Design, Simulation and Implementation of Zero Voltage Switching for PWM Inverter Using Quasi-Resonant Circuit

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Abstract: This paper presents Design, Simulation and Implementation of Zero Voltage Switching for pwm Inverter using Quasi-Resonant circuit. The main aim of this paper is to reduce voltage stress of the inverter and to ensure soft switching of the inverter thereby reducing losses, ripples and harmonics due to switching action. Here only one switching device is used to create zero voltage instants for all inverter switches in order to ensure soft switching. Control technique does not require the help of inverter switches to create the zero voltage instants in the dc-link and voltage and current sensors are eliminated from the control circuit. In this paper, the principle of operation and detailed analysis of the proposed Zero Voltage Switching for pwm three phase inverter using Quasi-Resonant circuit are presented and design considerations for achieving soft switching are obtained. Detailed MATLAB 7 Simulations studies are carried out to study the feasibility of the proposed topology. The experimental results of zero voltage switching for pwm three phase inverter using Quasi-Resonant circuit are also validated with the simulation results.

Key words: Quasi-Resonant inverter % Soft Switched inverter.

INTRODUCTION

Power Electronic Converters design should meet power losses, switching losses, conduction losses, voltage stress of the switches and also the EMI regulations, with the consequence of increased development costs. To reduce these drawbacks fast switching devices are built. These devices have very fast turn-ON and turn-OFF characteristics. With these characteristics if the switches are turned on and off at high di/dt and high dv/dt rating then the losses and stresses get increased and also causes EMI disturbances. To alleviate these difficulties soft switching concept was introduced. The soft switching resonant converters eliminate the rapid voltage change caused by fast switching devices and thereby reduces losses, stresses and EMI disturbances. Many research works on ensuring Zero voltage switching condition have been reported in [1-8]. In the literature [1-3] have three additional switches, the voltage stress on one of the switches in the circuits proposed in [1, 2] is high and the turn-off loss of two auxiliary switches in the circuit proposed in [3] is limited by the snubber action of the resonant capacitor.

The proposed circuit in [4] has two extra switches and one diode, here commutation losses are high and extra voltage stress on the inverter devices. In [5] The peak voltage of the dc-link varies between 1.3-1.5 times the input source voltage. Also, the work proposed in [6] concludes that, factors such as voltage stress on the switches, presence of sub-harmonics and difficulty of eliminating them in the three phase applications as well as the complexity of the modulation strategies, are the most significant drawbacks of the scheme proposed in [5].The circuit described in [7] uses three extra switches. Recently, Lipo proposed a new QRDCL inverter using coupled inductors [8]. This circuit reduces the device voltage stress to around (1.1-1.3) pu. In this paper the device voltage stress gets reduced further.

Soft Switching Techniques: There are two types of soft switching techniques i) Zero Voltage Switching (ZVS) resonant converter and ii) Zero current switching (ZCS) resonant converter.

The switches are turned ON or OFF when the voltage across the switch is made zero at the switching instant such switching scheme is called as Zero voltage

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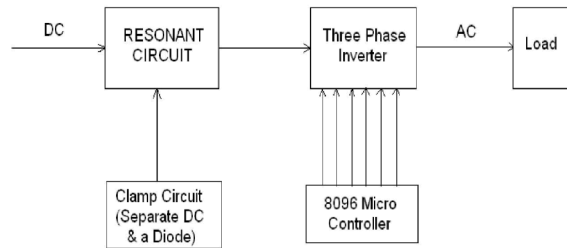
Fig. 1: Block Diagram

switching and the switches are turned on or off when the current through the switch is made zero at the switching instant such switching scheme is called as zero current switching scheme.

