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Simulation and Experimental Results of Wind Generator Fed Γ-ZSI Controlled PMSM Drive

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Abstract **-** This work deals with simulation and implementation of the wind generator fed Γ-ZSI controlled PMSM drive system. In this paper, Voltage Γ ZSI scheme is implemented for PMSM drive. The Γ shaped network can increase the input voltage. This drive system has advantages like high power density, high voltage gain and low maintenance cost. The experimental results are compared with the simulation results.

Keywords **-** Γ-ZSI Network, PMSM Drive

1. INTRODUCTION

In General inverter means the conversion of DC to AC voltage. By using the Γ-Z source inverter, the size and volume of the entire system got reduced by not compromising the overall efficiency. It uses very less number of switching components and boost operation is performed in single stage itself. Unlike the conventional inverter, Γ-ZSI utilizes a unique impedance network that links the DC source with the main inverter. The unique gamma shaped ZSI, the new inverter has been designed by building its two inductors on the single core itself so that it has a very low leakage inductance coefficient. As normal ZSI, the operation of new Γ-Z source inverter has shoot through states in the PWM technique in which two legs are shorted at the same time to increase the output voltage but this is not workable in conventional inverter VSI & CSI.

2. LITERATURE REVIEW

In the field of Power electronics, the grid related system had got a very low voltage generated using renewable sources of energy is badly require voltage boosting. VSI or CSI are the traditional techniques of step up or step down the voltage level in multiple stages [1], [2]. In order to avoid additional losses that occur during multiple stages, a novel method which uses single stage voltage boosting was required and that was fulfilled by inventing ZSI [3],this had got very high rate of growth because of its unique properties like buck and boost conversion technique. Normally Voltage type ZSI are operated using Pulse width modulation technique [4].Soft-start concept was introduced in ZSI to avoid the inrush current and resonance between the ZSI inductors and ZSI capacitors.[5] Voltage programmed mode and current programmed mode are analyzed and controlled and compared in order to control the peak DC Link voltage of ZSI [6]. The static operating cycles are not needed and has to be avoided for smooth operation of ZSI and hence they were avoided by selecting large size inductors and capacitors [7].The application areas in which ZSI has its presence like induction motors [8] solar generation [9] electric vehicles [10] The improved ZSI has higher capacitor voltage stress and as soft start strategy was proposed to avoid it [11]. To overcome the drawbacks of ZSI such as resonant current and input current ripple, quasi ZSI was introduced [12].Without adding additional passive elements, the EZ source inverters produces same voltage gain than that of

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ZSI thereby reducing cost [13]. Without loss of voltage buck-boost functionality and insert capability for dc source, Parallel embedded Z-source inverters showed superior voltage boosting operation than the classical ZSI [14]. Cascaded trans-Z-source inverters are proposed in order to prevent over voltage caused by Leakage inductances of the transformers [15].Z-source inverter combined with switched inductor forms a SL-ZSI that provides good output with step-up inversion which helps to overcome the boosting drawback of normal ZSI [16]. Tapped Type Z Source Inverter replaces the actual two inductors with modified two terminal TL cells and attains same voltage gain with short shoot - through period [17].The LCCT-ZSI have less number of components while compared with basic ZSI and still can be operated with same current and voltage gain along with same shoot - through ratio and its main advantage is with two built in capacitors that helps to prevent transformer core saturation [18].The T -Type Z Source Inverter has fewer reactive components to mainly join both power circuit and main circuit [19] and it uses common voltage source of passive element. The new network increased the voltage gain and reduced the voltage stress in the voltage-fed trans-ZSIs and the provide expansion for motoring operation range in the current-fed trans-ZSIs, when the turns ratio of the transformer windings is over 1 [20]. Even though the inverters which are presented [19], [20] are attractive it has a very big drawback of having common turns ratio which is too high for attaining too much voltage gain. A survey on various types of Z source inverters along with different types of wind generators are discussed [21]. Simulation of Z source inverter with improved voltage gain controlling the speed of PMSM is discussed [22]. Simulation of Γ shaped Z source inverter with improved voltage gain controlling the speed of PMSM are discussed [23]. Comparison of PID and Fuzzy Logic Controlled Wind Generator Fed Γ- Z Source Based PMSM Drive Systems are performed in [24]. Comparison of PI and PID Controlled Wind Generator Fed Γ- Z Source based PMSM Drives are discussed in [25].

