Small signal modeling and steady state stability analysis of PWM based switch model Boost converter using Pspise

Mrs. Swapna Manurkar

Assistant Professor,
Electrical Engineering,
Vishwaniketan's Institute of Management Entrepreneurship and Engineering Technology, Navi Mumbai, India

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Abstract*—Boost converters find special place in power electronics industr*y as they step up the applied dc voltage, present paper talks about boost converter in small signal model using PWM switch topology. The work undertakes step by step approach for finding stability of given boost circuit for small perturbations in discontinuous conduction mode in voltage mode configuration commonly called as DCM.

***Index Terms*—PWM, DCM, VM, perturbations.**

I. Introduction

Almost all the electronic circuits, such as radio receivers, and signal processing circuits which work on Dc, generally carry small time-varying (AC) signals on top of a constant (DC) bias. These ac signals how so ever small it may be must interfere with dc supply and disturb its working. This suggests that there must be some method to find out the effect of these small signal perturbations about the bias point. The bias point of a device, quiescent point, or Q-point, is the steady-state voltage or current at a specified terminal of an active device such as a transistor with no input signal applied. In electrical circuits working on dc supply for example SMPS,

i)If small ac signals interfere with input dc

OR

ii) If the duty cycle changes suddenly for a small time

OR

iii) If the connected load gets some variation ,

Then how the SMPS will behave, is the part of study.

Aim of this paper is to find out behavior of circuit under disturbance and to check, if the circuit can attend stability after applying this small disturbance, itself?

Else

A controller is proposed so as to make circuit to cope up with the disturbance and make the SMPS to regain its stability as fast as possible.

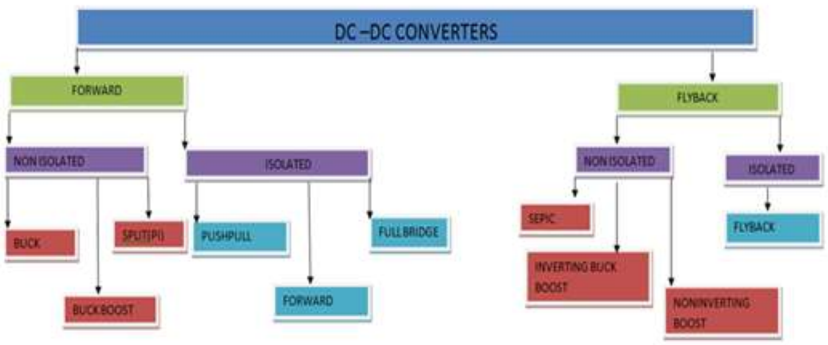
The process for linearising a non linear system about a bias point is to take partial derivative of the formula expressing the non linear system with respect to all the variables governing the system. The resultant partial derivatives are thereafter can be expressed by physical quantities like inductance, resistance and capacitance. Finally a circuit diagram can be proposed representing the system .Such a small signal model exists for devices like FET"s, diodes, electron tubes MOSFET and BJTs.

II. Switch Mode Dc-Dc converters (SMPS)

The dc-dc converter takes an unregulated dc voltage input and gives out a constant or regulated voltage. The regulators can be broadly classified into linear and switching regulators.

Switch mode DC-DC converters efficiently convert an unregulated DC input voltage into a regulated DC output voltage. Switching power supplies as compared to linear power supplies provide much more efficiency and power density. These systems employ solid-state devices such as transistors and diodes to operate as a switch: either completely on or completely off. Capacitors and inductors which are energy storage elements work as a low-pass filter and are used for energy transfer. The buck converter and the boost converter are the two fundamental topologies of switch mode DC-DC converters. Most of the other topologies are either buck-derived or boost-derived converters, because their topologies are equivalent to the buck or the boost converters.

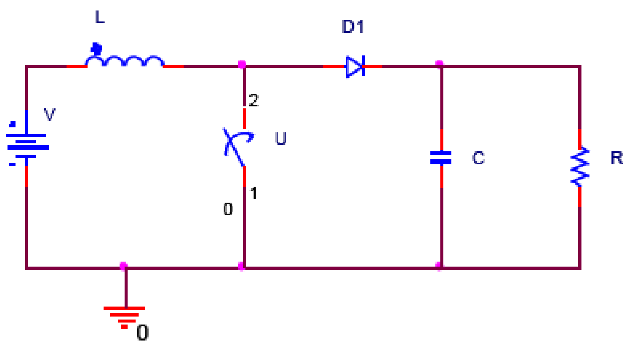
There are some different methods of classifying dc-dc converters. One of them depends on the isolation property of the primary and secondary portion. The isolation is usually provided by a transformer, with primary portion at input side and a secondary at output side as general practice. On the other hand in portable devices, as the area to implement bulky transformer and other off-chip component required is very big and costly, non-isolated dc-dc converters are more preferred.



