Optimization of Dc - Dc Boost Converter Using Fuzzy Logic Controller

Aymen Kalifa Soluman Ahteewash
Higher institute of science and technology
Libya , nalut
aymenalut@gmail.com
Mohamed saleh bagny
Higher institute of science and technology
Libya , nalut
aymenalut@gmail.com

الخلاصة:

محولات التيار المستمر الي التيار المستمر هي عبارة عن اجهزة الكترونية تستخدم لتغير القدرة المستمرة بكفاءة من مستوي جهد معين الي اخر فإن عملية جهاز التبديل تسبب خصائص غير خطية متلازمة لتحويلات التيار المستمر الي التيار المستمر وتتضمن أحد خصائص المحول، وهكذا فأن هذا المحول يتطلب او يستلزم تحكم بدرجة عالية من الاستجابة الديناميكية و ان المتحكم التفاضلي التكاملي التناسبي (PID) عادة تطبق علي المحولات لسهولتها وبساطتها، ولكن الاعاقة الرئيسية للمتحكم (PID) غير قادرة علي التكييف والوصول الي افضل الخصائص عندما تطبق النظام الغير خطي وسوف تعاني من الاستجابة الديناميكية، وانتاج تجاوزات واستغراق وقت طويل اكثر من الوقت المقرر مما يؤثر علي خرج المنظم من محول الرفع .

ولهذا تستند دراسة المتحكم المنطقي (FLC) باستخدام جهد الخرج كتغذية عكسية مميزة لتحسين الخصائص الديناميكية لمحول الرفع باستخدام برنامج المحاكاة MAT LAB فان الحسابات والتصميم للمكونات الكهربائية الخاصة بالمحت يتم عملها لغرض تأكيدها حتي يكون المحول في حالة التوصيل المستمر فالخرج المقدر سوف ينجز ويقارن باستخدام برنامج المحاكاة بين دائرة الحلقة المغلقة والحلقة المفتوحة، ونتائج المحاكاة سوف تظهر لنا بان جهد الخرج قادر علي التحكم بحالة الاستقرار للمحول (المحول التيار المستمر الي التيار المستمر) باستخدام هذه الطريقة، ويقتصر في هدا البحث محدد الي نوع واحد فقط هو الدالة المثلية .

ABSTRACT:

DC-DC converters are electronic devices used to change DC electrical power efficiently from one voltage level to another. Operation of the switching devices causes the inherently nonlinear characteristic of the DC-DC converters including one known as the Boost converter. Consequently, this converter requires a controller with a high degree of dynamic response. Proportional-Integral- Differential (PID) controllers have been usually applied to the converters because of their simplicity.

However, the main drawback of (PID) controller is unable to adapt and approach the best performance when applied to nonlinear system. It will suffer from dynamic response, produces overshoot, longer rise time and settling time which in turn will influence the output voltage regulation of the Boost converter. Therefore, the implementation of practical Fuzzy Logic controller (FLC) that will deal to the issue must be considered.

This study is based upon the Fuzzy logic controller (FLC) using voltage output as feedback for significantly improving the dynamic performance of boost dc-dc converter by using MATLAB Simulink software. The design and calculation of the components especially for the inductor has been done to ensure that the converter operates in continuous conduction mode. The evaluation of the output has been carried out and compared by software simulation using MATLAB software between the open loop and closed loop circuit. The simulation results have shown that voltage output is able to be control in steady state condition for DC-DC boost converter by using this methodology. Scope of this project is limited to only one type that is Triangle membership function.

Keywords Boost converter, fuzzy logic controller, PID controller, MATLAB@SIMULINK

INTRODUCTION

DC to DC step-up power converter, or more popularly known as the Boost converter, is widely used in power electronics systems. Its application is widespread and wide ranging-Boost power supply can be found in the tiniest cell phone (mill watt) to the high power train propulsion system (hundreds of kilowatts). One of the main requirements of the converter is the robustness of its controller.

A good controller should perform these tasks efficiently that is it should be able to regulate output voltage when the input voltage and reference is changed and also should be able to stabilize the system for any input disturbances and load changes. The performance of the controller is normally characterized by its response to a step input reference, i.e. transient percentage of overshoot, settling time and steady state error.

Due to its nonlinear and time-invariant nature, the design of high performance controller for the Boost converter presents a challenging task. Traditionally, classical methods such as frequency response and root locus/pole placement techniques are employed. Examples of classical controllers are the Proportional Integral Derivative (PID)[1], Deadbeat controllers [2] and sliding mode controllers [3]. These controllers are known as “model based. Among the most popular is the Fuzzy Logic Controller (FLC). In essence, FLC is a linguistic-based controller that tries to solve problems by means of systematic rule inferences. It does not require precise mathematical model, very robust and has excellent immunity to external disturbances [5]. Although promising, FLC requires substantial computational power due to complex decision making processes, namely fuzzification, rule base storage, inference mechanism and defuzzification operations. To obtain optimized performance, FLC require a much longer time because for most cases, the design is done heuristically [6],[7].

Problem Statement :

DC-DC converter consists of power semiconductor devices which are operated as electronic switches. Operation of the switching devices causes the inherently nonlinear characteristic of the DC-DC converters including one known as the Boost converter. Consequently, this converter requires a controller with a high degree of dynamic response. Proportional-Integral- Differential (PID) controllers have been usually applied to the converters because of their simplicity. However, the main drawback of PID controller is unable to adapt and approach the best performance when applied to nonlinear system. It will suffer from dynamic response, produces overshoot, longer rise time and settling time which in turn will influence the output voltage regulation of the Boost converter

Project objectives:

The objectives of this project are;

i) To model and analyse a DC-DC Boost converter without controller (open loop) and simulate using MATLAB Simulink.

ii) To design fuzzy logic controller (FLC) to control the switching of DC-DC Boost converter.

iii) To analyses the voltage output for DC-DC Boost converter between closed loop, and compare between PID controller and fuzzy logic controller.

Project scope:

The scope of this project is to simulate the proposed method of voltage tracking of DC-DC boost converter using triangle fuzzy logic controller with MATLAB Simulink software. Analysis of the converter will be done for continuous current mode (CCM) only. The scope of proposed fuzzy logic controller is limited to triangle membership function as a proposed controller. The analysis only covered the output voltage based on reading of overshoot ratio, rise time, peak time and settling time.

DC / DC CONVERTERS:

The DC/DC converter is a device for converting the DC voltage to step-up or step-down depending on the load voltage required. If the requirement of voltage is to step-up then it is necessary to use a boost converter.

If the requirement of voltage is to step-down , then it necessary to use a buck converter.

Sometimes, both step-up and step-down is required to cover the load, but at different times, then it is necessary to use a buck-boost converter. Therefore, different types of DC/DC converters are used for different voltage levels in load. Generally DC/DC converters are divided into two types [9]:

1- Non isolated DC-DC converter

2- Isolated DC-DC converter

2.1 Boost DC/DC converter:

A boost converter (step-up converter), steps up the input DC voltage value and provides at output. It consists of an inductor L, capacitor C, and controllable semiconductor switch Diode D, and Load resistance R as depicted by Figure 2-1. Capacitors are generally added to output so as to perform the function of removing output voltage ripple. The boost converter is one of the most important non isolated step-up converters.

