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DESIGN, ANALYSIS AND SIMULATION OF INTERLEAVED TWO PHASE INDUCTOR COUPLED DC-DC BUCK CONVERTER

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Abstract

A coupled inductor is a gadget principally utilized for vitality stockpiling during a power converter exchanging cycle, and the power entering the coupled-inductor isn't equivalent to the power leaving it in a given moment. Transformers are utilized for voltage and current scaling, for dc separation, and to get different yields from a solitary converter. Interleaved buck converter is utilized to change over the unregulated DC contribution to a controlled DC yield at an ideal voltage level . IBC topologies have gotten expanding consideration as of late for high power applications. The advantages of interleaving incorporate high power ability, particularity and improved dependability. the accompanying favorable circumstances when contrasted with traditional buck converter Low input current ripple

i. Low output voltage ripple
ii. High efficiency
iii. Reduces the size of filter components

Keyword: Coupled inductor, Multiphase converter, Non coupled converter.

1.INTRODUCTION

A coupled inductor is a gadget fundamentally utilized for vitality stockpiling during a power converter exchanging cycle, and the power entering the coupled-inductor isn't equivalent to the power leaving it in a given moment. Transformers are utilized for voltage and current scaling, for dc confinement, and to acquire different yields from a solitary converter[1].

The coupled inductor buck Converter Operates along these lines to the conventional buck converter. The activity of the converter is decreased to two sub circuits. At the point when the switch is on and off. The high buck capacity is on the grounds that the releasing procedure of the attractive component is made with a higher inductance esteem.

The connection somewhere in the range of L1 and L2 is controlled by the turns proportion of the attractive component that is:
L1/L2= [N2/N1]^2
The inductance is Proportional to the turn square of the inductor.
L1 =k(N1)2
At that point comparable inductance of L1 and L2 is:
Leq = k(N1 +N2)2
Taking into account that N2 =NN1, and utilizing (2) and (3):
Leq = ((N+1)/N)^2L2

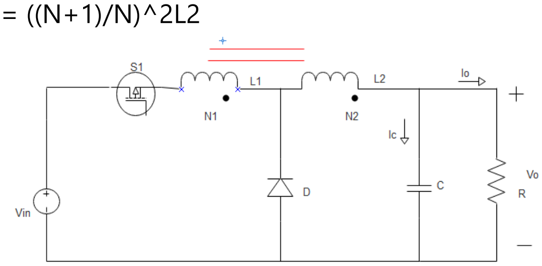

Fig.1. Single phase Buck converter with coupled inductor

From fig1 single stage Buck converter with coupled inductor creates more yield wave contrast with multiphase dc-dc converters. The interleaved buck converter is only Multi staging. The primary favorable position of interleaved parallel associated changes over expands the power handling capacity and to improve the unwavering quality of the power electronic framework. What's more, multiphase parallel associations of intensity converters diminish support, increment dependability and adaptation to non-critical failure.

2.TWO STAGE NON COUPLED INDUCTOR

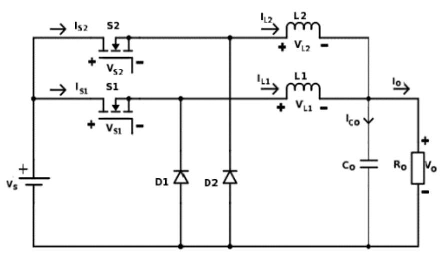

Fig.2. Two phase interleaved buck converter.

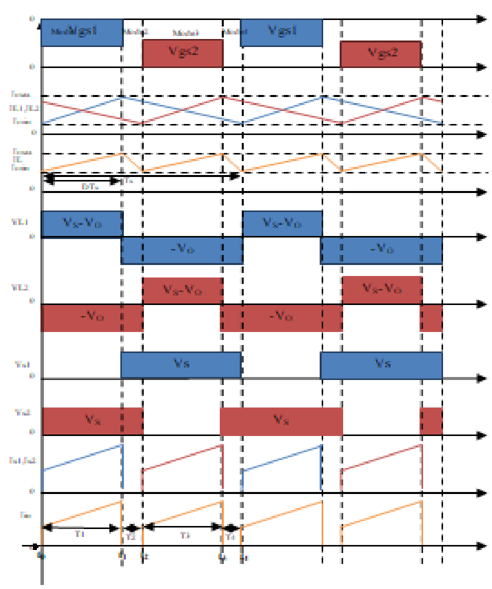

Fig 3 Waveform of Two phase interleaved buck converter

By thinking about that converter working in CCM under area 'a', the two stage IBC converter has four topological modes for every exchanging period. The two inductors are not coupled so there is no association between them.

