RECTIFIER CONTROL BY FUZZY LOGIC

Fakhrul Razi Bin Abd.Halim
Faculty of Electrical Engineering
Universiti Teknologi MARA (UiTM)
Shah Alam, Selangor, Malaysia
zer33333@yahoo.com

***Abstract* - This paper presents a fuzzy logic controller for rectifier output voltage. A rectifier is a circuit that converts ac signal to dc signal. The used of fuzzy logic controller is based on the error of the output voltage and the differences between new error and present error. Fuzzy logic controller will improve the simulation performances. The sinusoidal phase width modulation (SPWM) was used as the switching pattern for the rectifier circuit. The modeling and simulation model of the rectifier is using MATLAB/Simulink with the Sim Power System Block set. Performances of the rectifier are compared between one input of fuzzy logic and two inputs.**

Keywords : Sinusoidal Pulse Width Modulation, Controlled Rectifier, Insulated Gate Bipolar Transistor, Fuzzy Logic

1. INTRODUCTION

Many theoretical studies have been investigated on control rectifier. However in this paper rectifier will be controlled by fuzzy logic controller through the use of Insulated Gate Bipolar Transistor (IGBT) as the switch and Sinusoidal Pulse Width Modulation as the switching algorithm. Low and high frequency of models of the systems and small signal linearization for control purposes have already been investigated in [4].

Apart from converting AC input supply into DC signal, investigations are also carried out on how to control the output voltage of rectifier. Previous investigation in control rectifier has included a new sensorless control of the rectifier based on the duality with the PWM inverter induction motor control has been proposed [8]. In [7], a direct control of the converter instantaneous current called Direct Power Control (DPC), and an estimation of the power source voltage waveforms have been proposed in. In this paper, results of simulation are presented to verify that the proposed technique is feasible.

2. CONTROLLED RECTIFIER

Diodes are extensively used in rectifiers. A rectifier is a circuit that converts an ac signal into a dc signal. Depending on the type of input supply, the rectifiers are classified into two types which are single phase and three phase. A single phase half wave rectifier is the simplest type, but it is not normally used in industrial applications. However, it is useful in understanding the principle of rectifier operation. The output voltage for a rectifier can be control depending on the user needs. Almost all rectifiers comprise a number of diodes in a specific arrangement for more efficiently converting ac to dc. To get a full wave rectifier, we are going to use four diodes connecting as bridge. Full wave bridge rectifier is commonly used in industrial applications. The used of full wave bridge rectifier is to make sure that during negative half cycle, there will be output voltage.

The classical rectifier normally uses a bridge diode in implementation without affording any control function. The simplicity makes it easy for rectification of low power and some common high power but always caused current distortion [2]. For the controlled rectifier, IGBT is used as a switch instead of diode. The IGBT is combination for the fast-acting feature and high power capability of bipolar transistor with the voltage control features of the MOSFET gate. An IGBT has high input impedance, like MOSFETs and low on-state conduction losses.

3. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

The switching algorithm used for controlling the IGBT is Sinusoidal Pulse Width Modulation (SPWM). SPWM are gaining more and more interest in utility interfaced applications and high performance adjustable speed drive, due to the increasing requirements of reduced harmonic content in line currents, high efficiency, regeneration ability, fast dynamic response, as well as encumbrances, light weight and low cost [1]. Current control PWM rectifier has been investigated with the possibility to avoid the use of voltage sensor on the line side [5]-[6]. In SPWM the converter switches are turned on and off several times during a half cycle and the output voltage is controlled by varying the width of pulses. SPWM as shown in figure 1 the width of the pulses are generated by comparing a triangular reference voltage *Vr* of amplitude *Ar*, with a carrier sinusoidal voltage *Vc* of variable amplitude *Ac*.

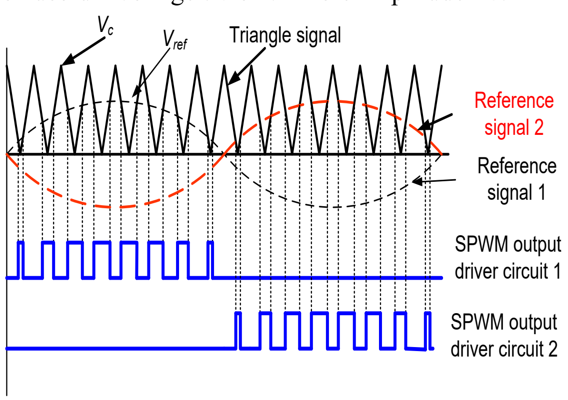

Figure 1. Formation of SPWM

Controlling the output voltage can be done by varying the width of pulses. The width of pulses varied by changing the amplitude of carrier sinusoidal *Ac*. Multiple pulse width modulation, the pulses is uniformly distributed. However in SPWM the widths of the pulses are not uniformly distributed and the widths for each pulse are different. In SPWM control the power factor is improved and the lower order harmonic is reduced or eliminated.

