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Control Techniques used to Improve Performance of Dc-Dc Converter: A Review

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ABSTRACT: The switched-mode dc-dc converters are most widely used power electronics circuits for flexible output voltage and high conversion efficiency. These converters are designed to regulate the output voltage against the changes of the input voltage and load current. This needs more advanced control methods for the real demand. Time to time different control methods are developed for the control of dc-dc converters. But to get best performances under any conditions is always in demand. By using Control techniques used to Improve Performance of Dc-Dc Converter is very much useful.

Keywords: Hysteresis control, Sliding mode control, Dc-dc buck converter, variable structure system.

I. INTRODUCTION

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. This is due to their wide applications like power supplies for personal computers, [1] office equipments, appliance control, telecommunication equipments, DC motor drives, automotive, aircraft, etc. The analysis, control and stabilization of switching converters are the main factors that need to be considered. Many control methods are used for control of switch mode dc-dc converters and the simple and low cost controller structure is always in demand for most industrial and high performance applications. Every control method has some advantages and drawbacks due to which that particular control method consider as a suitable control method under specific conditions, compared to other control methods. The control method that gives the best performances under any conditions is always in demand. The commonly used control methods for dc-dc converters are pulse width modulated (PWM) voltage mode control, PWM current mode control with proportional (P), proportional integral, and proportional integral derivative (PID) controller. These conventional control methods like P, PI, and PID are unable to perform satisfactorily under large parameter or load variation. Therefore, nonlinear controllers come into picture for controlling dc-dc converters. The advantages of these nonlinear controllers are their ability to react suddenly to a transient condition. The different types of nonlinear controllers are hysteresis controller, sliding mode controller, boundary controller, etc. The hysteresis control methods for power converters are also gaining a lot of interest due its fast response and robust with simple design and implementation. The hysteresis controllers react immediately after the load transient takes place. Hence the advantages of hysteretic control over other control technique include simplicity, do not require feedback loop compensation, fast response to load transient. However, the main factors need to be considered in case of hysteresis control are variable switching frequency operation and stability analysis [7].

The dc-dc converters, which are non-linear and time variant system, and do not lend themselves to the application of linear control theory, can be controlled by means of sliding-mode (SM) control, Which is derived from the variable structure control system theory (VSCS). Variable structure systems are systems the physical structures of which are changed during time with respect to the structure control law. The instances at which the changing of the structure occurs are determined by the current state of the system. Due to the presence of switching action, switched-mode power supplies (SMPS) are generally variable structured systems. Therefore, SM controllers are used for controlling dc-dc converters. SM control method has several advantages over the other control methods that are stability for large line and load variations, robustness, good dynamic response, simple implementation [8].

Ideally, SM controllers operate at infinite switching frequency and the controlled variables generally track a particular reference path to achieve the desired steady state operation. But an infinite switching frequency is not acceptable in practice, especially in power electronic circuits and therefore a control technique that can ensure a finite switching frequency must implemented. The extreme high speed switching operation results in switching losses, inductor and transformer core loss and electromagnetic-interference (EMI) generation. Variable switching frequency also complicates the design of input and output filter. Hence, for SM controllers to be applicable to dc-dc converters, their switching frequency should be constricted within a practical range. Though SM control compiles of various advantages, SM controlled converters suffers from switching frequency variation when the input voltage and output load are varied. Hence there are many control methods which have been developed for fixed switching frequency SM control such as fixed frequency PWM based sliding mode controllers, adaptive SM controller, digital fuzzy logic SM controller, etc. In case of adaptive control, adaptive hysteresis band is varied with parameter changes to control and fixate the switching frequency. But, these methods require more components and are unattractive for low cost voltage conversion applications. The different types of hysteresis controller are hysteretic voltage-mode controller, V2 controller, and hysteretic current-mode controllers. The current hysteresis control incorporates both the advantages of hysteresis control and current mode control. It can be implemented using two loop control method. The error between the actual output voltage and reference voltage gives the error voltage. A PI control block can use the voltage error signal to provide a reference current for hysteresis control. This is also called sliding mode control for dc-dc converter. Therefore, the current mode hysteretic controller can be considered as a sliding mode control system and the analysis of hysteretic controller can be done as per sliding mode control theory. The essential tools of this nonlinear control theory can be introduced for the study of the behavior of hysteresis controller.

