DEVELOPMENT OF A BOOST CONVERTOR FOR PHOTOVOLTAIC SYSTEM MPPT USING FUZZY LOGIC CONTROL

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ABSTRACT

Photovoltaic (PV) systems has received great attention in research for generating renewable energy due to its advantages over fossil based energy in terms of sustainability, environmental friendliness and price stability. However, the widespread use of PV meets several challenges such as increasing the efficiency of PV conversion. Another drawback of PV system is that it does not provide a constant energy source because its output power changes with temperature and irradiation or insulation. PV modules have unique current versus voltage characteristics. From the I-V characteristics, PV systems must be operated at a maximum power point (MPP) of specific current and voltage values so as to increase the PV efficiency. For any PV system, the output power can be increased by tracking the MPP of the PV module by using a controller connected to a boost converter. An important consideration in increasing the efficiency of PV systems is to operate the system near maximum power point (MPP) so as to obtain the approximately maximum power of PV array. To achieve maximum energy produced by a PV array, maximum power point tracking (MPPT) techniques are used. The position of the MPP is unknown but can be traced by using an MPPT To overcome this problem, Maximum Power Point Tracker DC-DC Boost convertor are developed using Fuzzy Logic Control. The Fuzzy Logic Controller and the MPPT it self are being represented and implimented using Mathlab Simulink.

ABSTRAK

Sistem Photovoltaic (PV) telah mendapat perhatian yang besar dalam penyelidikan kerana kelebihannya untuk menjana tenaga boleh diperbaharui dan dari segi kemampanan, mesra alam sekitar dan kestabilan harga. Walau bagaimanapun, penggunaan meluas PV mempunyai beberapa cabaran seperti meningkatkan kecekapan penukaran PV. Satu lagi kelemahan sistem PV adalah bahawa ia tidak menyediakan sumber tenaga yang berterusan kerana perubahan kuasa keluaran bergantung kepada suhu dan sinaran serta penebatan. Modul PV mempunyai ciri kuasa yang unik dengan mempunyai ciri-ciri Arus melawan Voltan yang unik. Daripada ciri-ciri Arus melawan Voltan tersebut, sistem PV mesti beroperasi pada titik kuasa maksimum (MPP) pada nilai arus dan voltan khusus untuk meningkatkan kecekapan PV. Bagi mana-mana sistem PV, kuasa keluaran boleh ditingkatkan dengan menjejaki titik dimana keluaran tenaga maksimum pada modul PV tersebut dengan menggunakan pengawal disambungkan kepada penukar DC. Satu pertimbangan yang penting dalam meningkatkan kecekapan sistem PV adalah untuk mengendalikan sistem pada titik kuasa maksimum (MPP) supaya sistem ini mendapatkan kuasa maksimum dari modul PV. Untuk mencapai tenaga maksimum yang dihasilkan oleh modul PV, Teknik Pengesanan Titik Kuasa Maksimum (MPPT) digunakan. Kedudukan titik maksimum kuasa adalah diketahui dan boleh dikesan dengan menggunakan pengesan titik kuasa maksimum dan Untuk mengatasi masalah ini, pengesan kuasa maksimum dan Penukar DC dibangunkan menggunakan Kawalan Logik Fuzi. Pengawal Logik dan MPPT tersebut di implimentasi dengan menggunakan perisian Mathlab Simulink.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

This project presents the application of a novel fuzzy logic controller (FLC) as an intelligent MPPT method for PV system operating under variations in external disturbances. The paper is so structured as follows: firstly a brief insight into the P-V characteristic of a PV module is given, the model of considered grid-connected PV system is illustrated, and the P&O then the proposed FLC is discussed and the relative control scheme is presented and some numerical results are reported in order to validate the effectiveness of the proposed FLC method.

The fuzzy logic based MPPT controller can be installed in either the standalone or grid connected PV generation system schemes. Basically, a PV system consists of a PV array to generate electric power, dc-dc controller with maximum power point tracker (MPPT), inverter with filter and static or dynamic load. The power drawn from the PV modules is maintained around its maximum value by a MPPT algorithm. For a standalone PV system, the excess energy is stored in a battery that will be used to supply power to the loads when the energy from the PV modules is not sufficient.

1.2 Problem Statements

Photovoltaic (PV) as a renewable energy resource naturally is not stable by location, time, season and weather and its installation cost is comparatively high. An important consideration in increasing the efficiency of PV systems is to operate the system near maximum power point (MPP) so as to obtain the approximately maximum power of PV array. To achieve maximum energy produced by a PV array, maximum power point tracking (MPPT) techniques are used. The position of the MPP is unknown but can be traced by using an MPPT algorithm to extract power from the PV array at its MPP [1]. However, the MPP is always changing with irradiation level and temperature due to the characteristic of PV array and this makes MPPT control a complicated problem [2]. A typical MPPT controller is a component that provides pulse width modulation (PWM) signal which is controlled by a triggering signal with a specific duty cycle to trigger the switch of the DC-DC converter in order to locate the operating point of the PV system as close as possible to its MPP [3]

The conventional boost converter operates in hard switching thus making it inefficient where voltages and currents in semiconductor devices changed abruptly from high values to zero and vice versa at turn-on and turn-off times, thus causing switching losses and electromagnetic interference. , the tracking control of MPP is a complicated problem. To overcome this problem, many MPPT (MPP tracking) control algorithms have been proposed such as the perturbation and observation (P&O), incremental conductance (IncCo), Constant voltage and fuzzy logic control [2]. Fuzzy logic has been used for tracking the MPP of PV systems because it has the advantages of being robust, relatively simple to design and does not require the knowledge of an exact model.

1.3 Project Objectives

This project has been developed to enhance the achievement in the following matters:

a) To develop the design of DC-DC Boost convertor PV system MPPT using Fuzzy Logic Control.
b) To implement the simulation of DC-DC Boost convertor PV system MPPT using Fuzzy Logic Control Matlab® simulink software.

1.4 Scope Of Project

The scope of project has been determined in order to achieve the objective of this project. This project are to get high efficiency MPPT using FLC . The development of the DC-DC Boost convertor Photovoltaic System MPPT using Fuzzy Logic Control design and the implementation of the simulation are using the MATLAB simulink software.

