

Comparison of PI and PID Controlled Wind Generator Fed Γ -Z Source based PMSM Drives

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Abstract

The steady state response of the Γ -Z source inverter implementing in the field of wind energy conversion systems is investigated in this paper. The Proportional Integral (PI) and Proportional Integral Derivative (PID) controller are employed to find the responses of the system by using the rectifier output voltage as feedback for closed loop operation. The proposed system is designed and simulated using the blocks of MATLAB/Simulink. The simulation results help to compare the controllers in terms of rise time, steady state error and peak over shoot.

Keywords: Controller, Wind Generation, PI, PID, Γ -ZSI

1. Introduction

Traditional inverters like voltage-source inverters and current source inverters¹ have their own limitations. VSI has got only step down inverters where as CSI need to be implemented with the help of large inductance which increase the cost. Hence in order to get more and more boost functionality, dc to dc converters can be added before the inverter side and like buck-boost converter². Z Source Inverter is being used as a single stage converter and it has got different topologies. It has got very fast growth rate because of its unique characteristics of both buck and boost operation within a single converter with high output voltage gain³. Voltage type Z source inverters have two modes of operation namely continuous and discontinuous mode and it is governed by using the technique known as pulse width modulation⁴. There are various control schemes are available to operate ZSI. Simple Boost Control (SBC) which has high voltage stress in switches when high voltage gain achieved. Maximum Boost Control (MBC) which has much less voltage stress when compared with SBC for a given modulation index. Harmonic Injection method's voltage gain remains same

as MBC but it has large modulation index⁵. q-ZSI has the implicit qualities of z source inverter and has unique advantage of lower component rating and a perfect interface for renewable applications⁶. Extended boost q-ZSI had provided an good boost factor range by having shoot through duty cycle of between 0..0.15 along with continuous input current⁷. The area of application of ZSI like electric vehicles⁸, electrical motor drive system⁹ and solar generation system¹⁰. The condition of Z-source inductors and capacitors are removed and a new soft switching technique is introduced to minimize the inrush spike current¹¹. The dynamic behavior of Quasi Z-Source inverter are analyzed by small signal analysis for the stand alone application¹². The EZ source inverter produced the voltage gain same as that of basic ZSI with smooth current and voltage that is prevailed across DC input voltage without any additional passive filter and reduced cost¹³. The new T-Type ZSI employs unique SL impedance network in order to couple main circuit and power circuit¹⁹. Parallel embedded Z-Source inverters showed their superior functionality for clean energy harnessing without any loss of voltage buck-boost capability¹⁴. Cascaded quasi Z source inverter with additional components added can be

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used to increase the output voltage by adjusting the duty cycle¹⁵. SL-q-ZSI has only one additional inductor and three diodes additionally added as compared to q-ZSI but has good very high boost factor for the same input current with providing common ground for DC source and continuous input current¹⁶. Tapped-inductor Z-source inverters uses multiple lower rated components rather than a few higher rated ones which results into enhanced voltage boosting capability¹⁷. The LCCT-ZSI helps to boost the output voltage by employing two built-in capacitors block DC currents in transformer windings and prevents core saturation of the transformer¹⁸. T-source inverter has got a very few passive elements and has most important edge over conventional Z-source inverter in terms of using common voltage source of the reactive components arrangement¹⁹. Trans-z source inverter has wide operation in motoring application using current fed trans ZSI and less voltage stress in the voltage-fed trans-ZSIs²⁰. Γ Z source inverter used very less components and a coupled transformer in order to produce high gain and high modulation index with reduced voltage stress on switches²¹. A survey on various types of Z source inverters along with different types of wind generators are discussed²². Simulation of wind generated fed Γ Z source z inverter is used to run permanent magnet synchronous motor was studied²³. The dynamic performance of wind turbine using permanent magnet synchronous generator under various load circumstances was studied²⁴. The modeling of a direct-driven permanent magnet synchronous generator based wind turbine using sliding mode controller is used to eradicate voltage fluctuations in the dc-link and decreases the stress of both voltage and current of converters²⁵.

