COMPARATIVE ANALYSIS OF SINGLE PHASE INTERLEAVED TAPPED- COUPLED INDUCTOR BOOST CONVERTER

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Abstract

In this paper , two different single phase boost converters with both directly coupled inductors and one with indirectly coupled inductors are compared. Output voltage equations ,Duty Ratio , Equivalent inductances, Mutual inductances for the both the circuits have been calculated. For the same simulations have been made using MATLAB/SIMULINK software and have been presented. Different waveforms have been obtained from simulations and presented in this paper.

Keyword: Interleaved , coupled- inductor , boost converter MOSFET, ,Continuous conduction mode(CCM),MATLAB/SIMULINK

1.INTRODUCTION

The boost converter is a very popular non-isolated topology to transfer the input voltage into a higher output voltage. DC-DC Converters with a high boosting function are required in emerging applications, with no isolation. Applications examples are photovoltaic systems, uninterrupted power supplies, automobile head lamps and telecommunication systems. Non-isolated tapped dc-dc converters are usually derived from the three basic converter topologies like buck, boost , and the buck-boost converter circuits. These circuits all employ a transistor switch , a tapped inductor , a capacitor, and a diode deployed in different ways. Tapping the inductor had the benefits that the duty cycle of the converter at the operating point can be chosen to be an appropriate value typically a value at which the efficiency of the circuit and the utilization of circuit components is optimal. By using a tapped inductor ,high or low voltage transfer ratios can be achieved with relatively high efficiencies and low component cost. Many applications demand the use of DC-DC converter with high voltage gain. Full utilization of renewable sources requires a converting stage to match the demanded voltage for effective grid connections.

However, the use of tapped-coupled inductor boost converter with a higher turns ratio makes it possible to achieve high step-up ratios with a low duty ratio.

The matrix of tapped inductor configuration is discussed below:

a) Switch-to-tap, where the switch is connected to the tapping point of the inductor rather than to one of the extremities of the inductor;
b) Diode-to-tap ,where the diode is connected to the tapping point of the inductor rather than to one of the extremities of the inductor; and
c) Rail-to-tap, where the tap is connected to one the power rails.

In this chapter ,a single phase boost converter with tapped-coupled inductors is described and analyzed. Analysis is done for both directly coupled and indirectly coupled inductor boost converter operating in Continuous conduction mode(CCM). Expressions for output voltage and converter waveforms in CCM will be presented.

2. ANALYSIS OF THE CONVERTERS

2.1. Directly tapped-Coupled inductor:

A Directly tapped-coupled-inductor boost converter is shown in Figure 1(a). The circuit components include a MOSFET S, a diode D , tapped coupled inductors L1 and L2, a filter capacitor C and a load resistor R. The MOSFET is turned on by a pulse –width modulator output through a gate drive circuit , at a duty ratio = ton/(ton+toff) , where ton is the time when MOSFET is conducting and toff is the time when the MOSFET is not conducting.

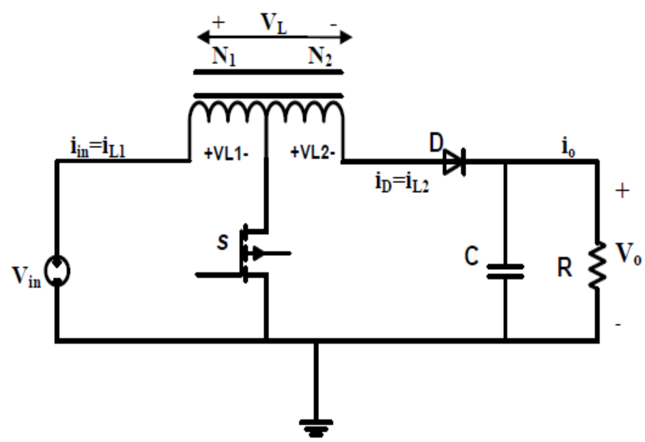

Figure 2(a).Single phase directly tapped –coupled-inductor boost converter

The windings N1 and N2 are on the same core, hence magnetically coupled. When N2=0 , the configuration reduces to that of the conventional boost converter. The relationship between L¬1 and L2 is determined by the turns ratio of the magnetic element , that is L2/L1 = (N2/N1)^2 = n2 , N1 is the number of turns in the first inductor L1 , and N2 is the number of turns in the second inductor L2 . The converter operates In two states , when the switch is on and off in CCM.[1]. The detailed analysis has been done on tapped inductors previously[1].

2.2. Inversely tapped-coupled inductor:

The Topology of inversely tapped-coupled inductor boost converter is same as that of directly coupled but the only major difference is the inductor L2 is inversely tapped with L1 as shown in the figure 2(b)below .

