PERFORMANCE VERIFICATION OF DC-DC BUCK CONVERTER USING SLIDING MODE CONTROLLER FOR COMPARISON WITH THE EXISTING CONTROLLERS - A THEORETICAL APPROACH

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ABSTRACT

In recent electronic applications the variable DC power supply is derived with light weight, occupying less size using 100 kHz switching frequency. When the frequency is high, the load experiences practically uninterrupted DC voltage. According to need of application buck converter is considered for analysis. It is observed that nature of DC- DC converter is nonlinear and time variant systems, and does not lend them to the application of linear control theory. The performance of buck converter has been studied and is undertaken for their theoretical verification, graphical representation and Matlab simulation. From the linear controller PI, PID is considered and non linear controller sliding mode control is taken as control method. The paper work will highlights nonlinear aspects of buck converter, non linear controller like sliding mode controller and hybrid type of controller SMC PID. This will also focuses the benefits of non linear control.

KEYWORDS*: *SMC (sliding mode control), PI and PID control.

I. INTRODUCTION

DC–DC converter convert DC voltage signal from high level to low level signal or it can be vise versa depending on the type of converter used in system. Buck converter is one of the most important components of circuit it converts 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 steady state can be achieved. In this paper work performance of buck converter is analyzed. The circuit may consist of nonlinearity like delay, hysteresis etc. and because of this output voltage is not constant. To settle the output voltage within minimum settling time and less overshoot different types of controllers are considered such as linear controller PI, PID and in nonlinear controllers SMC (sliding mode controller).The paper deals with comparison of performance of DC-DC buck converter using controllers PI, PID, SMC and SMC PID. The performance of buck converter has been analyzed in many papers amongst them papers [1][2] have been studied and are undertaken for their theoretical verification, graphical representation and Matlab simulation.

II. SIMULATED MODEL OF BUCK CONVERTER

Simulated model of buck converter by using Matlab are as shown in figure no.2.1. It consist of 24 V input DC supply, GTO (gate turn off thyristor) as switch, PWM (Pulse width modulation) generator for providing switching pluses to GTO. Inductor is of 69 μH[1] and capacitor is of 220μF[1], with load resistance of 13 Ω [1] .The desired output from this converter is 12 V DC.

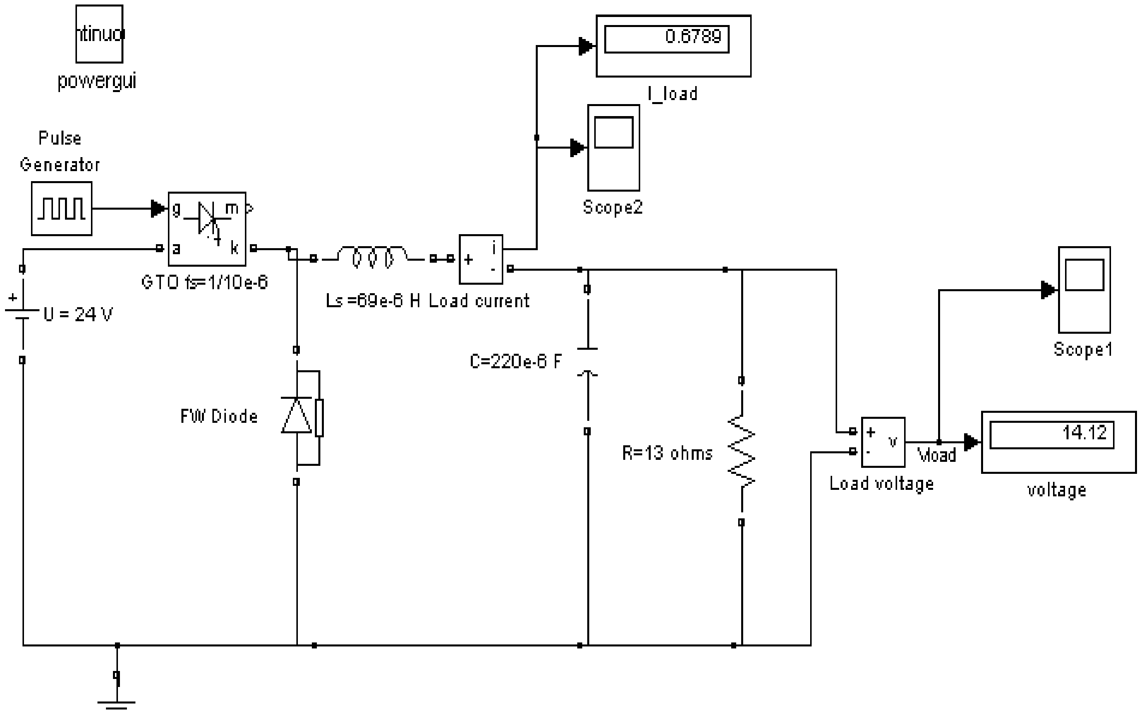


Figure No 2.1 Buck converter in Matlab Simulink.

The circuit has settling time of 2 msec and output voltage is 14.12 V which is required to settle at 12 V. To compensate these transients present in buck converter different types of controllers can be used.

III. CONTROL METHODS

Figure 3.1 shows the block diagram with some methods that can be used to control DC-DC converters and the disturbances that have influence on the behavior of the converter and its stability. The feedback signal may be the output voltage, the inductor current, or both. The feedback control can be either analog or digital control. From these control methods PI, PID are linear control methods and SMC, SMC PID are the non- linear control methods. Comparison between linear and nonlinear control methods are given below.

