

Simulation and Implementation of Quasi Resonant DC-DC Converter

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Abstract: Problem statement: A half-bridge LLC resonant converter with a voltage doubler rectifier has a simple structure and its Zero-Voltage-Switching (ZVS) capability is excellent from zero to full load condition. But conduction loss is more due to high circulating energy thus reducing the system efficiency. Moreover a variable frequency control method makes the control circuits more complicated than those using the Pulse Width Modulation (PWM) control method. Thus, DC drive has lower efficiency when it operates on light loads. **Approach:** To improve the efficiency of the DC drive under light loads, a PWM-controlled quasi-resonant converter is proposed. It has simple control circuits and less conduction loss compared to a half-bridge LLC resonant converter under light load conditions. The proposed converter has a half-bridge LLC resonant converter along with an auxiliary circuit. The load regulation of the proposed converter can be achieved by an auxiliary circuit. Thus the proposed converter is expected to be suitable sustaining power module for the efficiency enhancement of DC drives. As the magnetizing inductance of the proposed converter is larger the circulating energy is considerably reduced under light load conditions. In this study the operational principle, design and modeling of QRC DC-DC converters for DC drives are presented. The PWM controlled quasi resonant converter is implemented using PIC microcontroller 16F184A. **Results:** The capacitor filter in the output is replaced by pi filter to produce DC with minimum ripple. The experimental results and simulation results are compared. This converter has the advantages like reduced number of switches, reduced transformer and filter size, reduced ripple, reduced switching losses, reduced switching stresses and increased power density. **Conclusion:** The experimental results closely agree with the simulation results.

Key words: Zero voltage switching, DC to DC converter, PIC microcontroller, pulse width modulation

INTRODUCTION

For the DC motors operating in the textile mills high efficiency is needed primarily under light load conditions. Resonant converters have miniaturization, high efficiency and low noise (Xie *et al.*, 2007; Xu *et al.*, 2006) but a large variation in switching frequency is needed to control the output voltage. These converters have size reduction and noise problems (Zhang *et al.*, 2006; Eid *et al.*, 2006; Fathy *et al.*, 2006; Yao *et al.*, 2004; Singh *et al.*, 2002; Y. Ren *et al.*, 2003; Singh *et al.*, 2002). A half-bridge LLC resonant converter has many improvements over previous topologies (Hu *et al.*, 2005; Yang *et al.*, 2002). In the case of light load conditions, high circulating energy and variable frequency control method reduces the system efficiency. Thus, the PDP (Han *et al.*, 2006;

Lee, 2007; 2008; Han *et al.*, 2002) has lower efficiency. (Webber, 2004). In case of DC drives when they operate on light loads efficiency is very low. In order to improve the efficiency under light loads a PWM-controlled quasi-resonant converter is proposed which has simpler control circuits and less conduction loss (Xie *et al.*, 2007; Xu *et al.*, 2006) compared to a half-bridge LLC resonant converter under light load conditions. The circuit diagram of proposed converter is shown in Fig. 1. In this proposed converter the bidirectional auxiliary circuit consists of a two auxiliary MOSFETs A_1 and A_2 , auxiliary inductor L_A and auxiliary capacitor C_A . The main circuit consists of two main MOSFETs Q_1 and Q_2 . A transformer is used for isolation as well as to step down the voltage. The secondary side consists of a full wave uncontrolled rectifier with a voltage doubler circuit.

