# STABILIZATION AND ROBUSTIFICATION OF NEGATIVE OUTPUT SUPERLIFT LUO CONVERTER USING SLIDING MODE CONTROL APPROACH

V. Chamundeeswari[1], R. Seyezhai[2], A. Arul Robin[3]

[1]Assoc. Professor, Department of EEE, St. Joseph's College of Engineering, Chennai, India
[2]Assoc. Professor, Department of EEE, SSN College of Engineering, Chennai, India.
[3]PG. student, St.Joseph's College of Engineering, Chennai,-119, India

***ABSTRACT***

*This paper depicts the design and implementation of non-linear control approach called sliding mode control for Negative Output Elementary Superlift Luo converter (NOESLLC).DC-DC converters finds its applications majorly in all power electronic industries nowadays. In order to provide a good regulation of output in these converters it is mandatory to make them operate in the closed loop mode using various controllers like P, PI and PID controller. But the usage of these controllers has resulted in an unsatisfactory regulation of the output voltage under large variation of system parameters. To overcome this, an approach called sliding mode control (SMC) technique is proposed and discussed here. The NOESLLC converts the positive input voltage into a negative output voltage in geometric progression. The design of the controller is done with the tuning of its gain parameter and implemented in the circuit by using the state space model of the converter. The main advantage of SMC over conventional control is its stability and good response variations with respect to the input. Simulation results are presented using PSPICE and MATLAB to validate the theoretical design and to illustrate the strength of the proposed controller.*

***KEYWORDS:*** *DC-DC converter, Negative output Elementary superlift Luo converter, Sliding mode controller (SMC)*

## I. INTRODUCTION

Voltage lift technique has been successfully employed in design of DC/DC converters, e.g., Luo-converters. However, the output voltage increases in arithmetic progression. Super lift technique in this system implements the output voltage increasing in geometric progression. It effectively enhances the voltage transfer gain in power-law. The sliding mode control for the above system is implemented to achieve a closed loop control. The NOESLLC performs the voltage conversion from positive source voltage to negative load voltage. The SMC is designed by using state-space average modeling of NOESLLC. Conventionally, proportional-integral-derivative (PID) and (PI) controllers are used for the control of various types of DC-DC power converters which has provided an unsatisfactory regulation of the output voltage in a closed loop control. The technique of introducing sliding mode control has resulted in good regulation of the output voltage. The following sections will reveal the entire modeling and design of the controller for the converter. The modes of operation of the converter has been explained in section II followed by the state space model in section III. The section IV and V has been dealt with design of sliding mode controller and the calculation of control and tuning parameters. Simulation results of the converter and the gate pulse generated are depicted in section VI and ended with a conclusion in section VII.

# II. OPERATION OF THE CONVERTER

a. Operation of NOESLLC

The NOESLLC is a new series of DC-DC converters[5] possessing high-voltage transfer gain, high power density, high efficiency, reduced ripple voltage and current. Fig.1 (Ref.17) shows the elementary circuit of NOESLLC.It consists of DC supply voltage $V_{in}$, capacitors $C_1$ and $C_2$, inductor $L_1$, power switch S (n-channel MOSFET), freewheeling diodes $D_1$ and $D_2$ and the load resistance R.The working principle is explained with the switch 'S' on and off as two modes of operation as shown in Figs.2& 3. (Ref.17)During the on period of the switch 'S' i.e. DT interval, voltage across capacitor $C_1$ is charged to $V_{in}$. Current flowing through inductor $L_1$ increases with slope $V_{in}$ /$L_1$ and decreases with slope $-(V_o - V_{in})/L_1$ during switch-off (1-D) T.