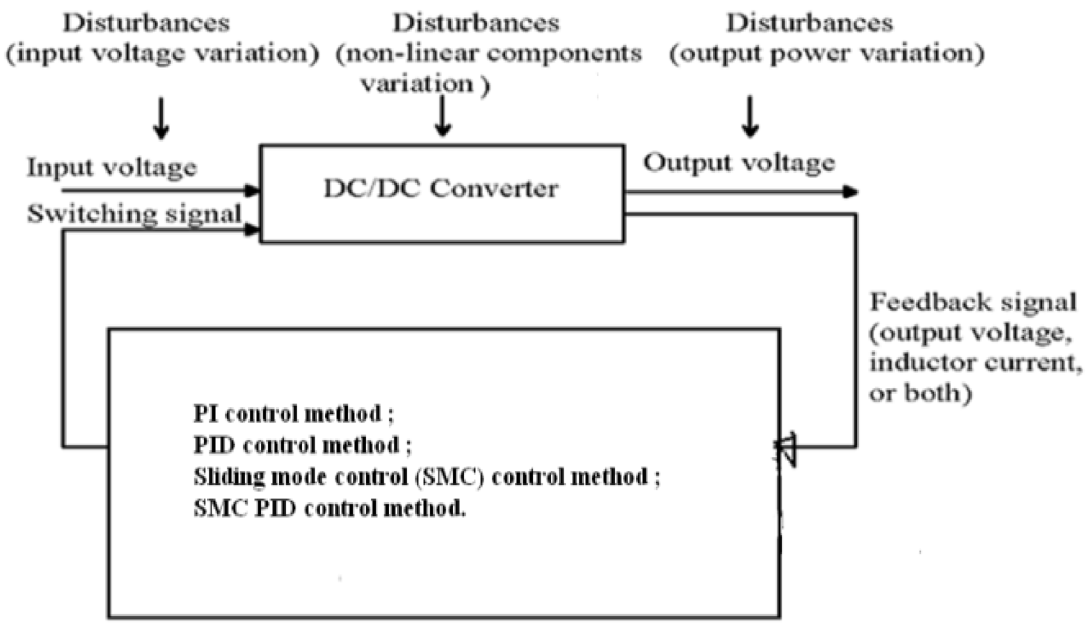


Figure No. 3.1 Types of controller.

3.1 PI control method

Settling time of PI compensated buck converter circuit is 11 msec initial overshoot for output voltage is 27 V and 43 A for inductor current. After settling time of 11 msec output voltage is at 12V and inductor current is at 1.738 A.

Load Voltage:-

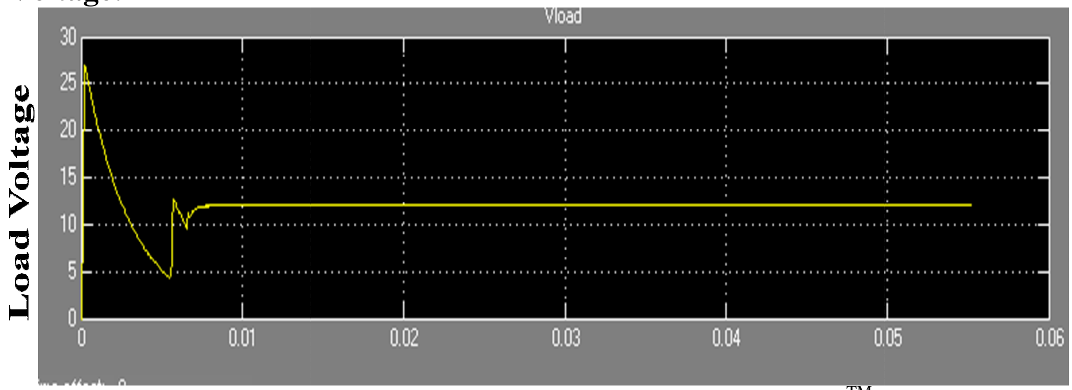
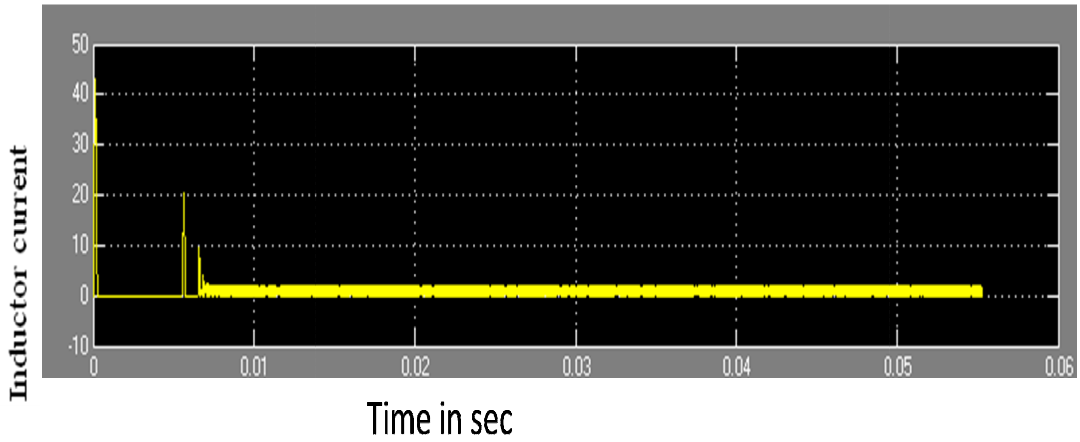


Figure No. 3.1.1 Load voltage of buck converter in Matlab/Simulink™ model.

Inductor current:-



FigureNo.3.1.2 Inductor current from simulation.