The above mentioned literature does not have comparison between PI and PID controlled Γ z source inverter to improve the power quality in wind energy conversion systems.

This paper is structured as follows: section II deals with the concepts of Γ -Z Source inverters. Section III discusses about the proposed system of wind energy system with PI/PID controllers. Simulation diagram and its result analysis are studied in section IV. Section V is devoted for conclusion and future scope of work.

2. Γ -Z Source Inverter

The schematic diagram of Γ -Z source inverter is shown in Figure 1. It consists of a diode in series with input dc voltage, a capacitor connected across the source voltage, gamma shaped z source inveter and six mosfet arranged in three different legs. This inverter outputs the voltage with high gain when it is operated in 'Shoot through state' in which any two switches in a leg is shorted simultaneously⁵. The governing equation of both steady state and transient state, in shoot through condition, determine the behavior of the converter. The specific physical arrangement of the inductor coils in the shape of 'gamma' expedites the output voltage even though the number of windings is lesser than the commercial transformer winding.

3. Proposed System using Γ - Zsi

Figure 2 depicts the closed loop PI/PID controller in the field of wind energy conversion system using Γ -Z-source inverter. The low dc output voltage from the wind generator that house induction generator is not sufficient

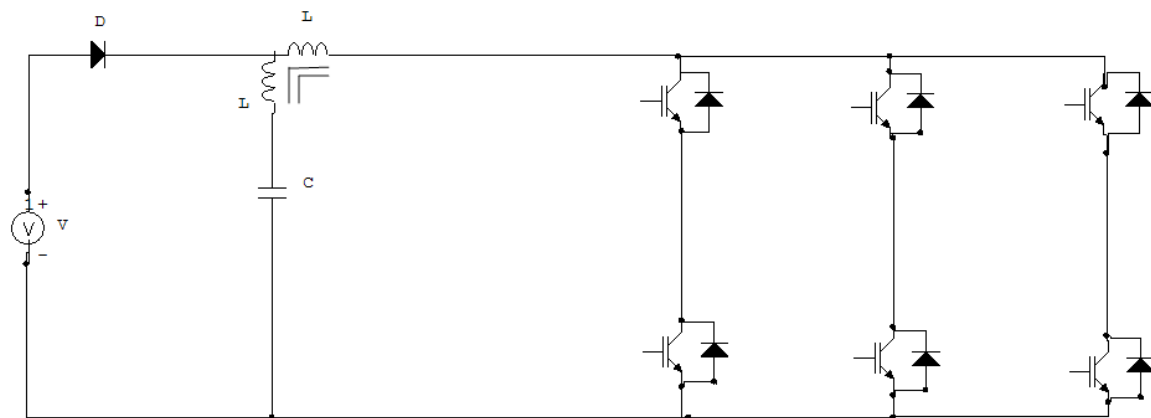


Figure 1. Γ -Z source inverter.

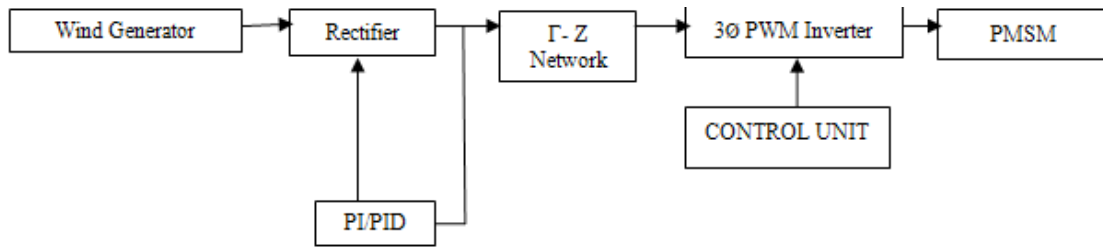


Figure 2. PI/PID controlled wind energy conversion system with Γ -ZSI.

