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TAPPED-INDUCTOR BOOST CONVERTER

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Abstract

In many emerging applications it is required a high boosting gain; in the literature has been proposed many topologies to make this possible, since the traditional dc-dc boost converter cannot make the very high boosting function by itself. "
"In this paper a different approach to obtain the high boosting gain is proposed: the tapped-inductor boost converter. This converter has few components and high efficiency, and also operates in a simple way. Analysis and experimental results are presented.

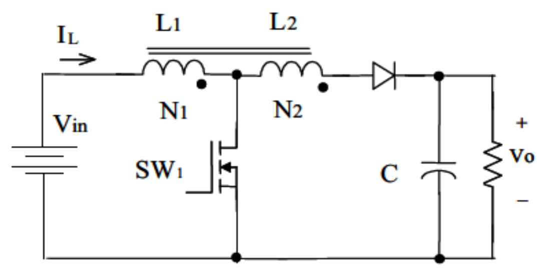
Keyword: tapped inductor,coupled inductor, pi controller

1.INTRODUCTION

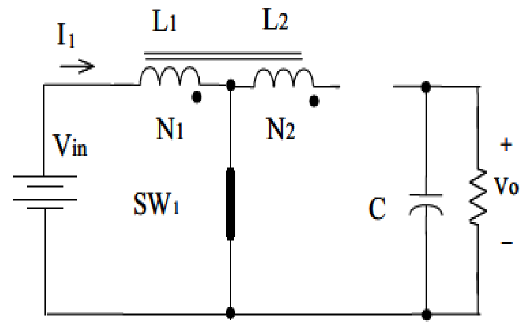
DC–DC converters with a high boosting function are required in emerging applications, with no isolation . Applications examples are photovoltaic systems, uninterruptible power supplies, automobile head lamps, and telecommunication systems. As the traditional dc-dc boost converter cannot provides a high boosting gain, many topologies have been proposed. In topologies like the boost/flyback converter and the cascade boost converter is analyzed in other topologies, but with a clamped mode coupled inductor is analyzed; the disadvantage of the integrated topologies is the amount of semiconductors that it is required to make the boosting function. In a coupled inductor boost converter with a regenerative snubber is discussed, but a complex circuit is proposed. All the schemes reported in literature present a good approach to obtain the high boosting function; but complex circuits are obtained, or many components are required. For a different kind of applications it has been proposed the tapped-inductor buck converter to reduce the voltage significantly with a reasonable duty cycle . In this paper the tapped-inductor boost converter is proposed. This is a different approach to obtain the desired high boosting capability, resulting in a simpler converter, with high efficiency and without the complexity of stages integration or complex regenerative snubbers. The analysis and experimental results of the tapped-inductor boost converter are presented in this paper."

2.OPERATION OF THE CONVERTER

"The circuit diagram of tapped-inductor boost converter shown below:"

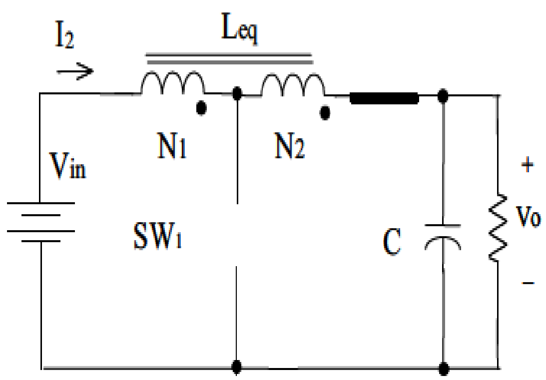


Mode-1: The equivalent circuit when the switch is closed is as shown below:



"When the switch is "ON": the diode is not conducing, due to the voltage polarity of the magnetic element. The magnetic element is being charged through the inductor L_1."

Mode-2: The equivalent circuit when the switch is open is as shown below:



"When switch is "OFF": the diode is conducting and the magnetic element is being discharged through the equivalent inductance of L_1 and L_2."

