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Analysis of ZVS Isolated Converter using MATAB-SIMULINK

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ABSTRACT: This paper analyses zero voltage switching of an isolated DC-DC converter using MATAB-SIMUINK. Partial resonant technique is used in this converter to have zero voltage switching at the turn-on and turn-off of the power switches. Galvanic isolation is provided with a high frequency transformer, whose magnetizing inductance is used for resonance with the capacitors which is connected on both sides of the transformer. Thus resonance is achieved with less number of components. Open loop and closed loop simulation results are provided to verify the performance.

KEYWORDS: Galvanic isolation, Partial resonance, Soft switching, Zero current switching ,Zero voltage switching.

I.INTRODUCTION

Hard switching topology is used in conventional PWM converters. In hard switching conditions rectangular voltages and currents of semiconductor devices are changed abruptly from high values to zero and vice versa at turn-on and turn-off. These changes cause switching losses and electromagnetic interference. Now, one of the major trends in power electronics is increasing the switching frequencies. Fast converters which are operating at high switching frequencies results in reducing the size of passive components. The total size and weight of the equipment thus reduces. This high switching frequency operation increases the amount of power that is lost due to switching losses and thus reduces power converter efficiency.

Soft switching is the technique to eliminate the losses due to hard switching conditions and to have high frequency operation without any reduction in the efficiency of the converter. In this method either the voltage across or the current flowing through a switch is made zero during switch transition, then switching losses will be zero since at that instant there will not be any power loss. There are two types of switching: Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS). Soft switching is achieved by using resonant circuits consist of capacitance and inductance. Quasi-resonant converters[1], multi-resonant converters[2], resonant transition converters[3] etc. are the converters which uses soft switching DC-DC topologies. These soft switching converters are made with the expense of adding an additional auxiliary circuit. Also these converters shows poor performance over wide range of input voltages and load resistances.

In this paper an isolated soft switched DC-DC converter, using partial resonant topology, which does not having an auxiliary circuit is analysed. Open loop simulation and closed loop simulation are provided in this report for performance evaluation.

Next section discusses the principle of operation of proposed Isolated soft switched DC-DC converter and also its modes of operation. Third section deals with the closed loop and open loop simulation diagrams and results.
Fourth section concludes the topic.

II. LITEARTURE SURVEY

Quasi-resonant converters, multi-resonant converters, resonant-transition converters, active-clamp and phase-controlled converters are different types of soft switching converters. In quasi-resonant converters the power switch is replaced with a circuit containing resonant elements to have soft switching operation for the main switch, whereas all the

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semiconductor devices are operated in soft switching mode in multi-resonant converters. But current or voltage stress is high in these converters. Resonant-transition converters are the one which needs an additional cost of adding an auxiliary circuit, which shape the switching waveforms without much increase in the switch stress. A large capacitor is needed in active-clamp converters and a full bridge network is loaded with a inductive load in phase-controlled converters to have zero voltage switching condition. These converters have the drawbacks of poor performance.

III. PRINCIPLE OF OPERATION

Isolated soft switched DC-DC converter is shown in Fig.1. The converter consist of a high frequency transformer T which provides the galvanic isolation. Capacitors C_1 and C_2 are placed on both sides of the transformer, which results in resonance with the magnetizing inductance L_M of the transformer. Semiconductor switches S_1 and S_2 are controlled by measuring the magnetizing current and voltages of the transformer. Resistor Ro is connected at the output side as a load. Output capacitor is denoted as Co.

Mainly there are four modes of operation. Charging and discharging of the magnetizing inductance is described in mode 1 and mode 3. Mode 2 and mode 4 are for the partial resonance of magnetizing inductance and total parallel capacitance. Four modes are explained by ignoring the transformers leakage inductances and winding resistances.

