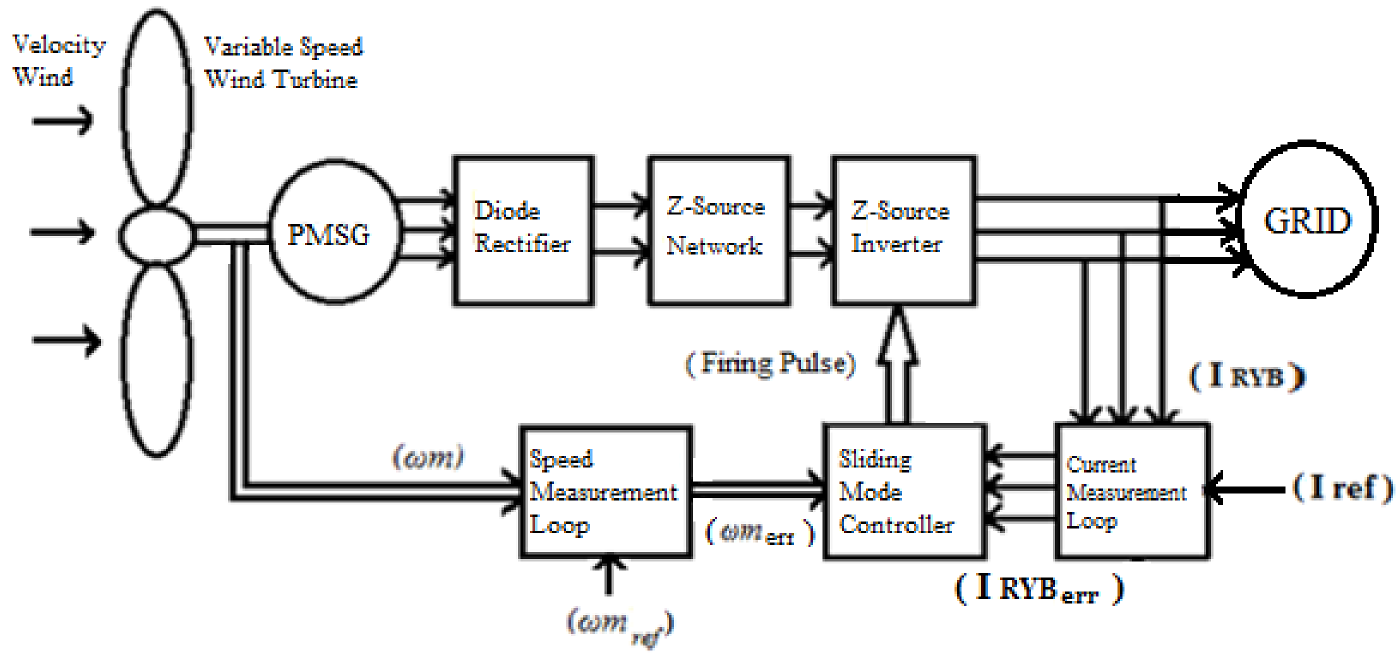

Figure 2: Block Diagram of Proposed Variable Speed Wind Energy Translation Structure.

The figure (2) includes blades, Permanent Magnet Synchronous Generator (PMSG), Z-source network, sliding mode controlled Z-source inverter and grid. Whenever wind is blowing towards the blade, the blade will be rotate according to wind speed. This blade is straightly united with the shaft of the PMSG. So whenever blade is rotate, the rotor of the PMSG is also get rotate .The obtaining AC power from PMSG is reliably nourished to the rectifier. The main principle of rectifier is changing the AC supply to DC supply. Then after tremendous performing of rectifier, the DC supply is given to the Z-source network as well as inverter. This inverter converts the DC power to required AC power. Here the Z- source inverter is controlled by Sliding mode controller. In the state space sliding mode control is a nonlinear control method which modifies the dynamics of a nonlinear system by function of a discontinuous control signal that services the system to "slide" besides a cross-section of the system's normal performances. The state feedback control law is not a continuous function of time. As an alternative, it can switch from one continuous arrangement to another based on the present position. Consequently, sliding mode control (SMC) is a variable structure control method. The main role of this Sliding mode controller is control the Z- source inverter, compares the actual current (I_{RYB}) with reference current (I ref) and actual rotor speed (ωm) with reference speed (ωmref) as an error signals fed to the sliding mode controller. Then the sliding mode controller depends upon the error signals, it gives the efficient firing pulses to the inverter system. The sliding mode control it is maintaining the required turbine speed. Because adjusted in blades in the different air flow conditions. Then the quality power supply from the Z-source Inverter is connecting to grid for various customer applications. Here SMC controlled the turbine speed and inverter output power. Figure (3), shows the illustration of Simulink diagram of Variable Speed Wind Energy Translation Structure using PMSG with Z- Source Inverter. In this inverter block enclosed Rectifier, Z- source network, and Z-source inverter, subsystem for sliding mode controller, Low pass filter and load. The AC power produced by PMSG and by using rectifier AC power converted into DC power. The DC power unswervingly fed to the Z-Source Network as well as Z Source Inverter. Then the incredibly boosted DC power converted into AC power by Z- source inverter. Here this Z- Source inverter controlled by sliding mode controller. The main advantage of Z-source inverter is it absorbs the shoot-through state. Because by using the shoot through state, we can increase DC voltage boosts capability. But in current source inverter and voltage source inverter the shoot through state is not available. In this state, load terminals are shorted via both the upper and lower devices of any one phase leg, two phase legs or three phase legs. This inverter improves voltage boost capability with the turning ON of both switches in the same inverter phase leg (shoot-through state) source inverter.