The above literature does not employ the hardware implementation of Γ Z source inverter for controlling PMSM Drive in wind energy systems.

This paper is sectioned as follows: Section II deals about the operation modes of Γ Z Source inverter. Section III discuss about Simulation results of shoot - through pulses are discussed. Section IV deals with Experimental results and finally Section V presents the Conclusion and the Scope for future work.

3. Γ -Z SOURCE INVERTER

Fig.1 depicts the Γ-Z source inverter. The merits of Γ-Z source inverter is that it requires single transformer and only one capacitor and hence false triggering caused by EMI is likely avoided. This converter is better than traditional ZSI by working with high modulation where as it obtains high output voltage gain with less voltage stresses on the components. As the winding requirement is less, the transformer size is also very small than normal transformer. Γ-Z source inverter has got two modes of operation as follows:

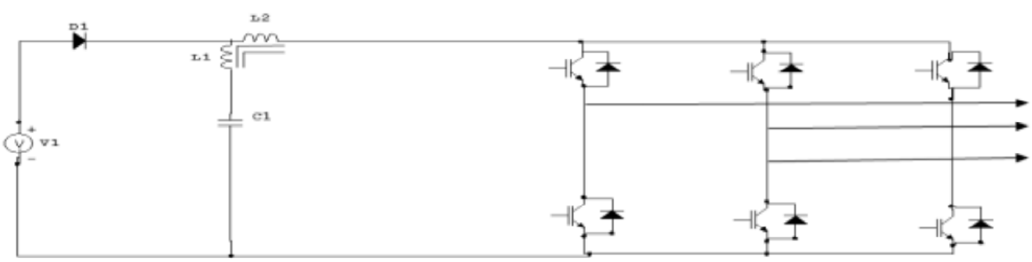

Figure 1: Γ- Z Source Inverter

3.1. Shoot through state (ST)

In this mode of operation, the shoot through state is achieved by shorting all the phase leg simultaneously of inverter.

3.2. Non-Shoot through state (NST)

In this mode of operation, the non-shoot through state is achieved by closing the switches on the different legs of the inverter.

4. SIMULATION RESULTS

The MATLAB/SIMULINK model of wind based Γ-ZSI type AC-AC converter fed PMSM drive system with shoot through (ST) state along with LC Filter added at the motor is shown in Fig.2a.

The output of the wind ac voltage is at 55v AC as shown in Fig.2b.

The output voltage of the Γ-Z source network is shown in Fig.2c and its value boosts up to 500v DC.

The speed response of the PMSM is shown in Fig2d and it runs at 1500 rpm with a torque of 2Nm as shown in Fig 2e.