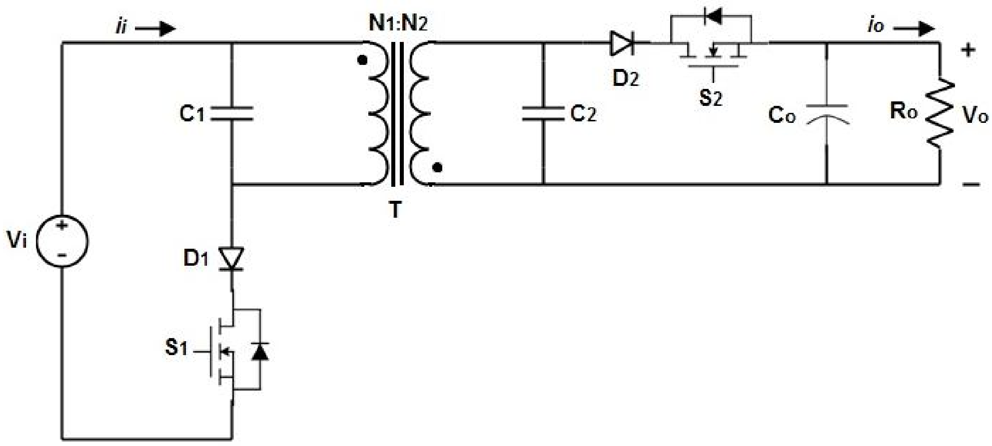

Fig.1: Converter Circuit

1.1. Mode 1

Fig.2 shows the equivalent circuit for mode 1.

- Switch S_1 is on
- L_M charges in the positive direction
- This mode is continues to run until $i_L(t)$ reaches the value of I_{E1}

$$I_{E1} = \frac{V_i T_1 + L_M I_{E4}}{L_M} \quad (1)$$

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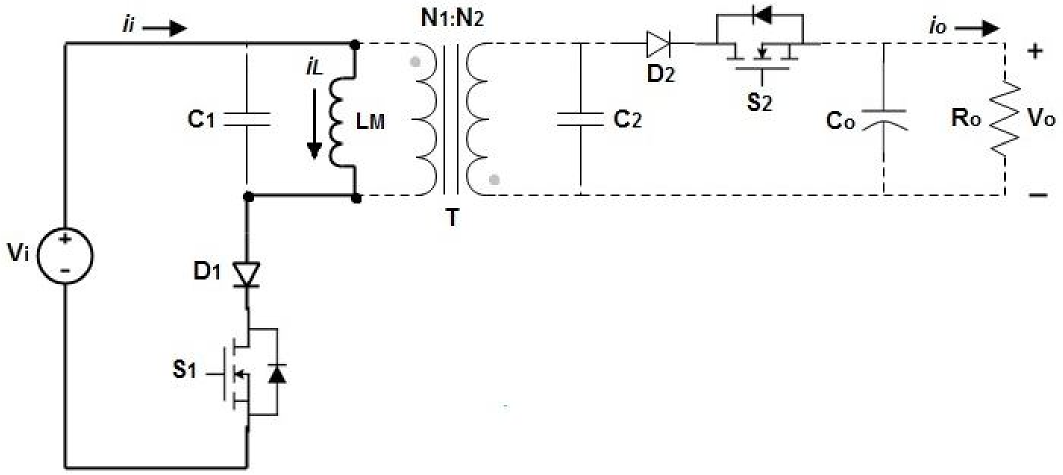

Fig.2: Equivalent circuit of mode 1

1.2. Mode 2

Fig:3 shows the equivalent circuit diagram for mode 2

- Switches S_1 and S_2 are off
- L_M starts to resonate with its total parallel capacitance, $C_t=C_1+n^2C_2$
- This mode is continues to run until $V_L(t)$ becomes equal to output reflected voltage ($-V_{out}/n$)
- Magnetizing current reaches its positive peak value during mode 2,

