Performance Improvement of Wind Turbine Driven PMG with Multi Level Inverter

R.Bharani Kumar, S.Bhuvaneswari

Abstract: ***This paper presents the performance improvement of wind turbine PMG by incorporating multilevel inverter and maximum power point tracking controller with perturb and observation method is proposed. To reduce the number of stages and improve the efficiency a cacade MLI with reduced number of power switches is proposed. The proposed wind turbine driven PMSG and MLI is modelled.The proposed wind turbine, mPMG with multilevel power converters are madelled in MATLAB and results are analysed for various input and output load conditions.***

Keywords: ***Wind Turbine, PMG, Perturbation and Observation, MPPT, Multilevel Inverter, Power Quality***

I. INTRODUCTION

Now a day's wind power is increasingly installed to meet the additional loads in developed countries like India. The several types of wind turbine generators are available and installed. Out of which the PMSG is most employed generator for wind turbine rating above 1 MW because PMSG has the advantages of variable speed with constant frequency and separate control of active and reactive powers[1][2]. Also the converter rating depends only on stator power which results in reduced size, less weight. PMSG based wind turbine system is connected to grid for supplying the load reliability especially from the point of grid fault.[3]. There are several MPPT control techniques are available such as hill climb searching, sensor control and perturb and observation methods. out of which perturb and observation method having the lot of advantages such as sensorless operation faster response,simple control algorithm and easy to implement.

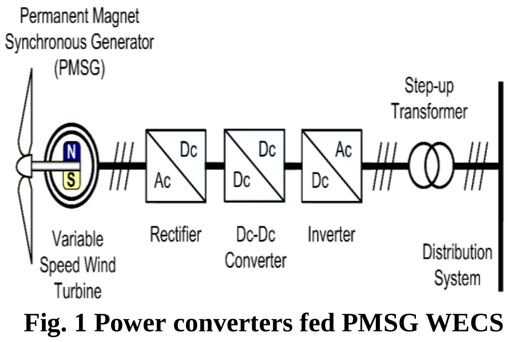

Fig. 1 Power converters fed PMSG WECS

This work presents modeling of permanent magnet generator and wind turbine with multilevel inverter. To increase the efficiency of wind energy conversion system a MPPT controller is proposed. The paper is organized as follows; the section 2 presents modeling of permanent magnet generator. Section 3 describes the modeling of permanent generator Section 4 provides the MPPT controller and section 6 presents the results and discussion the wind turbine model.

II. WIND TURBINE MODEL

The developed power of the wind turbine depends on the cube of the wind velocity The power of the turbine is given by equation (1).

$$P_m = C_P(\lambda, \beta)\frac{\rho A v^3}{2} \quad (1)$$

The power co-efficient is given by

$$C_P(\lambda, \beta) = C_1\left(\frac{C_2}{\lambda_2} - C_3\beta - C_4\right)e^{\frac{-C_3}{\lambda}} + C_6 \quad (2)$$

$$\frac{1}{\lambda} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad (3)$$

Tip speed ratio is expressed as

$$\lambda = \frac{r\Omega}{v} \quad (4)$$

Where r is the blade radius (m)

Fig. 3 shows power extraction co efficient and tip speed characteristics of turbine for wind velocities [7].

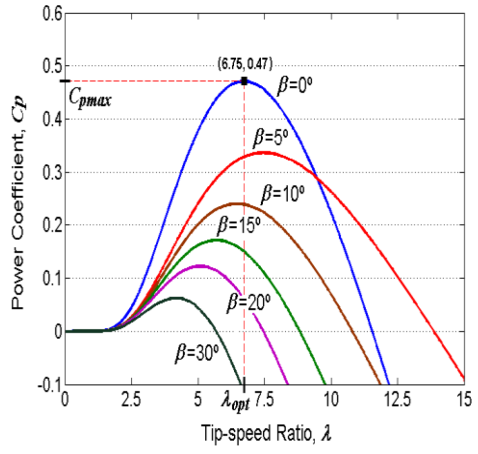

Fig. 2 The C_p-λ Curve of turbine

The variable speed system can control the maximum power of the turbine for all speed of range [5]. As shown in Fig.3

