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A Custom High Power Grid Connected Cascaded H-Bridge Multilevel Inverter for Wind Energy Converter

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Abstract :*In modern power systems, a small increase in the energy efficiency is a significant improvement for power system operators (PSOs). This can be achieved by installing a clean and sustainable energy source which has no fuel costs .With mentioned advantages, it is most promising and fastest growing energy source that represents the largest amount of the renewable energy sources connected to the electric grid In general, a wind energy consists of an alternator with power conversion devices to meet the grid codes. In this regard, mostly, DC to AC power conversion devices i.e., inverters act as interface between the wind energy conversion and grid. The conventional inverters are two level voltage source converters with limited abilities for new topologies and control schemes. However, with the advanced power electronic technologies, there is a possibility of developing three phase multi-level inverter topologies and sophisticated control strategies. So, the technology will be targeted to improve the capability of conventional inverter of WEC into a CPD. This kind of transaction reduces the economic burden on the PSOs and improves the power quality of the grid.*

A wind energy conversion system run by a variable speed wind turbine having pitch mechanism and two mass direct driven permanent magnet synchronous generators is implemented in this paper. Multilevel inverter is an emerging power technology Recently for high-medium application. Out of different topologies, cascaded H bridge multilevel inverter is implemented with WECS as it requires fewer components as compared to other multilevel inverter. One Of the major limitations is the use of separate dc source for each H Bridge in cascaded multilevel inverter which can be overcome by inserting isolation transformer. For generation of seven level controlled output voltages, a phase- multi-carrier pulse width modulation is used. The proposed WECS having seven-level inverter having isolation transformers is simulated in MATLAB/SIMULINK. The simulated waveform of the output obtained from PMSG, DC link voltage, Pitch angle and three phase CHB MLI voltages are shown.

Index terms:
Cascaded H-Bridge multilevel inverter topology, Permanent-magnet synchronous generator (PMSG), Pulse Width Modulation, Isolation Transformer, Wind energy conversion system (WECS, CPD,

I INTRODUCTION

Wind power is undergoing the fastest rate of growth than any other form of electricity generation in the world. The low environmental impact of wind energy makes it a very attractive solution. The resource potential is large. Integration of wind power plant into the electric power system presents challenges primarily due to the natural characteristic of the wind plants which differ in some respect from the conventional plants A typical windenergy conversion system includes a wind turbine, interconnection apparatus,controlsystemsandgenerators.Variable speed wind turbines are capable of producing 9% to 15% more energy output as compared to their constant speed. But it necessitates the need for power electronic converters to provide a fixed frequency and fixed voltage power to their loads. The most advanced generator type used for wind energy conversion system perhaps the permanent-magnet synchronous generator (PMSG).This machine offers, best efficiency compared to the same power level and machine size the best efficiency among all types of machines. With high robustness in construction, easymaintenance due to slip ring- less and exciter-less features. The inherent benefit of permanent magnet which supplies rotor flux in synchronous machines without excitation loss supports the wind

Powergeneration development.[3] The Electrical power output of the PMSG cannot be delivered directly to the grid. Power electronics converters are used to overcome this limitation. The main disadvantage of the PMSG is the high cost of the PM material and power converter. The three-level converter has been widely studied in

Literature but the application of diode-clamped converters with higher (four or more) levels havenot been analyzed for the production of wind power. In this paper, a diode clamped multilevel inverter is cascaded with the H-bridge forming ahybridtopology.TheDcinputtotheinverterisfedfrom fourindependentwindgenerators.Thecontrolledrectif ierconnected at the output of each generator gives the controlled and is maintained constant by means of regulator. This constant obtained from each is given as the input of inverter the output voltage of the inverters controlled by generating pulse from the control circuit. The rest of the paper is organized as follows section I describes the wind generator powered multilevel inverter. Section III describes Pulse Width Modulation., Simulation results are discussed in section IV, Section V FFT Analysis and finally, concluding remarks are given in section VI

II WIND GENERATOR POWERED MULTILEVEL INVERTER

In order to meet the demand, a wind power with high quality is obtained using the converter; multilevel converters are good alternative to the conventional converters for these systems. A multilevel converter enables the ac voltage to be increased without an output transformer, reducing the output voltage and currentsharmoniccontent and make the output waveform closer to sine wave.[6]In addition, the cancellation of low frequency harmonics from the ac voltages at the different levels means that the size of the ac inductance can be reduced, thus a consequent decrement in the expenses of the overall system.