FAMILY OF DC - DC CONVERTERS

III. Boost converter

A boost converter also called step-up converter is a DC-to-DC power converter, it gives an output voltage greater than its input voltage. It is a type of switched-mode power supply (SMPS) which contains, at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or both. Sometimes filters (made up of capacitors) are also added in combination with inductors to improve the output voltage wave and to get as pure dc as possible.



BOOST CONVERTER

The above figure shows a boost converter in switch diode topology. In order to prepare its small signal model we have to consider the given boost circuit in ON and OFF state.

IV. SMALL SIGNAL MODELING

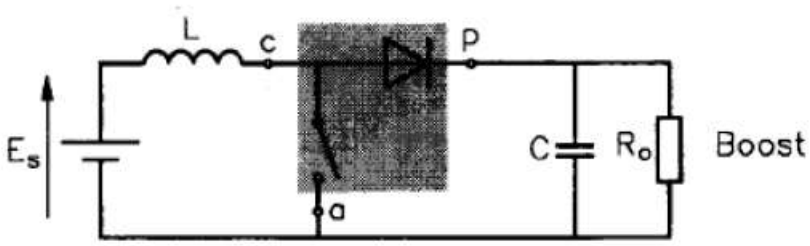
Modeling is the representations of physical phenomenon by mathematical means. Approximate models are thus important tool for designing and gaining physical insight of such models. In modeling process approximation techniques are use to neglect small but complicated phenomenon.

V. PWM switch

A PWM switch is a three-terminal nonlinear device, called the PWM switch, which consists of solely the active and passive switches in a PWM converter. Once the invariant properties of the PWM switch are determined, its average equivalent circuit model can be derived.

The introduced PWM-switch modeling technique is a simple technique for modeling pulse-width-modulated (PWM) dc-dc converters operating in the continuous conduction mode. The main advantage of this technique is its versatility and straight forward implementation compared to alternate methods. The fundamental idea is the replacement of the switches in the converter by their time averaged models.

VI. PWM switch model of Boost converter:



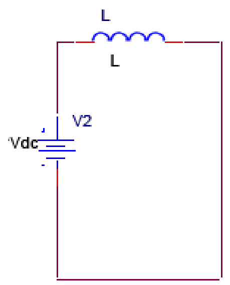
PWM SWITCH MODEL OF BOOST CONVERTER

VII small signal model of Boost converter (PWM switch):

In order to prepare small signal model of any converter following steps should be followed:

i. Select the converter from family of converters.
ii. Find duty cycle of converter
iii. Find it's dc transformer model and
iv. Find prepare small signal model

VII. Duty Cycle of Boost converter :

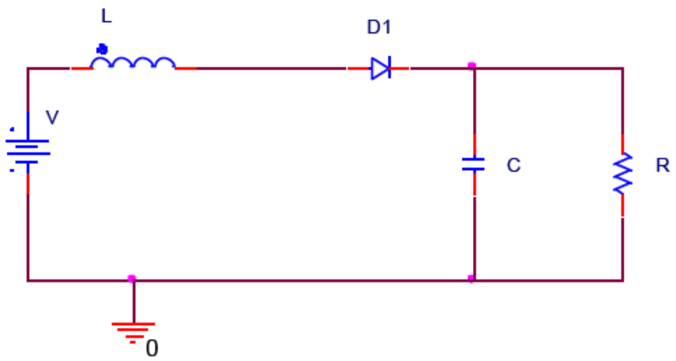


ON STATE OF BOOST CONVERTER

Equations for on state of boost

$V_L\ (t) = V_g$ (1)

OFF STATE CIRCUIT:



OFF STATE OF BOOST CONVERTER

$v_{L\,t} = V_g - (t) = V_g - V$ (2)

$v_{L\,t\,dt} = V_g DTs + (V_g - V)'Ts$ (3)

$0 = V_g D + (V_g - V)'$, *according to inductor volt second balance and ca*pacitor charge balance.
Again as $D + D' = 1$
$V_g - VD' = 0$
$V_g = VD'$
$V = V_G / D' = V_G / 1 - D$
$M\ (D) = V / V_G = 1/1-$ (4)

