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Simulation Modelling and Advance Control Techniques for DC-DC Converter with Improved Performance

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Abstract— **DC-DC converters are one of the important electronic circuits, which are widely used in power electronics1-3. 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. 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. Various kinds of voltage regulators with a variety of control schemes are used to enhance the efficiency of DC-DC converters. Today due to the advancement in power electronics and improved technology a more severe requirement for accurate and reliable regulation is desired. This has led to need for more advanced and reliable design of controller for dc-dc converters. In this paper, 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. Their principal characteristics are illustrated using MATLAB and the Simulink block diagram system along with experimental results.**

Index Terms— **DC-DC converters, DC voltage, current, control techniques, Sliding Mode Control, PID Mode.**

I. INTRODUCTION

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. 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. Various kinds of voltage regulators with a variety of control schemes are used to enhance the efficiency of DC-DC converters. Today due to the advancement in power electronics and improved technology a more severe requirement for accurate and reliable regulation is desired [5]. This has led to need for more advanced and reliable design of controller for dc-dc converters. 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 (PI), 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 electrical components can be combined and connected to each other in different ways, called topologies, each one having different properties. The buck, boost, and buck-boost converters are three basic converter topologies. The buck converter has an output voltage that is lower than the input voltage. The boost converter has an output voltage that is higher than the input voltage (in steady state). The buck-boost converter is able to have an output voltage magnitude that is higher or lower than the input voltage magnitude.

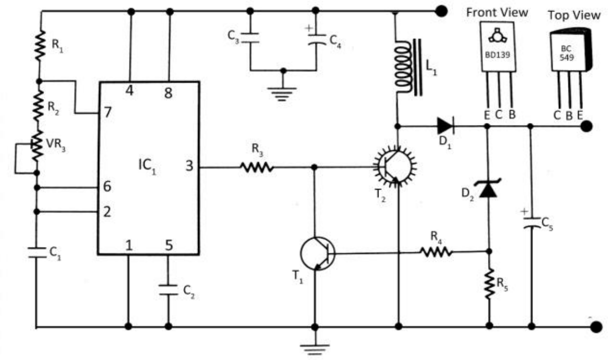

Figure 1 DC-DC Converter

II. VOLTAGE MODE CONTROL

It is a type of single loop controller connected to a reference voltage, so at first output voltage is measured and compared to a reference voltage (figure-1). This VMC method is used in research as well as in industry due its easy implementation. It uses measured output and reference voltage to generate the control voltage. After this the control voltage is used to determine the switching duty ratio by comparison with a constant frequency waveform. This duty ratio is used to

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maintain the average voltage across the inductor. This will eventually bring the output voltage to its reference value and which help in the delivery of constant voltage without any variation. Voltage-mode control of dc-dc converters has several disadvantages including:

- Poor reliability of the main switch.
- Degraded reliability, stability, or performance when several converters in parallel supply one load.
- Complex and often inefficient methods of keeping the main transformer of a push-pull converter operating in the center of its linear region.
- A slow system response time, this may be several tens of switching cycles.

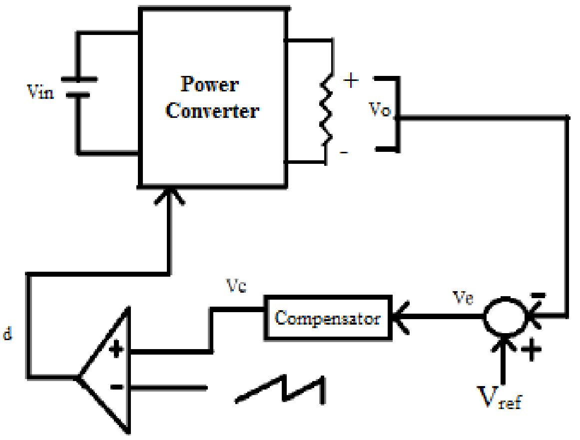

Figure 2 Voltage Mode control of Power Converter

III. CURRENT MODE CONTROL

It is more complex than VMC as it contain dual loop including voltage and current control loops (Figure- 3). There are various application of CMC for different application. After sensing the inductor current it is used to control the duty cycle. An error signal is produced after comparing the output voltage *Vo* with fixed reference voltage *Vref* and this error signal is used to generate control signal *ic*. The next step is to sense inductor current and compared with control signal *ic* to generate the duty cycle of particular frequency and drive the switch of the converter.