The inductor current wave is determined as

$\Delta I_{L1}=(V_S-V_O)/L1\ (T_1)Ts\ldots\ \ldots\ 1$

$\Delta I_{L2}=(-V_O)/L2\ (T_1)Ts\ldots\ \ldots\ \ldots\ ..2$

From the waveform $T_1 = D$

Ts is exchanging time of the converter

3.TWO STAGE COUPLED INDUCTOR

The expanded inductor current wave diminishes the converter proficiency. To accomplish both inductor current wave and yield current wave the two inductors ought to be coupled somehow or another. From a study the yield current wave and inductor current wave will be relies upon the benefit of coupling coefficient (k). The estimation of coupling coefficient increments so as to get an ideal exhibition of the coupled inductor and the power converter.

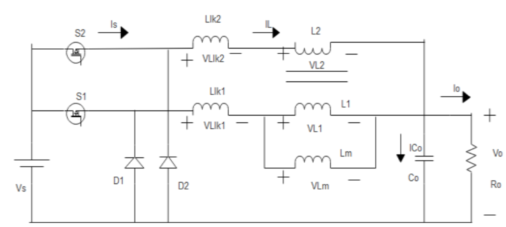

Fig4 Two phase Buck converter with coupled inductor

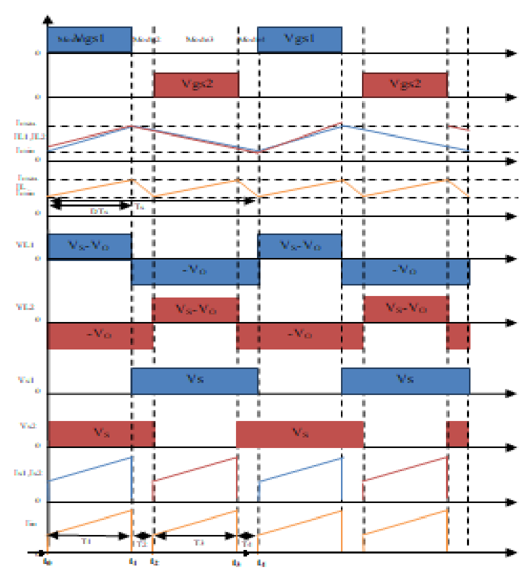

Fig 5 waveform of interleaved buck converter with coupled inductor

The figure 4 shows Two stage interleaved buck converter with coupled inductor. The Ideal transformer is utilized.

iLm = iL1 – iL2

There are 4 modes in buck converter with coupled inductor. The accompanying articulation is gotten from the circuit outline.

$v_{L1} = V_{Llk1} + V_{Lm}$

$V_{L2} = V_{Llk2} - v_{Lm}$

$V_{Lm} = L_m\, i_{Lm} = L_m \frac{d}{dt}(i_{L1}-i_{L2})$

The methods of activity of Two stage buck converter with coupled inductor as pursues.

3.1. Mode 1 [0 – DTs]

In Mode 1 the switch S1 and S4 are turned on. The voltage over the inductor and current over the inductor as pursues

$V_{L1} = V_{in} - V_o$

$V_{L2} = - V_o$

From above equations the leakage voltages across the inductors V_{Llk1} and V_{Llk2} are expressed as

$V_{Llk1} = L_{lk1} \frac{di_{L!}}{dt} = V_{L1} - V_{Lm} = (V_{in} - V_o) - v_{Lm}$

$V_{Llk2} = L_{lk2} \frac{di_{L2}}{dt} = V_{L2} + V_{Lm} = (-V_o) + v_{Lm}$

$L_{lk1} = L_{lk2} = L_{lk}$, and substitute in the above equation then the equation for magnetizing inductance is

$V_{Lm} = \left[\frac{L_m}{2L_m + L_{lk}}\right] V_{in}$

All in all coupled inductor hypothesis the spillage inductors and Magnetizing inductor Llk and Lm are communicated as pursues

Llk = (1-k)Ls

Lm = kLs

Where Ls and k speak to self inductance and the coupling coefficient of the coupled inductor, individually.