3.2. Effect of variation of load resistance on buck converter with PI control

When buck converter is considered with PI control it has settling time of 11 msec and output voltage is at 12 V. When the circuit was tested under the load variation from 0 (open circuit) to short circuit, it was found that as load resistance increases load current decreases.

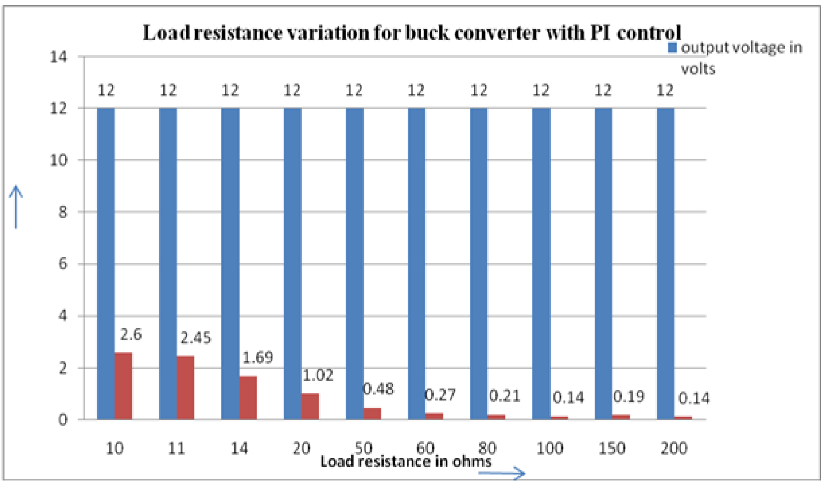


Figure No.3.2.1 Bar graph for the variation of load resistance.

3.3. Effect of variation of line voltage on buck converter with PI control

When the circuit was tested under the line variation from 20 V to 34 V, it was found that as line resistance increases, load current increases settling time is almost remains constant for PI controller.

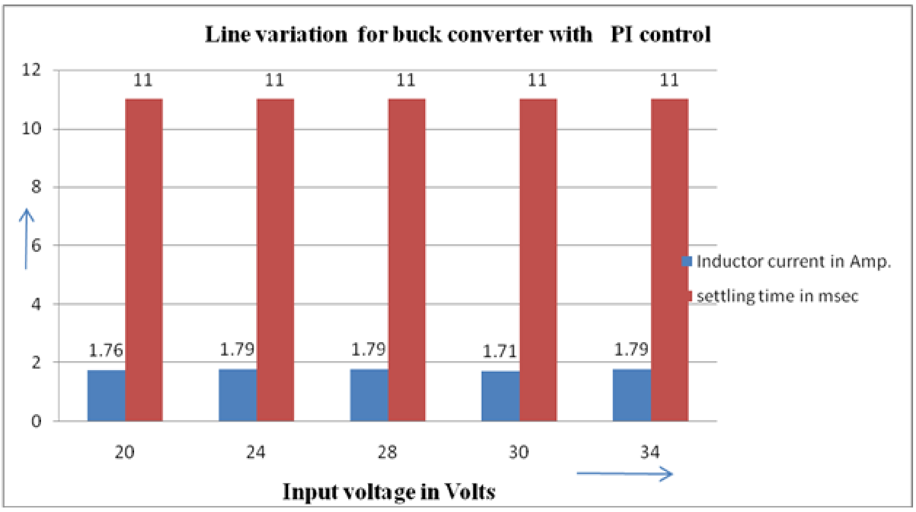


Figure No.3.3.1 Bar graph for the line variation.

3.4. PID control method

PID controllers are dominant and popular and, have been widely used since the 1940's because one can obtain the desired system responses and it can control a wide class of systems. The basic AC modeling approach is a common averaging technique used for PID modeling. After the circuit is modeled, we go through the design of PID controller with the help of Matlab in a simple way to get an overall system with good quality performance. Simulink model of the converter is built up and the controller obtained is added to the model.

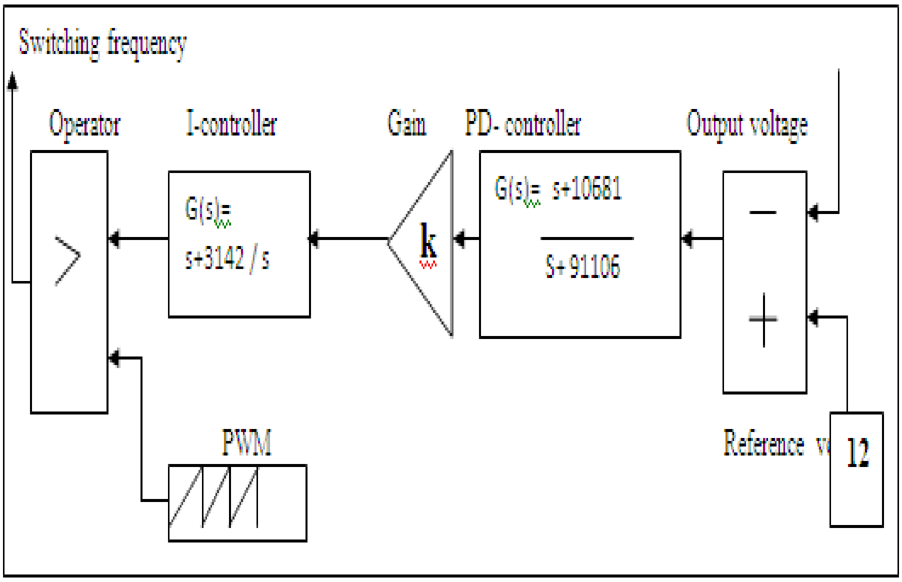


Figure No 3.4.1 The block diagram of controller includes PID control.