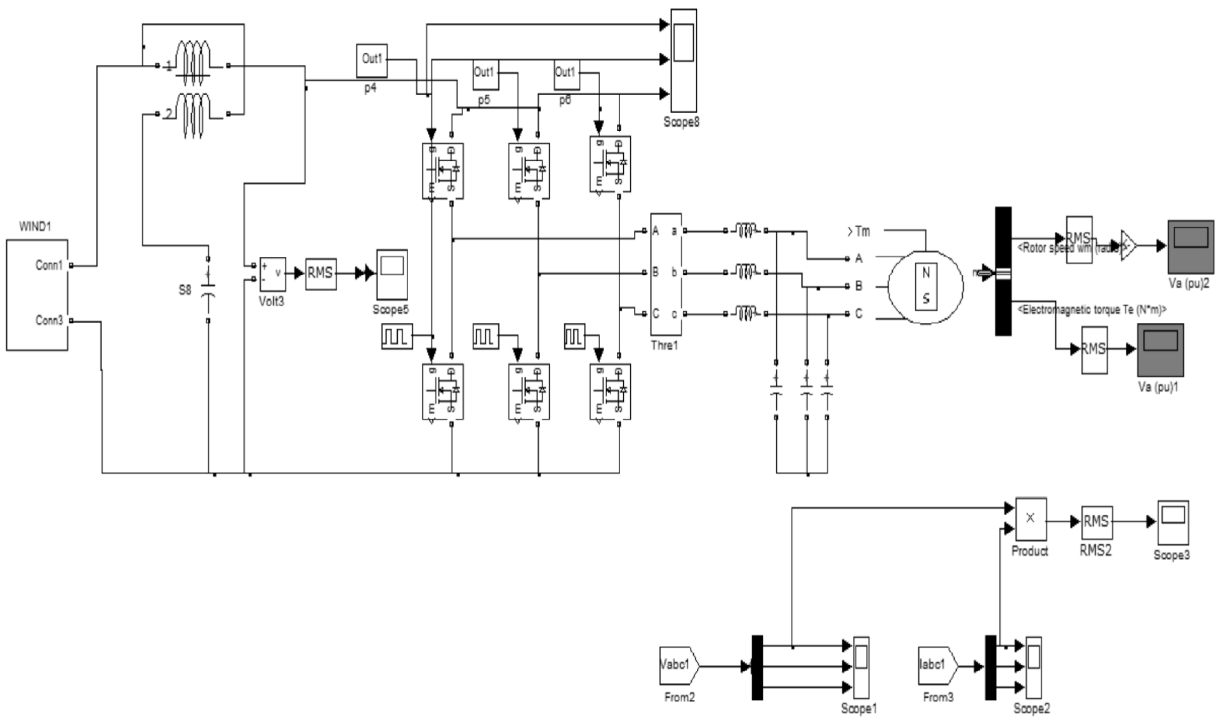

Figure 2a: AC to AC Converter using Γ ZSI with ST State

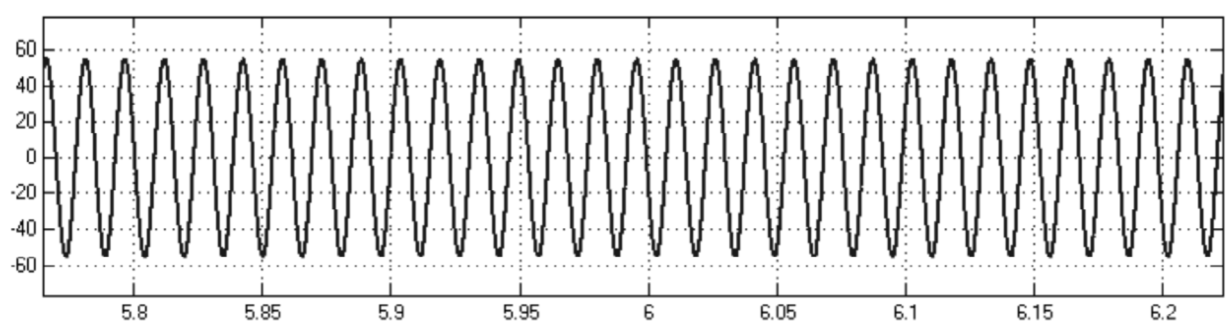

Figure 2b: Output Voltage of the Wind

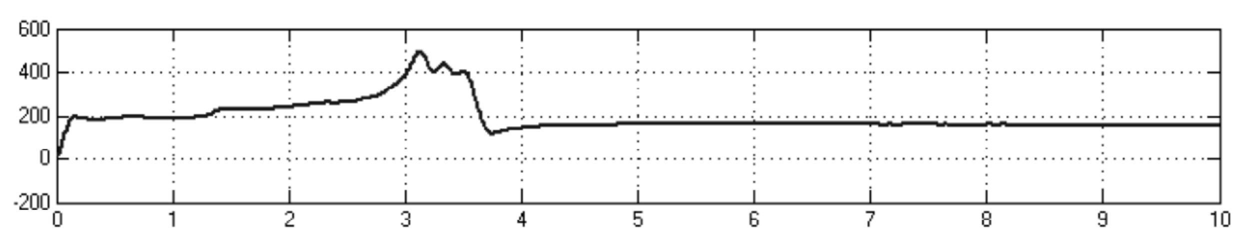

Figure 2c: Output Voltage of the Γ ZSI - ST state

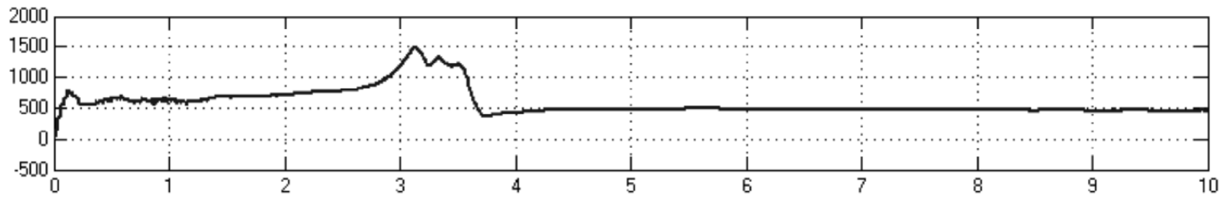

Figure 2d: Motor Speed of Γ ZSI - ST State

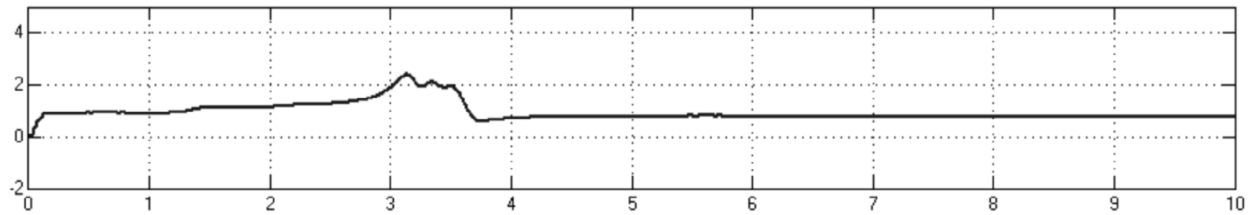

Figure 2e: Motor Torque of Γ ZSI - ST State

5. EXPERIMENTAL RESULTS AND DISCUSSION

The hardware of Γ Z source inverter systems is fabricated and tested in the laboratories using the following components and are listed in Table 1. The hardware consists of controller, power board and three phase PMSM motor.

Table 1
Hardware Details

Sl.no	*Component*	*Model*	*Count*
1	MOSFET	IRF 840	6
