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Performance Analysis of Techniques Used For Designing Of Closed Loop Dc-Dc Boost Converters

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Abstract

This paper gives a brief review of the techniques used for deigning of closed loop DC -DC boost converter. The prominent modes of operation which are analysed are voltage mode control (VMC), current mode control (CMC), sliding mode control (SMC), cascaded control (CC). Cascaded control is found to be the most suitable approach for designing of DC-DC boost converter. MATLAB/SIMULINK tool environment is used for plotting the waveforms and implementing mathematical equations.

Index terms- *DC-DC converter, VMC, CMC, SMC, CC.*

1. Introduction

DC to DC converter is a class of power converter efficiently used for converting one level of electrical voltage to another by transferring energy from a dc voltage source to load. Two conversion methods are used in DC to DC converters:

1) Linear conversion
2) Switched mode conversion.

Switched mode conversion is much preferred over linear mode as in case of switched mode conversion the input energy so transferred is momentarily stored by DC –DC converter in a magnetic field storage or electric field component and then later on released at a different output voltage level. Above mentioned process includes transistors and diodes as switching elements and inductors and capacitors as storage devices. Thus in this way energy is first transferred via electronic network to energy storage devices and aftermath switched from storage into the load. The resultant output voltage of DC-DC converter is related to the input voltage by the duty ratio of switches. While in the latter case the linear regulators can only be practically used if current is low and power dissipated is being small, thus linear regulators can only output at lower voltages from the input.

There are four basic topologies of DC to DC converters when used as switching mode regulators:

- **Buck regulators** It is a step down DC to DC converter in which the output voltage is lower than the input voltage as well as inhibits the same polarity.

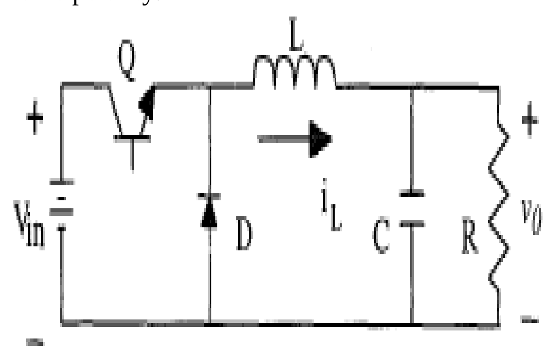

Fig: 1

- **Boost regulators** As the name suggests in ‘Boost’ converter the output voltage is certainly higher than the input voltage. It is a non inverting regulator in which the output voltage exhibits the same polarity as input.

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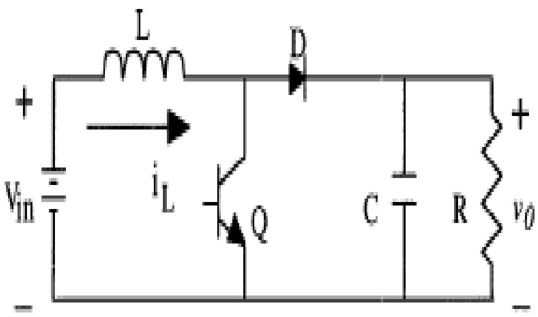

Fig: 2

- **Buck-Boost regulator**: A buck boost regulator provides an output voltage that may be less than or greater than the input voltage. It is a non inverting type of regulator as the output voltage exhibits same polarity to the input voltage.

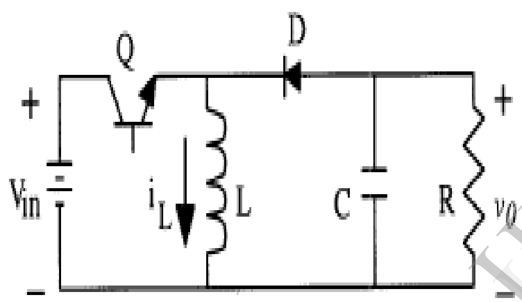

Fig: 3

- **Cuk regulators**: A Cuk regulator has the same properties as that of a buck-boost regulator as the output voltage can be lesser or greater than the input voltage, but unlike the buck-boost regulator output voltage of Cuk regulator exhibits opposite polarity to the input voltage.

