PI Controller Based New Soft-Switching Boost Converter With A Coupled Inductor

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Abstract— Novel full bridge DC-DC boost converters is mainly used in research applications, where the output voltage is measurably higher than the source voltage. In this project designing of a new topology of a non isolated boost converter with zero voltage switching control technique is discussed. To achieve ZVS condition the auxiliary circuit has a coupled inductor and a diode. The advantages of the ZVS are reverse recovery problem of MOSFET anti parallel body diodes are resolved and also the voltage and current stress on the switch components are reduced. This topology has a light weight and cost less. This technique will reduce the switching losses and improve the efficiency by ZVS technique, but it does not improve the turn-off switching losses by a ZCS technique. In this topology have two operational conditions depending on the situation of the duty cycle. The detailed operating analysis of the proposed converter and the design method of the main circuit are presented. To improve the effectiveness and feasibility of the proposed boost converter PI controller is used. Here microcontroller is used in the proposed topology.

Keywords*- Boost converter, Zero- voltage switching (ZVS), PI Controller, Zero-current switching, MOSET, Microcontroller***.**

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I. INTRODUCTION

A boost converter is a DC-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors, one energy storage element, a capacitor and inductor or the two in combination. Filters made of capacitors are normally added to the output of the converter to reduce output voltage ripple. Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is sometimes called a step-up converter since it steps up the source voltage, soft switching can mitigate some of the mechanisms of switching loss and possibly reduce the generation of EMI, semiconductor devices are switched on or off at the zero crossing of their voltage or current waveforms. Zero-current switching is a transistor turn-off transition occurs at zero current. Zero-current switching eliminates the switching loss caused by IGBT current tailing and by stray inductances. It can also be used to commutate SCR's. Zero-voltage switching transistor turn-on transition occurs at zero voltage. Diodes may also operate with zero-voltage switching. Zero-voltage switching eliminates the switching loss induced by diode stored charge and device output capacitances. Zero-voltage switching is usually preferred in modern converters. Zero-voltage transition converters are modified PWM converters, in which an inductor charges and discharges the device capacitances.

Coupled inductor is electronic components that regulate and distribute the signal they receive, and make sure it reaches its intended destination in a steady flow. To achieve this, they store energy in magnetic fields. If a person deliberately brings the magnetic field of two inductors attached to two different circuits together, the inductors can transfer energy from one to the other through their magnetic fields. When inductors are used like this they are called a coupled inductor. This energy transfer between a coupled inductor allows people to charge mobile devices like phones, music players, and other small devices with rechargeable batteries. Increasing magnetic field strength increases the amount of energy that can be transferred. This can be accomplished by increasing the number of coils in the inductors, increasing the overall size of the coils, and adding a metal core to the coils. Usually a core made of iron. To control the amount of energy that inductors send to electronics, switches are used. These quickly alternate on and off, stopping the flow of electricity into inductors and allowing it to be stored in a magnetic field for brief amounts of time. More electricity is lost the longer it is stored, so the longer a switch is off the lower the amount of power is being supplied. This is known as the switch frequency and it is customized to meet the needs of specific electronics.

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II. SOFT-SWITCHING SCHEME

Switching transitions occur under favorable conditions i.e., device voltage or current is zero. The advantage of soft-switching are reduced switching losses, switching stress, possibly low EMI, easier thermal management and must be very high frequency operation (also medium frequency at high power levels) usually involves compromises in conduction loss, switching rating passive components etc. it has two types of switching, zero current switching and zero voltage switching.

Zero Voltage Switching means that the power to the load (heater or cooler or other device) is switched on or off only when the output voltage is zero volts. Zero Voltage Switching can extend the life of a controller and of the load being controlled. Controllers with Zero Voltage Switching use TRIACS instead of mechanical relays, and, in fact, all of our temperature controllers which use a triac are inherently Zero Voltage Switching. With AC current the voltage is zero 50 to 60 times a second. For example, with 120VAC at 60 Hz the voltage swings from 0V-120V and to 0 V to +120 volts and back to 0 volts 60 times a second. The controller only turns the power to the load on or off when the voltage is zero. (Since the cycle described above repeats itself, there are, at 60 Hz, 120 times every second that the AC voltage is at zero volts and power switching can occur.) With DC power, as used with thermoelectric controllers, the DC voltage is first converted by the controller to DC PWM (Pulse Width Modulated). The lowest voltage of these DC pulses is zero, and so this power source for a load can also be switched on or off when the voltage is zero. The frequency of these pulses is high enough that a peltier device considers the DC PWM power to be simple DC power, and so pulsing the voltage in this way does not harm a peltier device. Zero Voltage Switching has an advantage over the kind of switching that would normally be accomplished with a relay because there is a reduced chance for arcing. A relay could turn the power on when the voltage is, say, 120VAC, and an electrical arc (spark) could result.