Substituting spillage inductor and charging inductor in condition of

$V_{Lm} . V_{Lm} = \left[\frac{k}{1+k}\right] V_{in}$

Substituting VLm in Inductor current conditions and utilizing the connection Vo = DVin , the inductor flows in mode 1 will be communicated as.

〖di〗_L1/dt=V_o/L_lk [(1-D-kD)/(1+k)D]

〖di〗_L2/dt=V_o/L_lk [(k-D-kD)/(1+k)D]

k speaks to the coupling coefficient and the estimation of k ought to be under 1. In the buck converter the obligation proportion ought to be under half. So the estimation of inductor current of L1 is more prominent than inductor current of L2.

The yield inductor current is aggregate of two inductor current and is communicated as

di_Lo/dt=V_o/L_lk [(1-2D)/D]

3.2. Mode 2 [DTs - Ts/2]

In mode 2 VL1 = VL2 = - VO , along these lines

VLlk1 = Llk1 〖di〗_L1/dt = VL1 – VLm = – Vo - vLm

VLlk2 = Llk2 〖di〗_L2/dt iL2 = VL2 + VLm = – Vo +vLm

Substitute spillage inductor voltages in VL1 and VL2 and the polarizing voltage vLm is equivalent to zero, so the inductor flows are communicated as pursues 〖di〗_L1/dt= 〖di〗_L2/dt= - V_o/L_lk

The yield inductor current is communicated as pursues di_Lo/dt=-V_o/L_lk [(1-2D)/(0.5-D)]

3.3. Mode 3 [Ts/2 – (Ts/2+DTs)]

In the Mode 3 The main distinction is that VL1 = - VO and VL2 = Vin – VO rest all equivalent as mode 1. The inductor and yield current is communicated as pursues.

〖di〗_L1/dt=V_o/L_lk [(k-D-kD)/(1+k)D]

〖di〗_L2/dt=V_o/L_lk [(1-D-kD)/(1+k)D]

k speaks to the coupling coefficient and the estimation of k ought to be under 1. In the buck converter the obligation proportion ought to be under half. So the estimation of inductor current of L2 is more prominent than inductor current of L1.

3.4. Mode 4 [(Ts/2 + DTs) ~ Ts]

The Mode 4 is same as mode 2 . Voltage over the inductors are same.

In the mode1 the dt is equivalent to the DTs the inductor current and yield current is communicated as
ΔiL = V_o/L_lk [(1-D-kD)/((1+k))]Ts
ΔiLo = V_o/L_lk [1-2D]Ts

4.ENDURING STATE QUALITIES

Enduring state activity necessitates that the inductor current toward the finish of theswitching cycle be equivalent to that toward the start, implying that the net changein inductor current more than one period is zero. This requires
ΔI_L1 (close)+ΔI_L1 (open)=0
There fore using Eqs. 9and 12 ,

$$\frac{(V_S - V_O) - VLm}{Llk} DT + \frac{-V_O + VLm}{Llk}(1-D)T = 0$$

Since from the above equation

$$\frac{(V_S - V_O) - VLm}{Llk} T_1 T + \frac{-V_O + VLm}{Llk} T_2 T = 0$$

Where T_1 = D and T_2 = 1-D
Illuminating for VO ,
V_O=(D+K(1-D))/(1+k) Vs
The all out normal inductor current must be equivalent to the normal current in the heap resistor, since the normal capacitor current must be zero for unfaltering state activity:

$$I_L = I_O = \frac{V_O}{R_O}$$

Here

$$I_L = I_{L1} + I_{L2}$$

Since the adjustment in inductor flows is known from Eqs. 9 and 12 the greatest and least estimations of the inductor current are can be composed as

