Design and Control of Half-Bridge Resonant Converter Topology of PID Controller

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ABSTRACT- ***The closed loop LLC resonant DC-DC half bridge converter are used in low medium and high power applications for an high efficiency. This paper presents the closed loop PID converter for an LLC DC-DC half-bridge converter with both linear and non-linear loads. These converter are used in high power density for a battery charging and conventional energy systems. These converter are used for more high power switching frequency for reducing the loss of switching devices and conduction losses. Power factor is improved by soft switching technique by a closed loop PID controller. The measured maximum efficiency is 95% and the hardware and simulation result of the resonant LLC DC-DC half bridge is presented.***

INTRODUCTION

In the closed loop resonant LLC DC-DC half bridge converter are commonly used in now a days where 10% of electric vehicles charging stations has installed India. Where by estimating of the electric vehicles is increasing up to 50% of previous year by increasing the electrical vehicles there is no fuel gases are presented whereas the pollution will not occur the greenhouse will be presented by the economical and concerns of environmental. Hence nowadays both fuel gas and the electric energy is used for the vehicles where it is known as hybrid vehicles. The charging batteries are used for the electrical motors and vehicles. Where the batteries will provides the constant current and constant voltage of battery pack charge. The efficiency, power density, switching frequency, switching losses, conduction losses, and constant voltage should be gained from the DC-DC resonant half bridge converter. The ZVS and ZCS is used for the MOSFET on and off losses. In the resonant tank is used for the half bridge AC-DC converter. The resonant tank includes the resonant inductor, resonant capacitor and magnetizing inductor. For a constant output voltage the closed loop PID controller is used which reduces the power losses and improves the power quality. The converters are connected to linear loads and non- linear loads like batteries, motor. The linear loads voltage is directly proportional to current. The non- linear loads voltage is inversely proportional to current that are rectifiers, variable speed drives and electronic devices. There are three types of resonant converters that is series resonant converters, parallel resonant converters, series-parallel resonant converters. The zero voltage switching and zero current switching technique is used for a soft switching method to reduce the switching losses and conduction losses. Hence the loss decreases the power quality and the efficiency increases. The harmonics are also reduced due to soft switching method by a resonant LLC circuit and LC filters where the LC filters is known as low pass filters that which attenuates the low pass bandwidth signal. The main aim of this project is to obtain the constant output voltage with high efficiency, high power quality and low conduction losses and low switching losses. The calculation is done detailed with the design procedure in detail of transformer windings current of primary side and secondary side. The theoretical value and practical value obtained same. The experimental result is obtained and presented.

Specification of the converter

Input Voltage	375V - 400V
Output Voltage	12V
Switching Frequency	50 – 70 kHz
Efficiency	> 95%
Rated Output Power	30

HALF BRIDGE RESONANT CONVERTER

Half bridge resonant LC DC-DC converter has a switching circuit, resonant circuit and a rectifier circuit for the DC output voltage where the switching circuit has two MOSFETs Q1 and Q2 that are power switches which is known as soft switches that reduces the switching losses and conduction losses in high switching losses and conduction losses in high switching frequency. The inductor Lr and the capacitor Cr are in series where it is formed by a resonant tank circuit. The resonant conductor inductor Lm is connected parallel across the primary side of transformer. The tank consists of Lr, Lm and Cr which are in series with a load. The resonant circuit and the load as voltage divider method.