Specifically means zero-current turn-off, i.e., the current flowing through the device is reduced to zero before the voltage increases. In ZCS the switch is required to conduct a peak current that is higher than the load current, I_0 must not exceed V_d / Z_0 therefore, there is a limit on how low the load resistance can become. By placing a diode in anti parallel with the switch, the output voltage can be made insensitive to load variation.

III CONVENTIONAL ZVS BOOST CONVERTER TOPOLOGY

Super abundant auxiliary components, complex control methods, as well as possible high voltage and current stresses, a simple new ZVS boost converter topology based on the coupled inductor is proposed, which just needs an auxiliary winding and a diode compared with the conventional synchronous boost converter.

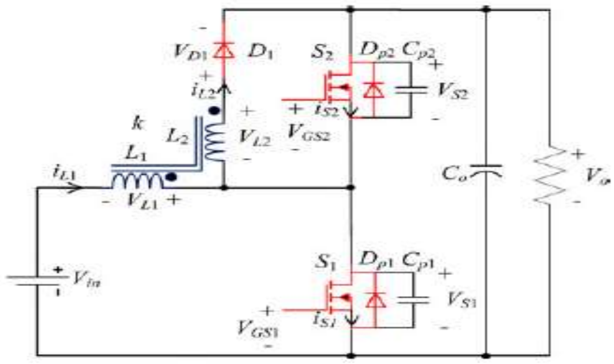

Figure.1 ZVS Boost Converter Topology

Soft-switching boost converter topology is Shows in Figure 1. Two inductors are coupled with the same magnetic core to reduce the iron core loss, size, and cost of the converter. In addition, the auxiliary winding in the coupled inductor can help implement ZVS conditions as mentioned above. The control method is the same as that of conventional pulse width-modulated (PWM) controllers. The main MOSFETs can operate under ZVS conditions in all load conditions, and the auxiliary diode operates with a ZCS condition Inductors L_1 and L_2 are coupled on the same ferrite core and the leakage inductance exists which has an important role in achieving ZVS conditions. L_1 is the main Inductor, and L_2 is the auxiliary coupled inductor. K is the coupling coefficient. S_1 and S_2 are the main power switches. cp_1 and cp_2 are the snubber capacitors of S_1 and S_2, respectively, and they include the parasitic output capacitances.Dp_1 and Dp_2 represent the intrinsic anti parallel body diodes of S_1 and S_2 respectively.

IV. ZVS CONVERTER WITH CLOSED LOOP SYSTEM

The basic circuit of the microcontroller consists of a power supply unit, External Crystal oscillator and a reset circuitry. The power supply consists of a voltage regulator which is used to regulate the voltage to a fixed voltage of 5v. Normally 7805 voltage regulators are used for this purpose. Normally the crystal oscillators provided with the microcontrollers are of 16MHz and to 22pf capacitors are used with the microcontroller as decoupling capacitors for decreasing the noise. The reset circuitry used here consist of a switch and a resistor normally a HIGH signal is present in the mCLR pin of the microcontroller when the switch is pressed a LOW presents at the pin and microcontroller gets reset and as there is a resistor provided in circuit the Vcc and ground never get direct short while resetting.

