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Performance Improvement of PMSG Based Power Generation System using Switched Inductor Based Quasi Impedance Source Inverter

S. Sivaganesan* and D. Kirubakaran**

Abstract : The requirement of power demand is increased the use of renewable energy based power generation. The PV source and wind energy are major source for renewable energy system. The permanent magnet synchronous generator (PMSG) is recently used in Wind energy based power generation system due to their advantages such as maintenance free and no need separate excitation. The performance of the PMSG is needed to improve due to variable wind speed. The PMSG based high-performance voltage source inverters are extensively required in various industrial uses with reduced cost and more stable operation. Compared to the quasi impedance source inverter based PMSG system, the proposed quasi switched inductor based PMSG system increases the voltage gain and inversion ability and reduce the harmonic. Minimum switching stress on semi conductor switches can be achieved by choosing accurate capacitor voltage reference. The sine PWM technique is used to reduce the current harmonics and control the inverter output voltage. The circuit is simulated using MATLAB simu-link. The simulation results are compared. From the results, it can be proved that the proposed PMSG based inverter has low voltage stress high voltage gain, and less harmonic compare than qzsi inverter.

Keywords : PMSG generator, Switched inductor network, Quasi impedance network, Inverter and Shoot through state.

1. INTRODUCTION

The requirement of power demand is increased the use of renewable energy based power generation. Variable speed wind energy systems mainly used due to their advantages such as yielding maximum power output, low mechanical stress, improving efficiency and power quality compared with fixed speed wind energy systems [1].Power electronics devices with a variable speed system are very important to convert ac to dc and dc to ac [2-3]. The reliability of the variable speed wind energy systems can be improved mainly by using a permanent magnet synchronous generator (PMSG).Recent days PMSG is used for wind energy systems based power generation due to their advantages such as its simple structure, self-excitation capability leading to high efficiency operation and high power factor and ability of operation at slow speed [4].The low speed of PMSG operation is affects the gearbox setup and required maintenance [5, 6]. During low speed the system generates low power output. PMSG is interfaced with power converters to convert fixed frequency and constant voltage output. Different converters are developed for interfaces between PMSG and the load [7, 8].

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Voltage and current source inverters (VSI and CSI) are not suitable where interfacing with low voltage source due to their narrow obtainable output range, shoot-through problems caused by mis-firing. After 2000, the topology of the Z-source inverter [9] was proposed to overcome the problems in the VSI inverters in which the functions of the traditional dc–dc step up converter and the PWM inverter have been successfully combined. Different ZSI inverters are proposed in different application and different period [10-11].Many research works is going on continuously to improve the impedance source inverter voltage gain and performance [12-13].PWM method with shoot through concept is applied for increase the voltage gain of the impedance source inverter [13-15].

The quasi z-source inverter has many advantages compare than other z-source inverter such as more voltage gain, less capacitor rating [14]. The switched inductor based quasi impedance source inverter is proposed in this paper. The switched inductor network is included in the qusi source inverter for improving the voltage gain and reduces the current harmonic. The circuit performance is compared and verified using simulation results. The following section describes the inverter operation and simulation results.

2. CIRCUIT DESCRIPTION

The PMSG based power generation system is as shown in fig 1. This circuit consists wind turbine, PMSG, rectifier, switched inductor based quasi impedance source (Sl-Qzi) inverter and motor load. The wind generator generates the ac voltage it's given to rectifier for converting ac to dc. This dc supply is fed to Sl-Qzi for converting dc to ac with voltage boosting. The impedance network with inverter produces the constant voltage with fixed frequency output. This ac voltage is given to the motor load.

A. Switched inductor based quasi impedance source (Sl-Qzi) inverter

It is used to convert dc to ac voltage. It consists of three inductors (L1, L2, and L3), two capacitors (C1 and C2), and four diodes (D1, D2, D3 and D4).

The combination of L1–L3–D1–D2–D3 performs the function of the SL module This SL modules are used to store and transfer the energy from the capacitors and dc source to the dc bus under the switching action of the main circuit