$$I_{LP+} = \sqrt{(I_{E1}^2 + \frac{(C_1 + n^2C_2)V_{in}^2}{L_M}} \qquad (2)$$

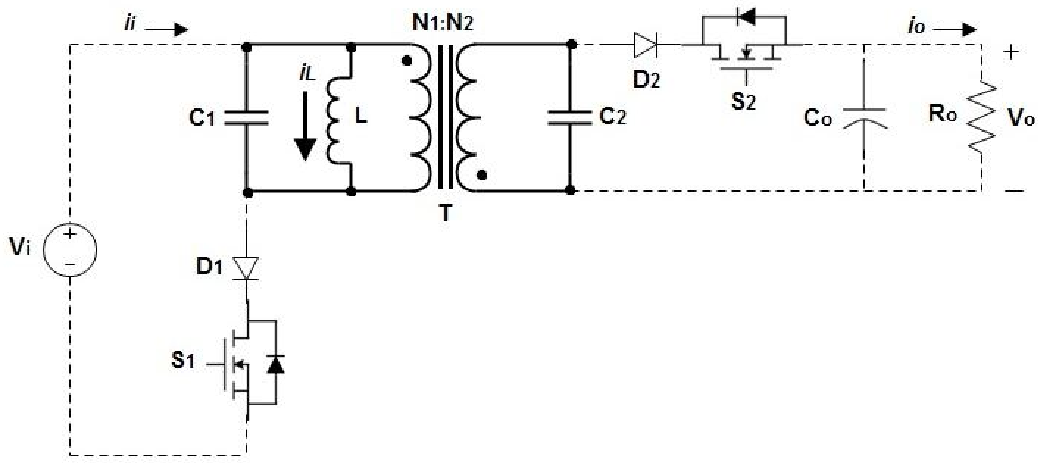

Fig.3: Equivalent circuit of mode 2

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1.3. Mode 3

Fig:4 shows the equivalent circuit diagram for mode 3

- Switch S2 is turned on
- Magnetizing inductance energy discharges to the output
- This mode continues to run until IL(t) reaches the value of IE3

$$I_{E3} = \sqrt{(\frac{C_1 + n^2 C_2}{L_M}(V_{LP}^2 - \left(\frac{V_O}{n})^2\right)))} \qquad (3)$$

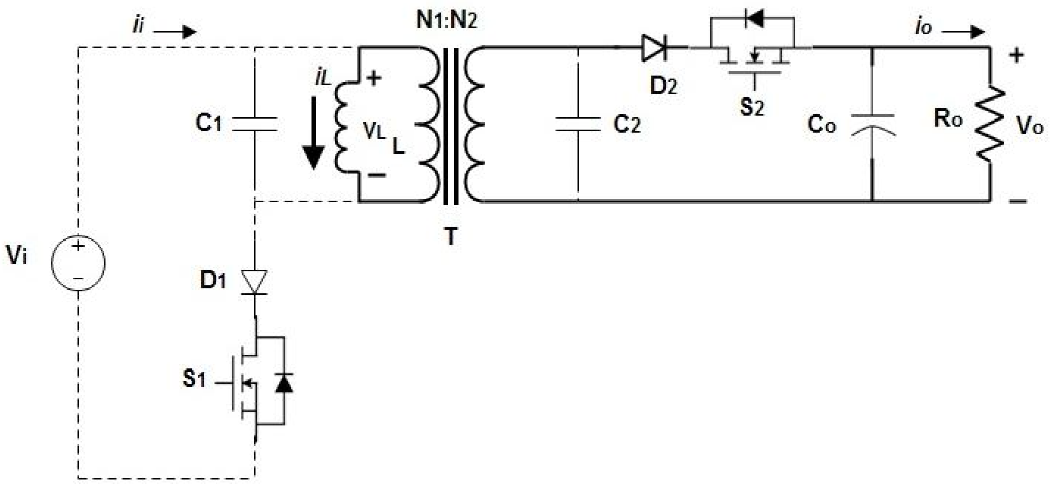

Fig.4: Equivalent circuit of mode 3

1.4. Mode 4

Fig:5 shows the equivalent circuit diagram for mode 4

- Switches S_1 and S_2 are off
- L_M and C_t resonante together again
- This mode is continues to run until $V_L(t)$ is equal to the input voltage
- $I_L(t)$ reaches its negative peak value during this mode,