2.2. SIMULINK DIAGRAM

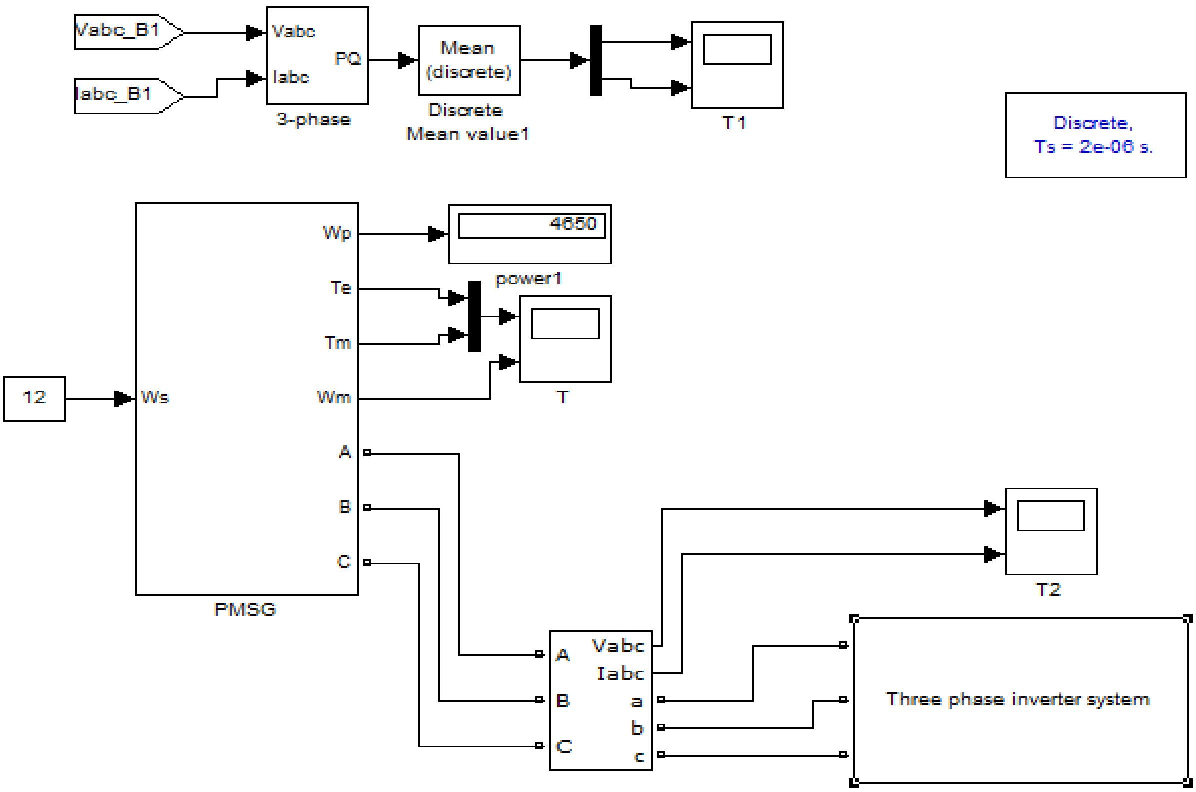

Figure 3: Simulink Diagram of Variable Speed Wind Energy Translation Structure

Here sliding mode controller plays the main task for Z-source inverter that is it controls all over performace of Z-source inverter for achieving Shoot through state . Furteher more it compares the motor speed (load) as well as output current as the error signals i.e the output current is integrated and motor speed is swervingly Conected to the sliding mode controller. And it compares those signal and given its to the Z-