2	DIODE	1N4007	4
3	PULSE AMPLIFIER	IR2110	2
4	TRANSFORMER	MINI/12V	2
5	3 PHASE MOTOR	PMSM	1
6	INDUCTOR	2.5 µH	2
7	CAPACITORS	2200 µF	2
8	CONTROLLER	PIC16F84A	1

The value of the components was calculated using the following equations:

$$C = \frac{P(1-D)}{0.01\,fv^2} \tag{1}$$

$$L = \frac{V_{in}^2}{0.2\,pf}\frac{D_s(1-D_s)}{(1-D)} \tag{2}$$

The snap shot of hardware is shown in Fig.3a.

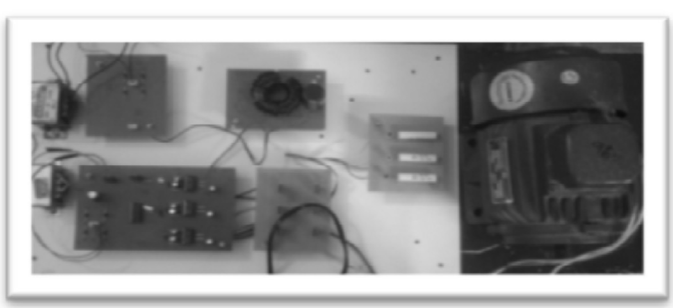

Figure 3a: Hardware Snapshot

The 230v AC input voltage of is stepped down and rectified to 48v DC as shown in Fig.3b.

The output Γ Z source is shown in Fig.3c. The output voltage is 65v DC. It can be seen that the output is free from ripple.

The switching pulses for M1, M3 and M5 are shown in Fig's.3d, Fig.3e and Fig.3f respectively. The output of each pulse is 10v.

