A HIGH POWER GRID CONNECTED 11-LEVEL HYBRID MULTILEVEL INVERTER FOR WIND FARMS

Merin Rose Mathew[1], Amaljith. M.K[2], Geethanjali.R[3]

[1,2,3]Department of Electrical and Electronics, SNS College of Technology

Coimbatore, (India)

ABSTRACT

This paper proposes a single phase multilevel inverter used with less number of switching devices compared to conventional diode clamped multilevel inverter to achieve desired level of output voltage for wind farm applications, The switches are arranged in the two legs of multilevel inverter along with the H bridge form the hybrid topology to generate 11 level output voltage, conventionally achieved by 16 switches. In this, the number of switches has been reduced to obtain the same level, hence the gating circuit requirements and associated switching losses are considerably reduced. The output ac voltage is filtered and supplied to the grid. The simulation of the entire circuit has been carried out in MATLAB Simulink to validate the results and to monitor the Harmonic profile

IndexTerms: Wind Energy Conversion System (WECS), Wind Generator (WG), Multilevel Inverter (MLI), Sinusoidal Pulse Width Modulation (SPWM),), Total Harmonic Distortion (THD).

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[1].A typical wind energy conversion system includes a wind turbine, interconnection apparatus, control systems and generators. 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 , easy maintenance 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 power generation 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 has not been analyzed for the production of wind power.

In this paper, a diode clamped multilevel inverter is cascaded with the H-bridge forming a hybrid topology[4].The DC input to the inverter is fed from four independent wind generators. The controlled rectifier connected at the output of each generator gives the controlled DC and is maintained constant by means of regulator. This constant obtained from each is given as the input of inverter[2].The output voltage of the inverter is controlled by generating pulse from the control circuit. The rest of the paper is organized as follows section II 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 highquality is obtained using theconverter, a multilevel converters are good alternative to the conventional converters forthis systems.A multilevel converter enables the ac voltage to be increased without an output transformer, reducing the output voltage and currentsharmonic content 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.