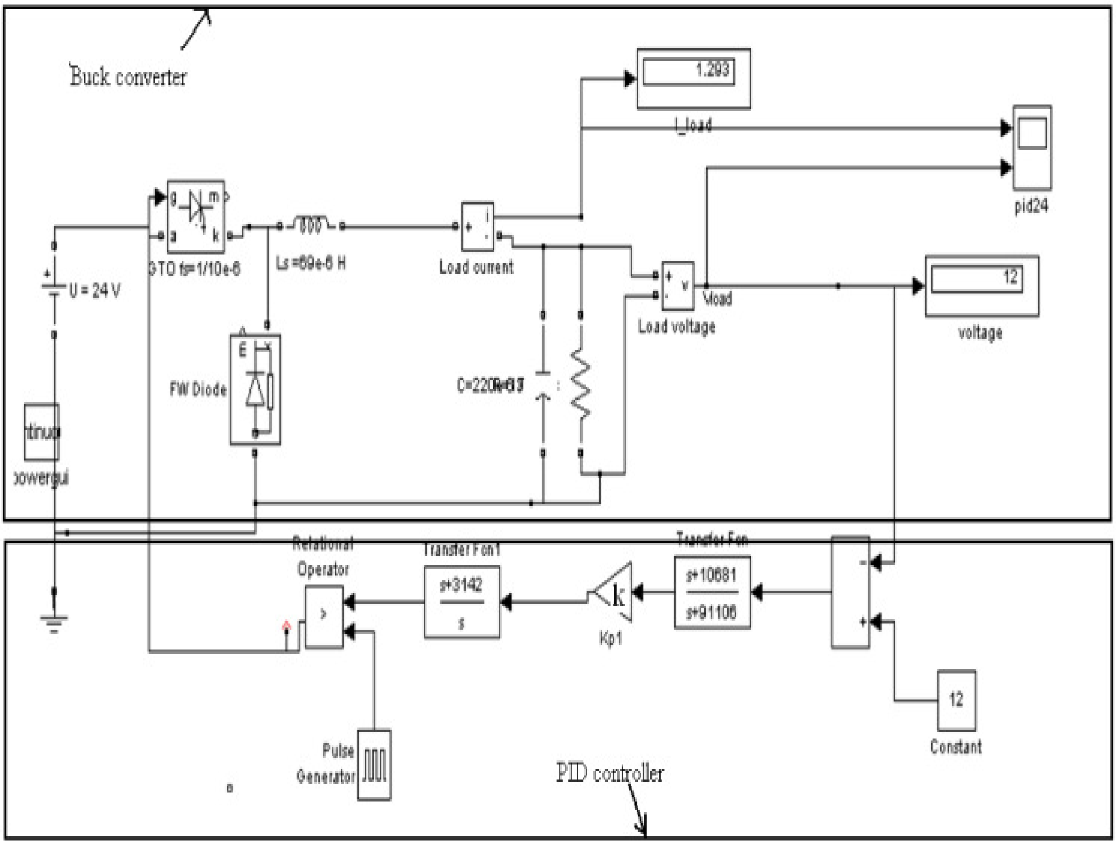


Figure No. 3.4.2 Buck converter with PID control Matlab model

3.4.1. Inductor current waveform

By considering above scenario in which a buck converter when considered with PID controller it has been observed that the circuit has settling time of 2.5 msec. The output voltage attends steady state value of 12 V, which is expected output from this application. Settling time for PID controlled buck converter is 2.5 msec and transient voltage is of 16 V and transient current is of 28 A which are less as compared to PI controller.

3.5 Effect of variation of load resistance on buck converter with PID control

When PID controlled buck converter is considered with load variation, in a range of 10 Ω to 13 Ω settling time and inductor current almost remains same. When load regulation is found out for this circuit it is found to be 29.82 %.

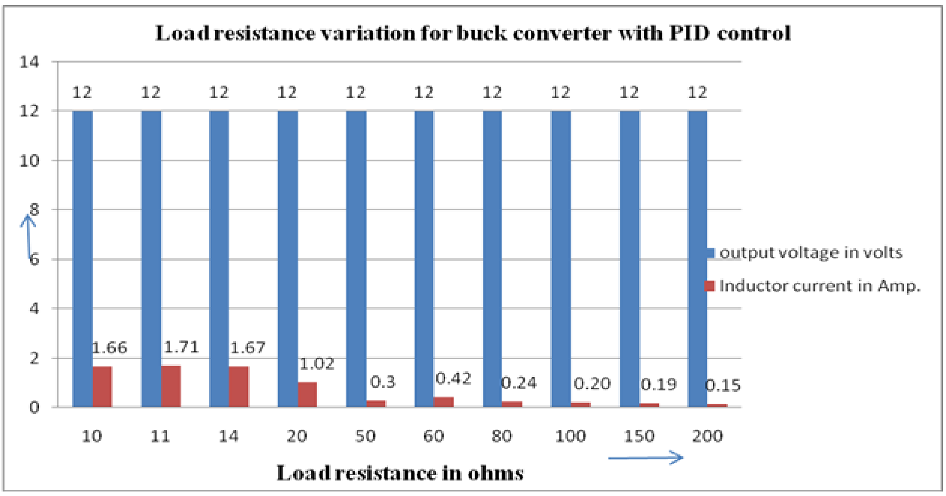


Figure No.3.4.1.1 Bar graph for variation of load resistance in PID control circuit.

