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A Comparative Analysis on Different Control Techniques for Buck Converters

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Buck converters are basically step down DC-DC converter which converts high DC input voltage to low DC output voltage. These buck converters are used extensively in industry and in research. One of the basic disadvantages of buck converters is the unregulated supply of voltage and current. To solve this problem various control techniques are used in combination with buck converters. In this paper some of these control techniques are compared summarized. Some of the famous control methods are Voltage Mode Control (VMC), Current Mode Control (CMC), PID control and Pulse width Modulation (PWM) control.

Keywords: *Buck converters, Current Mode Control, DC-DC converters, Switching converter, Voltage Mode Control.*

1.0 INTRODUCTION

Buck Converters, due to their high efficiency are the widely acceptable DC-DC and have numerous applications worldwide [1-3]. But the limitation of these buck converters is the unregulated power supply, which leads to improper operation of the converters. The application of any voltage regulator is to maintain constant or fixed output voltage irrespective of variation in load current or input voltage [3-5]. The input to the buck converter is generally unregulated DC voltage but the output required should be a constant or fixed voltage. Also due to the evolution in technology and change of requirements, in the recent past, accurate and reliable output voltage is desired [6]. Hence there is a need for more advanced and reliable design of controllers for converters. Various types of control schemes viz. Pulse width Modulation (PWM) technique, Voltage Mode Control (VMC) technique, Current Mode Control (CMC) technique, PID Control technique etc. are used to improve the efficiency of buck converters [2-4].

The aim of this paper is to compare all these control techniques which used to facilitate the performance of buck converters for different applications. In the paper, an attempt is made to compare the basic concepts, merits and demerits of each control technique using the MATLAB/ Simulink. The results viz. output voltage, input voltage; load current, gate pulses for each control technique is compared.In pulse width modulation control, the duty ratio is linearly modulated [8]. When an input voltage is given, it must be sensed as an output voltage change and the error produced in the output voltage is used to change the duty ratio to keep the output voltage to the reference value. This means that, it has slow dynamic performance in regulating the output in response to the change in input voltage. A large number of switching cycles is required before steady-state is regained [9].

Voltage mode control and Current mode control can be classified as a type of single loop controller which is connected to the reference voltage. This output voltage is measured and compared with a

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reference voltage. This error voltage is used to determine the switching duty ratios [10-11]. PID control is one of the oldest and classical control technique used for DC-DC converters [12-13].

This paper is organized as follows. The various type of controlling techniques are reviewed in section II. In Section III, the simulation of these techniques is carried out and the results obtained are studied.

2.0 CONTROL TECHNIQUES

2.1 Pulse Width Modulation (PWM) Control

In PWM control, the output voltage is first compared with reference voltage. The output of the error detector is then compared with a saw tooth signal which is the gate pulse. As a result the control reference is linearly modulated into the duty ratio signal or gate pulse. A buck converter with PWM control is given in Figure 1. The duty ratio is modulated in a direction that reduces the error.

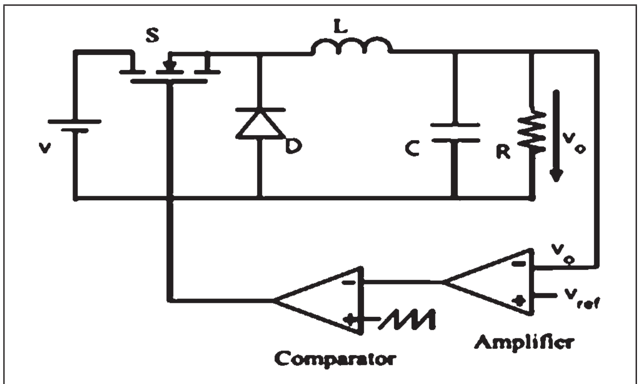

FIG. 1. BUCK CONVERTER WITH PWM CONVERTER

The PWM control is a commonly used technique but it has the following disadvantage:

(a) At low loads, its efficiency is compromised.

(b) Power drawn by the loads is not constant.