CHAPTER 2

LITERATURE REVIEW

2.1 Theories

In this chapter, each part in MPPT controller is being discussed. Advantages and disadvantages for each of them will be highlighted. The part discussed is boost convertor, MPPT and FLC.

2.2 Boost Convertor

Boost converter is a DC-DC converter that steps up its input voltage based on the formula given :

$$Vout = \frac{1}{1-D}Vin \tag{2.1}$$

Where Vout is the output voltage of the boost converter, Vin is the input voltage and D is the duty cycle which is the ratio between the time within which the IGBT. The circuit diagram of the boost converter is shown in Fig. (1). It consists of an inductor, an IGBT switch, a fast switching diode and a capacitor. The configurations of the boost converter circuit during switching ON and OFF intervals are shown in Figs. 2 and 3, respectively. When the IGBT is switched ON ($0 \leq t > t_{on}$), the inductor is directly connected to the input voltage source. In this case, the inductor current rises charging it and the inductor is storing energy while the diode is reverse biased disconnecting the load (R) and output capacitor (C) from the source voltage. During this interval, the pre-charged capacitor assures constant voltage across the load terminals. When the IGBT is switched OFF ($t_{on} \leq t > Ts$) where Ts is the switching period, the diode is forward biased and both the source and the charged inductor are connected to the load. The inductor releases the energy stored in it. This energy is transferred to the load in the form of voltage that adds to the source voltage. Hence, the converter boosts the input voltage. Figure 1,2 and 3 shows the basic circuit of a boost convertor, boost convertor in on state, and the convertor in off state.

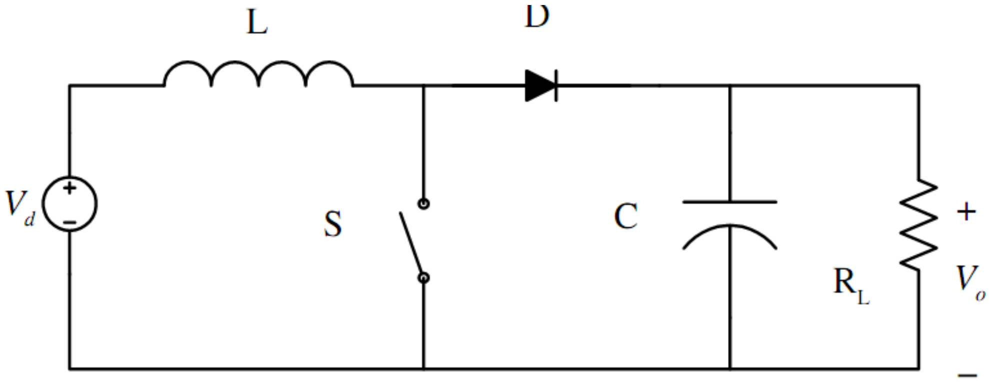


Figure 2.2.1 : Basic circuit of a boost convertor

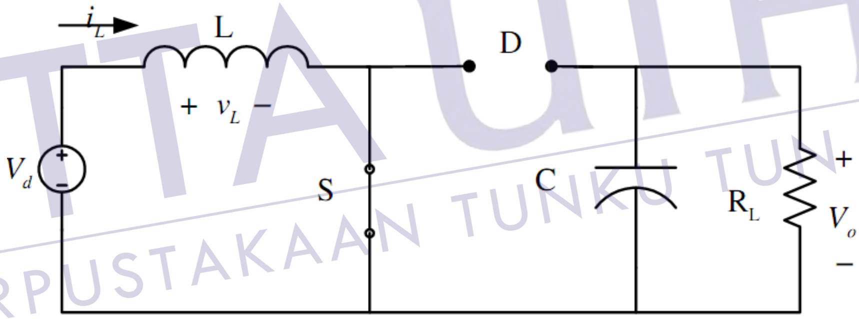


Figure 2.2.2 : Boost convertor in on state

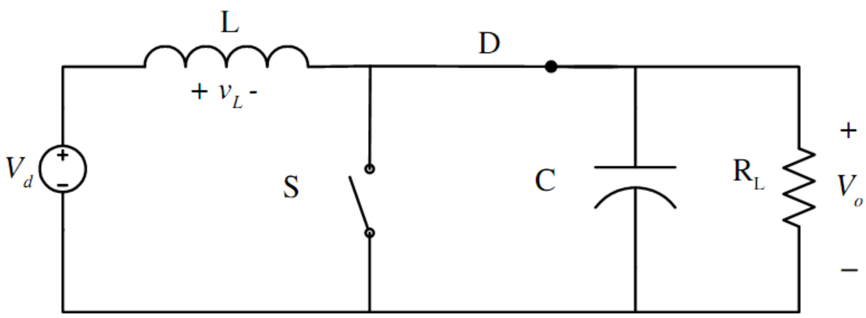


Figure 2.2.3: Boost convertor in off state

2.3 Maximum Power Point Tracking

Maximum power point tracking (MPPT) is a technique that grid tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more solar panels. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency known as the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions.

Controllers usually follow one of three types of strategies to optimize the power output of an array. Maximum power point trackers may implement different algorithms and switch between them based on the operating conditions of the array.

2.3.1 Perturb & Observe

In one method, the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common, although this method can result in oscillations of power output. It is referred to as a *hill climbing* method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

The nature of the P&O is a self-optimizing process. If the maximum power point Pm is the demarcation point, when V (k)> V (k-1), if P (k)-P (k-1)> 0, then the solar cell work in the left section of the curve, To make the operating point close to the maximum power Pm point, need to continue to increase the output voltage V; In contrast, V (k)> V (k-1), if P (k)-P (k-1) <0, then the solar cell work in the right part of the curve, in order to make the operating point near the point of maximum power Pm, require to reduce the output voltage V. Perturbation and observation method of the control flow chart in Figure 2.3.1.

