VOL. 10, NO 20, NOVEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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COMPARISON OF PID AND FUZZY LOGIC CONTROLLED WIND GENERATOR FED Γ- Z SOURCE BASED PMSM DRIVE SYSTEMS

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ABSTRACT

This work dealt with comparison of responses of PID and FL controlled Γ-ZSI based wind energy conversion systems. A coupled inductor was employed to produce high voltage gain. Open loop and closed loop control systems with PID and FL controllers were designed and simulated using MATLAB. The principle of operation and simulation case studies was presented in detail. The comparison was made in terms of rise time, steady state error and peak over shoot.

Keywords: PI, PID controller, wind generation, Γ-ZSI, fuzzy logic controller.

INTRODUCTION

In the era of power electronics, semi conductor plays a vital role in the industrial sectors in order to automate the process efficiently and more over it is compact and reliable and requires less maintenance. The applications which uses power electronics have to depend on considerable amount of voltage boosting and the application that is connected to the grid will always require good amount of boost level. The VSI and CSI are the traditional source inverters but has its limitations like they need two stage of power conversion and also VSI has got step down inverters only whereas CSI has to be constructed along with large inductance which results in high cost (J. Kikuchi., *et al* 2002; G. Moschopoulos., *et al* 2006). DC to DC converters are to be added in front of the inverter area so as to retrieve more voltage boost functionality. Before many years, ZSI was proposed which has unique x shaped characteristics in terms of large inductors and capacitors and it is a single stage converter which performs both boost and buck converter operation with high output voltage gain(F. Z. Peng, 2003). Continuous and discontinuous mode of operation can be realized by using pulse width modulation technique for both voltage and current type Z Source inverters (P. C. Loh*et al*, 2005). Simple boost control (SBC), Maximum boost control (MBC), Maximum Constant boost control (MCBC), Harmonic Injection method's are some of control schemes available to operate ZSI with high voltage gain (bymakeshNayak., *et al* 2013). q-ZSI has got less component and rating also but it acts as a good interface for connecting renewable applications like solar, wind energy (Yuan Li., *et al* 2009). Extended q-ZSI has very good voltage boost factor by holding the shoot through cycle for a period range between 0.0.15 with input current which is continuous (D. Vinnikov.,*et al* 2011). ZSI has wide application area such as battery operated electric vehicles (F. Z. Peng., *et al* 2005), electrical machines (F. Z. Peng., *et al* 2007) and solar power generation (M. Hanif*et al* 2011). Z source inductors and its capacitors are replaced by a new concept called soft switching method which helps to reduce the input current rush (Y. Tang., et al 2009). Quasi Z-Source inverter has good dynamic characteristic that is analysed for the stand alone system (J. Anderson., *et al* 2008) without any addition of passive filter. The EZ Source inverter has produced the output voltage gain equal to the normal z source inverter which ultimately reduces cost (P. C. Loh., *et al* 2010). Parallel EZ-Source inverters proved that with minimal loss of voltage boost-buck functionality it can perform better than its earlier versions of ZSI in terms of harnessing energy from renewable energy sources (F. Gao., *et al* 2008).Cascaded q-ZSI added with extra components performed much better in terms of increased output voltage by changing duty cycle (D. Li., *et al* 2011). For the same input current, Switched inductor-quasi-z-source inductor has high boosting factor besides giving common ground for DC source (M. Zhu., *et al* 2010). For producing enhanced voltage boosting with lower rated equipments, Tapped-inductor ZSI is ideal rather than keeping normal ZSI with higher rated components (M. Zhu., *et al* 2010). LCCT-ZSI performed boosting the voltage gain of ZSI in addition to blocking DC current in the transformer winding and stop core saturation (M. Adamowicz., *et al* 2011). T-source inverter has high frequency low leakage inductance transformer and one capacitance and with low reactive components it can boost output voltage (R. Strzelecki., *et al* 2009). Improved Trans-z source inverter has high boost inversion capability along with suppression of resonant current during start-up and performs better than Trans-z source inverter (M.S.Giridhar., *et al* 2014). With less components and a transformer placed as gamma shaped, Γ-ZSI produces high voltage gain with high modulation index with less switching voltage stress (Poh Chiang Loh., *et al* 2013). Various types of ZSI with different wind generators types are presented in detail (Ali, A. Jaffar., *et al*, 2014). Speed control of PMSM Motor was

VOL. 10, NO 20, NOVEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

performed with Γ Z source studied in (A. Jaffar Sadiq Ali., *et al* 2015).

