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Simulation Analysis of PWM Based Sliding Mode Controller for DC-DC Buck Converter

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ABSTRACT

A voltage control loop with nonlinear control action is proposed for the buck type dc-dc converter which operates with continuoussourcecurrent. The non -linear sliding-mode controltechnique is mainly acclimated to achieve less complex uniform control for buck converter operates in steady state as well as transient conditions. Instead of the suggested design methods, the output voltage should be provided to the control loop without the need for a synchronous capacitor for the proposed control scheme. As a result, the analog implementation value decreases and the difficulty of connecting the sensor in order to measure the capacitor current of the converter is eradicated. The equation of control action is accomplished using some op-amps and resistors in a simple analog circuit best suited for automated operations. Design and modelling of the proposed system are provided to facilitate the existence of system manipulation and the derivation of equilibrium conditions. the efficiency of buck converter with PI controller is around 96%, with SMC control is around 96% and with ANN controller is around 97.2%.The proposed work will be simulated in Matlab / Simulink software.

KEYWORDS: Simulink, DC-DC converter, Synchronous capacitor, Control loop, Controller comparative study.

1.INTRODUCTION

Linear management techniques with classical voltage- and contemporaneous-mode manipulation are used in many packages, including DC drives, motors and household apparatus. The Linear functioning controllers are adequate for minor changes on the surrounding conditions for operation of the converter as they depends on short-signal version. Therefore targets for the controllers may not function as precise even at heavy-signal interruptions. Consequently, many studies have been devoted to implementing the Sliding-Mode Manipulate (SMC) method as asubstitute, due to the rigidity, balancing of large-scale signal and also compatibility with Varying Size Structures (VSS).

Despite the great functions of SMC, still the linear controllers dominate most of the industrial programs. As the conventional controllers need very little effort for designing and are easy to implement in analog form, as the SM controller design requires more calculations and complex structure for controllers. In addition, the approach of SMC can lead to optimal problems such as chatter and varying cycle of frequency for switching operations. More number of study efforts was made combined to determine the effectiveness of the SMC for efficient operation of DC-DC converters with the help of embedded machine systems, with various researchers proposing analog SMC schemes.

Embedded architecture technologies are powered by the use of an FPGA, DSP and microcontroller. In addition, Labview, DSPACE, Digital Signal Controller and DQ-Advantech have been implemented. Although previous control schemes were not cost-effective for commercial packages, they were characterized by advanced capabilities such as programmability, accuracy and fast signal processing capability. Introduced some analog SMC schemes as competing applicants for analog linear controllers. HM-based is fully SMC proposed, but it is low enough to maintain a fixed frequency of switching operations, which made the layout of power converters entering and filters at output side as more complex one.

More number of research attempts are made, manipulation of HM / PWM joints to stabilize the optimal HM-based complete SMC and switching frequency has been introduced. However, a complex circuit is required. Likewise, PWM-based SMC control circuits with driver speakers and simple parts are said to have various kinds of transducers. An orderly framework to plan simple SM regulators as voltage regulators for normal DC-DC converters and to address the most useful restrictions related with SMC. There is as yet an interest for improvement of simple PWM-based SMC designs to stretch out solid non-straight options in contrast to customary direct regulators.

2.RELATED WORK

Sliding Mode Management (SMM) is utilized to control DC-DC converters. At first, an extensive outline of the appropriate algorithm is developed. The fundamental issues that prevent SMMin implementation in modern DC-DC converters have been explored. Consistent arrangements are required, and simple plan techniques are presented.The work of SM controls has been displayed to direct further developed perceivability in giving a constant impermanent criticism on an enormous fluctuate of in activity conditions. [1]

A clear and organized way to deal with an exquisite slip-mode voltage regulator for buck converters working in persistent mode. Different parts of the region unit unmistakable with significant right issues and projected answers. Directand clean design strategy is also clarified. Trial results region unit displayed to describe the design strategy [2].

