DEVELOPMENT OF A POWER FACTOR CORRECTION
BOOST CONVERTER IN SINGLE PHASE RECTIFIER
USING FUZZY LOGIC

SALAMIYAH BINTI MOHAMAD

A project report submitted in partial fulfillment of
the requirement for the award of the Master of
Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

JULY, 2013

ABSTRACT

Power factor correction (PFC) provides well-known benefits to avoid poor power factor penalty and to reduction bill utility. The voltage support release of the system capacity and reduce system losses. There are two kinds of power factor correction techniques- passive power factor correction and active power factor correction. This thesis tried to develop a boost converter with applied active power factor correction method for improve of the power factor. MATLAB software is used to design Fuzzy logic to control scheme for boost converter from single phase rectifier. The methodology integrates fuzzy logic controlling the output voltage of DC-DC converter and improves performance of the boost converter during transient operation. Instead of generating fast pulse-width-modulated (PWM) signal, the digital signal processor is required to generate a slow-varying dc signal only for determining the PWM ramp function. A model for Power Factor Correction has been developed using the MATLAB software. The simulation result shows that the power factor has been improved.

ABSTRAK

Pembetulan faktor kuasa (PFC) memberi faedah yang baik untuk mengelakkan faktor kuasa memungkinkan penalti dan pengurangan bil utiliti. Pembebasan sokongan voltan kapasiti sistem dan mengurangkan kerugian sistem. Terdapat dua jenis Pembetulan fakto kuasa ialah teknik pembetulan faktor kuasa pasif dan pembetulan faktor kuasa aktif. Tesis ini adalah untuk membangunkan rangsangan penukar digunakan dengan kuasa aktif kaedah pembetulan faktor kuasa untuk memperbaiki faktor kuasa. MATLAB perisian yang digunakan untuk merekabentuk logik kabur (FL) untuk mengawal skim rangsangan penukar penerus dari satu fasa. Kaedah ini menggabungkan logik kabur(FL) mengawal voltan keluaran DC-DC penukar dan meningkatkan prestasi rangsangan penukar semasa operasi fana. Sebaliknya menjana pantas nadi lebar termodulat isyarat (PWM), pemproses isyarat digital yang diperlukan untuk menjana AT isyarat perlahan yang berbeza-beza hanya untuk menentukan fungsi PWM. Satu model untuk Pembetulan Faktor Kuasa telah dibangunkan dengan menggunakan perisian MATLAB. Hasil simulasi menunjukkan bahawa faktor kuasa telah bertambah baik.

CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol

V_o	Output voltage
V_i	Input voltage
$Vref$	Reference voltage
k_p , kI	Proportional gain and integral gain of P-I controller
$k1$	Voltage reduction factor
C	Capacitor
L	Inductor
CCM	Continuous Conduction Mode
de	Change of Error
D	Duty Cycle
DC	Direct Current
AC	Alternating Current
DCM	Discontinuous Conduction Mode
e	Error
f	Frequency
T	Period
I_L	Inductor Current
PFC	Power Factor Correction
KD	Derivative gain
KI	Integral gain
KP	Proportional gain
L	Inductor
PID	Proportional Integral Derivative
PWM	Pulse Width Modulation
R	Resistor
S	Switch
V_{C-}	Voltage (Calculation)
V_{o-}	Output Voltage
V_{s-}	Input Voltage
V_{ref}	Reference output
ZE	Zero
SMPS	Switch Mode Power Supply
P	Power

LP   Low Pass filter

THD   Total Harmonic Distortion

CHAPTER 1

INTRODUCTION

1.1   PROJECT BACKGROUND

The usage electronic equipment is increasing rapidly in daily life to fulfil consumers and industrial needs. All these electronic equipments have power supplies that obtain required energy from utility grid. A load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor. In order to overcome this problem, Power Factor Corrector is used. There are two kinds of power factor correction techniques- passive power factor correction and active power factor correction. This thesis tried to develop a boost converter with applied active power factor correction method for improve of the power factor.

Alternatively, most of power supplies consist of AC/DC converter element based on diode or thyristor rectifier circuit. This rectifier circuit will lead to main harmonic distortion. Line-frequency diode rectifiers convert AC voltage to DC voltage in an uncontrolled way. For appliances that consumed low power such as PCs, TVs, and other home appliances, the single phase rectifier is chosen owing to its low cost and simple configuration.

Moreover, the DC-DC converter is also important in devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. For that reason, DC-DC converter application will become more potential market in the future.

Operation of the switching devices causes the inherently nonlinear characteristic of DC-DC converter including one knows as boost converter.

The boost converter attempts to maintain a constant DC voltage on its output while drawing a current that is always in phase with and at the same frequency as the line voltage. Another switch mode converter inside the power supply produces the desired output voltage from the DC input voltage. This approach requires additional semiconductor switches and control electronics, but permits cheaper and smaller passive components.

Thus, this research is done to study the control switching converter the control of switching converter constitute at the present time a borderline problem, which can be handled with Fuzzy-Logic based technology.

1.2 PROBLEM STATEMENTS

Control of switching power supplies has always been a daunting task for nonlinear and time variant cases. DC-DC converters change state momentarily from one to another and especially the boost one contains non-minimum phase behaviour, which makes control mechanism more difficult. Linear control techniques don't show robustness against sudden load and input voltage variations. It is required for a DC-DC converter to provide regulated output despite all kinds of perturbations. The conventional proportional-integral-derivative (PID) controller has been used in many control application because of its simplicity and effectiveness. The disadvantage of PID controller is its poor capability of dealing with system uncertainly. For example parameter variation and external disturbance.

Therefore, the implementation of practical Fuzzy Logic controller that will deal to the issue must be investigated. The Fuzzy control is a practical alternative for a variety of challenging control applications because Fuzzy logic control is nonlinear and adaptive in nature that gives it a robust performance under parameter variation

and load disturbances. Fuzzy controllers are more robust than PID controllers because they can cover wider range of operating conditions than PID, and can also operate with noise and disturbance of different natures. Developing the fuzzy controller is cheaper than developing a model based or other controllers for the same purpose. Fuzzy logic is suited to low-cost implementations and systems of fuzzy can be easily upgraded by adding new rules to improve performance or add new features.