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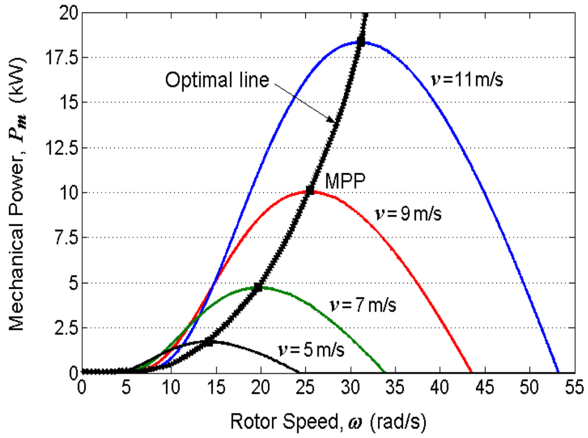

Fig. 3 Power and speed curves for different wind speeds.

The Power in turbine is given in Equation (5).

$$P_m = T_m \Omega = T_m n_P w \quad (5)$$

Where, T_m is mechanical torque [10]

$$T_m - T_g = J\frac{d\Omega}{dt} \quad (6)$$

$$P_m - P_g = \Omega . J\frac{d\Omega}{dt} \quad (7)$$

III. PERMANENT MAGNET GENERATOR MODEL

Permanent Magnet Generator can be modeled in synchronously rotating reference frame theory. The synchronous reactance of the machine is calculated by EMF method and stator resistance is measured by dc supply method[7]. The generated voltage is varied with respect to speed of the turbine to regulate the generated voltage the wind turbine PMG requires the full scale power converter. In this paper a cascade MLI is proposed as a full scale power converter.

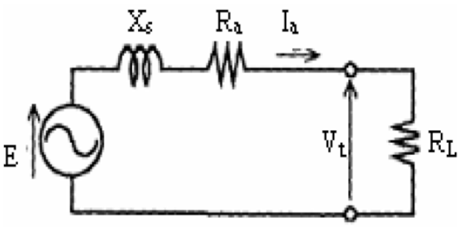

Fig. 4 per phase circuit diagram of PMSG

The PMG modeling equations can be written as [13]

$$V_q = - (R+Lp)\, Iq - \omega_r L I_d + \omega_r \lambda_m \quad (6)$$

$$V_d = - (R+Lp)\, Id + \omega_r L I_q \quad (7)$$

The toque developed by the generator is given by

$$T_e = \left(\frac{3}{2}\right)\left(\frac{P_n}{2}\right)[(L_d - L_q)I_q I_d - \lambda m I_q] \quad (8)$$

Torque by the turbine T_e to the generator T_m is expressed as

$$T_m = \frac{T_t}{G} \quad (9)$$

IV.PERTURBATION AND OBSERVATION ALGORITHM

To increase the speed of maximum power tracking in the turbine generator system the perturbation and observation method is the best choice In this method the duty ratio of the dc to dc converter is controlled by the separate controller with respect continuously varying wind velocity[1][5]. Hence it is considered as one of the easiest algorithm for maximum power point tracking in wind turbine generator SYSTEM

The optimum speed of this method is expressed as [12] follows

$$\omega_{opt} = \left(\frac{v\lambda_{opt}}{R}\right) \quad (13)$$

The corresponding power extracted from the turbine is given as follows

$$P_m = C_{p\,max}\,(\lambda_{opt})\,\frac{\rho A}{2}\left(\frac{R\omega_{opt}}{\lambda_{opt}}\right)^3 \quad (14)$$

The algorithm for maximum power tracking of wind generator is given in Figure 6.