In the plan of extreme-frequency frequency device conversion, the authors demonstrate the existence of an ideal equivalence between the slippery regimes of variable-structure comment management and therefore the Pulse-Width-Modulated (PWM) responses in nonlinear dynamic systems. This equivalence is that the basis of the geometric technique accustomed maintain the loop style for PWM. An example of energy conversion during a lossless switch-managed [3].

A systematic method for mapping the slip-mode sensitive voltage regulator for buck converters working in a relentless mode actual marvel. The different components of the look are exact, with important restorative problems and planned solutions. Straightforward and straightforward compliance with the layout system is equally delineate. Experimental results are presented demonstrate the layout methodology. [4]

The Sliding Mode Management (SM) applied to the control of DC-DC converters. The usage of SM the executives has been displayed to {supply to produce} higher perceivability inside the stockpile of reliable transient reactions to a decent shift of current things. [5]

For DC-DC dollar synchronous converters, the Second Order Sliding Mode(SOSM) management method is used. The proposed SOSM controller installs DC-DC synchronous buck converters using the typical digital system architecture, eliminating the need for complex word in current sensing or management loops. The SOSM controller has fast loading time and brief initial feedback and is resistant to parameter uncertainty. In general, the console setting adjustment fixes the current issue during the jump and startup. To change the shift frequency, the physical phenomenon technique is also used. The proposed strategy is a legitimate inquiry into the abuse, which ended in a trial. Example with a voltage of 25 volts and a current of 10 amps [6]

3.DC-DC BUCK CONVERTERMODEL

The block diagram of the proposed system is as shown in the Fig. 1 and it has the three controllers to change the voltage as per the requirement at the load.

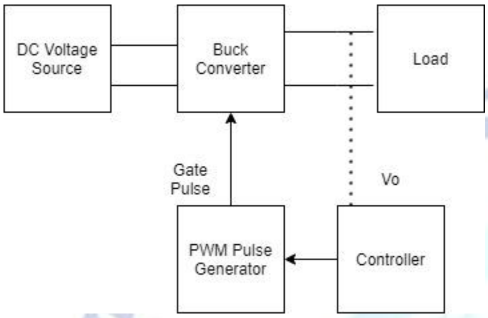

Figure.1: Proposed system.

DC-DC converters are electronic devices that can be utilized to effectively change over DC power starting with one voltage level then onto the next. It is an electronic circuit that changes over a DC signal starting with one voltage level then onto the next. They use an inductor and a capacitor as power storage factors so that electricity may be transferred from the input to the output. DC- DC converters are widely utilized in switched-mode electricity elements (SMPS) and feature a wide range of uses these days and are getting an increasing number of vital in everyday use. The types are as follows,

A. Buck Converter

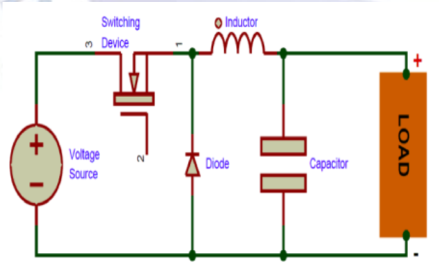

Figure.2: Buck converter.

Fig.2 showsonly one of the converter's switches Q, is operational, thus it has two distinct switching states. The converter is ON while the Q is ON, and OFF when the Q is OFF. Each state has a unique set of behavioral characteristics. The length of time the converter spends in any of these states is dependent on the duty cycle of the active switch.

B. ON-state

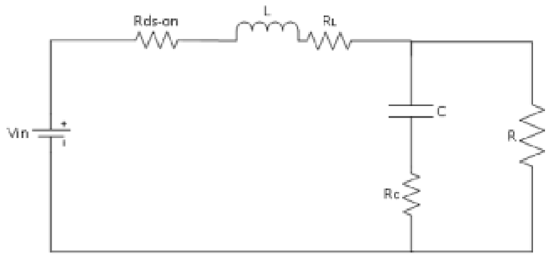

Figure.3: ON state of the converter.