1.3 PROJECT OBJECTIVES

The objectives of this project are as follows:

a)   To develop a model circuit of Power Factor Correction boost converter in single phase rectifier using MATLAB software.

b) To design Fuzzy logic to control scheme Power Factor Correction boost converter in single phase rectifier.

c) To simulate the desing of Power Factor Correction boost converter in single phase rectifier using MATLAB software.

1.4 PROJECT SCOPES

The scopes of this project are:

a) Developed a DC-DC boost converter with input 230Vrms and will be produced the output voltage $300V_{dc}$.

b) Design fuzzy logic to control Power Factor Correction nearest power factor to unity

CHAPTER 2

LITERATUR REVIEW

2.1 EXISTING MODEL

Since fuzzy logic controller can mimic human behavior, many researchers applied fuzzy logic controller to control voltage output. A thorough literature overview was done on the usage of fuzzy logic controller as applied Power Factor Correction DC-DC Boost Converter.

K.Periyasamy ,proposed power factor correction (PFC) based on Fuzzy Logic controller with average current mode for DC-DC Boost Converter. The PFC strategy uses Proportional & Integral (PI) to correct the input current shape and Fuzzy controller to control the output voltage. The simulation result show that the high power factor can be achieve under wide output power condition. Fuzzy logic control has an advantage of coping with larger parameter variation of the system and it overshoot limitation and sensitivity to parameter variation. [4]

A. Kessal, L. Rahmani, M. Mostefai KaunasProposed an application of different methods to regulate the output voltage of AC-DC converter associated with power factor corrector (PFC), a classical PI regulator was used, and another based on fuzzy logic was built, the both regulators were inserted in the voltage loop. To reduce the total harmonic distortion of the input current to give it a sinusoidal shape, hysteresis bands control were used, the variable band hysteresis give better results compared to other bands. All these controllers have been verified via simulation in Simulink and experimental test. The fuzzy logic inference based controller can achieve better dynamic response than its PI counterpart under large load disturbance

and plant uncertainties. Furthermore, the variable hysteresis band control in the current loop gives a low THD of the input current compared to classical bands control.[5]

Ing.Esp.Fredy H. Martenez S, Ing. Teg. Diego F. Gomez M. ,proposed Fuzzy Logic Controller for Boost Converter with Active Power Factor Correction. The simulation result shows the fuzzy control scheme allows working on three different problem at the same time: voltage regulation, dynamic response and active power factor correction; this is possible because the fuzzy rules could be assigned for different operation areas.

Huseyin Dogan and Razaman Akkaya, proposed Modeling and simulation of a Fuzzy-Genetic Controller for a Boost PFC Converter in Matlab/Simulink. Proposed control scheme comprises a fuzzy logic based controller for dc bus voltage regulation and a standard hysteresis current controller for obtaining gating signals of the power switch.

Based on those related work, the researchers make a great efforts to propose the good to overcome the DC-DC Converter problems. Their applications of each method differ, thus the further investigation of this controller is needed.

2.2 POWER FACTOR CORRECTION TECHNIQUES

Power factor is defined as the ratio of the real power drawn by the load to the apparent power in the circuit. Most commonly encountered loads are inductive (linear loads) in nature and hence draw lagging current resulting in reduced values of power factor. Non-linear loads such as rectifiers distort the supply current waveform and also lower the power factor to much less than unity. Hence it is necessary to use suitable power factor correction techniques to counteract the distortion and to improve the power factor.

Power factor correction topologies can be classified into:

a)   Passive Power Factor correction

b)   Active Power Factor Correction

2.2.1   PASSIVE POWER FACTOR CORRECTION

Harmonic current can be controlled in the simplest way by using a filter that passes current only at line frequency (50 or 60 Hz).Harmonic currents are suppressed and the non-linear device looks like a linear load. Power factor can be improved by using capacitors and inductors i.e. passive devices. Such filters with passive devices are called passive filters.

Disadvantage: They require large value high current inductors which are expensive and bulky.

A passive PFC circuit requires only a few components to increase efficiency, but they are large due to operating at the line power frequency
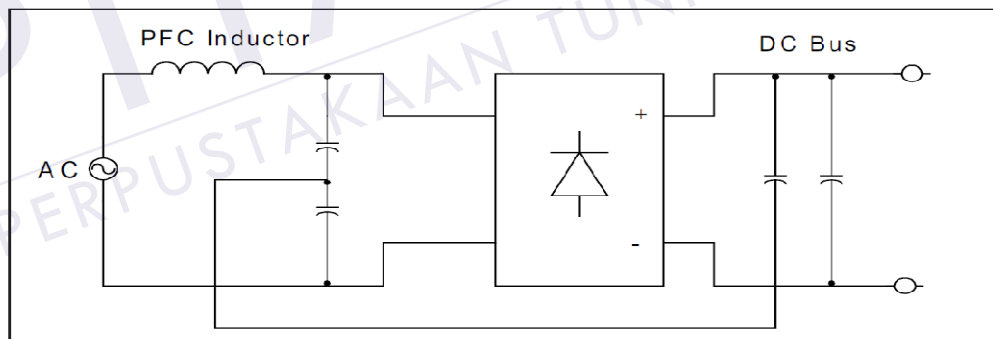

Figure 2-1 : A passive PFC circuit [2]

2.2.2 ACTIVE POWER FACTOR CORRECTION

An "active power factor corrector" (active PFC) is a power electronic system that changes the wave shape of current drawn by a load to improve the power factor. The purpose is to make the load circuitry that is power factor corrected appear purely resistive (apparent power equal to real power). In this case, the voltage and current are in phase and the reactive power consumption is zero. This enables the most efficient delivery of electrical power from the power company to the consumer.

Some types of active PFC are:

- Boost
- Buck
- Buck-boost

Active power factor correctors can be single-stage or multi-stage.