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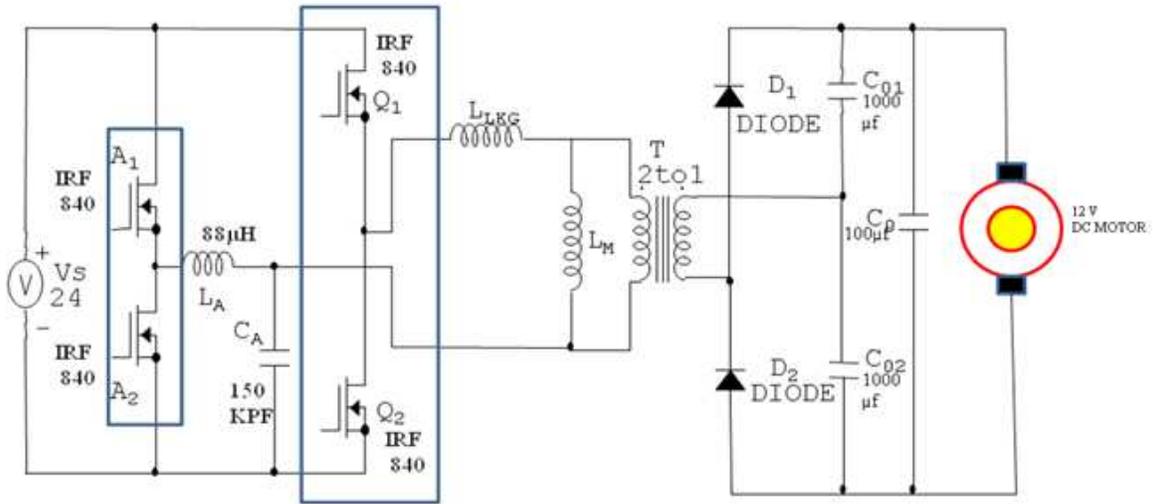
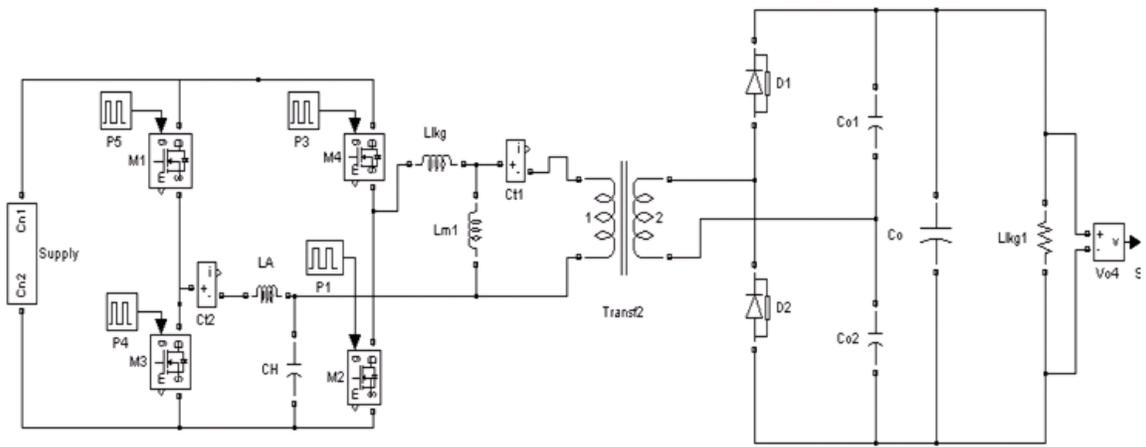
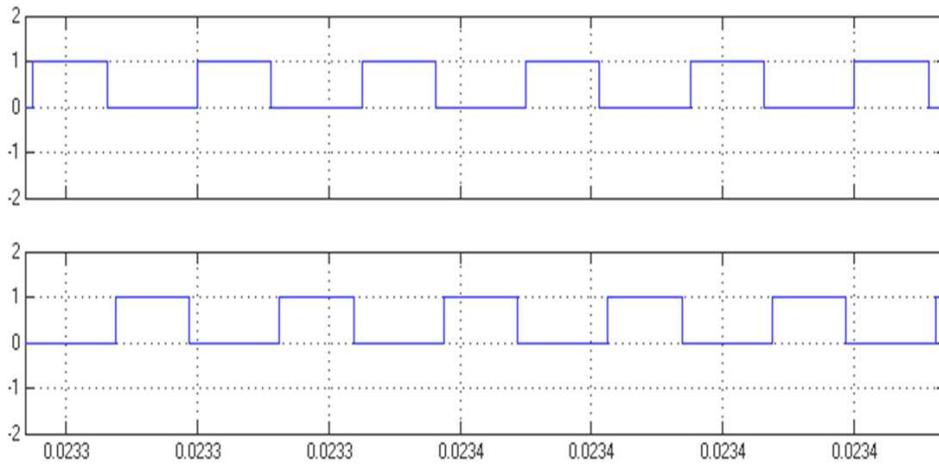