Buck converter when operated in CCM, gives a continuous output current, with smaller current ripple and low switching noise. CCM operation is usually preferred for large current applications, because it can deliver more current than the converter operating in DCM. However, a DCM converter has a much faster transient response and a loop gain that is easier to compensate than a CCM converter. Hence, for fulfill of both the requirements, a new converter that combines the advantage of both CCM and DCM converters is developed. Converters operate in a new operation mode-the pseudo CCM. This new switching converter that is operating in pseudo-continuous-conduction-mode

II. BASIC PRINCIPLES OF SM CONTROL

The basic idea of SM control is to design first a sliding surface in state space and then the second is to design a control law direct the system state trajectory starting from any arbitrary initial state to reach the sliding surface in finite time, and finally it should come to a point where the system equilibrium state exists that is in the origin point of the phase plane. The existence, stability and hitting condition are the three factors for the stability of sliding mode control. SM control principle is graphically represented in [12] where, represent the sliding surface and $x1$ and $x2$ are the voltage error variable and voltage error dynamics respectively. The sliding line (when it is a two variable SM control system in two-dimensional plane) divides the phase plane into two regions. Each region is specified with a switching state and when the trajectory arrives at the system equilibrium point, the system is considered as stable.

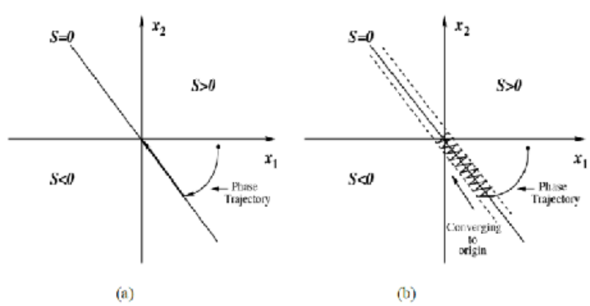

Fig.1. Phase Plot for (a) ideal SM Control (b) actual SM control.

The switching converters convert one level of electrical voltage into another level by switching action. They are popular because of their smaller size and efficiency compared to the linear regulators. Dc-dc converters have a very large application area. These are used extensively in personal computers, computer peripherals, and adapters of consumer electronic devices to provide dc voltages. The wide variety of circuit topology ranges from single transistor buck, boost and buck-boost converters to complex configurations comprising two or four devices and employing soft-switching or resonant techniques to control the switching losses. There are some different methods of classifying dc-dc converters. One of them depends on the isolation property of the primary [17] and secondary portion. The isolation is usually made by a transformer, which has a primary portion at input side and a secondary at output side. Feedback of the control loop is made by another smaller transformer or optically by optocoupler. Therefore, output is electrically isolated from input. This type includes Fly-back dc-dc converters and PC power supply with an additional ac-dc bridge rectifier in front. However, in portable devices, since the area to implement this bulky transformer and other off-chip components is very big and costly, so non-isolation dc-dc converter (step down dc-dc converter), Boost converter (step up dc-dc converter), Buck-Boost converter (step up-down dc-dc converter, opposite polarity), and Cuk converter (step up-down dc-dc converter). Similar type of methods for analysis and control are applied to many of these converters. The dc-dc buck converter is the simplest power converter circuit used for many power management and voltage regulator applications. Hence, the analysis and design of the control structure is done for the buck converter circuit. All the terms, designs, figures, equations and discussions in this thesis are most concerned with dc-dc buck

III. DC-DC BUCK CONVERTER

The buck converter circuit converts a higher dc input voltage to lower dc output voltage. The basic buck dc-dc converter topology is shown in figure. It consists of a controlled switch , an uncontrolled switch (diode), an inductor, a capacitor, and a load resistance . w S DL C R converter circuit. The switched mode DC-DC converter are some of the most widely used power electronics circuits for its high conversion efficiency and flexible output voltage. The different control techniques and method implemented on DC-DC converter. DC-DC converters are used to convert one DC voltage to other. A new sliding mode controller is proposed as the indirect control method in order to control a buck converter and we summarized some other well developed control techniques voltage, current and PID for DC-DC converter.

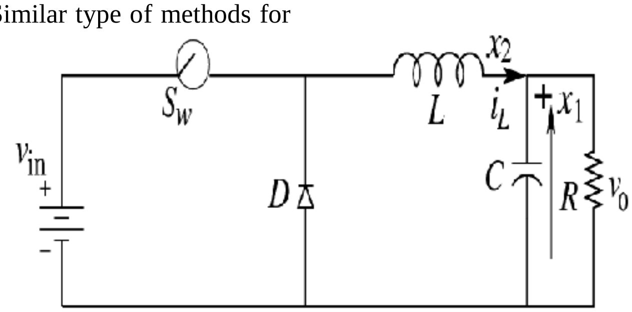

Fig. 2. Dc-dc buck converter topology.