2.2 Voltage Mode Control (VMC)

It is a single loop controller. In this technique, the output voltage is measured and compared to a reference voltage as given in Figure 2. It uses measured output voltage and reference voltage to generate the control signal voltage. Then this control voltage is used to determine the switching signals by comparing with a constant frequency waveform. Hence this duty ratio is used to maintain the average voltage across the inductor L, which eventually bring the output voltage to its reference value. Hence it helps to deliver the constant voltage without any changes. Due to the simplicity in operation, it is preferred by Industry and Research [10, 11].

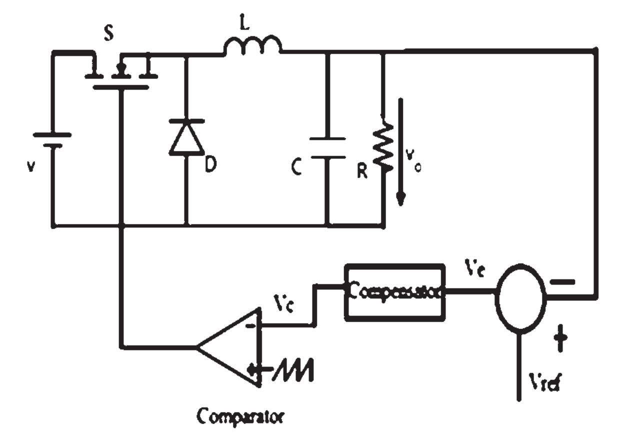

FIG. 2. BUCK CONVERTER WITH VMC

The merits in this control technique are:

(a) Easy to design and Implement

(b) Immunity to Disturbances

(c) Simply feed backing loop.

The drawbacks in using this technique are.

(a) Poor stability and reliability of the switch S.

(b) Low reliability, stability, and performance when several converters are in parallel supply with one load.

(c) The response time is longer for switching cycles.

2.3 Current Mode Control (CMC)

Current mode control CMC is more complex technique compared to Voltage Mode Control as it contains double loop including voltage control loop and current control loops as shown in Figure 3. Current mode control is an effective method with many applications as explained in [13-16]. In this technique, the load current is first sensed and then used to control the duty cycle. An error signal is produced by comparing the output voltage V_o with fixed reference voltage V_{ref} and this error signal is used to generate control signal i_c. The sensed load current is compared with control signal i_c to generate the duty cycle of a given frequency and that drives the buck converter switch.

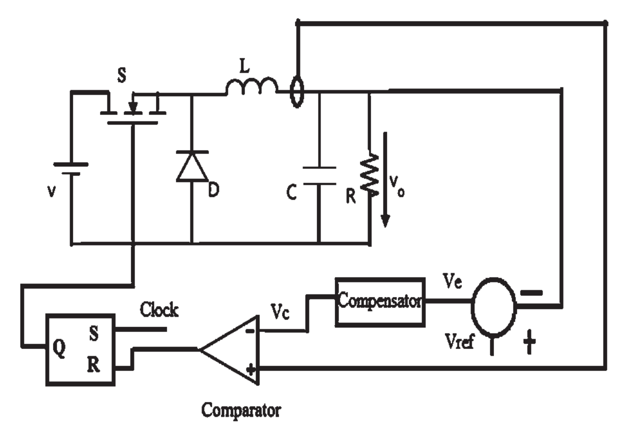

FIG. 3. BUCK CONVERTER WITH CURRENT MODE CONTROL

The response of the system depends upon the feedback loop. If the feedback loop is closed, the load current is proportional to the control signal ic and then the output voltage becomes equal to reference voltage Vref. Current mode control method is suitable when converters are operating in parallel.

The advantages of current mode control techniques are [5]:

(a) It shows an improved transient response.

(b) An improved performance in the line regulation.

(c) It is more suitable for converters operating in parallel.

(d) Overload is opposed by self protection.

(e) Main switch adopt more protection.

The disadvantages of current mode control techniques are:

(a) It is very unstable when duty ratio exceeds 0.5 in the peak current mode- control.