Fig.3 depicts the ON state of the converter operational circuit. Here, the gate pulse provided to switch Q is HIGH and the inductor gets charged during this time period. The load voltage is given by the following Eq. (1)

$$V_o=V_{in}-V_L \qquad (1)$$

When the switch is closed (ON) for a ton of time, the induction current is maintained and the diode is reverse biased. As a result, a positive voltage is generated across the inductor

$$v_{in} = L\frac{di_L}{dt} + v_o \qquad (2)$$

$$L\frac{di_L}{dt} = v_{in} - v_o \qquad (3)$$

C. OFF state

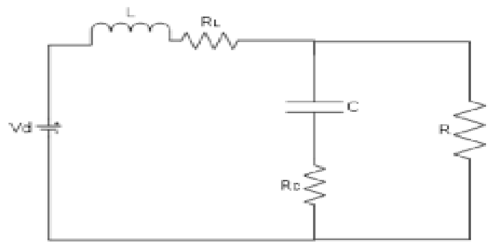

Figure.4: OFF state of the converter.

The mode2 operational circuit is provided by Fig. (4). Here, the gating pulse provided for the switch, S is LOW and the inductor gets discharged during this time period. The load voltage is given by the Eq. (4)

$$V_o = V_L \qquad (4)$$

Since the signal is repeated from signal to cycle during the steady-state process, the induction voltage of the induction voltage V_L over a period of time is set to zero

$$\int_0^T v_L\,dt = \int_0^{t_{on}} v_L\,dt + \int_{t_{on}}^T v_L\,dt = 0 \quad (5)$$

D. Mode of operation

There are two modes of operation namely, Dis-Continuous Conduction Mode (DCM) and Continuous Conduction Mode (CCM).

i. Discontinuous Conduction Mode (DCM)

Fig.5, depicts the Dis-Continuous Conduction Mode (DCM) waveform. When the inductor cutting-edge has zero without a charge and discharge all through a switching length. Inside the discontinuous conduction mode each switching cycle is split into three parts that is DT, D'T and D''T (D+D'+D''=1). In the course of the primary and 2nd mode that is in DT and D'T the inductor contemporary boom and decrease respectively, while throughout the 0.33 mode that is in D''T the inductor current stay at zero without a price and discharge.

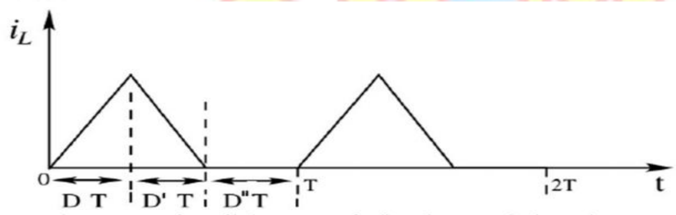

Figure.5: DCM Mode.

ii. Continuous Conduction Mode (CCM)

Fig. 6 shows the waveform of the continuous conduction mode.When the inductor of contemporary weft price is non-stop and releases everything in one switching period. In CCM, each switching cycle consists of two components, DT and D'T (D + D' = 1). Induction mode surge during primary and second mode and decrease in DT and D'T respectively.

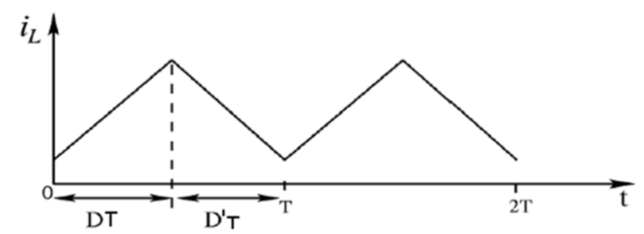

Figure.6:CCM Mode.