The above literature does not compare PID and FL controlled Γ Z source inverter systems for power quality improvement in wind energy conversion systems.

Γ-Z SOURCE INVERTER

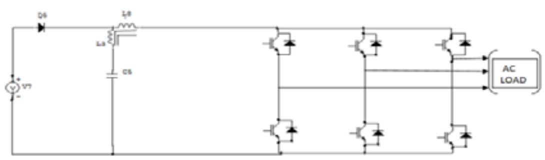

Figure-1.Γ-Z source inverter.

The diagram of gamma z source inverter is shown in the Figure-1. It includes a parallel connected capacitor and serially connected diode along with input dc voltage, gamma shaped z source inverter and MOSFET arranged in three different legs. The 'Shoot through' state of the inverter enhances output with high voltage gain by simultaneously shorting two switches in a leg. By having less transformer's ratio, this inverter boosts up voltage when compared with normal transformer that helps result into reduced cost and size of the inverter.

PROPOSED SYSTEM USING Γ- ZSI

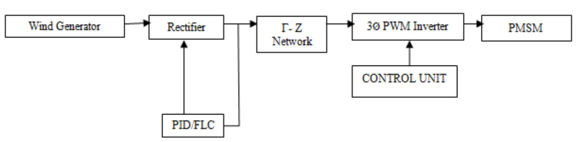

Figure-2.PID/FLC controlled Wind Energy Conversion System with Γ-ZSI.

Figure-2 shows the closed loop control using PID/FLC used in Wind Energy System employing Γ-Z-source inverter. The output of the wind generator is not enough to drive any application and it is fluctuating in nature and needs regulatory mechanism to get a constant output voltage to run PMSM motor at constant speed. The feedback of PID/FLC controller is employed to ensure the rectifier output voltage is constant. Thus the wind generator output voltage needs to be leveled up using Γ-ZSI but at the same time keeping the modulation index of the converter at low level that helps in reducing voltage stresses on the switches. The boosted voltage is converted into 3 phase ac voltage by MOSFET based inverter that feeds PMSM motor which has speed variation. A PID/FLC feedback loop is taken from the PMSM Motor and feds back to 3 phase inverter that regulates its speed to a constant even when the wind speed varies.

SIMULATION RESULTS

Open loop system

Open loop system with a step change in wind speed is shown in Figure-3(a).

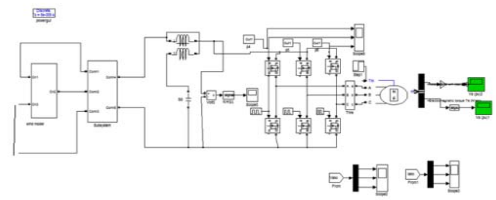

Figure-3(a). Open loop system.

An increase in the speed of the wind produces a step voltage as shown in Figure-3(b).

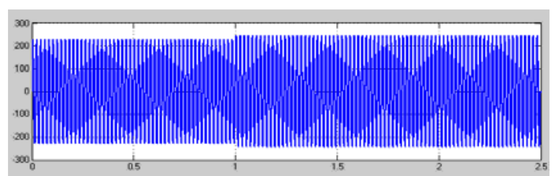

Figure-3(b). Output voltage of the wind generator.

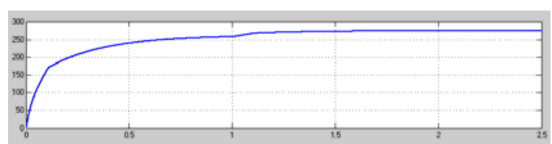

Figure-3(c). Output voltage of the rectifier.

The effect of increase in the wind speed can be seen in the output of the rectifier as shown in Figure-3(c).