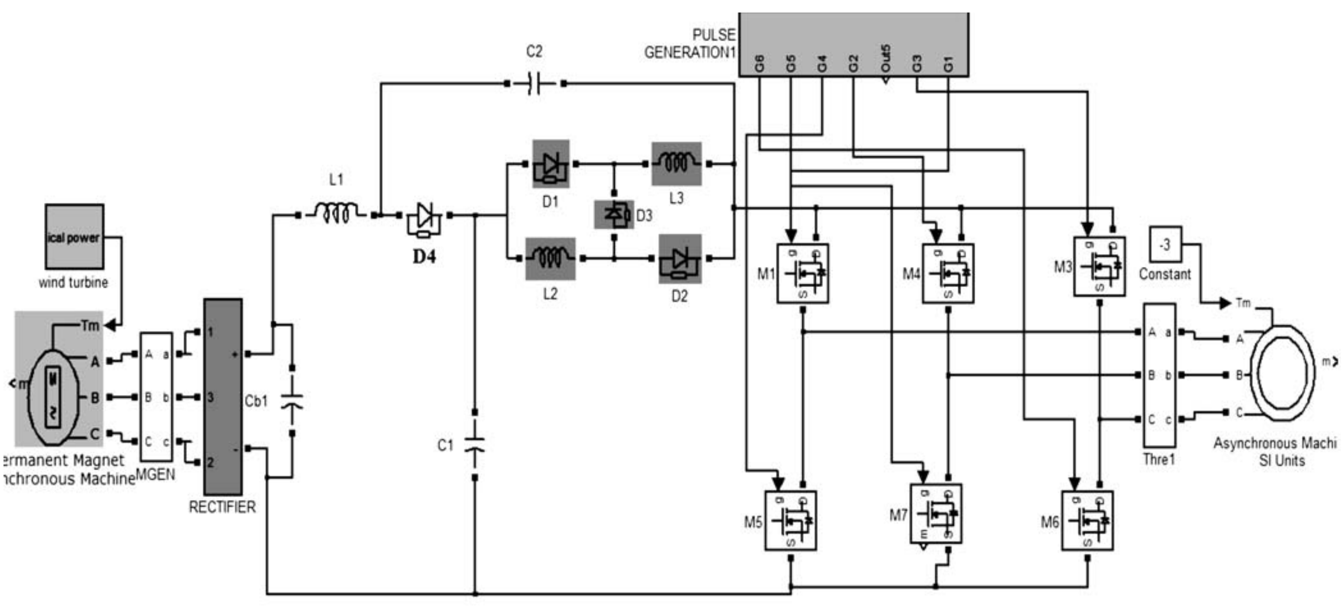

Figure 1: Proposed Circuit Diagram

B. Operating Principles

The operating principles of the proposed impedance network are similar to the classical Z-source impedance network. For the convenience of analysis, the equivalent circuit of the proposed switched impedance network viewed from the dc bus is shown in Fig 2. This circuit has totally eight modes of operation. Two modes relevant to shoot through condition and another six modes are normal inverter operation. Shoot through states is classified into non shoot through and shoot through modes.

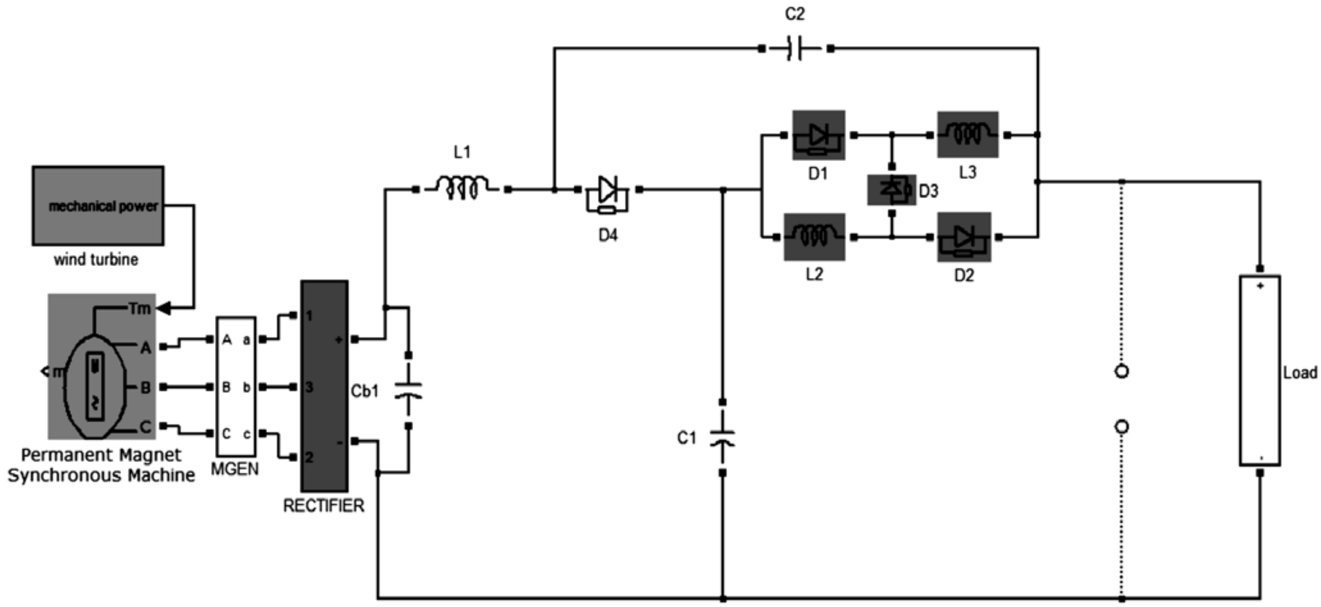

Figure 2: Switched inductor based quasi impedance source (Sl-Qzi) inverter

Shoot-Through State *:* During this mode, inverter one leg both switch becomes conduction mode, while both D3 and D4 are reverse bias. At the same time the SL module, D1 and D2 are forward bias as a result L3 get charging from dc source through D1. Similarly L2 get charging through D2. The shoot through operation equivalent circuit is as shown in Fig 3. The capacitors C1 transfer their electrostatic energy to magnetic energy stored in the inductors L2 and L3.