$$I_{LP-} = \sqrt{\left(\frac{C_1 + n^2 C_2}{L_M} V_{LP}\right)} \qquad (4)$$

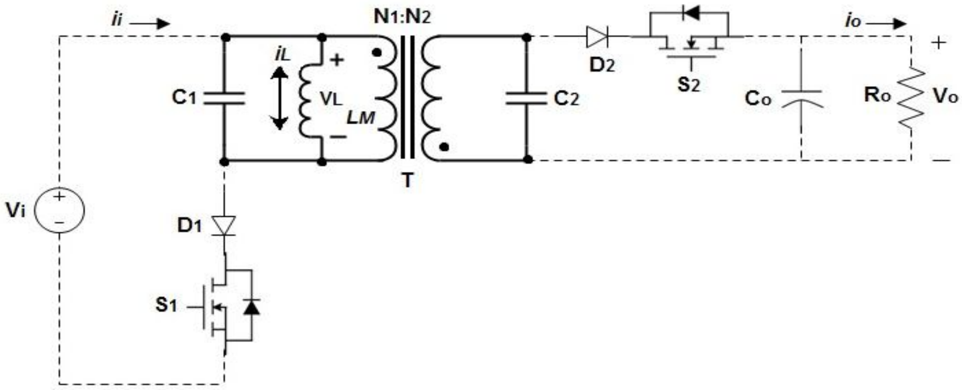

Fig.5: Equivalent circuit of mode 4

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IV. SIMULATION

Fig:6 shows the open loop simulation diagram of the converter. In open loop simulation, pulses to switches S_1 and S_2 are given by comparing the magnetizing inductance current with the I_{E1} and I_{E3} . The speciality of this circuit is both step-up and step-down of the voltage is also possible with the same converter by appropriately selecting the switching frequency. During step-down mode it can buck the voltage from 400V to 300V at a switching frequency of 24.6kHz. And during step-up mode boost the voltage from 200V to 300V at a switching frequency of 18.7kHz. Here the converter is simulated for an input and output voltage of 300V, switching frequency of 22kHz and the elements are selected accordingly.