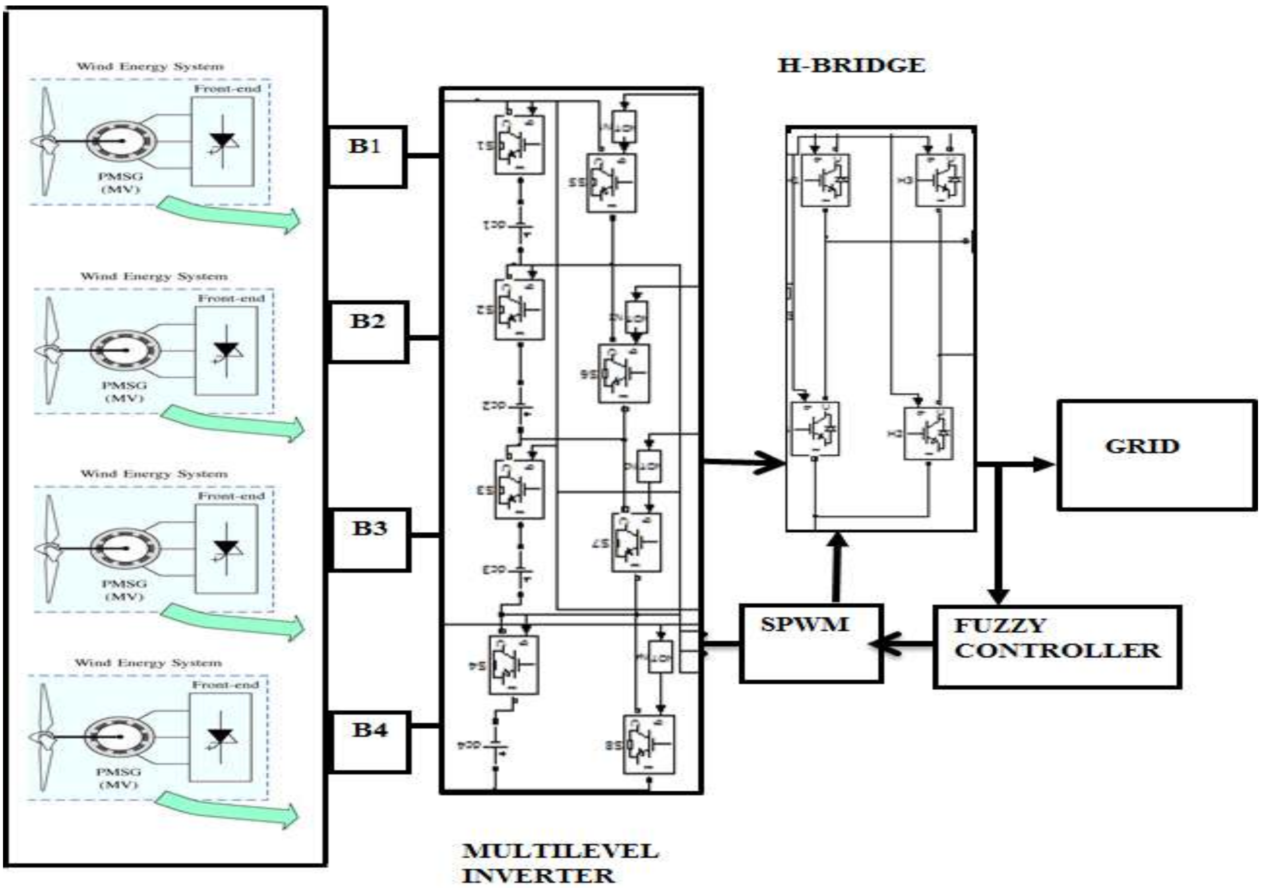

Fig.1. Block Diagram of Overall System

The block diagram for the constant output multilevel inverter is shown in figure 1.In this diagram it consists of wind farm,an inverter, fuzzy logic controller and sinusoidal pulse width modulation block. Four DC source voltage is given as input to the hybrid inverter which combines the diode clamped multilevel inverter and H-bridge inverter. By using twelve switches in hybrid multilevel inverter with each switch having different voltage to generate the eleven step voltage of symmetrical output. The eleven step output is applied to fuzzy controller to maintain the constant output, by giving reference voltage to the fuzzy logic controller . 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.

Table 1: Switching Statesof Diode Clamped Inverter

SWITCHES								
LEVEL	S4	S3	S2	S1	S4’	S3’	S2’	S1’
I	ON	OFF	OFF	OFF	OFF	ON	ON	ON
II	ON	ON	OFF	OFF	OFF	OFF	ON	ON
III	ON	ON	ON	OFF	OFF	OFF	OFF	ON
IV	ON	ON	ON	ON	OFF	OFF	OFF	OFF
-I	ON	ON	ON	OFF	OFF	OFF	OFF	ON
-II	ON	ON	OFF	OFF	OFF	OFF	ON	ON
-III	ON	OFF	OFF	OFF	OFF	ON	ON	ON
-IV	OFF	OFF	OFF	OFF	ON	ON	ON	ON

The term H bridge is derived from the typical graphical representation circuit. An H bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 are closed (and S2 and S3 are open) a positive voltage will be obtained across the load. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse voltage across the load. Using the nomenclature above, the switches S1 and S2 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches S3 and S4[9]. This condition is known as shoot-through.

III PULSE WIDTH MODULATION

In sinusoidal PWM instead of maintaining the width of all pulses the same as in the case of multiple PWM, the width of each is varied in proportion to the amplitude of a sine wave evaluated at the same pulse. The distortion is reduced significantly compared to multiple PWM. In order to generate pulses for twelve switches a sinusoidal wave is compared with twelve carrier wave having different amplitude as shown in the figure.A Fuzzy

Controller Output is given as an input to the PWM in order to maintain constant output voltage from multilevel inverter.

Inverter output voltage, V_{ao} = Vdc/2, When $v_{control} > v_{tri}$, and V_{ao} = -Vdc/2, When $v_{control} < v_{tri}$. PWM frequency is the same as the frequency of v_{tri} . Amplitude is controlled by the peak value of $v_{control}$ and Fundamental frequency is controlled by the frequency of $v_{control.}$. Modulation Index (m) is given by :

$$m = \frac{V_{control}}{V_{tri}} = \frac{\text{peak of } (V_{A0})}{V_{dc}/2} \qquad (1)$$