The block diagram for the constant output multilevel inverter is shown in figure 1.In this diagram it consists of wind farm, an inverter, and sinusoidal pulse width modulation block. Four DC source voltagesare given as input to the hybrid inverter which combines the diode clamped multilevel inverter and H-bridgeinverter. By using twelve switches in hybrid multilevel inverter with each switch having different voltage to generate thee level stepvoltageofsymmetrical output. The eleven step output is applied to If there any deviation in output, the controller is used to compensate the output voltage and SPWM signal for the switch is varied. The

Constant dc supply for the inverter is from the wind farm and the pulses for each switch are obtained from Sinusoidal Pulse Width Modulation Technique. The Diode Clamped Inverter switching states is given in the Table 1.The number of output phase voltage level is defined by m=2s+1, where s is the number of DC source.

2. WIND ENERGY SYSTEM

The block diagram of the proposed system is shown in fig. 1. The system comprises of wind turbine, two mass direct driven PMSG, an uncontrolled diode bridge rectifier, a seven level cascaded H-bridge inverter with PWM control and a three phase load

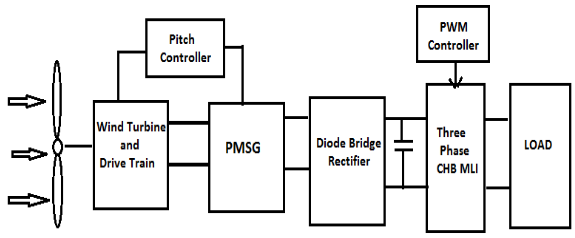

Fig 1: Block diagram of variable speed PMSG based WECS

2.1 Wind Turbine Modeling

Wind turbine plays a major role in a wind energy conversion system. Wind turbines produce electricity by using the power of the wind and drive the generator connected to it. The conversion kinetic energy contained in the wind that passes over the blade to rotational mechanical energy is done by wind turbine.

The power in the air flow is given by

$Pair$ = 12 ρ A $\upsilon 3$ (1.1)

Where ρ is the air density (1.25 kg/$m3$), A is the swept area of rotor in ($m2$) and υ is speed of the wind in (m/s). The power transferred to the rotor depends upon power coefficient CP given by

CP=$PMech$/ pair(1.2)

The mechanical torque in (N-m) is given by

TM= $PMech/\omega M$ (1.3)

Where $PMech$ is the output mechanical power in (watts) and ωM is the mechanical speed of the wind turbine in (radian/sec). The proposed model uses a PI based control design scheme for the control of blade pitch angle in a variable speed wind turbine. The purpose of control design are (1) optimizing the power output when wind speed is less than rated wind speed (2) when the wind speed is above rated wind speed it keep the output power at rated value by turning the blades out of wind direction [3].

2.2 Permanent Magnet Synchronous Generator

In the PMSG, the rotor magnetic flux is generated by permanent magnets instead of electromagnets and therefore brushless .Because of the absence of the rotor windings, a high power density can be achieved, reducing the size and weight of the generator. In addition, there is no rotor winding losses and reducing thermal stress on the rotor. However, the drawback of this generator lies in the fact that, permanent magnets are more expensive and prone to demagnetization. In direct driven PMSG, the primary advantage is elimination of gearbox which reduces the maintenance cost. In this configuration, a generator is directly coupled to the rotor of a wind turbine known as Two Mass Model [12]. The equation used to develop the dynamic model of permanent magnet synchronous generator are given as

$Vds = - Rs + \omega rLqiqs - Lddidsdt$ (1.4)

$Vqs = -Rsiqs - \omega rLdids + \omega r\lambda r - Lqdiqsdt$ (1.5)

The electromagnetic torque of PMSG is given by

$Te = 3P2\ (iqs\lambda ds - id\lambda qs)$ (1.6)

Where Vds , Vqs are stator voltage in d and q axis, Rs is the stator resistance, ids , iqs are stator current in d and q axis , ωr is the rotor mechanical speed, λr is rotor flux linkage, Ld,Lq are inductance in d and q axis respectively. The quantities are given in P.U.

2.3 Diode Bridge Rectifier

The universal bridge or three phase diode bridge rectifier converts the AC power generated by PMSG into the DC power in an uncontrolled way. For filtering purpose a DC capacitor is connected across the output terminal of rectifier. The DC voltage can be calculated as

$$VO = 3\ \sqrt{2}\ Vrms/\pi \quad (1.7)$$

Where, VO is the output DC voltage and $Vrms$ is the input AC line voltage.

3. CASCADED H-BRIDGE MULTEVEL INVERTER

Cascaded H-bridge MLI comprises of series of power conversion modules that synthesize a desired ac voltage. Fig. 2 shows the structure of single phase seven level cascaded H bridge inverter having three units of H-bridge power cells connected in series. The output AC voltage is the sum of the voltage generated by each H-bridge module. Each half bridge module consists of four IGBT provide flexible operation.