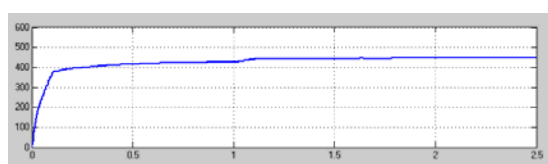

Figure-3(d). Output voltage of Γ Z-network.

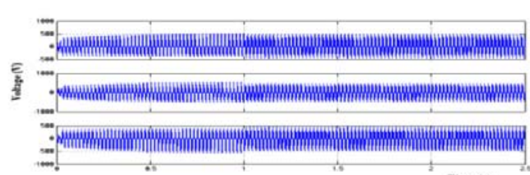

Figure-3(e). Inverter voltage waveform.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

The output voltage of the MOSFET based three phase inverter is shown in Figure-3(e).

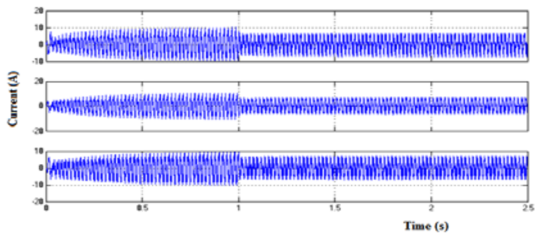

Figure-3(f). Output current waveform.

The output current of the inverter is shown in Figure-3(f).

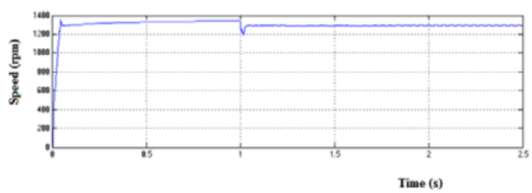

Figure-3(g). Motor speed.

The speed response curve is shown in Figure-3(g).

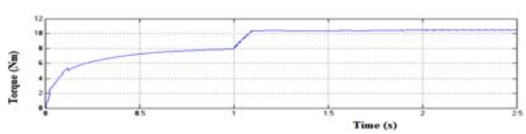

Figure-3(h). Torque.

The torque curve is shown in Figure-3(h).The developed torque increases due to the addition of the load torque.

Closed loop system with PID controller

The Closed loop system with PID controller is shown in Figure-4(a).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.

$k_p = 0.5$ $k_i = 0.9$ $k_d = 0.23$

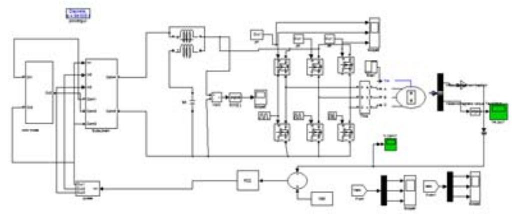

Figure-4(a). Closed loop with PID controller.

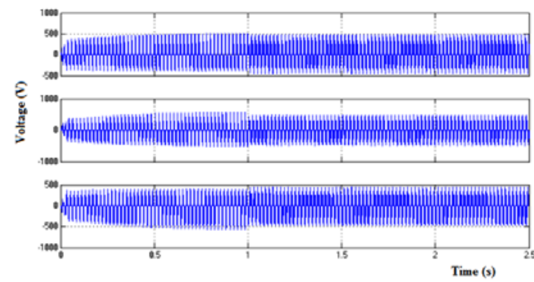

Figure-4(b). Inverter voltage waveform.

The output of the inverter is shown in Figure-4(b).The output voltage is regulated using closed loop system.

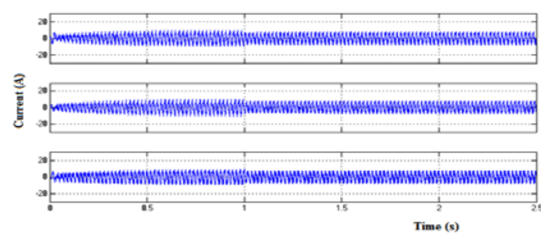

Figure-4(c). Inverter current waveform.

Output current waveforms of the inverter are shown in Figure-4(c).