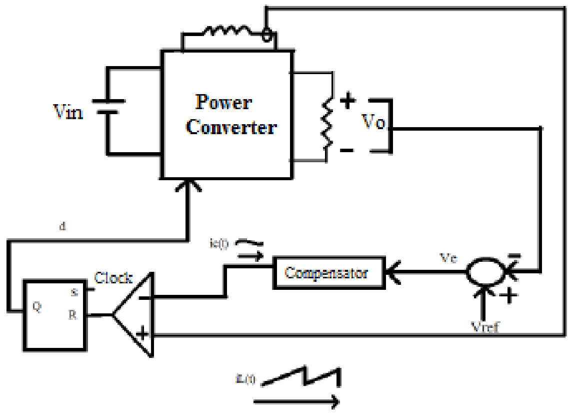

Figure 3 current mode controls of DC-DC converters

All response depend on the position of feedback loop as if the feedback loop is closed, the inductor current is proportional to the control signal *ic* and the output voltage becomes equal to reference voltage *Vref*. Irrespective of the various advantages of CMC it also has some drawbacks as: Advantages of current mode control techniques:

- It shows the improved transient response as from the begging it reduces the order of the converter to a first order system.
- Good and improved performance in line regulation.
- It is more suitable for converters operating in parallel.
- Overload is opposed by self protection.
- Main switch adopt more protection. vi. Main transformer core is present in the centre of its B-H curve as a result of Anti-saturation.
- Disadvantages of current mode control techniques.
- It is very unstable when duty ratio exceeds 0.5 in the peak current mode- control.
- Presence of Sub-harmonic oscillations.

IV. SLIDING MODE CONTROLLERS

SMC will drive these variations in nonlinear plant's state trajectory on a user chosen surface called switching surface. To control the converter Feedback path will have different gains when plant trajectory is below or above surface. Proper switching rule is then defined by the surface (called sliding surface). Once the process is started, switched control will maintain the plant's state trajectory on the sliding surface for all subsequent time intervals. Stability, regulation and tracking etc are achieved for variable structure systems by properly designed sliding surface. SMC requires the knowledge of parameter variation range for its design instead of accurate mathematical models. Irrespective of the order of system to be controlled, SMC will be designed to have first-order response. Proper sliding surface selection will ensure that even the worst-case dynamics would be handled. Mattavelli*et. al*, proposed a general The basic principle behind the SMC controlled system is to drive the converter to the steady surface called the sliding surface and maintain the stability of the system thus giving the regulated output voltage for any variations in the load or switching frequency [9].

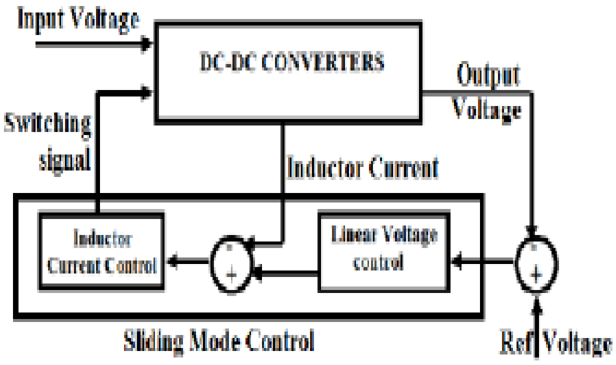

Figure 4 Block Diagram of Sliding Mode Control

SM controller is a type of non-linear controller. It is employed and adopted for controlling variable structured systems (VSSs). It is very easy to implement as compared to other types of nonlinear and classical controllers13-14. Two important steps in SM control is to design a sliding surface in state space and then prepared a control law to direct the system state trajectory starting from any arbitrary initial state to reach the sliding surface in finite time, and at the end it should arrive to a point where the system equilibrium state exists that is in the origin point of the phase plane.

V. PROPORTIONAL, INTEGRAL AND DERIVATION CONTROLLER (PID)

PID control is one of the oldest and classical control technique used for DC-DC converters. It uses one of its families of controllers including P, PD, PI and PID controllers (figure-5). These different combinations will gives us various ways to regulate dc power supply in these converters. But here we will discuss only PID in details. Due to the various advantages of PID it is widely used for industrial applications in the area of power electronics. One of the main causes for the use of this classical technique still in industrial applications is easy implementation of tuning method like Ziegler-Nichols tuning procedure by which we can easily optimize proportional, integral and derivative term of this control method needed to achieve a desired closed-loop performance.