4.PWM BASED CONTROLLERS DESIGN

A.Sliding Mode Control (SMC)

Fig.7 indicates the sliding mode control.The proposed system consists of DC voltage source providing supply to the buck converter which provides the required DC/DC conversion and the output of buck converter is to be provided to load. The SMC controller provides the duty ratio depending on the error voltage and it is provided to pwm pulse generator. The PWM pulses is provided to the buck converter which provides the voltage regulation as per the reference voltage.

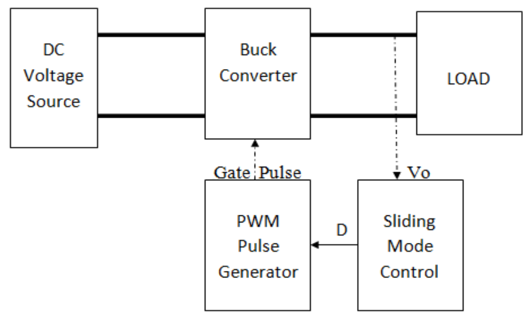

Figure.7.Sliding mode control.

Buck converter gives venture down activity to DC voltage. In a buck converter, when the switch is in the on position, the inductor is charged and furthermore gives the stockpile to the heap. The heap voltage is given by Eq. (6)

$$V_o = V_{in} - V_{ind} \quad (6)$$

The DC voltage when the switch is in off state is given by the Eq. (7)

$$V_o = V_{ind} \quad (7)$$

The buck converter with SM control circle is given in the Fig.8.

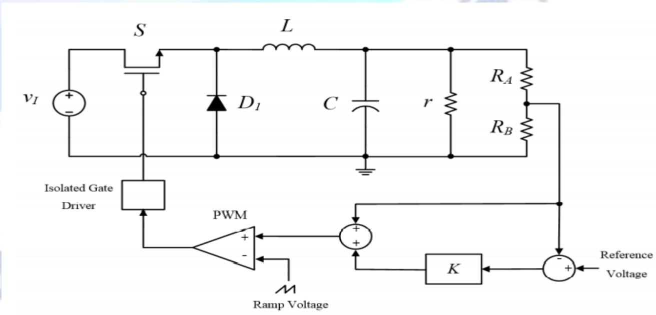

Figure1: Buck Converter with SM Control Circuit

The sliding surface of the sliding mode controller is provided as

$$\varphi = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 \quad (8)$$

The boundaries $\alpha 1$, $\alpha 2$, and $\alpha 3$ are positive constants that signify the coefficients of sliding surface. A law for controlling the switching action that satisfies the given constraint is,

$$u = \begin{cases} 1 \; if \; \varphi > 0 \\ 0 \; if \; \varphi < 0 \end{cases} (9)$$

The Eqs. (10) and (11) provide the controller and the duty ratio

$$u_e = K(V_r - \beta \overline{v_o}) + \beta \overline{v_o} (10)$$

$$V_T = \beta \overline{v_{I(nom)}} (11)$$

B. PI Controller

The P-I controller is used specifically to deal with frequent state errors caused by the P controller.But, in terms of reaction rate and general stability of the system, it has terrible implications. This controller is basically used in areas where system speed is not always a problem.

i. Proportional controller

With proportional bands, the controller output error or amplitude is proportional to the conversion.
Controller output = e(t) * 100/(proportional gain)
(12)
Offset (deviation from set-factor) with proportional controller is good. The loop pass is unstable due to increasing controller gain. To get rid of this offset, key speed controllers have joined

ii. Integral control

With mandatory movement, the controller output error is proportional to the time at which the reward occurs. The critical movement gets rid of the offset.
Controller output=(1/critical time) * (critical of E (T)(12)
The upper controller output U in the S-region is given by the Eq.(13)

U(s) = K (1+ 1/Tis + Tds/ (1+Tds/N)) E(s) (13)

C.ANN Controller

The school education was completed with the help of data taken from the gadget below. A set of Levenberg-Marquard rules is used for neural community learning. This rule requires additional memory but minimal time. As the validation of the validation patterns is indicated by the square error increase, the practice stops when the improvement in normalization stops. An appropriate curve for training a neural community controller is provided in the graph shown in Fig.9.