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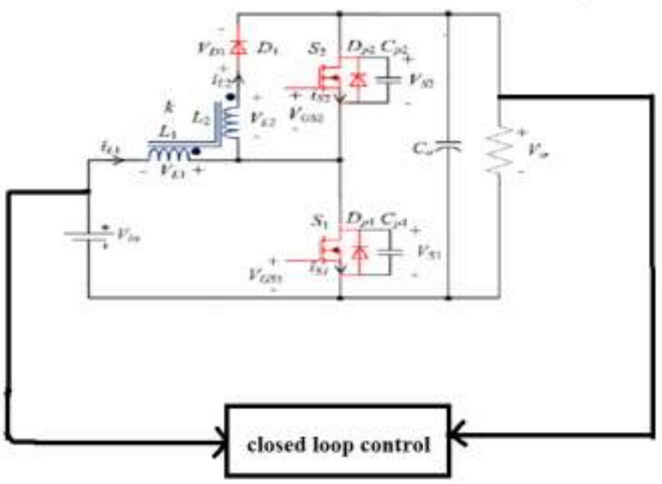

Figure .2 ZVS Boost Converter with Closed Loop System

The microcontrollers consist of an internal ADC module this ADC module is used to convert the ADC reading from the sensor to a digital value. The ADC provided with microcontroller is of 10 bit resolution. This reads value from 0-1023.The Devices which output the analog variation can communicate with controller using this module. The Optocoupler is device acting as interface between microcontroller and switch the switching pulses are feed to MOSFET through opt coupler. Optocoupler provide unidirectional signal flow. The voltage to switch are given across Vgs, Optocoupler also has isolated supply for operation.

V. SIMULATION ANALYSIS

The modified closed loop system using zero voltage switching with PI control scheme is simulated in the MATLAB. MATLAB is a high performance language for technical computing. It integrates computation, visualization, and programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation. Simulink, developed by Math Works, is a graphical programming environment for modeling, simulating and analyzing multi domain dynamic systems which is used for simulating the boost converters . Following are the simulation models for both existing and proposed boost converter.

A. Simulation Model Of ZVS Boost Converter With PI Controller

Figure.3 shows the simulation model of ZVS Boost Converter Topology with Arduino micro controller. Here input voltage is 40V and outputs gets from the converter is 140V. It consist of two switches are S_1 and S_2.

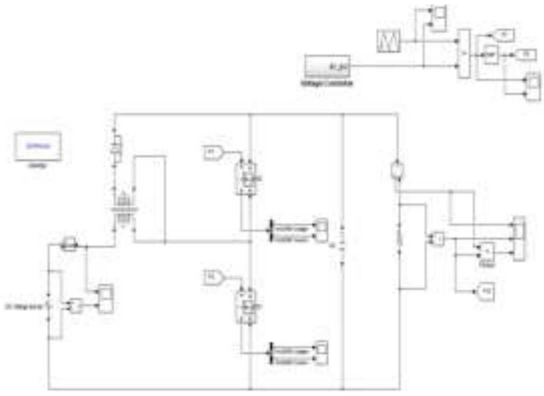

Figure 3. Simulation Model of ZVS Boost Converter with PI Controller

In the simulation model we are using transformer instead of coupled inductor. A voltage controller is used to generate the gating pulses to the switches. Here the output voltage is compared with high frequency triangular wave. The generated pulses are being fed to the switch S_1 and negated gate pulse is given to switch S_2.It consist of dc source, coupled inductor, MOSFET switches, voltage controller, resistor, capacitor etc. In the simulation model we are using transformer instead of coupled inductor. A voltage controller is used to generate the gating pulses to the switches. Here the output voltage is compared with high frequency triangular wave. The generated pulses are being fed to the switch S_1 and negated gate pulse is given to switch S_2.It consist of dc source, coupled inductor, MOSFET switches, voltage controller, resistor, capacitor etc.

B. Simulation Results

The Figure 4 shows the input voltage waveform of the ZVS boost converter with pi controller . Here DC source is used as the input to the system and the input voltage is given as 40V.

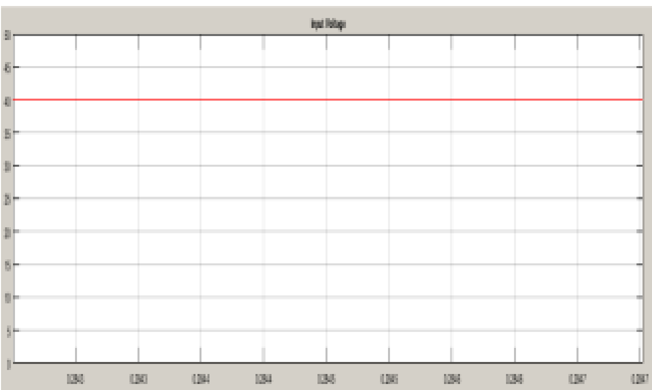

Figure 4. Input Voltage

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The Figure 5 shows the input inductor current waveform of the ZVS Boost Converter with PI Controller. Here the input inductor current is given as 42.5A. This input current waveform is obtained by comparing the output of the voltage controller with the high frequency triangular carrier wave.