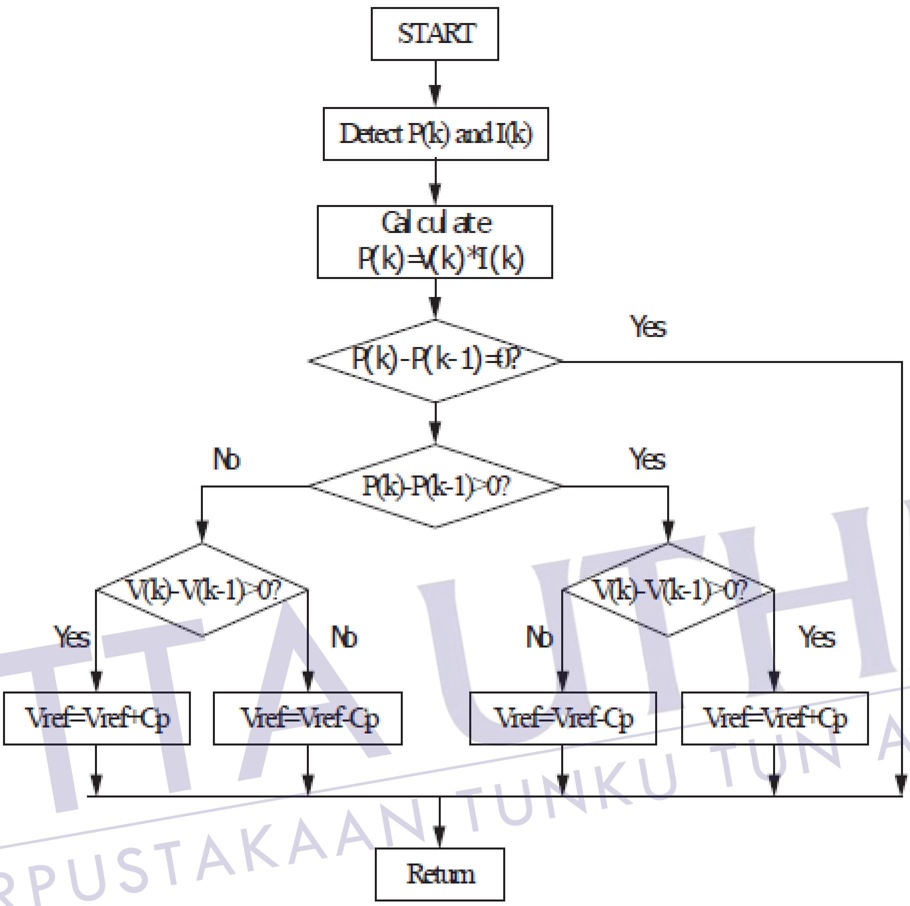


Figure 2.3.1: Module control flow of perturbation and observation method

2.3.2 Incremental conductance

In the incremental conductance method, the controller measures incremental changes in array current and voltage to predict the effect of a voltage change. This method requires more computation in the controller, but can track changing conditions more rapidly than the perturb and observe method. Like the P&O algorithm, it can produce oscillations in power output. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV). The incremental conductance method computes the maximum power point by comparison of the incremental conductance ($\Delta I/\Delta V$) to the array conductance (I/V). When the incremental conductance is zero, the output voltage is the MPP voltage. The controller maintains this voltage until the irradiation changes and the process is repeated.

2.3.3 Constant voltage

In the constant voltage method, the power delivered to the load is momentarily interrupted and the open-circuit voltage with zero current is measured. The controller then resumes operation with the voltage controlled at a fixed ratio, such as 0.76, of the open-circuit voltage, which has empirically been determined as the estimated maximum power point. The operating point of the PV array is kept near the MPP by regulating the array voltage and matching it to a fixed reference voltage Vref. The Vref value is set equal to the maximum power point voltage of the characteristic PV module or to another calculated best fixed voltage.

One of the approximations of this method is that variations of individual panels are not considered. The constant reference voltage can be considered as the maximum power point voltage. The data for this method varies with geographical location and has to be processed differently for different geographical locations. The CV method does not require any input. It is important to observe that when the PV panel is in low insolation conditions, the CV technique is more effective than either the P&O method or the IC method (analyzed below). Thanks to this characteristic, CV is sometime combined together with other MPPT techniques.

2.3.4 Fuzzy Logic Control (FLC)

Fuzzy control method is applied for the nonlinear characteristics of photovoltaic cells. It is the changes to power on the voltage or current, and its rate of change as fuzzy input variables, by fuzzy processing and fuzzy identification based on expert experience, the membership adjusting the output is given, the final membership values carry on defuzzification to gain Adjust volume, to achieve control of the maximum power output. Advantage of this method is not dependent on accurate mathematical model of control object, and has good dynamic performance and accuracy, good robustness.

Fuzzy control has adaptive characteristics in nature, and can achieve robust response to a system with uncertainty, parameter variation, and load disturbance. It has been broadly used to control an ill-defined, nonlinear, or imprecise system. In the field of power electronics, fuzzy control has been successfully applied to regulate and handle dc–dc converters, pulse width modulated (PWM) source inverters and maximum power point tracking in energy conversion systems. Among these systems, fuzzy control does not require accurate models of them.

2.4 Introduction to switching

Two switching conditions taken place in the dc to dc converter;

i. power semiconductor devices switching (such as igbt, mosfet, scr)

ii. switching mode (continuous conduction mode and discontinuous conduction mode)

Power semiconductor devices is a physical component that needed in constructing dc to dc converter while switching mode can be achieved from calculation regarding the value of inductance in the dc to dc converter circuit.

2.4.1 Power semiconductor device

The range of power devices developed over the last few decades can be represented as a in figure 2.3 on the basis of their controllability and other dominant features.