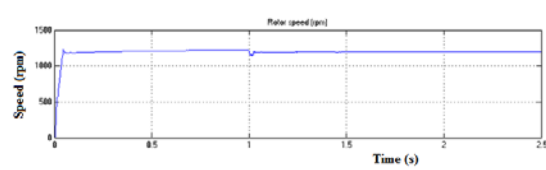

Figure-4(d). Motor speed.

Speed and torque curves are shown in Figures-4(d) and 4(e) respectively. It can be seen that speed remains constant.

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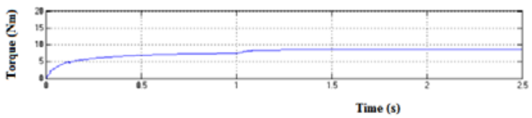

Figure-4(e). Torque.

Closed loop system with FLC

The simulink model of closed loop system with FLC is shown in Figure-5(a).The actual speed of the motor is compared with the reference speed. The error and its derivative are applied to FLC. The output of FLC is compared with the repeating sequence to produce the pulses required by the MOSFETs.

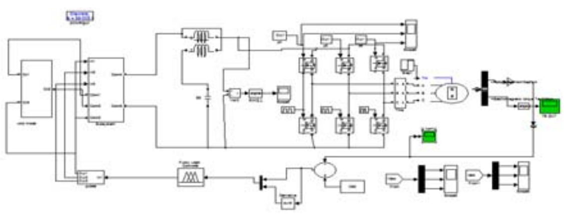

Figure-5(a). Closed loop control with FLC.

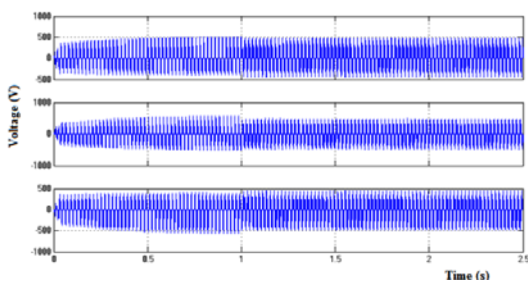

Figure-5(b). Inverter voltage waveform.

Output voltage and currents of inverter are shown in Figure-5(b) and 5(c) respectively.

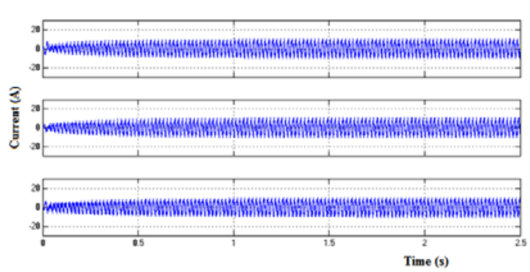

Figure-5(c). Inverter current waveform.

The speed and torque responses are shown in Figure - 5(d) and 5(e) respectively. It can be seen that the speed reaches set value smoothly.

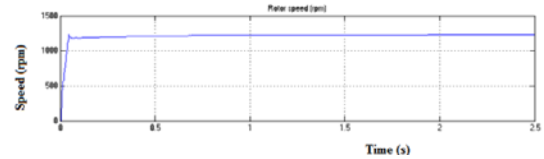

Figure-5(d). Motor speed.

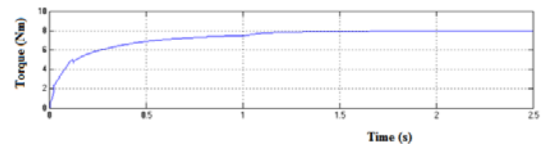

Figure-5(e). Torque.

The comparison of closed loop PID and FLC responses is given in Table-1 below.

Table-1. Comparision of responses.

Controllers	**Rise time** (s)	**Settling time** (s)	**Steady state error** (v)
PID	0.05	0.1	0.2
FLC	0.02	-	0.1

CONCLUSIONS

Wind generator fed Γ-ZSI based PMSM drive with PID & FL controllers are designed, modelled and simulated using MATLAB. The results with PID and FL controlled systems are compared. The comparison indicates that FL controlled system produces faster response when compared to PID controlled system. This drive has advantages like quick response, high power density and low maintenance.

The results of closed loop system with Neural Network controller will be done in future.

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