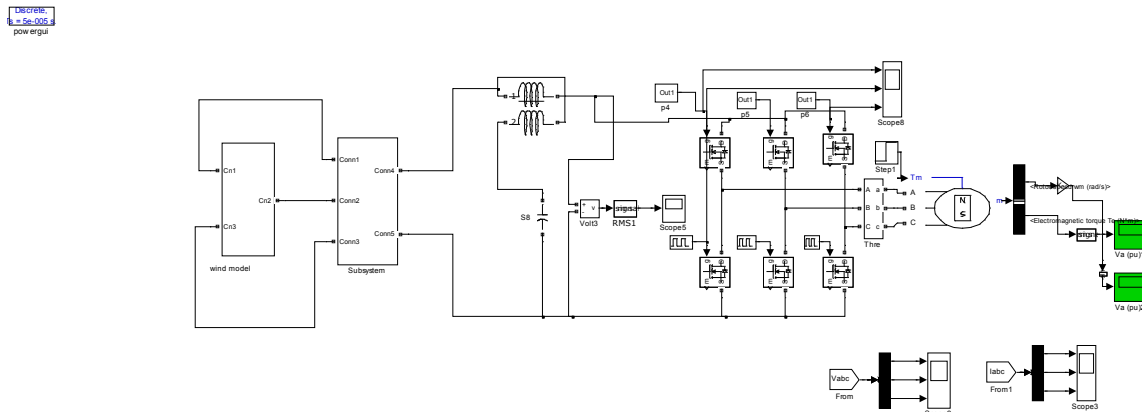


Figure 3a. Open loop system.

enough for the utilities that employs power inverters and PMSM motor to operate. Hence this voltage needs to be boosted up using Γ -ZSI with high gain while keeping the low modulation index of the converter so that it results in low voltage stresses on the components used. MOS-FET based three phase PWM inverter is used to convert boosted DC voltage into 3Ø AC voltage by employing the control unit pulses which is generated by separate control circuit. The derived AC output voltage feeds PMSM motor that runs with high speed. The input voltage to the rectifier as well as three phase inverter is controlled by using PI/PID controller. This will maintain constant output voltage even when the wind speed varies.

4. Simulation Results and Analysis

4.1 Open Loop System

Open loop system employing Γ -ZSI with a step change in wind speed is shown in Figure 3a. An increase in the speed of the wind produces a step voltage as shown in Figure 3b. The output voltage of the rectifier is shown in Figure 3c. The effect of increase in the wind speed can be seen in the output of the rectifier and the value is 275v DC.

The output voltage of Γ -z network is shown in Figure 3d. The rectified output voltage is boosted with the help of z network and value is 450v DC. The three phase output

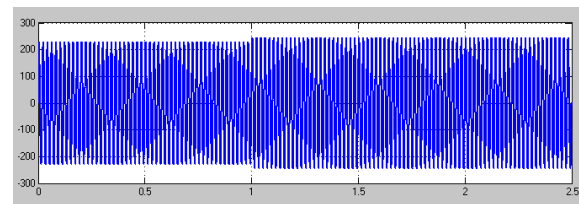


Figure 3b. Output voltage of the wind generator.

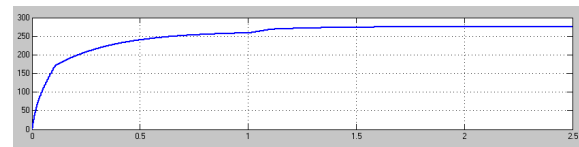


Figure 3c. Output voltage of the rectifier.

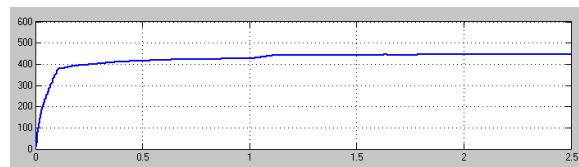


Figure 3d. Output voltage of Γ -ZSI.