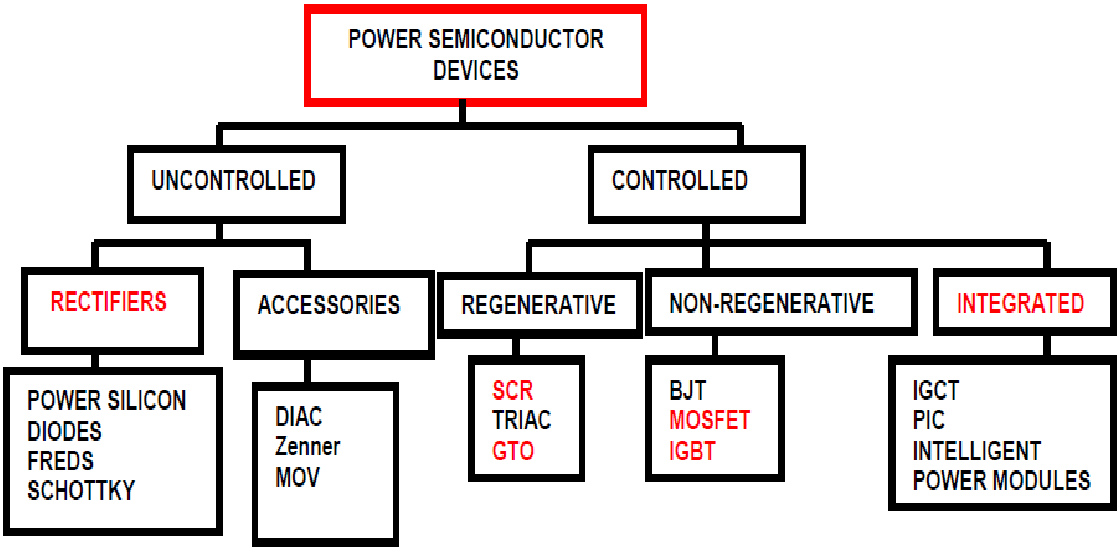


Figure 2.4.1: Power semiconductor device variety

In designing boost converter, controlled with non-regenerative power semiconductor components is selected to be a switching device. Most of buck-boost converter designed only used either mosfet or igbt nowadays.

2.4.2 MOSFET (Metal Oxide Semiconductor Field Effect Transistor)

The Power MOSFET technology has mostly reached maturity and is the most popular device for lighting ballast type of application where high switching frequencies are desired but operating voltages are low. For low frequency applications, where the currents drawn by the equivalent capacitances across its terminals are small, it can also be driven directly by integrated circuits. At high current low voltage applications the MOSFET offers best conduction voltage specifications as the internal resistance is current rating dependent. However, the inferior features of the inherent anti-parallel diode and its higher conduction losses at power frequencies and voltage levels restrict its wider application.

2.4.3 IGBT (Insulated Gate Bipolar Transistor)

It is a voltage controlled four-layer device with the advantages of the MOSFET driver and the Bipolar Main terminal. The switching times can be controlled by suitably shaping the drive signal. This gives the IGBT a number of advantages: it does not require protective circuits, it can be connected in parallel without difficulty, and series connection is possible without snubbers. The IGBT is presently one of the most popular devices in view of its wide ratings, switching speed of about 100 KHz, an easy voltage drive and a square safe operating area devoid of a second breakdown region.

2.4.4 Switching mode

As mention in introduction to swiching, the CCM and DCM can be achieved from calculation regarding the value of inductance in the dc to dc converter circuit. When the current through the inductor can fall to zero, the condition is known as *discontinuous conduction mode* (DCM) operation. When the inductor current never falls to zero, or when the power supply employs synchronous rectification, the condition is said to be in *continuous conduction mode* (CCM). Figure 2.4 shows the inductor current in CCM and DCMcondition.

2.4.5 Advantages of DCM

i. The CCM boost, buck-boost, and flyback topologies have a right half planes zero (RHPZ) in their control to output transfer function. The right half plane zero is nearly impossible to compensate for in the compensation loop. As a result, the control loop in these CCM converters is typically made to cross over at a frequency much lower than the RHPZ frequency resulting in lower transient response bandwidths. The DCM version of the boost, buck-boost, and flyback converters do not have a right half plane zero and can have higher loop crossover frequency allowing higher transient response bandwidths.

ii. In the buck, boost, buck-boost, and all topologies derived from these, the input to output and control to output transfer functions contain single pole responses while operating in DCM. Converters with only single pole transfer functions are easier to compensate than converters having a double pole response.

2.4.6 Disadvantages of DCM

i. In DCM, the inductor current reaches zero while in non-synchronous operation, the end of the inductor connected to the switch (also called the freewheel end), must immediately transition to the voltage at the other end of the inductor. However, there will always be inductive and capacitive parasitic elements which will cause severe ringing if damping is not implemented. This ringing can produce undesirable noise at the output of the power supply.

ii. Boost, buck-boost, and derived topologies are commonly operated only in DCM to avoid the adverse effects of the RHPZ described earlier. However, to achieve the same power in DCM as in CCM, the peak and RMS currents are substantially higher resulting in greater losses in the conduction paths and greater ringing because the energy stored in inductances is proportional to the square of the current. Energy stored that is not delivered to the output causes ringing and losses.

iii. In DCM, the inductance must be much smaller in value to allow the current to fall to zero before the start of the next cycle. Smaller inductance results in higher RMS and peak inductor currents. Because the RMS and peak currents are greater in DCM than in CCM, the transformers must be sized larger to accommodate greater flux swings and copper and core losses. DCM has a physically larger transformers and inductors required for same power output as CCM.

2.5 Introduction to Fuzzy Logic controller

Since its introduction in 1965 by Lotfi Zadeh (1965) [8], the fuzzy set theory has been widely used in solving problems in various fields, and recently in educational evaluation. Fuzzy control is a practical alternative for a variety of challenging control applications since it provides a convenient method for constructing nonlinear controllers via the use of heuristic information. Figure 2.3 shows the structure of the fuzzy logic controller.

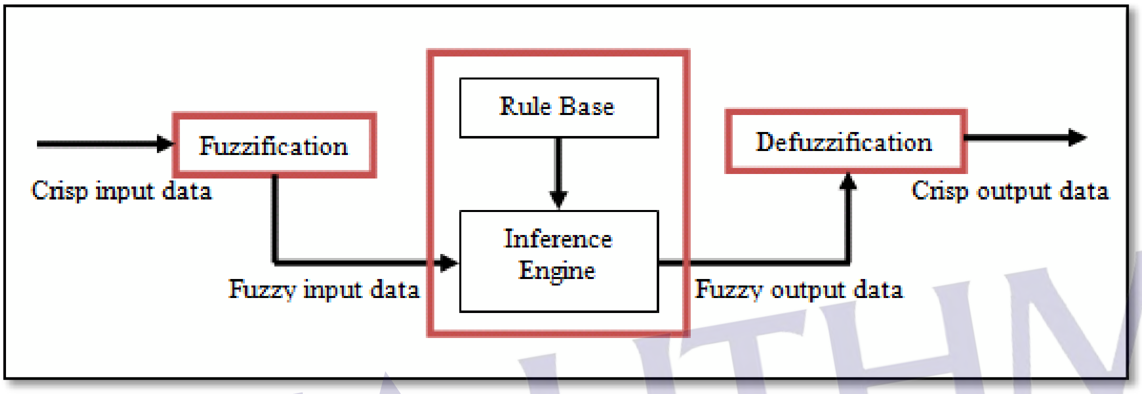


Figure 2.5.1: Structure of the fuzzy logic controller

Fuzzy logic works by executing rules that correlate the controller inputs with the desired outputs. Generally the key aspects of fuzzy logic comprises of fuzzy sets, membership functions, linguistic variables and fuzzy rules:

i. A rule-base (a set of If-Then rules), which contains a fuzzy logic quantification of the expert's linguistic description of how to achieve good control.