$$I_{L1}max = I_{L1} + \frac{\Delta I_{L1}}{2}$$

$$I_{L1}max = \frac{V_O}{2R_O} + \frac{-V_O}{Llk}\frac{(1-D)T}{2}$$

$$I_{L1}max = V_O\left(\frac{1}{2R_O} - \frac{(1-D)}{(k^2-1)D2L1f}\right)$$

Similarly

$$I_{L2}max = V_O\left(\frac{1}{2R_O} - \frac{(1-D)}{(k^2-1)D2L2f}\right)$$

$$I_{L1}min = I_{L1} - \frac{\Delta I_{L1}}{2}$$

$$I_{L1}min = \frac{V_O}{R_O} - \frac{-V_O}{Llk}\frac{(1-D)T}{2}$$

$$I_{L1}min = V_O\left(\frac{1}{2R_O} + \frac{(1-D)}{(k^2-1)D2L1f}\right)$$

Similarly

$$I_{L2}min = V_O\left(\frac{1}{2R_O} + \frac{(1-D)}{(k^2-1)D2L2f}\right)$$

Eqs. 34 can be utilized to decide the mix of L1 and f that will bring about nonstop current. Since I_L1 min = 0 is the limit among constant and intermittent current,

$$(L1f)_{min} = \frac{(1-D)R_0}{(k^2-1)D}$$

$$L1_{min} = \frac{(1-D)R_O}{(k^2-1)Df}$$

Similarly

$$L2_{min} = \frac{(1-D)R_O}{(k^2-1)Df}$$

By and by, the yield voltage can't be kept impeccably steady with a limited capacitance. The variety in yield voltage, or wave, is processed from the voltage-current relationship of the capacitor. The current in the capacitor is

$$i_{CO} = i_{L1} + i_{L2} - i_O$$

While the capacitor current is certain, the capacitor is charging. From the meaning of capacitance,

Q=C_O V_O

ΔQ=C_O 〖ΔV〗_O

ΔV_O=ΔQ/C_O

The adjustment in control ΔQ is the region of the triangle over the time pivot

$$\Delta Q = \frac{1}{2}\left(\frac{T}{4}\right)\left(\frac{\Delta i_{L1}}{2}\right)$$

$$\Delta Q = \left(\frac{T\Delta i_{L1}}{16}\right)$$

$$\Delta V_O = \left(\frac{T\Delta i_{L1}}{16C_O}\right)$$

From eqs 44 eqs 45 can be written as

$$\Delta V_O = \frac{T}{16C_O}\left(\frac{-V_O}{Llk}(1-D)\right)T$$

In this condition, ΔVo is the top to-top wave voltage at the yield, as appeared in

Figure12. It is likewise valuable to express the wave as a small amount of the yield voltage,

$$\frac{\Delta V_O}{V_O} = \frac{(1-D)}{16C_O f^2}\frac{1}{(1-k)L1}$$

$$C_O = \frac{(1-D)}{16\frac{\Delta V_O}{V_O}f^2}\frac{1}{(1-k)L1}$$

5.THE COMPARISON BETWEEN COUPLED AND NON COUPLED CONVERTERS

Table 1. Comparison between Coupled and Non coupled Converters

Duty ratio	Output Ripple Current	
	Coupled	Non Coupled
0.1	0.015	1.724
0.2	0.016	2.58
0.3	0.0164	2.58
0.4	0.011	1.72
0.5	0	0

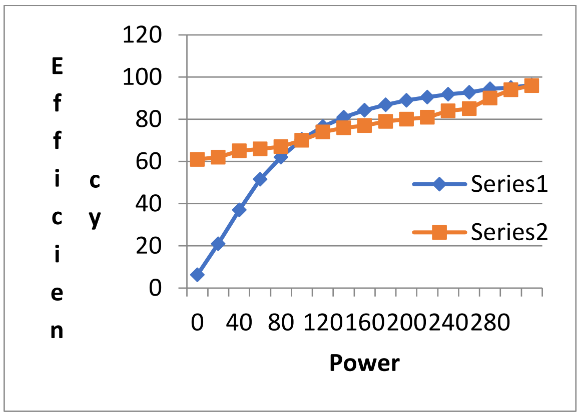

Fig6 Efficiency versus Power

6.SPECIFICATION OF TWO PHASE INTERLEAVED BUCK CONVERTER WITH COUPLED INDUCTOR

Table 2 Specification of the Converter

PARAMETERS	VALUES
Input voltage	48
Output voltage	12
Switching frequency	100KHZ
Current ripple	Less than 5% of output current
Output voltage ripple	Less than 1%
Turns Ratio	0.9
Output power	250W