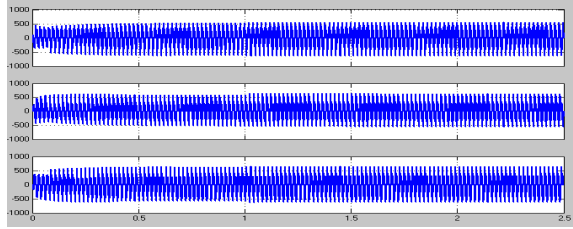


Figure 3e. Output voltage of the inverter.

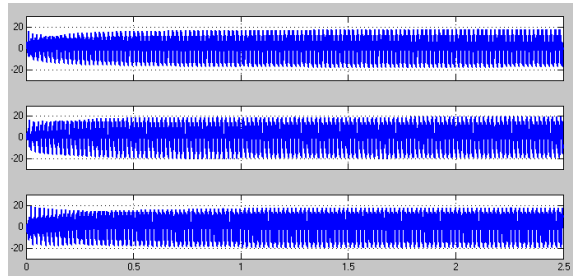


Figure 3f. Output current of the inverter.

voltage of the inverter is shown in Figure 3e. The current waveforms of the three phase inverter are shown in Figure 3f. The speed response curve of the motor is shown in Figure 3g. The speed is having variations and settles down to a steady value after a long time. The motor torque curve is shown in Figure 3h. The torque steady increases and

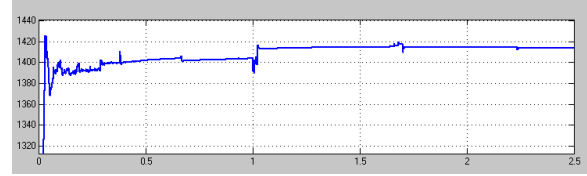


Figure 3g. Motor speed.

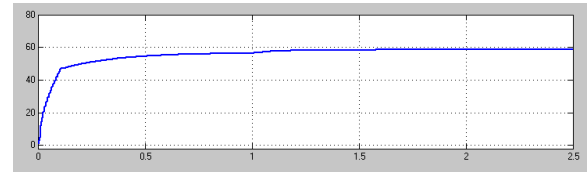


Figure 3h. Torque.

reaches at 60 Nm. The closed loop system is simulated with PI and PID controllers and its results are compared in detail in the following sections.

4.2 Closed Loop Pi Controlled System

The closed loop PI controlled wind energy system is shown in Figure 4a. A step increase in input voltage is considered. The speed response curve is shown in Figure 4b. The speed reached its steady state within 1.93 seconds. The motor torque reaches 82 Nm with rise time of 0.07 seconds and reaches steady state value without overshoot.

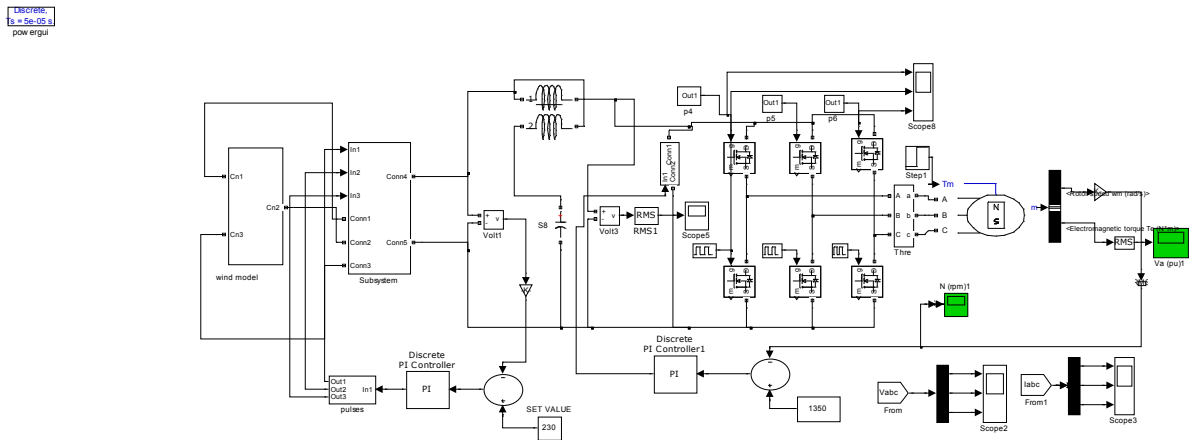


Figure 4a. Closed loop PI controlled system.