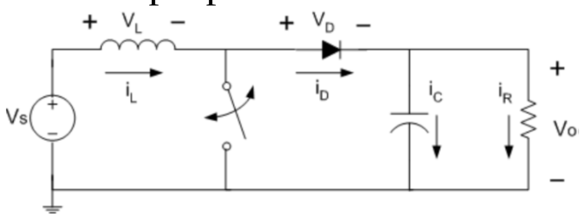


Figure 2-1 A Boost Converter Circuit

Boost converter operates, assuming that the inductor is charged in the previous cycle of operation and the converter is at the steady state operation and CCM Condition.

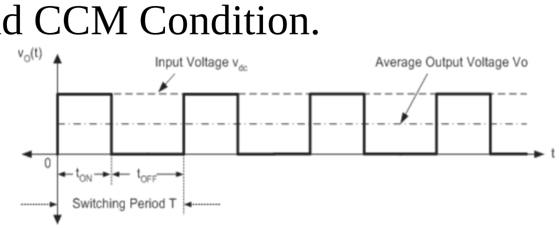


Figure 2- 2 the Duty Cycle For Switching Period During Steady State

Define Duty Cycle (D) which depends on t_{on} and switching frequency f_s

$$D = \frac{t_{on}}{t_{on}+t_{off}} = \frac{t_{on}}{T} = t_{on}f_s \quad (2\text{-}1)$$

During steady state operation the ratio between the output and input voltage is $\frac{1}{1-D}$, the output voltage is controlled by varying the duty cycle. Range of Duty Cycle: $0 < D < 1$.

$$t_{on} = DT \quad (2\text{-}2)$$

$$t_{off} = (1 - D)T \quad (2\text{-}3)$$

2.1.1 Analysis for switch closed $(\boldsymbol{ON})$

Initially the power switch S is closed. Now the diode will be reversed-biased by the capacitor voltage, hence it will act as open. The equivalent circuit is shown in Figure 2-4 [10]. When, Diode is reverse-biased, Input is disconnected from the output, no energy flows from input to output, output gets energy from capacitor. $V_{LON} = V_S$.

The inductor voltage, $V_L = V_S$

$$= L\frac{d_{il}}{d_t} \Rightarrow \frac{d_{il}}{d_t} = \frac{V_S}{L} \quad (2\text{-}4)$$

Since the derivative of i_L is a +ve constant, therefore i_L must increase linearly;

$$\frac{d_{il}}{d_t} = \frac{\Delta_{il}}{\Delta_{dt}} = \frac{\Delta_{il}}{\Delta_{dt}} = \frac{V_S}{L}$$

$$(\Delta_{iL})._{closed} = \left(\frac{V_S}{L}\right) DT \quad (2\text{-}5)$$

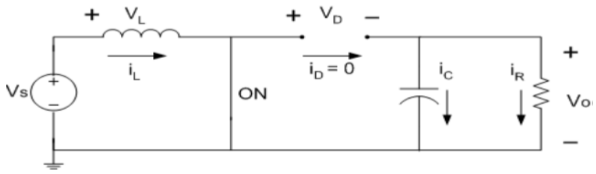


Figure 2- 3 The Equivalent Circuit of Boost Converter When the Switch S is closed

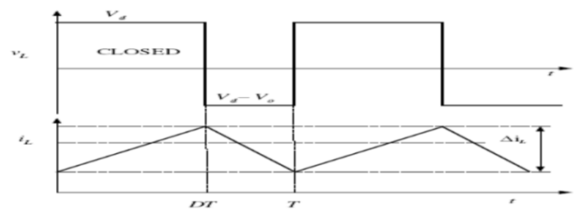


Figure 2- 4 Analysis for switch closed (on)

2.1.2 Analyses for switch open (OFF)

For the next cycle, the power switch S is open. The condition is depicted in Figure 2- 5. Because the inductor is fully charged in the previous cycle, it will continue to force its current through the diode D to the output circuit and charge the capacitor. Inductor is discharging, diode is forward-biased, and Input is connected to the output, energy flows from input to output while capacitor's energy is replenished. The output stage receives energy from the input as well as from the inductor $V_{LOFF} = V_S - V_O$.

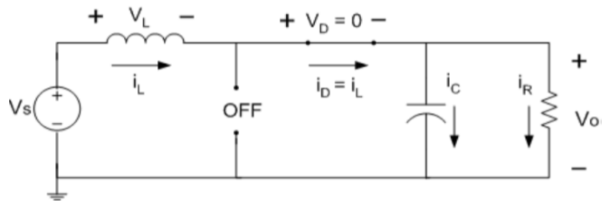


Figure 2-5 The Equivalent Circuit of Boost Converter When the Switch S Open

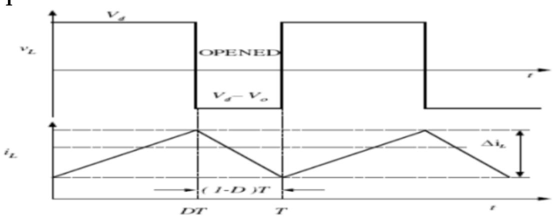


Figure 2-6 Analysis for switch opened (off)

- **Inductor voltage**

$$V_L = V_S = V_O$$
$$= L\frac{dt_L}{dt} \Rightarrow \frac{di_L}{dt} = \frac{V_S - V_O}{L}$$

(2-6)

Since the derivative of $i_L$is a -ve constant, therefore $i_L$must decrease linearly.

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta dt} = \frac{\Delta i_l}{(1-D)T} = \frac{V_S - V_O}{L}$$

$$(\Delta i_l)_{opened} = \left(\frac{V_S - V_O}{L}\right)(1 - D)T \quad (2\text{-}7)$$

Steady-state operation

$$(\Delta i_L)_{closed} + (\Delta i_L)_{opened} = 0$$
$$\left(\frac{V_S}{L}\right)DT + \left(\frac{V_S - V_O}{V_L}\right).(1 - D)T = 0$$
$$\Rightarrow V_O = \frac{V_S}{1 - D} \quad (2\text{-}8)$$

In steady state the average inductor voltage is zero over one switching period known as **Volt Second Balance,**

$$V_{Lon}t_{on} + V_{Loff}t_{off} = 0$$

$$V_S DT + (V_S - V_O)(1 - D)T = 0$$

$$V_O = \frac{1}{1-D} V_S \qquad (2\text{-}9)$$

From the equation (2.9) average output voltage is higher than input voltage.

- **Inductor current:**

Input power = Output power

$$I_L = \frac{V_S}{(1-D)^2 R}$$

CONTROL METHODS FOR DC-DC CONVERTERS

In most of the applications it is needed to maintain the output voltage of converter regardless of changes in the load or input voltage. The DC-DC power converters are sited in middle stage of most of electrical power systems; their input is connected to sources and output is connected to inverters. Both input and output sides are prone to sudden changes in values, slow transient response increase losses in the system and leads to dramatic reduction of efficiency.

Several methods have been proposed by researchers to control output voltage of DC - DC converters as illustrated. Classical methods (model based) rely on mathematical model of system hence they are sensitive to changes in transfer function. In opposite to classical methods, non-model based approaches use intelligence techniques which are not dependent on system mathematical model.