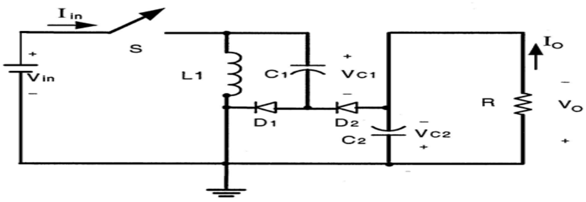


**Fig 1:** Circuit diagram of NOESLLC

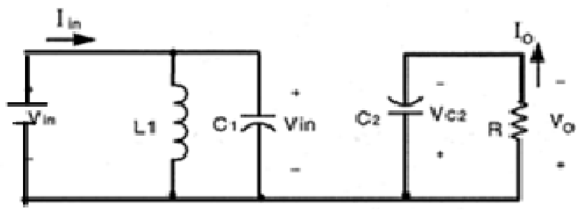


**Fig 2:** Mode 1- circuit diagram of NOESLLC

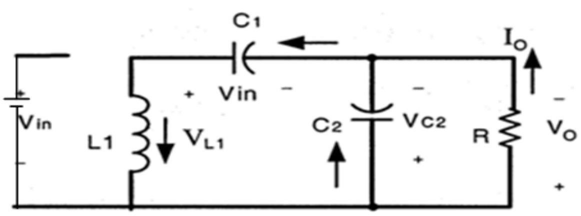


**Fig 3:** Mode 2- circuit diagram of NOESLLC.

During mode-1, the switch is closed and the supply flows through the inductor $L_1$ and $C_1$ charges during this time the capacitor $C_2$ produces a load voltage. During mode-2, the switch is open and the inductor $L_1$ and capacitor $C_1$ discharges through the load which gives the boosted output $V_o$.

b. Energy equations during ON and OFF state

Considering the modes of operation as by above figures,

Energy during ON state is ,

$$W_{on} = V_{in} I_L T_{on} \tag{1}$$

Energy during OFF state is,

$$W_{off} = V_L I_L T_{off} \tag{2}$$

Therefore output voltage is given by,

$$V_o = \frac{V_{in}}{1-D} \tag{3}$$

The variation ratio of inductor current $i_{L1}$ is,

$$\xi = \frac{\Delta i_{L1}/2}{i_{L1}} = \frac{D(1-D)TV_{in}}{2L_1 I_0} = \frac{D(1-D)}{G_1}\frac{R}{2fL_1} \tag{4}$$

The ripple voltage of output voltage $V_o$ is,

$$\Delta V_0 = \frac{I_0(1-D)T}{C_2} = \frac{(1-D)}{fC_2}\frac{V_0}{R} \tag{5}$$

Therefore, the variation ratio of output voltage $V_o$ is,

$$\xi = \frac{\Delta V_0 / 2}{V_0} = \frac{(1-D)}{2RfC_2} \tag{6}$$

The variation in the inductor current is given by,

$$\Delta i_{L1} = \frac{V_{in}}{L_1}DT = \frac{V_o - V_{in}}{L_1}(1-D)T \tag{7}$$

The voltage transfer gain is,

$$Vo = \left(\frac{2-D}{1-D} - 1\right)V_{in} \tag{8}$$

$$G_1 = \frac{2-D}{1-D} - 1 \tag{9}$$

c. SMC in Variable structure system (VSS)

Nowadays, all the modern power electronics systems need high quality, simple, lightweight, cheap, highly reliable and efficient power supplies. To regulate the output voltage of DC-DC converters[6] irrespective of load variations and line disturbances, it is necessary to operate the converters in closed loop mode. In recent days, the use of sliding mode control (SMC)[8] method in variable structure system (VSS) makes the system very robust to parameter variations and external variations. Variable structure systems are characterized by a discontinuous control action which changes structure on reaching a set of switching surfaces. Here the switching commutations of a static converter constitute the VSS.

## III. MODELLING OF NOESLLC

The state-space modeling of the equivalent circuit of NOESLLC with state variables $i_L$, VC1 and VC2 are given below. According to the switching condition (Y), the V1, $V_2$, V3 are expressed for the ON condition and the status of the switch is determined as,

$$Y = [\{0 \rightarrow S \rightarrow OFF\}]$$

$$Y = [\{1 \rightarrow S \rightarrow ON\}]$$

$$V_1 = 0 = \frac{di_{L1}}{dt}$$

$$V_2 = \frac{V_{in}}{R_{in}C_1} - \frac{V_{in}}{L_1} - \frac{I_{L1}}{C_1} = \frac{dV_{C1}}{dt} \tag{10}$$

$$V_3 = -\frac{V_{in}}{L_1} = \frac{dVc2}{dt}$$

In this, the sliding surface has to be chosen, within the state variables space, where control functions are discontinuous. The sliding condition[9] occurs when the system state does not leave the switching surface and the system dynamics can be described by a reduced order system. In general, two dynamic conditions can be distinguished and that is derived by assuming the ideal hypothesis of infinite commutation frequency of electronic switches which satisfies the above switching condition given as 'Y'. Thus the switch off state is taken and the equations are described with respect to the switch off condition as considered in mode 2.