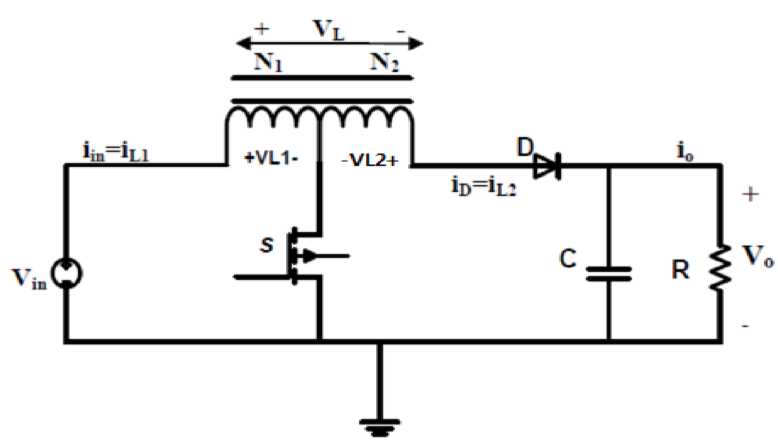

Figure 2(b): Single phase inversely tapped –coupled-inductor boost converter

3. SIMULATION RESULTS AND DISCUSSION:

3.1. Directly tapped-coupled inductor boost converter:

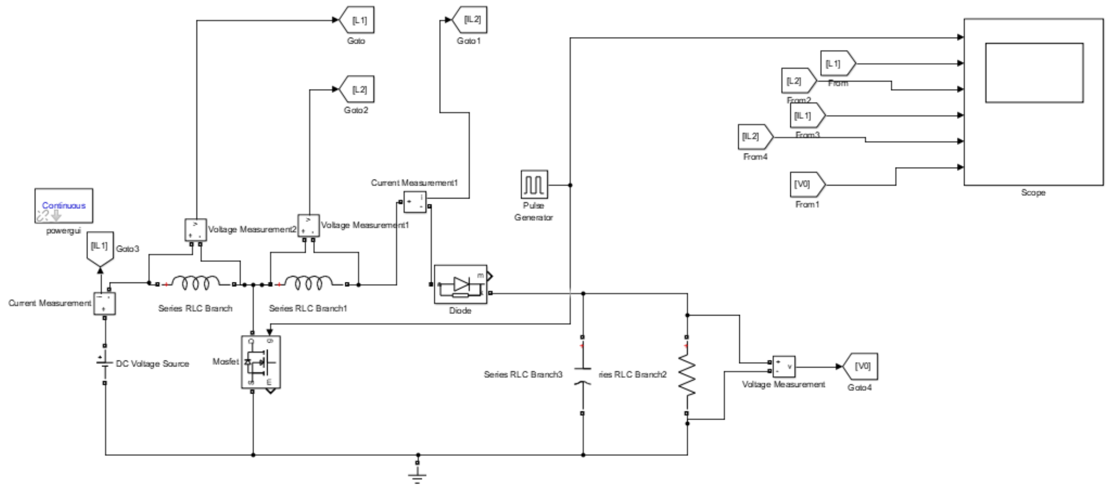

Figure3(a).Simulink model of directly tapped-coupled inductor converter

Simulation parameteres:

V_i = 12V, V_o=48V ,Pout=500W ,fs=100KHz , n=3 , η = 100%
Where n = number of turns, fs = switching frequency.

Calculations[1]:

i). $V_o/(V_{in}) = (1+nD)/(1-D)$…………………………………………………………(1)

Solving for D , in the above equation we get D = 0.42.

ii).$I_{0,avg}$ = $1/2 \Delta i_{L2}$ pk-pk = $((0.7\times10^{(-4)})/L2)$………………………………………(2)

iii).Po= VoIo , solving for Io we get Io = 10.41A

15 % of Io ,avg = 1.56/2 = 0.78

iv).Hence solving for L2 from equation(2) we get L2 = 8.9Mh.

We know that $L2/L1 = n^2 = N2/N1$ ……………………………(3)

On solving equation (3) we get L1 = 980µH

Hemce L1 = 980µH and L2 = 8.9mH

v).Now for mutual indcutance calculation $M = \sqrt{L1L2}$ = 92.4µH…….(4)

vi). For output capacitor $C_o = (I_o\times D\times T_{sw})/(\Delta V_{c,pk-pk})$ = 72.8µF …………………….(5)

vii).For resistor $P = V^2/R$ = 4.6Ω…………………………………………(6)

viii). Equivalent Inductance $L_{eq} = L1 + L2 + 2M$ = 10.0648mH…………(7)

Simulation plots:

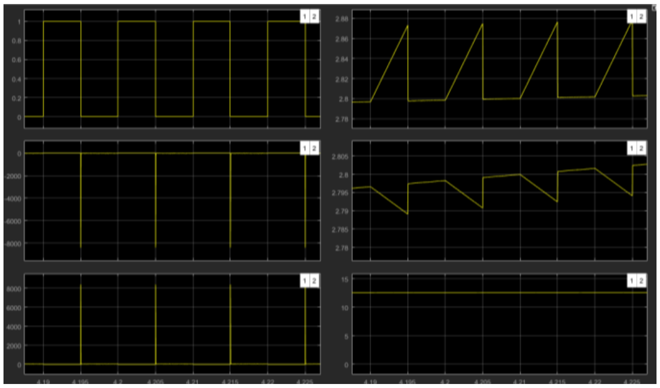

Figure 3(b): Simulation plot(a) for Gate pulses,VL1,VL2,I L1 ,I L2, Output voltage Vo