4. FUZZY LOGIC

In the past few years, the tern fuzzy has demanded a wide variety of electrical and electronic products. Much of the development is mainly due to a better understanding of the concept of the fuzzy logic. This controller used elements of everyday language to represent desired system behavior. There are a few reasons why fuzzy logic is implemented in this project:

- Conceptually easy to understand, where the mathematical concept behind fuzzy reasoning are simple.
- Fuzzy logic is tolerant of imprecise data and can be model non-linear.
- Can be built on top of experience of expert and can be blended with conventional control for example PIC.

Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. Fuzzy logic membership allows for set membership values to range inclusively between 0 and 1. In fuzzy, linguistic modifier is used to modify the meaning of a fuzzy set such as more or less, more than and less than. Reasoning is based on fuzzy logic rules which are specified in response to prompt by users and are introduced in a simple IF or THEN form [9]. Fuzzy controller does not require a computational of microcontroller. Figure 2 shows the block diagram of fuzzy logic control common process.

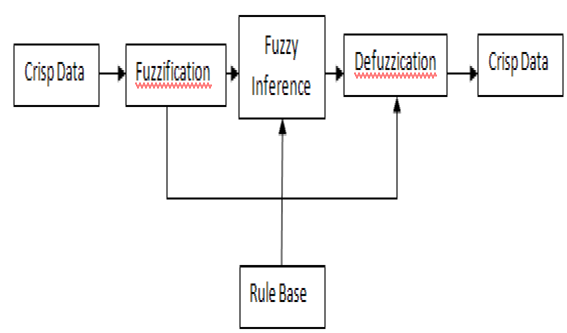

Figure 2. Block diagram of fuzzy logic control common process

The input in this project is output voltage error of the rectifier and the differences between the present error and previous error [1]. A rule base is formed to control the output voltage so that it will give the chosen value. There are three general forms in fuzzy rules which are assignment statement, conditional statement and unconditional statement. However in this paper conditional statement is used. The conditional statement can be thought of as conditional restriction with their IF clause condition. A few of the rules based can be seen in the table 1.

If	**And**	**Then**
Error	Differences of error	Amplitude of sinusoidal carrier
small	zero	medium
zero	neg	medium
zero	zero	low
big	zero	high
big	pos	low

Table 1. Rule base

The input for fuzzy will be first analyzed by fuzzy set and fuzzy rules that had been set up [9]. Then the inputs are translated into linguistic variable in a process name fuzzification. Linguistic variables are represented with linguistic values which are neg_large, neg_small, medium, pos_small and pos_large just like in the membership as shown in figure 4 and figure 5. After the translation, fuzzy inference process is performed where it evaluates the set of rule base and defines the system behavior. Once fuzzy inference is done, the linguistic values from the process will be defuzzified into linguistic variables or crisp data. The max-prod method is used for the conclusion scale and mean of maxima method is used for defuzzification. Crisp data from the process of defuzzification can be seen in the output membership function which is small, big and medium.

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces in Membership Functions, Logical Operations, and If-Then Rules. The inference will then be defuzzified into some values of modulation index. A membership function (MF) is a curve that defines how each point in the input is mapped to a membership value (or degree of membership) between 0 and 1.

Inside the fuzzy logic controller of rectifier, FIS file needs to be verified before fuzzy logic controller block can fully operated [9]. Inside the FIS file, membership functions for each input and output need to be specified. Figure 3, 4 and 5 shows how the membership functions are set for error, difference of error and amplitude of the carrier signal relationship. Relationship between input and output follow the fuzzy rule base of table 1.

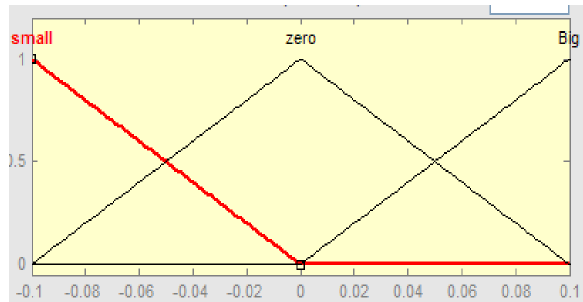

Figure 3. Membership function for input (error)