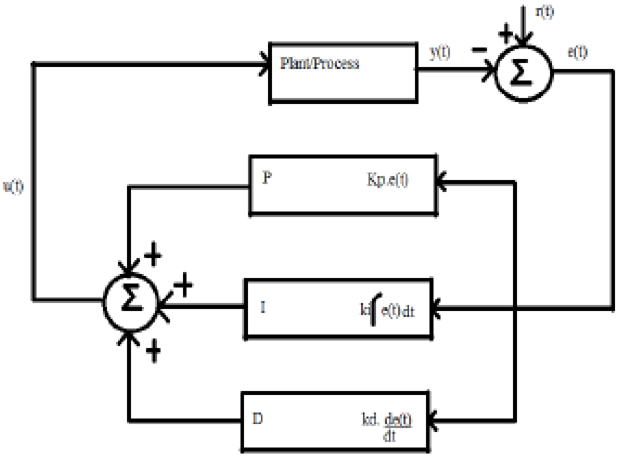

Figure 5 Block diagram of PID controller

VI. RESULS AND ANALYSIS

This part implemented in MATLAB simulation tool as per evaluation parameters. Firstly show as SIMULINK block diagram of current mode control.

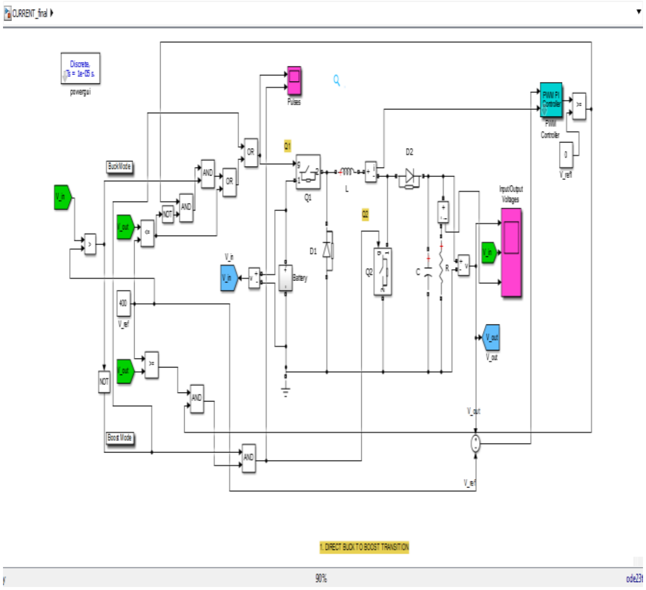

Figure 6 SIMULINK block diagram of current control.

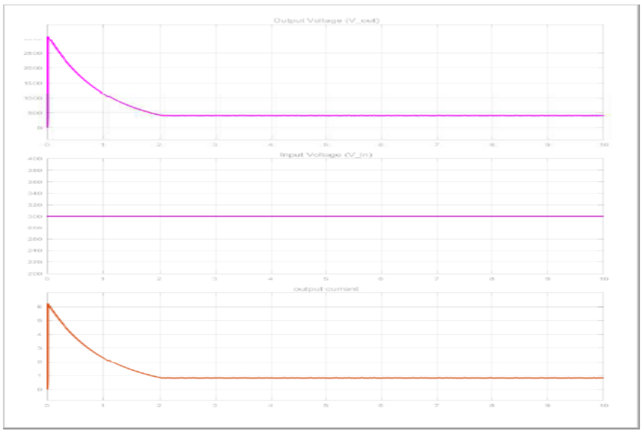

Figure 7 Input/output voltage, output current in Boost Mode.

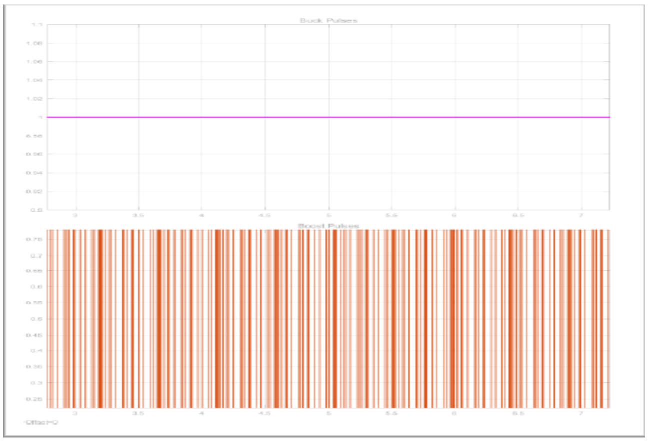

Figure 8 Switching Pulses in Boost Mode.