According to the switching condition (Y) of circuit, i.e. in OFF condition, the V1, $V_2$, $V_3$ are expressed as,

$$V_1 = -\frac{V_{in}}{L_1} = \frac{di_{L1}}{dt}$$

$$V_2 = -\frac{i_{L1}}{C_1} - \frac{V_{in}}{L_1} = \frac{dV_{C1}}{dt} \tag{11}$$

$$V_3 = \frac{i_{L1}}{C_2} - \frac{V_{in}}{L_1} = \frac{dV_{C2}}{dt}$$

Therefore,

$$\begin{bmatrix} \frac{di_{L1}}{dt} \\ \frac{dV_{C1}}{dt} \\ \frac{dV_{C2}}{dt} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{L} & \frac{1}{L} \\ \frac{1}{C_1} & 0 & 0 \\ \frac{1}{C_2} & 0 & -\frac{1}{RC_2} \end{bmatrix} \begin{bmatrix} i_{L1} \\ V_{C1} \\ V_{C2} \end{bmatrix} + \begin{bmatrix} \frac{V_{C1}}{L_1} - \frac{V_{C1}}{L_1} + \frac{V_{in}}{L_1} \\ -\frac{2i_{L1}}{C_1} + \frac{V_{in}}{R_{in}C_1} \\ -\frac{i_{L1}}{C_2} \end{bmatrix} Y + \begin{bmatrix} -\frac{V_{in}}{L_1} \\ 0 \\ 0 \end{bmatrix} \tag{12}$$

Where, Rin is internal resistance of the source.

State-space modeling of the circuit is given by,

$$\dot{X} = Ax + By + Cw$$

Where, $\dot{X}$ & $x$ are the vectors of the state variables and their derivatives respectively and C is the disturbance matrix and ω is the input.

## IV. SMC DESIGN AS VARIABLE STRUCTURE CONTROLLER (VSC)

a. Controller design

In sliding mode theory, the SMC requires sensing of all state variables of NOESLLC and generation of suitable references for each of them as shown in fig.4 The principle of the SMC is to make the capacitors voltage Vc1 and Vc2 of NOESLLC follow as faithfully as possible the capacitor voltage references. However, the inductor current reference is difficult to evaluate since that generally depends on load power demand, supply voltage, and load voltage. To overcome this problem, the state variable error for the inductor current can be obtained from feedback variable iLl by means of a high-pass filter in the assumption that their low-frequency component is automatically adapted to actual converter operation. The high-pass filter must be suitably lower than the switching frequency to pass the ripple at the switching frequency, but high enough to allow a fast converter response. When good output voltage regulation of NOESLLC is required, a sliding surface equation in the state space can be expressed by a linear combination of state-variable errors, can be given by

$$S = (i_{L1}, V_{C1}, V_{C2}) = K_1\varepsilon_1 + K_2\varepsilon_2 + K_3\varepsilon_3 \tag{13}$$

Where coefficients $K_1$, $K_2$ and $K_3$ are proper gains, $\varepsilon_1$ is the feedback current error, $\varepsilon_2$ is the feedback voltage error and $\varepsilon_3$ is the feedback voltage error.

$$\begin{aligned} \varepsilon_1 &= i_{L1} - i_{L1ref} \\ \varepsilon_2 &= V_{C1} - V_{C1ref} \\ \varepsilon_3 &= V_{C2} - V_{C2ref} \end{aligned} \tag{14}$$

By substituting (14) in (13) we get,

$$S = (i_{L1}, V_{C1}, V_{C2}) = K_1(i_{L1} - i_{L1}ref) + K_2(Vc_1 - Vc_1 ref) + K_3(Vc_2 - Vc_2 ref) \tag{15}$$

The signal $S = (i_{L1}, V_{C1}, V_{C2})$ obtained by (10) and applied to a simple circuit (hysteresis comparator), can generate the pulses to supply the power semiconductor drives. Status of the switch y is controlled by hysteresis block H, which maintains the variables near zero.

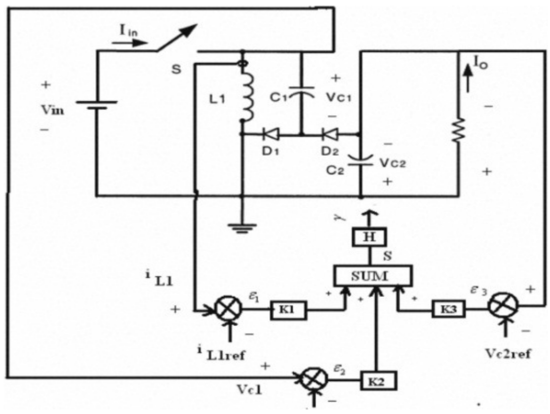


**Fig.4:** Sliding mode controller of NOESLLC

b. Control parameter selection

Once the negative output elementary super lift Luo converter parameters are selected, inductance $L_1$ are designed from specified input and output current ripples, capacitors $C_1$ and $C_2$ are designed so as to limit the output voltage ripple in the case of fast and large load variations and maximum switching frequency is selected from the NOESLLC ratings and switch type. According to the variable structure system theory, the converter equations must be written in the following form,

$$\dot{X} = Ax + By + Cw \tag{16}$$

Where X represents the vector of state-variables errors, given by

$$\begin{aligned} \dot{X} &= v - V^* \\ V^* &= [i_{Lref}, V_{C1ref}, V_{C2ref}]^T \end{aligned} \tag{17}$$