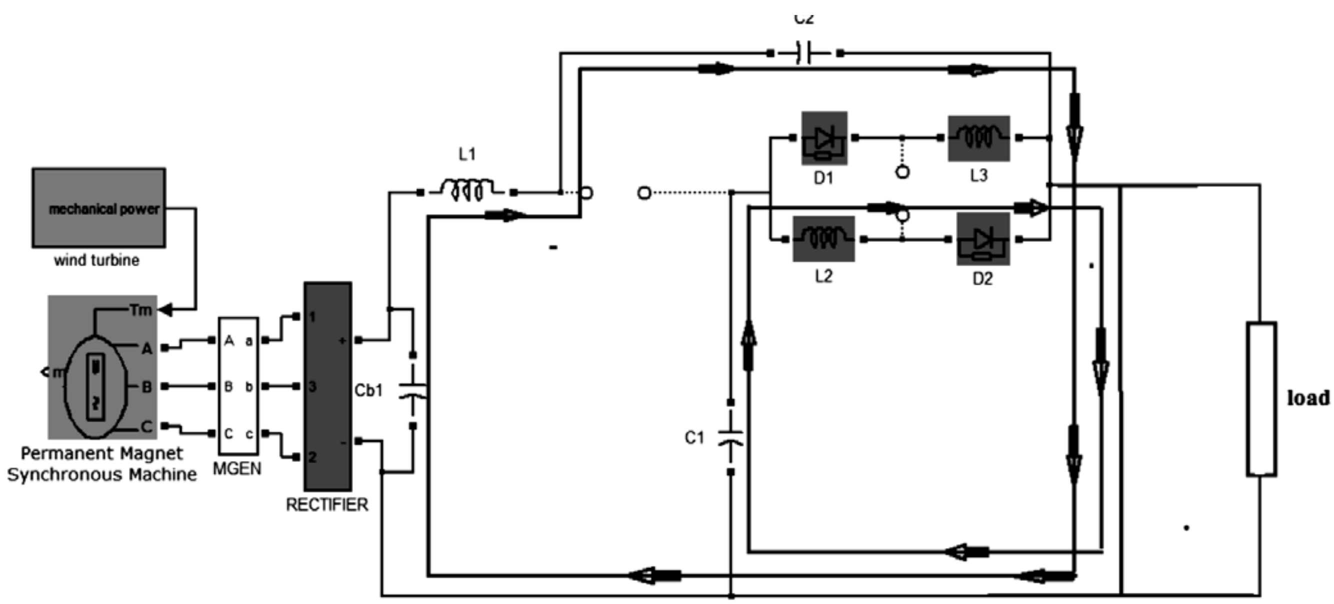

Figure 3: Shoot-Through State

Non-Shoot-Through State : This mode corresponds to the six active states and two zero states of the main circuit and the equivalent circuit is shown in Fig 4. During this active state, inverter one leg top or bottom switch is OFF condition, while both D3 and D4 are ON. At that time SL module, D1 and D2 are becomes reverse bias. L1, L2 and L3 are connected in series, and the stored inductor energy is transferred to the main circuit. The dc power source, as well as the inductors energy is delivered to load as well as charges the capacitors C1 and C2. Thus the dc link voltage is increased with help of inductor and capacitor stored energy.

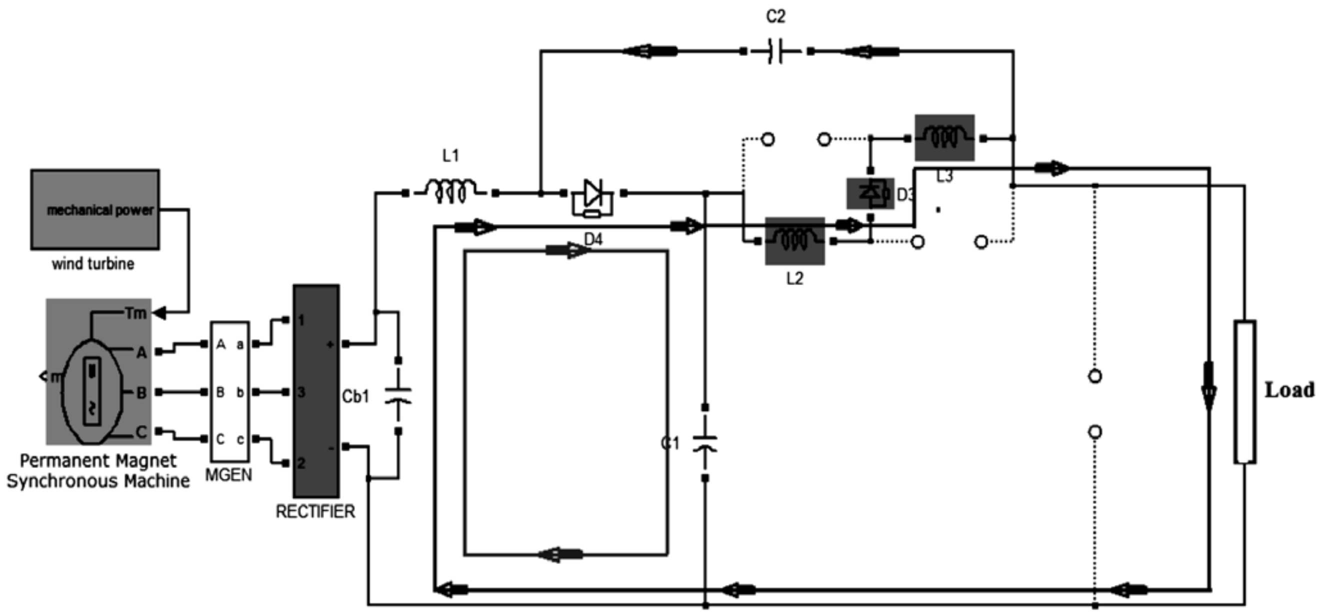

Figure 4: Shoot-Through State

C. Control technique

Three phase ac volatge is taken as reference this reference signal is compared with tringular carrier signal. This control method is called as Sine pwm technique. Durning Normal operation of the inverter at any instant two device in same leg not conduct.but proposed Z source inverter this operation is possible. this operation is called as shoot throgh mode.this pulse pattern as shown in the figure 4 and fig 5.

