State Space Modelling with Coupling Inductor of DC-DC Boost Converter

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Abstract- *Optical Power Converters, due to their switching are periodic system variants. In order to increase low solar panel voltage (12V) to high voltage the high-grade DC-DC converters is particular useful. The wide spread state house technology described in this paper is a way to mannequin converters as time unbiased system, defined by using a single set of differential equations which is a time based. This article shows the state area modelling further use of coupling inductor in a propose dc-dc boost converter topology.*

Indexed Terms- *state space model of DC-DC boost converter, coupling inductor, High gain boost converter.*

I. INTRODUCTION

In lot of industrial applications DC-DC converters that operate at excessive voltage control typically are used. In theory an enhancement of dc -dc can achieve excessive step-up voltage with an exceedingly high liability ratio nearly to 100%. In reality however, the increased voltage level is limited because of the impact of the intensity switches, the current diode, the equivalent resistances of injectors and condensers to the series (ESR). The coupling inductor procedure used in DC-DC Boost converters. Proposed High Acquisition offers the solution for excessive voltage gain, and high performance, while maintaining excessive obligation ratio. The first is a circuit averaging-based methodology while the second is a kingdom space averaging-based methodology for modelling converters. In this research, we derive a country space- model of a high-performance dc -dc improve converter with Coupling inductor topology.

II. TOPOLOGY

DC-DC converters come in a variety of topologies, each with its own set of components and efficiency. Due to the high cost of electricity generated by PV modules, an environmentally friendly converter is necessary. The non-isolated is more efficient than the isolated one

The boost input inductor was replaced with a coupled-inductor switching cell generated by a transistor in a new suggested topology. The output voltage clamped the voltage stress on the transistor. The output voltage is absorbed by the rectifier diode. A novel solution is being studied to further reduce current strains on the switches, which involves connecting a current limiting inductor in series with the secondary coil of the connected inductor. A capacitor and two diodes are added. The new converter has a high conversion ratio, as well as a high gain and low voltage stress on the switches. It maintains the soft-switching operation and solves the recovery problems. The steady state technique is used to model high gain dc-dc boost converters. the circuit is as follows,
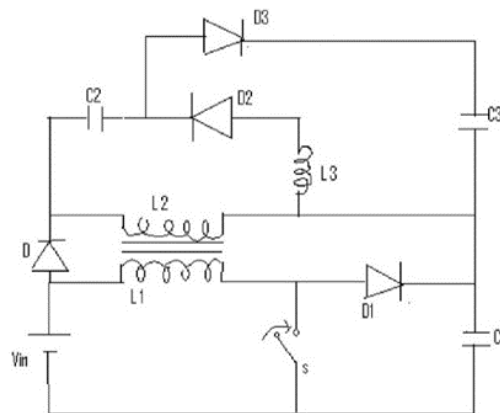

Fig. (a) Proposed dc-dc boost converter

The proposed High gain DC-DC boost converter is having coupling inductor provides 360Vdc from the small input voltage of 12Vdc with good efficiency.

III. OPERATION OF BOOST CIRCUIT

Because of the inductor zero   presently, rather than specific zero, the circuit operates in continuous mode. As a result, it is possible to ensure that the inductor's stored energy is totally discharged. The following diagrams show how the works. The suggested converter circuit has two modes of operation. When the switch is turned on, mode 1 is active, and mode 2 is inactive (when swap is off). When swap is enabled, mode 1 is used