In the case of a switched-mode power supply, a boost converter is inserted between the bridge rectifier and the main input capacitors. The boost converter attempts to maintain a constant DC bus voltage on its output while drawing a current that is always in phase with and at the same frequency as the line voltage. Another switch mode converter inside the power supply produces the desired output voltage from the DC bus. This approach requires additional semiconductor switches and control electronics, but permits cheaper and smaller passive components. It is frequently used in practice. For example, SMPS with passive PFC can achieve power factor of about 0.7–0.75, SMPS with active PFC, up to 0.99 power factor, while a SMPS without any power factor correction has a power factor of only about 0.55–0.65.

Due to their very wide input voltage range, many power supplies with active PFC can automatically adjust to operate on AC power from about 100 V (Japan) to 230 V (Europe). That feature is particularly welcome in power supplies for laptops.

2.3   DC to DC CONVERTER

DC to DC is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. In other word, converting the unregulated DC input to controlled DC output with a desired voltage level. Dc to dc converter are widely used in switched-mode power supplies (SMPS), battery chargers, adjustable speed drives, uninterruptible power supplies and many other applications to change the level of an input voltage to fulfill required operating conditions.

There are typically three types of dc to dc converters, which are:

 i. Buck converter

 ii. Boost converter

iii. Buck-Boost converter

2.3.1   BOOST CONVERTER

A **boost converter** (**step-up converter**) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple
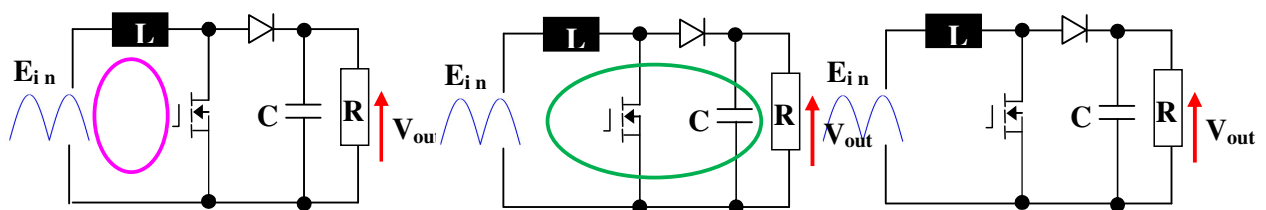
Figure 2-2 : Boost Converters

Higher Boost efficiency because the input is coupled directly to the output in the second sub interval as shown in Figure 2-2.

Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power ($P = VI$) must be conserved, the output current is lower than the source current

Boost PFC advantages include

    i)   Good power factor correction provided $V_{out}(t) > V_{in,max}(t)$

    ii)   Low side drive

    iii)   Smaller LP filter

Boost PFC disadvantages include

    i)   Mosfet V_{DS} rating = V_{out}

2.3.2 BOOST CONVERTER OPERATING IN CONTINUOUS MODE
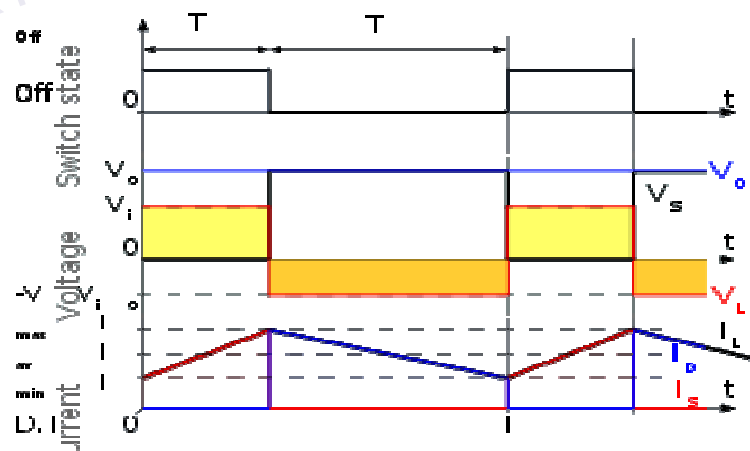
Figure 2-3: Waveforms of current and voltage in a boost converter operating in continuous mode.

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure 2-3 shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e. using components with an ideal behavior) operating in steady conditions

During the On-state, the switch S is closed, which makes the input voltage (V_i) appear across the inductor, which causes a change in current (I_L) flowing through the inductor during a time period (t) by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L}$$

(2.1)

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{L_{On}} = \frac{1}{L} \int_0^{DT} V_i dt = \frac{DT}{L} V_i$$

(2.2)

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is On. Therefore D ranges between 0 (S is never on) and 1 (S is always on).

During the Off-state, the switch S is open, so the inductor current flows through the load. If we consider zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$V_i - V_o = L \frac{dI_L}{dt}$$

(2.3)

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{L_{Off}} = \int_{DT}^{T} \frac{(V_i - V_o)\, dt}{L} = \frac{(V_i - V_o)\,(1 - D)\,T}{L}$$

(2.4)

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at

the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2}LI_L^2$$
(2.5)

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{LOn} + \Delta I_{LOff} = 0$$
(2.6)

Substituting ΔI_{LOn} and ΔI_{LOff} by their expressions yields:

$$\Delta I_{LOn} + \Delta I_{LOff} = \frac{V_i DT}{L} + \frac{(V_i - V_o)(1 - D)T}{L} = 0$$
(2.7)

This can be written as:

$$\frac{V_o}{V_i} = \frac{1}{1 - D}$$
(2.8)

Which in turn reveals the duty cycle to be:

$$D = 1 - \frac{V_i}{V_o}$$
(2.9)

The above expression shows that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1), and that it increases with D, theoretically to infinity as D approaches 1. This is why this converter is sometimes referred to as a *step-up* converter.