Block Diagram: Fig. 1 shows the block diagram of Zero Voltage Switching for pwm Inverter using Quasi-Resonant circuit. In this paper the dc supply is given to the resonant circuit which consists of a resonant switch S_{r1}, an antiparallel diode D_{r1}, an inductance L_1, mutual inductance L_2 and L_3, a capacitor C_1 and a diode D. A separate DC supply is given to the clamp circuit which clamps the input DC voltage to the required level for the three phase inverter. The pulses for the three phase inverter are obtained from 8096 microcontroller. The resonant circuit will provide the Zero voltage instant for all inverter switches using single resonant switch S_{r1} whose resonant frequency is about 21.936KHZ in order to ensure soft switching. The three phase inverter will convert the dc supply into ac supply which is given to the load (three phase induction motor or resistive load).

In this paper three phase induction motor of 0.5HP, 2800 rpm, 1.05Amps, 400v and three star connected resistance of about 1.2 kilo ohm is considered as load.

Simulation of Zero Voltage Switching for Pwm Inverter Using Quasi-resonant Circuit: Initially the resonant switch S_{r1} is in off state at that time the voltage across the capacitor is $V_k = V_S + V_C$ which is the total input source voltage. The resonant cycle of the Quasi-Resonant inverter begins with the switching ON of the resonant switch S_{r1}. This initiates the resonance between L_1, L_2 and C_1. The capacitor discharges to zero by transferring its stored energy to L_2. Reverse charging of C_1 is blocked by the anti-parallel diodes of the inverter devices. The dc-link voltage remains zero till S_{r1} is ON. During this period inverter devices can be switched ON or OFF under ZV condition. When S_{r1} is turned OFF under ZV condition, the energy stored in L_2 is transferred to L_3 which recharges the capacitor C_1 to a value determined by the clamp circuit. This process is done by applying high frequency of about 21.936 Khz to the resonant switch
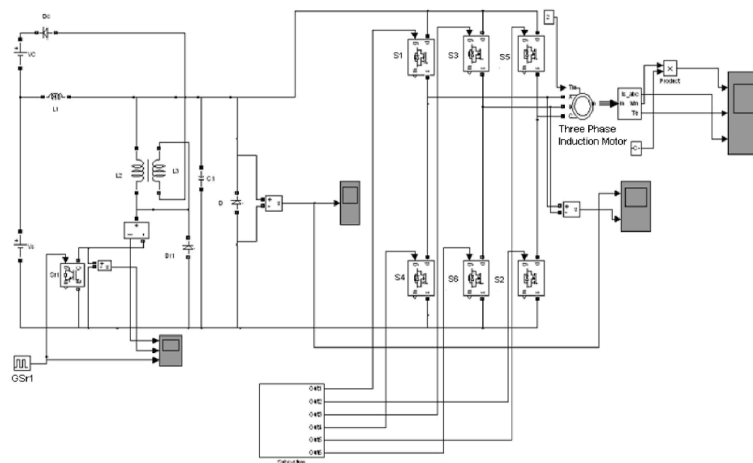

Fig. 2: Simulation Diagram for Zero Voltage Switching for pwm inverter using quasi-resonant circuit

inorder to ensure soft switching for the three phase inverter. So that switching losses, power losses, conduction losses, voltage stress, harmonics and EMI gets minimized.

RESULTS

Fig 3 to 8 shows the simulation result for Zero Voltage Switching for pwm Inverter using Quasi-Resonant circuit with Three Phase Induction motor (load). The voltage across the capacitor is shown Fig 3 which is given as the input to three phase inverter and the desired ac output voltage is obtained and it is shown in Fig 4. Fig 5 shows the Zero Voltage Switching for three phase inverter. These results shows that the voltage stress of the inverter gets reduced and the soft switching for three phase inverter has also been achieved, thereby the aim of my paper is satisfied. The output current, speed and torque of three phase inverter are shown in Fig 6, 7 and 8.

Detailed MATLAB simulation studies are carried out to verify the analysis and to predict the performance of the Quasi-Resonant and the three phase inverter.

