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PWM Based Sliding-Mode Control For a DC-DC Boost Converter

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Abstract

DC to DC converters iscommonly applicable the many applications, fluctuating from computer to remedial electronic systems, devices of consumer electronic devices, spaceships,telecommunication and other power systems equipment's. The advantage of converters in the electricity system is to continue the required production voltage and to control the parameters according to variation in load. Converter arecontrol output voltage from the converter are necessary to control duty of cycle of semiconductor device used in the system. The application of nonlinear control, is controlled thesliding-mode (SM) control is a variable control structure system theory .This Variable structure systems are fleshly structures which is chang the during time of structure control rule.When this structure is changing they are determine the system current state. Switching action is present, thenpower supplies of switched-mode is generally variable structured systems. Hence sliding-mode controller is controlling the dc to dc boost converters.

1.Introduction

When DC to DC converter are electronic equipment they convert the voltage too one level to another level. This is most valuable supply apparatuses for serving the electronic system, they association with direct power supply. There is low cost and simple.[1],[2]. DC to DC converters is used tocertain electronic equipment like electric traction, DC determination system, distributed power supply system, machine tools, and electric vehicles and fixed system to additional battery life is less consumption of power. The DC to DC converter is design to closed loop method. Still, these converters is non-linear. This is gives to switch and component of converter characteristics. The DC to DC converter are used for some application, it is delivera controlled output voltage this is low wrinkleratio. Converter need to theforceful because they compared to input voltage variation or load and converter parametric worries. Thus, outputpower of regulation necessity toachieved to closed loop mode. [3],[4].The Sliding-Mode Controller are variable structure system (VSSs) and they are nonlinear controller developed by VladimUtkin. This controllers control the fluctuating, unlimited, andself-oscillating switching frequency.[8]-[13]. Definite stability and the toughness are theleading advantages to slidingmode (SM)control against line, parameter, and load worries. The sliding mode controller scheme aremostlyfit tomanagement nonlinear system toundefinedsubtleties and disordersas of the order ofdiscountthings, they reducesload of requirement of particularforming.Similarly, comparison of S M controller and PI controller main advantages such as on overshoot and smaller response time. controller is high point toelasticity toscheme of SM Controller is quite relaxed theinstrument arelated to manycategories are non-linear controller.

The DC to DC converter is basically variable structure. Sliding mode (SM) controllers are fit for control of DCDC converters. Idea that this excellent large signal handling capability can offer sliding mode control seems more appropriate. Then,plan of traditional pulse width modulation (PWM) are the controllers are the power electronics of small signal based. Controlled scheme work for certain conditions, and frequently fails to compress under big parameters and load differences. Thehugeindicatorworkingailment. When replacing linear pulse width modulation controllers recycled to power converters .This is linear controller, improvedparameter iscompleted a wider effectiveseries. Sliding mode controlin them seems to be the perfect fit themonitoring to nonlinear dc to dcconverters system.

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1.1 SLIDING MODE CONTROL

Sliding mode method areflexible structure system gives another technique a device is control the action of is mainly flexible structure of dc to dc converter.Actually, converter of switches is operated to function of suddenethics of variable so that system path is forced remaining the certain surface area at sliding surface point space. The maximum notable chin of sm controller arecapability of produce results in extremely forceful control method. The principle ofsmc are variable construction control method. They are non-linear method so changes in speed of system through the use veryextraordinary frequency moving. Multiple controller structures have been plannedtopaths are constantly in the direction of switching positions, and therefore the final path is not fully present in a control organization. Theultimate route was described above boundary to control structure. When sliding mode of system is called sliding mode while sliding along these boundaries. Direct controller are not solve control difficulties to dc dc converter so non-linear controller is being made such actualaction. A SMC issuitable control method for is robust variable structure (VS). Related to any other non-linear controller of sliding mode controller easy to implement. However, being a generalresearch topic, sliding mode controller areoftenuseful dcdc converters. There are several reasons for this. Unlike the first pulse width modulation (PWM).Sliding mode integrated circuit is not available for power electronic application. Another drawback is that the power supply engineers do not understand their design principles. Thirdly, they are strongaverseness toservice of sliding mode controller to dc dcconverter sincethe high and flexiblemoving frequency, leading to unwarranted power loss, electromagnetic interface generation and riddle design complexity.

