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Different Types of Control Strategies for Dc-Dc Buck Converter

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Abstract*: In dc-dc converters, the average output voltage must be controlled to equal a desired level, though the input voltage and the output load may fluctuate. Switch-mode dc-dc converters utilize one or more switches to transform dc from one level to another. Though the control strategies can be implemented in various types of dc-dc converters, in this paper, buck converter is taken for analysis. There are various types of techniques used for controlling the design of buck converter. But in order to obtain a control it is always desirable to implement a control method that has the best performance under any condition. This paper primarily focuses on implementing the control strategies, particularly the voltage mode control and the current mode control on dc-dc buck converter, also to study the various waveforms of voltage mode control and current mode control of buck converter.
Keywords: voltage mode control, current mode control, buck converter, PWM, duty cycle

I. INTRODUCTION

The dc-dc converters are widely used in regulated switch-mode dc power supplies and in dc motor drive applications. The input to these converters is an unregulated dc voltage, which is obtained by rectifying the line voltage, and therefore it will fluctuate due to changes in the line voltage magnitude. Switch-mode dc to dc converters are used to convert the unregulated dc input into a controlled dc output at a desired voltage level [1].A dc-dc converter thus convert DC voltage signal from high level to low level signal or it can be vice versa depending on the type of converter used in system. There are several types of methods of classifying the dc-dc converters. One of them depends upon the isolation property of the primary and secondary portion. The isolation is usually made by a transformer and the feedback of the control loop is made by another smaller transformer or optically by optocoupler. Thus, the output is electrically isolated from input . However, in portable devices, non-isolation dc-dc converters are mostly preferred because the area to implement this bulky transformer and other offchip components is very big and costly [2].
The non-isolated dc/dc converters can be classified as follows:
Buck converter (step down dc-dc converter),
Boost converter (step up dc-dc converter),
Buck-Boost converter (step up-down dc-dc converter, opposite polarity),
Cuk converter (step up-down dc-dc converter).
The converter components values depend upon various parameters like time, temperature, pressure and so forth. Hence with the help of negative feedback mechanism the output voltage should be controlled in a closed loop manner [2]. There are several types of control strategies that can be applied to many of these converters. But here we will implement the control strategies on dc-dc Buck converter. However, we will consider only those control strategies which can perform effectively under any condition. The linear controllers like P, PI, PID doesn't give satisfactorily results under large load operating conditions i.e they donot offer a good large signal transients[3].So in this paper we will implement mainly the two control strategies ,Voltage Mode Control and the Current Mode Control on dc-dc buck converter.
There are several advantages and disadvantages of Voltage Mode Control and Current Mode Control strategies which are given below:

A. Voltage Mode Control (VMC)

1) Advantages: [6]

a) Consist of single feedback loop which is easier to design and implement.
b) Better cross regulation can be provided for multiple output supplies as a result of low impedance power output.
c) As result of large amplitude ramp waveform, good noise margin is provided for a stable modulation process.

2) Disadvantages:

a) As the loop gain varies with input voltage, hence compensation is complicated. [6]

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b) When several converters are in parallel supply with one load, VMC results in less stability, reliability or performance.
c) VMC respond is much longer of switching cycles, hence it is a very slow system. [5].

B. Current Mode Control (CMC)[5]

1) Advantages:
a) Current mode control technique results in good and improved performance in line regulation.
b) In case of converters operating in parallel, current mode control technique is more suitable for that purpose.

2) Disadvantages
a) The control loop becomes unstable at duty cycles above 50% unless slope compensation is added.

II. OPERATING PRINCIPLE OF CURRENT MODE CONTROL(CMC) & VOLTAGE MODE CONTROL(VMC)

A. Operating Principle of Current Mode Control(CMC)

The prime objective of current mode control of dc-dc buck converter is to control the current through the inductor. The buck converter comprises of a semiconductor switch which is to be controlled. The semiconductor switch can be controlled with the help of PWM (Pulse Width Modulation).So a controller is to be designed which can give the PWM output to control the semiconductor switch. For the effective operation of the current mode control, the inductor current and the constant current reference are to be compared. At first the inductor current will increase linearly up to the constant current reference value. When the inductor current, IL is slightly greater than the constant reference current Iref, the switch will turn off and the switch will turn on again by the next clock signal and the process will be repeated again and again [4].