(b) Presence of Sub-harmonic oscillations.

2.4 PID Controller

PID control is one of the oldest and classical control technique used for DC-DC converters [17, 18]. It uses one of the controllers including P, PD, PI and PID controllers as shown in Figure 4. These various combinations of controller will give many ways to regulate dc power supply in buck converter. In this paper will discuss about PID control in detail.

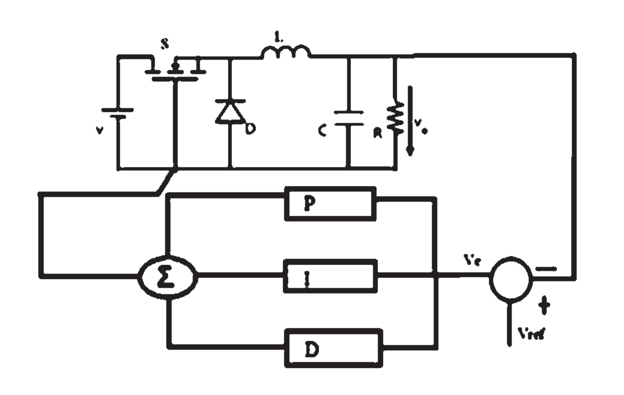

FIG. 4. BUCK CONVERTER WITH PID CONTROLLER

Because of its numerous advantages, PID controller is widely used for industrial applications in power electronics. This technique has the ease in implementing the tuning method likes Ziegler-Nichols tuning. Using this it is simple to optimize proportional, integral and derivative term, which is needed to achieve a desired closed-loop performance.

A Proportional-Integral-Derivation controller (PID Controller) is a generic control feedback loop mechanism widely used in industrial control systems and in research areas of power electronics. PID controllers are commonly used as controllers for boost converters in PV system.

The advantages in using PID controllers are:

(a) Easy to design and implement.

(b) Reliable for linear systems.

The disadvantages in using PID controllers are:

(a) Not reliable in case of non-linear systems. The performance is also not satisfactory.

(b) It displays longer rise time when overshoot in output voltage decreases.

(c) It suffers from dynamic response and produces overshoot affecting the output voltage regulation of converter.

3.0 SIMULATION AND RESULTS

These different controlling methods are applied in buck converter for same input voltage and are compared using MATLAB/SIMULINK.

TABLE 1

SPECIFICATIONS USED FOR SIMULATIONS

S.No	Topology	Buck Converter
1	Switching Frequency	100 kHz
2	Output Filter Inductor	1.38 mH
	Parasitical Resistor	0.2 Ω
3.	Output Filter Capacitor	220 µ F
	Parasitical Resistor	0.29 Ω
4.	Load Resistance	25 Ω
5.	DC Input Voltage	100 V

The input voltage is shown in the Figure 5. The input voltage is a DC voltage of constant value (100V).

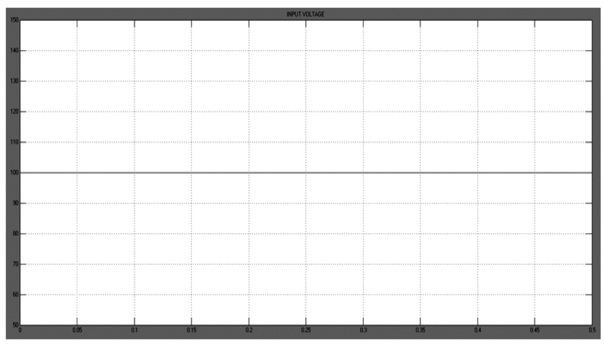

FIG. 5. THE INPUT VOLTAGE FOR WAVEFORM

The MATLAB/Simulink model for buck converter using various converters and their Steady State analysis is as explained below.

3.1 PWM Simulation and Results

In PWM converter the output voltage is first compared with reference voltage and the control voltage is compared with a saw tooth waveform. The comparator output is given as gate pulses as in the Figure 6.