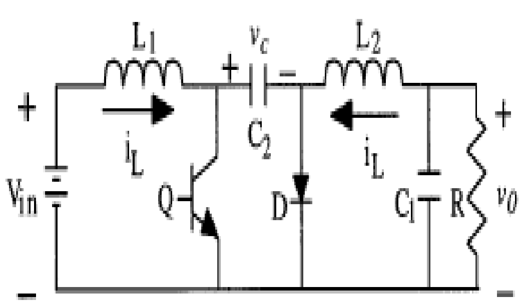

Fig: 4

These topologies can be widely used either in open loop modelling or in the closed loop modelling of DC –DC converter.

Open loop modelling It is a manual modelling. Open loop systems are simpler in their layout and hence are economical due to their simplicity, also they are easier to construct. But as open loop systems do not have a feedback mechanism they suffer from the disadvantage of being inaccurate in terms of result output as they get disturbed in the presence of non linearity's. Due to the absence of a feedback mechanism, they are unable to remove the disturbances occurring from external sources.

Closed loop modelling It is an automatic control system modelling. Closed loop systems are much more accurate than open loop systems as they do not get disturbed in the presence of non-linearity. These systems possess noise reduction ability, as they are composed of a feedback mechanism, so they clear out the errors between input and output signals, and hence remain unaffected to the external noise sources.

The switching scheme used in this paper is PWM (pulse width modulation) switching scheme. In this scheme the switch between supply and load is turned on/off at a very fast pace so as to control the average value of voltage and current fed to the load. The longer the switch is on as compared to the off periods, the higher the power supplied to load is. Thus the switch basically operates on the above mentioned principle using PWM switching scheme. The term **duty cycle** expresses the ratio of 'on' time to the entire 'period' of the time in percentage. It is generated by comparing DC reference signal with a saw-tooth signal as a carrier wave. PWM switching scheme thus offers an advantage of bearing low power loss in the switching devices.

In this paper we study the detailed review of open loop and closed loop modelling thereby proving closed loop boost regulators to be an efficient and durable design as compared to other regulator designs. Simulation is done using MATLAB SIMULINK.

2. Background Work

In the background work we briefly mention open loop & closed loop boost converter performance in various control modes as devised in some of the recent research papers published by the authors.

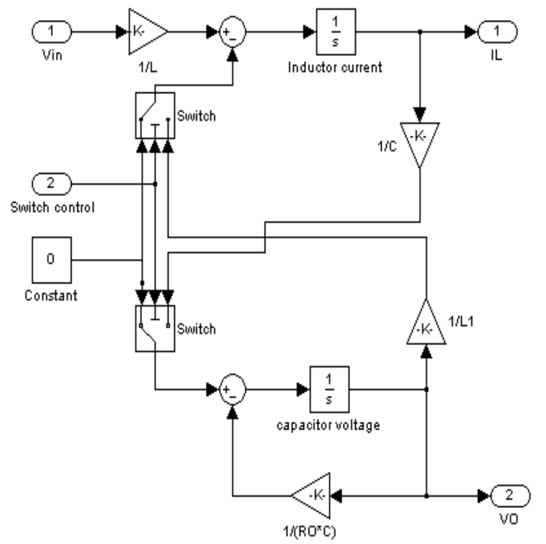

Fig.1 (a) Open loop boost converter modelling

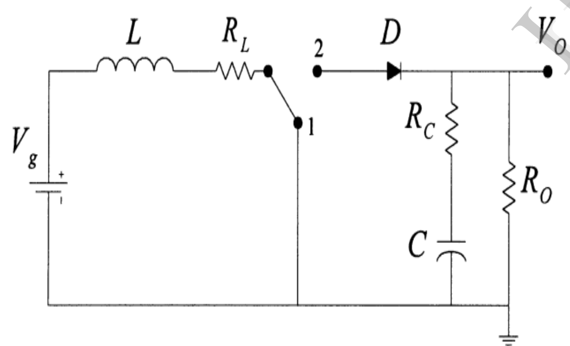

Fig: 1(b)

Boost converter with a switching period T and a duty cycle D is shown in the above diagram. Operation of this boost converter is carried out in continuous conduction mode. The state space equations as mentioned below are derived using Kirchoff's voltage and Kirchoff's current law (KVL &KCL).