3.6 Effect of variation of line voltage on buck converter with PID control

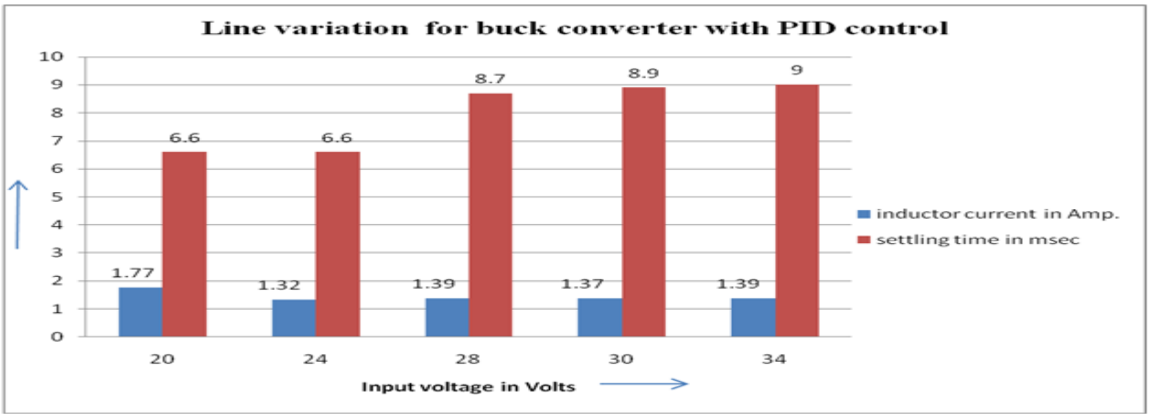


Figure No. 3.4.1.2 Bar graph line variation.

Figure 3.4.1.2 shows the line variation for PID controlled buck converter circuit. As input voltage increases, inductor current also increases and settling time also increases. The settling time is in msec for this circuit. From this variation we can say that this controller can be used in range of 20 V to 28 V with same output voltage, settling time and inductor current.

IV. SMC CONTROL METHOD

From above all control methods sliding mode control is the only non linear method and its performance is studied for comparison with other linear methods. SMC could be implemented for switch mode power supplies. The controller block diagram of SMC is shown in figure no. 4.1

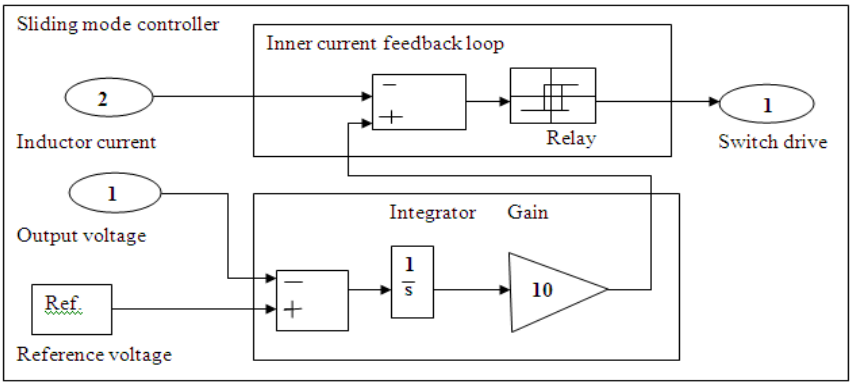


Figure No. 4.1 The simulation controller block diagram SMC.

4.1Selection of various parameters for the circuit

The control topology consists of a linear and non-linear part. The non-linear parameter can be selected, while it is left to the designer to tune the linear part and get the optimum values depending on the application. The output of the integral is amplified through a gain and the result is subtracted from the inductor loop, the difference is passed through a hysteresis. One major drawback of this model is the lack of a standard procedure to select the gain. The hysteresis parameter can be selected by measuring the peak-to-peak inductor current and these are the limits for the hysteresis parameters.

Table 2:- Main Circuit Parameters:-

Parameter name	symbol	Value
Input voltage	V_{in}	24 volts
Output voltage	Vo	12 volts
Capacitor	C	220μF
Inductor	L	69μH
Load resistance	R_L	13 Ω
Nominal switching frequency f		100 kHz
Switch off	SW1	u= 0
Switch on	SW1	u= 1

4.2. Buck converter with sliding mode control simulated circuit diagram

Considering above circuit in which a buck converter when considered with SMC controller it has been observed that the circuit has settling time of 20 msec. The output voltage attends steady state value of 12 V , which is expected output from this application. Under the load variation of SMC circuit from 0 to ∞ , it was found that as load resistance increases load current decreases and settling time increases continuously