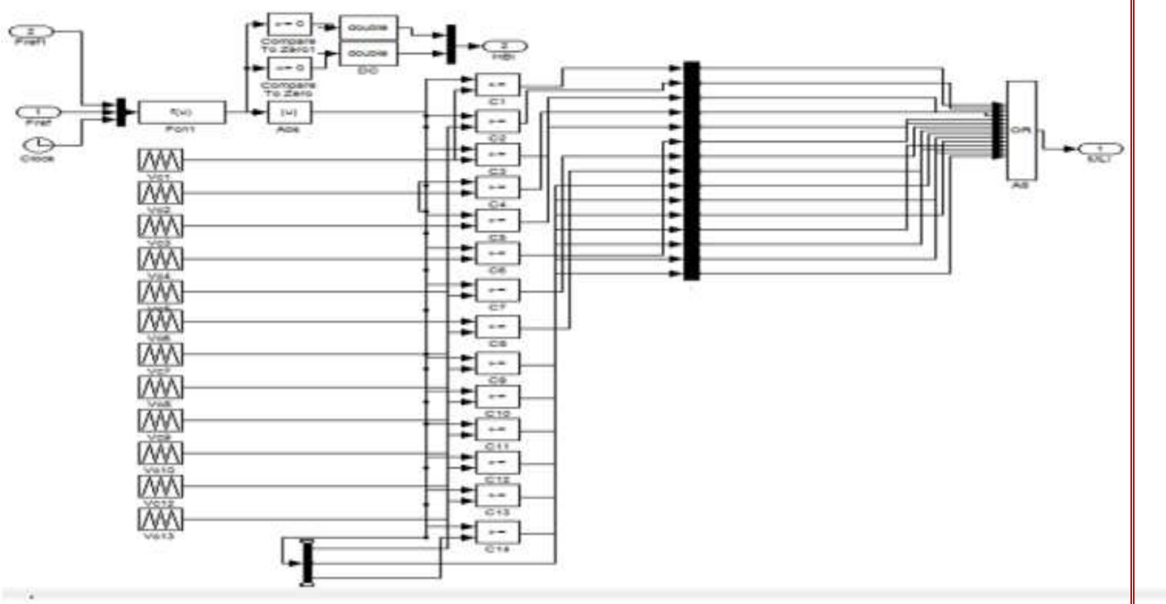

Fig.2 Logic Circuit for Pulse Generation

IV SIMULATION RESULTS

The overall simulated system for the proposed system is implemented below and each section is shown separately for better understanding.

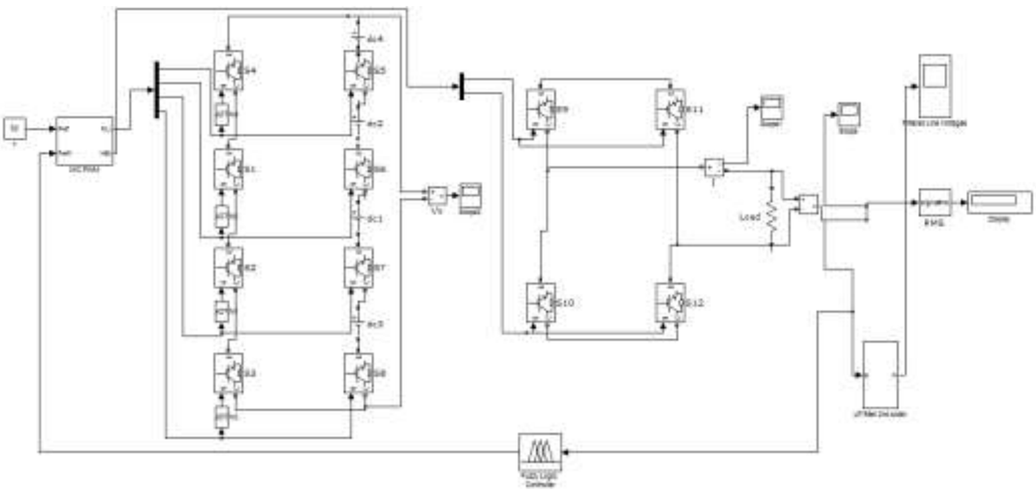

Fig.3Grid Interface of a PMSG Based Wind Energy Conversion Systems inverter

The system under consideration employs PMSG-based variable speed WECS .The wind turbine converts the power of the wind to mechanical power in the rotor shaft. This is then converted to electricity using a permanent magnet synchronous generator (PMSG). The output voltage is rectified using a three-phase diode bridge rectifier. The result is fed into a PI controller whose output is compared to a triangular waveform to determine when to turn the dc-dc boost converter switch ON or OFF.

The simulation have shown that the developed waveform have less harmonics compared to the conventional system and extracting maximum power from the air stream at any wind speed without the knowledge of wind speed or rotor speed.