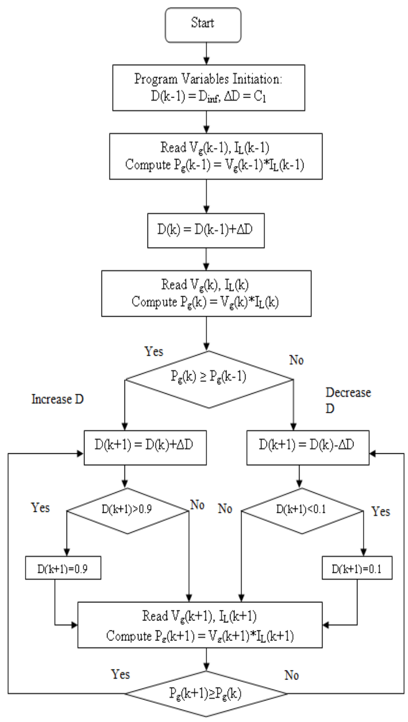

Fig. 5 Perturbation and Observation Algorithm

V. MULTI-LEVEL INVERTER

The conventional type of power conversion stages and rectifier,dc-dc converter and PWM inverter. The sensorless voltages are feed to these three stages of full scale power converter for regulating the terminal voltage across the grid. This three stages of full scale power converter suffers from lower efficiency, poor power quality, requires larger values of dc filters. To overcome this drawbacks this paper suggest the cascade MLI as a full scale power converter for grid interfacing of wind turbine driven PMG .Traditionally for producing 7 level of staircase waves the MLI requires the three H-bridges. This paper suggests only two H Bridge topology for producing 7 level stair casing waveforms. Figure 6 shows the suggested topology of cascade MLI.

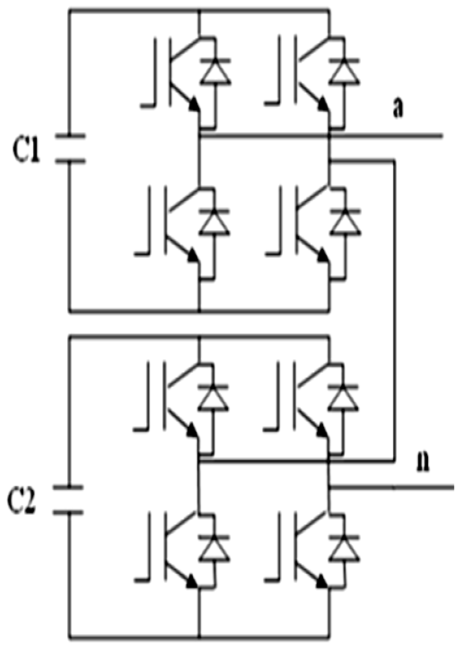

Fig. 6 Cascaded Multilevel Inverter

a. Membership Function

Fuzzy controller is used to provide a proper control signals for maximum power operating point .Figure 10shows the membership function for MPPT controller.