Figure 4b. Motor speed.

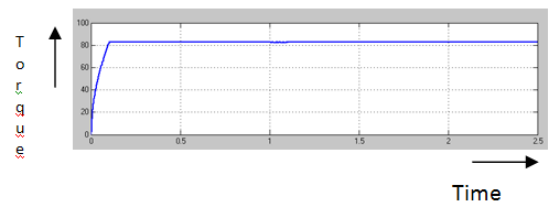


Figure 4c. Torque.

Discrete
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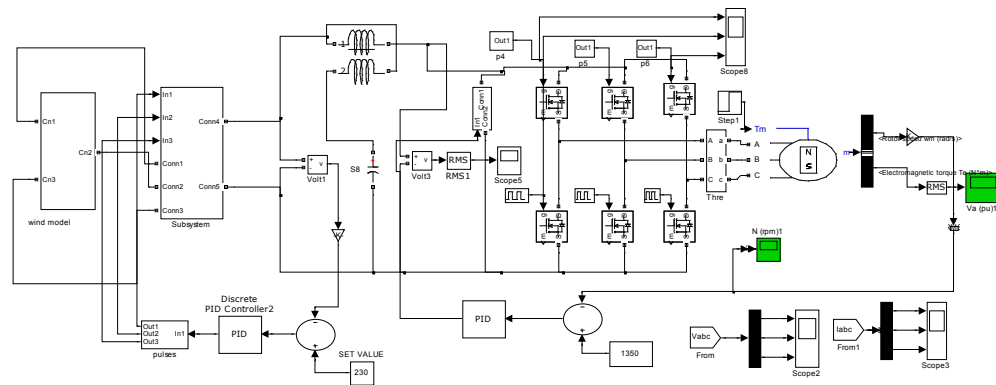


Figure 5a. Closed loop system with PID controller.

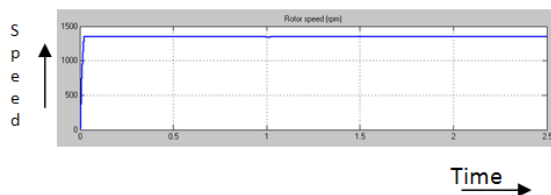


Figure 5b. Motor speed.

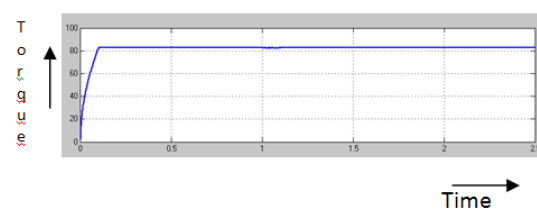


Figure 5c. Torque.

4.3 Closed Loop System with Pid Controller

The Closed loop system with PID controller is shown in Figure 5a. The DC Link voltage is compared with the reference voltage and the error is applied to a PID controller. The output of PID controller adjusts the pulse width of the signals applied to the rectifier. Thus the output voltage is regulated using closed loop system.

The speed response curve is shown in Figure 4b. The speed reached its steady state within 1.51 seconds. The motor torque rises to 82 Nm as same as that of earlier case but reaches steady state with rise time of 0.05 seconds.

The comparison of the closed loop PI and PID responses is given in Table 1 below.

Table 1. Comparison of responses

Controllers	Rise time(s)	Settling time (s)	Steady state error (rpm)
PI	0.07	1.93	0.5
PID	0.05	1.51	0.2

5. Conclusion

Wind generator fed Γ ZSI based PMSM drive system with PI and PID controllers were designed, modeled and simulated using matlab. The results with PI and PID

controlled systems were compared. The comparison indicated that PID controlled system produces faster response when compared to PI controlled system. This drive has advantages like quick response, high power density and low maintenance. The simulation of closed loop system with fuzzy logic controller will be done in future.

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