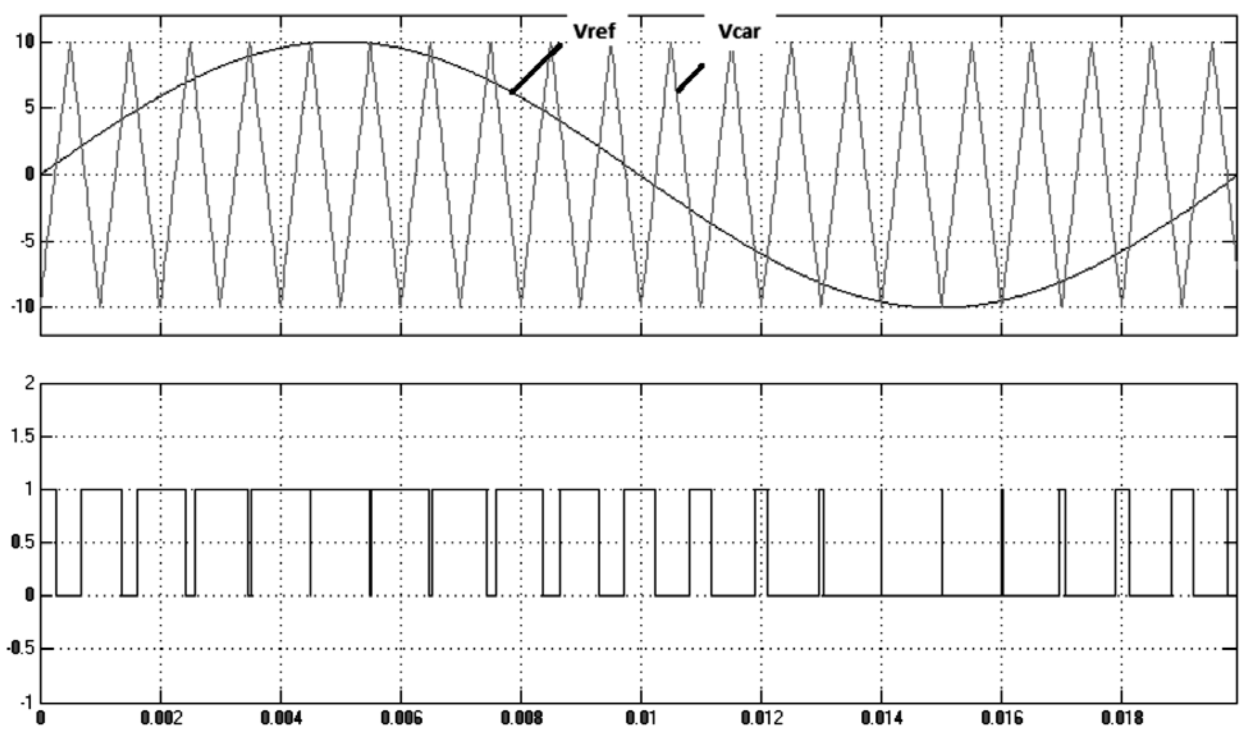

Figure 5: Sine Pwm Generation Method and Pulse Pattern

D. Boost Ability Analysis of SL q Z-Source Impedance

For the convenience of mathematical derivation, all inductors and capacitors are assumed to have the same inductance (L) and capacitance (C), respectively; therefore, both the equivalent circuits in Fig. 3 and 4 show the symmetry characteristics. In addition, since C1 and C2 are sufficiently large, thus, in the steady state, we have

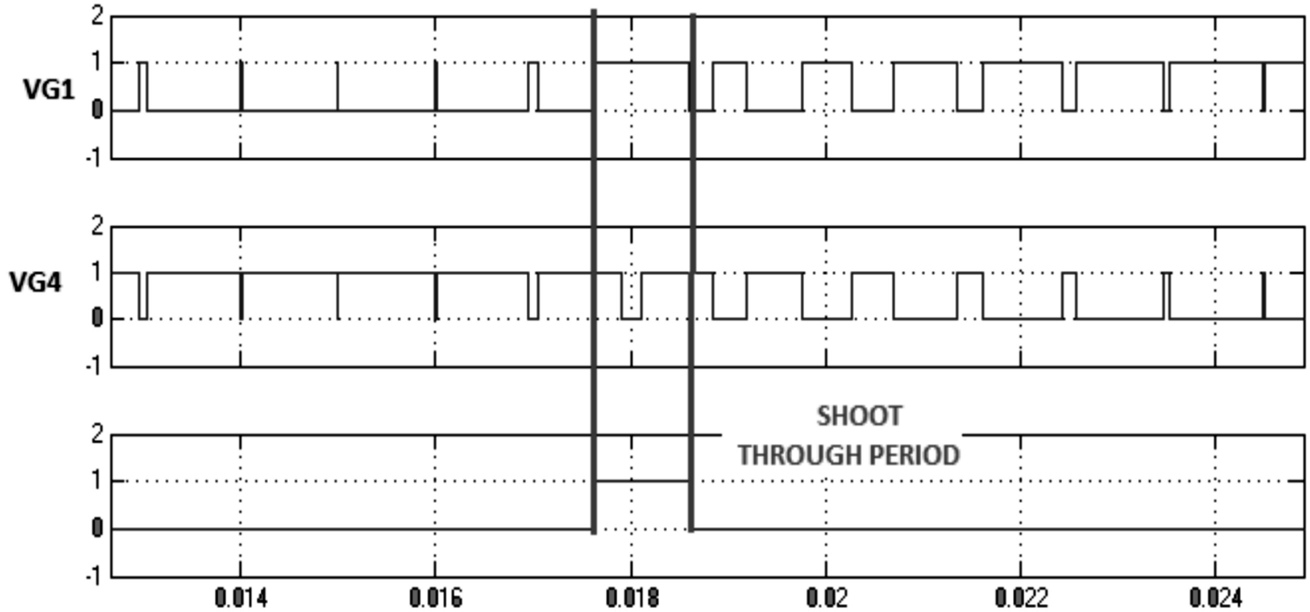

Figure 6: Shoot through pulse pattern for switch s1 and s4

$$V_{C1} = V_{C2} = V_C \quad (1)$$

The inductor current iL1 increases during switching ON period and decreases during switching OFF period. During switching ON, the corresponding voltage across L1, V_{L1}-ON is equal to V_C. Applying the volt–second balance principle to L1, we can get the corresponding voltage across L1 during switching OFF condition, V_{L1}-OFF, which is expressed by

$$V_{L1-OFF} = -\frac{D}{1-D}V_C$$
$$= V_{L3} - OFF. \quad (2)$$

The inductor current iL3 increases during switching ON period and decreases during switching OFF period. The corresponding voltages across L3 are equal to V_{C1} and $-(V_{C2} - V_{in} + V_{L1}$-OFF).