"The two subcircuits of the converter are determined by the main switch and these subcircuits are shown in the figure below. The high boosting capability is because the discharging process of the magnetic element is made with a higher inductance value (the equivalent)."

"The relation between L_1 and L_2 is determined by the turns ratio of the magnetic element, that is:"

$$\frac{L_2}{L_1} = \left(\frac{N_2}{N_1}\right)^2 \text{ ------------------- (1)}$$

The inductance is proportional to the turns square of the Inductor

$$L_1 = k(N_1)^2 \text{ ---------------- (2)}$$

Then equivalent inductance of L_1 and L_2 is:

$$L_{eq} = k(N_1 + N_2)^2 \text{ --------------- (3)}$$

On substituting $N_2 = NN_1$ in the above equation we get,

$$L_{eq} = \left((N+1)\right)^2 L_1 \text{ --------------- (4)}$$

"This is the equivalent of the coupled inductance L_1 and L_2 when the magnetic element is discharged."

"Another important equation of the magnetic element is that just before and after the switch is turned on or off, the energy stored is the same that is:"

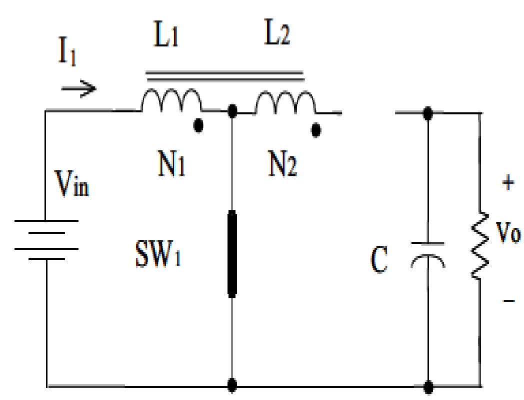
$$\frac{L_1 i_1^2}{2} = \frac{L_2 i_{eq}^2}{2} \text{ ----------------- (5)}$$

$$i_1 = i_2(N+1) \text{ -------------- (6)}$$

"Where: i_1 is the input current when the switch is on i_2 is the input current when the switch is off. This important equation is considered for the average model of the converter. With this equation the waveforms of the converter can be obtained."

3.STEADY STATE ANALYSIS OF THE CONVERTER

Mode-1



On applying KVL,

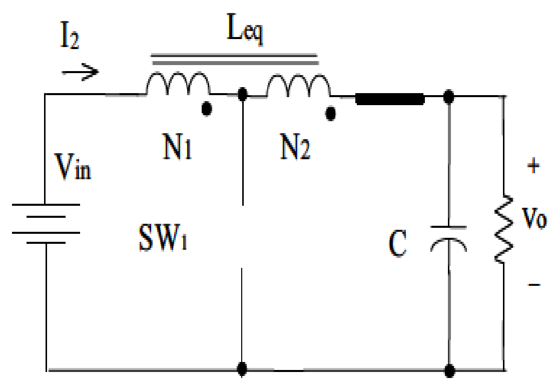
$$V_{in} = V_{SW_1} \text{ -------------- (7)}$$

$$L_1 \frac{d_{iL_1}}{dt} = V_{S_1} \text{ ------------- (8)}$$

$$\frac{d_{iL_1}}{dt} = \frac{V_{S_1}}{L_1} \text{ --------------- (9)}$$

$$\Delta I_L \text{ (closed)} = \frac{V_S DT}{L_1} \text{ --------- (A)}$$

Mode-2



On applying KVL to the above circuit,

$$V_{Leq} = V_{in} - V_o \text{ ----------(10)}$$

$$L_{eq} \frac{d_{iL}}{dt} = V_{in} - V_o \text{ --------- (11)}$$

$$\Delta I_L \text{ (open)} = \frac{V_{in} - V_o}{L_{eq}} \text{ -------- (12)}$$