IX. Dc equivalent of boost converter

To find out the dc equivalent of boost converter, we write the equations for two states (On & OFF)and combine them we get final inductor voltage and capacitor balance equation in the following form
$v_l t = V_g - IR_l - D'V = 0$ (5)
$i_c = 0 = D'I - V/R$ (6)
Now let us draw the equivalent circuits for these equations.
Circuit for eq (5)

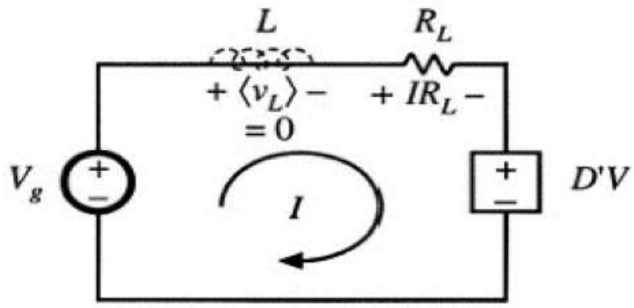


Fig - circuit for representing equation 5

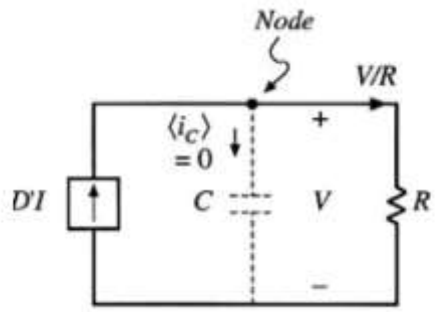
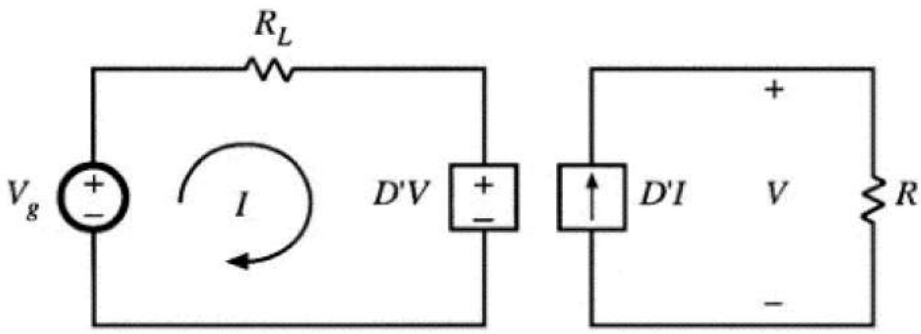


Fig – Circuit for representing equation 6

Final dc transformer model for boost converter after joining these two circuits is as follows.



DC Transformer model of Boost converter

X. Small signal model of boost converter :

Derivation for small signal model of boost converter consists of writing the three equations i.e. for inductor current capacitor voltage and input current.
Thus we get after averaging, linearization and perturbation

$L_{(I+i\,(t))/dt} = -D'v\; t - d\,(t)V$ (7)

$C=_{(V+v\,(t))\;/dx} = -D'i\; t - Id\,(t)$ (8)

Drawing the circuits for above equation and combining to get final small signal model of boost converter yields into;

