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Study Effect of Performance Wind Turbines on the Performance of Dc-Ac Converter for Dc Motor Application Using Fuzzy Logic Control

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ABSTRACT

Generation of electricity from wind power has received considerable attention because it is plentiful, renewable, produces no greenhouse gas emissions during operation and uses little land In order to meet the fast dynamic response requirement of the three phase voltage resource rectifier system, this paper designed a voltage fuzzy logic voltage controller with the direct busbar voltage error and the slope of the error based on the theory of fuzzy logic control, and got the parameters of the fuzzy logic controller. A simulation model was created in Matlab. The overshoot of the system response and time of system dynamic response were compared with the experiments of traditional PI controller versus Fuzzy controller based on Matlab-Simulink platform during the operation including starting, increasing load and decreasing load. From the simulation results, this control strategy could improve the dynamic and static performance of the system with the waves of Matlab simulation model, not changing the topology of the system without obviously adding implementation burden of fuzzy controller.

Keywords: applications, current, energy, speed, fuzzy.

دراسة تأثير أداء توربينات الرياح على أداء محول التيار المستمر إلى التيار المتردد لتطبيقات محركات التيار المستمر باستخدام التحكم المنطقي الضبابي

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ملخص البحث

حظي توليد الكهرباء من طاقة الرياح باهتمام كبير نظرًا لوفرة مواردها المتجددة، وعدم انبعاثات غازات الدفيئة أثناء التشغيل، وقلة استهلاكها للموارد. ولتلبية متطلبات الاستجابة الديناميكية السريعة لنظام مقوم موارد الجهد ثلاثي الطور، صممت هذه الورقة وحدة تحكم منطقية ضبابية للجهد، مع خطأ جهد ناقل مباشر وميل الخطأ بناءً على نظرية التحكم

المنطقي الضبابي، وحصلت على معاملات وحدة التحكم المنطقي الضبابي. تم إنشاء نموذج محاكاة باستخدام نظام على برنامج ماتلاب Matlab. حيث تمت مقارنة تجاوز استجابة النظام وزمن الاستجابة الديناميكية للنظام بتجارب وحدة تحكم PI التقليدية مقابل وحدة تحكم ضبابية قائمة على منصة ماتلاب–سيمولينك Matlab–Simulink أثناء التشغيل، بما في ذلك بدء التشغيل وزيادة الحمل وتقليله. أظهرت نتائج المحاكاة أن هذه الاستراتيجية التحكمية يمكنها تحسين الأداء الديناميكي والثابت للنظام، كما يتضح من موجات نموذج المحاكاة، دون الحاجة إلى تغيير هيكلية النظام أو إضافة عبء تنفيذي كبير على المتحكم الضبابي.

الكلمات المفتاحية: التطبيقات، التيار، الطاقة، السرعة، الضبابي.

1. Introduction

1.1 Project Background

The ac to dc converter is an integral part of any power supply unit used in the all-electronic equipments. And can be used as an interface between utility and most of the power electronic equipments. These electronic equipments form a major part of load on the utility. Generally, to convert line frequency ac to dc, a line frequency diode bridge rectifier is used. And sometimes a large filter capacitor is used To reduce the ripple in the dc output voltage [1].

And the ac-dc converters serve as rectifiers. They convert ac to dc in a number of industrial, domestic, agricultural, and other applications. Rectifiers are used as stand-alone units feeding signal and multiple dc motor and as input stages of ac drives because of their virtually unlimited output power and fine controllability. Their response is usually adequate to handle electromechanical transient occurring in drives.

Ac-dc line-commutated converters or, as they also called, converters with natural commutation or passive rectifiers, are the most usual choice for applications, where a single-phase and three-phase supply is available. This is due to simplicity of the circuit requiring a minimum number of active and passive components. Thyristors are the line-commutated power switches. The term (line-commutated) describes the type of commutation, i.e. the transfer of current from one conducting element to the next.