3.1 PID Controller

PID stands for proportional, integral, derivative are one of the most popular feedback controller widely use in processing industry. It is easy to understand the algorithm to produce control performance.

The PID consists of three basic modes that are proportional modes, integral modes and derivative modes. Generally three basis algorithm uses are P, PI and PID. This controller has a transfer function for each modes, proportional modes adjust the output signal in direct proportional to the controller output [2]. A proportional controller (K_P) reduces the error but not eliminates it [3]. An integral controller (K_I) will have the effect of eliminating the steady-state error but it may worsen the transient response. The derivative controller (K_d) will have the effect of increasing the stability of the system, reducing the overshoot and improving the transient response.

3.2 Fuzzy logic controller system(FLC)

Since its introduction in 1965 by Lotfi Zadeh (1965) [8], the fuzzy set theory has been widely used in the control area with some application to DC-to-DC converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink Simulation model is built to study the dynamic behavior of DC-to-DC converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide both small signal and large signal dynamic performance at same time as required, which is not possible with linear control technique. Thus, fuzzy logic controller possesses the potential ability to improve the robustness of DC-to-DC converters. The basic scheme of a fuzzy logic controller is shown in figure 2 and consists of four principal components such as: a fuzzification interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a defuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [4].

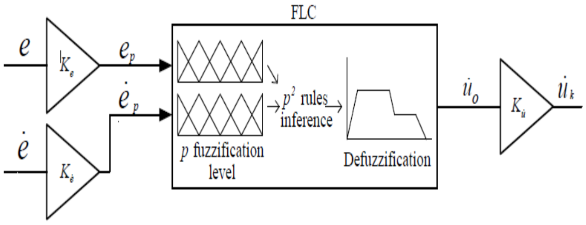


Figure (3.1): General structure of the fuzzy logic controller on

Closed-loop system

RESEARCH METHODOLOGY

This chapter will cover the detail explanation of methodology that is being used to make this project complete and working well. MATLAB/Simulink software is used to achieve the objectives of the project. With the aim to evaluate this project, the methodology based on system development is shown in Figure 3.1. Generally, there are three major steps in the development of projects, which are planning, implementation and analysis. Flow chart in Figure 3.2 shows the flows and methods that will be used for finding and analysing data related to the project.

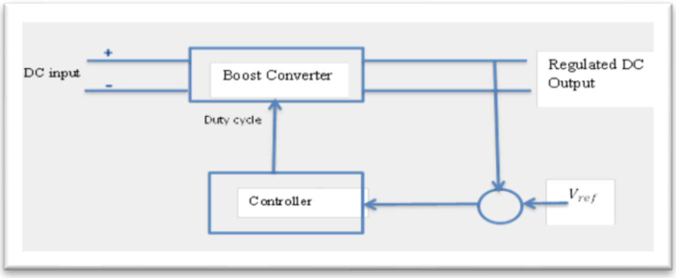


Figure 4 . 1: Block Diagram For Propose DC-DC Boost Converter Using Fuzzy Logic Controller

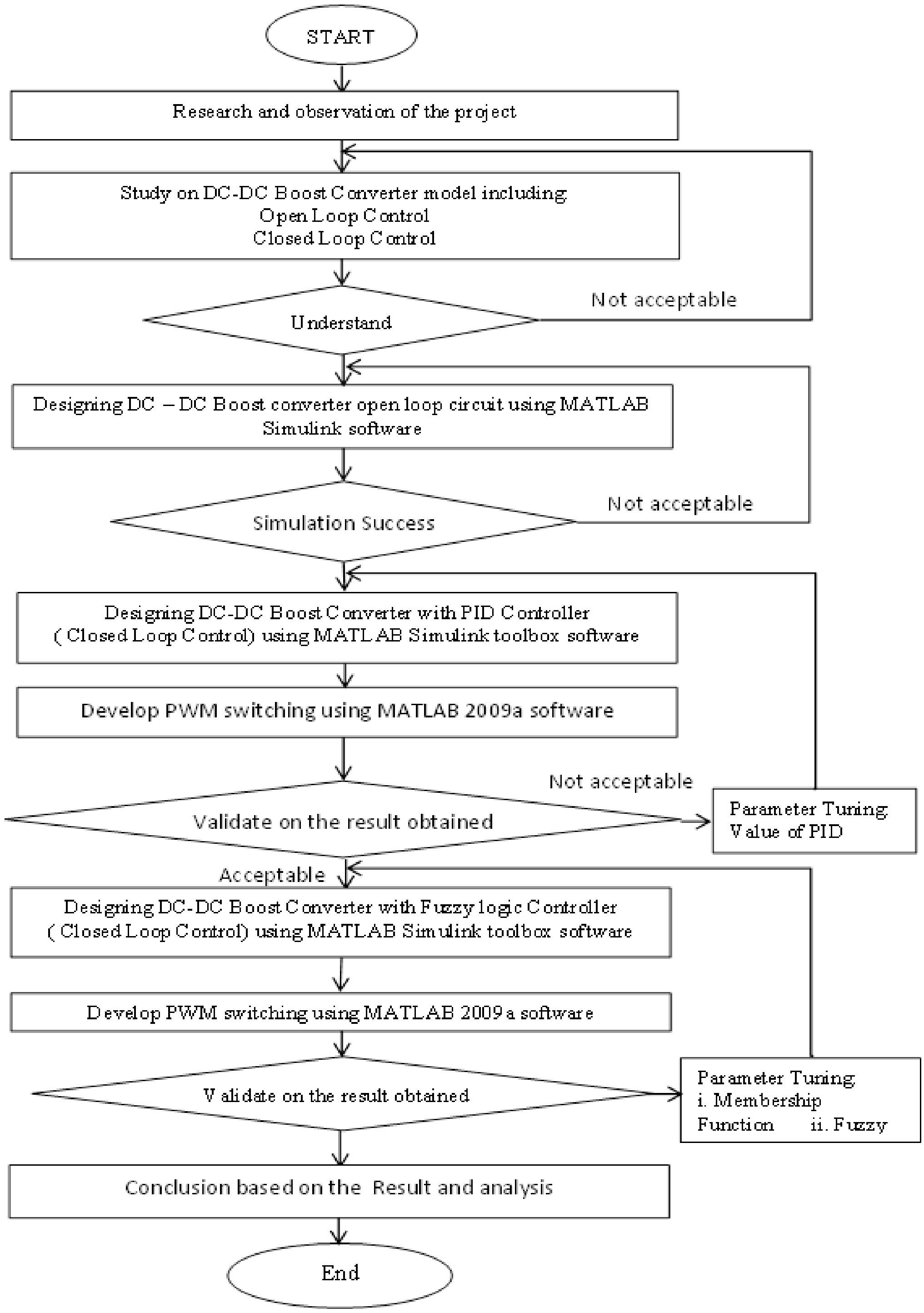


Figure 4.2 shows the overview of the methodology flow chart of this project.

Boost converter parameter:

Figure 3.4 shows the diagram of open loop DC-to-DC boost converter by using Matlab/Simulink. The power switching device that is used to develop the simulation of boost converter is MOSFET. This is because the characteristics of MOSFET are fast switching due to its operating frequency is very high. While designing the DC-to-DC boost converter, the parameters value of design requirement has been set. The voltage range of converter is setup from 12V to 24V, switching frequency that is used is about 27 kHz and the load resistor is fixed at 50Ω. The values of all parameters and components have been decided by calculation, which refers from the previous equation.

