Design of a Hysteresis Controller for Dc Buck Converter

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***Abstract*: This paper is about the use of non linear Hysteresis Controller for DC-DC Buck converter to improve the performance of the converter in terms of its transient response. The non linear control method is then compared with the linear Proportional Integral (PI) controller and it is find that non linear control strategy is better suited for fast response of the system. Also, a Soft switching technique using ZVS scheme is used with the buck converter to minimize the losses and EMI.**
Keywords: Hysteresis Controller, PI Controller, Soft switching, Zero voltage switching (ZVS).

I. INTRODUCTION

A. Dc-Dc Converters

The switched mode dc-dc converters are some of the simplest power electronic circuits which convert one level of electrical voltage into another level by switching action. These converters have received an increasing deal of interest in many areas like automation, aircraft, battery chargers, computers and laptops, DC motors etc. The analysis, control and stabilization of switching converters are the main factors that need to be considered. Like other power supplies, an SMPS transfers power from a DC or AC source to DC loads, while converting voltage and current characteristics. The switch mode DC-DC converters are some of the simplest circuit which converts power level of DC power effectively. These converters used for electronic devices are designed to regulate the output voltage against the changes in parameters, input and output load variations.

A DC-DC converter or chopper circuit is a static power electronic device which converts fixed DC voltage/power to variable DC output voltage/power directly. Switched-mode DC-to-DC converters convert one DC voltage level to another, which may be higher or lower, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors).A chopper is a DC equivalent of an AC transformer; as they can step up or down the output DC voltage. The one step conversion in choppers makes them more efficient, fast with smooth control. The power semiconductor devices used in chopper circuits are generally commutated thyristor; power BJT, power MOSFET, GTO or IGBT. These devices works as a switch which connects or disconnects the load to the source at a high speed.

B. Zero voltage switching

The traditional switching technique used in power converters is hard switching. It is the simplest switching technique. But for high frequency applications, when switching loss increases proportionally with the frequency, this switching technique does not offers effective and accurate results [1]. Thus, soft switching techniques came into picture which utilizes resonant components to minimize the losses in power converters. Though they require more number of components and is not as simple as hard switching, but it offers accurate and efficient results. Further, the resonant switch converter is classified in two categories namely:

1) Zero current switching
2) Zero voltage switching

In ZVS a capacitor is placed in parallel with the power switch in ZV resonant converters to obtain zero voltage switching condition. The transistor turn on transition occurs at zero voltage. The basic aim is to shape the switch voltage during turn off time in order to create a zero voltage condition during turning on of the switch. Transistor turn-on transition occurs at zero voltage. Diodes may also operate with zero-voltage switching. Zero-voltage switching eliminates the switching loss induced by diode stored charge and device output capacitances.

C. Control Methods

For a DC-DC converter, the parameters, input and load variations are major reasons which alter the proper functioning. The controller for such DC-DC converter is a circuit or an algorithm which changes the Pulse Width Modulation (PWM) waveform by

adjusting the ON-OFF timings thereby keeping the output at the desired value. Quick settling time and rise time to the desired output along with high efficiency, required phase margin, loop bandwidth are the main constraints on the controller.
Linear controllers like proportional (P), proportional integral (PI), and proportional integral derivate (PID) do not offer a good large-signal transient conditions. The controlling of non linear systems with linear controllers is also not gives very accurate results. Therefore, major research has been performed in investigating non-linear controllers like Hysteresis controller and Sliding Mode Control (SMC) etc. DC Buck converters are non linear circuits, so non linear controllers are well suited for their controlling. Nonlinear controllers provide a promising alternative to the linear average controller [2].

II. PRINCIPLE OF DC-DC BUCK CONVERTER

The buck converters are used in SMPS circuits, where there is a requirement of low DC voltage from the high DC input voltage. The DC input can be derived from rectified AC or from any DC supply. The switch used between the input and output of the buck converter circuit (which is generally a power device) switches on and off at high frequency. The energy is stored in the inductor L during the on period, which is supplied to the load during the off period.