Condition for continuous inductor current and capacitor voltage

If I_L is the average inductor current, the inductor ripple current $\Delta I = 2I_L$.

$$\frac{DV_s}{fL} = 2I_L = 2I_a = \frac{2V_s}{(1-D)R} \qquad (3.0)$$

Which gives the critical value of the inductor L_c as

$$L = \frac{D(1-D)^2 R}{2f} \qquad (3.1)$$

If V_c is the average capacitor voltage, the capacitor ripple voltage $\Delta V_c = 2V_a$.

$$2V_a = 2I_a R \qquad (3.2)$$

Which gives the critical value of the capacitor C_c as

$$C_c = C = \frac{DxV_{out}}{f\Delta VR} \qquad (3.3)$$

2.4   FUZZY LOGIC CONTROLLER

The most important specifications of fuzzy control method are their fuzzy logical ability in the quality perception of system dynamics and the application of these quality ideas simultaneously for power systems [4]. A simple block diagram of a fuzzy system is shown in Fig.2-4.
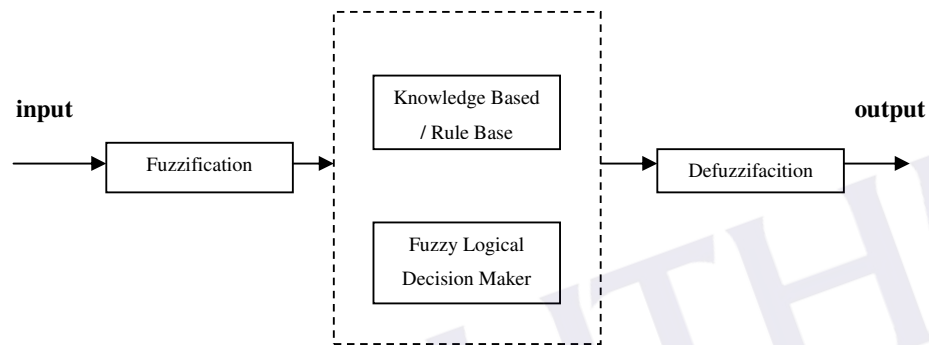
Figure 2-4: Structure of fuzzy logic controller

a) Input

The inputs are most often hard or crisp measurement from some measuring equipment is converted into fuzzy values for each input fuzzy set with the fuzzification block. [4]

b) Fuzzification

The fuzzification block performs the following tasks:

- Measures the value of input variables.
- Performs a scale mapping that transfers the range of values of input variables into the corresponding universes of discourse.
- Performs the function of fuzzification, which converts input data into suitable linguistic values that may be viewed as labels of fuzzy sets.

c) Knowledge based/rule base

The collection of rules is called a rule base. The rules are in "If Then" format and formally the If side is called the conditions and the Then side is called the conclusion. The computer is able to execute the rules and compute a control

signal depending on the measured inputs error (e) and change in error.(de). In a rule based controller the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.[4]

d) Fuzzy logical

The fuzzy engine is the kernel of a fuzzy logic controller, which has capability of simulating human decision making based on fuzzy concepts and of inferring fuzzy control actions using fuzzy implication (fuzzy relation) and the rules of inference in fuzzy logic. This means that the fuzzy inference engine handles rule inference where human experience can easily be injected through linguistic rules.

e) Defuzzication

Defuzzification is when all the actions that have been activated are combined and converted into a single non-fuzzy output signal which is the control signal of the system. The output levels are depending on the rules that the systems have and the positions depending on the non-linearities existing to the systems. To achieve the result, develop the control curve of the system representing the I/O relation of the systems and based on the information; define the output degree of the membership function with the aim to minimize the effect of the non-linearity.[4]

f) Output

The output is output gain that can be tuned and also become as an integrator .The output crisp value can be calculated by the centre of gravity or the weighted average.[4]

METHODOLOGY

3.1 RESEARCH DESIGN

The proposed general block diagram for Power Factor Correction boost converter single phase rectifier using Fuzzy Logic is shown in Figure 3-1 The operation of this circuit consist single phase rectifier, boost converter, PWM and Fuzzy Logic.

The source of the circuit from DC input from single phase rectifier. The output from boost converter is controlled by Fuzzy Logic control technique in the feedback path and linear programming rule on PWM ramp voltage to control duty cycle of the switch for shaping the input current waveform.
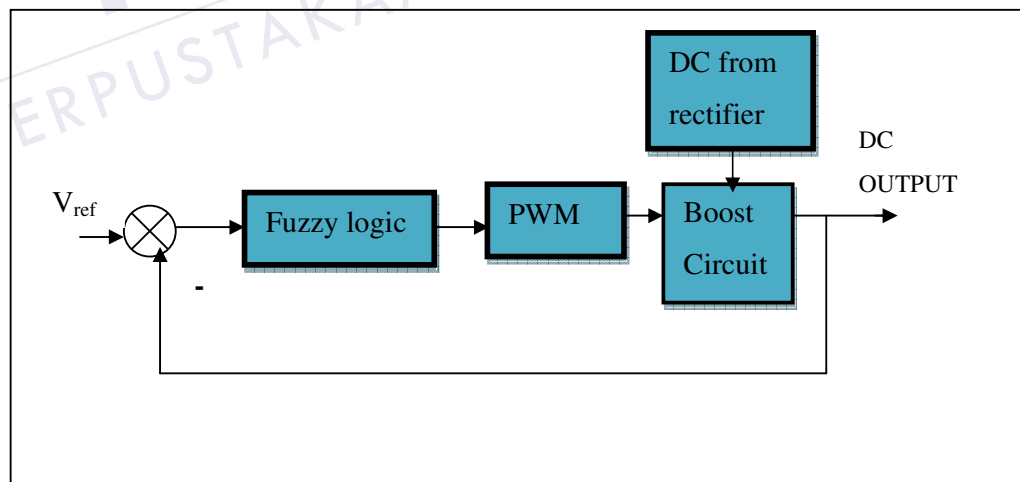