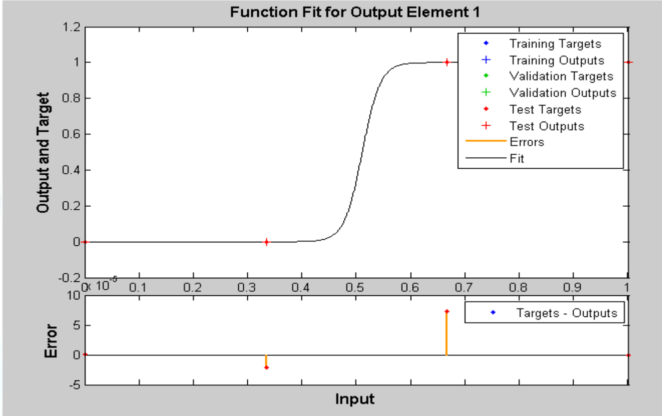

Figure2: Fitting Curve during the Training of ANN.

The regression value obtained from the training of neural network control is 0.99953. The graphs
Of the regression curve are provided in Fig.10.

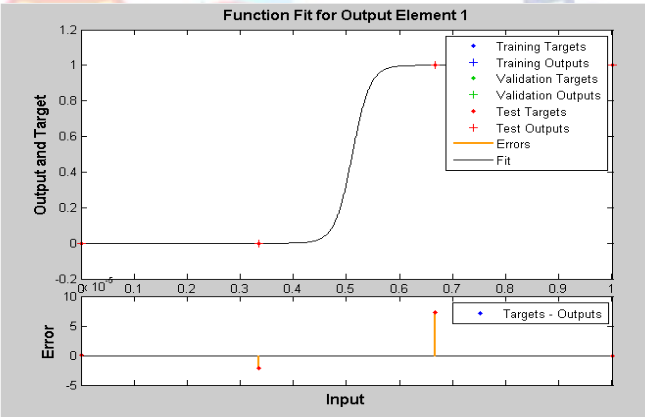

Figure3: Fitting curves from neural network training.

5.IMPLEMENTATION

The modeling of the circuits is performed in this sub-section, the three controllers are implemented in the proposed system.The simulation parameters used for the controller are tabulated in the table 1.

Table 1: Simulation Parameters.

Input Voltage	24-16 V
Switching Frequency	5 kHz
Inductor	2.86mH
Capacitor	87.5µF
R Load	3Ω
Load voltage	12V
Load Power	48W

The simulation circuit for the buck converter with PI controller is provided below figure, In this, the information voltage is differed from 24V to 16V at t=0.5s. The reference voltage of 12V is contrasted and estimated load voltage and the blunder voltage is given to PI regulator. The PI controller provides the duty ratio based on the error voltage and the duty ratio is compared with carrier signal of 5KHz in order to generate pulses.

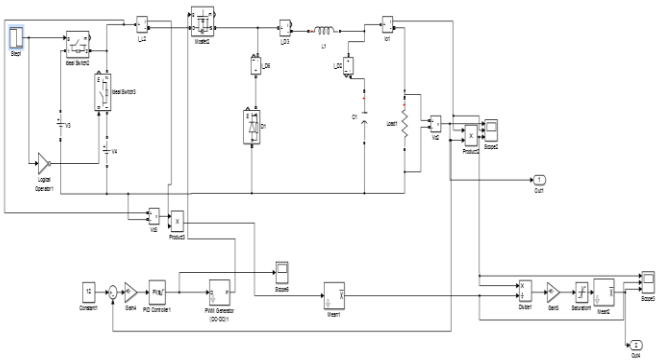

Figure4: PI controller-based Buck converter.