Where, $V^*$ is the vector of references. By substituting (17) in (12), we obtain,

$$D = AV^* + Cw \tag{18}$$

$$D = \begin{bmatrix} 0 & \frac{1}{L_1} & \frac{1}{L_1} \\ \frac{1}{C_1} & 0 & 0 \\ \frac{1}{C_2} & 0 & -\frac{1}{RC_2} \end{bmatrix} \begin{bmatrix} i_{L1ref} \\ V_{C1ref} \\ V_{C2ref} \end{bmatrix} + \begin{bmatrix} -\frac{1}{L_1} \\ 0 \\ 0 \end{bmatrix} V_{in} \tag{19}$$

Therefore,

$$D = \begin{bmatrix} \frac{V_{C2ref}}{L_1} - \frac{V_{C1ref}}{L_1} - \frac{V_{in}}{L_1} \\ \frac{i_{L1ref}}{C_1} \\ \frac{i_{L1ref}}{C_2} - \frac{V_{C2ref}}{RC_2} \end{bmatrix} \tag{20}$$

Substituting (17) in (15), the sliding function can be rewritten in the form,

$$S(x) = K_1 x_1 + K_2 x_2 + K_3 x_3 = K^T x \tag{21}$$

Where,

$$K^T = [K_1 + K_2 + K_3]$$

and

$$x = [x_1 + x_2 + x_3]^T$$

The existence condition of the sliding mode requires that all state trajectories near the surface be directed toward the sliding plane. It is necessary and sufficient that

$$\begin{cases} S(\dot{X}) < 0, if \ \ S(X) > 0 \\ S(\dot{X}) > 0, if \ \ S(X) < 0 \end{cases} \tag{22}$$

sliding mode control is obtained by means of the following feedback control strategy, which relates to the status of the switch with the value of S (x)

$$Y = \begin{cases} 0, \ for \ S(x) > 0 \\ 1, \ for \ S(x) < 0 \end{cases} \tag{23}$$

The existence condition (18) can be expressed in the form,

$$S(x) = K^T Ax + K^T D < 0, S(x) > 0 \tag{24}$$

$$S(x) = K^T Ax + K^T B + K^T D > 0, S(x) < 0 \tag{25}$$

From a simulation point of view, assuming that error variables X1 are suitably smaller than references V*, (20) and (21) can be rewritten in the form

$$K^T D < 0, S(x) > 0 \tag{26}$$

$$K^T B + K^T D > 0, S(x) < 0 \tag{27}$$

By substituting the matrices B and D in (26) and (27), we obtain

$$\frac{K_1}{L_1}[-Vc_{1ref} + Vc_{2ref} - V_{in}] + \frac{K_2 i_{L1ref}}{C_1} + \frac{K_3}{C_2 R}[Ri_{L1ref} - Vc_{2ref}] < 0 \tag{28}$$

$$\frac{K_2}{C_1 R_{in}}[V_{in} - R_{in} i_{L1ref}] - \frac{K_3 Vc_{2ref}}{RC_2} > 0 \tag{29}$$

The existence condition is satisfied if the inequalities (28) and (29) are true.

$$f_s = \frac{1}{\Delta t_1 + \Delta t_2} \tag{30}$$

Where $\Delta t_1$ the conduction is time of the switch S and $\Delta t_2$ is the off time of the switch S. The conduction time, $\Delta t_1$ is derived from (29) and it is given by,

$$\Delta t_1 = \frac{2\delta}{\frac{K_2}{C_1 R_{in}}[V_{in} - R_{in}] - \frac{K_3 V_{C2ref}}{RC_2}} \tag{31}$$

Where, $\delta$ is an arbitrary small positive quantity and $2\delta$ is the amount of hysteresis in S(X).The off time, $\Delta t_2$ is derived from (29), and it is given by

$$\Delta t_2 = \frac{-2\delta}{\frac{K_1}{L_1}[-V_{C1ref} + V_{C2ref} - V_{in}] + \frac{K_2 i_{L1ref}}{C_1} + \frac{K_3}{C_2 R}[Ri_{L1ref} - V_{C2ref}]} \tag{32}$$

The maximum value of switching frequency is obtained by

$$f_{s\max} = \frac{K_1 V_{in}}{2\delta L_1}\left(1 - \frac{V_{in}}{V_{c1ref\ \max} + V_{c2ref\ \max}}\right) \tag{33}$$