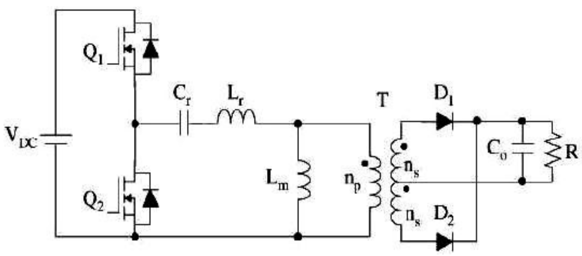

Fig.No1.Half bridge resonant converter

HALF BRIDGE RESONANT CONVERTER OPERATION

MODE1

When the supply voltage is given to the half bridge resonant LLC DC-DC converter, the MOSFET switch Q1 s turned on while the switch 2 is turned off. When the switch Q1 s turned on the resonant inductor LR current reverses and it is flowing through the diode which is anti-parallel to MOSFET switch. The zero voltage switch condition is used for the switch Q1 the gate signal of pulse width modulation is applied. When the switch Q1 s turned on the transformer of the secondary side of the diode D1 acts as a forward bias. The magnetizing conductor Lm is charged with the constant voltage.

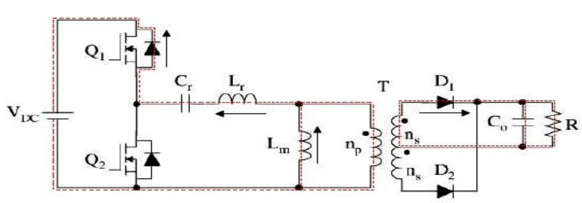

Fig.No2.Mode1 operation of resonant converter

MODE2

When MOSFETs switch Q1 is on in mode1 operation the current is lowing trough the switch Q1. This mode will be turned on when the resonant inductor Lr, current becomes positive. The magnetizing inductor Lm is charged by an output voltage when it is in forward bias circuit. When the resonant inductor and magnetizing inductor are same this mode of the operation will ends and the output value becomes zero.

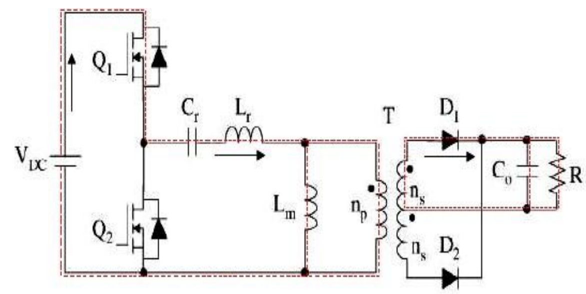

Fig.No3.Mode2 operation of resonant converter

MODE3

When the both resonant conductor and magnetizing inductor are same as output current is null. The secondary sides of the rectifier both diode D1 andD2 are reverse biased. The system voltage is very less than theput voltage and MOSFET Q1 s turned off.

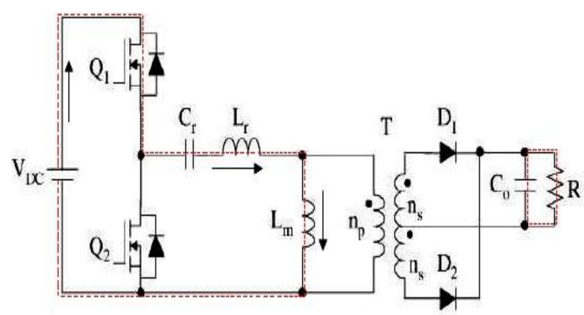

Fig.No4.Mode3 operation of resonant converter

HALF BRIDGE RESONANT DC-DC CONVERTER

OPEN LOOP

Resonant converter has a two switches and the resonant tank with two capacitors. The capacitors divides the voltage level with the input supply voltage where the MOSFET switches is turned on by an gate signals with an different pulse signals due to the open loop where primary voltage is varied then secondary voltage should be constant voltage where it can be step input variation waveform is shown in the simulation waveform.