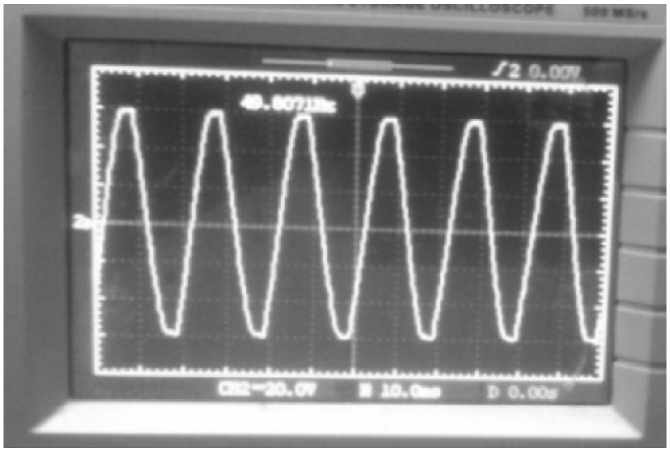

Figure 3b: Input Voltage

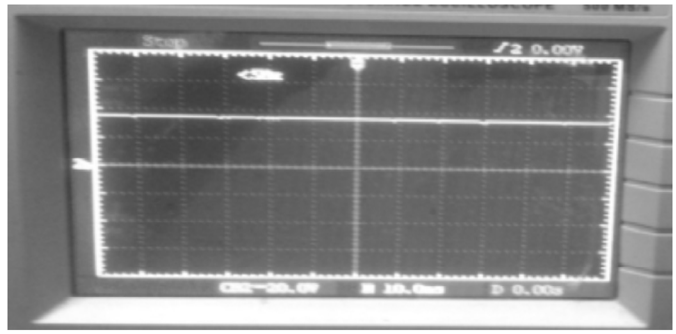

Figure 3c: Output Voltage of Γ Z source

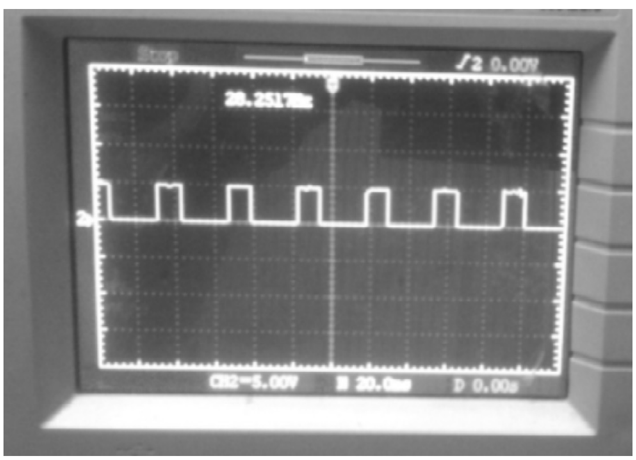

Figure 3d: Switching Pulse for M1

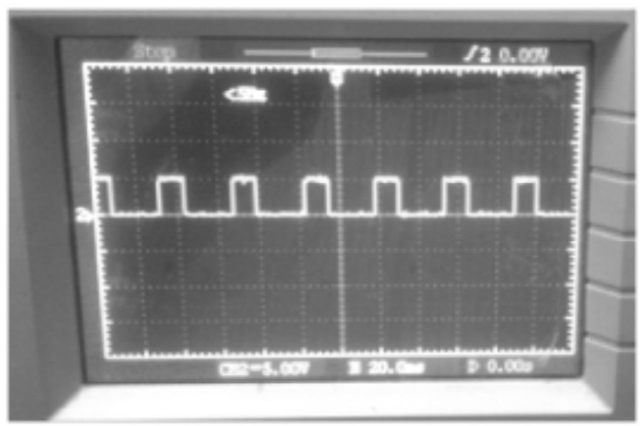

Figure 3e: Switching Pulse for M3

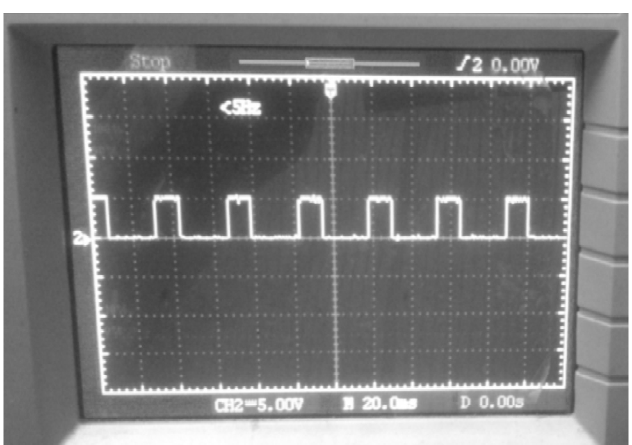

Figure 3f: Switching Pulse for M5

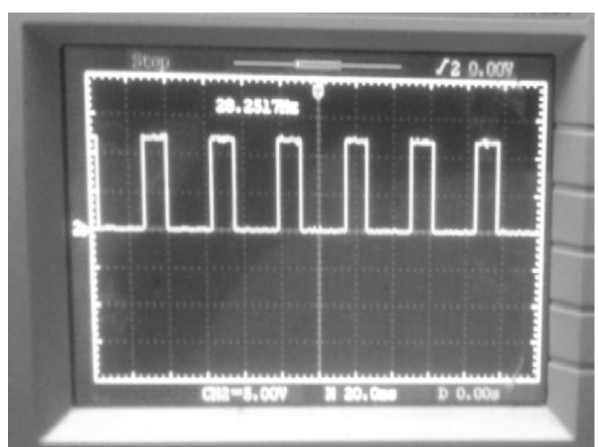

Figure 3g: Driver Output Pulse for M1

The output of the driver circuit for M1, M3 and M5 are shown in Fig's.3g, 3h and 3i respectively. The amplitude of each pulse is 10v.

The line to line voltage is shown in Fig.3j. The peak value of line voltage is 116v AC. The PMSM motor runs at 430 rpm.

Figure 3h: Driver Output Pulse for M3