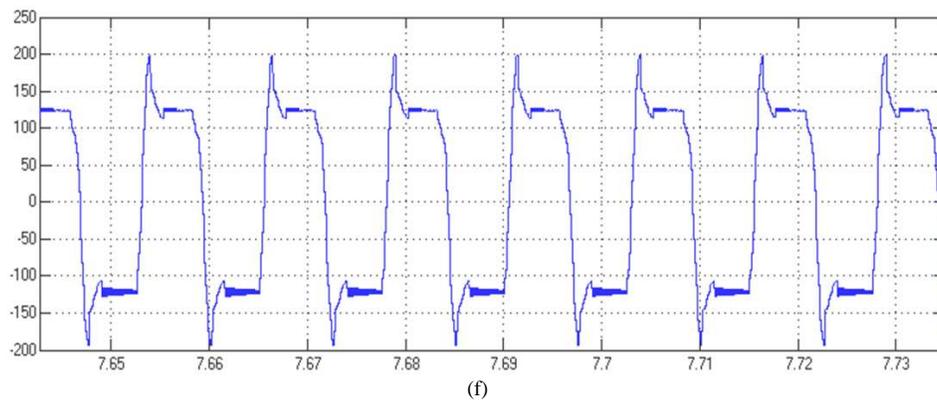
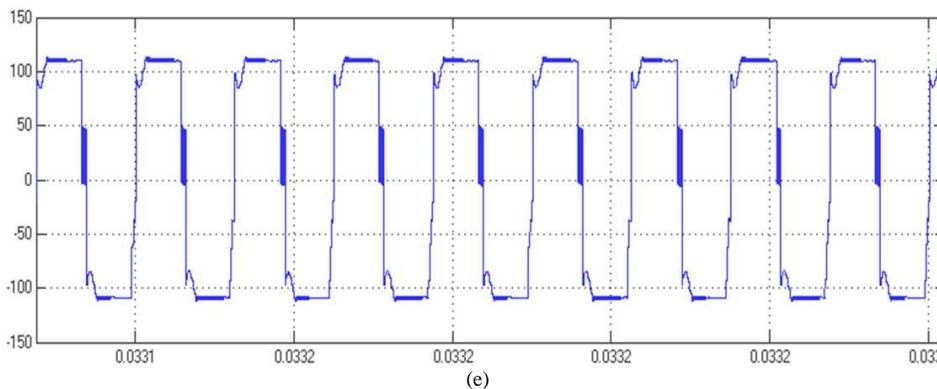
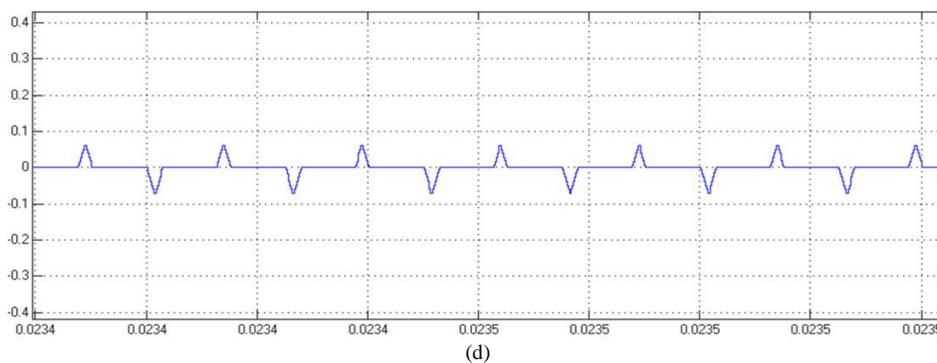
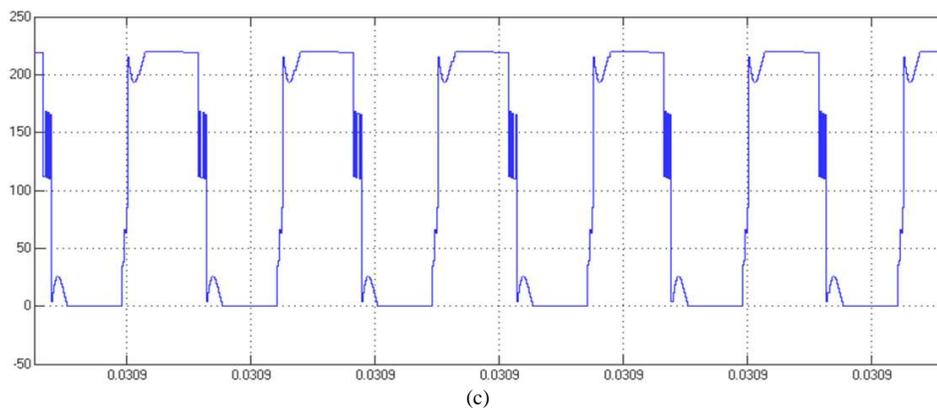
Fig. 1: Proposed PWM Controlled Quasi Resonant DC-DC Converter for DC drives under light load



(a)