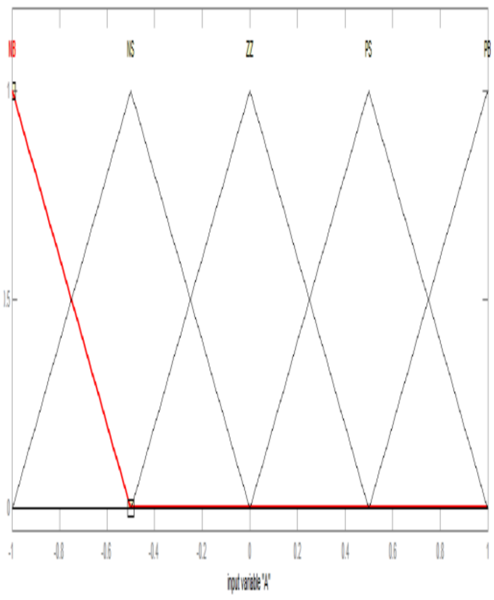

Fig. 7 Input Functions for Error

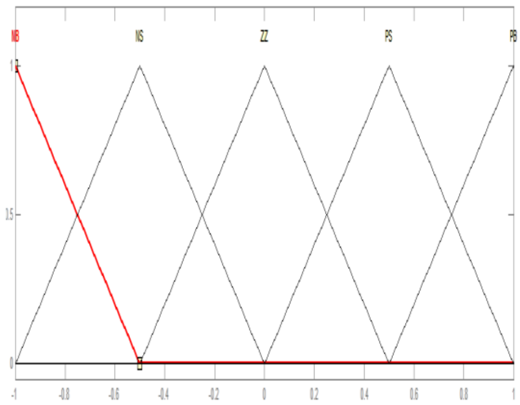

Fig. 8 Input Function for Change in Error

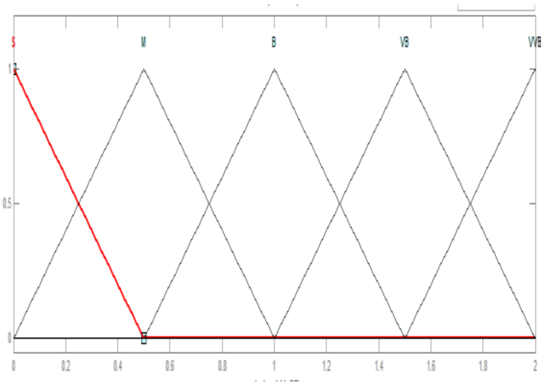

Fig. 9 Output Function for Error

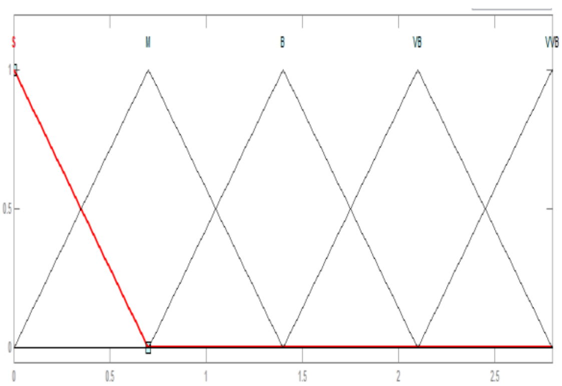

Fig. 10 Membership Function for MPPT controller

VI.SIMULATION RESULTS

The proposed MLI and wind generator are simulated in the MATLAB and its results are discussed for different wind speeds and domestic load conditions. Figure 9 shows the MATLAB/simulink model of wind turbine ,PMG and multilevel inverters. Fig.10 shows the generated voltages of PMG for different wind speeds ,the generated voltages and frequency are increased with increase in turbine speed

The simulation diagram for proposed wind energy conversion system is shown in below Fig. 11.

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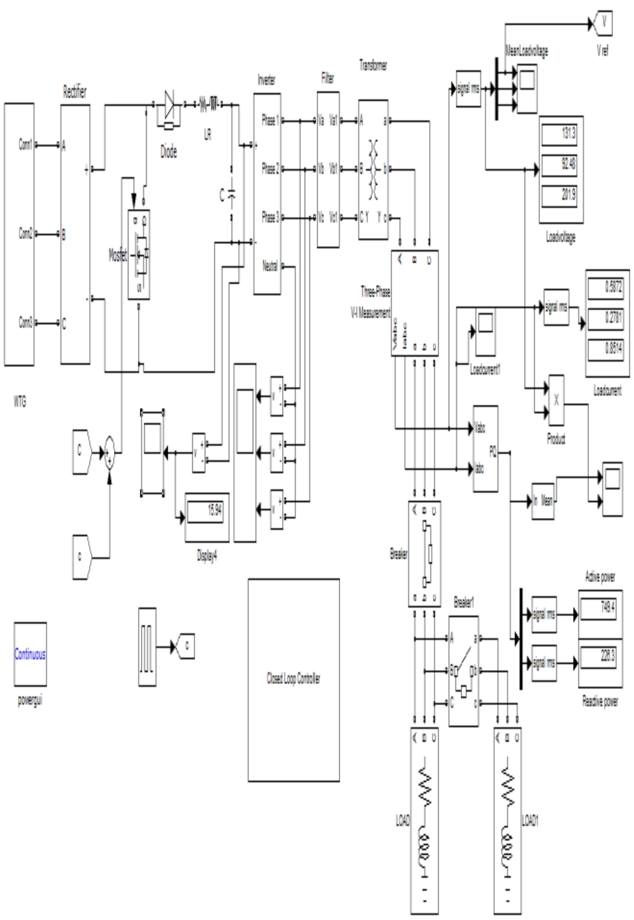