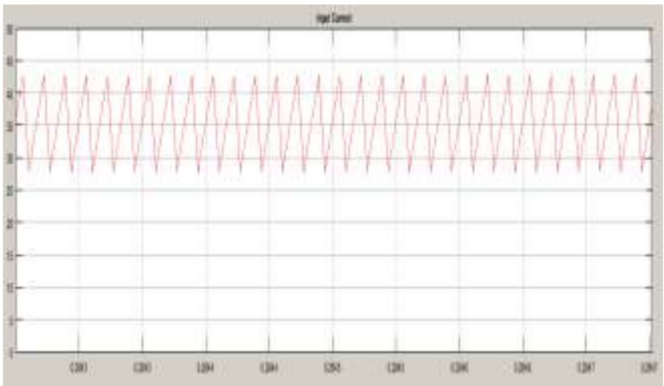

Figure 5.Input Current Wave Form

The Figure .6 shows the output current waveform of the overall ZVS Boost Converter System with PI Controller. Here DC source is used as the input to the system and the input voltage is given as 40V. The obtained output current is measured as 11.8A.

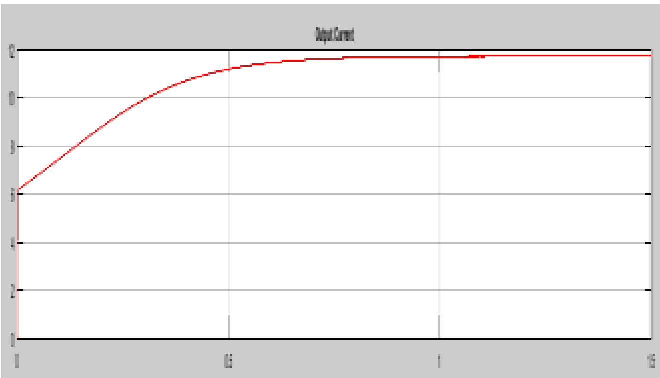

Figure.6 Output Current Wave Form

The Figure 7 shows the output voltage waveform of the overall system. Here DC source is used as the input to the system and the input voltage is given as 40V. The obtained output voltage is measured as 150V.

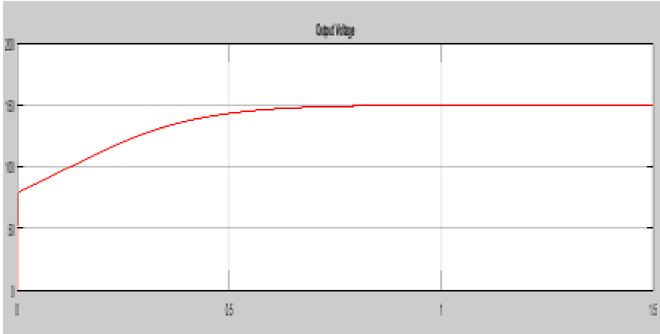

Figure .7 output voltage waveform

VI. HARDWARE IMPLEMENTATION

The ZVS boost converter is developed using the controller ATMEGA328. The hardware implementation of the circuit is explained. The circuit parameters were according to the circuit requirement and the prototype is created with the parameters for observations

A. System Overview

The basic circuit of the microcontroller consists of a power supply unit, External crystal oscillator and a reset circuitry. The power supply consists of a voltage regulator which is used to regulate to a fixed voltage of 5V. Normally 7805 voltage regulator is used for this topology. Normally the crystal oscillators provided with the microcontroller are of 16MHz and to 22pF capacitor are used with the microcontroller as decoupling capacitors for decreasing the noise. The reset circuitry used here consists of a switch and a resistor normally a HIGH signal is present in the microcontroller. when the switch is pressed a LOW presents at the pin and microcontroller gets reset and a there is a resistor provided in the circuit the V_{cc} and ground never get direct short while resetting. The microcontroller consist of an internal ADC module is used to converter the ADC reading from the sensor to a digital value. The ADC provided with microcontroller is of 10 bits resolution. Reads value from 0-1023.The device which output the analog variation can communicate with the controller using this module. It consists of driver circuit. This driver circuits have divide into two parts one is photo diode and other one is photo transmitter. The photo diode can emits get the 5V from the microcontroller and given to the corresponding MOSFET switching.