The value of all parameters can be determined as below :-

Table 3.1: Parameters and values for boost converter

Parameter	Value
Voltage Input, Vs (V)	12
Voltage Output, Vo (V)	24
Output Power, P (W)	57.6
Duty Cycle, D	0.5
Switching Frequency, f (kHz)	27.7
Resistance, R (Ω)	10
Inductor, L (mH)	25
Capacitor, C (μF)	250
output Voltage Ripple (%)	0.173
Input Current, Is (A)	9.132
Output Current, I0 (A)	2.4
Diode forward voltage Vf (v)	1.05

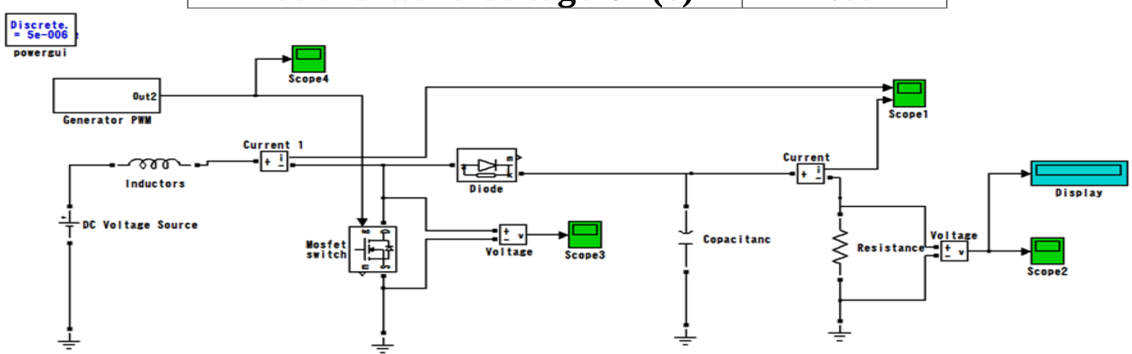


Figure 4.3 : Diagram of open loop dc to dc boost converter by using Simulink

4.2 Generate SPWM switching using Matlab Simulink

The SPWM switching signal is generated by comparing the sinusoidal reference signal and triangular carrier. The switching time is the time when these two different waveforms (reference signal and carrier signal) are intersected depending on theoretical switching scheme. The programming of SPWM switching by using S-Function block on Mat lab Simulink software [11] .

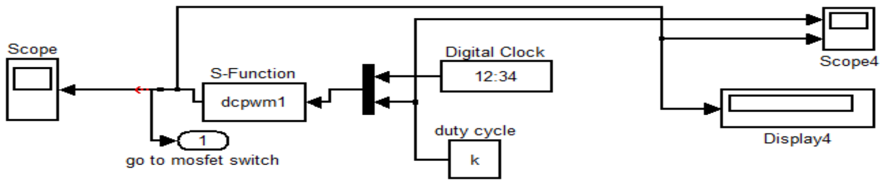


Figure 4.4: Simulink Generate SPWM Switching

4.3 PID Controller design for boost converters

A PID and a PI controller were designed for the boost converter for operation during a start-up transient and steady state, respectively. The controllers were designed based on the measured small signal model of the boost converter using MATLAB Simulink software 2009a.

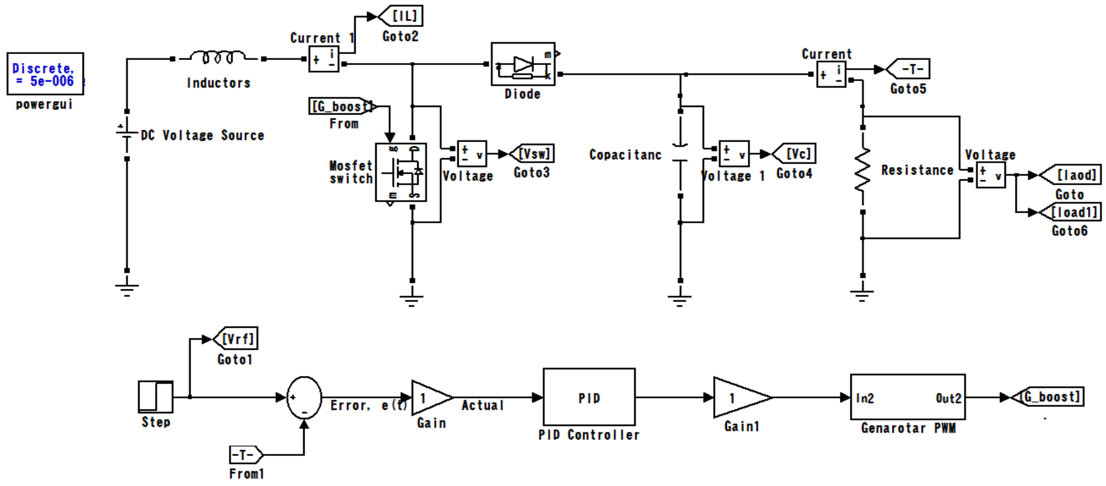


Figure 4.4 Simulink model of the PID controller for the DC-DC boost converters

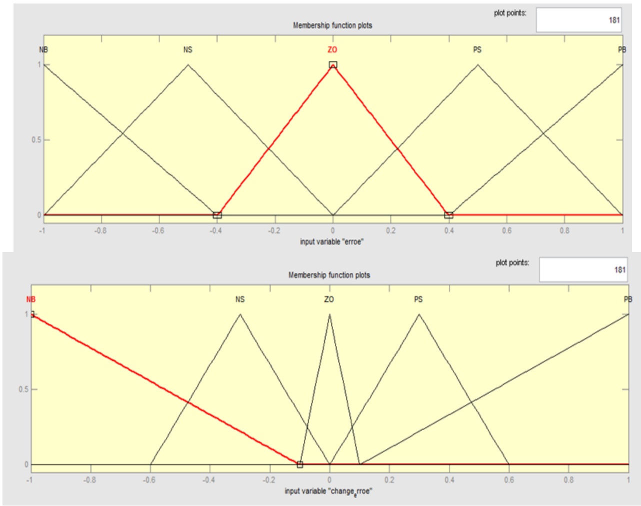
4.4 Fuzzy logic controller and its operational methodology

4.4.1 Fuzzification

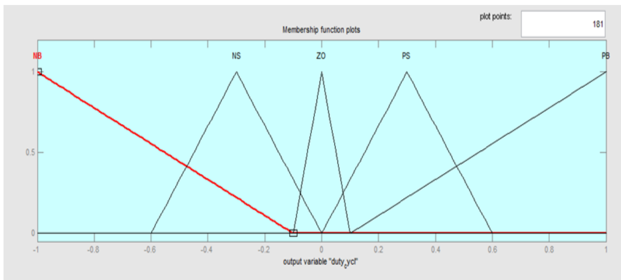
First, the linguistic values are quantified using membership functions. Each universe of discourse is divided into fuzzy subsets. There were 5 fuzzy subsets in the fuzzy controller for the boost converter: NB , NS , ZO , PS , and PB, where N indicates negative, Z represents zero, and P indicates positive. The membership functions for e[k] , che[k] and change duty cycle δd[k] of PWM output are shown in Figure 3.8. The variables μe(e[k]) and μche(che[k]) are the membership degrees assigned to each fuzzy subset to quantify the certainty that the input can be classified linguistically into the corresponding fuzzy subsets. A triangle-shaped membership function was used for this controller design for the ease of implementation. Of the 5 subsets, there were 2 subsets for the positive parts and 2 subsets for the negative parts of the universe of discourse, respectively.