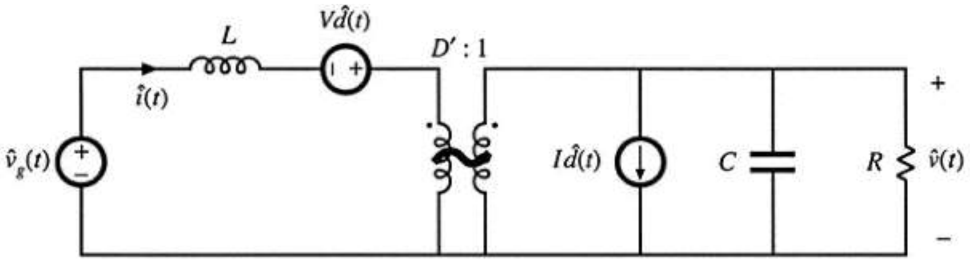


FIG SMALL SIGNAL MODEL OF BOOST CONVERTER

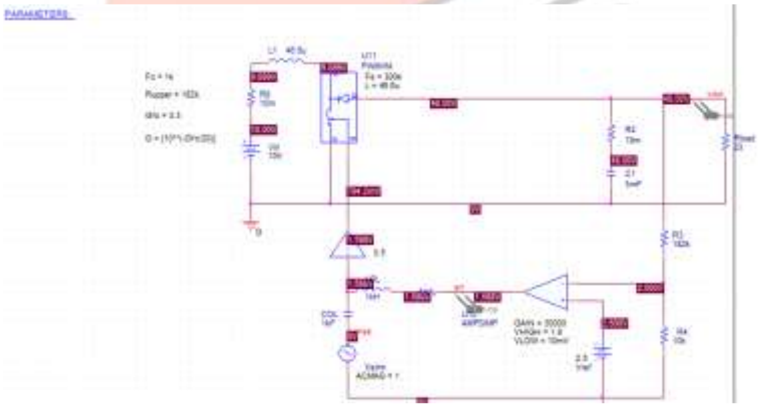
XI. STABILITY ANALYSIS OF SMALL SIGNAL MODEL OF BOOST CONVERTER

In order to perform steady state stability analysis we can follow procedure as mentioned:
After preparing small signal model

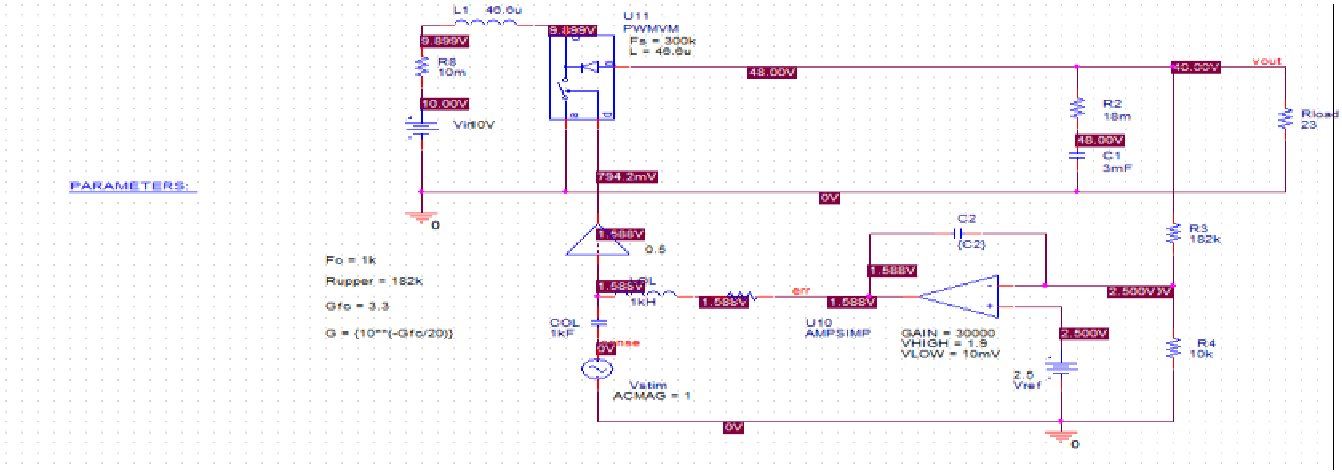
i. Find stability of converter circuit without anty controller
ii. Then apply some controller eg type1.
iii. Again find stability
iv. Replace controller by another option from list say type 2,type3 and so on..

In present paper same procedure is followed for boost converter and following results are obtained for small signal model of boost converter without controller, with type1 and type 3 controller.