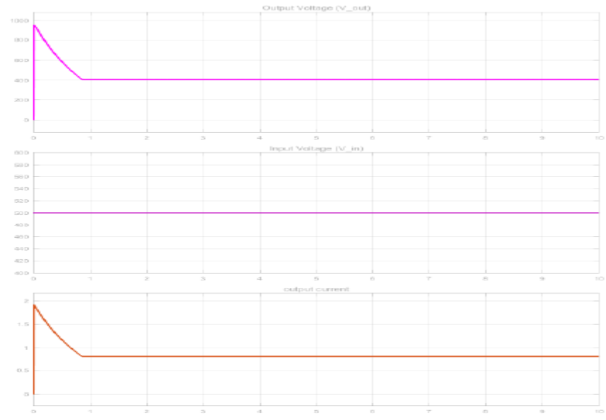

Figure 9 Input/output voltage, output current in Buck Mode.

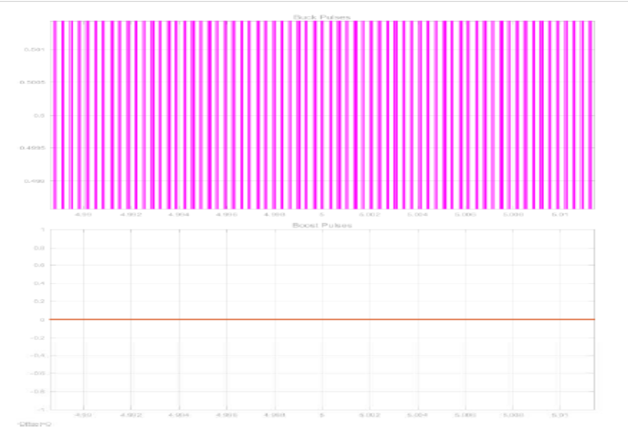

Figure 10 Switching Pulses in Buck Mode.

This part implemented in MATLAB simulation tool as per evaluation parameters. Firstly show as SIMULINK block diagram of Voltage mode control.

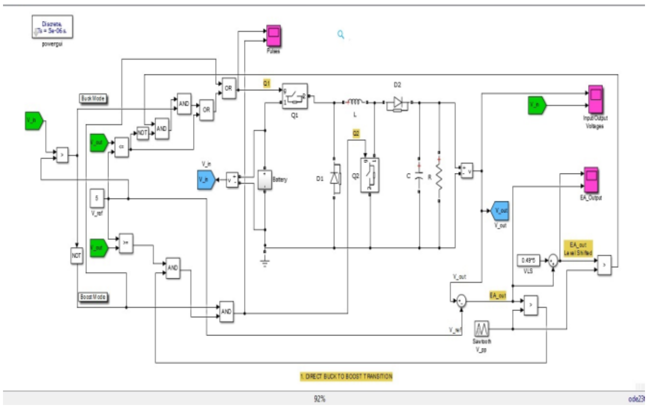

Figure 11 SIMULINK block diagram of voltage control.

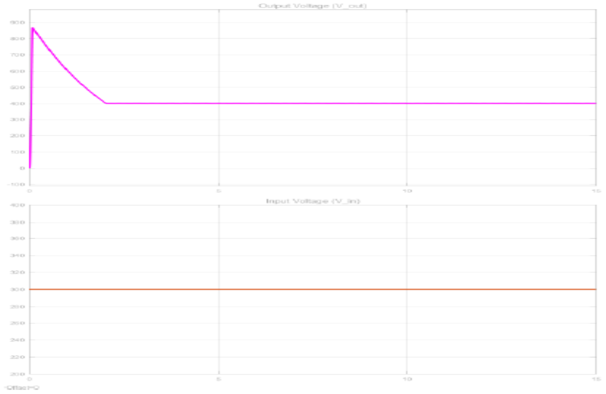

Figure 12 Input output voltage in boost mode.

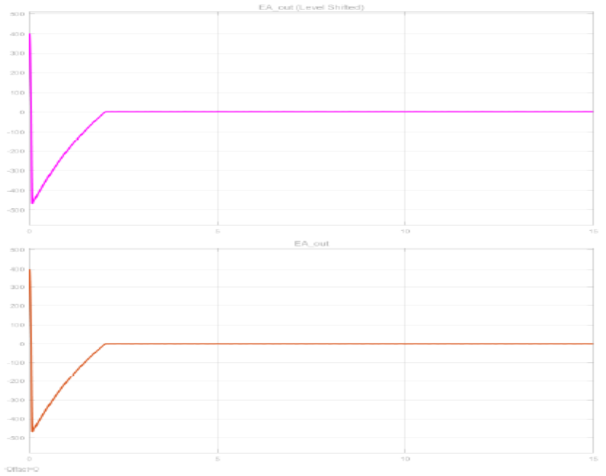

Figure 13 Error output in boost mode.