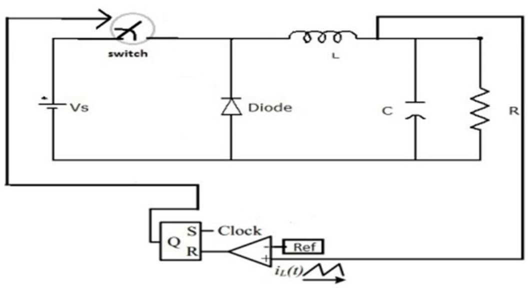

Fig 1: A Schematic diagram of dc-dc buck converter connected with the current mode controller

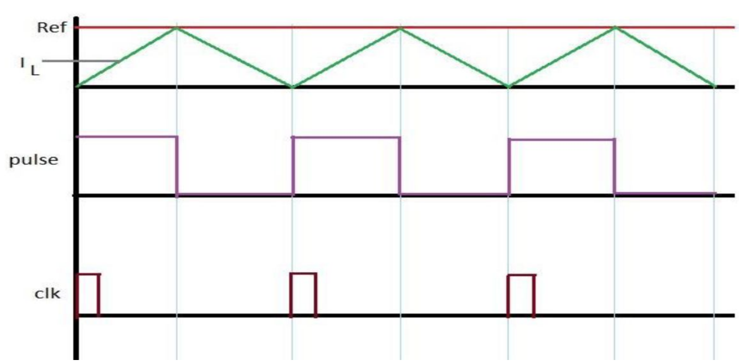

Fig2: Schematic waveform for the operation of Current mode control (CMC)

B. Operating Principle of Voltage Mode Control(VMC)

For the operation of voltage mode control of dc-dc buck converter, at first the output voltage is measured and it is compared to a reference voltage. The VMC method then uses the measured output voltage and the reference voltage to generate the control voltage. The reason behind the generation of control voltage is that the control voltage is used to determine the switching duty ratio by comparison with a constant frequency waveform. This duty ratio is used to maintain the average voltage across the inductor. As a

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result, this will eventually bring the output voltage to its reference value. Thus it will help in maintaining the constant voltage without any variation [5].In this method a control signal V**con** is generated and compared with V**ramp** and switching signal q is sent on the basis of following conditions [4].

If Vramp<Vcon;   q=1
If Vramp>Vcon ;   q=0

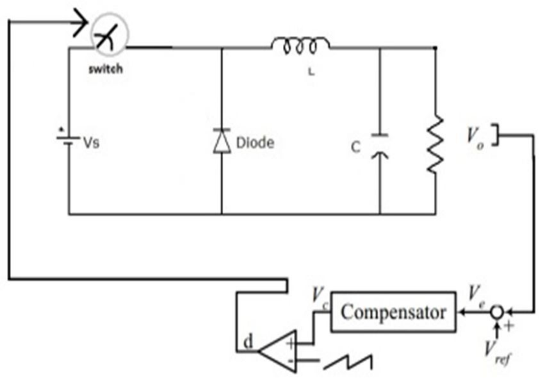

Fig3: A Schematic diagram of dc-dc buck converter connected with the Voltage mode controller

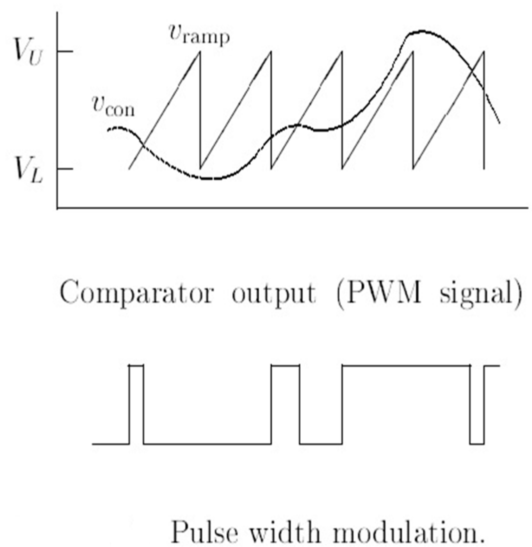

Fig4: Schematic waveform for the operation of VMC

III. ANALYSIS OF CONTROL TOPOLOGIES OF DC-DC BUCK CONVERTER

A. Current Mode Control

In this paper we will consider a buck converter which operates in continuous conduction mode. The control loop will operate within 50% duty cycle because the control loop becomes unstable at above 50%unless slope compensation is added. The dc-dc buck converter comprises of a controlled switch S, an uncontrolled switch D(diode),an inductor L, a capacitor C, and a load resistance RL.