Applying the volt–second balance principle to L3, we have

$$DTV_{C1} = (1-D)T(V_{C2} - V_{in} + V_{L1} - OFF) \text{ or}$$

$$DTV_{in} = (1-D)T\left(V_C - V_{in}\frac{D}{1-D}V_C\right) \quad (3)$$

Hence,
$$V_C = \frac{1-D}{1-3D}V_{in}$$
$$= V_{C1} = V_{C2}. \quad (4)$$

During switching OFF period, C1, L1, L3, and the voltage source Vdc form a close loop; therefore we have

$$V_C = V_{dc} + V_{L1} - OFF + V_{L3} - OFF. \quad (5)$$

Therefore,

$$V_{dc} = \frac{1+D}{1-3D} V_{in} = BV_{in} \quad (6)$$

The boost factor of the SL Z-source impedance, B is thus expressed by

$$B = \frac{1+D}{1-3D} = \frac{1+(T_0/T)}{1-3(T_0/T)}. \quad (7)$$

3. SIMULATION RESULT

The Quasi Z-source inverter circuit diagram is as shown in figure 7. The proposed switched inductor based quasi impedance source inverter circuit is as shown in figure 8. Figure 9 shows the proposed wind generator output voltage. Figure 10 shows the rectifier output voltage. Figure 11 shows the switched impedance network output voltage. The dc link voltage gain is increased it is proven that from fig11. Figure 12 shows the driving pulse for switches M3 and M6 with shoot through condition. Figure 13 and 14 shows the inverter output current and voltage. Figure 15 shows the rotor speed.