## V. DESIGN OF CIRCUIT COMPONENTS AND CONTROL PARAMETERS

a. Duty cycle

The duty cycle D is defined by the ratio between the conduction time of the switch S and the switch period time, as represented by,

$$D = \frac{\Delta t_1}{\Delta t_1 + \Delta t_2} \tag{34}$$

Considering the SMC, an instantaneous control, the ratio between the output and the input voltages must satisfy the fundamental relation at any working condition.

$$\frac{V_0}{V_{in}} = \frac{1}{1 - D} \tag{35}$$

b. Inductor current

The high-frequency maximum inductor current ripple is obtained from Fig.5 (b) and given by (18).

$$\Delta i_{L1} = \frac{V_0 - V_{in}}{L_1}\Delta t_1 \tag{36}$$

C.Capacitor voltage

The controller operates over the status of the switch to make the voltage $V_{c2}$(t) to follow the reference. As a consequence, on the capacitor $V_{c2}$ (t), a high

$$\Delta Vc = \frac{V_{C2}}{RC}\Delta t_1 \tag{37}$$

Frequency voltage ripple (which is a characteristics function switching frequency) is imposed. The capacitor voltage ripple is given by (15).

D.To find the value of $V_{c2}$

From (35) and a simulation point of view, the output voltage is chosen to produce a variation of the duty cycle close to 0.66.

e. To find $K_1$ / $L_1$

Substituting $V_{in}$, $V_{c1ref(max)}$ = $V_{c1(max)}$ and $\delta$ = 0.9 in (33) we get $K_1$ / $L_1$ = 6666.

f. To find $K_2$ / $C_1$ and $K_3$ / $C_2$

From (28) and (29) and taking $i_{L1ref}$= $i_{L1(max)}$= 2.353A,one obtains 1208 <

$K_2$ / $C_1$ < 248433 and 1208 < $K_3$ / $C_2$ < 248433.

g. Calculation of $L_1$

The maximum inductor current ripple is chosen to be equal to 15 % of maximum inductor current, and $L_1$ = 100 uH which is obtained from (36).

h. Calculation of $C_1$, $C_2$ and values of the coefficients $K_1$, $K_2$ and $K_3$

The maximum capacitor ripples voltage $\Delta V_{c1(max)}$ and $\Delta V_{c2(max)}$ is chosen to be equal to 0.5 % maximum capacitors voltage, and $C_1$ = $C_2$ = 30 uF which is obtained from (37). ($K_1$=0.667). Similarly the $K_2$ = $K_3$ = 0.217 is computed using the ratio $K_2$ / $C_1$ and $K_3$ / $C_2$ and the $C_1$, $C_2$.

## VI. SIMULATION RESULTS

a. Simulation of NOESLLC without SMC controller

Simulation is carried out for the negative output elementary super-lift Luo converter with the values, Vin =12V, f =100 KHz, L=10uH, C1, C2=30uF, R=50Ω, D=0.667. The simulation is done in PSPICE with the calculated values and the diagram is given below

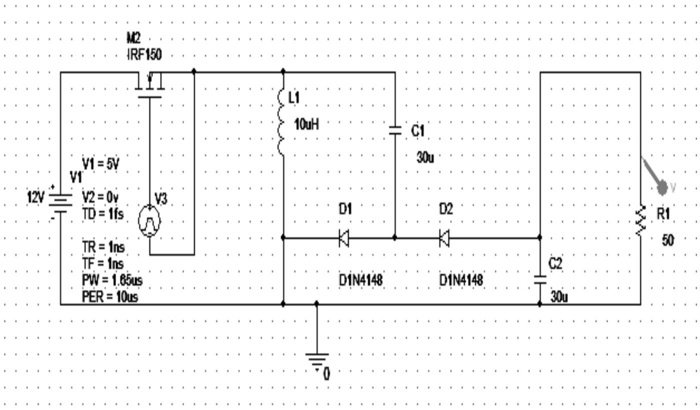


**Fig.5:**Simulation Diagram of NOESLLC

From the simulation, an output voltage of -36V is obtained for the NOESLLC which is shown below. This shows the increase of the output voltage in geometric progression. With a time period of 10us the output Voltage is depicted.