B. Experimental Setup

The reset circuitry used here consist of a switch and a resistor normally a HIGH signal is present in the mCLR pin of the microcontroller when the switch is pressed a LOW presents at the pin and microcontroller gets reset and as there is a resistor provided in circuit the Vcc and Ground never get direct short while resetting. The microcontroller consists of an internal ADC module this ADC module is used to convert the

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ADC reading from the sensor to a digital value. The ADC provided with microcontroller is of 10 bit resolution. This reads value from 0-1023. The Devices which output the analog variation can communicate with controller using this module.

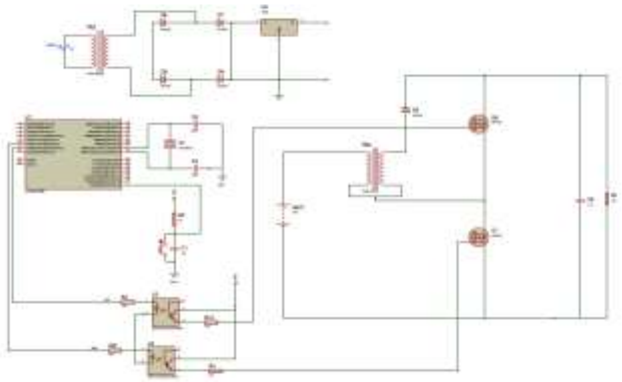

Figure.8 Circuit Diagram of Controller Board

Figure .9 Experimental Setup

The figure.9 is shown in experimental setup of the system and the hardware section of the system consists of power supply, driver circuit, control unit with microcontroller ATMEGA328.Here the microcontroller produces the switching pulses. Here the input voltage applied is 12V by using DC supply. In addition to this 12V DC source is used for the coupled inductor.

C. Experimental Results

Figure.10 shows the output voltage obtained from the whole system .Here output voltage obtained around 20V.

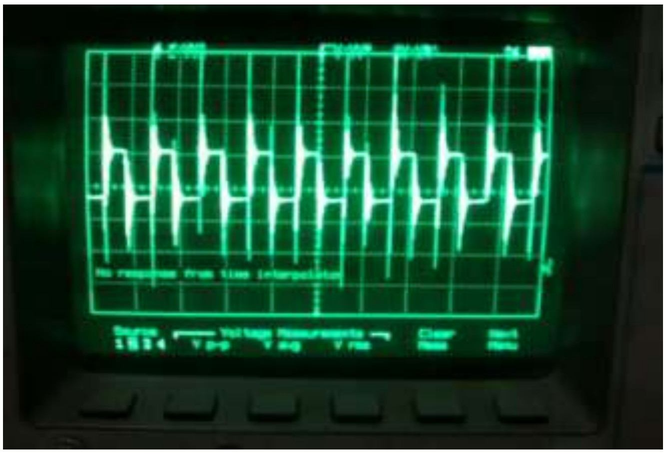

Figure 10 output voltage

VII. CONCLUSION

A new non-isolating ZVS converter which can be used for operating a DC motor is implemented. The auxiliary circuits that only consist of a coupled inductor and diode are very simple and additional cost is high. The simulation model of the circuit is developed using MATLAB/SIMULINK. This topology is only applicable for fixed load driver application only. Here open loop control topology is used which results in lower efficiency. Based on the survey conducted it is understood that the ZVS boost converter topology and implementation of closed loop control with PI control can effectively control the converter. The detailed simulation diagrams and the corresponding waveforms have been provided. This modified circuit can be used for high power dc motor. At the same voltage will be increased by using converter. The implementation of hardware we can see that output voltage is increased.

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