Thus, the parameter values for the experimental buck converter are given below:

PARAMETERS	VALUES
Vin	10 V
L	.62e-3 H
C	1000e-6 F
RL	1 ohms
D	RON=0.001Ohms,LON=0H, Vf =0.8V,RS=500ohms, Cs=250e-9 F

Here, the constant current reference value to which the inductor current is compared is set at 1 amp.
Now, the simulink model of buck converter in matlab with the designed current mode controller and the results waveforms are given below:

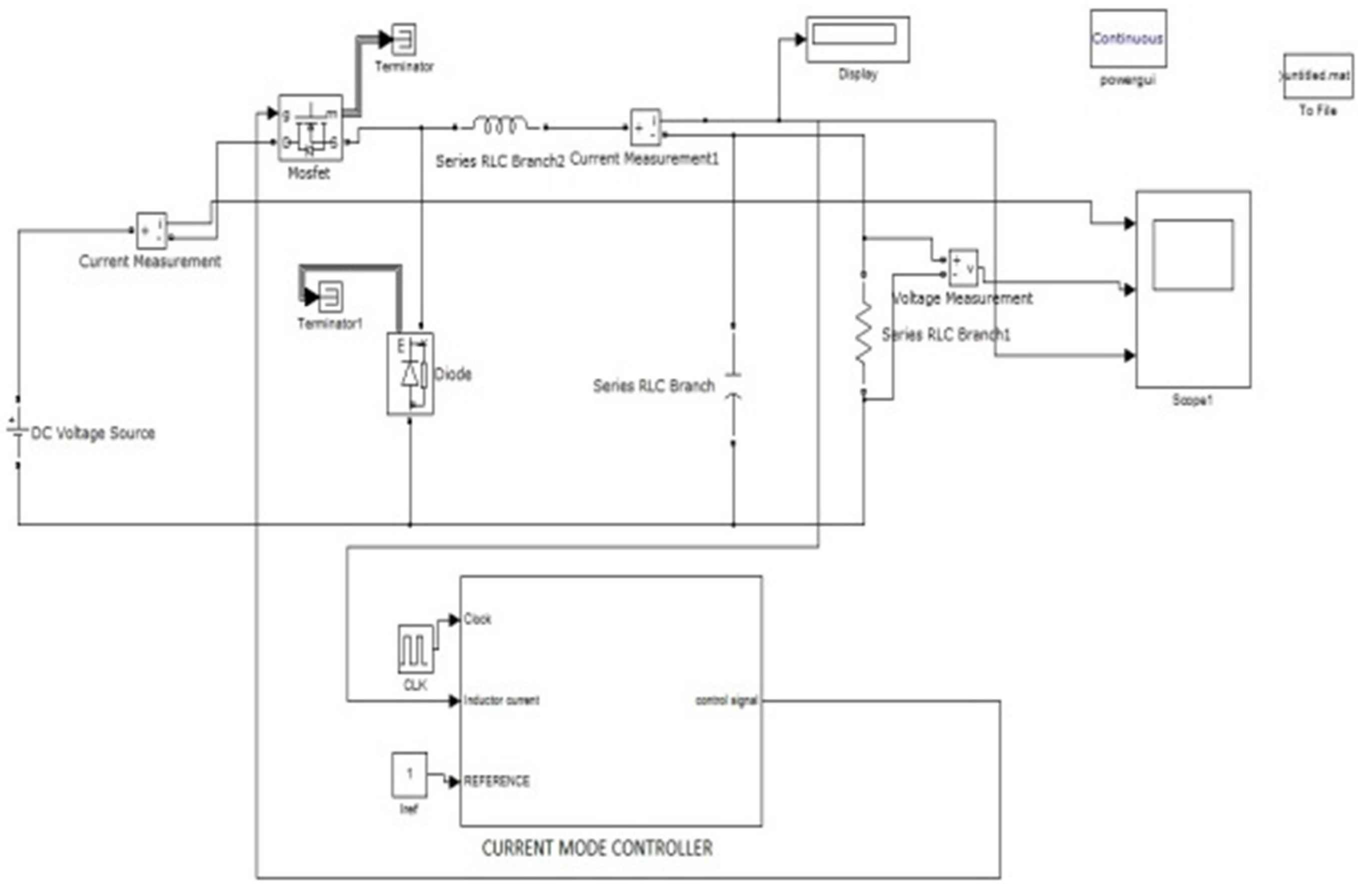

Fig5: Simulink model of the Buck converter with the designed current mode controller