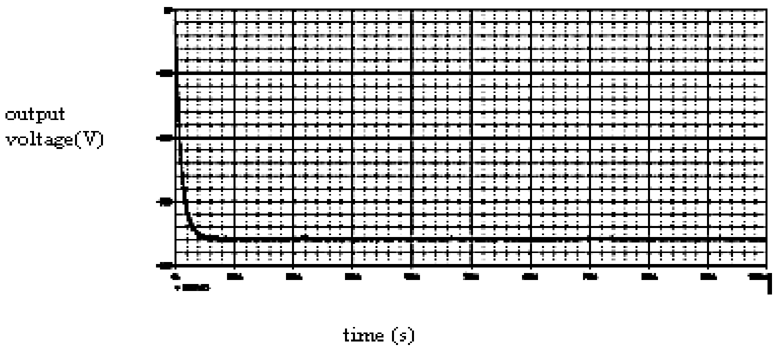


**Fig 6:** Output voltage Wave Form of NOESLLC without SMC controller

b. Simulation of NOESLLC with SMC controller

The simulation study of NOESLLC with SMC is presented in this section. The validation of the system performance is done for five regions viz. transient region, line variations, load variations, steady state region and also components variations. Simulations have been performed on negative output elementary super lift luo converter circuit with parameters calculated.

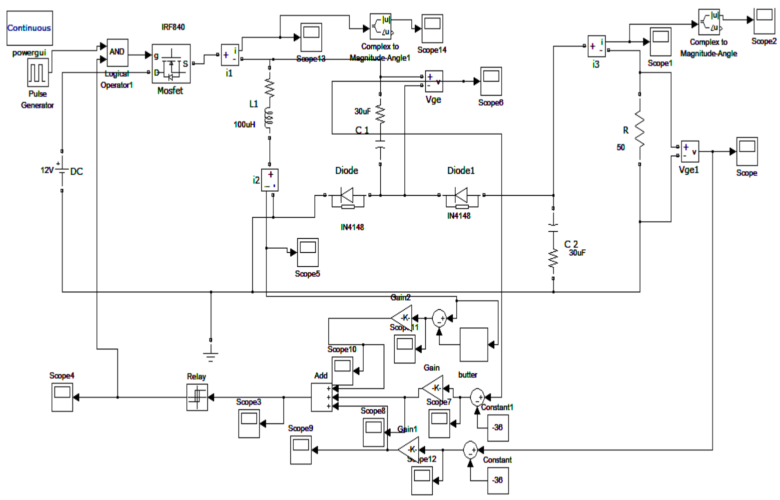


**Fig:7** Simulation Diagram of NOESLLC with SMC controller

The static and dynamic performances of SMC for NOESLLC are evaluated in Matlab/Simulink. The Matlab/Simulink simulation of system with control method is depicted in Fig 7. The detailed operation of NOESLLC with SMC is discussed. The output voltage is obtained to be -34.7V where the geometric progression of input voltage (12V) is shown. It can be observed that input current of NOESLLC goes up to 2.35A and output voltage of NOESLLC travels up to -34.7V without overshoot.

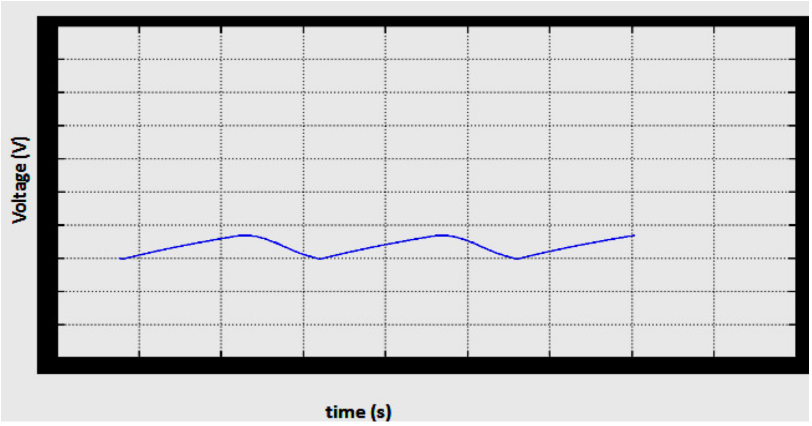


**Fig.8:** Output Voltage waveform of NOESLLC with SMC controller

c. Gate pulse of the switch given from SMC output

The gate pulse of the switch S (MOSFET) is given with a duty ratio of 0.66 i.e. 66% of the total period. The adapted value of duty ratio is selected to be 0.66 for an enhanced output voltage.