1.2 Problem Statements

Due to the volatility and the uncontrollability of the motor load, hence speed of the DC motor become unstable. Further a motor integrated with power electronic Interface is becoming popular because it can save the energy and maintain constant speed. In this project the problem statements are how to develop simulation model of controlled rectifier converter using Fuzzy Logic Controller (FLC) to save the energy and maintain constant speed. Also how to implement hardware converter circuit wiring with DSP board.

1.3 Project Objectives

The major objectives of this proposal are:

i To better understanding of direct power transfer scheme, closed loop simulation and analysis of proposed AC/DC converter.

ii To develop modelling system of regulated AC-DC converter for DC motor.

iii To develop modelling a controller that suitable for AC-DC converter of DC motor.

project block diagram

This system model will cover the explanation of methodology as show Figure 1.

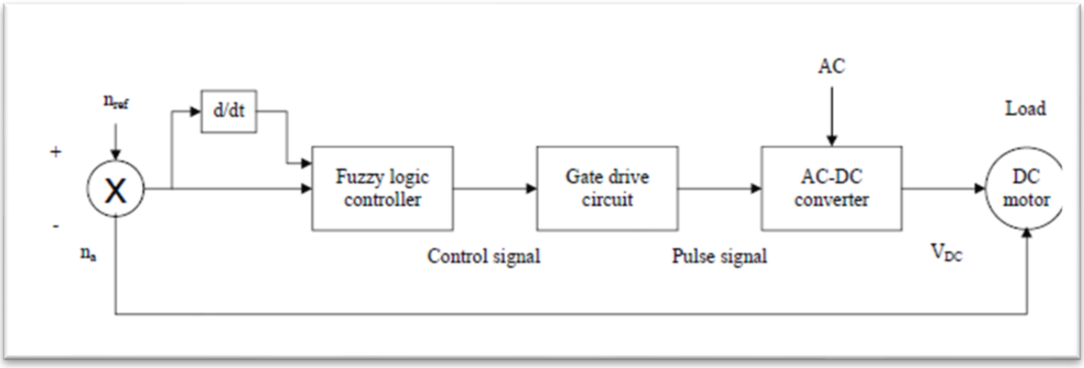

Figure 1: The system model.

The image displays a block diagram illustrating a control system for a DC motor, likely within the context of a Thermoelectric Cooler (TEC) control system, specifically focusing on the current loop.

2.1 AC-DC Converter Parameter

Figure 2 shows the diagram of open loop AC-to-DC converter by using Matlab/Simulink. The power switching device that is used to develop the simulation of converter is SCR. While designing the AC-to-DC converter, the parameters value of design requirement has been set. The voltage of converter is setup 13.5 V. Table 1 shows the parameters that used in AC-DC converter.

Table 1: The value of all parameters can be determined as below Parameters and values for AC-DC converter feeds DC motor.

Parameter	Value
Voltage Input, Vs (V)	**13.34V**
Voltage Output, Vo (V)	**12**
firing angle, ᾱ	**180-0**
Armature Resistance, R (Ω)	**1.7**
Armature Inductor, L (mH)	**6.7**
Motor constant, k_e	**0.0436**
Total inertia, j (kg.m^2)	**0.173**
Torque, T (N.m)	**0.01**

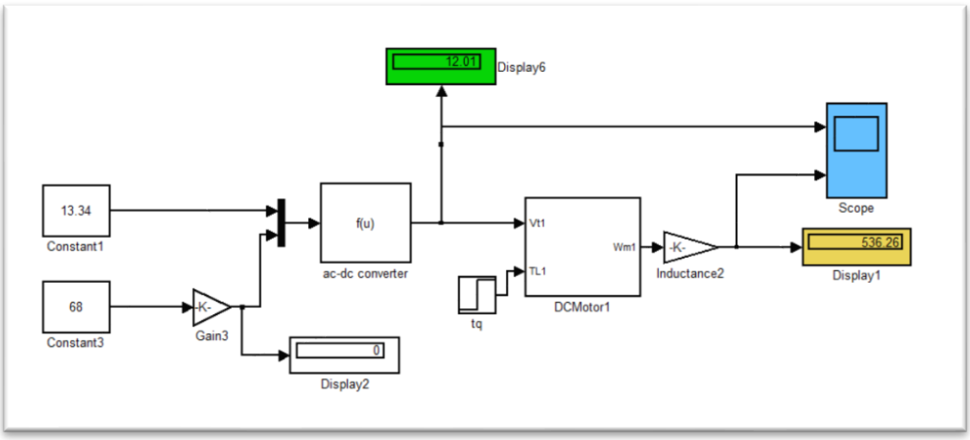

Figure 2 : Diagram of open loop AC to DC boost converter by using Simulink.