ii. An inference mechanism (also called an "inference engine" or "fuzzy inference" module), which emulates the expert's decision making in interpreting and applying knowledge about how the best way to control a plant.

iii. A fuzzification interface, which converts controller inputs into information that the inference mechanism can easily use to activate and apply rules.

iv. A defuzzification interface, which converts the conclusions of the inference mechanism into actual inputs for the process.

2.5.1 Fuzzification

Fuzzification is a process of making a crisp quantity fuzzy. Before this process is taken in action, the definition of the linguistic variables and terms is needed. Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally decomposed into asset of linguistic terms. Example, in the air conditioner system, Temperature (T) is linguistic variable represents the temperature of a room. To qualify the temperature, terms such as "hot" and "cold" are used in real life. Then, Temperature (T) = {too cold, cold, warm, hot, too hot} can be the set of decomposition for the linguistic variable temperature. Each member of this decomposition is called a linguistic term and can cover a portion of the overall values of the temperature. To map the non-fuzzy input or crisp input data to fuzzy linguistic terms, membership functions is used.

2.5.2 Membership Function

The membership function is a graphical representation of the magnitude of participation of each input. It associates a weighting with each of the inputs that are define functional overlap between inputs, and ultimately determines output response.

The "shape" of the membership function is an important criterion that has to be considered. There are different shapes of membership functions such as triangular, Gaussian, trapezoidal, generalized bell and sigmoidal. The triangular shape is the most popular and widely used membership function. The degree of membership function is normally lies in the range [0 1].

The membership functions classify the element in the set, whether it is discrete or continuous. The membership function in the continuous form is a mathematical function, possibly a program. In the discrete form the membership function and the universe are discrete points in a list (vector). The discrete representation is more convenient for certain application.

Although triangular membership function consisting of simple straight line segments and very easy to implement in fuzzy control but the Gaussian membership function facilitate obtaining smooth and continuous output.

2.5.3 Fuzzy Rules

In a fuzzy logic control system, a rule base is constructed to control the output variable. The primary goal of fuzzy systems is to formulate a theoretical foundation for reasoning about imprecise propositions, which is termed *approximate reasoning* in fuzzy logic technological systems. Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. These if-then rule statements are used to formulate the conditional statements that comprise fuzzy logic. A single fuzzy if-then rule assumes the form if x is A then y is B where A and B are linguistic values defined by fuzzy sets on the ranges (universes of discourse) X and Y, respectively. The if-part of the rule "x is A" is called the antecedent or premise, while the then-part of the rule "y is B" is called the consequent or conclusion [9]. A fuzzy rule is a simple IF-THEN rule with a condition and conclusion. Rules are usually expressed in the form of:

If variable IS set THEN action

For example, a simple temperature regulator that uses a fan has the following rules:

IF temperature IS very cold THEN stop fan
IF temperature IS cold THEN turn down fan
IF temperature IS normal THEN maintain level
IF temperature IS hot THEN speed up fan

The procedures of fuzzy logic control are where A set of input data from an array of sensors is fed into the control system. The values of input variables undergo a process termed as "fuzzification," which converts the discrete values into a range of values. Fuzzified inputs are evaluated against a set of production rules. Whichever production rules are selected will generate a set of outputs. Output data are "defuzzified" as distinctive control commands.

2.5.4 Inference engine

In general, inference is a process of obtaining new knowledge through existing knowledge. In the context of fuzzy logic control system, it can be defined as a process to obtain the final result of combination of the result of each rule in fuzzy value. There are many methods to perform fuzzy inference method and the most common two of them are Mamdani and Takagi-Sugeno-Kang method.

Mamdani method was proposed by Ebrahim H.Mamdani as an attempt to control a steam engine and boiler in 1975. It is based on Lofti Zadeh's 1973 paper on fuzzy algorithms for complex system and decision processes. This method uses the minimum operation R_c as a fuzzy implication and the max-min operator for the composition. Suppose a rule base is given in the following form;

IF input x = A AND input y = B THEN output z = C

2.5.5 Defuzzification

Defuzzification is performed to converts the fuzzy output of the inference engine to crisp using membership functions analogous to the ones used by the fuzzifier. There are many different methods for defuzzification such as Centroid of Gravity (COG), Mean of Maximum (MOM), Weighted Average, Bisector of Area (BOA), First of Maxima and Last of Maxima strategy, but the selection of defuzzification procedure is depends on the properties of the application. Centroid of Gravity (COG) is the most frequent used and the most prevalent and physically appealing of all defuzzification methods. The basic equation of Centroid of Gravity (COG) is;

$$u_o = \frac{\int_u \mu_u(u)udu}{\int_u \mu_u(u)du} \quad (2.2)$$

Where u_o is control output obtained by using Centroid of Gravity (COG) defuzzification method.

2.5.6 Controller analysis

In order to investigate the effectiveness of fuzzy logic controller (FLC), another controller needs to be designed. P&O controller performance in term of maximum overshoot ratio, peak time (tp), settling time (ts) and voltage deviations are used as benchmark to investigate the effectiveness of MPPT using fuzzy logic controller.