(i) When the switch is ON ($0 < t < dT$)

$$di_l/dt = 1/L\ (V_{in})$$

$$dv_0/dt = 1/C\ [-(v_o/R)]$$

(ii) When the switch is OFF ($dT < t < T$)

$$di_l/dt = 1/L\ (V_{in} - V_{out})$$

$$dv_0/dt = 1/C\ [i_l - (v_o/R)]$$

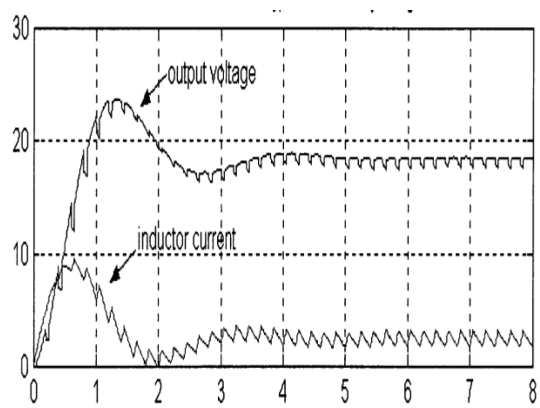

Fig.1(c)

(ii) Closed loop boost converter modelling:

There are three prominent modes of operation in closed loop modelling which are as follows:

- Voltage mode control
- Current mode control
- Sliding mode control

(a) Voltage mode control:

Voltage mode control is the traditional method of regulation. In this method the output voltage (V_{out}) is compared to the reference voltage (V_{ref}) via a voltage divider R_1 and R_2 and then amplified by a PI (proportional integrator) regulator. PWM scheme results in the conversion of the output voltage of PI regulator into PWM output voltage t1/T. Finally the output of the PWM controls the transistor drive of the boost converter.

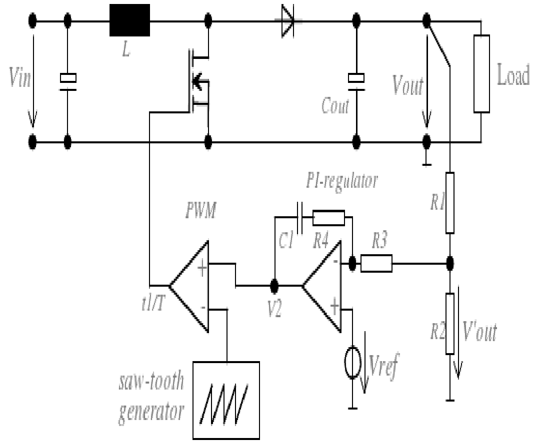

Fig: 2 Voltage mode control

The operation of the closed loop is as follows:

If V_{out} is too low then the output voltage V'_{out} (across the resistance R_2 cascaded with R_1 thereby forming the voltage divider arrangement) will be lower than the V_{ref}. resulting in an increase in V_2 (output voltage of PI regulator). Subsequently in the PWM circuit V_2 is compared with the saw-tooth signal. This results in an increase in output voltage until $V_{out} = V_{ref}$.

(b) Current mode control:

In current mode control the output voltage (V_{out}) is compared to the reference voltage (V_{ref}) via a voltage divider R_1 and R_2 and then amplified by a PI (proportional integrator) regulator. Unlike the voltage mode control the output voltage of PI regulator in case of current mode control is compared with ramp voltage across the current measuring resistor R_i. When the voltage across R_i exceeds V_2 the output of the comparator resets a RS flip flop and turns the transistor off. Thus in this way the PI regulator directly gets hold of the inductor current and controls it by turning the transistor on by the clock and turning it off when ramp voltage reaches a certain value.

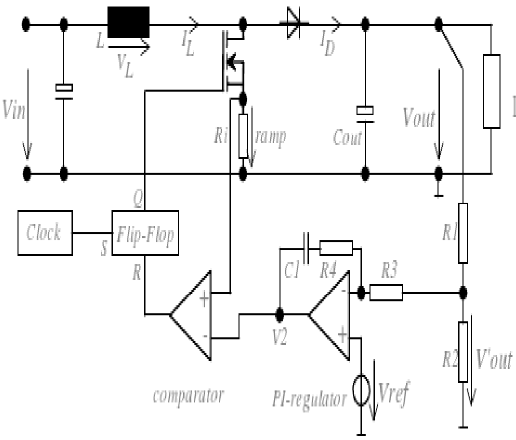

Fig: 3 Current mode control

The operation of the closed loop is as follows:

If V_{out} is too low then the output voltage V'_{out} (across the resistance R_2 cascaded with R_1 thereby forming the voltage divider arrangement) will be lower than the V_{ref}. resulting in an increase in V_2 (output voltage of PI regulator). Subsequently in the PWM circuit V_2 is compared with the ramp signal. In this way V_2 determines the value to which ramp voltage across R_i increases.