2.3. Sliding Mode Controller

Sliding mode controller is appropriate for an explicit class of nonlinear systems. This is being relevant in the presence of modelling erroneousness, parameter difference and turbulence, presented that the upper bounds of their supreme values are known. Modelling inexactness may come from certain insecurity about the plant that is unknown plant parameters or from the preference of a shortened representation of the system dynamic. Sliding mode controller design offers a systematic approach to the problem of maintaining constancy and adequate performance in presence of modelling deficiency. The sliding mode control is particularly suitable for the tracking control of motors, robot manipulators whose mechanical load change over a wide range. Induction motors are used as actuators which have to follow complex course specified for manipulator travels. Compensation of sliding mode controllers are that it is computationally effortless compared adaptive controllers with parameter estimation and also robust to parameter variations. It also leads to chattering of the system states.

The sliding mode control methods are used to an indirect vector controlled induction machine for both position and speed control. It is also used to position control loop of an indirect vector control induction motor drive, with no rotor resistance detection scheme. A sliding mode based adaptive input output linearizing control for induction motor drives. In this case the motor flux amplitude and speed are separately embarrassed by sliding mode controllers with unpredictable switching gains. In the sliding mode controller with rotor flux assessment in the induction motor drives. Rotor flux is also ball parked using a sliding mode observer. Even though many speed estimation algorithms and sensor less control schemes are urbanized during the past few years, growth of a simple, effective and little sensitivity speed evaluation scheme for a small power induction motor (IM) drive is deficient in the literature. Sliding mode controller is a superior choice for handling this type of problems.

Therefore, sliding mode control (SMC) is a variable structure control method. The several control structures are designed so that trajectories forever shift toward an adjacent region with a dissimilar control structure, and so the definitive trajectory will not survive entirely within one control structure. As an alternative, it will slide beside the boundaries of the control structures. The movement of the system as it slides beside these boundaries is called a sliding mode and the geometrical locus having the boundaries is called the sliding facade. In the background of modern control theory, any variable structure system, like a scheme under Sliding Mode Control, may be viewed as a extraordinary case of a hybrid dynamical system as the system both flows through a continuous state space but also moves via dissimilar discrete control modes.

3. RESULT AND DISCUSSION

The Proposed Method has employed in MATLAB 9 and executed for sliding mode control based Z- Source Inverter shown in Fig.3. By using this method we can enhance the phase to phase voltage upto 880V for wind turbine output voltage 600V. And here phase to phase current is maintained as constant that is 40 amps shown in figure (4). The inverter output voltage shown in below

figure (5). Then the V_{rms} and I_{rms} outputs are detailed in below figure (6) and (7). But in the conventional method i.e. simple PWM based Z-Source Inverter we can improve the phase to phase voltage very less for wind turbine output voltage same as in proposed method. So sliding mode control based Z-Source Inverter is most professional compared to conventional method. The real and reactive powers are maintained as 2 KVA and 1.5 KVAR simultaneously in our proposed circuits that is shown below figure (8). The reduction of harmonics is more in proposed method compared with conventional method. By using harmonics filters here we can control and reduced the harmonics level.