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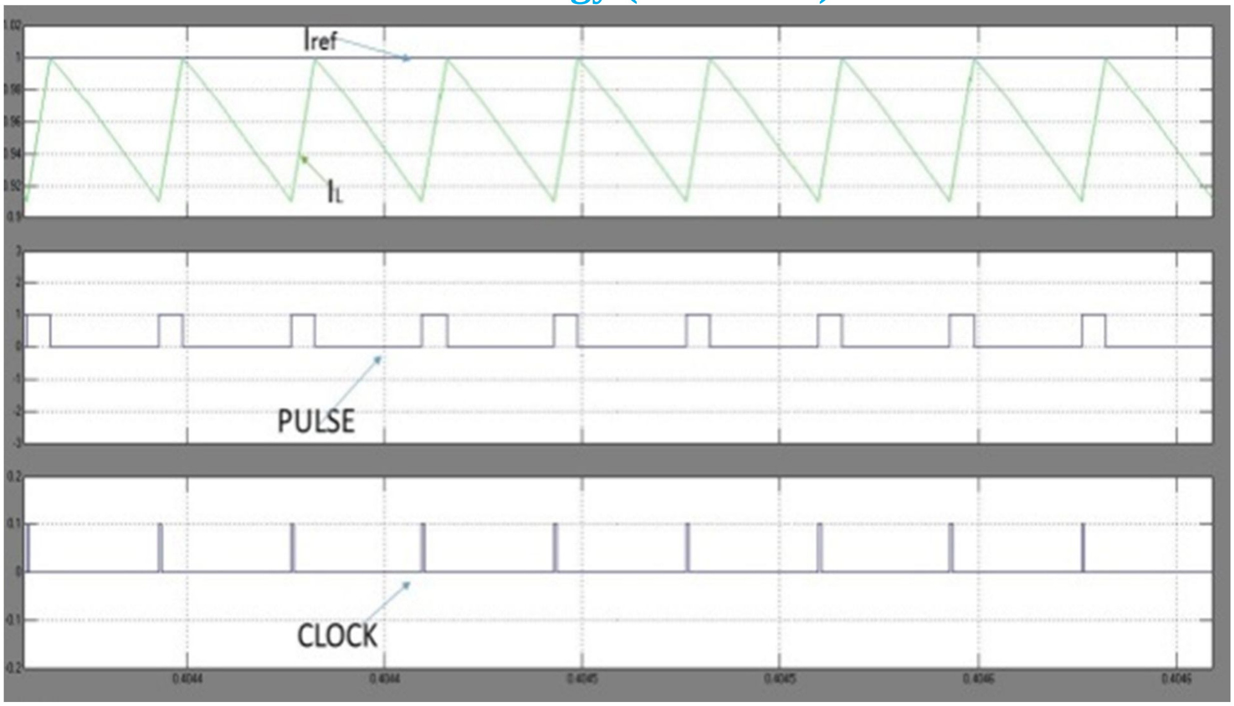