1.2 OBJECTIVES:

The purpose of this work are introduce a original topology for power conversion that eliminates the problems already mentioned. This topology has the following specific features:

1) To study of dc dc converter and SM controllers and sliding mode control.
2) To design and simulation of pulse width modulation based sliding mode control for dc dc boost converter.

1.3 PROPOSED WORK

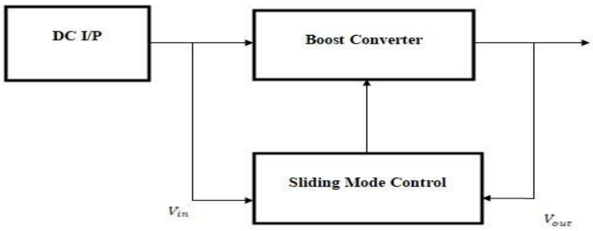


Fig.no.1.3 Block Diagram of DC-DC Boost Converter By Sliding Mode Controller

The Block Diagram 1.3show, sliding mode control for dc dc boost converter. It consist Dc Input source, boost converter and sliding mode control(SMC). DC input voltage given to the boost converter and sliding mode control .Also feedback signal given to sliding mode control from boost converter.

The sliding mode control will compare both input value i.e. DC input voltage and DC output voltage obtain from boost converter. By comparing this two input the sliding mode control gives to signal boost converter and constant voltage will obtain from boost converter.

2. SLIDING MODE CONTROLLERS

2.1 Perfect Controller:

Simple principle of the Sliding Mode control is work is assured sliding outward is reference path, this controller states variable projection is focusednearpreferredbalance point. Ideally, a Sliding Mode control can be completed the three certain conditions, like a,stability condition, existence condition and hitting condition, and this condition can be works at the unlimited switching frequency. Here there is no system uncertainties or external disturbances and very fast dynamic response. Actually Sliding Mode controller is ideal controller for Variable Structure system.[5]

2.2 Principle of Operation:

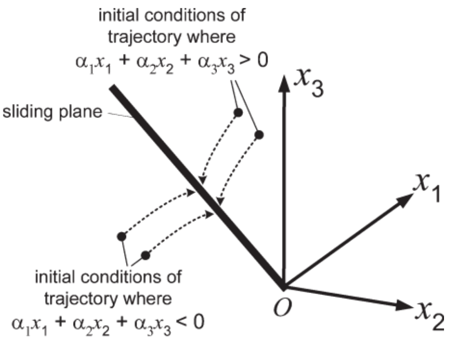
The Sliding Mode control of principle is design the sliding shallow of its control act this will be through apath to state variable near topreferred source is covered. DC Dc singles of switch converter are suitable the control decree to accepts switching purpose likely,

$U = \frac{1}{2}$ (1 + sign (S)) (1)

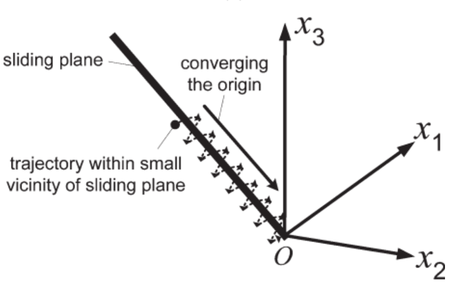
when u are sensibleness state power switch converter and S areinstant state variablepath this is the second order controller defined the,

$S = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3$ (2)

Thusα_1, α_2 and α_3 denote control factors, generally raised the sliding constants, then x_1, x_2, and x_3 represent preferred state feedback variable controller. Through applying S = 0 sliding plane shownthe Figure 2.2 it is achieved. The process Sliding Mode control isdistributed in too phase. First phase (realization phase), irrespectiveto startinglocation, then the performes of controller will control to decision this drive topath to formal variable to join sliding outward [Figure 2.2 (a)]. That is conceivable over throughagreementcalled "hitting condition".[5]



(a)



(b)

Fig.no. 2.2 Graphical representations SM control method. (a) Phase I - Initial condition. (b) Phase II- small vicinity of sliding plane simultaneouslyactuality directed thejoin origin O.