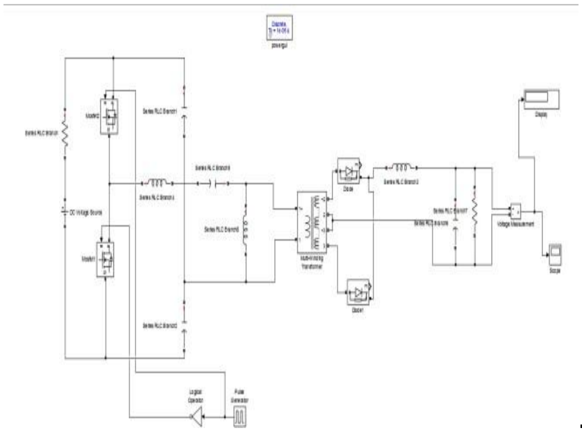

Fig.No5.Open loop converter

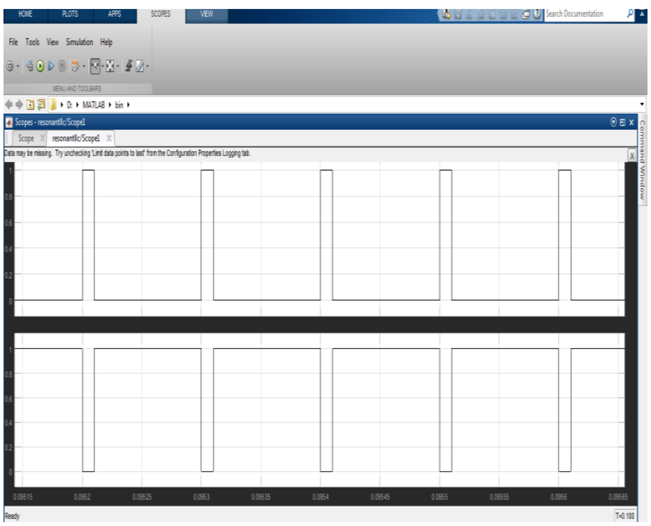

Fig.No6.Driving pulse of Mosfet switching

MOSFET OPERATIONS

In this half-bridge DC-DC resonant converter there are two MOSFET's are presented where mosfet switch Q1 is turned on then mosfet Q2 will be off and vice versa. Due to present on soft switching method the ZVS and ZCS is provide the switching losses and conduction losses will be decreased whereas when the Q1 is turned on it is in the rise time and starts conducting up to current flow of resonant inductor when the current reverses the diode voltage of magnetizing inductor the switch is in the fall time and the switch Q1 will be off then the Q2 will be on then it will starts conducting up to an delay time that Q2 will be turned off than vice versa.

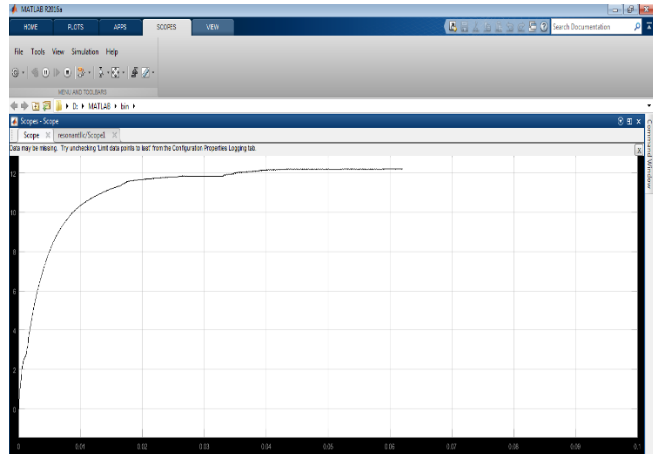

Fig.No7.Output waveform

CLOSED LOOP

In this closed loop circuit the working is same as the open loop cycle but the gate signal of MOSFETs switches is given by the proportional integral derivative controller is given to the gate signal by an NOT gate due to the switching time where NOT gates used to switch ON and OFF only one switch where two switch cannot turn ON at a time. By using proportional integral derivative controller the switching losses and the conduction losses are reduced by an soft switching method. When the primary voltage is varied the secondary voltage is constant by an good efficiency, power quality and good switching frequency by an constant output voltage.