Figure 3-1:Boost Converter with proposed controller

Lastly, to investigate the effectiveness of proposed Fuzzy Logic Control, simulation with MATLAB simulink will be conducted.
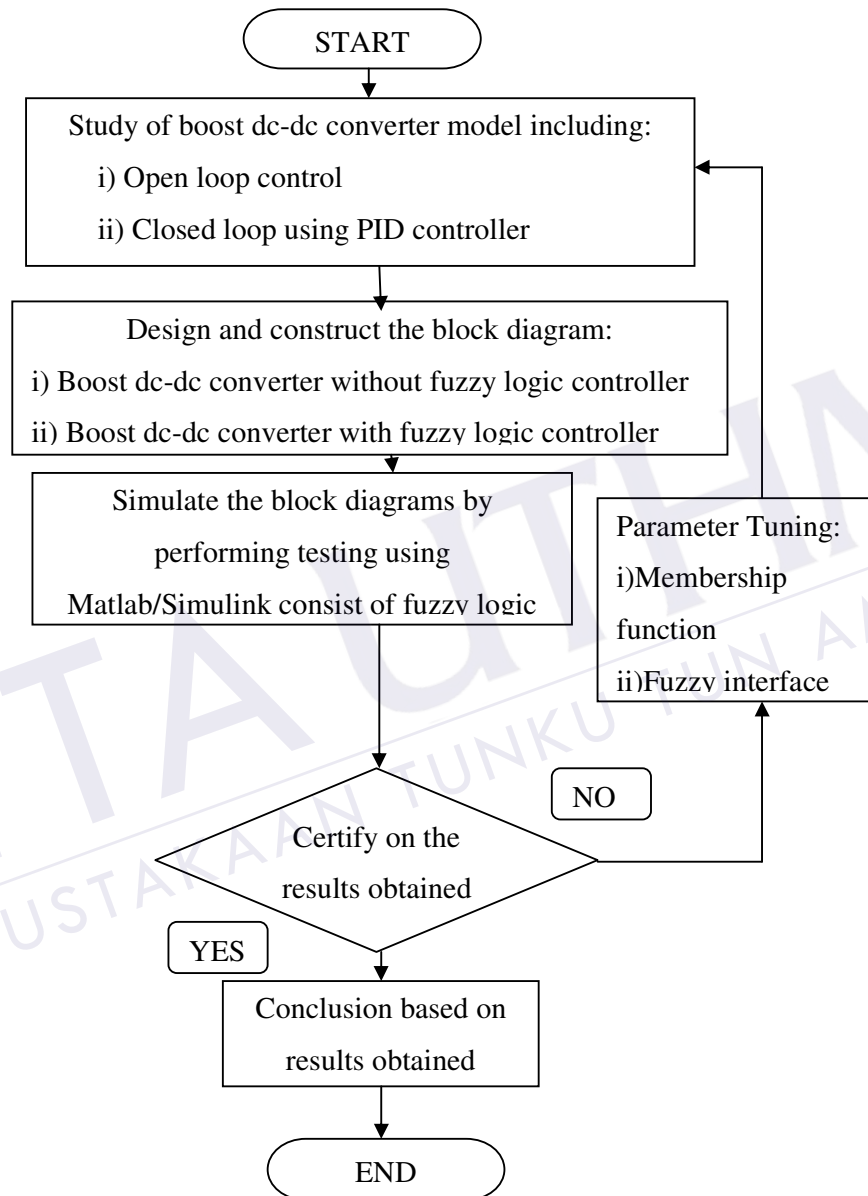
```
                    ┌──────────────┐
                    │    START     │
                    └──────────────┘
                           │
                           ▼
    ┌──────────────────────────────────────────────┐
    │  Study of boost dc-dc converter model         │
    │  including:                                    │
    │      i) Open loop control                      │
    │      ii) Closed loop using PID controller      │
    └──────────────────────────────────────────────┘
                           │
                           ▼
    ┌──────────────────────────────────────────────┐
    │  Design and construct the block diagram:       │
    │  i) Boost dc-dc converter without fuzzy logic  │
    │     controller                                 │
    │  ii) Boost dc-dc converter with fuzzy logic    │
    │      controller                                │
    └──────────────────────────────────────────────┘
                           │
                           ▼
    ┌──────────────────────┐       ┌───────────────────┐
    │ Simulate the block   │       │ Parameter Tuning: │
    │ diagrams by          │       │ i)Membership      │
    │ performing testing   │       │ function          │
    │ using                │       │ ii)Fuzzy interface│
    │ Matlab/Simulink      │       └───────────────────┘
    │ consist of fuzzy     │
    │ logic                │
    └──────────────────────┘
                           │
                           ▼          NO
                    ◇ Certify on the ◇ ────────►
                    ◇ results obtained◇
                           │ YES
                           ▼
    ┌──────────────────────┐
    │ Conclusion based on  │
    │ results obtained     │
    └──────────────────────┘
                           │
                           ▼
                    ┌──────────────┐
                    │     END      │
                    └──────────────┘
```

Figure 3-2:Methodology Flowchart

3.2   FUZZY LOGIC CONTROLLER FOR BOOST DC TO DC CONVERTER

An analysis of boost converter circuit revealed that the inductor current plays significant task in dynamic response of boost converter. Additionally, it can provide the storage energy information in the converter. Thus, any changes of inductor may effect output voltage and output voltage will provide steady state condition information of converter. However, the three main parameter need to be considered when designing boost converters are power switch, inductor and capacitor. In this objective to achieve the desired output voltage[9].

Figure 3-3 shows Block diagram Fuzzy Logic Controller for Boost Dc to Dc Converter. Fuzzy controller is based on Mamddani Fuzzy system with contain two input variables that are defined by equation 3.4, equation 3.5 and only ouput variable equation 3.6.

$$e = V_{ref} - V_o \qquad (3.4)$$

$$de/dt = e_{(k)} - e_{(k-1)} \qquad (3.5)$$

$$\Delta U = k_1 e + k_2 \frac{de}{dt} \qquad (3.6)$$

The fuzzy controller, control the output voltage,V_o. Fuzzy controller have two input , error voltage(e) and change of error voltage (de). The error voltage is obtain from Difference between output feedback voltage(V_o) and refference voltage (V_{ref}). The change in voltage (de/dt) is the difference between error voltage and previous voltage.
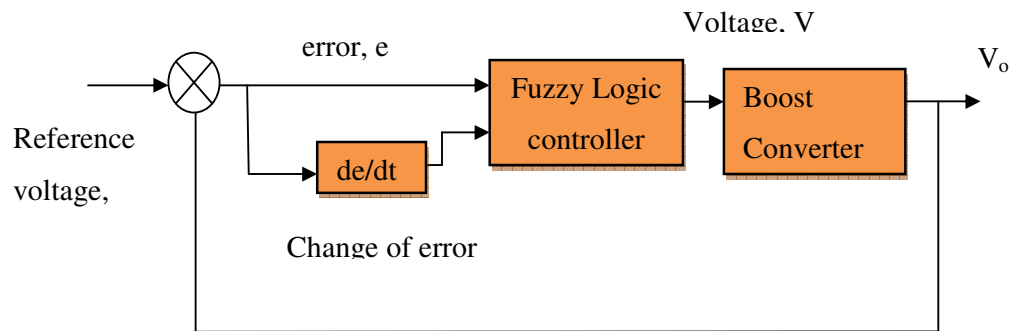
Figure 3-3: Block diagram Fuzzy Logic Controller for Boost
Dc to Dc Converter