The number of fuzzy subsets was determined based on the experimental results of boost converters. 5 fuzzy subsets were the smallest number of fuzzy subsets in order to obtain satisfactory results.

The membership functions for e[k] , che[k] and δd[k] are shown in Figure 4.5.



Membership functions of the inputs e[k] Membership functions of the inputs che[k]



Membership functions of the inputs δd[k]

4.4.2 Rule base

The rule base is derived from general knowledge of DC-DC converters and adjusted based on experimental results. There is a trade-off between the size of the rule base and the performance of the controller. A 5*5 rule base was also designed and implemented for the boost converter. Experimental results indicate that the fuzzy controller with a 5*5 rule base exhibited less oscillation during steady state, and faster transient response was achieved by increasing the output gain h. For the same universe of discourse, more membership functions resulted in finer control. The output of the controller had less variation when either of the inputs had small changes, and a more accurate control was achieved; chattering or oscillation were reduced [48].

A small 5×5 rule base for the fuzzy logic controller is shown in Table 3.1 for illustration purposes. In the table five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter

Table 4.1: 5×5 Rule base of the fuzzy logic controller

		Change in error (Che)				
		NB	NS	ZO	PS	PB
Error (e)	NB	NB	NB	NB	NS	ZO
	NS	NB	NB	NS	ZO	PS
	ZO	NB	NS	ZO	PS	PB
	PS	NS	ZO	PS	PB	PB
	PB	ZO	PS	PB	PB	PB

4.4.3 Inference mechanism

The results of the inference mechanism include the weighing factor (wi) and the change in duty cycle ci of the individual rule [4]. The weighing factor (wi) is obtained by Mamdani's min fuzzy implication of µe(e[k]) and µche(che[k]), where wi = min{µe(e[k]), µche(che[k])} and µe(e[k]), µche(che[k]) are the membership degrees [10]. The change in duty cycle inferred by the ith rule, zi is written in (4.1).

$$zi = wi \times ci = \min\{ \mu (e[k]), \mu (che[k])\} \times ci \quad (4.1)$$

4.4.4 Defuzzification

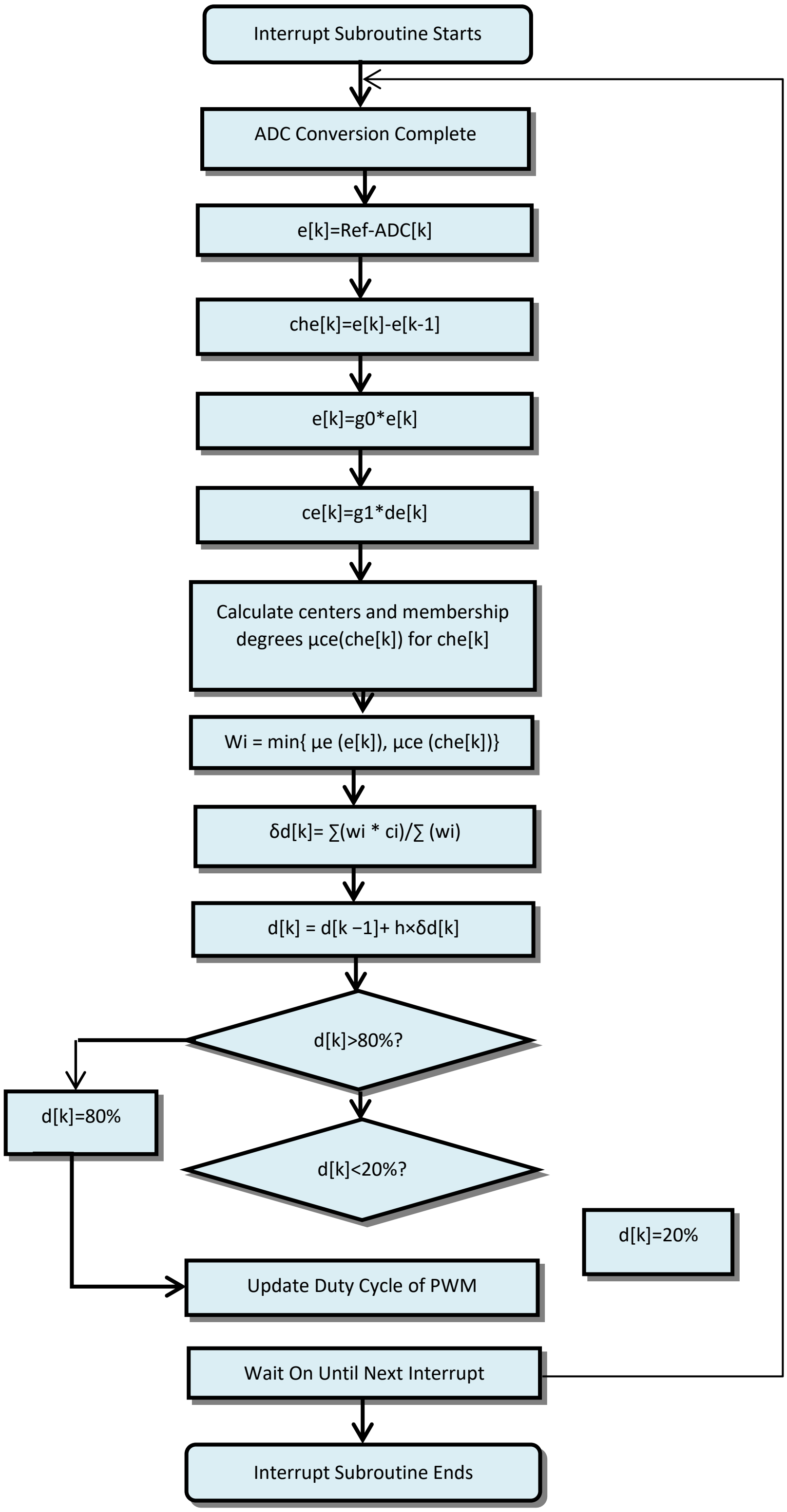
The centre of average method is used to obtain the fuzzy controller's output δd[k], which is given in (4.2). When using triangle-shaped membership functions, there are at most four rules that are effective at any one time; therefore,

$$\delta d[K] = \frac{\sum_{i=1}^{N} w_i * c_i}{\sum_{i=1}^{N} w_i} \qquad (4.2)$$

4.4.5 Implementation of fuzzy controllers

The flowcharts of the fuzzy controllers are shown in Figure (4.6) shows the flowchart of the fuzzy controller using the method to calculate the new duty cycle, which corresponds to the Simulink model.

Figure(4.7) shows the flowchart of the fuzzy controller with a linear integrator.