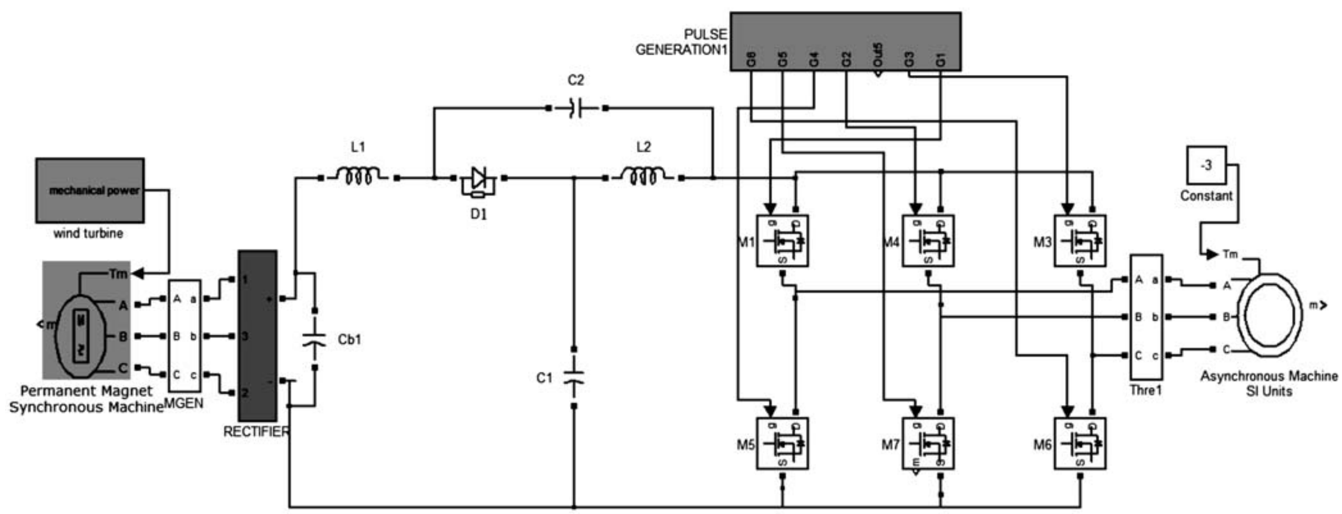

Figure 7: Conventional circuit diagram

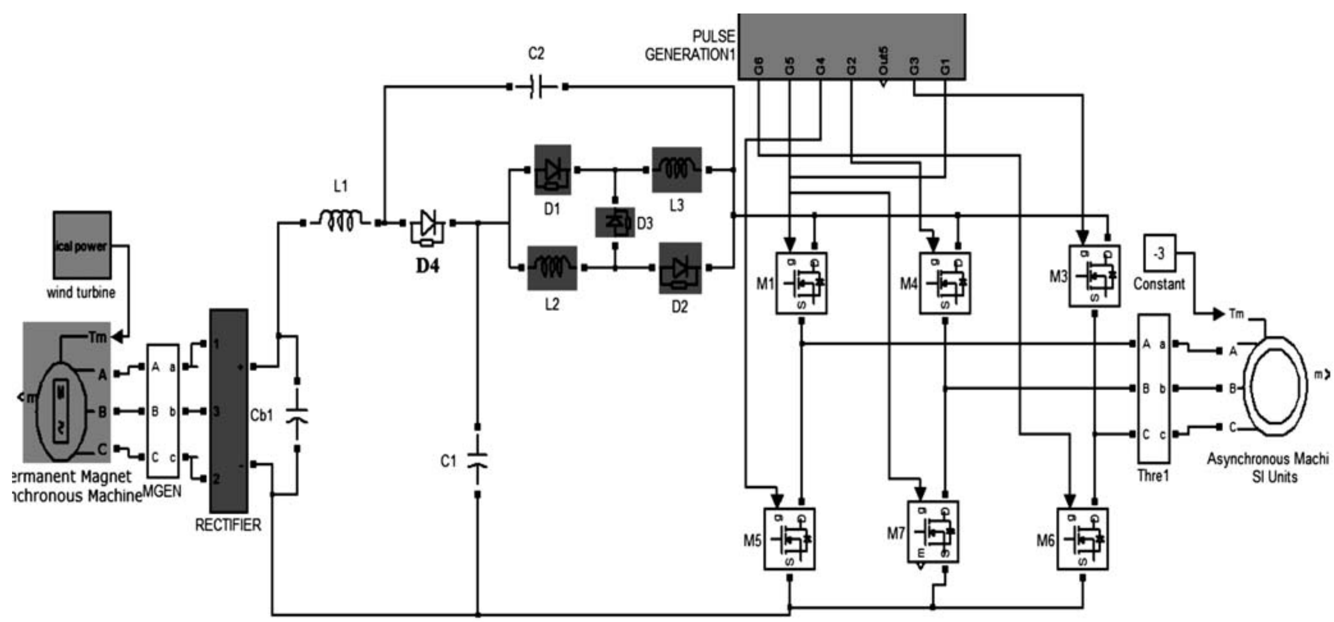

Figure 8: Proposed circuit diagram

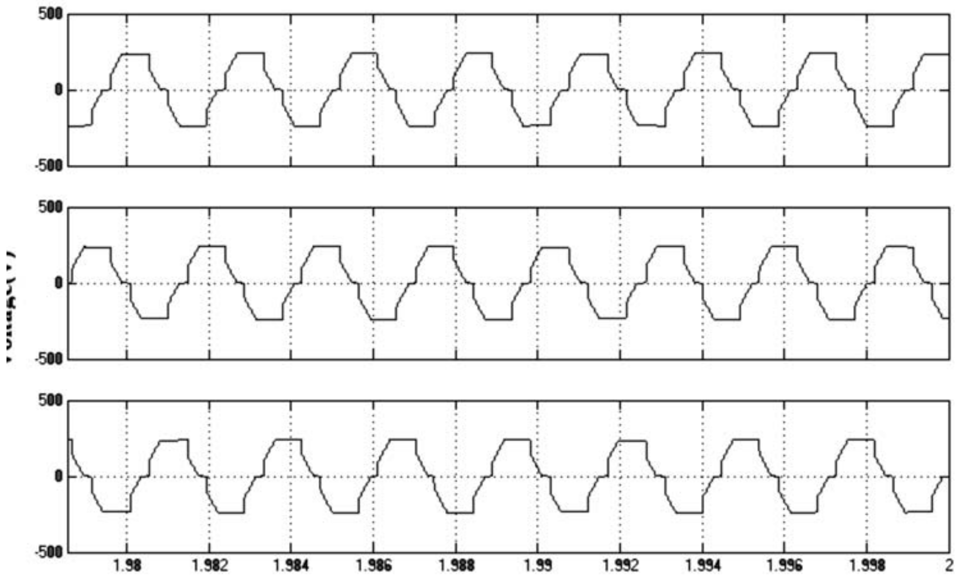

Figure 9: Wind generator output voltages

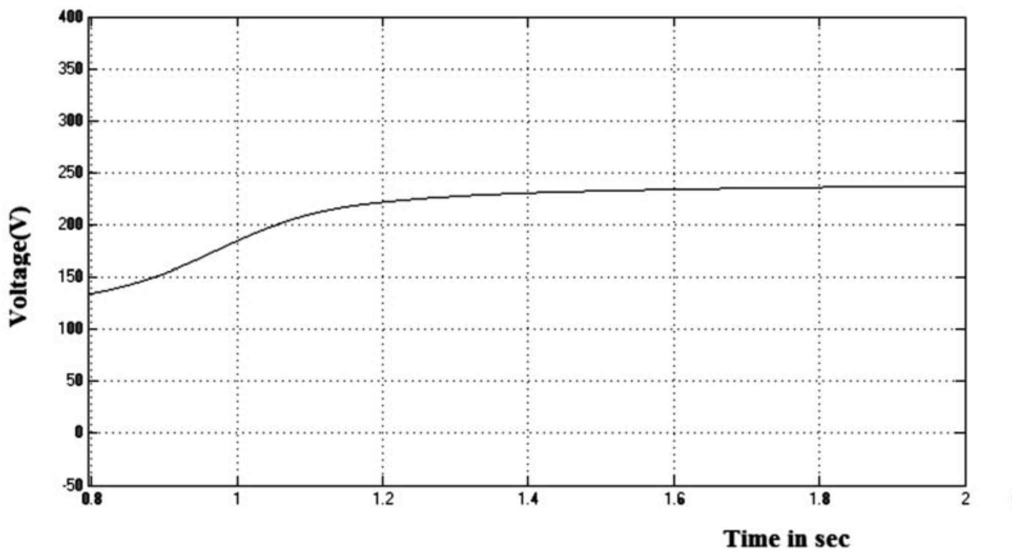

Figure 10: Rectifier output voltage

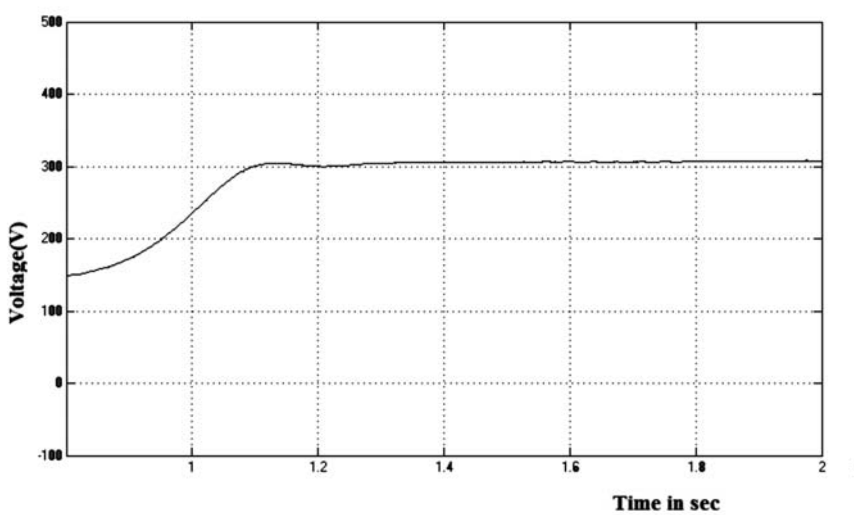

Figure 11: Quasi network output voltage

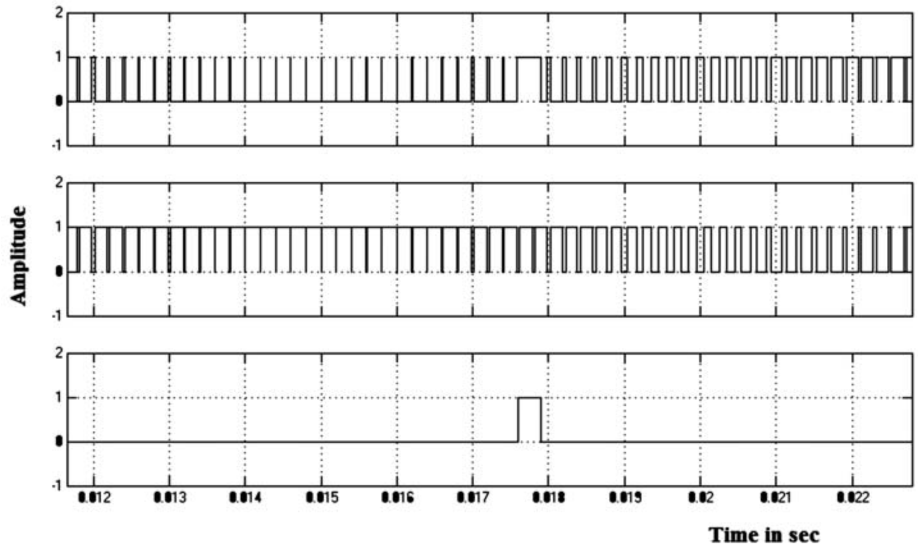

Figure 12: Triggering pulses for M3, M6 and shoot through period

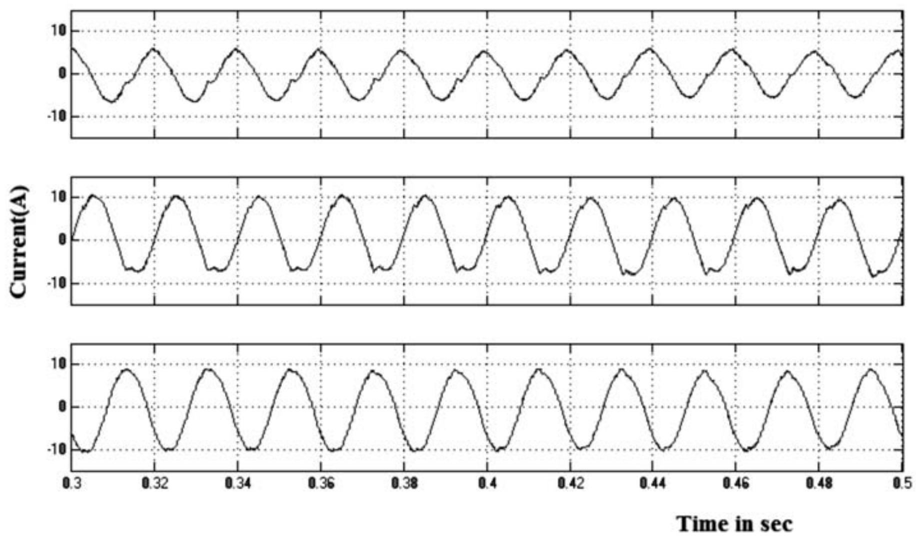

Figure 13: Inverter output current