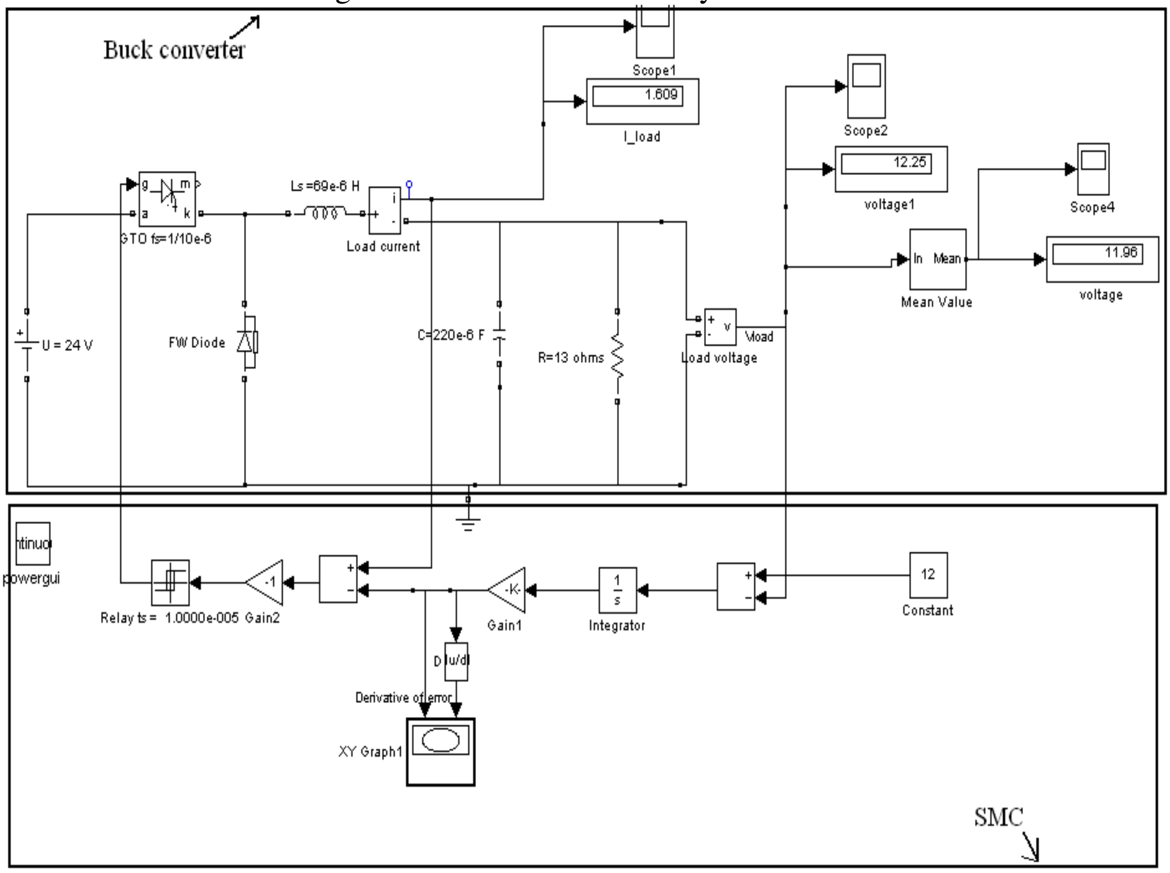


Figure No. 4.2.1 Simulation diagram for buck converter with SMC

4.2.1 Effect of variation of load resistance on buck converter with SMC control

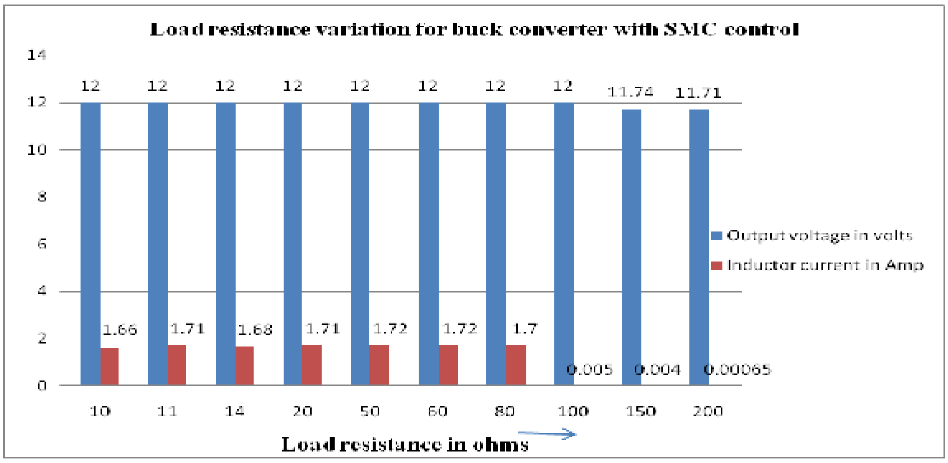


Figure No.4.2.1.1 Bar graph for load resistance variation

Above bar graph shows the effect of load variation on buck converter with SMC controller. As resistance value increases inductor current decreases. For ∞ resistance voltage is 23.69 and inductor current is 1.16e-10 A. But in the range of 10 Ω to 13 Ω load resistances inductor current and load voltage almost remain constant.