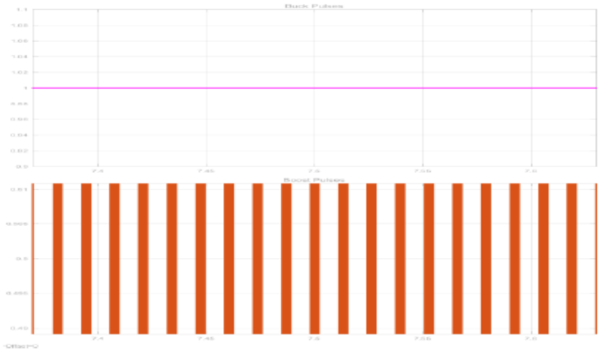

Figure 14 Switching Pulses in Boost Mode.

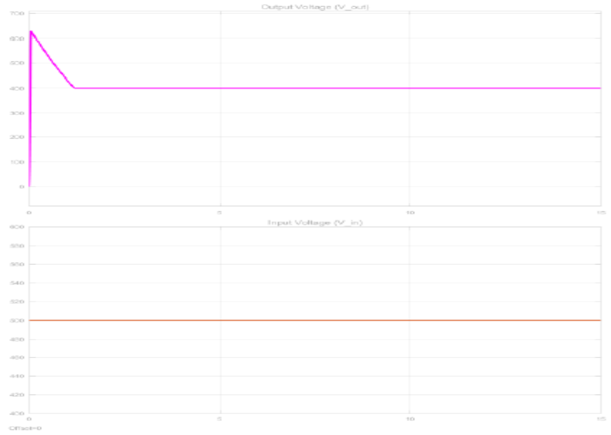

Figure 15 Input output voltage in buck mode.

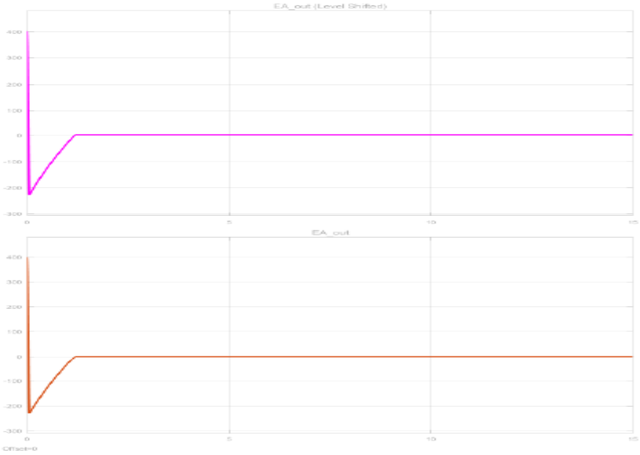

Figure 16 Error output in Buck mode.

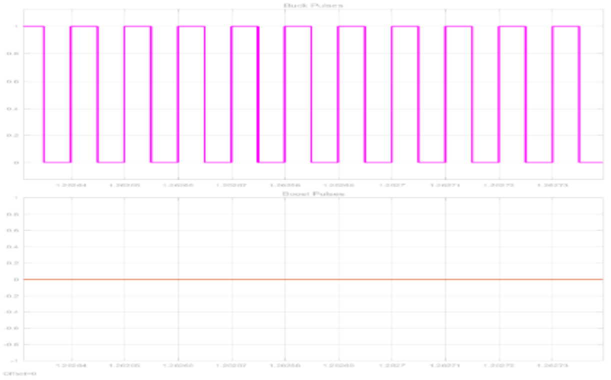

Figure 17 Switching Pulses in Buck Mode.

This part implemented in MATLAB simulation tool as per evaluation parameters. Firstly show as SIMULINK block diagram of PID mode control.

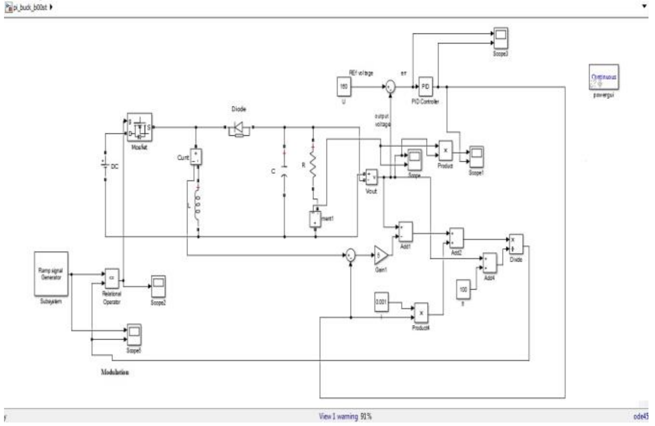

Figure 18 SIMULINK block diagram of PID mode control.