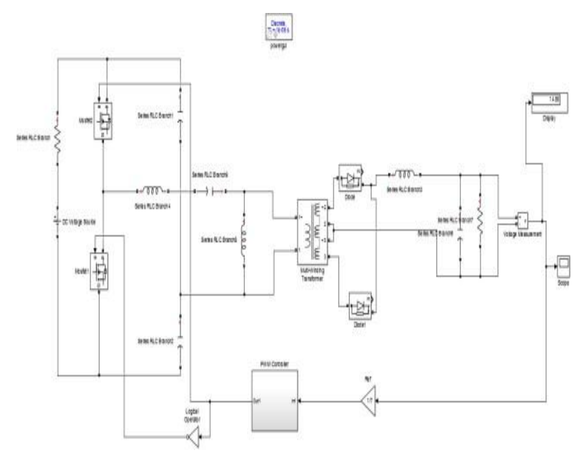

Fig.No8.Closed loop converter

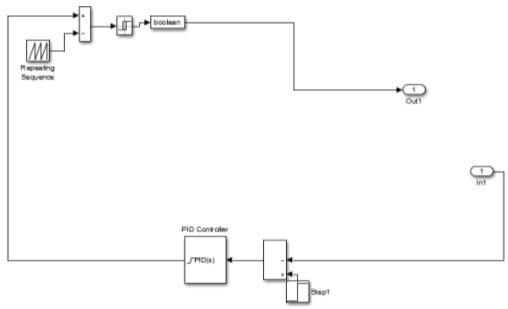

Fig.No9.PID Controller

PID Controller

PID controller is a sensor signal which is used for feedback control unit where it senses the signal and compare the output of the circuit and gives a certain output voltage. The PID denotes the proportional integral and derivative. Where the P is used for the improving the transient response rise time and settling time, I and D used for the integral and derivative of the component.