With the increase in the level of multilevel inverter, the output voltage waveform become more sinusoidal and THD (Total harmonic Reduction) value decreases [6]. Three phase system can obtained by connecting three identical single phase cascaded H bridge MLI in star or delta configuration and this configuration provides elimination of triplet harmonics components

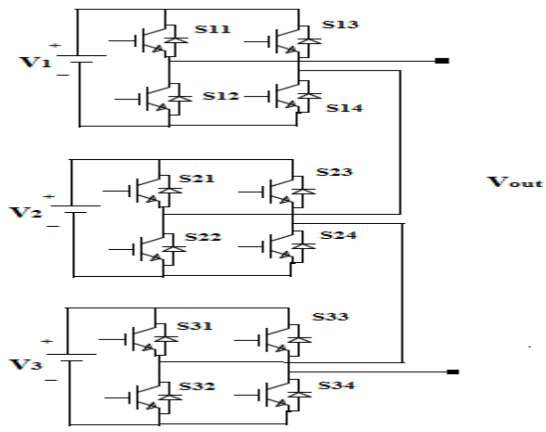

Fig 2: A Single phase cascaded H-bridge MLI

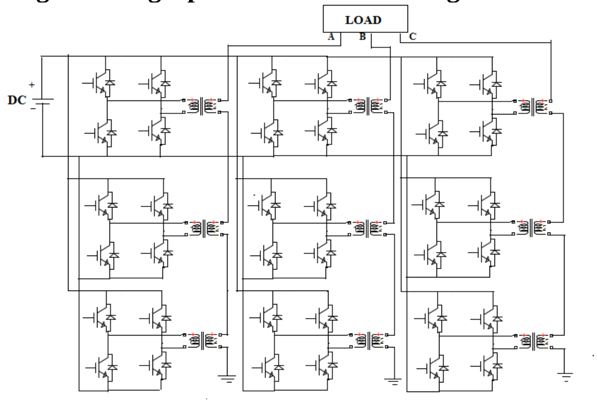

Fig 3: Three Phase Cascaded H bridge MLI with Single DC Source

In this model, the problem of cascaded H-bridge inverter of using of separate DC source for each H-bridge cell can be overcome by taking single DC source with isolation transformer. Fig. 3 shows the circuit of proposed three phase seven level CHB MLI using single DC source. Here, three H-bridge module are connected to same DC source input obtained from wind energy system. Single Phase Isolation transformers are used to isolate each H-bridge from AC output. Primary winding of isolation transformer is connected to the H bridge module whereas secondary of each module connected in series the grounded. But power of the DC source must be bigger than the DC source in the conventional cascade topology.A sinusoidal PWM technique is used for control of multilevel inverter with different carrier signal. In this paper, Phase shifted PWM scheme has been implemented which require (N-1) triangular carrier and phase shift between any two adjacent carrier wave, given by $\Phi = 360N-1$ where N is the level of inverter. The advantage of this method is that the switches in the multi-level converter operate at a fixed switching frequency $fcarrier$ while harmonic cancellation is achieved up to 2N $fcarrier$ frequency, thus generating better quality of output. In Phase shifted modulation, the switching of the inverter is related to the device switching frequency by

$$fsw,\ inv = 2n\ fsw,\ dev = (m-1)\ fsw,\ dev \quad (1.8)$$

Where, m is the modulation index. The flexibility of the system is maintained and AC voltage level can be increased by increasing the level of inverter.The simulation model of wind energy system based on cascaded H-bridge inverter using single dc source.

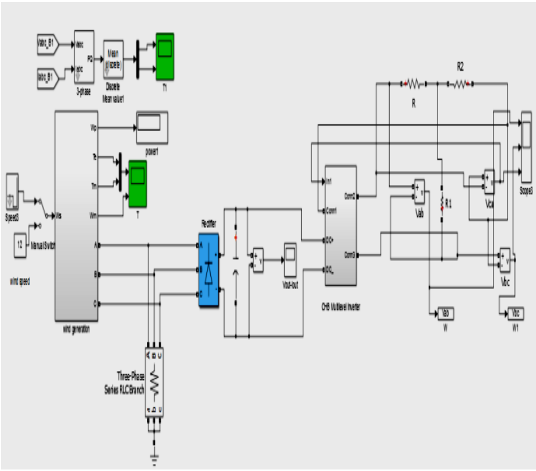

Fig 4: Simulation model of Wind energy Conversion using CHB MLI

Fig 5-9 show the simulated waveform of phase voltage and line current of PMSG, rotor speed of PMSG, Pitch angle, DC link voltage and output voltage of cascaded H-bridge MLI in three phases.