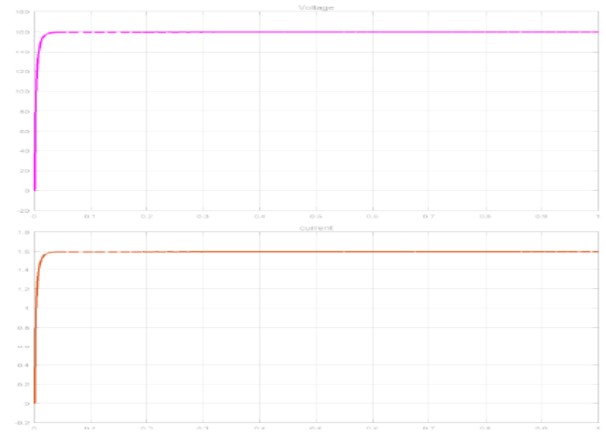

Figure 19 Input voltage & current in boost mode.

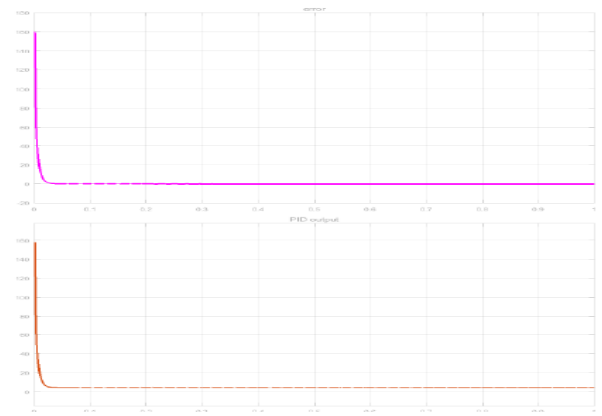

Figure 20 Output current in boost mode.