Fig6: Observed Waveforms of IL and Iref and their switching operation

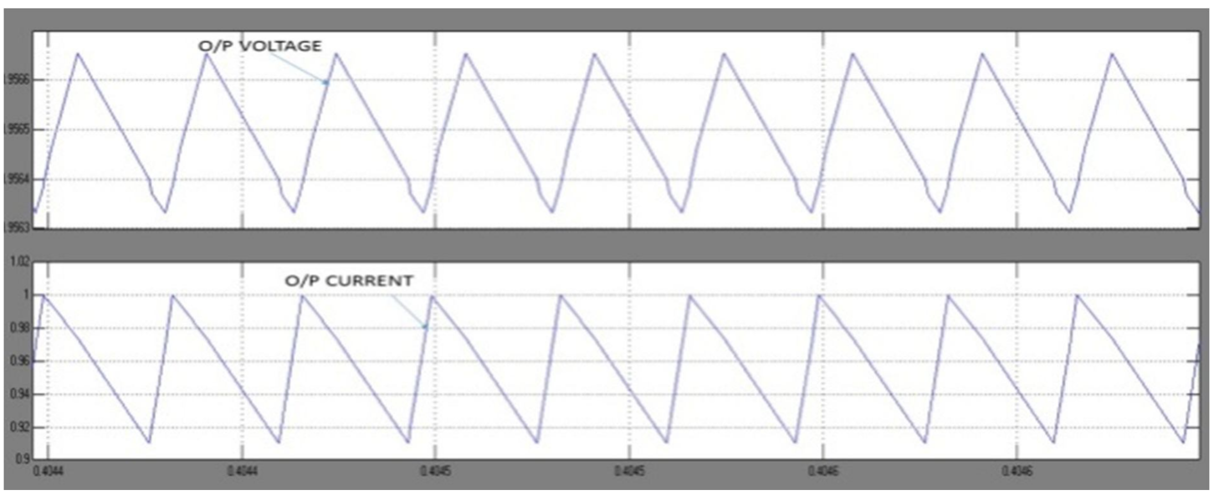

Fig7: Output voltage and output current waveform of buck converter

B. Voltage Mode Control

The voltage mode controlled buck converter circuit shown in fig.8 comprises of controlled switch S (Mosfet), uncontrolled switch D(diode), an inductor L, a capacitor C, a load resistance RL, and a voltage mode controller. The output voltage of the buck converter is fed to the controller and it is compared with the reference voltage taken as 5 volt, given to controller. A ramp signal is also fed to the controller so that it can be compared with the control signal generated as a result of the output voltage and the reference voltage. The comparison of the ramp signal Vramp with the controlled voltage Vcon to determine the switching action is shown in fig.9.Thus, in fig 9. It is seen that when the magnitude of control signal voltage is greater than the magnitude of the ramp signal voltage, the switching signal is high and when the magnitude of control signal is less than the magnitude of ramp signal voltage, the switching signal remains off.

Thus, the parameter values for the operation of experimental buck converter with the voltage mode controller are given below:

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PARAMETERS	VALUES
Vin	10 V
Vref	5 V
L	.62e-3H
C	1000e-6 F
D	RON=0.001Ohms,LON=0H, Vf =0.8V,RS=500ohms, Cs=250e-9 F
f (Frequency)	3 kHz
A(Amplitude)	1

Now, the simulink model of the buck converter with the designed voltage mode controller and its result waveforms are shown below:

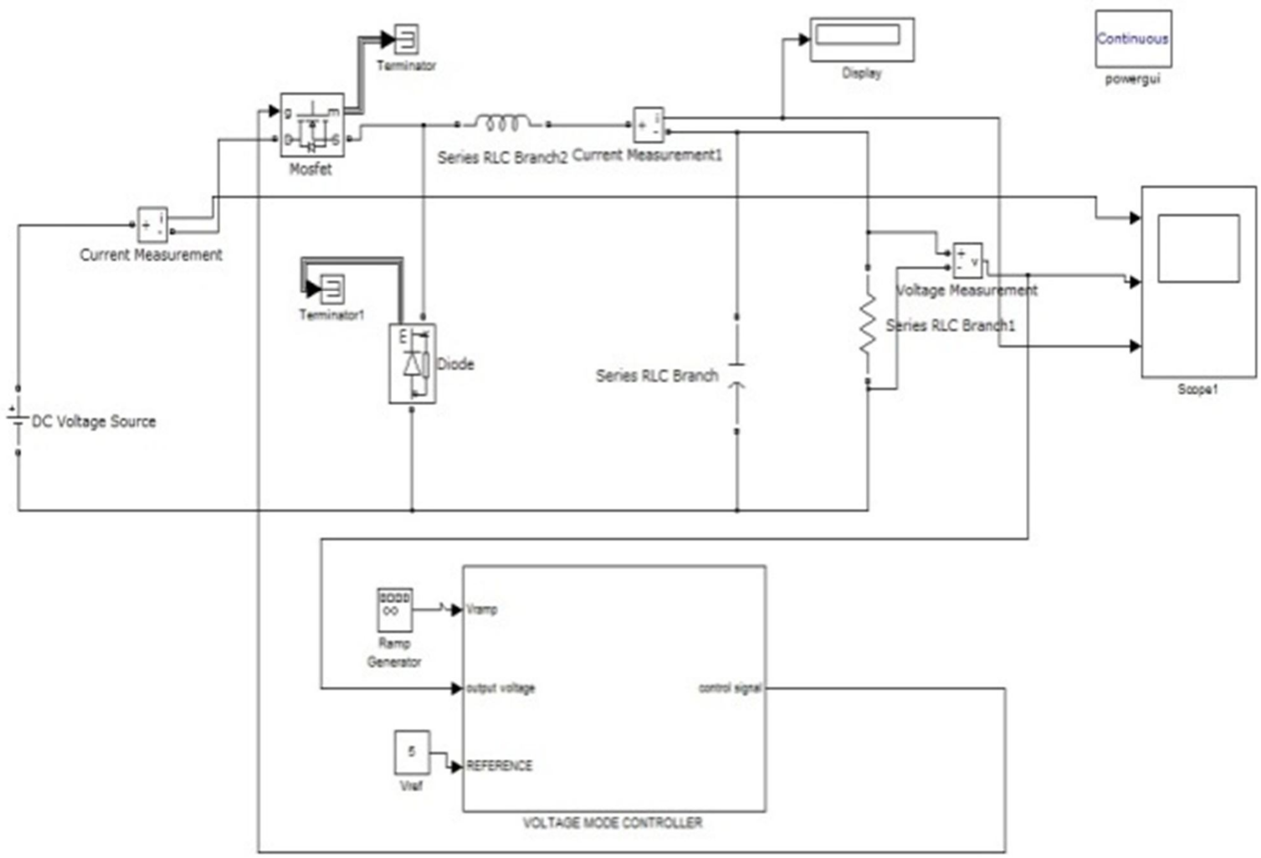

Fig8: Simulink model of the buck converter with the voltage mode controller

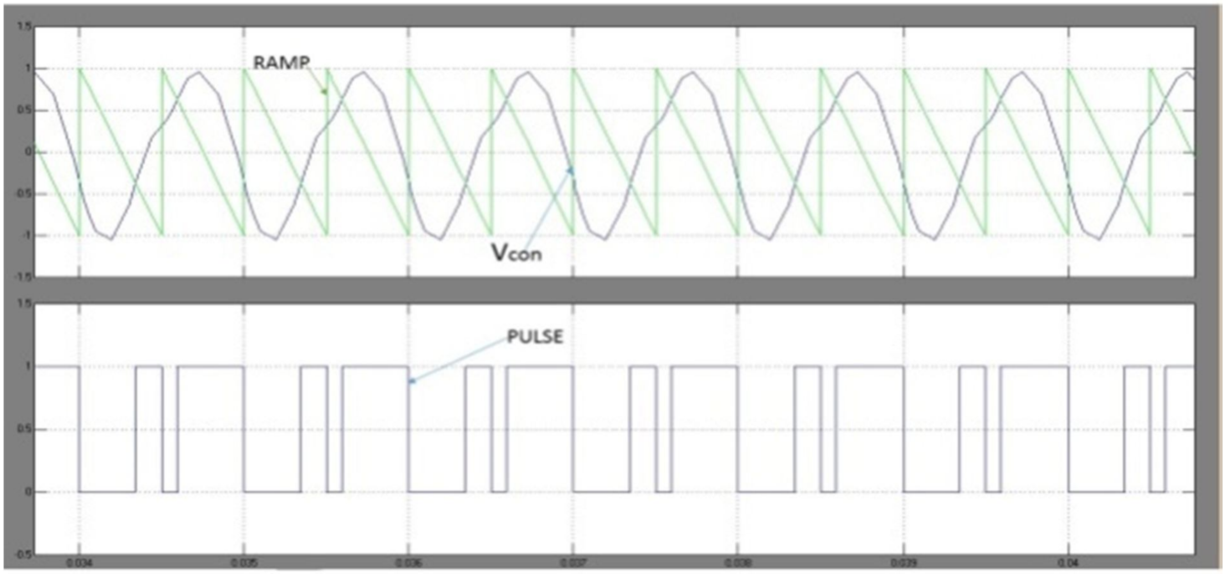

Fig 9: Waveform of Vcon and Vramp and the corresponding switching action

IV. CONCLUSIONS

In this paper, the two main control strategies, namely, the Current mode control and the Voltage mode control are implemented in the dc-dc buck converter. The simulation results are presented along with the simulink model for the effective understandings of the control strategies. The schematic waveforms of each control strategies are also given such that the simulation result waveforms can be compared with the schematic waveform and thus it can be concluded that the voltage mode control and the current mode control are implemented in the buck converter.

A. Following are the Areas of Future Study which can be Considered for Further Research Work

1) Implementation of control strategies on different converters.
2) Transient analysis can be done.
3) Slope Compensation

V. ACKNOWLEDGMENT

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