4. SIMULATION AND RESULTS

The proposed model shown in Fig 1 with the PS-PSW modulation scheme has been simulated in MATLAB/SIMULINK for variable speeds. Fig 4 represents

Fig 5-9 show the simulated waveform of phase voltage and line current of PMSG, rotor speed of PMSG, Pitch angle, DC link voltage and output voltage of cascaded H-bridge MLI in three phases.

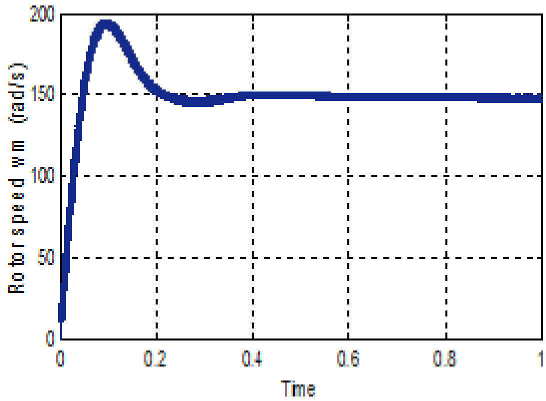

Fig 5: Rotor Speed of PMSG

The above graph shows the rotor speed of permanent magnet synchronous generator

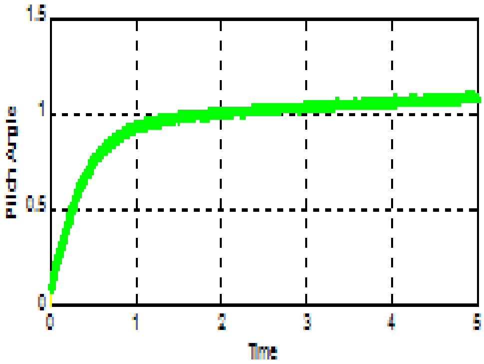

Fig 6 shows the simulation output of pitch angle at wind speed 12 m/s.

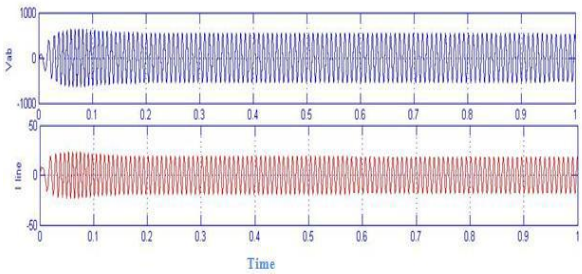

Fig 7: Line voltage and line current ofPMSG

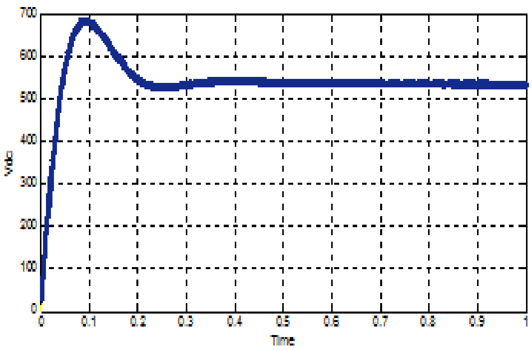

Fig 8: DC link Voltage

The above graph shows the voltage across capacitor which is given to cascaded H-bridge MLI.

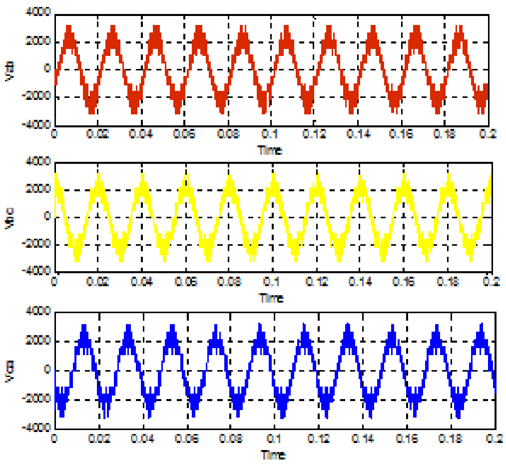

Fig 9: Line voltage of Cascaded H-bridge MLI

5. CONCLUSION

A combination of variable speed wind energy set and cascaded H-bridge multilevel inverter is modeled in MATLAB/SIMULINK. DC to AC power conversion devices i.e., inverters act as interface between the wind energy conversion and grid. The conventional inverters are two level voltage source converters with limited abilities for new topologies and control schemes PI based pitch controller is proposed to limit and regulate the output power at variable wind speed. The seven level cascaded multilevel inverter using single DC source based on isolation transformers is designed to supply power with better output quality. The proposed CHB inverter is controlled by Phase Shifted multicarrier PWM which reduces Total Harmonic Distortion in phase voltage.

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BIOGRAPHY

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