4.2.2 Effect of variation of line voltage on buck converter with PID control

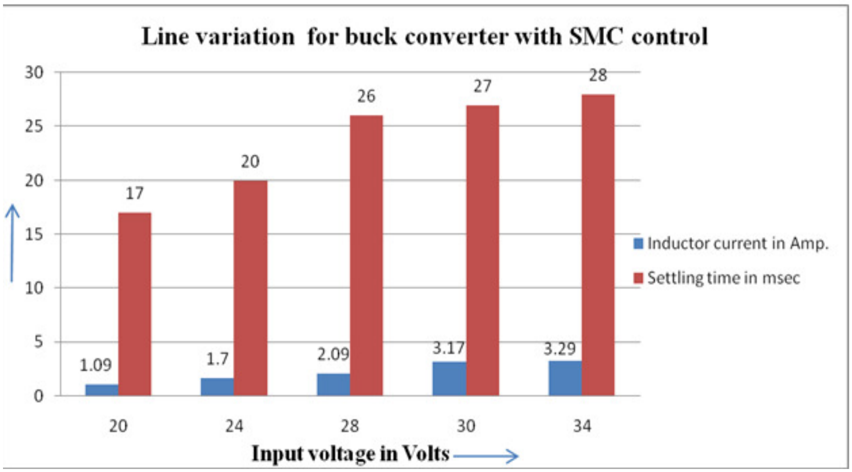


Figure No.4.2.2.1 Bar graph for line variation

V. MATLAB SIMULATION MODEL OF BUCK CONVERTER WITH SMC PID CONTROLLER

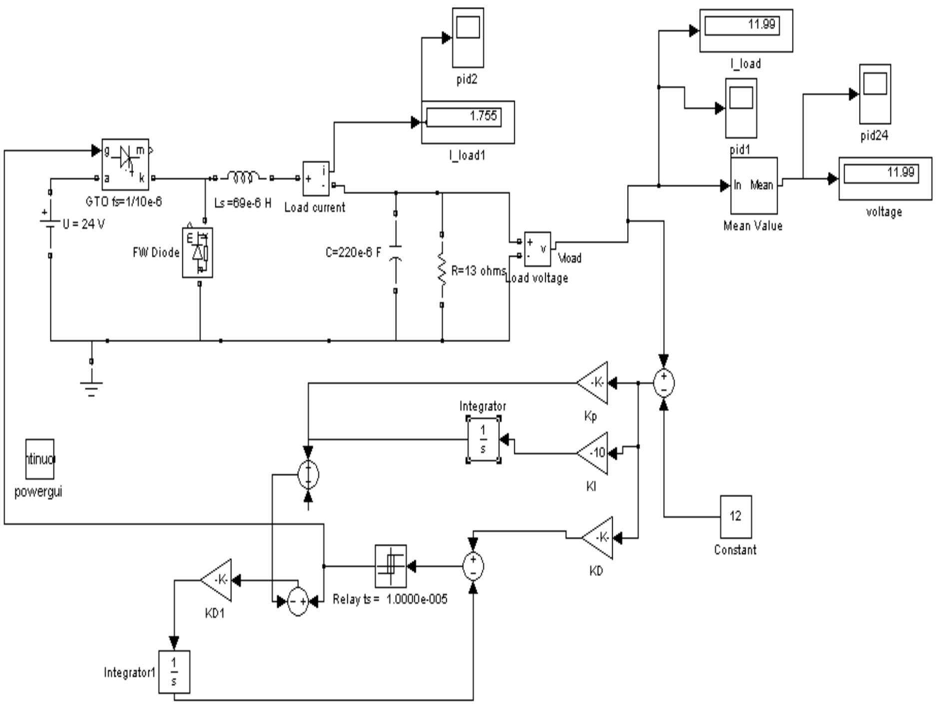


Figure No.5.1 Buck converter with SMC PID controller.

Above figure shows simulated model of buck converter with SMC PID controller. In this model SMC and PID controllers both are considered to get advantages of both control methods. From performance comparison of SMC PID with other controllers we can say that this circuit has large settling time but very less overshoot or no overshoot in voltage. Whenever we can consider this settling time and required more accuracy we can go for SMC PID model.

5.1Effect of variation of load resistance on buck converter with SMC PID control:-

Above bar graph shows the effect of load variation on buck converter with SMC PID controller. As resistance value increases inductor current decreases. For ∞ resistance voltage is 23.69 V and inductor current is 1.06e-12 A. But in the range of 10 Ω to 15 Ω load resistances inductor current and load voltage almost remain constant