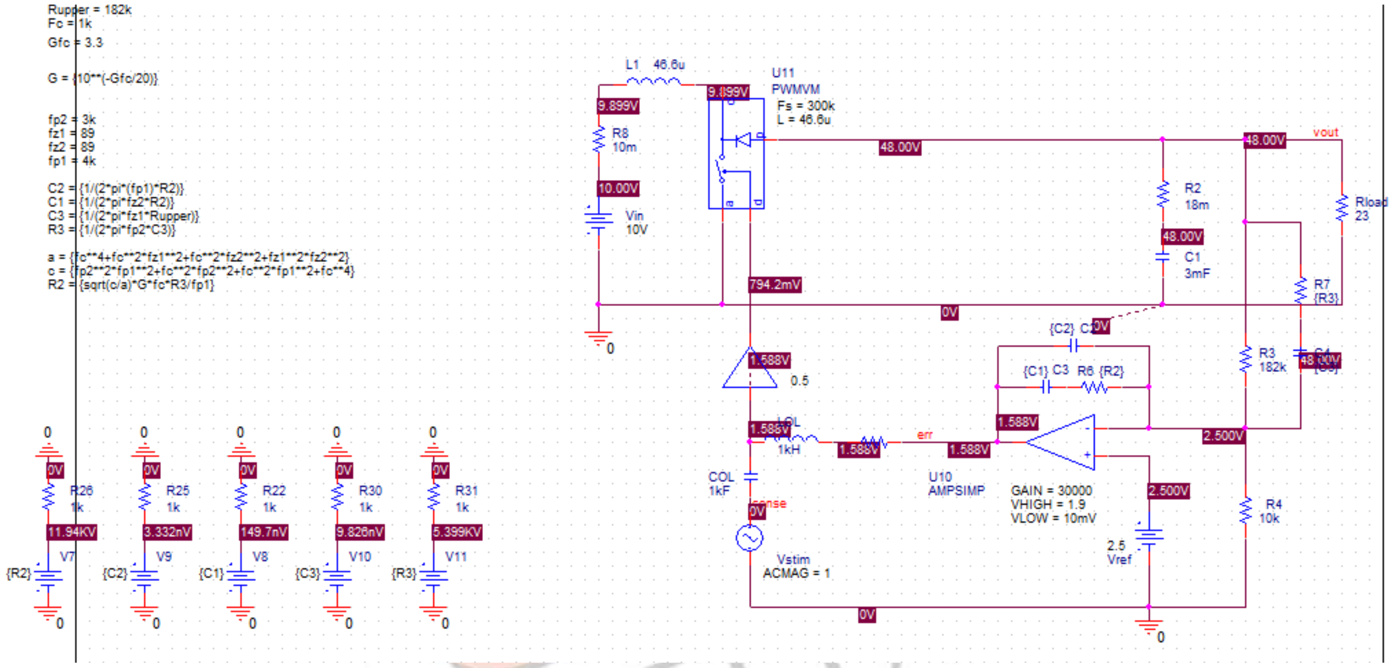
XII. RESULTS:



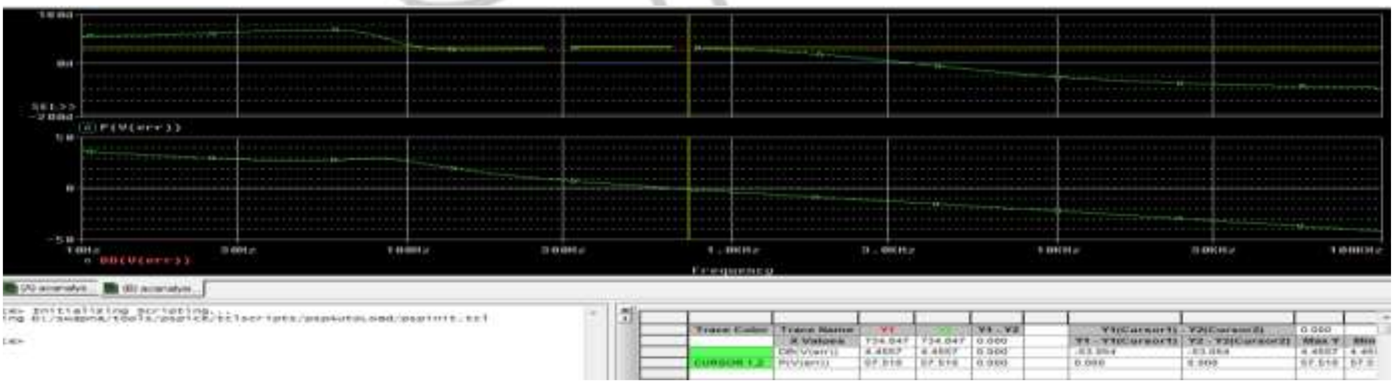
BOOST CONVERTER WITHOUT CONTROLLER



BOOST VM PWM CONVERTER WITH TYPE 1 COMPENSATOR



BOOST VM PWM CONVERTER WITH TYPE 3 COMPENSATION



	Results obtained for small signal modeling of Boost converter		
s.no	***Type of converter***	***Phase margin***	***Phase margin after compen sation***
1	Boost converter in VM PWM configuration without compensator	-175°	-------
2	Boost converter in VM PWM configuration with type 1 compensation	-175°	-83.03°
3	Boost converter in VM PWM configuration with type 3compensation	-175°	57.51°

CONCLUSION:

Boost topologies in VM without and with compensator are compared and presented. It has been observed that type 3 compensator makes system stable with phase margin of 57.51°.

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