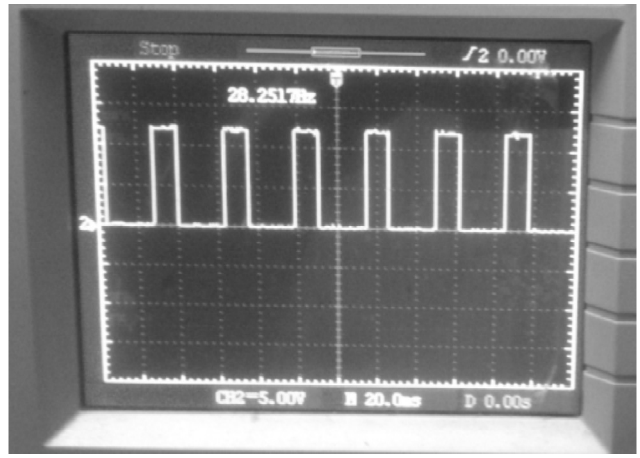

Figure 3i: Driver Output Pulse for M5

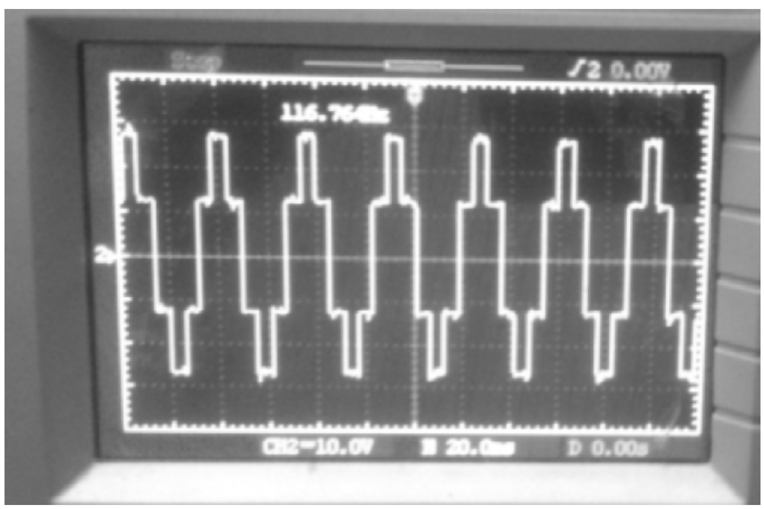

Figure 3j: Line to Line Voltage

5. CONCLUSION

Wind generator fed Γ ZSI based AC to AC converter controlled PMSM drive was designed and implemented. The open loop hardware results show that it boosts up the input voltage enough to run PMSM motor and it matched with simulation results proportionally. This AC to AC converter has advantages like low voltage operation, limited fault current. The disadvantage is that it requires a coupled inductor. This paper deals with Investigations on implementation of open loop controlled wind generator fed PMSM drive and the studies on closed loop system will be done in future.

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