Sliding surface with a small vicinity, then sliding controller isprovided control actions in series. Byswitching action apath is continued and is simultaneously directed near topreferred reference to origin O [in Figure 2.2 (b)]. Sliding Mode controller will performed of control result is using sliding

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plane toorientation path, thispath is finally join to origin complete steady state condition. Then called sufficient “existence condition” and “stability condition”.

2.3 Design Procedure:

Modelling to system and design processfor pluse width modulation created sliding mode controller to boost converter are explained.[10]

A. System Modelling:

The first step of design the sliding mode controller areimproveformal space description to converter model in term of variables that is, voltage and current.

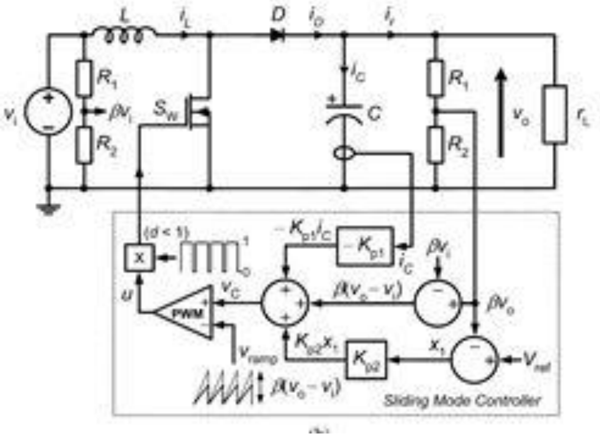

Fig.no.2.3 Schematic diagrams of the PWM based SMC for dc to dc boost converter

Fig.2.3Illustrations schematic diagrams of pluse width modulation (PWM) created Sliding mode converters. Here, L, C and $r_L$represent inductance, capacitance and instantaneous load resistance of converter ; i_r, i_c and $i_L$represent load current, instant capacitor and instantaneous inductor individually ; thenfurtherapparatuses comprising of the instant input voltage vi or instant output voltage βv_o, reference voltage V_{ref}, β denotes the feedback network ratio. This feedback network ratio is very important.When u = 0 or u = 1 then switching power of state switch (S_W).

Nowcase of Pluse width modulation created sliding mode controller (SMC) this controller is flexible x may be stated in following form :

$$X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} V_{\text{ref}} - \beta v_o \\ \frac{d(V_{\text{ref}} - \beta v_o)}{dt} \\ \int (V_{\text{ref}} - \beta v_o) dt \end{bmatrix} \qquad (3)$$

Thex_1, x_2 ,and x_3 are voltage error,dynamic voltage error, and essential voltage error, individually. Form equation (3) the control variables descriptions: x_{boost} converter.[13]

$$= \begin{bmatrix} x_1 = Vref - \beta v_0 \\ x_2 = \frac{\beta v_0}{r_L C} + \int \frac{\beta (v_0 - v_i)\bar{u}}{LC} dt \\ x_3 = \int x_1 dt \end{bmatrix}$$

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Then, differentiatingtoreverence time is important todesign the boost converter [10].