The simulation circuit of buck converter with sliding mode control is provided in below figure,

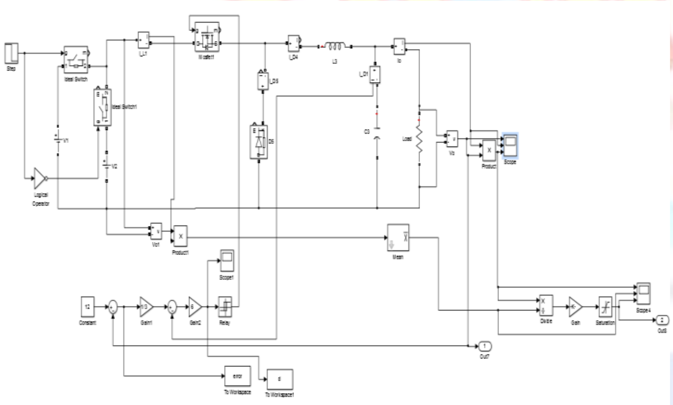

Figure5: Sliding Mode Controller based Buck Converter.

The simulation circuit of buck converter with ANN control is as shown in Fig.13.

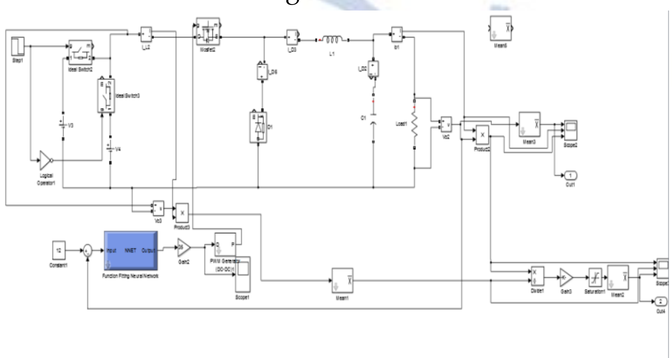

Figure6: ANN based Bulk Converter.

6. Results and Discussion

A. PI controller based Bulk convertor

In this the voltage deviation from the reference voltage is around 0.6V which 5% of the required load voltage. The voltage, current and power waveforms are shown in Fig.14at the load side.

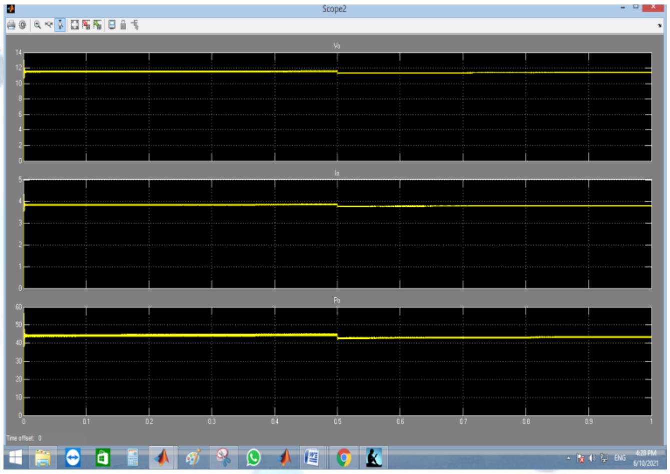

Figure7: Voltage, Current & Power at the load.

B. Sliding Mode Controller (SMC) based Bulk Converter

Fig.15 shows voltage, current and power waveforms using SMC controller on Bulk Converter. In this the voltage deviation from the reference voltage is around 0.1V which 0.83% of the required load voltage.