Fig. 11 Simulation Diagram for Proposed Method

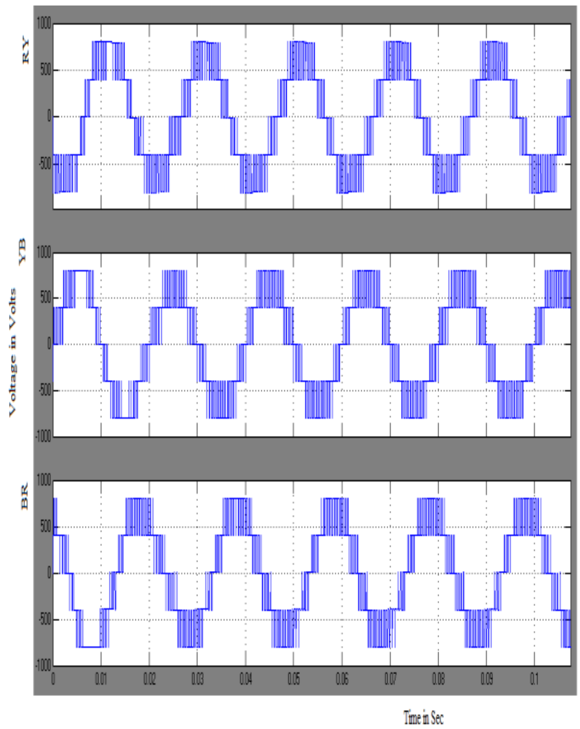

Fig. 12. Multilevel Inverter Output Voltage Waveform for different values of PMSG generated voltage

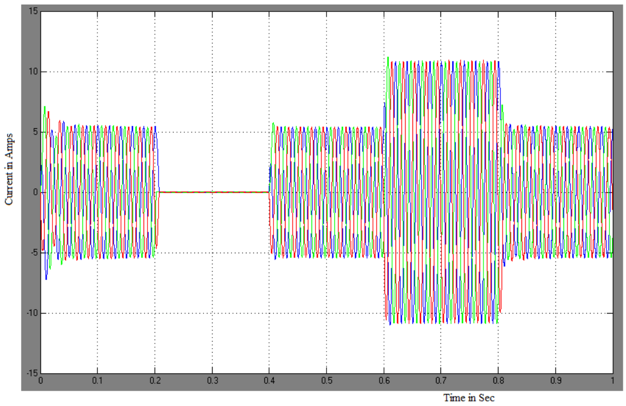

Fig. 13 Grid Side Inverter Output Current Waveform

In this above Fig.13 shows grid side output voltage. Here output voltage is 440 volts and maintain it constant.

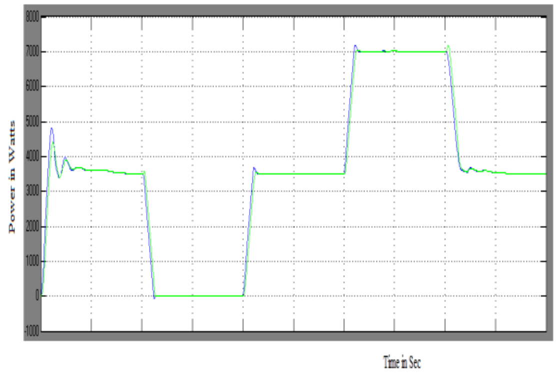

Fig. 14 Output Real and Reactive Power

To predict the performance of proposed MLI based WECS the PMSG is loaded from 0.25kW to 3kW the corresponding values of input current THD and output voltage THD are measured and tabulated in Table 3.The THD spectra for a load of 0.25kW as shown in Figure 20. shows that a Total Harmonic Distortion of 6.94% in the proposed multilevel inverter is as shown above Fig. 15.

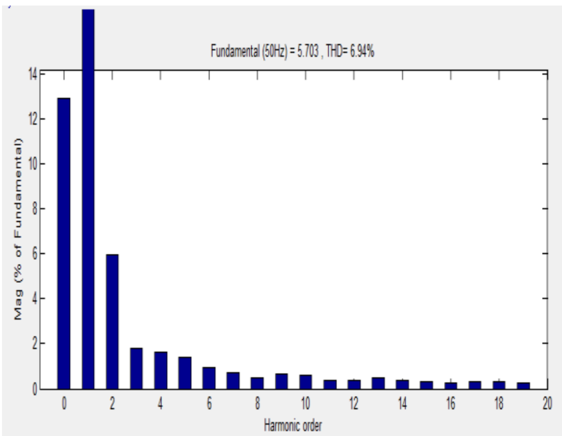

Fig. 15 THD spectra in the PMG Current

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VII.CONCLUSION

The maximum power extraction of a wind energy conversion system with controller and multilevel inverter has been simulated and results are analyzed for various wind velocities. The P&O algorithm provides the greater accuracy and faster response. The MLI inverter reduced the harmonics and improves the reactive power control.

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