3.2.1 FUZZY LOGIC MEMBERSHIP FUCTION

The input error voltage (e) and changing error voltage(de) have seven membership
function. Fuzzy controller compare two voltage membership function and produced
one output voltage membership function represent at FIS Editor as shown in Figure
3-4. Figure 3-5 shows the input error voltage (e) in the fuzzy system have seven
membership function. Figure 3-6 represent the input variable (de) in the fuzzy system
have seven membership function. The output variable has seven membership
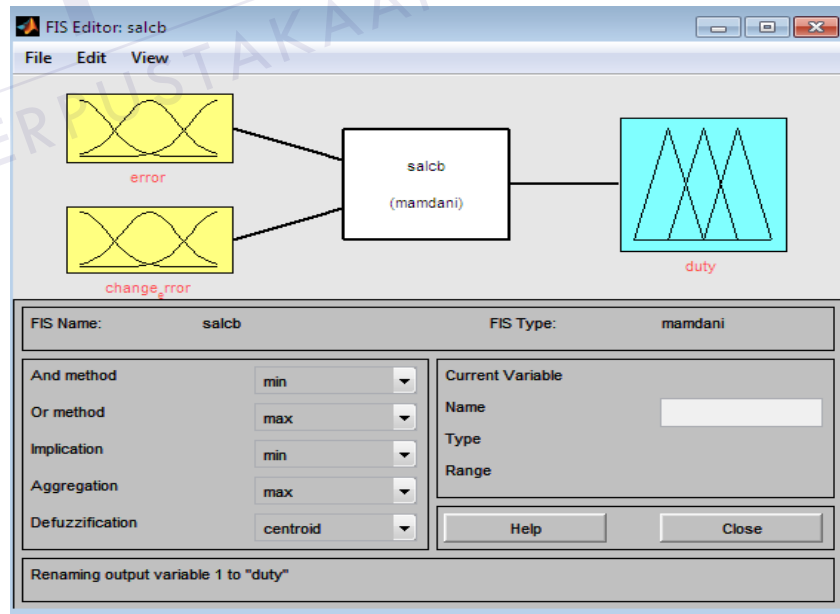function as shown in Figure 3-7.
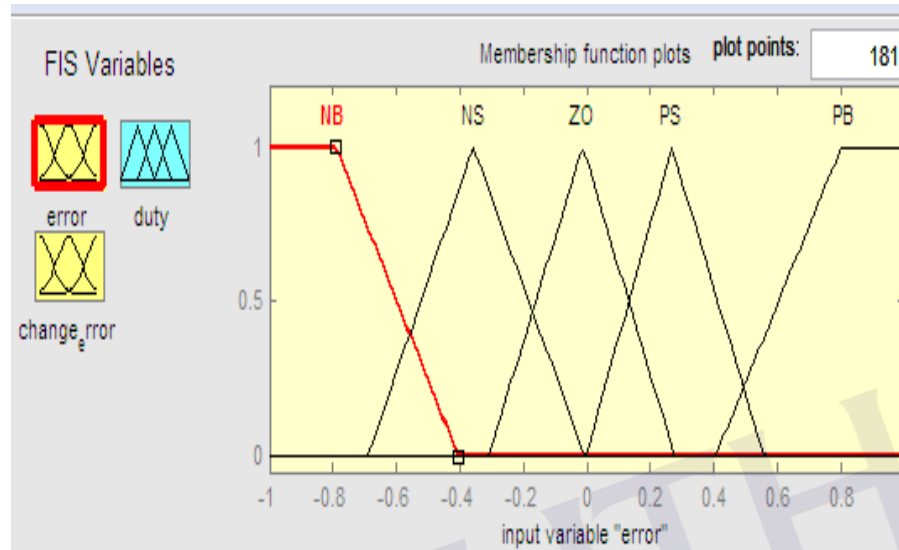

Figure 3-4: FIS Editor
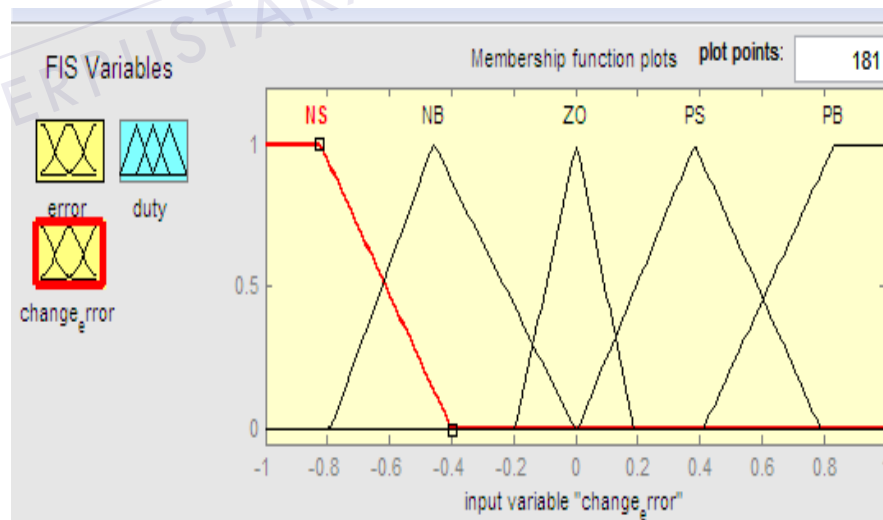
Figure 3-5:Membership Function of input error(e)