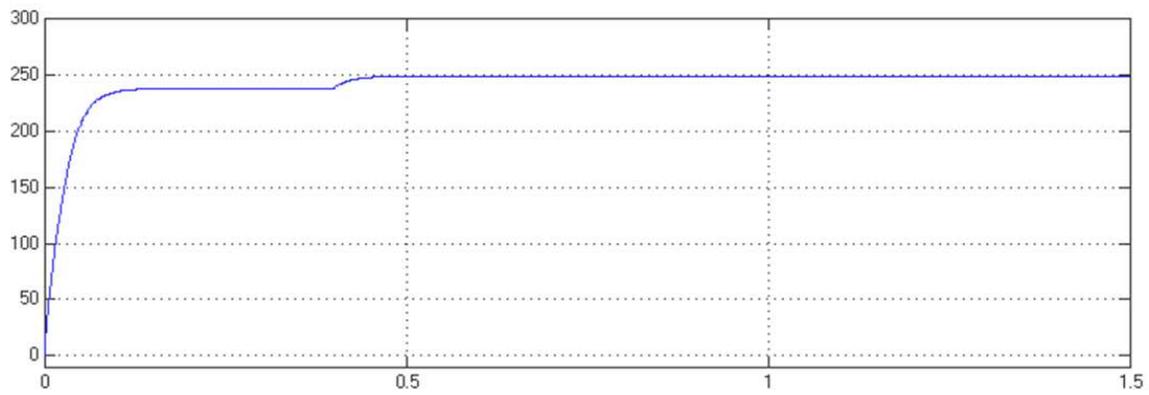


(b)

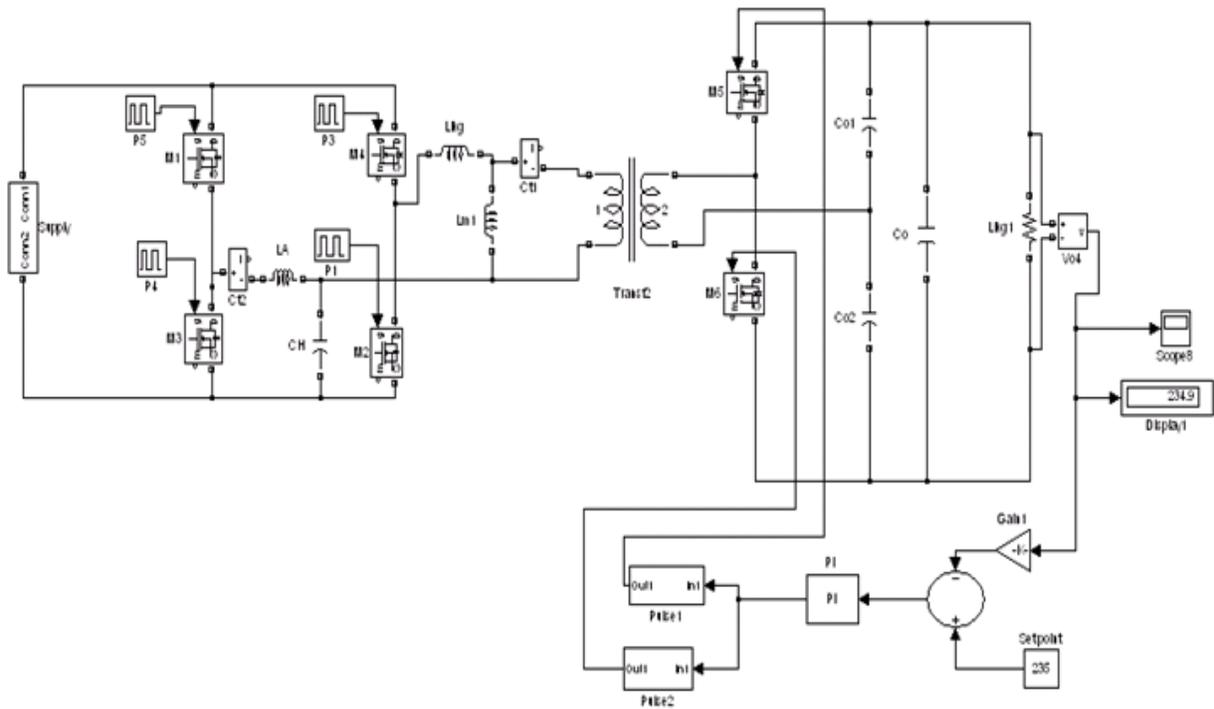




(g)



(h)



(i)