3.1. Simulation Parameters

fs = 22kHz
Vi = 300V
C1 = 47nF
C2 = 47nF
Co = 100µF
Ro= 120Ω
n = 0.92
Lm = 225µH

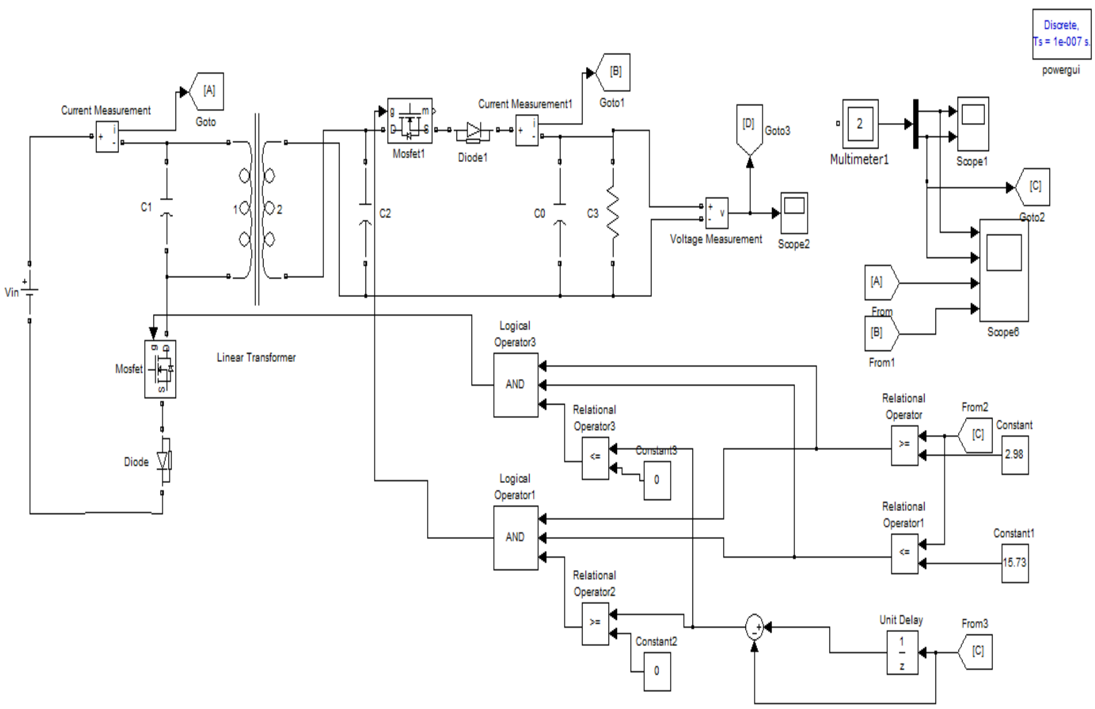

Fig.6: Simulation diagram for open loop control

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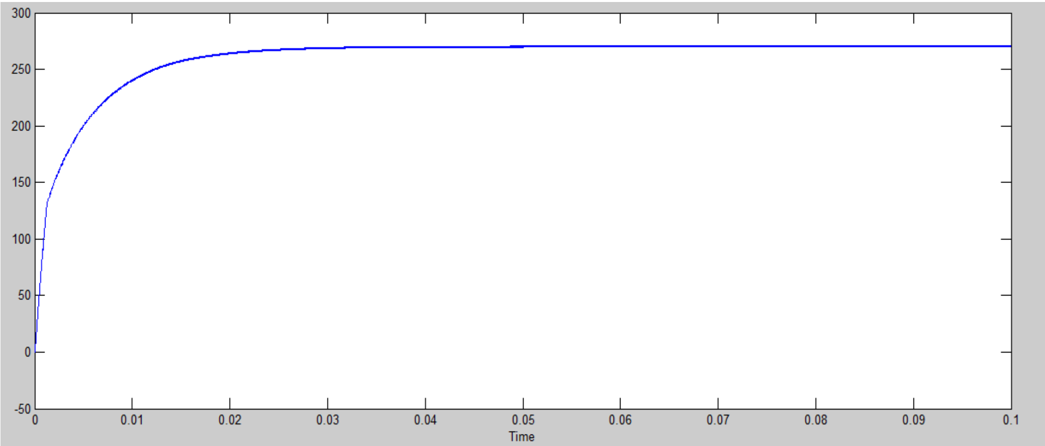

Fig.7: Output Voltage Waveform

Output voltage waveform of the converter is shown in Fig.7. For an open loop system output voltage is at 270V instead of 300V. So closed loop system has to use to get a constant output voltage.