Hardware Implementation and Results: In order to validate the simulated results, a laboratory prototype was built and tested. The circuit and supply parameters used for experimental investigations are: V_s=12V, V_c=13V, L_1=1177 ~ H, L_2=66.7 ~ H, L_3=5.5 ~ H, C_1=31.8nF and K_M=0.89. Implementation of Zero Voltage Switching for pwm Inverter using Quasi-Resonant circuit is shown in Fig 9. Fig 10 shows the Zero Voltage Switching for Quasi-Resonant circuit. Fig 11 and 12 shows the phase and line voltages of the three phase inverter.
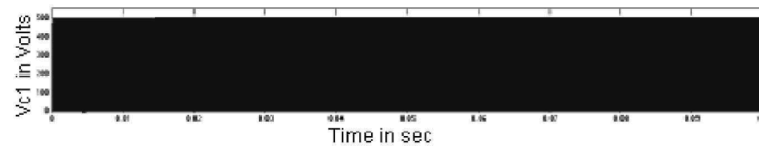

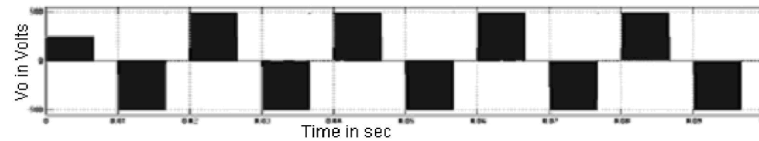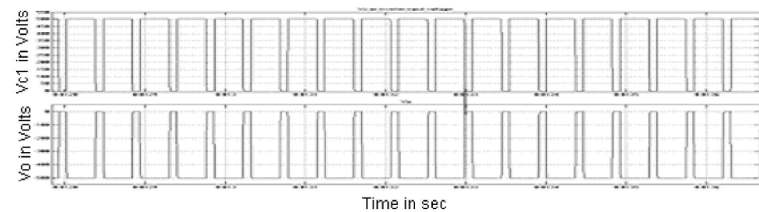Fig. 3: VC1 or inverter input voltage

Fig. 4: Output Voltage (Volt)

Fig. 5: Zero Voltage switching for three phase inverter
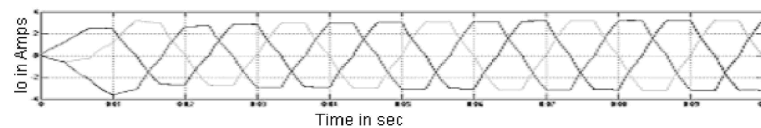

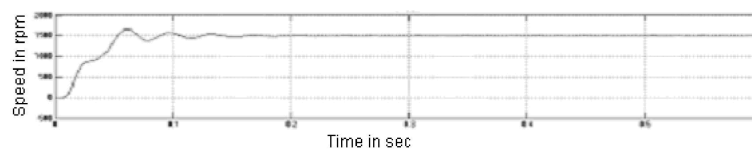
Fig. 6: Output Current (Amps)
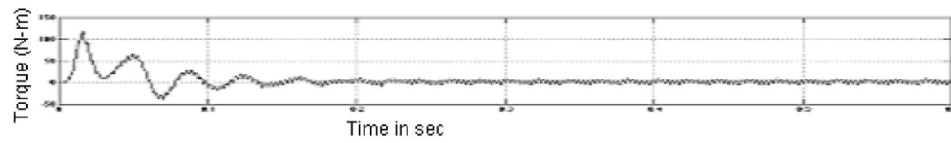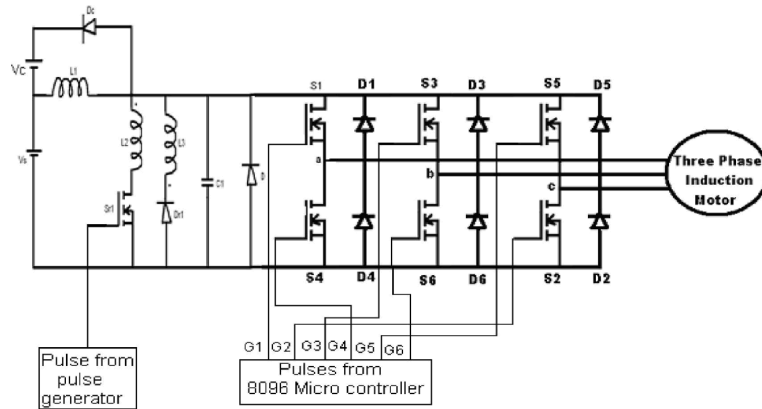