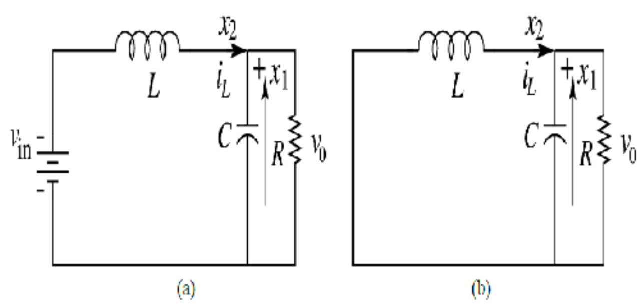

Fig. 3. Buck converter circuit when switch: (a) turns on (b) turns. Off.

The switching converters convert one level of electrical voltage into another level by switching action. They are popular because of their smaller size and efficiency compared to the linear regulators. DC-DC converters have a very large application area. These are used extensively in personal computers, computer peripherals, and adapters of consumer electronic devices to provide dc voltages. DC-DC converters are one of the important electronic circuits, which are widely used in power electronics [1-3]. The main problem with operation of DC-DC converter is unregulated power supply, which leads to improper function of DC –DC converters. There are various analogue and digital control methods used for dc-dc converters and some have been adopted by industry including voltage- and current-mode control techniques [2, 4]. The DC-DC converter inputs are generally unregulated dc voltage input and the required outputs should be a constant or fixed voltage. Application of a voltage regulator is that it should maintains a constant or fixed output voltage irrespective of variation in load current or input voltage. Buck converter is one of the most important component of circuit it convert voltage signal from high DC signal to low voltage. In buck converter, a high speed switching devices are placed and the better efficiency of power conversion with the study state can be achieved. There are various types of DCDC converters required for particular purpose like Buck, Boost, Buck and Boost, Cuk and fly back. These all DC-DC converters have their specific configurations to complete their

Step-down (“buck”) DC-DC voltage regulator circuit design is getting harder because power density (W/m3) is rising, DC power supply voltage levels are rising, and silicon voltage demands are dropping in order to increase efficiency. The difference between the supply voltage and that required by the silicon creates a big drop across the regulator, increasing switching losses and ultimately limiting the device’s switching frequency a process-control system may call for regulation from 24 to 3.3 V – a gap that would typically have to be covered using two regulation stages, thereby increasing board space, cost, and reliability issues. Moreover, limited switching frequency is a drawback because it forces engineers to use larger magnetic and other passive components for filtering circuits, increasing the solution size and working against power density. One solution enabling a return to faster switching frequency at higher input voltage and voltage drop is Zero Voltage Switching (ZVS). This technique, like virtually all contemporary switching voltage regulators, uses pulse width modulation (PWM)-based operation, but with an additional separate phase to the PWM timing to allow for ZVS operation. ZVS enables the voltage regulator to engage “soft switching”, avoiding the switching losses that are typically incurred during conventional PWM operation and timing. This article describes ZVS and explains its advantages. Hard-switching losses Most contemporary non-isolated buck voltage regulators incur high-switching losses due to the simultaneous occurrence of high-current and -voltage stress imposed on the regulator’s integrated metal oxide semiconductor field-effect transistor (MOSFET) switch during the turn-on and turn-off transitions. These losses increase with switching frequency and input voltage and limit maximum frequency operation, efficiency, and power density.

Hard switching occurs during the overlap between voltage and current when switching the MOSFET on and off. Voltage regulator manufacturers try to minimize the overlap to in turn minimize the switching losses by increasing the rate of change of current (di/dt) and voltage (dv/dt) in the switching waveform. Figures 1 and 2 illustrate where the switching losses occur and show an actual switching waveform with fast-changing voltage designed to minimize these losses.

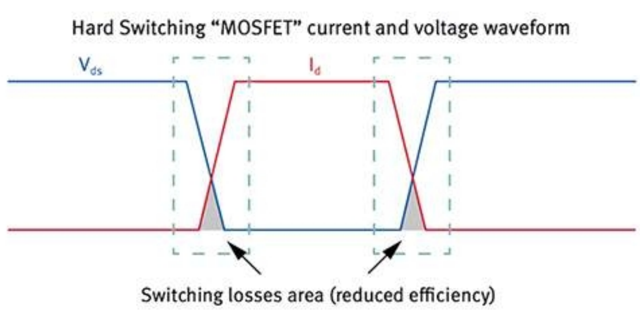

Fig. 4. Voltage regulator losses occur during voltage/current overlap when the MOSFET switches (Courtesy of Infineon Technologies).