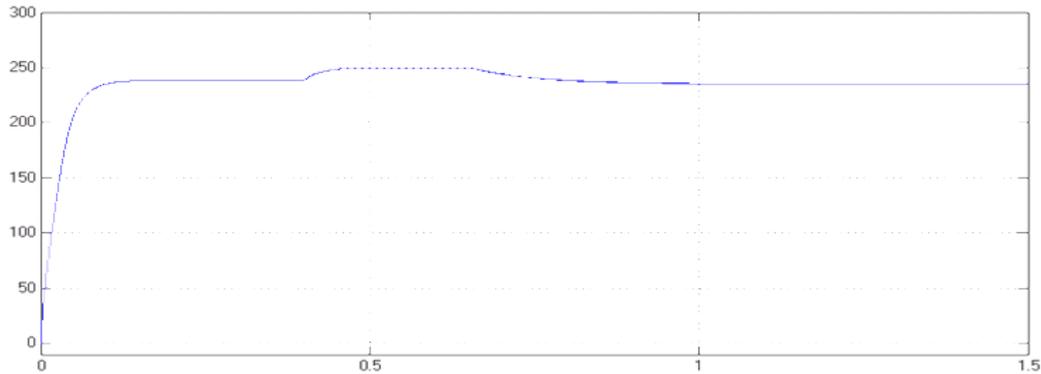


Fig. 2:(a) Open Loop Controlled DC to DC Converter (b) Driving pulses for M2 and M4 (c) Voltage across M4 switch. (d) Current through La inductor (e) Transformer primary side voltage (f) Transformer secondary side voltage (g) Input voltage with disturbance. (h) Output voltage with disturbance (i) Closed loop circuit model (j) Dc output voltage with disturbance

Due to the large inductance, the ZVS of Q_1 and Q_2 is easily achieved even at light load conditions. When the DC motor is operating on light loads, high efficiency is needed in some industrial application. The circulating energy of the proposed converter is considerably reduced under light load conditions. In the proposed converter, the output voltage can be regulated by controlling the voltage across the primary resonant capacitor while two main switches are operating at a fixed duty ratio and fixed switching frequency.

Simulation results: Digital simulation is done using Matlab and the results are presented here. Open loop controlled DC to DC converter is shown in Fig. 2a. Driving pulses for M2 and M4 is shown in Fig. 2b. Voltage across M4 switch is shown in Fig. 2c.

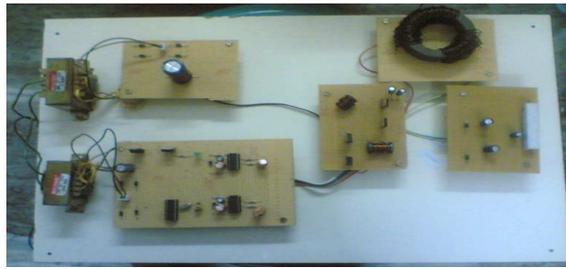
Current through La inductor is shown in Fig. 2d. Transformer primary side voltage is shown in Fig. 2e. Transformer secondary side voltage is shown in Fig. 2f. Input voltage with a step disturbance is shown in Fig. 2g. Output voltage with a step disturbance is shown in Fig. 2h. The output voltage increases with the increase in the input voltage. When the input voltage was disturbed and increased at 0.4 sec., the output voltage also increased from 240 V to 250V at 0.4 sec and settles at 250V. In order to maintain the required output level irrespective of supply disturbances, closed control is required. The simulink model of closed loop system is shown in Fig. 2i. Output voltage is sensed and it is compared with the reference voltage. The error is processed through a PI controller. A controlled rectifier is recommended at the output to regulate the output voltage. When the output voltage increases, the error increases and the pulse width applied to the MOSFETs of the rectifier decreases to maintain the output voltage

constant. There is a step rise in the input. In order to regulate the output, controlled switches M5 and M6 are used in the secondary side of the transformer instead of diodes. The output voltage is measured and compared with the reference value and the error signal is fed to PI controller. The control signal obtained from the PI controller circuit is fed to PWM controller circuit which generates the required driving pulses for the MOSFETs M5 and M6. By PWM control of M5 and M6 the output voltage can be maintained at the required level. The output voltage in closed loop control is shown in Fig. 2j. As observed from Fig. 2j.