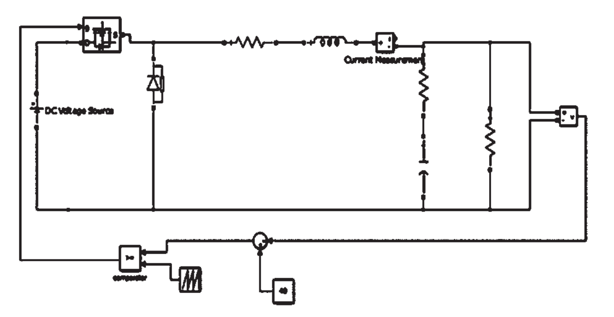

FIG. 6. CIRCUIT DIAGRAM FOR PWM CONTROL

In Figure 7, the output voltage of PWM converter is given. The Fluctuation is from 39V – 41V and the variation makes 5 % error in the output voltage. This is the one of the simplest method.

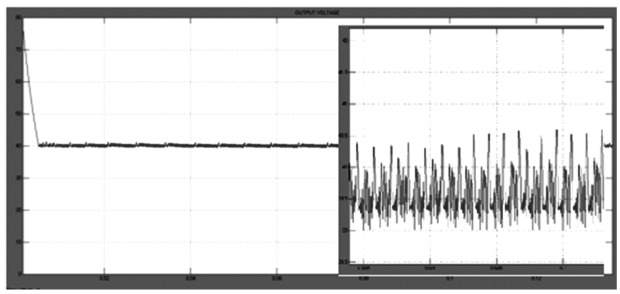

FIG. 7. THE OUTPUT VOLTAGE FOR PWM CONTROL

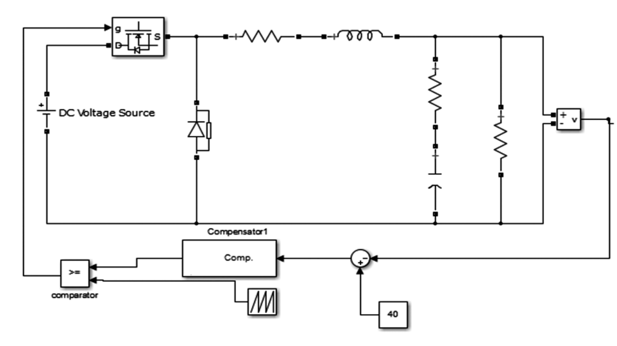

FIG. 8. CIRCUIT DIAGRAM FOR VMC CONTROL

3.2 VMC Simulation and Results

In Voltage mode control, uses measured output voltage and reference voltage to generate the control signal voltage. Then this control voltage is used to determine the switching signals by comparing with a constant frequency waveform.

Hence this duty ratio is used to maintain the average voltage across the inductor L, as shown in Figure 8.

In Figure 9 the output variations of voltage mode control are given. Here the output variation is non uniform in very closer vision. The output is varied from 38.9 to 40.2. The error in the output is 3.25 %. These variations are occurs in fraction of seconds.

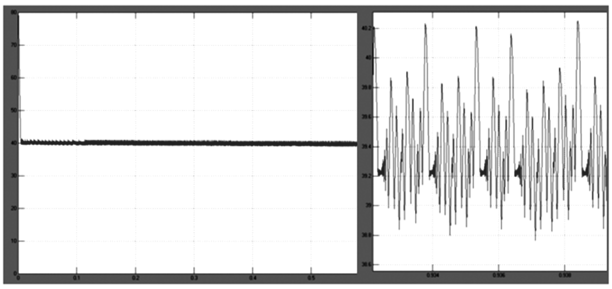

FIG. 9. THE OUTPUT VOLTAGE FOR VMC CONTROL

3.3 CMC Simulation and Results

In current mode control, the load current is first sensed. After it is used to control the duty cycle. An error signal is produced by comparing the output voltage V_o with fixed reference voltage V_{ref} and this error signal is used to generate control signal i_c. The sensed load current is compared with control signal i_c to generate the duty cycle of a given frequency and that drives the buck converter switch as given in the Figure 10.