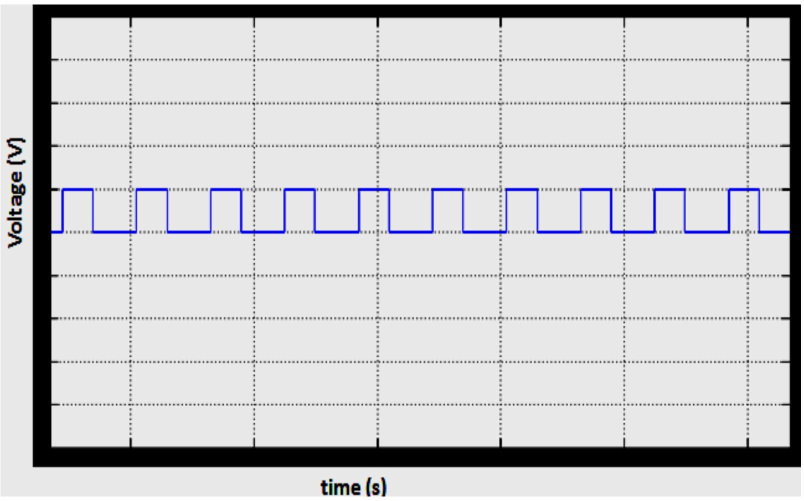


**Fig.9:** Gate Pulse of the Switch from SMC output

d. current through the inductor $L_1$

The inductor current waveform is shown below in diagram which has $i_{L1}$=11.2A. The inductor energized when the supply is given with switch turned ON and during OFF condition the current discharges through load.

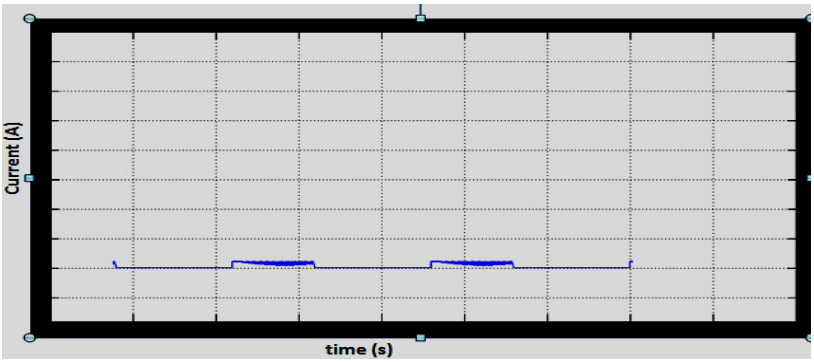


**Fig.10** current through the inductor $L_1$

e. Energizing pulse of the Relay

The relay is energized based on the summer output. Also a high pass filter is added to the current feedback, which are given to the gain amplifier and the relay is energized based on the range of value taken.

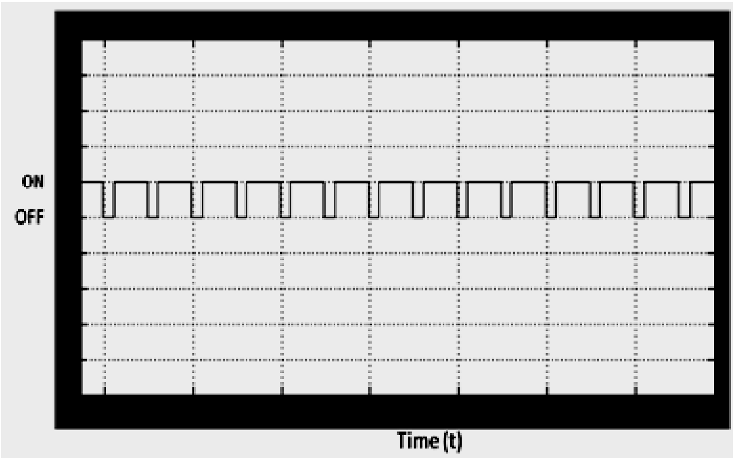


**Fig.11:** Relay Energizing Pulse

Thus the relay output is considered as input to the switch and a closed loop will be achieved. Based on the variation parameter of load, input voltage, and change in component values the gain parameter is chosen and converter in closed loop control is executed.

# VII. CONCLUSION

The design and analysis of Sliding mode control for NOESLLC has been successfully presented in this paper. This control technique will stabilize the output for any change in input voltage thereby boosting the output in geometric progression. The output capacitor voltage and the inductor current of the converters are taken as the parameters and compared with the reference thus producing the error signal .Thus the controller modifies and a proper control action is achieved with the correct maintenance of the duty ratio of the pulse applied to the switch. Thus the selection of the proper control parameters proved to provide excellent dynamic , static and transient response which is proved by implementing SMC using simulation softwares.