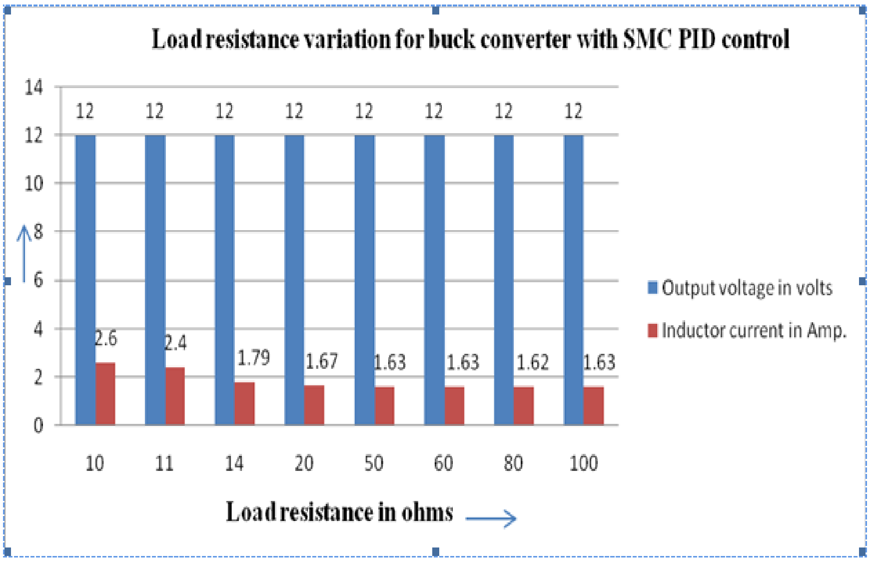


Figure No.5.1.1 Bar graph for load resistance variation

5.2 Effect of variation of line voltage on buck converter with SMC PID control

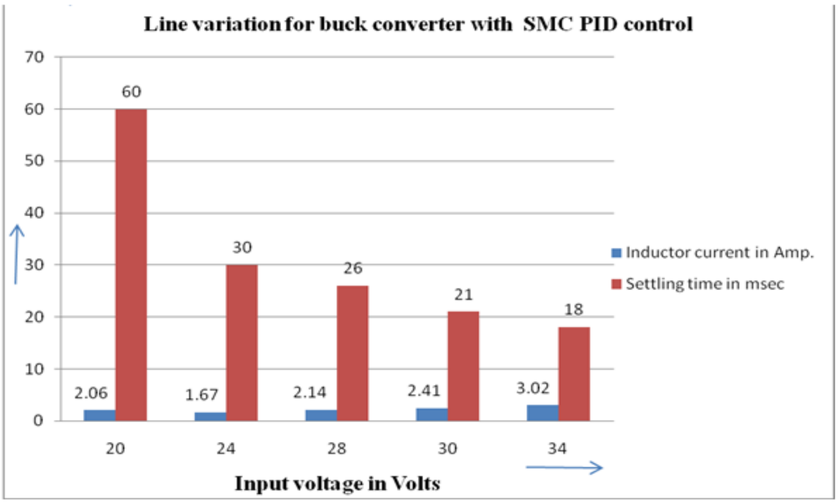


Figure No.5.2.1 Bar graph for line variation

Performance comparison

Table1 shows the summary of the performance characteristics of the buck converter between PI, PID, SMC and SMC PID controller quantitatively. Based on the data tabulated in Table 71, PID has the fastest settling time of 2.5 msec while SMC has the slowest settling time of 20 m seconds. An extra of 17.5 m seconds is required for the SMC controller for steady state voltage.

Table 1

Sr.No.	Type of circuit	Output voltage			Inductor current		
		Rise Time	Maximum Peak overshoot	Settling Time	Rise Time	Maximum Peak overshoot	Settling Time
1	Buck Converter	0.9 m sec	11V	4 m sec	0.9 m sec	2A	4 m sec
2	Buck Converter with PI controller	0.25 msec	25 V	6.5 msec.	0.25 msec	40 A	6.5 msec.
3	Buck Converter with PID controller	0.2m sec	16V	2.5 m sec	0.1 m sec	28 A	2 m sec
4	Buck Converter with SMC controller	3 m sec	0.5 V	20 m sec	3 m sec	3.5 A	20 m sec
5	Buck Converter with SMC PID controller	3 m sec	0.1V	30m sec	2 m sec	3.2 A	30 m sec

VI. Comparison Graph For Rise Time, Delay Time And Settling Time For All Existing Controllers

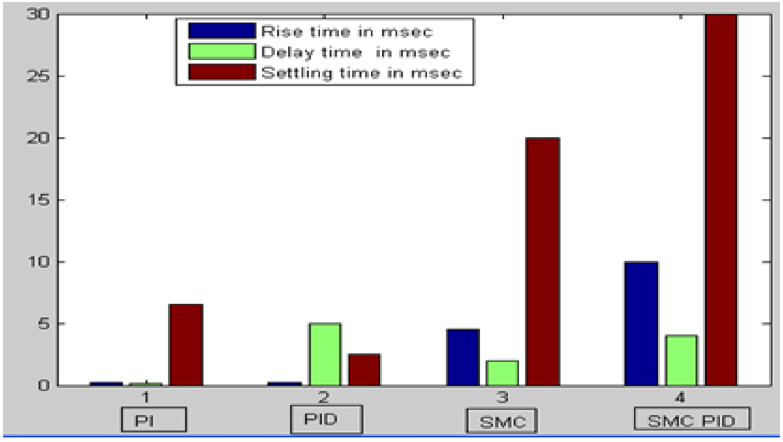


Figure No. 6.1.comparative graph for all existing controllers

6.1 Comparative graph for peak overshoot, regulation, output voltage and inductor current all existing controllers

From comparison we can say for same output voltage and inductor current peak overshoot is maximum for PI control and no overshoot for SMC PID control method. From the performance analysis of uncompensated buck converter we can say that because of disturbances and nonlinearities output voltage of converter is 14.12 V instead of 12 V.

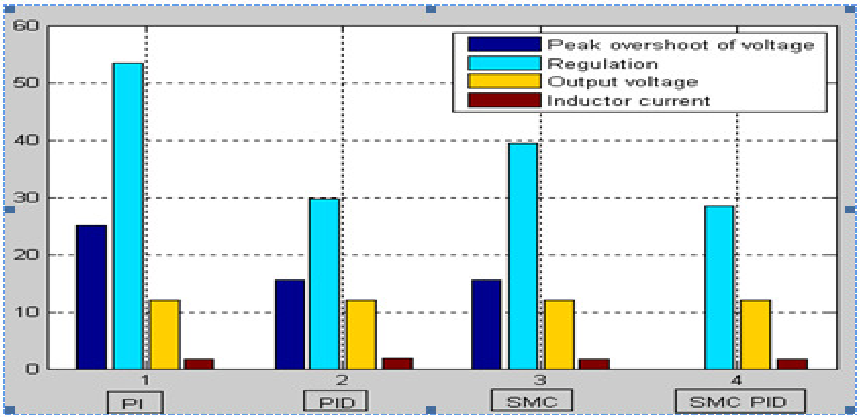


Figure No.6.1.1. Comparative graph for all existing controllers.

VII. Conclusion

As SMC is not operating at a constant switching frequency and converters have a highly nonlinear and time varying nature therefore it is selected to control such kind of DC- DC converter. Therefore it is also selected as control technique for performance analysis. The waveforms of simulated output voltage and current were obtained, studied and compared with the waveforms from other controllers for performance comparison. By studied references papers in details the waveforms were found to be in precise proximity of theoretical waveforms. Some concluding points which are analyzed in following points. From performance comparison of SMC with PI and PID it was found that it has large settling time. So when more voltage accuracy is required and large settling time can be considered then we can go for SMC or SMC PID control method. But when less cost, less accuracy and less complexity is required, than PI or PID control method can be used. When buck converter is considered with PI control within 6.5 msec output voltage attends 12 V.

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Biography

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