$\dot{x_1}=\frac{d}{dt}(V_{ref}$ - $\beta V_o)$ $=x_2$(5)

$\dot{x_1}$= -$\beta\frac{dV_o}{dt}$ $=x_2$(6)

$\dot{x_2}$ $=\frac{\beta}{R_L C}\frac{dV_o}{dt}+\frac{\beta}{LC}(V_o$- $V_i)\,\bar{u}$ (7)

$\dot{x_2}$= $\frac{-x_2}{R_L C}+(\frac{\beta V_o}{LC}$- $\frac{\beta V_i}{LC})\,\bar{u}$ (8)

$\dot{x_3}$= V_{ref} - βV_o = x_1 (9)

Obtaining equation (6), (8), (9) in matrix form, For the boost converter,

$\dot{x}$= Ax_{boost} + BV + D (10)

$$\begin{bmatrix}\dot{x_1}\\ \dot{x_2}\\ \dot{x_3}\end{bmatrix}=\begin{bmatrix}0 & 1 & 0\\ 0 & -\frac{1}{r_L C} & 0\\ 1 & 0 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}+\begin{bmatrix}\frac{\beta v_0}{LC} & \frac{0}{0} & \frac{\beta v_i}{LC}\end{bmatrix}\quad(11)$$

Where $\bar{u}$ = 1-u arereversereasoning of u, they aremostly for forming the boost converter. When v = u or $\bar{u}$ (contingent on topology).[12]

B. Controller Scheme:

Now, Switching purposeassumedsliding mode control rules such as,

u = $\begin{cases}1\\0\end{cases}$ when $\frac{S>0}{S<0}$(12)

Wherever, S are instant national variable and it distinct is ,S = αx_1+ αx_2+αx_3 = J^TX (13)

Where J^T $[\alpha_1\ \alpha_2\alpha_3]$ and $\alpha_1\ \alpha_2\alpha_3$representativeof sliding mode coefficients.

1. Hitting Conditions:

In hitting condition the main aim is make suret the regardless toprimary conditions. This condition,path isrelocatedinside the vicinity δ, to sliding mode controller.

At primary state,pathx_i □$x(t$ □0) , pathS_i □$S(t$ □0) Space of sliding various$\epsilon = 0$ condition isfulfilled inensuing control is u=u (t> 0) is a variables trajectory x (t> 0) then controller is S (t>0).This is necessary conditions take certainappearance.[10]

S $\frac{ds}{dt}$< 0

(when(t □ 0) then$|s|$>)

2. Existence Conditions:

The existence condition are necessary of the system this pointers is used to slidingdiverse then, 0 <$|S|$< δ to locations path.When the operation of sliding mode in existence conditions is fulfilledthroughcreation condition of native reachability.[10]

$\lim_{S\to 0} S\ \dot{S} < 0$ (14)Equation (14) determined by

$\begin{cases}\dot{S}_{s\to 0^+}\\ \dot{S}\end{cases}$

$$\begin{cases}\dot{S}_{S\to 0^+} = \boldsymbol{J}^{\mathbf{T}}\mathbf{A}\boldsymbol{x} + \boldsymbol{J}^{\mathbf{T}}\mathbf{B}v_{S\to 0^+} + \boldsymbol{J}^{\mathbf{T}}\mathbf{D} \\ \dot{S}_{S\to 0^-}\ \boldsymbol{J}^{\mathbf{T}}\mathbf{A}\boldsymbol{x} + \boldsymbol{J}^{\mathbf{T}}\mathbf{B}v_{S\to 0^-} + \boldsymbol{J}^{\mathbf{T}}\mathbf{D}\end{cases} \quad (15)$$

Boost Converter:

Example1:S → 0^+, $\dot{S}$< 0 :

Replacement theV_s → 0^+ = $\bar{u}$ = 0 then equation (11) gives,

$$-\alpha_1 \frac{\beta_i c}{C} + \alpha_2 \frac{\beta_i c}{r_L C^2} + \alpha_3 (V_{ref} - \beta v_0) < 0 \qquad (16)$$

Example 2: S→ 0^-, $\dot{S}$> 0:

Replacement of V_s → 0^- =$\bar{u}$ = 1 then equation (11) is ,

$$-\alpha_1 \frac{\beta_i c}{C} + \alpha_2 \frac{\beta_i c}{r_L C^2} + \alpha_3 (V_{ref} - \beta v_0) - \alpha_2 \frac{\beta v_i}{LC} + \alpha_2 \frac{\beta v_0}{LC} > 0 \qquad (17)$$