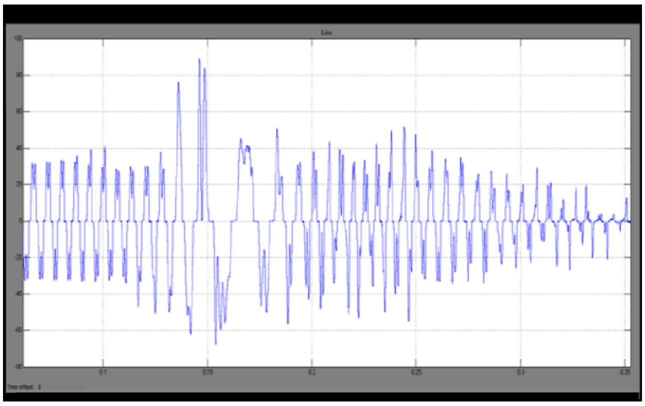

Figure 4: PMSG Output Current

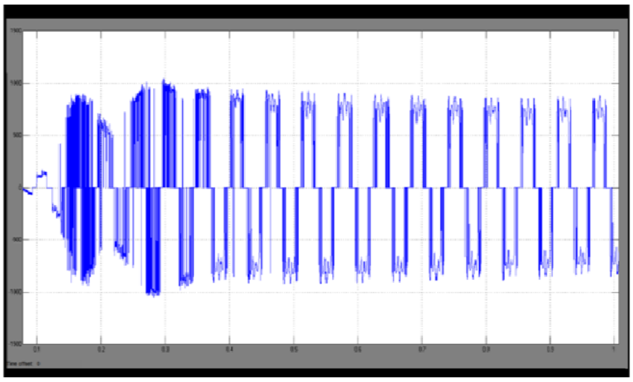

Figure 5: Inverter Output Voltage

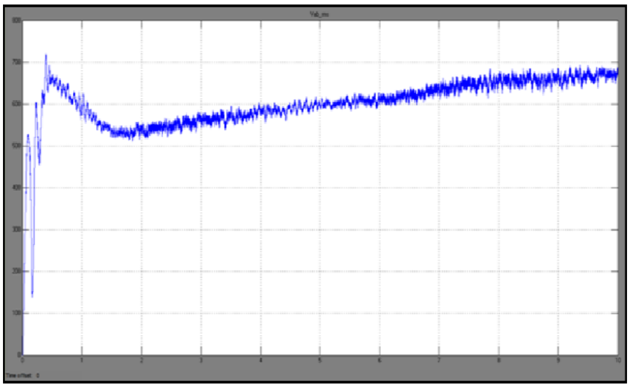

Figure 6: RMS Voltage

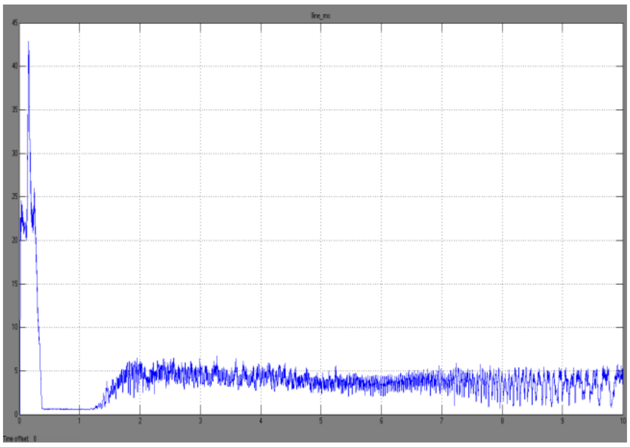

Figure 7: RMS Current

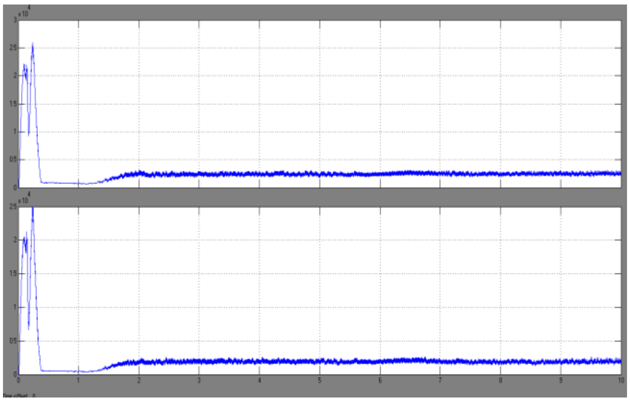

Figure 8: Real and Reactive Power for Source

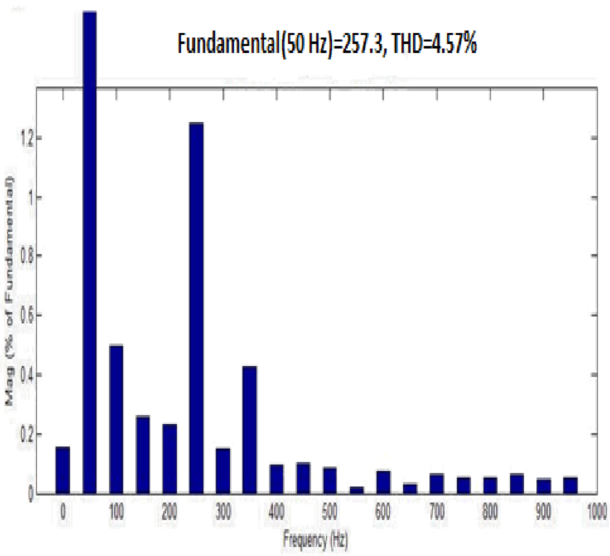

Figure 9: Harmonic spectrum for proposed method

5. CONCLUSION

This paper has accessible a new sliding mode control on the Z-source inverter. The functional principle and investigation have been specified. Simulations are results verified the operation and verified the talented features.The *Z*-source inverter is used for maximum power tracking control and delivering power to the grid. By means of an in-depth topology analysis, it is recognized that the proposed inverter can provide a strong boost inversion capability to overcome the restrictions of the classical inverters. Compared to conventional WECS with maximum constant boost control and third harmonics injection based converter, the number of switching semiconductors is reduced and consistency of system is improved. Because there is a no dead time a Z-source inverter. The two main objectives for WECSs are extracting greatest power from wind and feed to the grid with high-quality electricity. Compared to predictable WECS with maximum constant boost control and third harmonics injection based Z-Source inverter method, the voltage profile is enhanced.

6. REFERENCES

[1] E.Rajendran, Dr.C.Kumar, “Power Quality Improvement for Wind Energy Conversion System Using PMSG and Z-Source Inverter” International Journal of Engineering Science and Technology, Vol. 5 No. 04S Apr 2013.

[2] E.Rajendran, Dr.C.Kumar, G.Ponkumar, “ LVRT scheme of wind energy system using permanent magnet synchronous generator and hysteresis current controller” International Journal of Engineering Science and Technology, Vol. 5 No.04. April 2013.