On substituting equation (4) in equation (12) results in

$$\Delta I_L \text{ (open)} = \frac{V_{in} - V_O(1 - D)T}{L_1\left(1 + N\right)^2} \text{ ------ (B)}$$

"Steady-state operation requires that the inductor current at the end of the switching cycle to be the same as that at the beginning, meaning that the net change in inductor current over one period is zero. This requires Equations (A) + (B) implies"

$$\Delta I_L \text{ (closed)} + \Delta I_L \text{ (open)} = 0$$

$$\frac{V_S DT}{L_1} + \frac{V_{in} - V_O(1 - D)T}{L_1\left(1 + N\right)^2} = 0$$

On solving the above equation we get

$$V_o = \frac{V_{in}\left[D\,(N + 1)^2 + 1\right]}{\left(1 - D\right)} \text{ ---------(C)}$$

"Equation (C) is the expression for output voltage of the converter in terms of input voltage, duty cycle & turns ratio."

"Inductor current I_L is given by an expression,"

$$I_L = \frac{V_{in}}{R\,(1 - D)^2} \text{ ----------------- (13)}$$

"Maximum inductor current I_{max} is given by an expression,"

$$I_{max} = I_L + \frac{\Delta I_L\left(\mathbf{closed}\right)}{2} \text{ ------ (14)}$$

On substituting equations (13) and (A) in equation (14) we get,

$$I_{max} = \frac{V_{in}}{R\,(1 - D)^2} + \frac{V_S DT}{2L_1} \text{ -------(15)}$$

Minimum inductor current I_{min} is given by a expression,

$$I_{min} = I_L - \frac{\Delta I_L\left(\mathbf{open}\right)}{2} \text{ ----------- (16)}$$

On substituting equations (13) & (B) in equation (16) we get,

??
$$I_{min} = \frac{V_{in}}{R(1-D)^2} - \frac{V_{in} - V_o(1-D)T}{2L_1(1+N)^2}$$

-------- (17)

"To obtain an expression for $L_{\min}$ we equate $I_{min} = 0$ & replacing L_1 by $L_{\min}$ in equation (17) we get,"

$$\frac{V_{in}}{R(1-D)^2} - \frac{V_{in} - V_o(1-D)T}{2L^2_{\min(1+N)}} = 0$$

$$\frac{V_{in}}{R(1-D)^2} = \frac{V_{in} - V_o(1-D)T}{2L^2_{\min(1+N)}}$$

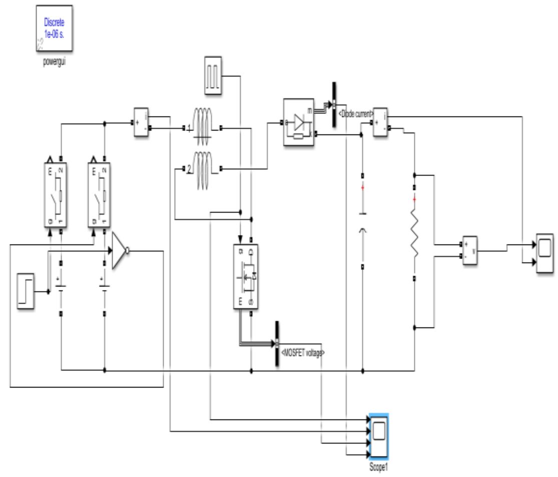
$$L_{min} = \frac{(V_{in} - V_o)(1-D)^3 R}{2f(N+1)^2 V_{in}}$$