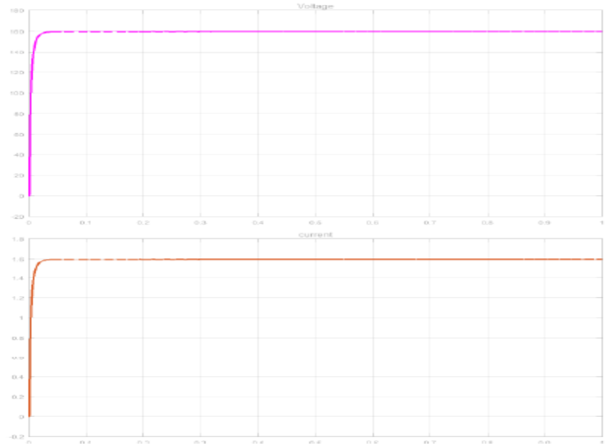

Figure 21 Output voltage & current in boost mode

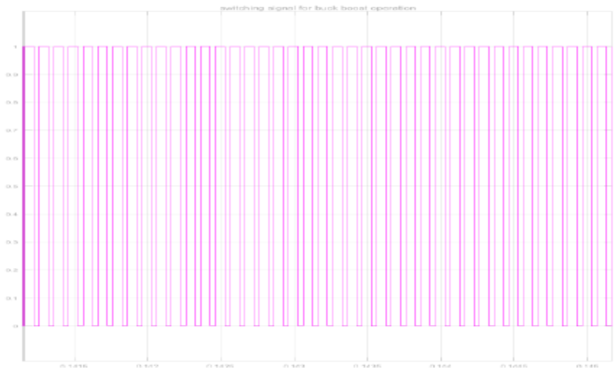

Figure 22 Switching Pulses in boost mode

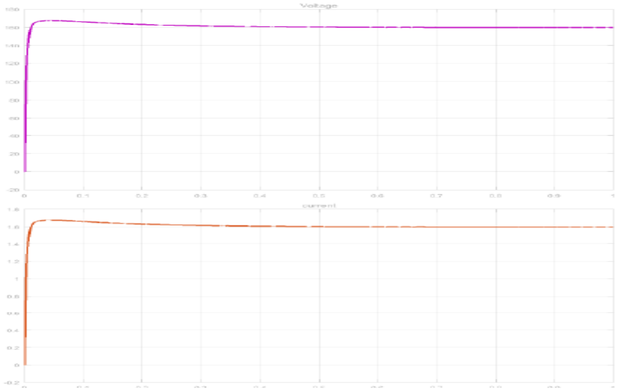

Figure 23 Output voltage & current in buck mode

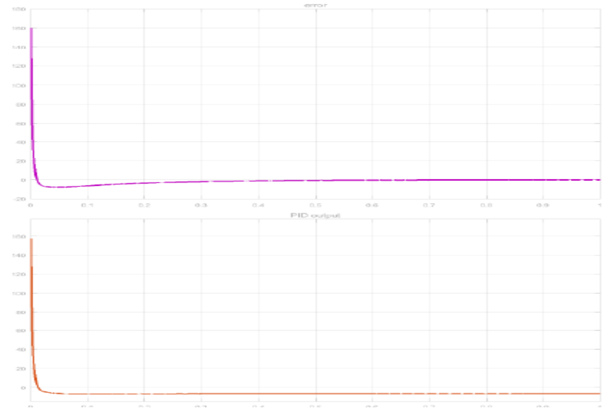

Figure 24 Output current in buck mode

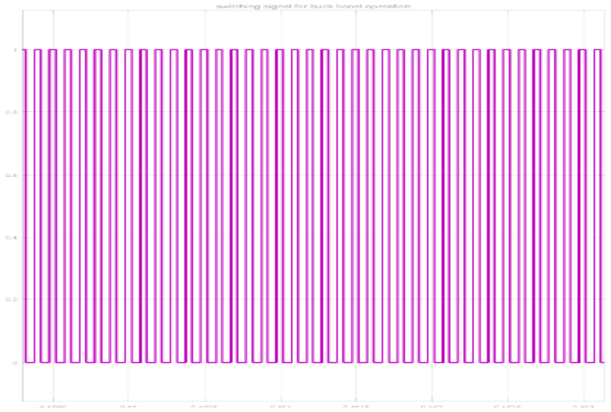

Figure 25 Switching Pulses in buck mode

This part implemented in MATLAB simulation tool as per evaluation parameters. Firstly show as SIMULINK block diagram of Slide mode control.

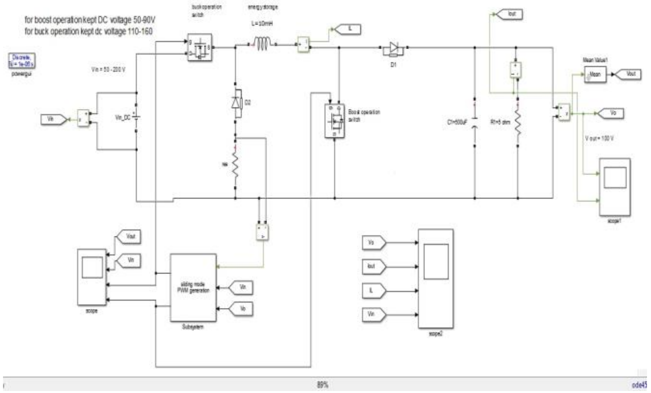

Figure 26 SIMULINK block diagram of Slide mode control

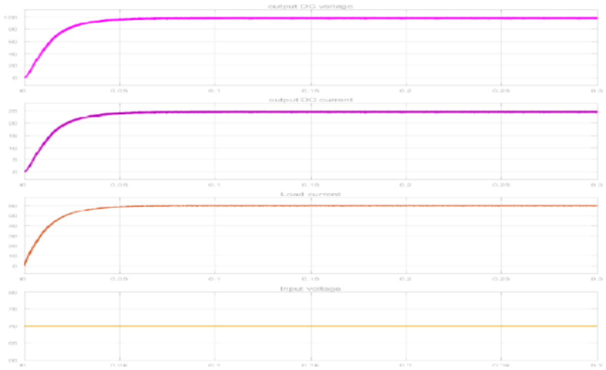

Figure 27 Input output vosltage in boost mode.