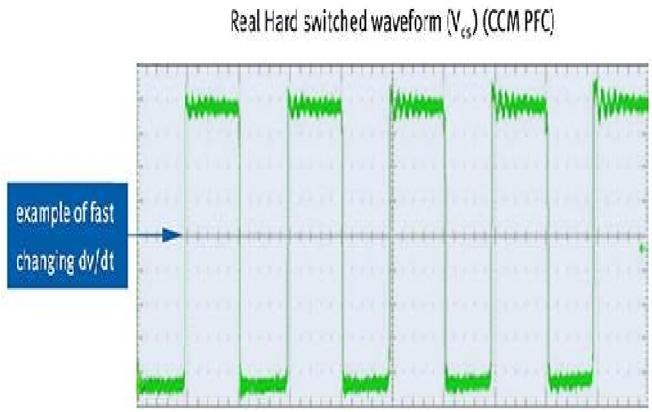

Fig. 5. Manufacturers increase dv/dt to minimize overlap and improve efficiency (Courtesy of Infineon Technologies).

The downside of fast switching is an increase in electromagnetic interference (EMI) emanating from the voltage regulator circuitry. One way to minimize EMI effects, while still taking advantage of fast switching to enhance efficiency, is to select a switching regulator that employs an improved hard-switching technique called quasi-resonant switching (also known as "valley" switching). Infineon Technologies offers a range of power MOSFETs, such as its Cool MOS series, for quasi-resonant fly back switching voltage regulators. During quasi-resonant switching the MOSFET is turned on when the voltage across drain and source is at a minimum (in a valley) in order to minimize the switching losses.

This allows the device to operate with a more modest rate of change in voltage or current, and thus reduces EMI. Another positive side effect of quasi-resonant switching is that because switching is triggered when a valley is detected, rather than at a fixed frequency, a degree of frequency jitter is introduced, spreading the RF emission spectrum and further reducing EMI. Quasi-resonant switching does have the disadvantage of inducing higher losses at light loads, but the problem is eliminated in modern devices by employing a frequency-clamp circuit to limit the maximum operating frequency. Fig. 3 shows a quasi-resonant switching waveform for a fly back converter where the MOSFET is switched in the valleys.

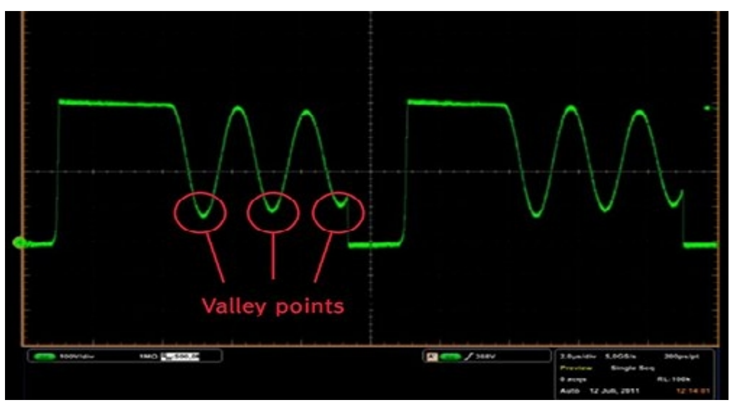

Fig. 6. Quasi-resonant switching waveform for a fly back converter (Courtesy of Infineon Technologies).

IV. SOFT SWITCHING AT ZERO VOLTAGE

Quasi-resonant switching is a good technique for improving voltage converter efficiency, but things can be further improved by implementing full soft switching.

During soft switching the voltage falls to zero (rather than just a minimum) before the MOSFET is turned on or off, eliminating any overlap between voltage and current.

V. CONCLUSIONS

Control of buck converter is implemented and different output parameter is observed. The output voltage and current is stable and satisfactory. The output is better than the PID control buck converter. Output reaches stability quite fast and ripple is minimum. Load variation up to a certain range does not affect the output. The overall performance of nonlinear control is good as compared to the PID controller. PID controller reaches its final value faster but contains ripple. For different load and PID parameters there overshoot may be seen. But in SM control the output is smooth and no overshoot observed.

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