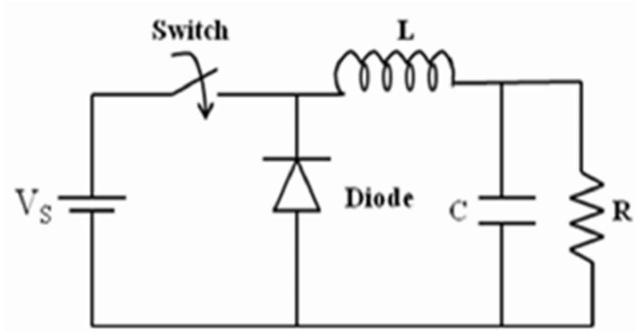

Fig. 1 DC-DC buck converter circuit

When the switching transistor (switch) is switched on, it is supplying the load with current. Initially current flow to the load is restricted as energy is also being stored in inductor L, therefore the current in the load and the charge on capacitor C builds up gradually during the ‘on’ period. Throughout the on period, there will be a large positive voltage on diode cathode and so the diode will be reverse biased and therefore play no part in the action
When the transistor (switch) is off, the energy stored in the magnetic field around L is released back into the circuit. The voltage across the inductor (the back e.m.f.) is now in reverse polarity to the voltage across L during the ‘on’ period, and sufficient stored energy is available in the collapsing magnetic field to keep current flowing for at least part of the time the transistor switch is open. The back e.m.f. from L now causes current to flow around the circuit via the load and D, which is now forward biased. Once the inductor has returned a large part of its stored energy to the circuit and the load voltage begins to fall, the charge stored in C becomes the main source of current, keeping current flowing through the load until the next ‘on’ period begins.
Thus, rather than a large square wave at the output, a ripple waveform i.e. small amplitude, high frequency triangular wave DC is obtained.
And, $Vo = Vs\, T_{ON} / T$
(T_{ON} / T is Duty cycle K)

III. METHODOLOGY USED

A. Design of a soft switched buck converter circuit by using ZVS strategy, and a non linear controller i.e. *Hysteresis Controller* in feedback loop of DC buck Converter for fast response of converter circuit.
B. Finally, the comparison of the non linear hysteresis controller with the linear PI controller.

IV. SIMULATION OF PROPOSED TECHNIQUE

In this paper, closed loop hysteresis voltage mode control of DC to DC buck Converter is simulated in MATLAB/Simulink environment. The simulation is done for both, PI controller as well as the hysteresis Controller and their performances are compared. Fig. 3 shows the diagram for DC to DC converter using hysteresis controller. The simulation using PI controller also is performed in order to observe the responses of both controllers and compare them. The pulse from the hysteresis controller is being given at the switch of buck converter. It is the controlling signal for the converter circuit and modifies all the transient parameters of the converter.

A. Hysteresis controller

Hysteresis controller is a digital non linear controller especially used for controlling non linear circuits. It is derived from the variable structure control theory (VSCS) and is well suited for non linear systems. The use of hysteretic controllers for low voltage regulators used in computer and communication systems has been gaining interest due its various advantages. Advantages of this control approach includes fast response and robust with simple design and implementation. They do not require components for feedback loop compensation [3]-[4]. This reduces the number of components and size of theoretical analysis for implementation. They response to disturbances and load change right after the transient takes place. Hence they give excellent transient performances.

B. Parameters for buck converter

The various parameters while the designing of buck converter in SIMULINK are given in Table 1.