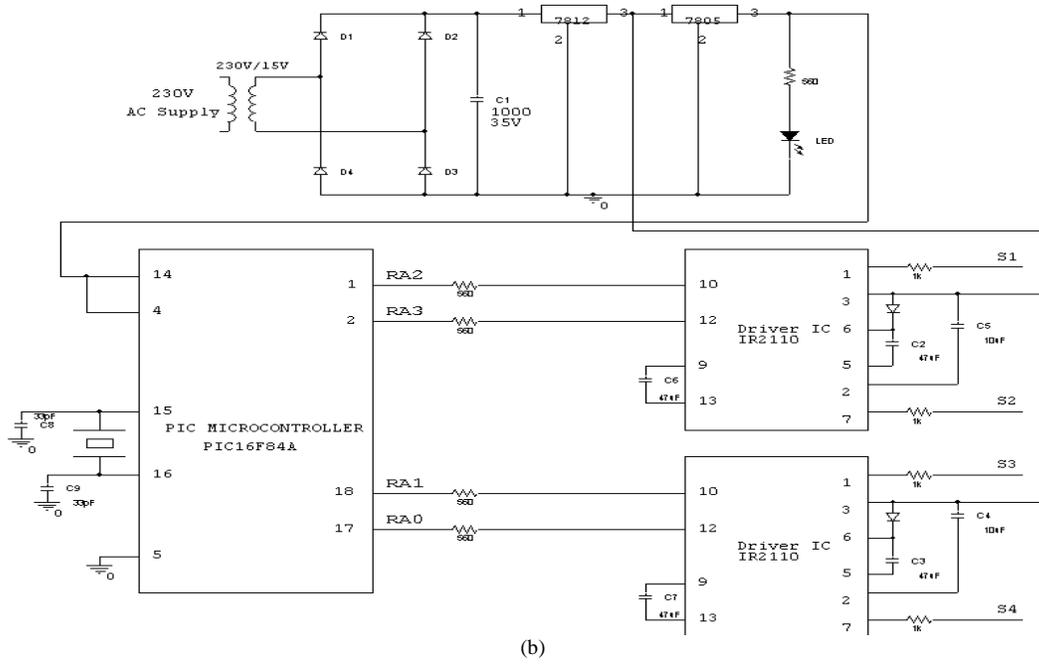
In closed loop control, whenever the input voltage is increases, the output voltage also slightly rises but comes back to the original value 240 V at 0.65 Sec. Therefore the output voltage is maintained constant irrespective of changes in the supply voltage. The output voltage reduces to the steady state value. Thus the steady state error is reduced by using closed loop system.

Hardware implementation: In order to verify the effectiveness of the proposed converter configuration and its control strategy, a cost effective new PWM controlled quasi resonant converter has been developed, simulated and successful implemented in real time in open loop using PIC 16F877A Micro controller for a prototype.

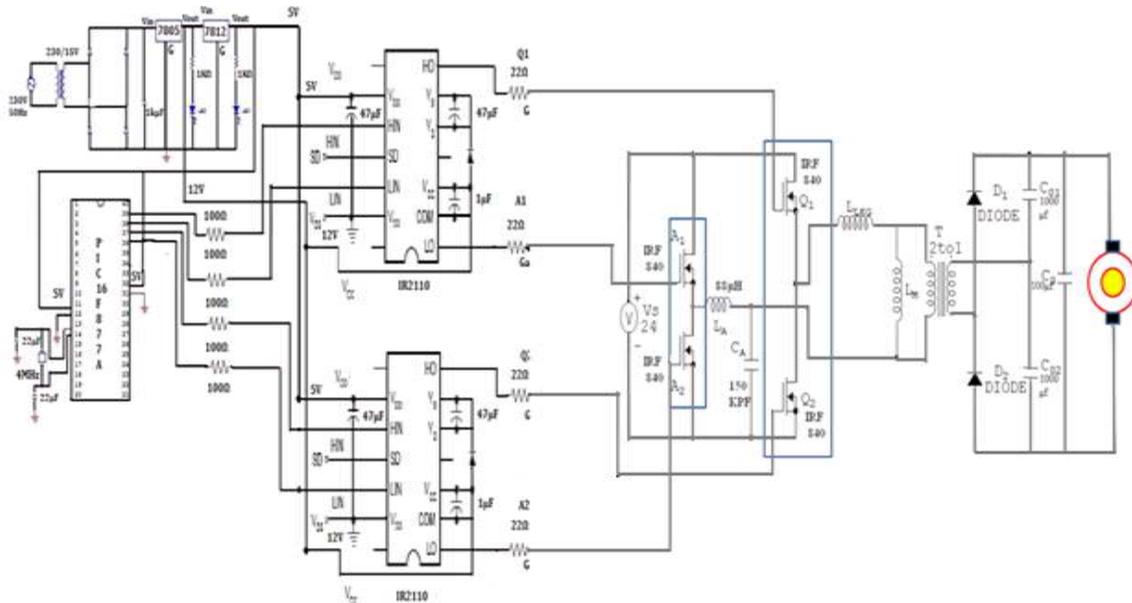
The hardware for PWM-controlled Quasi resonant converter is fabricated and tested in the laboratories. The overview of hardware model is shown in Fig. 3a. Control circuit is shown in Fig. 3b. The complete hardware model is shown in Fig 3c. The voltage across the MOSFET is shown in Fig. 3d. Transformer primary side voltage is shown in Fig 3e. The output waveform is complement of the driving pulse. The voltage across the secondary is shown in Fig. 3f. DC output voltage is shown in Fig. 3g.