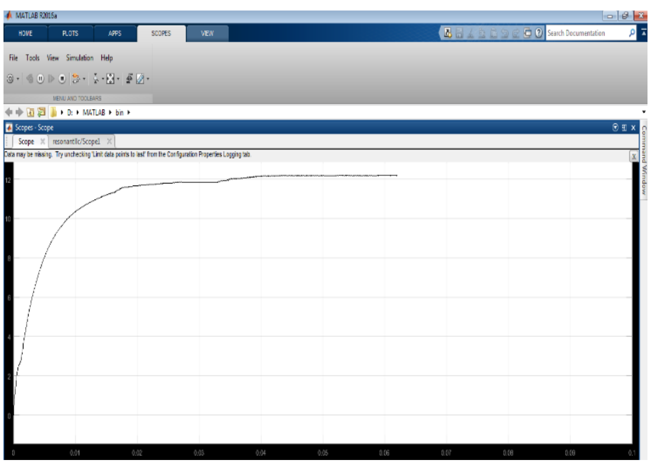

Fig.No10.Output waveform

SIMULATION

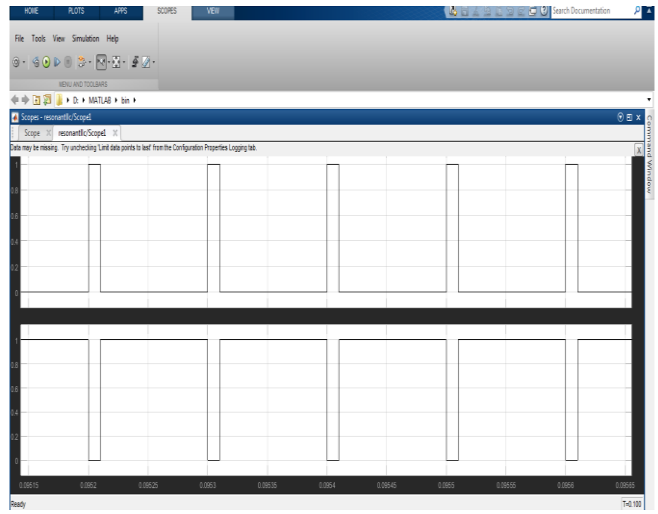

Fig.No11.Driving pulse of Mosfet switching

The resonant LLC DC-DC halfbridge converter is simulated in both open loop and closed loop cycle in a MATLAB/ Simulink where a constant output voltage waveform is obtained. The primary input voltage of MOSFETs and the capacitor voltage is shown in the waveforms. The primary current of the transformer is seen by an scope. All the waveforms like diodes, capacitors, MOSFET switches an input voltage, output voltage and the gate signals are shown in MATLAB/ Simulink waveforms.

Hardware Results

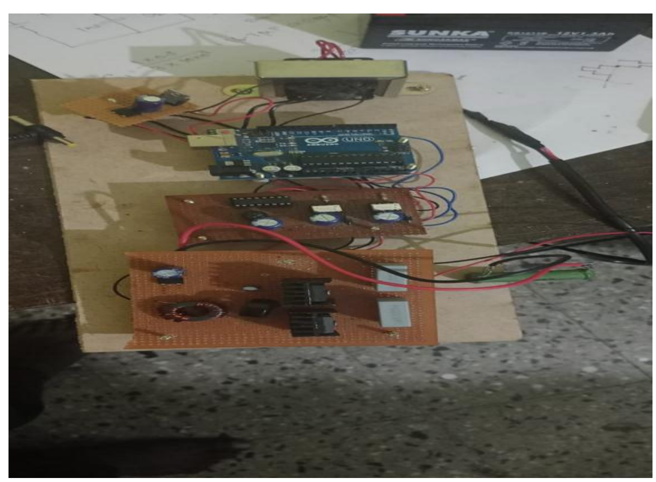

Fig.No12. Hardware of LLC resonant converter

In this, the battery supply is provided to the primary of the LLC converter which varies in the range of 12V to 18V. The secondary is rectified using the diode rectifier and provided to load. A voltage sensor is used to measure the load voltage and provide it as feed back to the controller. Based on the feedback signal the pulses will be varied and load voltage is regulated. The load voltage is maintained as 12V irrespective of the input changes.

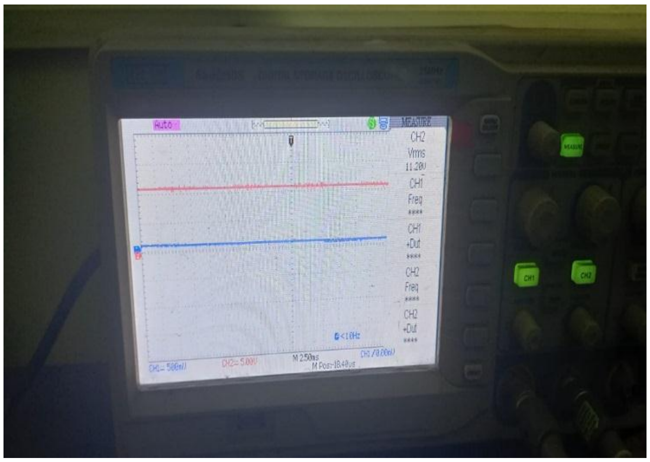

Fig.No13.Output DC Voltage

Fig.No14. Gate pulse of MOSFET switch-1

Fig.No15. Gate pulse of MOSFET switch-2

CONCLUSION

The series resonant LLC half-bridge DC-DC converter does not provide a constant output voltage. To obtain the constant secondary voltage theresonant tank circuit, the LC filters and proportional integral derivative controllers are used to get a constant output voltage by a switching frequency, power quality and efficiency. The zero voltage switching and soft switching methods are obtained to reduce the conduction losses and switching losses. The proportional integral derivative controller are used to provide constant output voltage. This resonant converter is simulated in MATLAB/ Simulink and waveforms are obtained.

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