Advantage of current mode control over voltage mode control:

It is observed that current mode control has a better control response as the PI regulator of CMC regulates the inductor current directly which is then fed into the output capacitor (C_{out}) and load resistance (R_l) thereby forming a first order system and the step response while in case of voltage mode control the voltage across L is controlled. This voltage operates on a second order system formed by L,C_{out} and R_l.

(c) Sliding mode control:

Though the control design of current mode control is tough still dynamic behaviour has been greatly improved by using this technique. Sliding mode control can overcome the above mentioned circuit designing issue as it is very sturdy and stable. Sliding mode control operates at an infinite switching frequency so that the controlled variables can possibly trace a certain reference path thus achieving the desired dynamic response and steady state operation. This reference path can be traced as per the **switching control law,** thereby resulting in superimposition of non linear plant state trajectory on a pre specified (user chosen) path for a proximate period of time. This surface is known as the switching surface .Thus if the plant state trajectory is above the switching surface the feedback path has one gain and a different gain if trajectory drops below the switching surface in this way sliding mode control imparts a proper switching rule by achieving goals of control, stabilization, tracking and regulation. Certain issues with the performance analysis of sliding mode control are as follows:

1) Extremely high speed switching in power conversion results in excessive switching losses.
2) Additional circuitry is used to reduce the chattering phenomenon caused by the input signal around the switching surface.

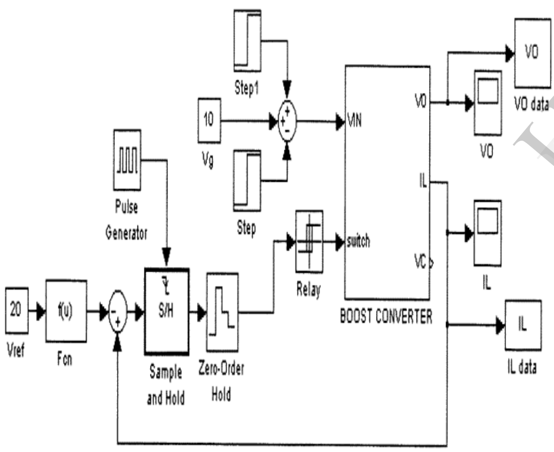

Fig.4(a)

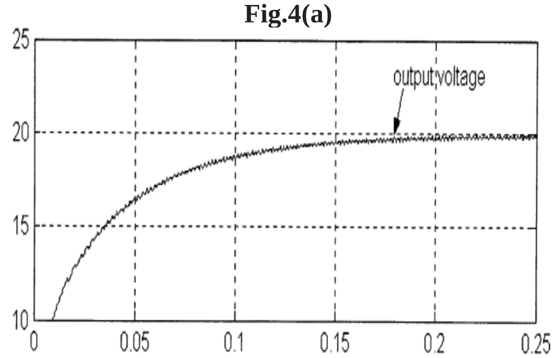

Fig.4(b)

The technique devised in this paper so as to overcome the design issues with voltage, current and sliding mode control is ***closed loop DC-DC converters using cascaded control*** thereby offering higher efficiency and noise suppression.

3. Performance Analysis of closed loop control techniques.

S.no	Parameters	Voltage Mode control	Current mode control	Sliding mode control	Cascaded mode control
1.	Efficiency	Average	Better than VMC	Offers higher efficiency than VMC &CMC	Equivalent than sliding mode control
2.	Design complexity	Tradition al	Much complex	Easy to construct	Easy to construct
3.	Losses	Higher	No dominant switching losses	Higher switching losses	Switching losses are highly reduced
4.	Compensati on	Not required	Slope compensat ion required	Not required	Not required
5.	Noise elimination	----------	Slope compensat ion is required	Hysteresis method used for noise elimination	Noise is suppressed in cascaded mode

Table: 1

4. Result and conclusion

The conclusion inferred from this paper is that though cascaded mode control of DC-DC boost converters offers an equivalent efficiency to sliding mode control but it is free from switching losses as well as no predominant method is needed for noise suppression. Thus there is a future scope for

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improving the design issues of DC-DC converters using cascaded mode control.

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