7. SIMULATION RESULT

7.1. Open loop Simulation of Interleaved buck converter with coupled inductor

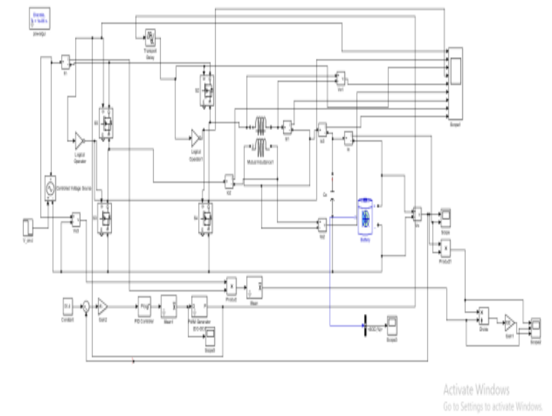

Fig 7 Open loop simulation of IBC with coupled inductor

From figure7 it is seen that exchanging beats Vgs1 and Vgs2 are 180o stage moved and obligation proportion is 0.25 individual inductor current are additionally stage moved and consequently both inductor flows get dropped each other so all out inductor wave will be diminished to zero. This case will happen in two stage IBC for just obligation proportion of 0.5.

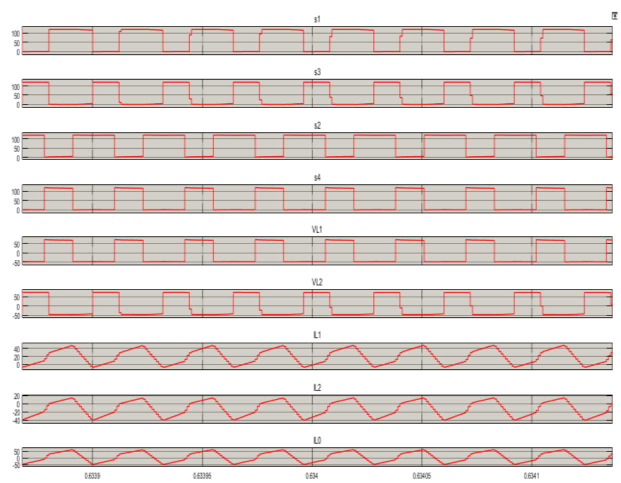

fig 8 simulated voltage and current waveforms of IBC with coupled inductor for open loop operation

7.2. Closed loop simulation of interleaved buck converter with coupled inductor

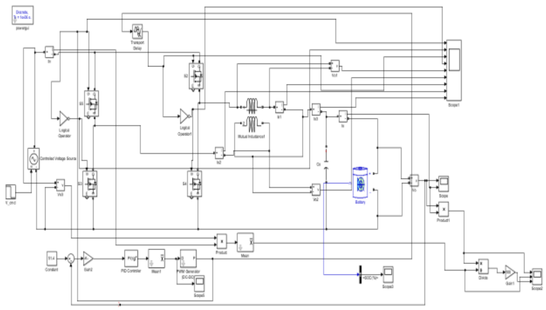

Fig 9 closed loop simulation of IBC with coupled inductor

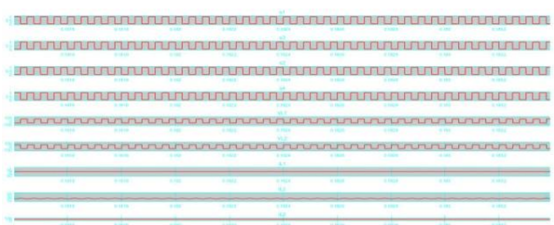

Fig 10 simulated voltage and current waveforms of IBC with coupled inductor for Closed loop operation

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