4.3.6 Fuzzy logic controller for boost converter

A fuzzy logic controller for a DC-DC Boost converter has two inputs. The first input is the error in the output voltage, $e[k] = Ref - ADC[k]$, where ADC[k] is the converted digital value of the K^{th} sample, and Ref is the digital value corresponding to the desired output voltage.

The second input, $che[k] = e[k] - e[k-1]$, is the difference between the error of the K^{th} sample and the error of the $(k-1)^{th}$ sample. The two inputs are multiplied by the scaling factors g0 and g1, respectively, and then fed into the fuzzy controller. The output of the fuzzy controller is the change in duty cycle $\delta d[k]$. It is scaled by a linear gain h. The scaling factors g0, g1 and h can be tuned to obtain a satisfactory response.

The output of the fuzzy logic controller, scaled by the output gain h, is added to the previous sampling period’s duty cycle d[k-1], which is written in (4.3)

$$d[k] = d[k-1]+h*\delta d[k] \quad (4.3)$$

The integration of the fuzzy controller’s output increases the system type and improves steady-state error. The Simulink model of the fuzzy logic controller using (4.3) to calculate the duty cycle d[k] is shown in Figure (4.7) . The disadvantage of this method is that the output gain h has to be tuned to be very small to avoid oscillation in steady state. Since the change in duty cycle is accumulated every sampling period, the duty cycle varies around its nominal value during steady state, which could lead to oscillation. Quantization errors in digital controllers increase the magnitude of the oscillation, because digital controllers are restricted to a finite set of values. Oscillation between the maximum and minimum values of the duty cycle may even occur if h is relatively large compared to the duty cycle range. A very small output gain h tends to increase the transient response time because more sampling periods are necessary to arrive at the desired duty cycle [4].

In order to prevent the MOSFET from being turned on or off for a full switching period, the duty cycle d[k] is limited to be between the 20% and 80% for the boost converter.

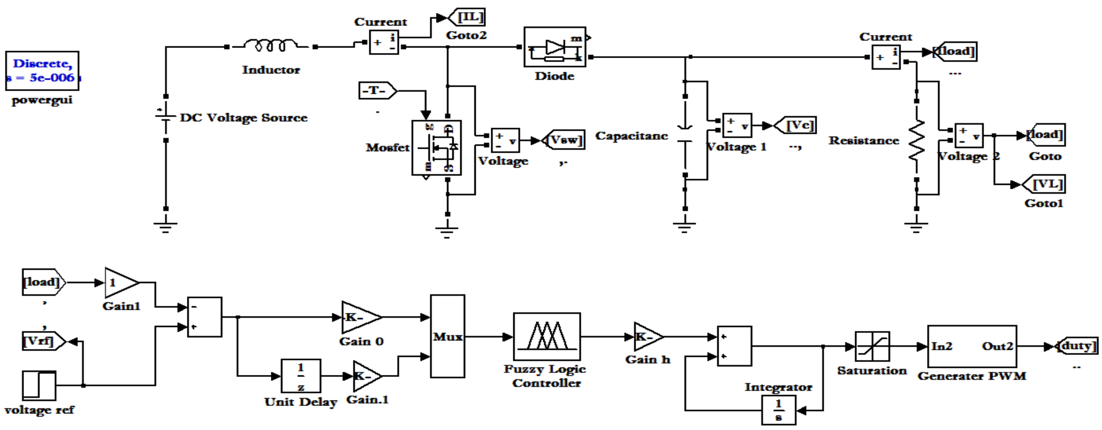


Figure 4.7 : Diagram of fuzzy logic controller for dc to dc converter by using Simulink

5. Results and analysis:

For simulation, input voltage was set at 12V and the voltage reference was set at 24V. The other values of parameters are setting same like the previous section. The simulation result has compared between open loop boost converter and close loop boost converter with fuzzy logic controller and PID controller.

5.1 Open loop Dc to Dc boost converter

From the simulation, the waveform of output voltage and capacitor voltage have same characteristic of waveform. The value of output voltage is about 24.05V. Then the mean values of input current or inductance current, I_L is about 10.24A and it has high overshoot compare the output current that has more stable. The value of output current is about 2.4A. The result from the simulation is nearest with the mathematical calculation. It is because of the losses at the components. The simulation result can see at Figure 5.1(a), 5.2(b), 5.3(c), 5.4(d).

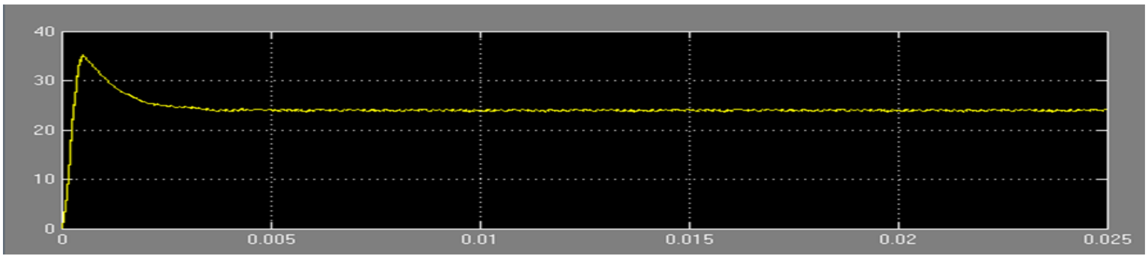


Figure 5.1(a): Results on output voltage for open loop circuit DC to DC boost converter.

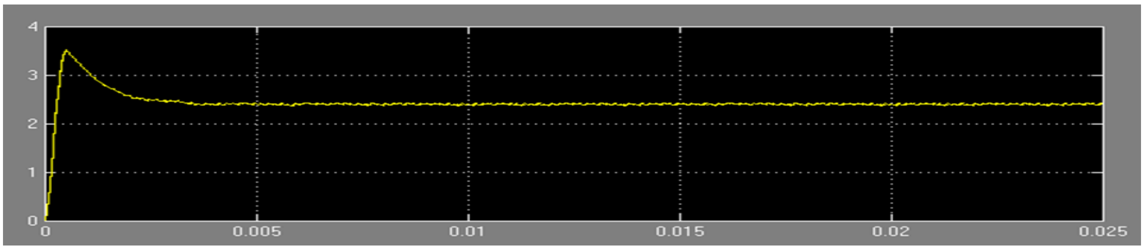


Figure 5.2(b): Results on output current for open loop circuit DC to DC boost converter

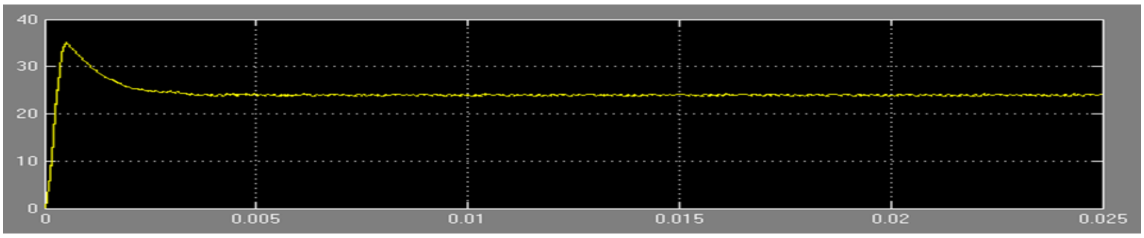


Figure 5.3(c): Results on Capacitor voltage for open loop circuit DC to DC boost converter