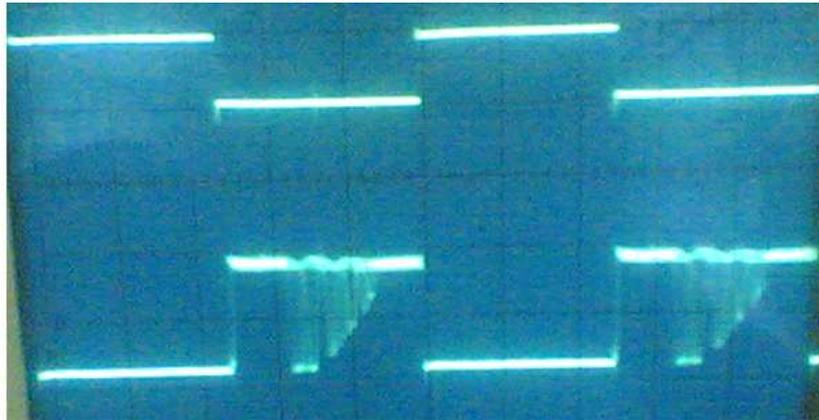
(a)



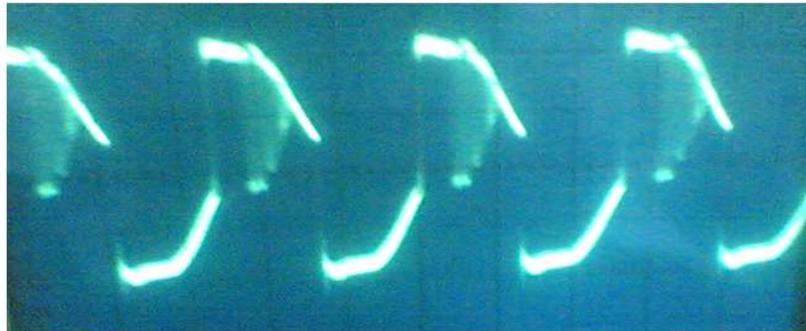
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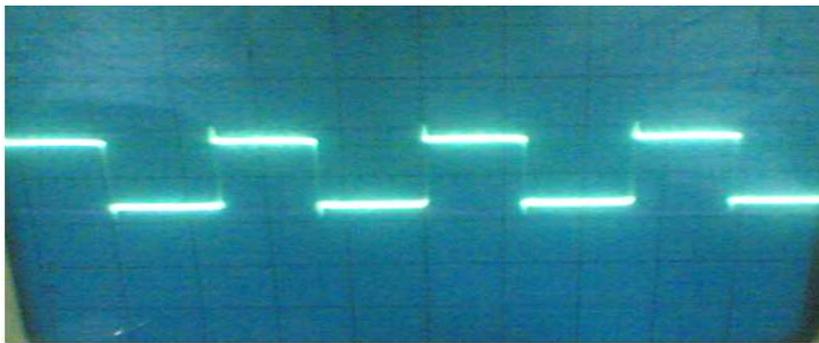
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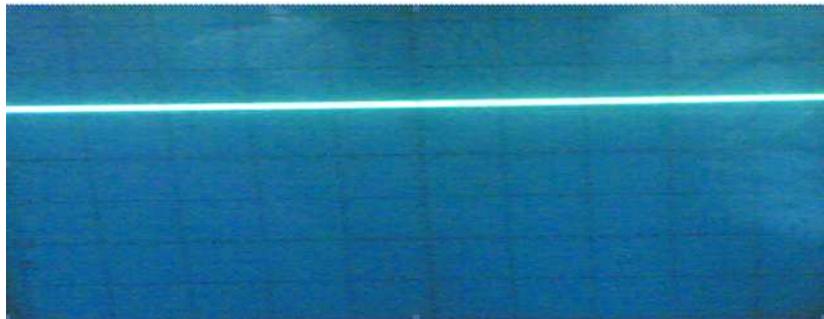
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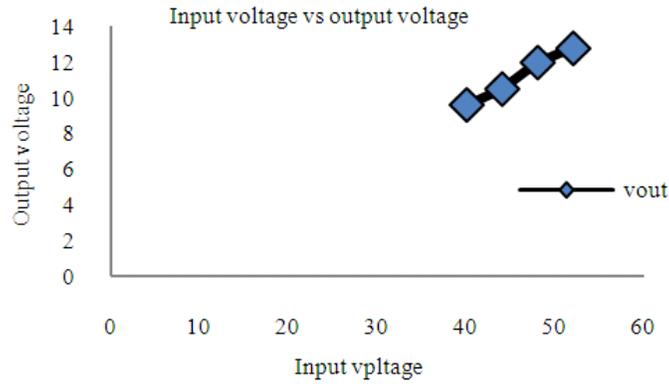
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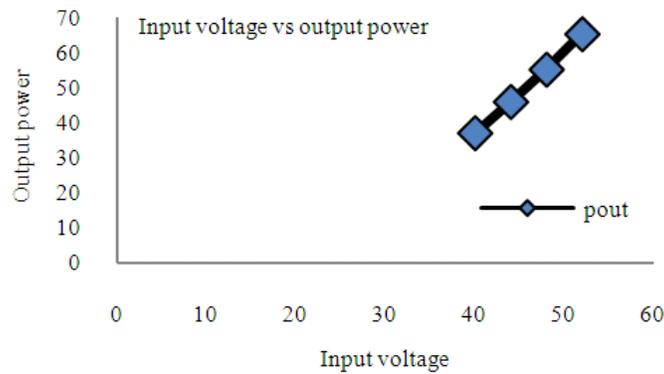
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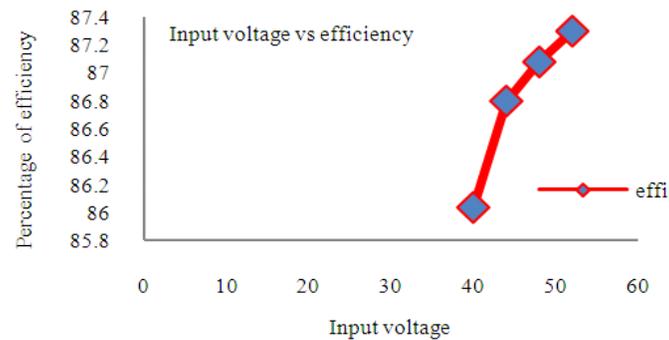
(g)