- Mode 1 when switch is ON: The figure. (2) Shows the inductor L1 draws current from the battery. In this stage the current will flow through inductor, switching device and back to the source. In this case the inductor current rises and energy is store in the inductor. The voltage across the inductor is equal to the input dc voltage (Vin) with the polarity as shown in circuit. Because the diode is not conducting remains in place. The condition of reverse bias However, because of the coupled When inductor L1 is connected to inductor L2, current will flow as well. Through the inductor L2, the diode D2, and the capacitor C2 (the capacitor) is charged. L3 is the inductor. (current limiting inductor) is used to control current. When the switch is turned on, current is directed through diode d2. So, when the switch is flipped current flows in two loops. When switch is in ON condition.
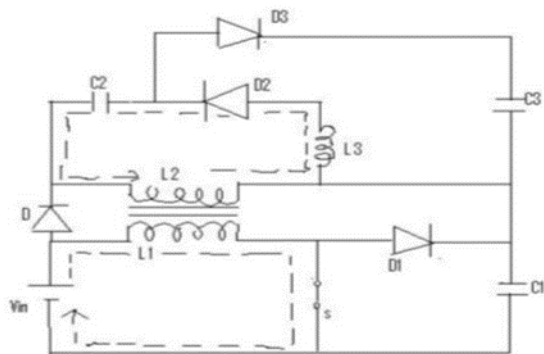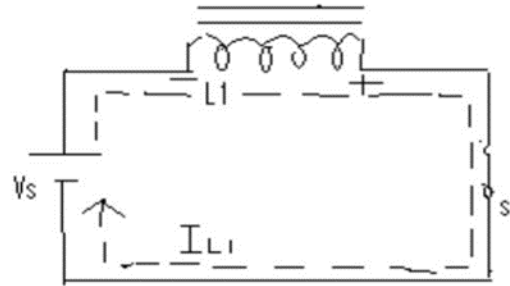

Fig.(b): Mode 1: switch is ON

Analysis: The equivalent circuit of when switch is as follows

Current across inductor L1:

Fig(c)

$$Vs = L1 \frac{dIL1}{dt}$$

$$IL1 = \frac{Vs}{L1} X \frac{1}{S} \text{ (Valid fot t=0 to Ton)}…………(a)$$

Voltage across the inductor L1:

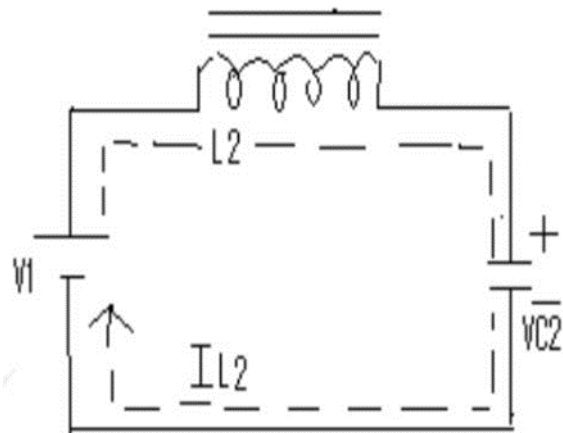

Fig (d)

$$V1 = Vs \times \left(\frac{N2}{N1}\right), \text{ At t=0, Vc2 =0, IL3=0}$$

$$V1 = L3 \frac{dIL3}{dt} + Vc2$$

$$IL3 = C2 \frac{dVc3}{dt}$$

Put the value of IL2, we get

$$V1 = L3C2 \frac{d^2Vc2}{dt} + Vc2 \text{(Valid for } IL3 \geq 0)$$

$$Vc2 = \frac{V1}{1+S^2 L3C3} ………………………………… (b)$$

- Mode 2: When switch is OFF: In figure. (e) When the switch is turned off, mode 2 is activated. When the switch is turned off, diode D1 becomes forward biased and conducts, as seen in figure (e). The current will travel through the inductor L1, the diode D1, the capacitor C1, and then back to This voltage is connected to the input voltage in series (Vin). So (Vin + Lid/dt) is the total voltage across the switch S1. The diode D1 is forward biassed, thus the inductor's stored energy is transmitted to the load. The current in the inductor L1 decreases, as illustrated in the waveform. In this case capacitor C2 acts as a voltage source. The capacitor C1and C3 continue to provide the output value of the power supply. There will be an induced voltage with the polarities as shown in fig. (a) to keep the current flowing in the same direction (3). Lid/dt is the voltage magnitude.
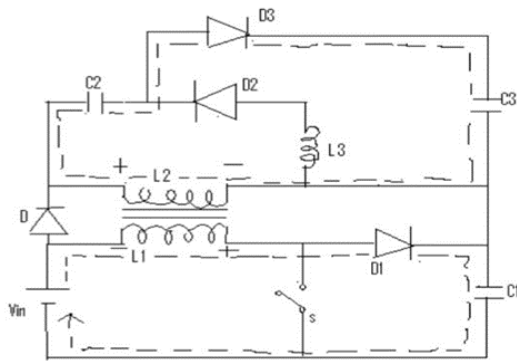