4.1PMSG Output Voltage

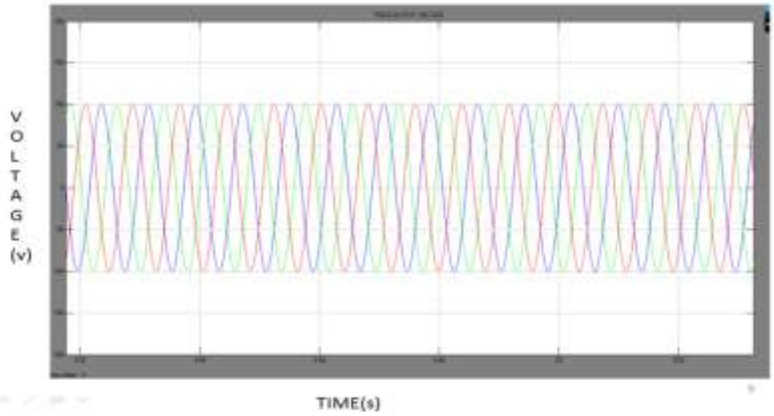

Fig.4.PMSG Output voltage

PMSG generator connected to the wind turbine is simulated and corresponding output voltage is showed in the figure7.In order to make the torque of the turbine equals to the torque of the generator a drive and train circuit is connected. The output of the system is equal to 100V.

4.2 Uncontrolled Rectifier Output

The output of the PMSG is given to an Uncontrolled Rectifier in order to convert the ac voltage to dc, the output voltage is not able to control because diodes are used in this rectifier. Inorder to control the output voltage and maintain it as a constant voltage a boost converter with a PI Controller is used.

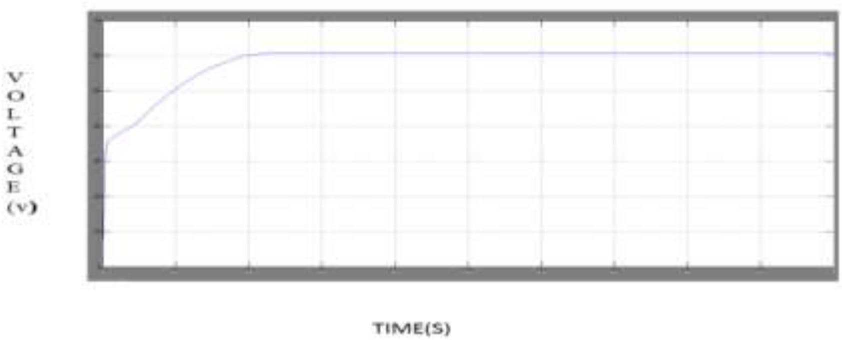

Fig. 5 output voltage of uncontrolled rectifier

4.3Boost Converter Output

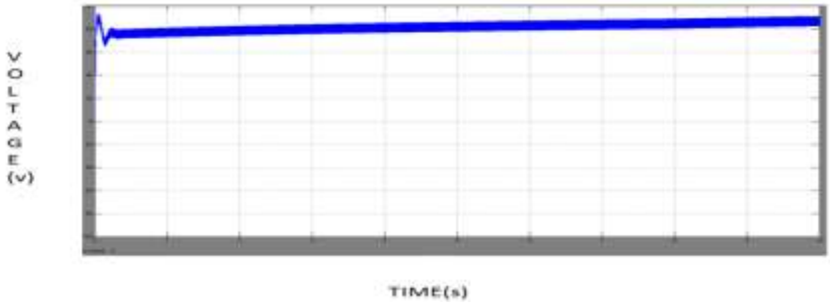

Fig.6.Output voltage of boost converter

A boost converter is used here, because as the wind speed varies the output of the uncontrolled rectifier varies and voltage drop will occur, so inorder to give inverter input a constant dc supply a boost converter with PI Controller is used. And thus the output obtained is equal to 60V.

4.4Output of Hybrid Multilevel Inverter

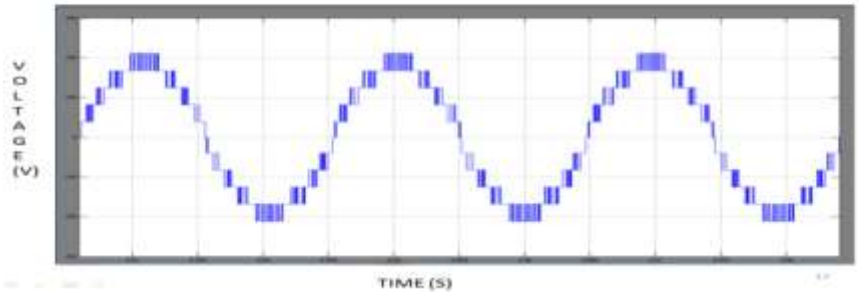

Fig.7. Output Voltage of Symmetric Multilevel Inverter

The H Bridge inverter is connected with the diode clamped multilevel inverter with switches to form a H ybridtopology.The level creator part produce output voltage which is always positive and the H-bridge part is to change the polarity of the output. Basically the inverter operation is to convert the variable DC into an AC. The input dc source is given by using batteries or photo voltaic cells to the cascaded circuit. Here fuzzy logic controller is used to control the output voltage of the inverter. By using sinusoidal pulse width modulation technique the triggering pulse given to the switches are controlled.