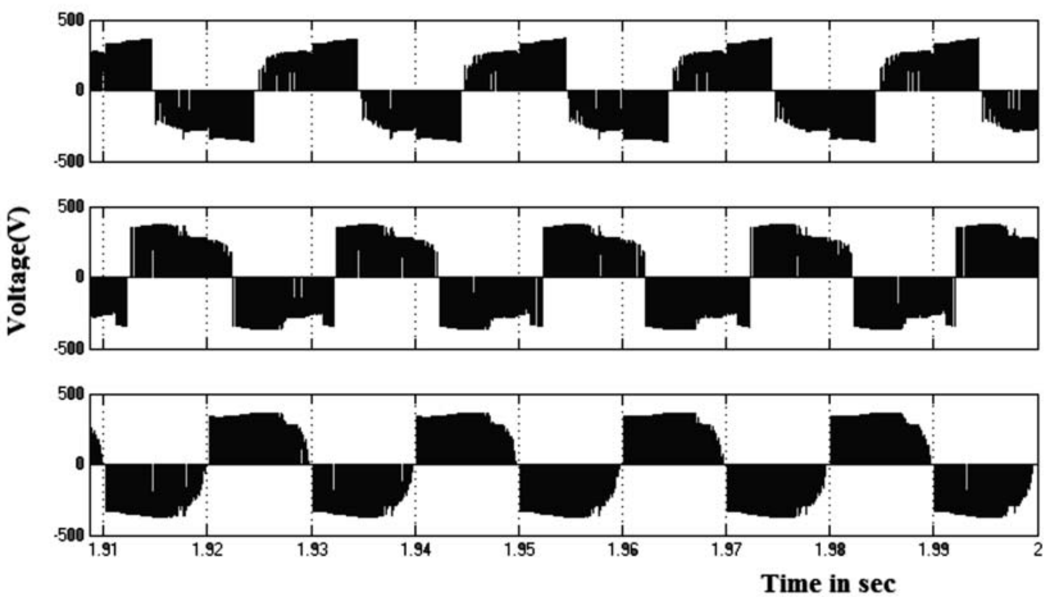

Figure 14: Inverter output voltage

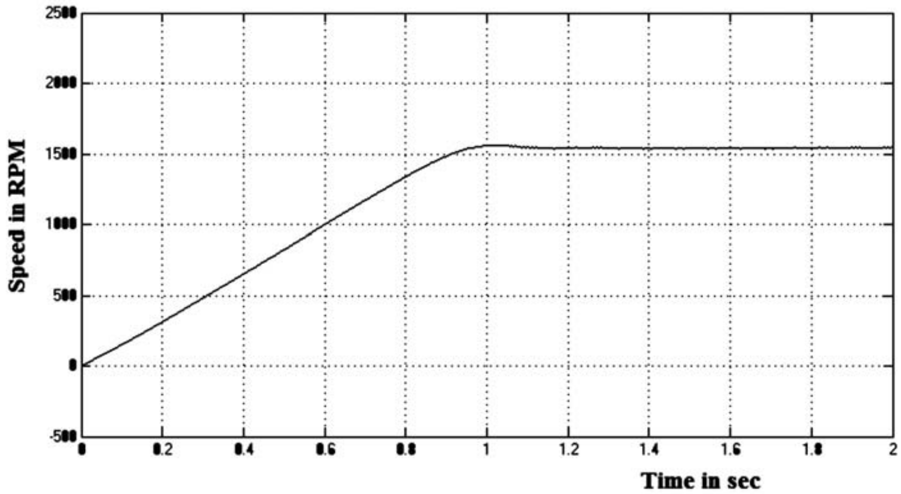

Figure 15: Rotor speed in RPM

4. COMPARATIVE ANALYSIS

Table-1 shows the conventional and proposed circuit input and output parameters the proposed circuit having high voltage gain and less current harmonics compare than conventional inverter. It is shown that table-1. Figure 16 and 17 shows the FFT analysis for conventional and proposed inverter current. The proposed inverters having less current harmonics compare than conventional inverter it is proven that figure 16 and 17.