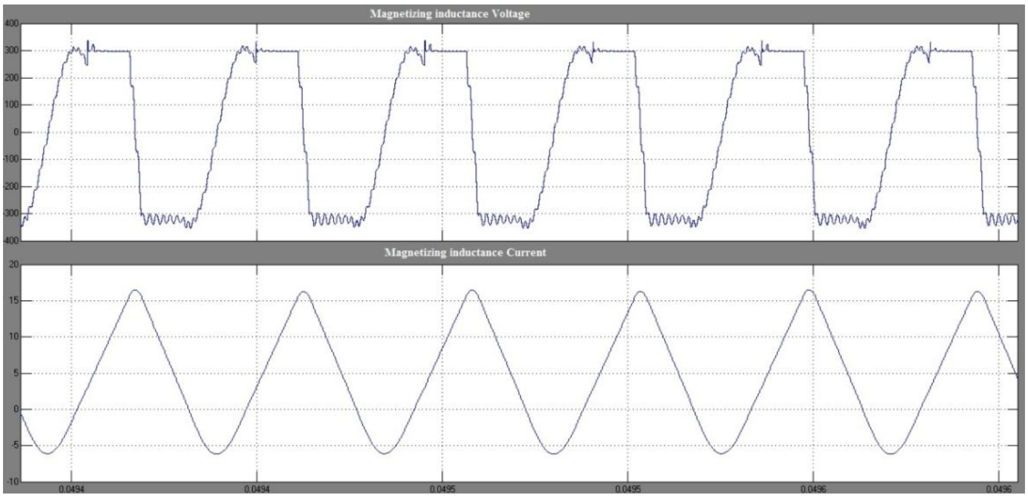

Fig.8: Magnetizing inductance voltage and current

Magnetizing inductance voltage and current are shown in Fig.8. Fig.9 and Fig.10 shows switching waveform, voltage and current of the two switches S_1 and S_2. From these two figures we can see that zero voltage is attained at the turn-on and turn-off of the switching devices by using this resonant circuit without using more resonating elements.

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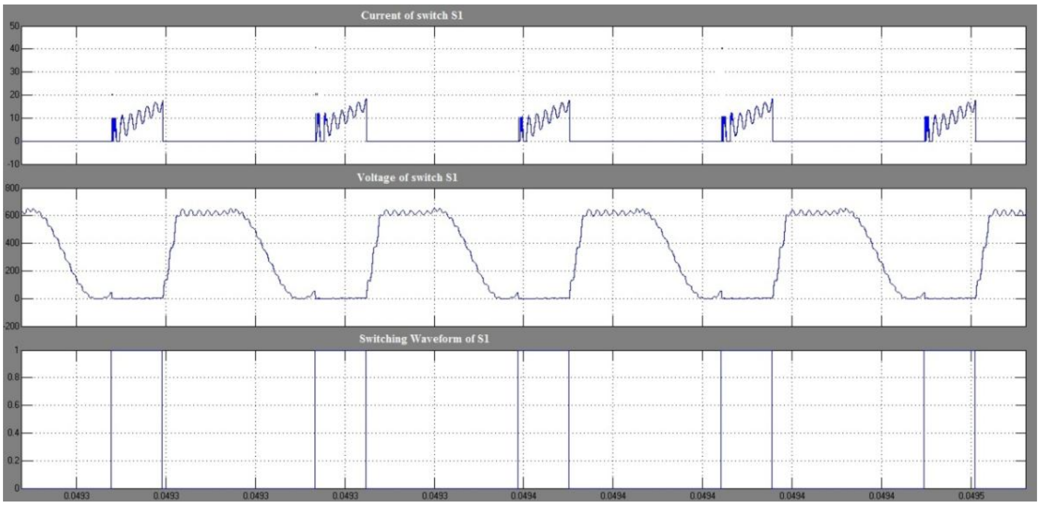

Fig.9:Current, voltage and switching waveforms of switch S_1

Fig.9 and Fig.10 shows switching waveform, voltage and current of the two switches S_1 and S_2. From these two figures we can see that zero voltage is attained at the turn-on and turn-off of the switching devices by using this resonant circuit without using more resonating elements.