V FFT ANALYSIS OF OUTPUT

5.1Output Voltage without Filter

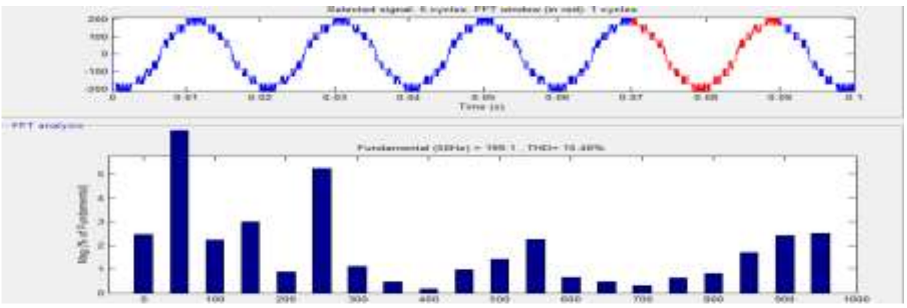

Fig. 8FFT Analysis

By using the sinusoidal pulse width modulation control we can control the output by changing the magnitude and the modulation index value of the reference and carrier waveform. Mostly the carrier wave is triangular wave and the sampling wave is either we take DC signal as reference or we take sine wave. The gate triggering is very important in the IGBT device compared to many semiconductor power devices IGBT device has the fast switching characteristics and high speed applications. so this device is mostly used in the inverter circuits nowadays. The Total Harmonic Distortion of the multilevel inverter output is equals to 15.46%, which will be more than 20% for conventional inverters by using same number of switches

5.2Output Voltage with Filter

In this symmetric multilevel inverter it consists of two parts as level creator part and a H-bridge part. The input voltage to the dc source is 60V.The level creator part produces a output voltage which is always positive and the H-bridge part is to change the polarity of the output. The voltage at the output of the level creator part is about 170V.The output voltage at the output is 240V.The THD get reduced to 5.56% after filtering. The filter inductance L and the filter capacitance C and L=560 μH with R_L= 0.34 Ω and C = 0.5 μF with R_C= 8.64 Ω,respectively.

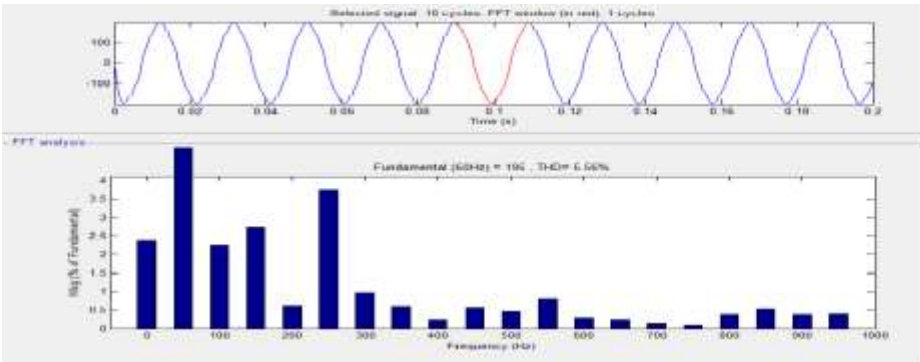

Fig.9FFT Analysis of Filtered Output

VI CONCLUSION

The performance of PMSG-based variable speed WECS has been demonstrated under varying wind conditions. The grid-side inverter is able to inject the generated power into the grid with harmonic compensation.. A new hybrid topology with fuzzy controller technique for the symmetrical configuration is proposed.The cascade multilevel inverter with equal DC sources are illustrated and the gate triggering pulse is given by fuzzy logic controller in the feedback. Here the inverter power device circuit used is IGBT device and it has the better switching frequency and gate control compared to all other semiconductor switching devices such.This fuzzy logic control technique enables us to obtain better selective harmonic reduction in the output AC voltage. Finally the better sinusoidal wave form is obtained with minimum number of switches to get the desired level output voltage.

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