Fig.(e): when switch is OFF

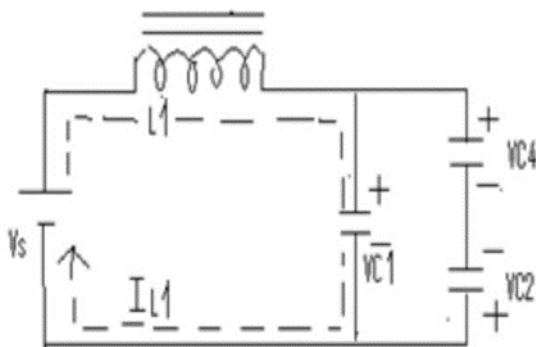Analysis when switch is off is as follows:

Fig.(f)

Calculate the inductor current and output voltage.
Current across the inductor L1:

$Vc4 = Vc3 \times \dfrac{N1}{N2}$

$Vc2 = Vc2(Ton)\left(\dfrac{N1}{N2}\right)^2$

$C4 = C2\left(\dfrac{N2}{N1}\right)^2$

At t = 0, Vc1 = 0, Vc4 = 0

$IL1 = C1\dfrac{dVc1}{dt} + C4\dfrac{dVc4}{dt}$,

$Vc4 = Vc1 + Vc2(Ton)\dfrac{N2}{N1}$,

Current across the inductor L1:

$IL1 = (C1 + C4)\dfrac{dVc1}{dt}$, ………………….(c)

Substitute the value of IL1,in this equation and we get value of across the capacitor.

$Vs = L1\dfrac{dIL1}{dt} + Vc1$

$Vs = L1(C1 + C4)\dfrac{d^2CL1}{dt} + Vc1$

Voltage across the capacitor C1:

$Vc1 = \dfrac{Vs}{1+L1(C1+C4)S^2}$……………………(d)

Vc1 nothing but output voltage.

IV.   STATE SPACE MODELLING

With a rudimentary understanding of matrix algebra, the state space technique provides a more convenient way to examine such systems. The state space approach is based on the analysis is done in the time domain by resembling the first-order differential equations-based system It's also arranged in a matrix format. In a SISO system (single input, single output), the output is a linear combination of the state variables. D is the null matrix, which has no variables. As a result, the situation exists. The SISO system's equation is as follows:

$\dot{x} = Ax + Bu$
Y= C x

The representation of the equivalent circuit of switching mode, DC-DC high gain boost converter shown in state space form. The circuit equation can be written by applying KVL and KCL to describe the dynamic behaviour of the circuit as follow [6]:

- STATE SPACE REPRESENTATION WHEN SWITCH IS ON:

Applying KVL in loop 1fig (c):
$$L1\frac{dIL1}{dt} = Vs$$

Applying KVL in loop 2 fig (d):

$$L2\frac{dIL2}{dt} + Vc3 = V1$$

Applying KCL in loop 2 fig (d):

$$C3\frac{dVc3}{dt} - IL1 = 0$$

These equations can be rearranged as:

$$\frac{dIL1}{dt} = \frac{Vs}{L1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(e)}$$

$$\frac{dIL2}{dt} = \frac{1}{L2}(V1 - Vc3) \ldots\ldots\ldots\ldots\ldots\ldots \text{(f)}$$