Table 1 Designing parameters

Inductance	1mh
Capacitance	100µF
DC input voltage	80 V
DC output voltage	40 V

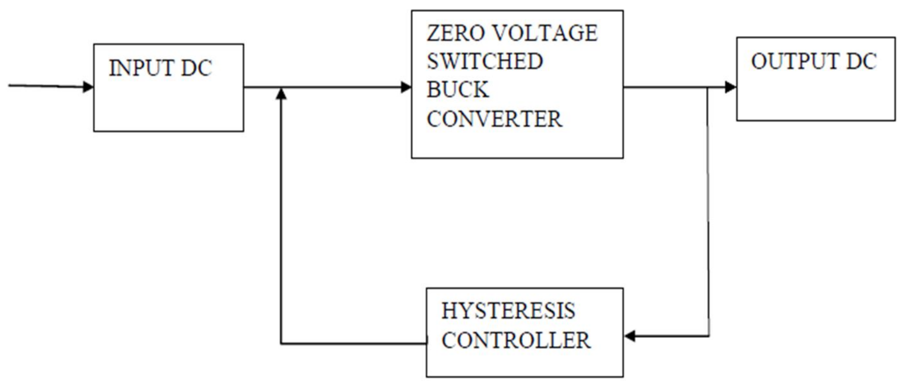

Fig. 3 Zero voltage switched Buck Converter using Hysteresis Controller

V. SIMULATION RESULT IN SIMULINK

The simulation result shows the output voltage with time for PI and hysteresis controlled ZVS buck converter, when a step change of 20V is made at time 0.025 seconds in the reference voltage. The vertical axis represents the output voltage in Volts. The horizontal axis represents time in seconds. The blue colour in the simulation graph represents hysteresis controlled buck converter and the pink colour represents PI controlled buck converter. Table 2 represents the transient response parameters for the converter circuit with PI and hysteresis controller.

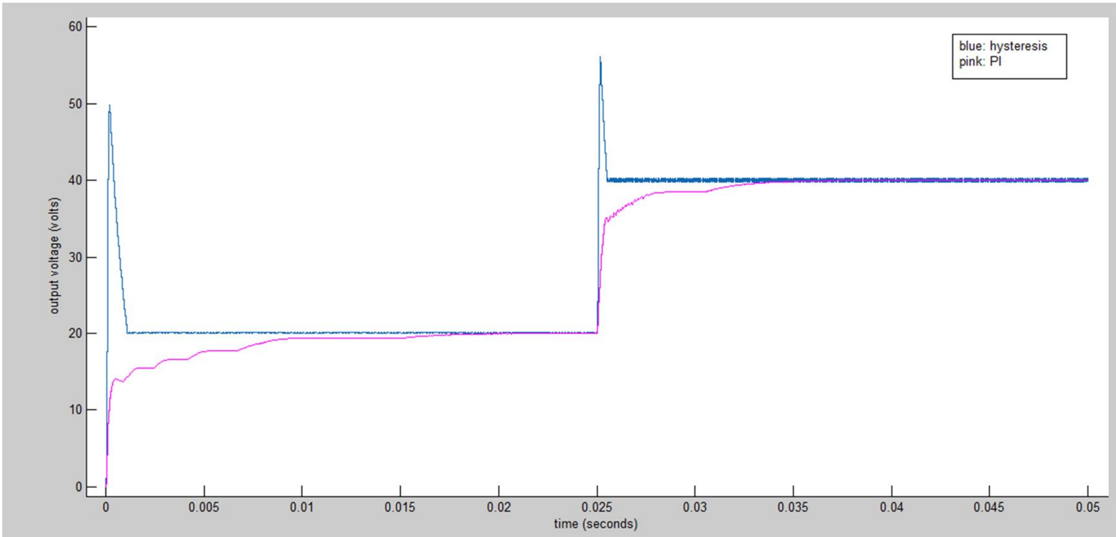

Fig. 4 Simulation result showing comparison between PI and hysteresis controlled Buck converter

Table 2 Transient Characteristics

PARAMETER	PI CONTROLLER	HYSTERESIS CONTROLLER
Rise time	0.0024secs	0.0001secs
Settling time	0.01secs	0.0005secs

From Table 2 it is clear that we get better results for Hysteresis controlled buck converters. As the system reaches its steady state earlier in comparison to PI controlled converter, making the system fast and robust.

VI. CONCLUSION

Hysteresis Controller for controlling transient response of a soft switched (ZVS) DC Buck converter has been modeled and simulated on MATLAB/SIMULINK in this research work. The PI controller has also been implemented for the same conditions. The result is shown as a comparison between PI controller and Hysteresis Controller which proves that under similar parameters the Hysteresis control has better results in terms of rise time and settling time. Thus, for step down converter circuits which require fast transient response in their operation, non linear Hysteresis controller can be used. The system with Hysteresis control gives stability and robustness irrespective of system uncertainties. It is also easy to implement as compared to other non linear controllers. These properties make this control methodology highly suitable for applications in nonlinear systems. It is pretty well suited in industrial applications, e.g., electrical drivers, automotive control, furnace control, etc.

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