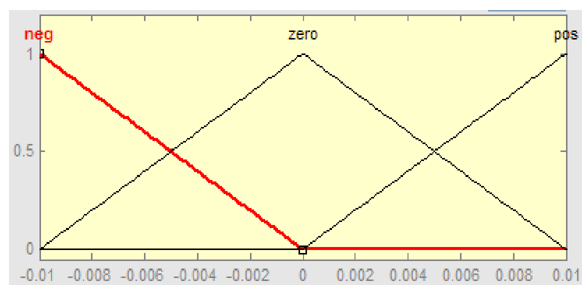

Figure 4. Membership function for input (differences between error)

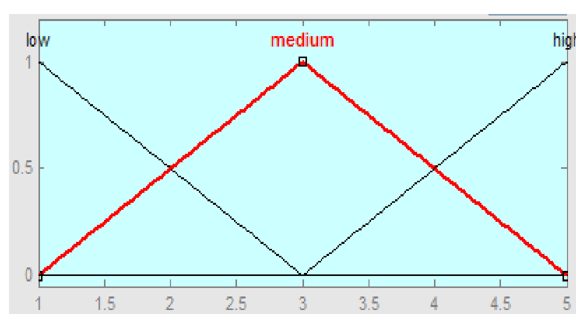

Figure 5. Membership function for output (amplitude of sinusoidal signal)

5. METHODOLOGY

The figure 6 show the method that been used to control the output voltage of the rectifier. This system used fuzzy logic as the controller. The input is error different of error and the output is amplitude of sinusoidal signal.

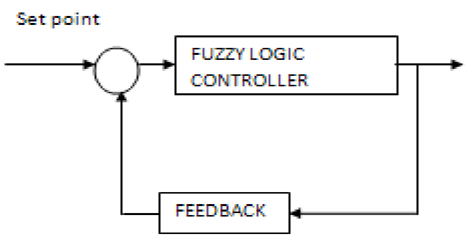

Figure 6. Close loop system

Figure 7 show the flow chart of the controller programming. Error calculation was performed to become the input. Then the amplitude of the sinusoidal signal will be choose as the output of the controller.

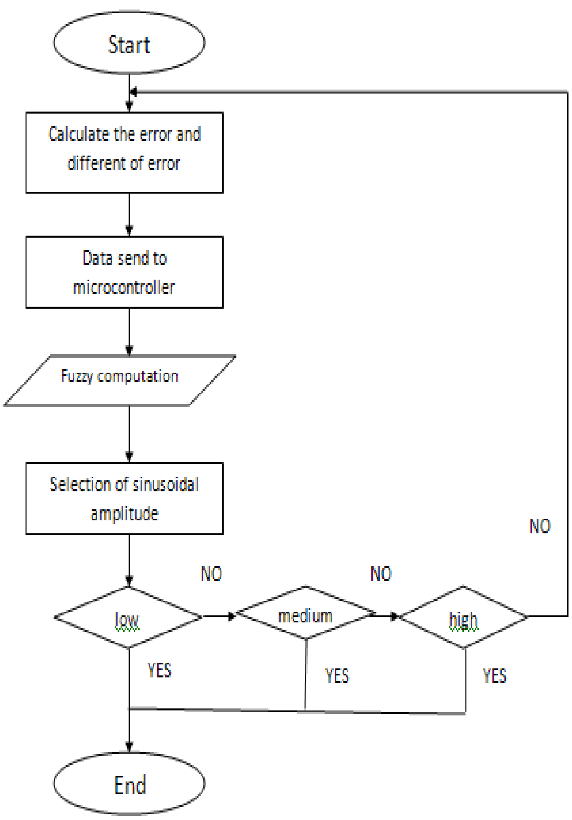

Figure 7. Flow chart for the system

5. MAIN SIMULATION MODEL

Figure 8, 9, and 10 are the circuits that have been used in the development of this paper.