$$\frac{dVc3}{dt} = \frac{1}{C3}IL1 \ldots\ldots\ldots\ldots\ldots\text{(g)}$$

Equation (e) (f) (g) can be expressed in state space form as follows:

$$\begin{bmatrix} \frac{dIL1}{dt} \\ \frac{dIL2}{dt} \\ \frac{dVc3}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & \frac{-1}{L2} \\ 0 & \frac{1}{C3} & 0 \end{bmatrix} \begin{bmatrix} IL1 \\ IL2 \\ Vc3 \end{bmatrix} + \begin{bmatrix} \frac{1}{L1} & 0 \\ 0 & \frac{1}{L2} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} Vs \\ V1 \end{bmatrix}\ldots\ldots\text{(h)}$$

The output equation is written as
$$Y = C1\,x$$
Y1 = IL1, Y2 = IL2, Y3 = Vc3
$$\begin{bmatrix} Y1 \\ Y2 \\ Y3 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} IL1 \\ IL2 \\ IL3 \end{bmatrix}$$

Equation (h) can be written in standard state space form is:
$$\frac{dx(t)}{dt} = A1x(t) + B1u(t)$$
Where x(t) is the (3x1) state variable vector, u(t) is the (2x1) input, A1 and B1 are matrices with constant elements given by

$$A1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & \frac{-1}{L2} \\ 0 & \frac{1}{C3} & 0 \end{bmatrix} \quad B1 = \begin{bmatrix} \frac{1}{L1} & 0 \\ 0 & \frac{1}{L2} \\ 0 & 0 \end{bmatrix}$$

$$C1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

- STATE SPACE REPRESENTATION SWITCH IS OFF:

KVL at the loop fig.(f)

$$L1\frac{dIL1}{dt} = Vs - Vc1$$
 KCL at the node 1:
$$(C1 + C4)\frac{dVc3}{dt} - IL1 = 0$$
These above equations can be arranged as:
$$\frac{dIL1}{dt} = \frac{1}{L1}Vs - \frac{1}{L1}Vc1 \ldots\ldots\ldots\ldots. (i)$$
$$\frac{dVc1}{dt} = \frac{1}{C1+C4}IL1 \ldots\ldots\ldots\ldots. (j)$$
Equation (i) and (j) can be written in state space form as follows:
$$\begin{bmatrix} \frac{dIL1}{dt} \\ \frac{dVc1}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{-1}{L1} \\ \frac{1}{C1+C4} & 0 \end{bmatrix} \begin{bmatrix} IL1 \\ Vc1 \end{bmatrix} + \begin{bmatrix} \frac{1}{L1} \\ 0 \end{bmatrix} [Vs]\ldots\ldots\ldots\text{(k)}$$
The output equation is written as:
Y=C2x
Y1 =IL1, Y2=Vc1
$$\begin{bmatrix} Y1 \\ Y2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} IL1 \\ Vc1 \end{bmatrix}$$
Equation (k) can be written in standard state space form as:
$$\frac{dx(t)}{dt} = A2x(t) + B2u(t)$$
Where x(t) is the (2x1) state variable vector, u (t) is the single input, A2 and B2 are matrices with constant elements given by

$$A2 = \begin{bmatrix} 0 & \frac{-1}{L1} \\ \frac{1}{C1+C4} & 0 \end{bmatrix} \quad B2 = \begin{bmatrix} \frac{1}{L1} \\ 0 \end{bmatrix} \quad C2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

CONCLUSION

The state space methodology, which was used to model a high gain DC-DC increase converter with coupling inductor, provides a number of advantages over circuit averaging, including a more compact description of equations and the ability to achieve more switch functions. Instead of utilising a model built with switches that takes a long time to simulate, this nation area averaged model equation can be utilised to simulate a converter using MATLAB. This State area equation can be used to analyse device performance and develop controllers for balance studies. As a result, deriving country area fashions of high gain DC-DC improve converter topology facilitates circuit analysis.

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