# REFERENCES

[1]. S. Arulselvi, G. Uma and M. Chidambaram, “Design of PID controller for boost converter with RHS zero", august 2004.
[2]. L. Guo, J.Y. Hung and R. M. Nelms, "Design and implementation of a digital PID controller for a buck converter", July/August 2001.
[3]. H. Mingzhi and X.Jianping, "Nonlinear PID in Digital Controlled Buck Converters", March 2007.
[4]. K. Ramash Kumar, S. Jeevananthan, "PI Control for Positive Output Elementary Super Lift Luo Converter", Summer 2010.
[5]. AJ. Foreyth and SV. Mollov, "Modeling and control of Dc-Dc converters", IEEE Power Engineering Journal.
[6]. Mahdavi, A Emadi, H.A. Toliyat, "Application of State Space Averaging Method to Sliding Mode Control of PWM DCDC Converters," IEEE Industry Applications Society Annual Meeting New Orleans, October 1997.
[7]. Y. B. Shtessel, A S. 1. Zinober, L. A. Shkolnikov, "Sliding mode control of boost and buck-boost power converters using the dynamic sliding manifold," International Journal of Robust and Nonlinear Control, July 2003.
[8]. K. Ramash Kumar, S. Jeevananthan, "Hysteresis Modulation Based Sliding Mode Control for Positive Output Elementary Super Lift Luo Converter", International Journal of Electrical and Electronics Engineering, December 2009.

[9]. P.F.Donoso-Garcia, P.C.Cortizo, B.R.de Menezes, M.A.Severo Mendes," Sliding mode control for current distribution in parallel-connected DC-DC converters. IEE Proc-Electr, Power Vol.145,No.4,July1998.
[10]. Pawan Gupta, Amit patra, "Hybrid Sliding mode control of DC-DC converters TENCON 2003.
[11]. J.Matas ,L.G.deVicuna, O.Lopez, M.Lopez and M.Castilla "Discrete sliding mode control of a boost converter for output voltage tracking"power electronics and variable speed drives,Sep 2000, conference publication No.475 IEE.
[12]. F.Ciccarelli ,D.Lauria" Sliding mode control of Bidirectional dc-dc converter for supercapacitor Energy storage applications" SPEEDAM 2010/IEEE.
[13]. Emil A.Jimenez Brea, Eduardo I. Ortiz-Rivera,Andres Salazar-Llinas,Jesus Gonzalez-Llorente "Simple photovoltaic solar cell dynamic sliding mode controlled maximum power point tracker for battery charging applications. IEEE 2010.
[14]. A.N.K.Nasir, R.M.T.Raja Ismail, M.A.Ahamed," Performance comparison between sliding mode control(SMC) and PD-PID controllers for a Non-linear inverted pendulum system,World academy of Science,Engineering and technology 70 2010.
[15]. Martin Pavlovsky, Yukinori Tsuruta, Atsuo Kawamura, "Recent improvements of Efficiency and power density of DC-DC converters for automotive applications -2010 International power conference.
[16]. K. Ramash kumar, Dr.S.Jeevanathan "Design of sliding mode control for negative output elementary superlift luo converter operated in continuous conduction mode"IEEE 2010.
[17]. Fang lin luo "Negative output superlift converters "IEEE transactions on power electronics, September 2003.
[18]. Jinhui zhang".Robust Adaptive Sliding-Mode Control for Fuzzy Systems With Mismatched Uncertainties" IEEE transactions 2010.
[19]. Wallace M.Bessa, Max.S.Dutra, Edwin kreuzer" An adaptive fuzzy sliding mode controller for remotely operated underwater vehicles"Robotics and autonomous system,Jan 2010.
[20]. G.shashikala. chandralekha, C.shashikala"High power luo converter for standalone photovoltaic system"IJAEST 2011.

**Author's profile**

**V.Chamundeeswari** was born in Chennai, India on December 5,1979.She received the B.E degree in Instrumentation and control Engineering from Sethu institute of technology, Madurai in 2001 and M.E degree from college of Engineering,Guindy,Chennai,India in2006.Currently she is pursuing Ph.D in the field of power electronics at Anna university of technology,Chennai,India.Her field of interest includes design of non-linear controllers for converters, modeling of converters, circuit analysis, digital controller design and development of algorithms for control. She has a teaching experience of 11years in Engineering colleges.Currently,she is working as a Associate professor in St.Joseph's college of Engineering,Chennai,Tamilnadu,India.

**R. Seyezhai** obtained her B.E. Electronics & Communication Engineering) from Nooru Islam College of Engineering, Nagercoil in 1996 and her M.E in Power Electronics & Drives from Shanmugha College of Engineering, Thanjavur in 1998 and PhD from Anna University, Chennai. She has been working in the teaching field for about 13 Years. She has published several papers in International Journals and International Conferences in the area of Power Electronics & Drives. Her areas of interest include SiC Power Devices, Multilevel Inverters, Modeling of fuel cells, Design of Interleaved Boost Converter, Multiport DC-DC Converter and control techniques for DC-DC Converter.