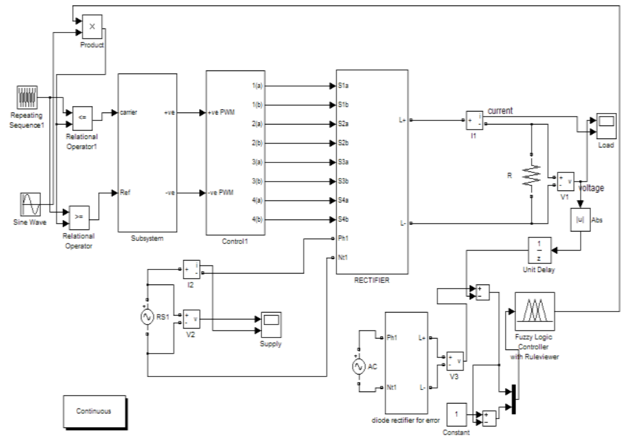

Figure 8. Full model of rectifier with MLS

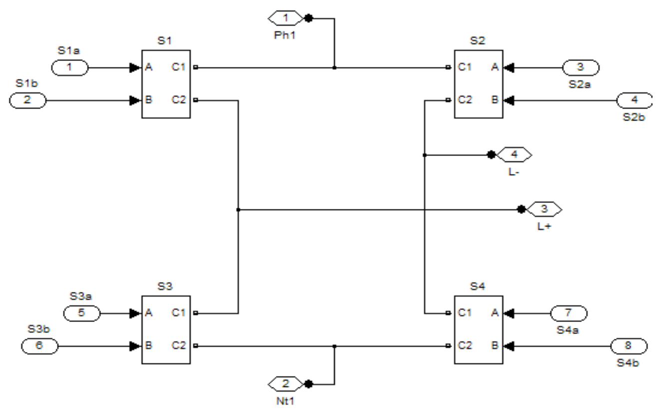

Figure 9.SPMC circuit with MLS

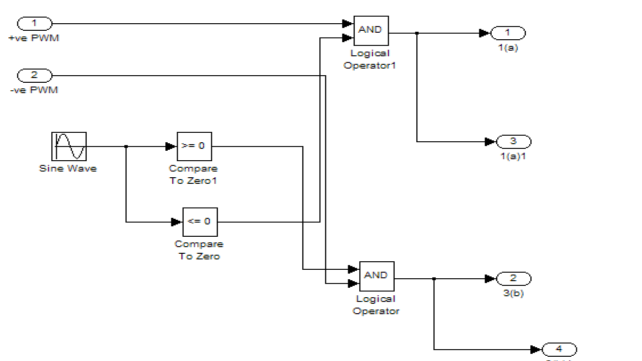

Figure 10. Logical operation to get SPWM

6. RESULTS

The rectifier was simulated using MATLAB/Simulink. Results for rectifier with and without the fuzzy logic controlled is shown in figure 14, 15, 16 and 17. Parameters used are as shown in table 2.

Table 2	
Input source (AC)	50Vrms
Reference frequency (fr)	50Hz
Carrier signal (fc)	5kHz
Load	R=300 Ω
Amplitude of sinusoidal signal	Controlled by fuzzy