Combination of equation (16) and (17) gives the simplified existence condition.

$$0 < \beta L \left(\frac{\alpha_1}{\alpha_2} - \frac{1}{r_L C} \right) i_C - LC \frac{\alpha_3}{\alpha_2} (V_{ref} - \beta v_0) < \beta (v_0 - v_i) \qquad (18)$$

3.Stability Condition:

In exitences condition the sliding factors to chance the preferred dynamical assets. Now the operation of sliding mode, the state path S is path of sliding outward as a point of strength by state path as sliding surface then setting is S=0.[5]

C. Selection of sliding coefficients:

In sliding mode control arechoice of sliding factorscreated dynamic assets or stability condition is automatically fulfilled. System are stable because the selectionof coefficients. It is also dependent on the worthof settling time, dampingratio and the sliding factors are acquired. when S=0, an this results is a linear. There is a three possible type of responses.[10],[12].

In under damped condition the converters are desired settling time is T_s = 5_{Ts}(1% critria),then T arenatural timeconstant this is set by tunning$\binom{\alpha_1}{\alpha_2}$ using,

$\frac{\alpha_1}{\alpha_2} = \frac{10}{T_s}$ *(19)*

$T_s = \frac{10}{2500}$ = *4**10^{-3}*=0.004*

$$T_s = 4ms$$

$$\frac{\alpha_1}{\alpha_2} = \frac{10}{0.004} = \frac{100}{4} = 2500$$

$\frac{\alpha_1}{\alpha_2}$= *2500*

And desired damping ratio can be used.

$\frac{\alpha_3}{\alpha_2} = \frac{25}{(\varepsilon\, T_s\,))^2}$ (20)

Where, $\varepsilon =$

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$$\sqrt{\frac{\left[\ln\left(\frac{M_p}{100}\right)\right]^2}{\pi^2+\left[\ln\left(\frac{M_p}{100}\right)\right]^2}}$$

(21)

Wherever, M_p is the ratio of the peak overshoot.

$$T_s = 0.4\text{ms}$$

$$\varepsilon = 0.2$$

$\frac{\alpha_3}{\alpha_2} = \frac{25}{(0.2)^2\,(4*10^{-3}))^2}$

$\frac{\alpha_3}{\alpha_2}$ =*39130435*

D. Derivationfor Pluse Width Modulation to sliding mode Controller:

Ramp and control signal isrelateda output movingmotion this aretaking a regularity of ramp signal. In first stage, equivalent control signal, u_{eq} aredesigned to use in invariance condition, then second stage areconvertu_{eq} is duty ratio as pluse width modulation this is approvedthrough derivation procedure.[10]

u_{eq}isgot the equation.

$\dot{S} = J^T \mathrm{Ax} + J^T \mathrm{B} u_{eq}$=0 (22)

$$u_{eq} = -[J^T B]^{-1} J^T [A_x + D]$$

$$= \frac{\beta L}{\beta v_i}\left(\frac{\alpha_1}{\alpha_2} - \frac{1}{r_L C}\right) i_C + \frac{\alpha_3 LC}{\alpha_2 \beta v_i}\left(V_{ref} - \beta v_0\right) + \frac{v_0}{v_i} \quad (23)$$

Multiplication of the inequality by $\beta(V_o - V_i)$such as ,

$0 < u_{eq} * = \beta L\left(\frac{\alpha_1}{\alpha_2} - \frac{1}{r_L C}\right) ic + LC\,\frac{\alpha_3}{\alpha_2}\left(V_{ref} - \beta V_o\right) + \beta(V_o - V_i) < \beta(V_o - V_i$

(24)

Now, equivalent regulator function (equation 24) it is responsibility to control d , such as 0 < d = $\frac{V_c}{\widehat{V_{ramp}}}$<1, when it isconnection for control signal V_c and ramp signal V_{ramp} toappliedexecution forpluse width modulation forsliding mode controller.