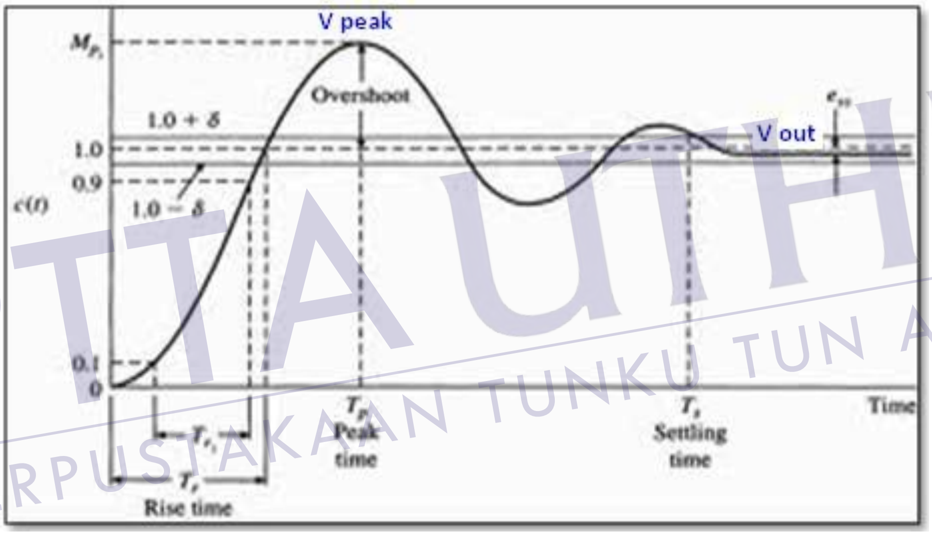


Figure 2.5.2: Waveform specifications

Peak time (tp) and settling time (ts) can be obtained directly from P&O controller and FLC output waveform. The equation for maximum overshoot ratio and voltage deviations ratio is as shown below;

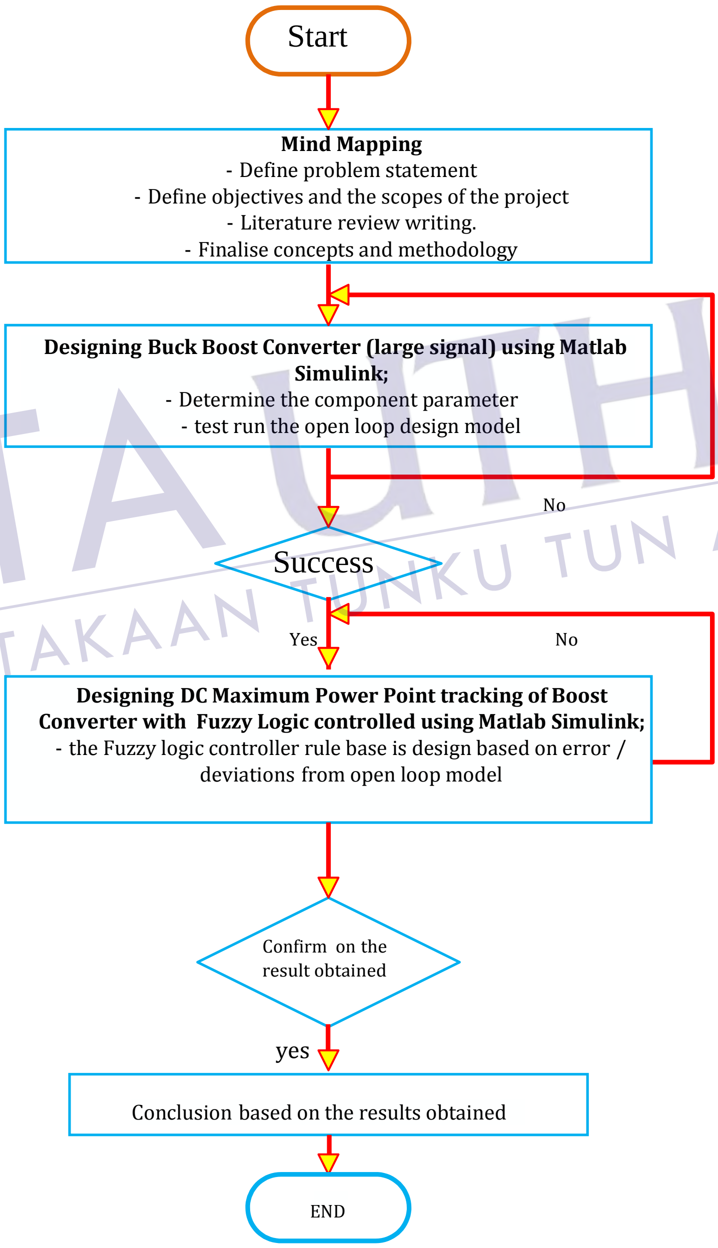
$$maximum\ overshoot\ ratio = \frac{V_{peak} - V_{out}}{V_{out}}\ x\ 100\% \quad (2.3)$$

$$voltage\ deviations\ ratio = \frac{V_{reference} - V_{out}}{V_{reference}}\ x\ 100\% \quad (2.4)$$

CHAPTER 3

METHODOLOGY

3.1 Project Methodology



3.1.1 Planning & Schedule

Planning is process to plan overall of the project. It is explain the method that will be used to implement this project. Overall schedule please refer Appendix A.

3.1.2 Literature Review.

Most are aware that it is a process of gathering information from other sources and documenting it, but few have any idea of how to evaluate the information, or how to present it. A literature review can be a precursor in the introduction of a research paper, or it can be an entire paper in itself, often the first stage of large research projects, allowing the supervisor to ascertain that the student is on the correct path. The entire of the literature review of this project was included at chapter 2.