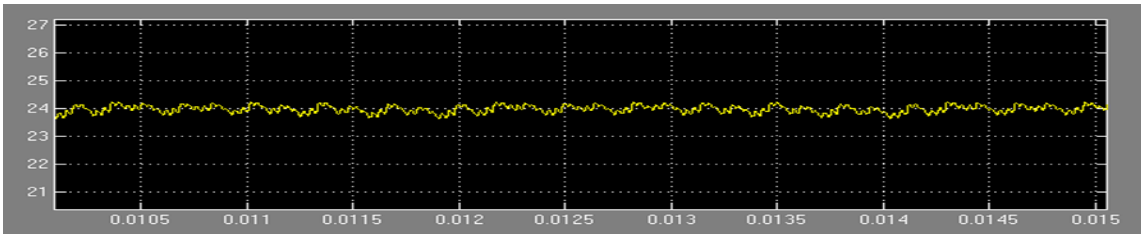


Figure 5.4(d): Results on ripple output voltage for open loop circuit DC to DC boost converter.

5.2 Boost conveter with PID controller

The simulation results of output voltage for boost converter with PID controller have shown at Figure 5. From the simulation result, the value of output voltage is getting about 24V.

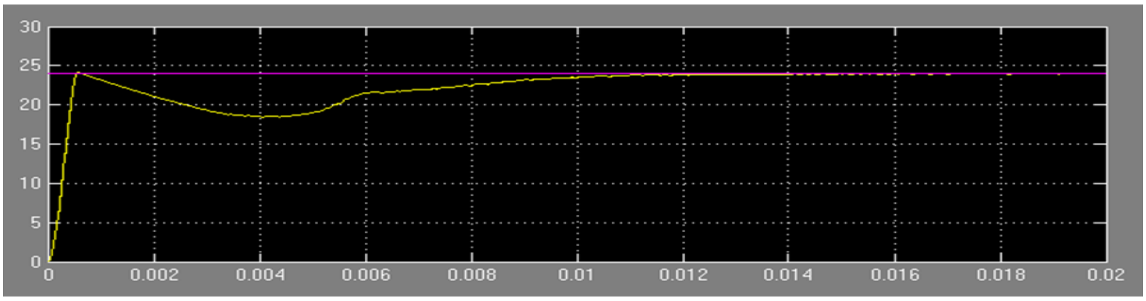


Figure 5.5(a): Results on output voltage for PID controller closed loop circuit DC to DC boost converter

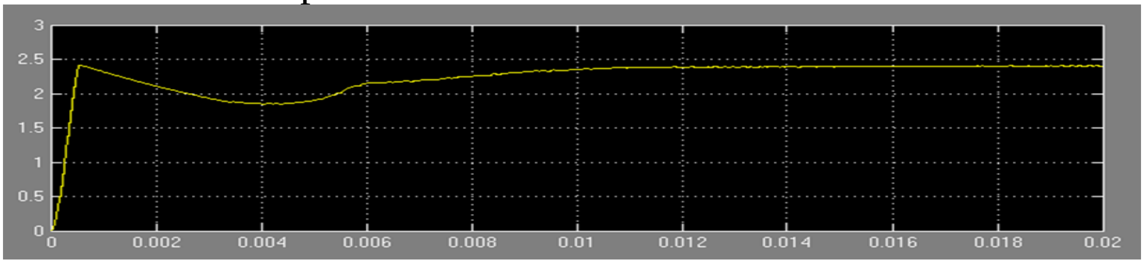


Figure 5.6(b): Results on output current for PID controller closed loop circuit DC to DC boost converter.

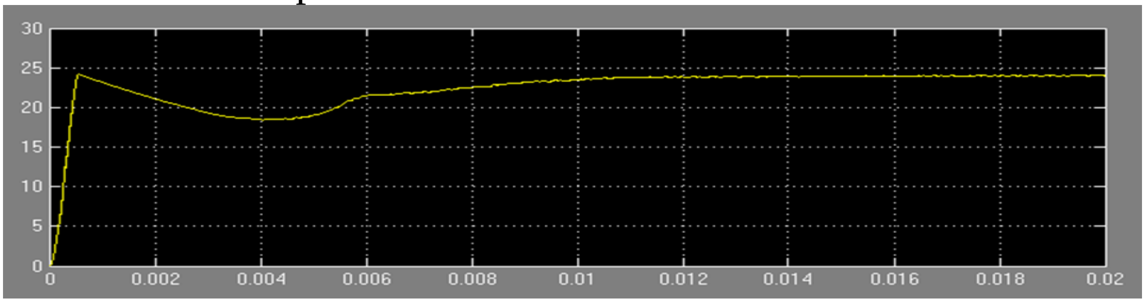


Figure 5.7(c): Results on capacitor voltage for PID controller closed loop circuit DC to DC boost converter

5.3 Boost conveter with fuzzy logic controller

The simulation results of output voltage for boost converter with fuzzy logic controller have shown at Figure the following. From the simulation result, the value of output voltage is getting about 23.74V and the duty cycle value was display at rules viewer is about 0.44. Figure 5.11(b) shows the output current. The value of output current is about 2.38A.

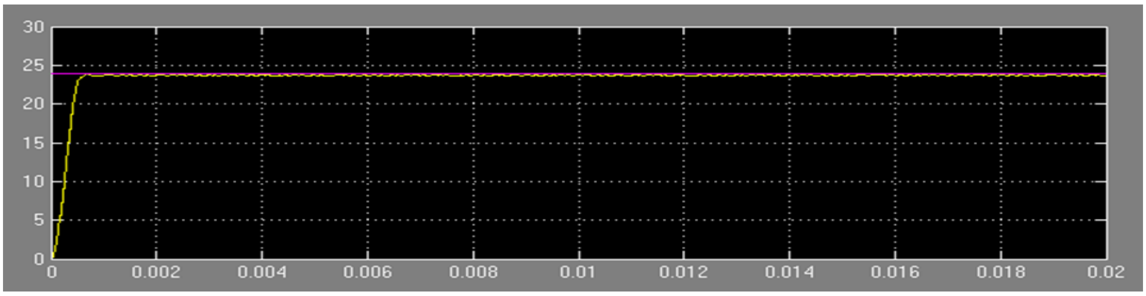


Figure 5.8(a) : Output voltage for boost converter with fuzzy logic controller

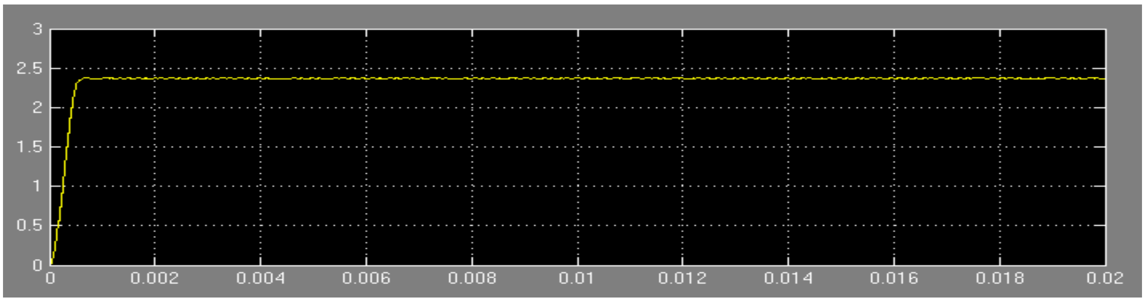


Figure 5.9(b): Results on output current for FLC controller closed loop circuit DC to DC boost converter.