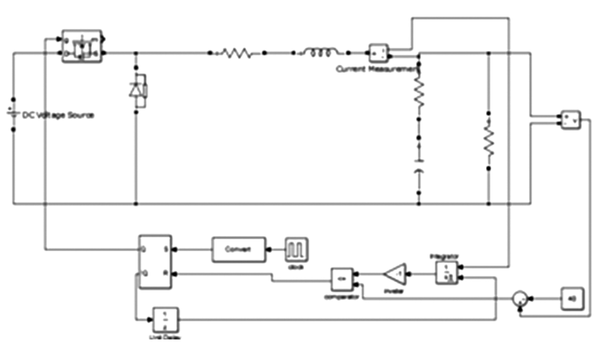

FIG. 10. CIRCUIT DIAGRAM FOR CMC CONTROL

Figure 11 shows the output voltage of current mode control. In this case the output is first reaches to 70% of its input voltage, after a fraction of seconds it reaches to the reference value. The output voltage fluctuations are given inside. Variation is from the 39.95 to 40 V. Hence the output voltage fluctuation is too low almost equal to 1.25%.

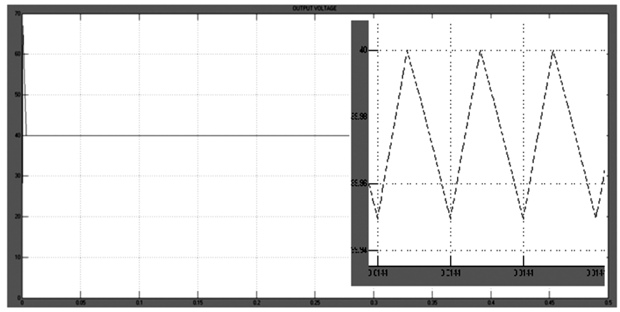

FIG. 11. THE OUTPUT VOLTAGE FOR CMC CONTROL

3.4 PID Controller Simulation and Results

In PID controller, the output is first compared with the reference voltage and the output is given to the PID controller. The output from the tuned controller is given as the switching pulses for the buck converter as given in Figure 12.

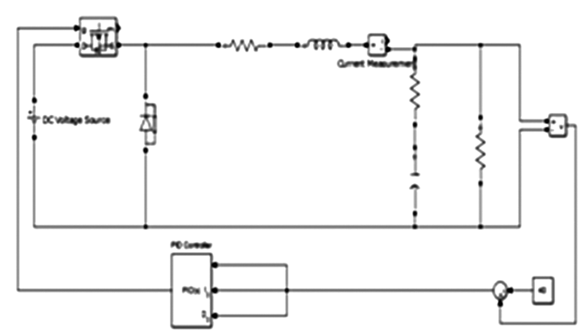

FIG. 12. CIRCUIT DIAGRAM FOR PID CONTROL

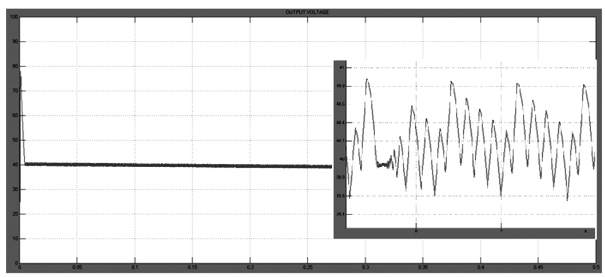

FIG. 13. THE OUTPUT VOLTAGE FOR PID CONTROL

Figure 13 shows the PID control output voltage. In this first the voltage reaches to 80% of the input voltage and then settle down to reference value. The output voltage fluctuations are given inside the Figure 13. In this case the fluctuations are non-uniform and it is varies from 39.5 to 40.5 within a fraction of seconds.

4.0 CONCLUSIONS

In this paper, the various control techniques used for buck converters are discussed using MATLAB/ Simulink. It is evident from the paper that each control method has its own merits and demerits. Depending upon the specific application, the particular control technique is used. It can also derived be derived from the results, there is still a scope to develop a more reliable and efficient control technique.

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