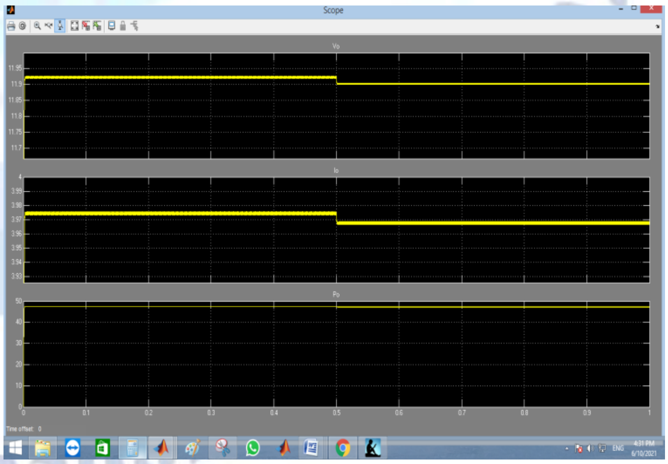

Figure8: Voltage, Current and Power using SMC controller on Bulk Converter.

C.ANN based bulk converter

Fig.16 depicts voltage, current and power waveforms of bulk converter using ANN.In this the voltage deviation from the reference voltage is around 0.065V which 0.54% of the required load voltage.

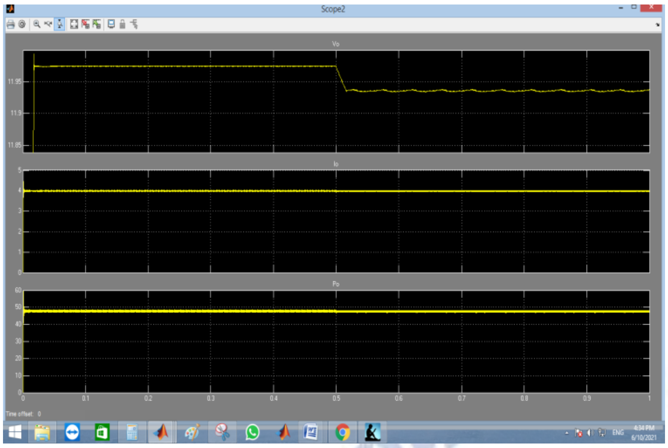

Figure9: Voltage, Current and Power waveforms of Bulk converter using ANN.

Fig.17 shows the efficiency waveforms of buck converter under the above-mentioned controllers.The efficiency of buck converter with PI controller is around 96%, with SMC control is around 96% and with ANN controller is around 97.2%.

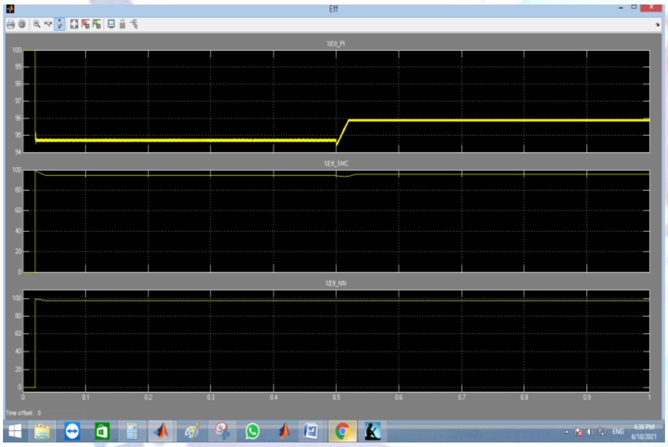

Figure10: Efficiency for the three controllers bulk converters.

7.Conclusion

In this paper, a voltage control loop with nonlinear control action is proposed for the buck type dc-dc converter which operates with continuous source current. Design and modeling of the proposed system are provided to facilitate the existence of system manipulation and the derivation of equilibrium conditions. The proportional Integral, sliding mode and Artificial neural network controllers are designed and provided to the buck converter individually and the performance of the converter under such controllers are noted. The source voltage is varied and the regulated load voltage is measured and the efficiency of buck converter with PI controller is around 96%, with SMC control is around 96% and with ANN controller is around 97.2%.

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