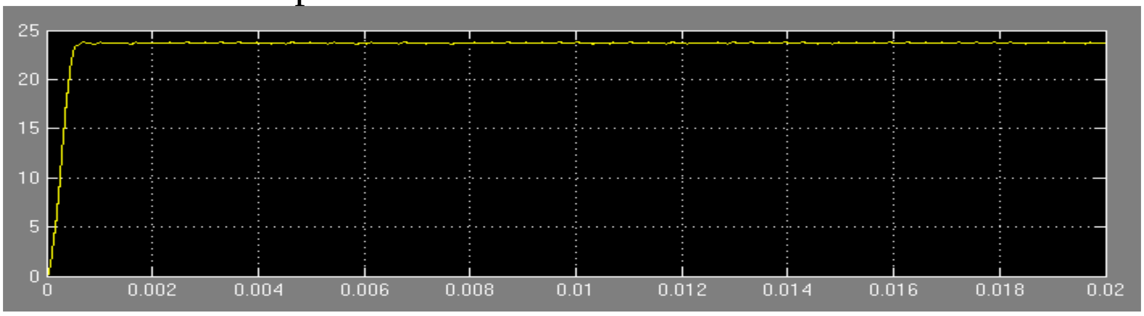


Figure 5.10(c): Results on capacitor voltage for FLC controller closed loop circuit DC to DC *boost* converter

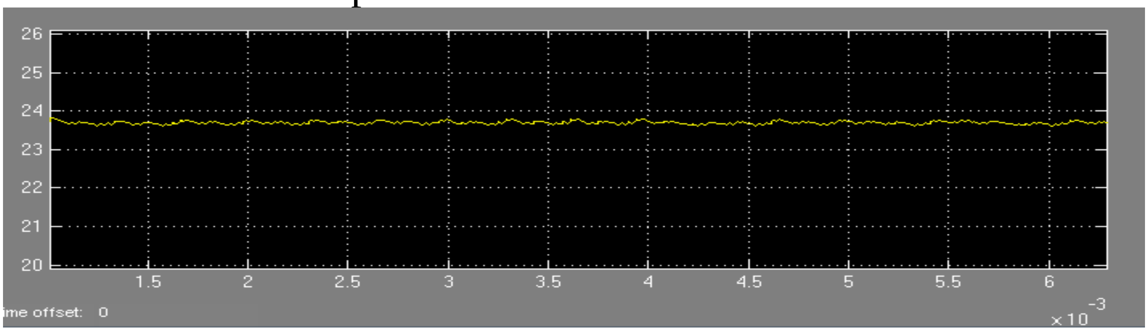


Figure 5.11(d): Results on ripple output voltage for FLC closed loop circuit DC to DC boost converter.

Figure 5.1(a),5.5(a) and 5.8(a) shows the simulation results on the output voltage of the open loop and closed loop circuit for PID and FLC. At output voltage of the open loop circuit showed that voltage boost up for a value of 35 V. This showed that open loop circuit produced an overshoot voltage however this scenario did not happen in closed loop circuit. In closed loop circuit for FLC was better than PID controller whence overshot and settling time. Overshot in the FLC equal zero and settling time is much faster. The fuzzy logic controller plays it roles to control the voltage output as the desired requirement. It proved that the fuzzy logic controller successfully control.

Next take a look at the output current simulation results on Figure 5.2(b) for open loop circuit , Figure 5.6(b) for PID closed loop circuit and Figure 5.9(b) for FLC closed loop circuit. The system with fuzzy logic controller had controlled the current of output by driving it to produce the desired current that needed by the system and eliminating the overshoot current.

Voltage results in Figure 5.3(c), 5.7(c) and 5.10(c). All the simulation results between open loop circuit and closed loop circuit for PID and FLC shows that the closed loop circuit gives a fast settling time value that was controlled by fuzzy logic controller. This purposely achieved in order to correspond on the output desired of the system.

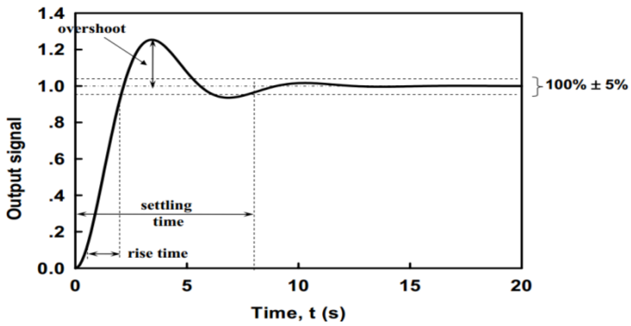


Figure 5.12: 2nd Order of step response reading on overshoot ratio, rise time, peak and settling

The comparison analysis between open loop and closed loop were continue on the simulation result based on the output voltage deviation, voltage overshoot percentage, rise time, peak time and settling time. These comparisons based on the 2nd order Step Response System. This analysis is shown as Figure 16 where the reading on overshoot ratio, rise time, peak time and settling time were taken.

Table (5.1) The reading on peak overshoot ratio, rise time, peak time and

Settling Time from open loop and closed loop for PID and FLC, circuit boost dc-dc converter.

	Voltage Input (V)	Voltage Reference e (V)	Peak Overshoot Ratio (%)	Rise Time (mS)	Peak Time (mS)	Settling Time (mS)
Open	20	24	46.7	0.29	0.512	4
PID	20	24	0.833	0.545	0.577	12
FLC	20	24	0.0	0.525	0.575	0.6

Based on the simulation results obtained and shown in Table (5.1), those circuits shown that both are having a different rise time, peak time and also have a different settling time. However, the analysis shows that the closed loop circuit with fuzzy controller is having the faster settling time.

Table (5.2) The deviations of voltage resulted from open loop circuit Boost dc-dc converter

	Voltage Input (V)	Voltage Reference e (V)	Voltage Output (V)	Deviation (V)	Deviation (%)
OPEN LOOP	12	24	23.79	0.21	0.875
PID	12	24	23.88	0.12	0.5
FLC	12	24	23.89	0.11	0.458

The analysis on the deviation of voltage resulted that the difference between reference voltage setting and the output voltage is always lesser. The comparison between open loop and closed loop for PID and FLC in Table (5.2) show that the open loop circuit having a bit higher on the deviation of voltage. The closed loop circuit boosts for FLC has a lesser deviation of voltage and proved that it is such a better performance on control the deviation of voltage during the boost mode.

Conclusions:

Design of the fuzzy logic controller for dc to dc boost converter by using Matlab@Simulink has been successfully achieved. From the observation simulation result, fuzzy logic controller has improved the performances in term of overshoot limitation system. Finally, we can conclude that the fuzzy logic controller is robust and better performance in system.

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