(h)



(i)



(j)

Fig. 3:(a) Overview of Hardware kit (b) Control circuit (c) Complete hardware diagram (d) Vgs and Vds voltage (e) Transformer primary side voltage (f) Transformer secondary side voltage (g) Output voltage (h) Input voltage Vs Output voltage (i) Input voltage Vs Output power (j) Input voltage Vs Efficiency

It can be seen that the DC output voltage is free from ripple. Input voltage Vs Output voltage characteristics are shown in Fig. 3h. Input voltage Vs Output Power characteristics are shown in Fig. 3i. Input voltage Vs Efficiency is shown in Fig. 3j. From the simulation results and oscillograms of the experimental results it can be seen that the experimental results coincide with the simulation results.

Figure 3a shows the overview of the hardware kit, which consists of the input diode rectifier, half bridge LLC resonant converter with auxiliary circuit, high frequency transformer and output rectifier with voltage doublers shows the input diode rectifier, filter capacitor, voltage regulators, PIC 16F877A microcontroller and IR 2110 drivers. Table 1 shows hardware components of power circuit.

Table 1: Hardware components of power circuit

Name of the components	Product no/value	Quantity
Q ₁ and Q ₂	IRF840	2
Q _{A1} and Q _{A2}	IRF840	2
Auxillary inductor	88mf	1
Auxillary capacitor	150Kpf	1
Driver	IR2110	2
Voltage regulator	7812 and 7805	2
Transformer	2:1 isolation type	1
Capacitors	1000mF	2

CONCLUSION

The PWM controlled Quasi resonant DC-DC converter for an efficiency enhancement of a DC motor is simulated using matlab simulink and implemented using PIC microcontroller 16F184A. The capacitor filter in the output is replaced by pi filter to produce DC with minimum ripple. This converter has the advantages like reduced number of switches, reduced transformer and filter size, reduced ripple, reduced switching losses, reduced switching stresses and increased power density.

The scope of this study is the simulation and implementation of quasi resonant DC-DC converter using PIC microcontroller. The experimental results closely agree with the simulation results. The efficiency of DC drive under light load conditions is improved.

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