Table 1.

Parameters	***Qzsi***	***Qzsi with switched inductor***
Input voltage	230V	230V
Impedance network output	281V	306V
Output current(RMS)	4.75A	5.02A
Output voltage (RMS)	140V	154V
%THD	9.99%	7.01%

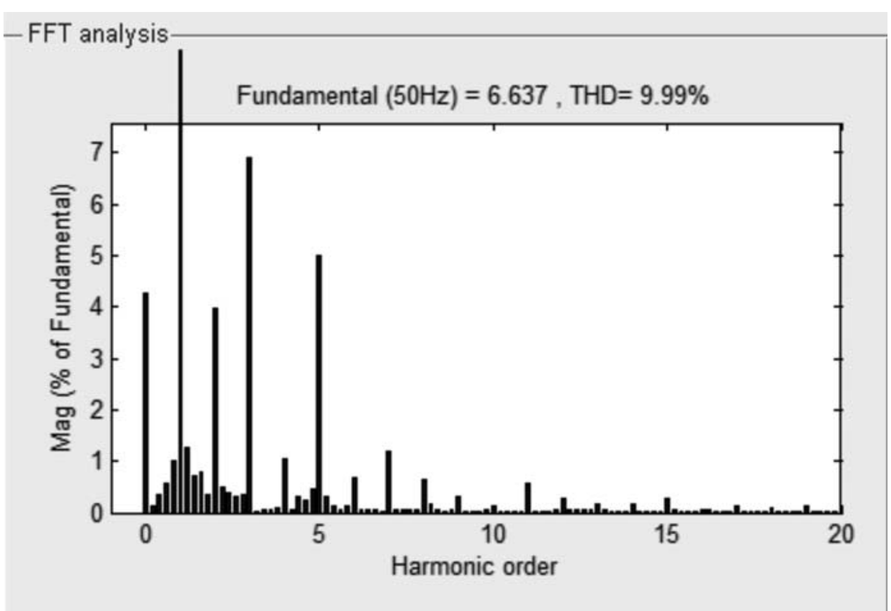

Figure 16: FFT analyses for conventional inverter current

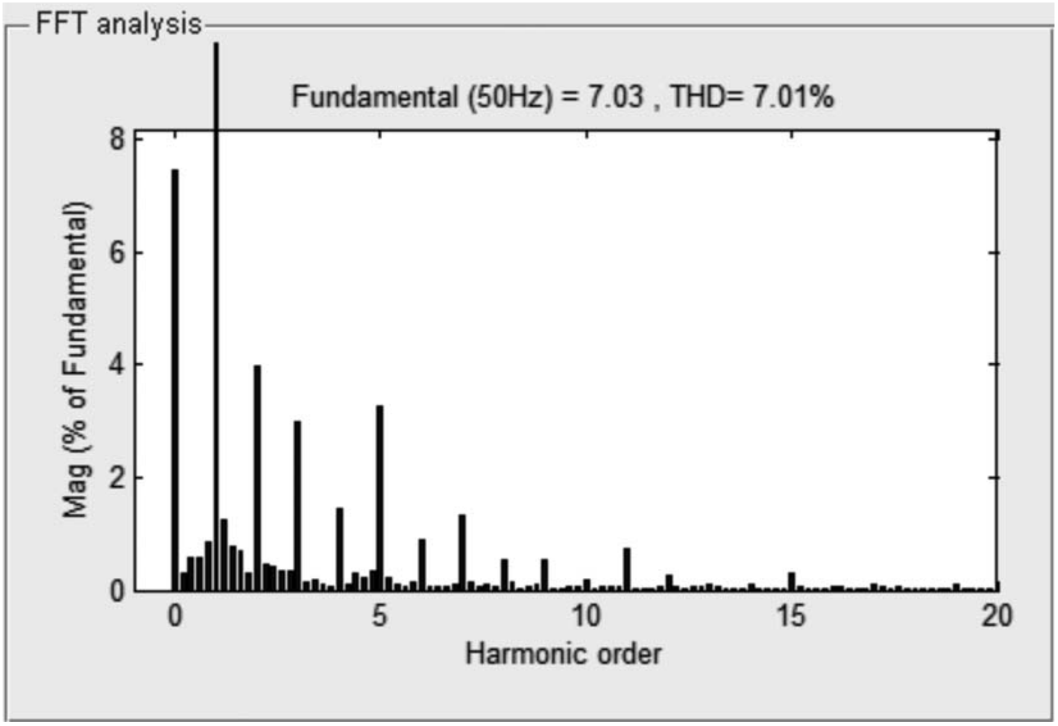

Figure 17: FFT analyses for proposed inverter current

5. CONCLUSION

This paper has presented PMSG based power generation using switched inductor based quasi impedance source inverter with sine PWM technique, which exhibits several merits. The wind generator produces the variable voltage. The impedance network based inverter gives constant voltage and fixed frequency output. During Shoot through state the high current is stored in inductor and capacitor as a result to avoid the short circuit and protect the switching devices. The switched inductor cell is used to store and transfer the energy from source to the load as a result it increase the voltage gain of the inverter. Waveform distortion of the ac output voltage caused by dead time is essentially avoided. Thus the proposed inverter has high voltage gain, less capacitor rating and less harmonics compare than conventional inverter.

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