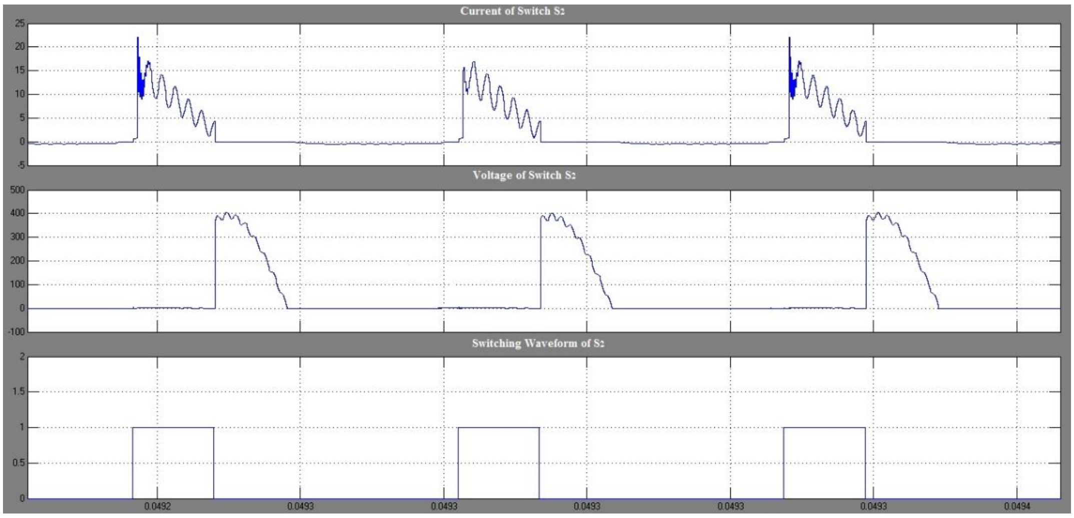

Fig.10: Current, voltage and switching waveforms of switch S_2

Closed loop simulation diagram of this converter is shown in Fig.11. In closed loop simulation the output voltage remains constant at 300V for input voltages from 290V to 310 V. Current, voltage and switching waveforms across S_1 and S_2 are same as got in the open loop simulation. Thus the designed output voltage 300V is attained without much changes in the performance.

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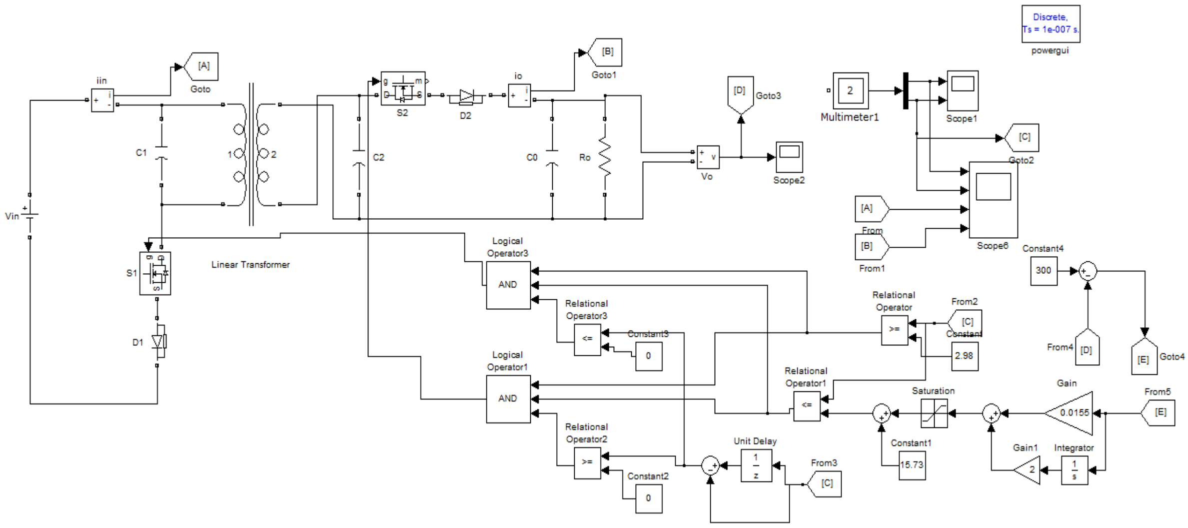

Fig.11: Simulation diagram for closed loop control

V .CONCLUSION

Open loop and closed loop of a soft switched partial resonant isolated DC-DC converter is analysed in this paper. Analysis is done based on the simulation results obtained from MATLABSIMULINK. In this converter the soft switching is achieved by using less number of components and thus switching losses get reduced. This circuit can be made to operate in buck and boost modes by changing the switching frequency. For isolation purpose also this circuit is suitable without much increase in the switching losses. And closed loop simulation can be used to get a constant output voltage.

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