$V_c = u_{eq} *$

$= -\,\beta L\left(\frac{\alpha_1}{\alpha_2} - \frac{1}{r_L C}\right) ic + LC\,\frac{\alpha_3}{\alpha_2}\left(V_{ref} - \beta V_o\right) + \beta(V_o - V_i)$

(25)

$\widehat{\mathrm{Vramp}} = \beta\,(V_o - V_i)$(26)

$V_c = K_{p1}\,ic + K_{p2}(V_{ref} - \beta V_o) + \beta(V_o - V_i)$ (27)

Where K_{p1} ,K_{p2} are constant gain parameter of feedback signals ic and $(V_{ref} - \beta V_o)$. The value of K_{p1} and K_{p2} are given to the converter parameter L, C and r_L then the value of sliding mode coefficient α_1,

α_2 and α_3 which must be fulfill on existence condition, Bandwidth of ω_n = 1.25K rad/s, that is, T=0.8ms and T_s =0.4ms and with damping coefficient ε = 0.2 from equation (19) and (20) the sliding coefficients is determined is $\frac{\alpha_1}{\alpha_2}$ =2500 and $\frac{\alpha_3}{\alpha_2}$ = 39130435.

Settling time of reference voltage to the controller likely, V_{ref} =8V ,thenresponsepartition ratio is calculated such as,

$$\beta = \frac{V_{ref}}{V_{od}} = \frac{8}{48} = \frac{1}{6} \quad (28)$$

$$\beta=0.16666 \quad (29)$$

Lastly, control parameter isresolute as the given,

$$K_{p1}= \beta L \left(\frac{\alpha_1}{\alpha_2} - \frac{1}{r_L C}\right) (30)$$

$$=0.1666*300*10^{-6}*2500- \frac{1}{24*230*10^{-6}}$$

$$K_{p1}=0.1249 \quad (31)$$

$$K_{p2}=\frac{\alpha_3}{\alpha_2} LC \quad (32)$$

$$K_{p2} = 39130435*300*10^{-6} *230*10^{-6} (33)$$

$$K_{p2}=2.7 \quad (34)$$

This is final output obtained form boost converter using sliding mode contoller.[12]

3. SIMULATION BLOCK DIAGRAMS

3.1 Boost Converter Simulation Block Diagrams:

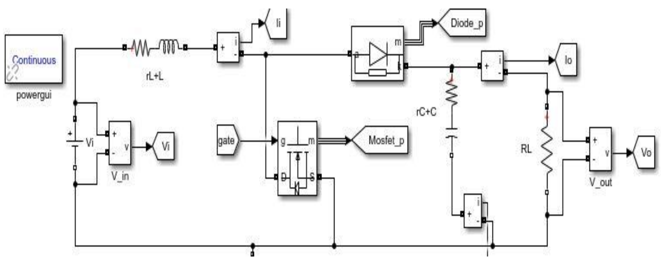

Fig.no.3.1Simulation figure of DC to DC boost converter

Figure 3.1 shown , implementation of closed loop dc dc boost converter used to voltage controller and current controller in MATLAB and Simulink situation.Then simulation parameter used in as per Table no.2.

Description	Value
Input voltage	24 V
Capacitance	230 μF
Inductances	300 μH

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Inductor resistance	0.14Ω
Switching frequency	200 KHz
Minimum load resistance	24 Ω
Maximum load resistance	230 Ω
Desired output voltage	48 V

Table no.3.1 Choice of system Parameter (Boost Converter)