3.1.3 Identify Design Requirement

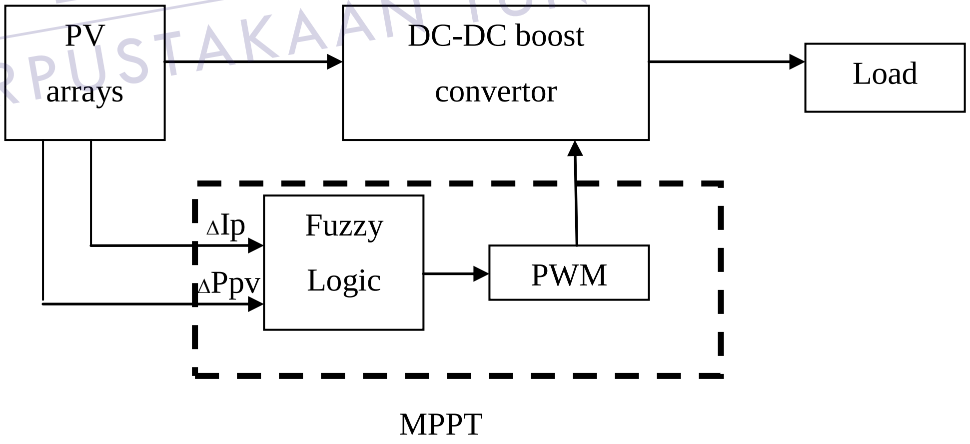


Figure 3.1.1: Proposed system diagram

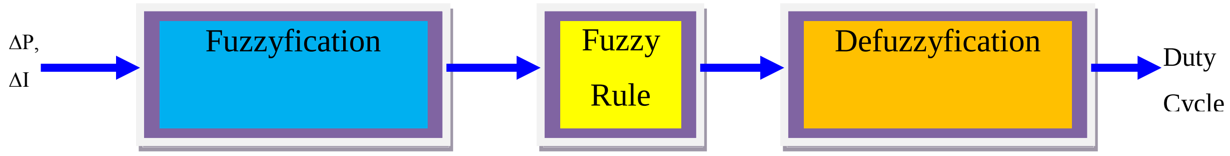


Figure 3.1.2: Proposed FLC configuration.

Figure 3.1.3 shows the simulation modeling design of Fuzzy Logic Controller for MPPT boost converter.

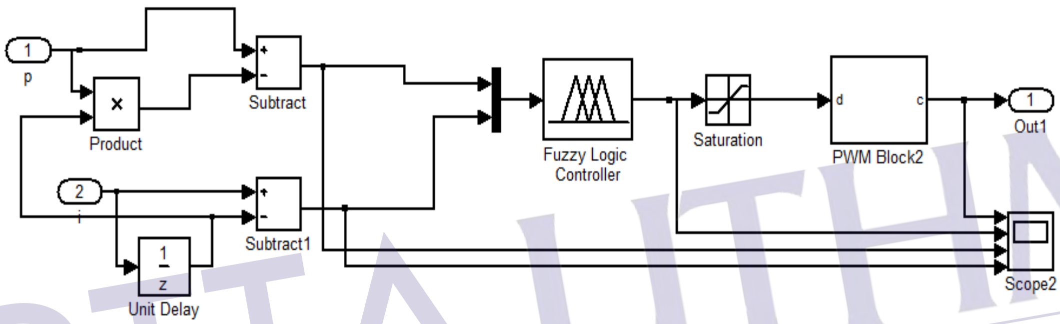


Figure 3.1.3: Power point tracking of boost converter using FLC controller circuit

3.1.4 Fuzzy logic control design

3.1.4.1 Perposed Fuzzy logic controller design

As shown in figure 3.1.3, the fuzzy logic subsystem model has been defined, hence the fuzzy controller needs to be designed. This design process will be conducted using Fuzzy Inference System (FIS) editor. Table 3.1 shows the parameter used in designing fuzzy controller using FIS editor.

Table 3.1.1: Fuzzy Controller FIS editor parameters

Parameter	Details
Membership function	mamdani
Inference engine	Mamdani
Input	2 (Power and Current delta error)
Output	1 (duty cycle)
Fuzzy rules	21
Defuzzification	Centroid (COG)

3.1.4.2 Fuzzy logic input and output parameter

Fuzzy logic input is composed of delta power error and delta current error. This input range setting is shown in figure 3.1.4 and figure 3.1.5.

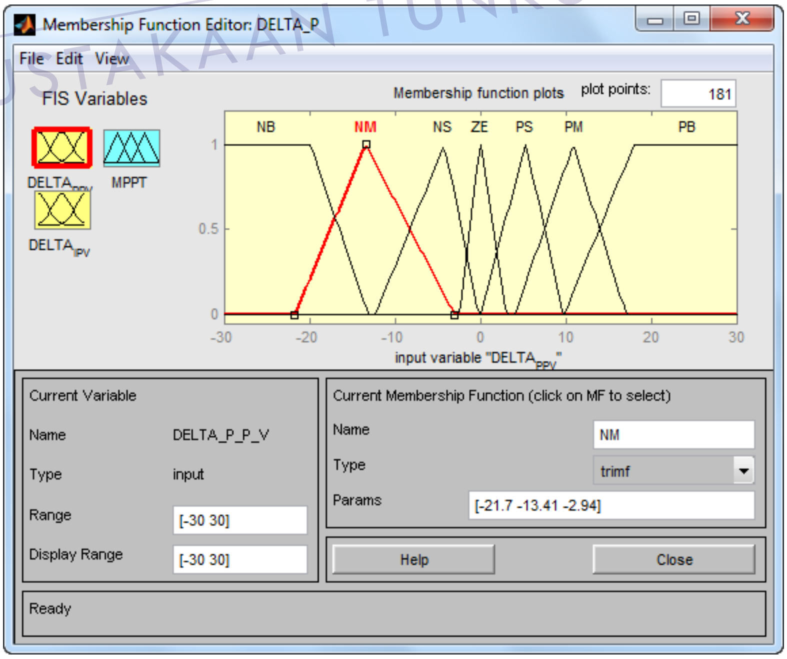


Figure 3.1.4: Input 'Delta Power Error' membership function and range

As shown in figure 3.1.5, input ‘ delta current error’ range is between -1A to 1A. This range is determined by voltage deviation between reference voltage and output voltage of large signal open circuit buck-boost converter.