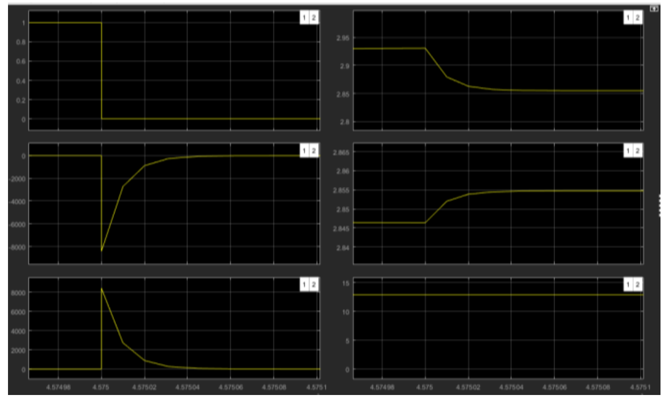

Figure 3(c): simulation plot (b) for directly tapped coupled inductor .

3.2. Inversely tapped-coupled inductor boost converter:

For the same parameters of directly coupled inductors the simulations have been done for the inversely tapped inductor boost converter.

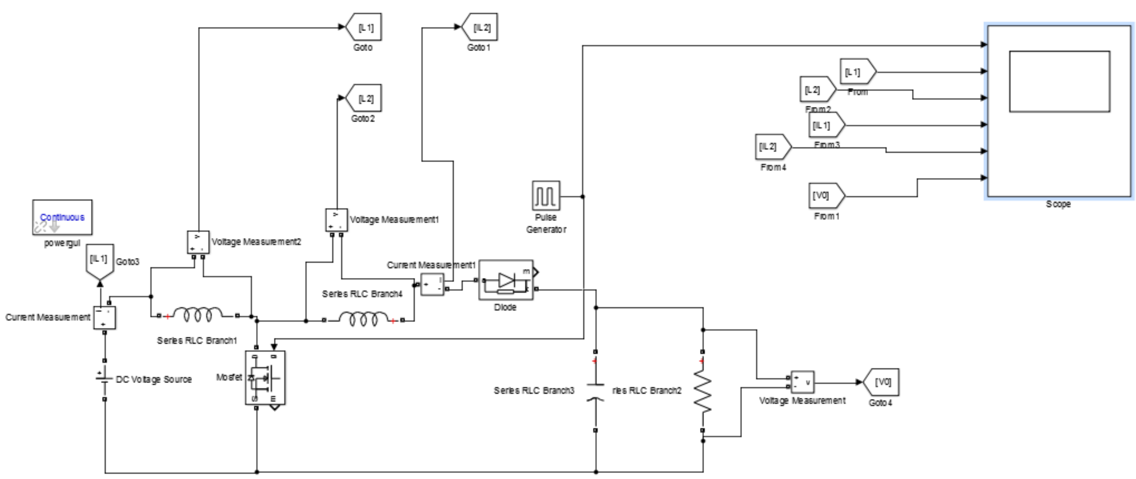

Figure 3(d): Simulink model for inversely tapped-coupled inductor boost converter

Calculations:

The calculations for inversely tapped-coupled inductor boost converter remains same as in directly coupled , The only difference is the total equivalent inductance which is calculated below.

Equivalent Inductance Leq = L1 + L2 -2M = 9.6952mH............................(8)

Simulation plots:

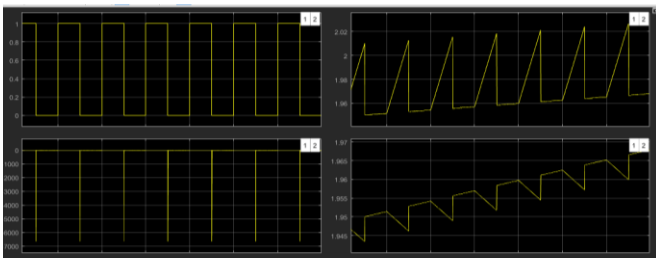

Figure 3(e) .Simulations plot(Gate pulses,IL1,VL1,IL2) for inversely tapped-coupled inductor boost converter

4. OBSERVATIONS:

- In case of Directly coupled inductors , calculated (Leq) obtained is greater than the(Leq) obtained in case of inversely coupled inductors hence we can observe that ripple current of the inductor is inversely proportional to the total equivalent inductance.

	Directly tapped-coupled inductor	**Inversely tapped-coupled inductor**
Phase current ripple	Increases	Increases/decreases
Overall current ripple	Decreases	Increases
Equivalent Inductance	(L_1+L_2+2M)	(L_1+L_2-2M)

5. CONCLUSION:

In this chapter we have discussed about the operation of a single-phase tapped-coupled-inductor boost converter. The effects of tapped-coupled-inductor on performance are explained. Analysis was done and the key waveforms for the converter is presented. The voltage transfer ratio of this DC-DC converter is shown. compared to the conventional boost converter , the single phase tapped-coupled-inductor boost converter achieves a high voltage boost ratio at lower duty ratios.

Both the coupled inductors are compared with their respective simulink models and simulation plots.

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