Table 2. parameters

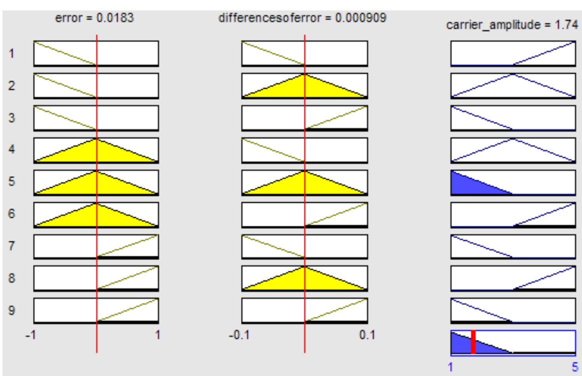

Figure 11. Rule viewer at carrier amplitude equal to 1.74

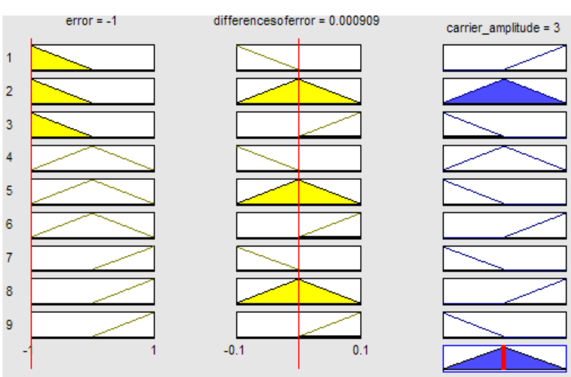

Figure 12. Rule viewer at carrier amplitude equal to 3

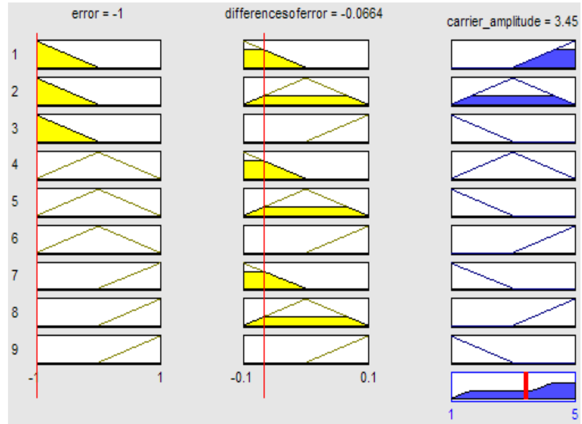

Figure 13. Rule viewer at carrier amplitude equal to 3.45

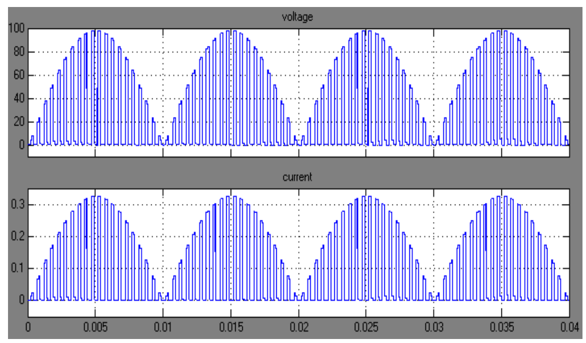

Figure14. Simulation result without fuzzy controller

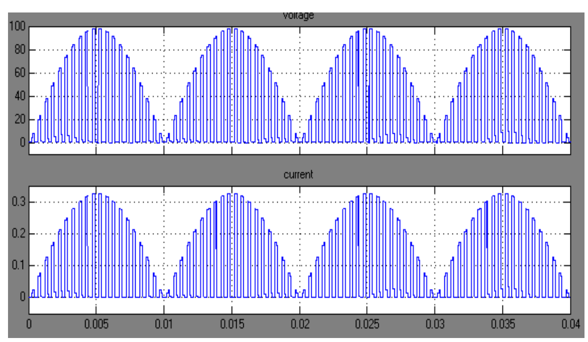

Figure15. Simulation result with fuzzy controller at amplitude of sinusoidal signal equal to 1.74

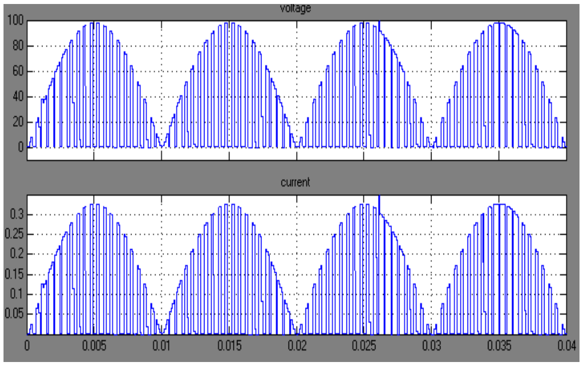

Figure15. Simulation result with fuzzy controller at amplitude of sinusoidal signal equal to 5

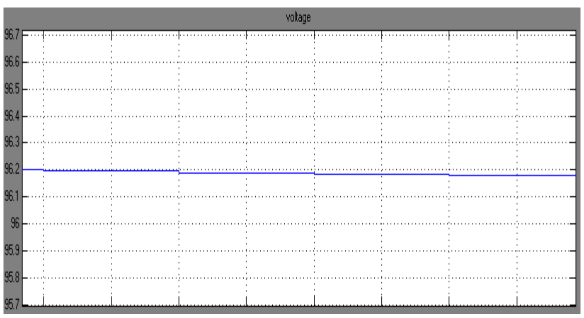

Figure 17. Simulation result with RC load.

7. DISCUSSION

There are a few observations has to be done in order to implement this project. The input and output of fuzzy logic controller that are going to be used need to be known. There are no differences can be seen in the output voltage of the control rectifier since the output of the fuzzy logic used is small enough and the simulation give the ideal result. However the changes in output voltage can be seen if the membership function is change. This is done just to show there are changes because of fuzzy logic controller. After one input fuzzy logic controller is applied to the system the simulation performance is much faster compared to non-fuzzy model. However the simulation time is much slower with two inputs applied to the fuzzy logic.

8. CONCLUSION

The fuzzy logic controller has been presented to operate as a controlled rectifier. In this paper the output voltage of a rectifier control by fuzzy logic has been proposed and investigated. As the controller does not need any knowledge about rectifier parameters, its practical realization is simpler than using other controllers. The fuzzy logic controller corrected the error and feedback the fuzzy output into the system to control the width of SPWM by changing the amplitude sinusoidal signal.

9. FUTURE DEVELOPMENT

A few research and developments can be done in this project to improve the performance of the system. These are some of the future development that can be done:

- Interfacing between hardware and fuzzy logic programming software.
- Design the filter to improve the output voltage of rectifier to get a better result.
- Blend fuzzy controller with conventional controller such as PIC.

8. References

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