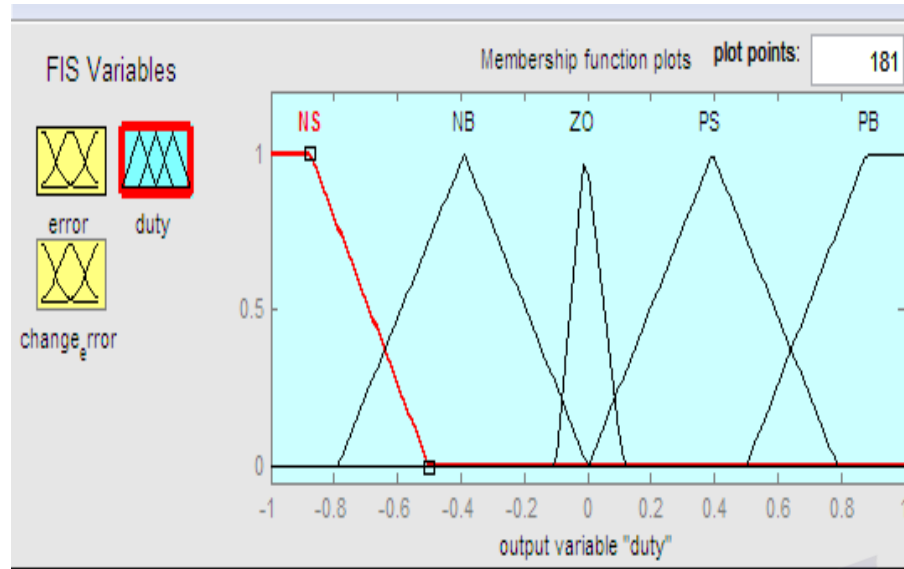Figure 3-6:Membership Fuction of input variable (de)

Figure 3-7:Membership function of output variabale

3.2.2 FUZZY RULES

The rules are set based upon the knowledge and working of the system. The rule base adjusts the duty cycle for the PWM of the boost converter based upon the changes in the input of fuzzy logic controller. The number of rules can be set as desired. The rules based include 25 rules, which are based upon the 5 membership functions of the input variable. Table 3.0 shows the fuzzy rules.

Table 3.0 Lookup table for the fuzzy control scheme

e / $\triangle$ e	NB	NS	ZO	PS	PB
NB	NS	NB	NB	NB	ZO
NS	NS	NS	NS	ZO	PB
Z	NS	NS	ZO	PB	PB
PS	NB	ZO	PB	PS	PS
PB	ZO	PS	PS	PS	PS

The 25 rules fuzzy rules are made by using the two input its is error,variable of error and seven membership function. For example;

1.   When the output of the converter is far from the reference point, the change of duty cycle must be large to bring the output to the reference point.

2.   When the output of the converter is approaching the reference point, a small Change of duty cycle is necessary.

3.   When the output or the converter is near the reference point and is approaching it rapidly, the duty cycle must be kept constant so as to prevent overshoot.

4.   When the reference point is reached and the output is still changing, duty cycle must be changed a little bit to prevent the output from moving away.

5.   When the set point is reached and the output is steady, the duty cycle is unchanged.
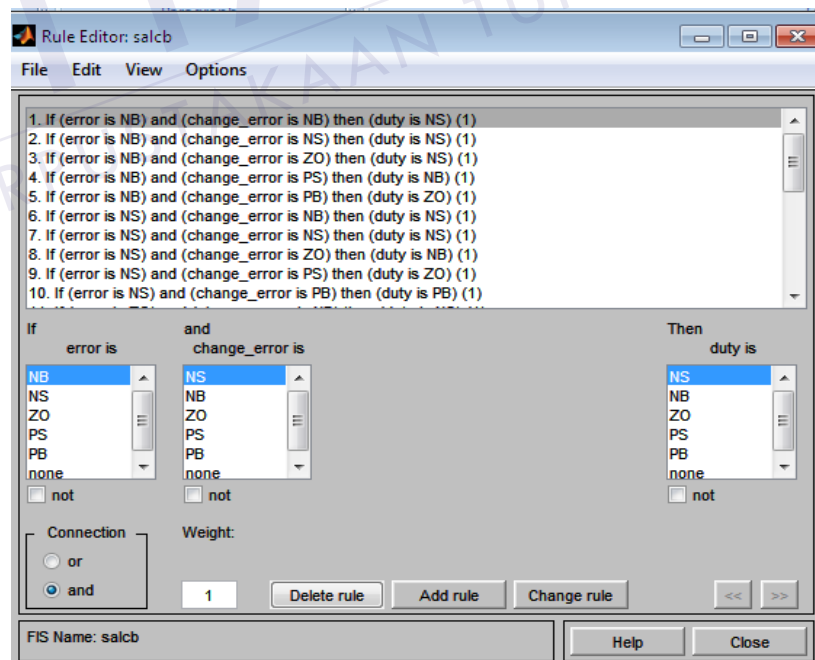

Figure 3-8: Rule Base For Propose Fuzzy Logic Controller

The rules for this system design are as follows:

1. If ("e" is NB) and (Change Error "de" is NB) then (Output "duty ratio" is NS)(1)

2. If ("e" is NB) and (Change Error "de" is NS) then (Output "duty ratio" is NS)(1)

3. If ("e" is NB) and (Change Error "de" is ZO) then (Output "duty ratio" is NS)(1)

4. If ("e" is NB) and (Change Error "de" is PS) then (Output "duty ratio" is NB)(1)

5. If ("e" is NB) and (Change Error "de" is PB) then (Output "duty ratio" is ZO)(1)

6. If ("e" is NS) and (Change Error "de" is NB) then (Output "duty ratio" is NS)(1)

7. If ("e" is NS) and (Change Error "de" is NS) then (Output "duty ratio" is NS)(1)

8. If ("e" is NS) and (Change Error "de" is ZO) then (Output "duty ratio" is NS)(1)

9. If ("e" is NS) and (Change Error "de" is PS) then (Output "duty ratio" is ZO)(1)

10. If ("e" is NS) and (Change Error "de" is PB) then (Output "duty ratio" is PS)(1)

11. If ("e" is ZO) and (Change Error "de" is NB) then (Output "duty ratio" is NS)(1)

12. If ("e" is NB) and (Change Error "de" is NB) then (Output "duty ratio" is NB)(1)

13. If ("e" is ZO) and (Change Error "de" is ZO) then (Output "duty ratio" is ZO)(1)

14. If ("e" is ZO) and (Change Error "de" is PS) then (Output "duty ratio" is PB)(1)

15. If ("e" is ZO) and (Change Error "de" is PB) then (Output "duty ratio" is PS)(1)

16. If ("e" is PS) and (Change Error "de" is NB) then (Output "duty ratio" is NB)(1)

17. If ("e" is PS) and (Change Error "de" is NS) then (Output "duty ratio" is ZO)(1)

18. If ("e" is PS) and (Change Error "de" is ZO) then (Output "duty ratio" is PB)(1)

19. If ("e" is PS) and (Change Error "de" is PS) then (Output "duty ratio" is PS)(1)

20. If ("e" is PS) and (Change Error "de" is PB) then (Output "duty ratio" is PS)(1)

21. If ("e" is PB) and (Change Error "de" is NB) then (Output "duty ratio" is NB)(1)

22. If ("e" is PB) and (Change Error "de" is NS) then (Output "duty ratio" is PB)(1)

23. If ("e" is PB) and (Change Error "de" is ZO) then (Output "duty ratio" is PB)(1)

24. If ("e" is PB) and (Change Error "de" is PS) then (Output "duty ratio" is PS)(1)

25. If ("e" is PB) and (Change Error "de" is PS) then (Output "duty ratio" is PS)(1)
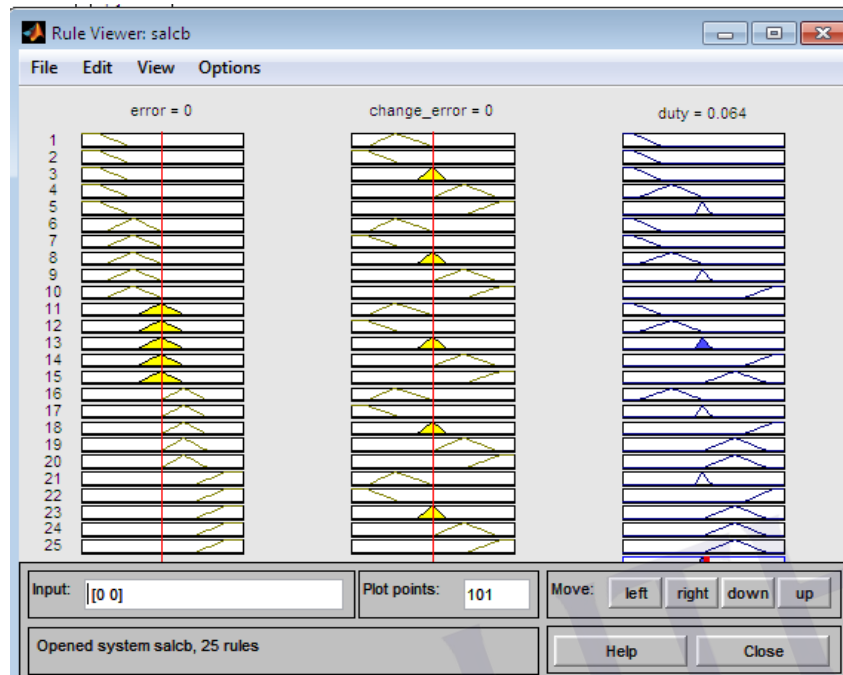
Figure 3-9: Rule View For Propose Fuzzy Logic Controller

REFERENCES

[1]   T.Gupta, R.R.Boudreaux, R.M. Nelms and J.Hung,"Implementation of Fuzzy controller for DC-DC converters using an inexpensive 8-b microcontroller," IEEE Trans. Industrial Electronics, vol 44, no.5, pp. 661-669, Oct.1997.

[2]   Purton K.D and Lisner R.P, "*average current mode control in power electronic converters- analog versus digital*," IEEE Trans. On Power Electron, vol.8, no.2,pp 102-523 2006

[3]   R. carbone, P. corsonello, M. Fantauzizi, A. Scappatura: *" Power Factor Correctors for Single-Phase Rectifier: a Comparative Performance Analysis"* 3th IASTED Intern. Conf. EUROPES 2003, September 3-5, 2003, Marbella, Spain.

[4]   K.Periyasamy, *"Power Factor Correction Based on Fuzzy Logic Controller with Average Current-Mode for DC-Dc Boosts Converter"* International Journal of Engineering Research and Application(IJERA), ISSN: 2248-9622 Vol.2, Issue 5, September-October 2012, pp.771-777

[5]`   A. Kessal, L. Rahmani, M. Mostefai, J. Gaubert*." Power Factor Correction based on Fuzzy Logic Controller with Fixed Switching Frequency // Electronics and Electrical Engineering*". – Kaunas: Technologija, 2012. – No. 2(118). – P. 67–72.

[6]   Martinez S., F.H," Fuzzy logic controller for boost converter with active power factor correction". Power Electronics, 2007. ICPE '07. 7th International Conference on

[7]   Jan Jantzen, (1998): *Design Of Fuzzy Controllers* Technical University of Denmark, Department of Automation, Bldg 326, DK-2800 Lyngby, DENMARK

[8]   Muhammad H.Rashid,2004: Power Electronics,Circuit,Devices, And   . Application.Third Edition, Prentce Hall

[9]   Ismail, N. I., Baharom, R., & Johari, D. (2010). Fuzzy logic controller on DC/DC boost converter. *Power and Energy (PECon), 2010 IEEE International Conference* . Kuala Lumpur.

[10]   Ing.Esp.fredy H. Martinez S, Ing.Teg.Diego F. Gomez (2007). Fuzzy logic controller for boost converter with active power factor correction. The 7th International conference on Power electronic.

[11]   Ismail Daut, Rosnazri Ali and Soib Taib(2006). Design of a single-phase rectifier with improved power factor and low THD using boost converter techniques.Amarican Journal of Applied Science 3(9):2025-2028,2006 ISSN 1546-9239.