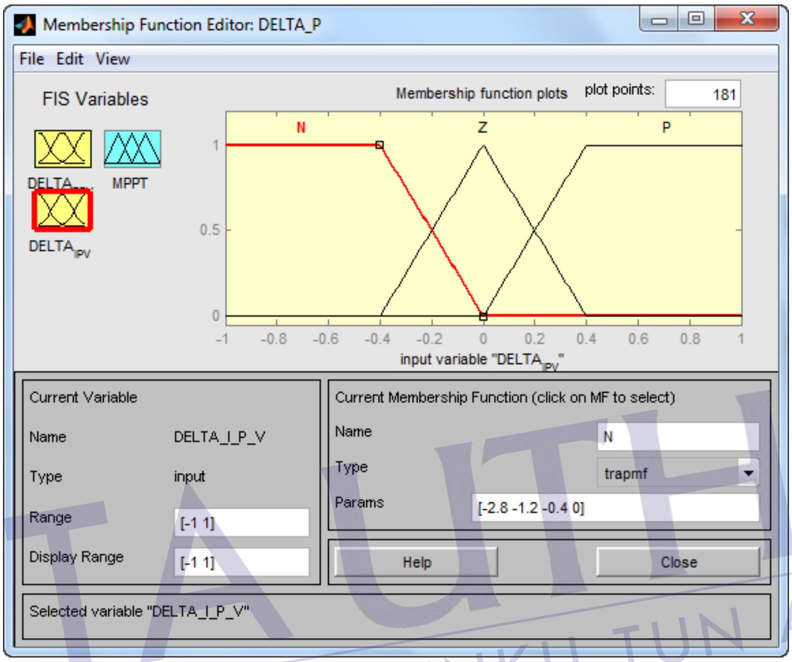


Figure 3.1.5: Input ‘Delta Current Error’ membership function and range

As shown in figure 3.1.6, input ‘delta current error’ range is between -1A to 1A. This range is estimation for voltage deviation between the up to date error and the previous error for close loop boost converter using. Figure 3.6 shows the output duty cycle parameter setting.

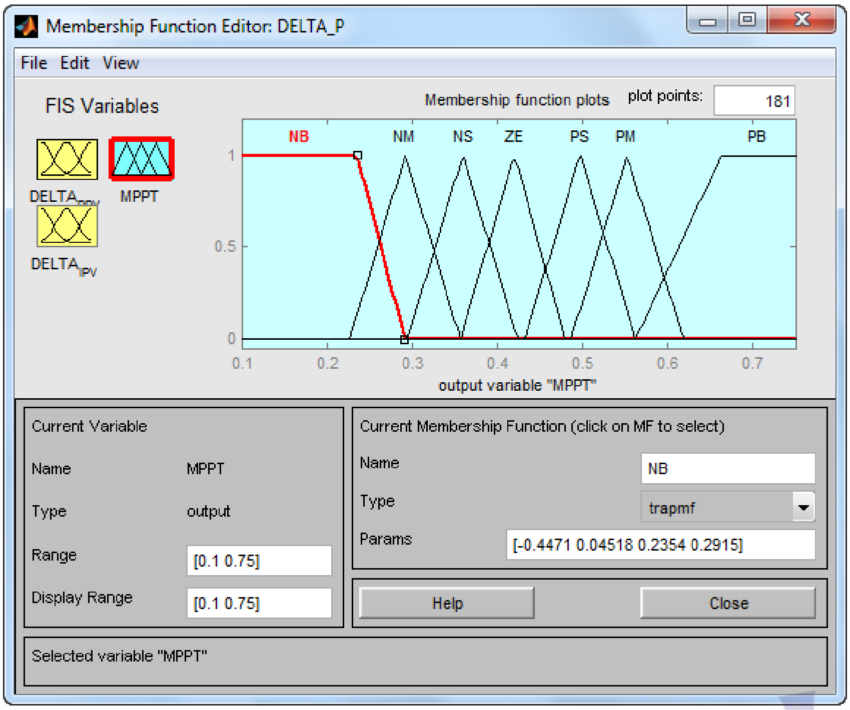


Figure 3.1.6: Output 'Duty Cycle' membership function and range

The boost converter duty cycle range is from 0 to 1 but in duty cycle membership function editor, the range is set from 0.0 to 0.8 Therefore, these distinct settings need to be scaling as shown in Table 3.1.2.

Table 3.1.2: Scaling for duty cycle membership function editor and buck-boost converter duty cycle

Duty Cycle Membership Function Editor	Duty Cycle Boost Converter
0.8	0.8
0.7	0.5
0.6	0.6
0.5	0.5
0.4	0.4
0.3	0.3
0.2	0.2
0.1	0.1
0.0	0

References

T. Esram and P. L.Chapman, “Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques” IEEE Transactions on Energy Conversion, Vol. 22, No. 2, June 2007, pp. 439-449.

R. Faranda and S. Leva, Energy Comparison of MPPT Techniques for PV Systems, WSEAS Transaction on Power Systems, vol. 3 n. 6, June 2008, pp. 446-455.

G. Petrone, G. Spagnuolo and M. Veerachary, “Reliability Issues in Photovoltaic Power Processing Systems “, IEEE Trans. on Industrial Electronics, Vol 5, No. 7, July 2008.

W.M.Utomo, A.A Bakar, M.Z Ahmad, Taufik and R.Herinsyah, “Online Learning Neural Network Control of Buck-Boost Converter” Eighth International Conference on Information Technology: New Generations (ITNG), pp. 485-489, April 2011.

Mario di Bernardo and Francesco Vasca, “Discrete-Time Maps for the Analysis of Bifurcations and Chaos in DC/DC Converters” IEEE Transactions on Circuits and Systems—Part I: Fundamental Theory And Applications, vol. 47, no. 2, February 2000

Robert W. Erickson, “DC-DC Power Converters” Wiley Encyclopedia of Electrical and Electronics Engineering, 2007

Witold Pedrycz, *Fuzzy Control And Fuzzy Systems*, Research Studies Press LTD.1989

Liping Guo, John Y. Hung, and R. M. Nelms, “Evaluation of DSP-Based PID and Fuzzy Controllers for DC–DC Converters”, IEEE Transactions On Industrial Electronics, VOL. 56, pp. 1654, June 2009

K. Guesmi, N. Essounbouli, A. Hamzaoui and J. Zaytoon, “DC-DC Converter Averaged Current Regulation and Nonlinear Phenomena Suppressing by Fuzzy Logic Controller”, IEEE International Conference on Control Applications, pp. 3139 – 3144, 2006

Liping Guo, “Design and Implementation of Digital Controllers for Buck and Boost Converters using Linear and Nonlinear Control Method” Phd thesis, Auburn University, Alabama, 2006

P. Ananthababu, B. Amarendra Reddy, K. Ram charan, “Design of Fuzzy PI+D and Fuzzy PID Controllers Using Gaussian Input Fuzzy Sets” Second International Conference on Emerging Trends in Engineering and Technology, ICETET-09, pp. 957 – 961, Dec. 2009