[3] E.Rajendran, Dr.C.Kumar, G.Ponkumar,“ LVRT Scheme of Wind Power System using PMSG and Sinusoidal Pulse Width Modulation” International Journal of Engineering Science and Innovative Technology, Volume 2, Issue 2, March 2013.

[4] M´onica Chinchilla, Member, IEEE, Santiago Arnaltes, Member, IEEE, and Juan Carlos Burgos, Member, IEEE,” Control Of Permanent-Magnet Generators Applied To Variable-Speed WindEnergy Systems Connected To The Grid.” *IEEE Trans. Energy Conversion*, Vol 21, No. 1, March 2006.

[5] Poh Chiang Loh, Member, IEEE, D. Mahinda Vilathgamuwa, Senior Member, IEEE,Chandana Jayampathi Gajanayake, Yih Rong Lim, and Chern Wern Teo,” Transient Modeling and Analysis of Pulse-Width Modulated Z-Source Inverter,” *IEEE Trans. Power Electron*, vol. 22, no. 2, march 2007.

[6] Miao Zhu, Member, IEEE, Kun Yu, Student Member, IEEE, and Fang Lin Luo, Senior Member, IEEE,” Switched Inductor Z-Source Inverter.” *IEEE Trans. Power Electron*, VOL. 25, No. 8, August 2010.

[7] Miao Zhu, Member, IEEE, Kun Yu, Student Member, IEEE, and Fang Lin Luo, Senior Member, IEEE,” Switched Inductor Z-Source Inverter.” *IEEE Trans. Power Electron*, VOL.25, No. 8, August 2010.

[8] Riya Jacob,P.S Lal Priya,"Sliding Mode Control of a Wind Energy Conversion System Based on a Permanent Magnet Synchronous Generator", 10th National Conference on Technological Trends (NCTT09) 6-7 Nov 2009

[9] Kiwoo Park, Kyo-Beum Lee, and Fredge Blaabjerg,"Improving Output performance of a Z-Source Sparse Matrix Converter Under Unbalanced Input-Voltage conditions."*IEEE Trans.Power Electron*.Vol.27,No.4, April 2009.

[10] Brice Beltran, Tarek Ahmed-Ali, and Mohamed El Hachemi Benbouzid," High-Order Sliding-Mode Control of Variable-Speed Wind Turbines", IEEE Trans. Industrial Electronics, VOL. 56, NO. 9, SEPTEMBER 2009.

[11]Zhi Jian Zhou, Xing Zhang, Po Xu, and Weixiang X. Shen," Single-Phase Uninterruptible Power Supply Based on Z-Source Inverter." *IEEE Trans., Industrial Electron*., VOL. 55, NO. 8, AUG 2008.

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