Fig. 7: Speed (rpm)

Fig. 8: Torque (N-m)

Fig. 9: Zero Voltage Switching for pwm inverter using quasi-resonant circuit
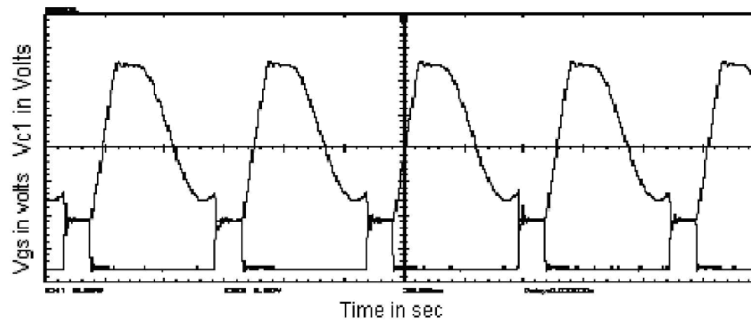

Fig. 10: Voltage across the capacitor VC1 with Clamp circuit and Vgs of Sr1(Zero Voltage Switching)
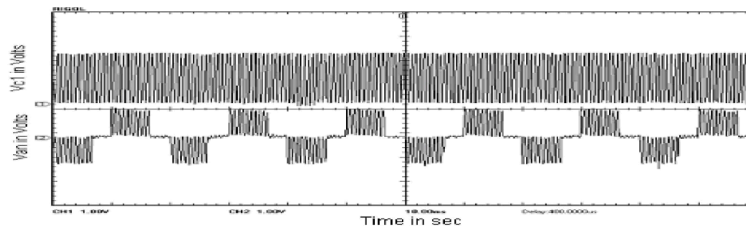

Fig. 11: Voltage across the capacitor, Vc1 and Phase Voltage Van of the three phase inverter
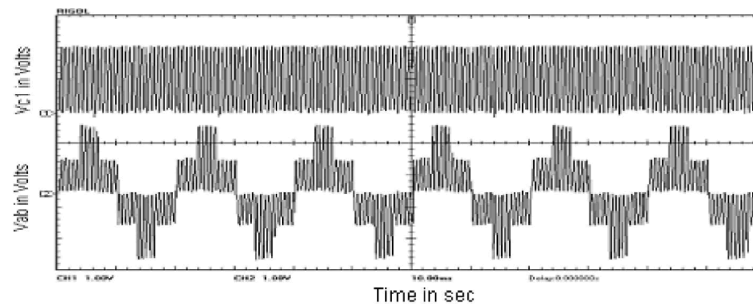

Fig. 12: Voltage across the capacitor, Vc1 and Line-line voltage, Vab of the three phase inverter
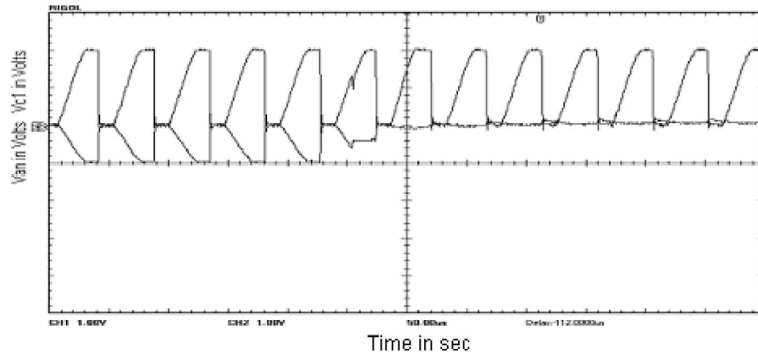
Fig. 13: Zero voltage switching for the three phase inverter

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