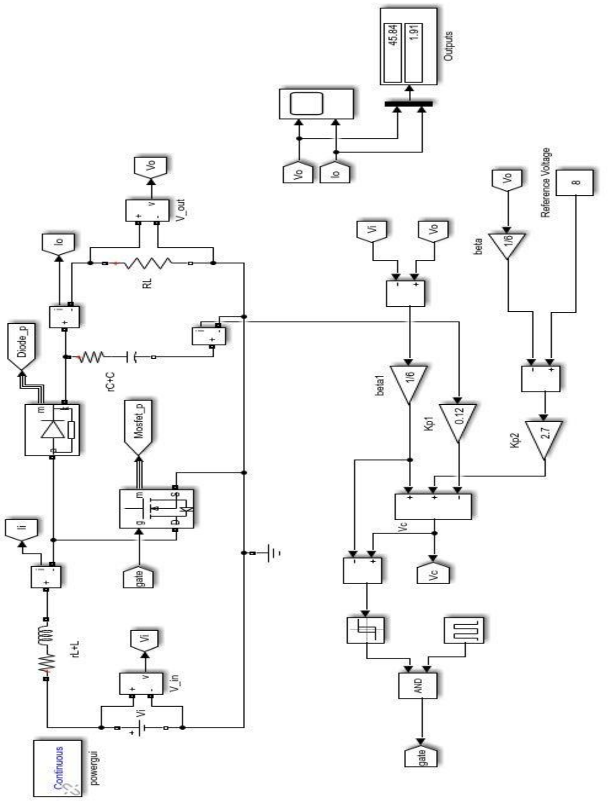

Figure no. 3.1Simulation diagram of DC- DC boost converter used in sliding mode controller.

Figure 3.2 shown the schematic diagram of closed loop dc dc boost converter using Sliding Mode Controller though the MATLAB or Simulink environment. The parameter of the controller are: K_p, K_i, K_d that is proportional, intiger, derivative respectively. Simulation can be use the following equation,

$S = \alpha x_1 + \alpha x_2 + \alpha x_3$

Where $\alpha_1\ \alpha_2 \alpha_3$ representing the sliding mode coefficients. and x_1 , x_2 ,x_3 is voltage error, voltage dynamic, rate as voltage error.

4. SIMULATION RESULTS

4.1 Input voltage:

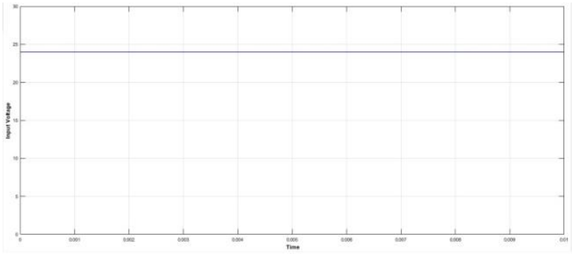

Fig.no.4.1 Input Voltage

For this proposed pluse width modulation based Sliding Mode Controller to DC to DC Boost converter we are giving 24 V as a input (I_0) voltage.

4.2 Output Voltage:

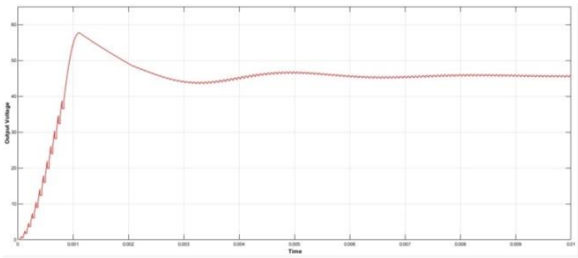

Fig.no.4.2 Output voltage

Fig 4.2 shown, closed loop simulationresult of DC-DC boost converter. On X axis signifies the duration time in msec and Y axis signifies the voltage in volts. After the MATLAB/Simulink we are obtained 46.04 V at time 0.004 msec output voltage as show in fig.4.2This results shows that the settling time is low and there is no overshoot present as compare to other types of converters.

5. CONCLUSION

Methodical step via step process is use to design of pluse width modulation based Sliding Mode controller used to boost converter is derived and controlled above equations are obtained tofulfilled to boost converter and replicated using MATLABandSIMULINK.Then, we canconcluded to result that the PWM-based SM voltage controllers are possible tomutual dc to dc renovation resolutions, and we are obtained the output voltage 46.04 V at 0.004 msec.

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