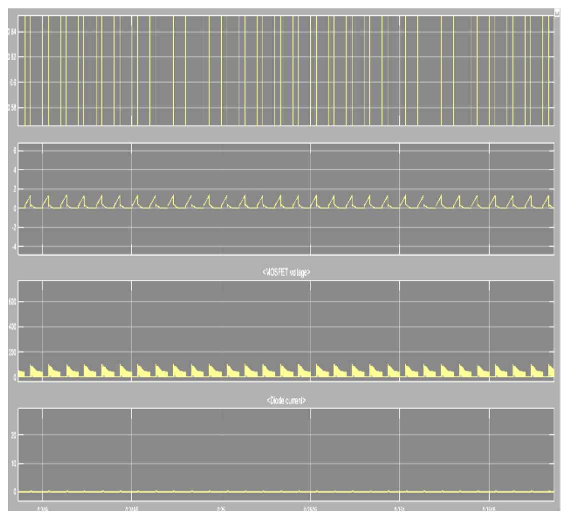
Output Ripple Voltage: $\Delta\frac{V_o}{V}$

$$\Delta\frac{V_o}{V} = \frac{D}{RfC_o}$$

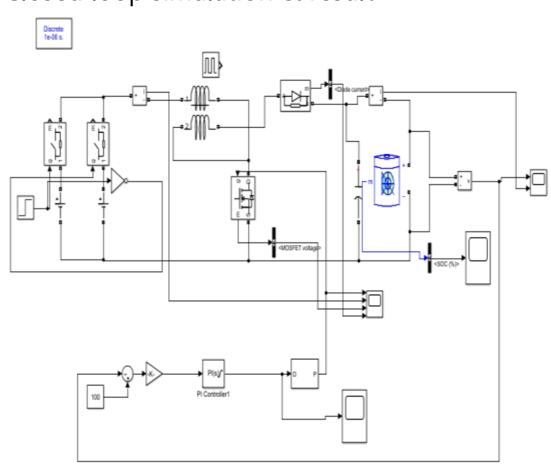
$$C_o = \frac{D}{Rf\left(\frac{\Delta V_o}{V_o}\right)}$$ -------------- (18)

Simulation:
Open loop simulation & result





Closed loop simulation & result



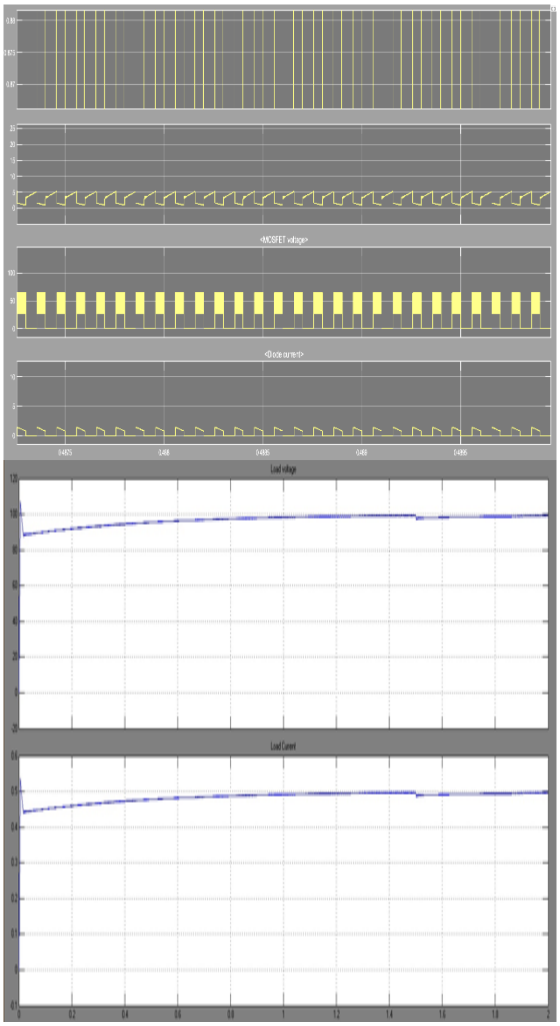


Table 1: parameters

Parameters	Values
Input voltage	36 volts
Output voltage	98 volts
L1 and L2	530µH and 2300µH
Lm	1100µH
Capacitor	28.5µF
Resistance	200 ohm

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