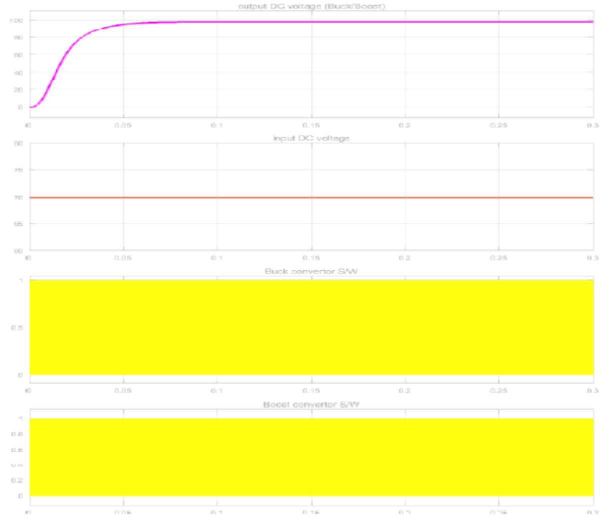

Figure 28 Output DC voltage in boost mode.

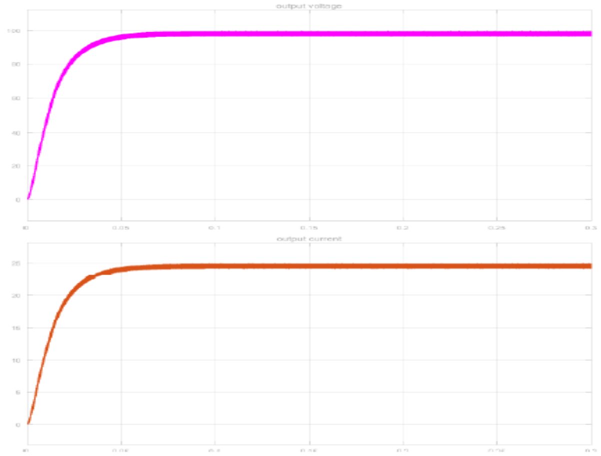

Figure 29 Output voltage & current in boost mode.

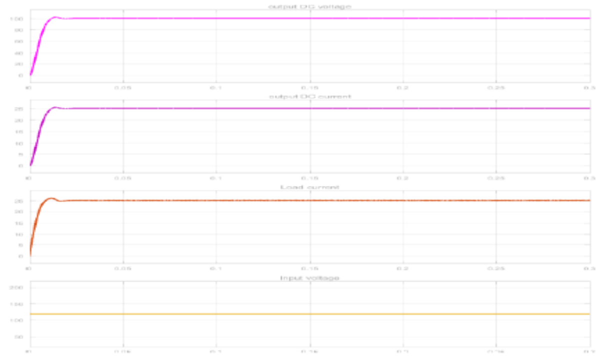

Figure 30 Input output voltage in buck mode.

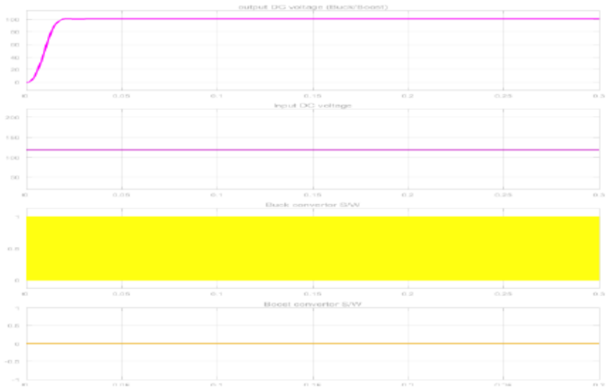

Figure 31 Output DC voltage in buck mode.

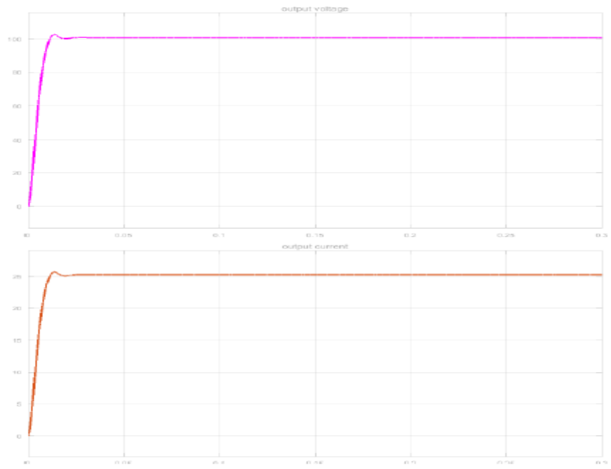

Figure 32 Output voltage & current in buck mode.

VII. CONCLUSION

We provided an overview of control techniques used for DC-DC converters. We briefly explained the basic concepts of each control techniques. Sliding Mode 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. Voltage and Current Mode Controller techniques used as specific purpose. All kind of control technique is needed for particular purpose. There is still scope for the development of more reliable and efficient control technique.

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