2.2 Generate PWM Switching using Matlab Simulink

The PWM 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 circuit of PWM switching shows in figure 3. by using block on Matlab Simulink software.

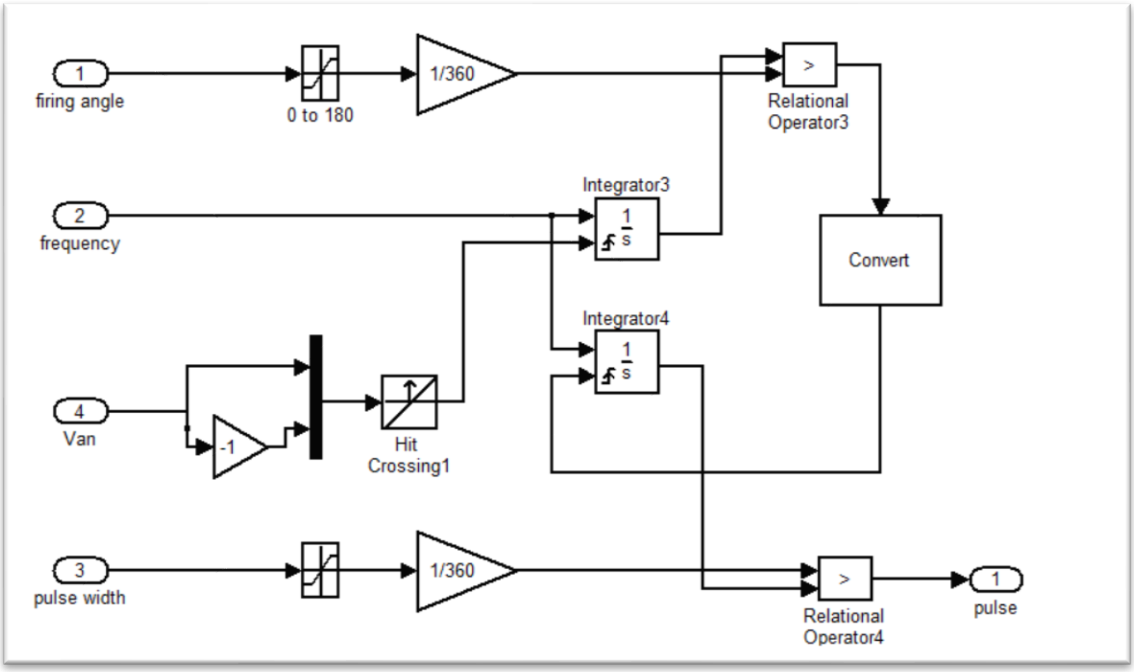

Figure 3 : Simulink generate SPWM Switching.

2.3 PID Controller Design for AC-DC Converters

A PID and a PI controller were designed for the AC-DC 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 AC-DC converter using MATLAB Simulink software 2009a. PID and PI controllers were first designed using the frequency response techniques based on the small signal models of the AC-DC converters, then transformed into digital controllers using the backward integration method. The difference equation to calculate a new firing angle for the digital PID controller is written in equation (1).

$$u[k] = k_p e[k] + k1T \sum_{i=0}^{k} e\,[i] + \frac{kD}{T}\{e[k] - e[k-1]\} \quad (1)$$

And the difference equation to calculate a new firing angle for the digital PI controller is given in (2).

$$u[k] = k_p[k] + k_1 T \sum_{I=0}^{K} e[i] \quad (2)$$

In the difference equation, u[k] is the controller output for the kth sample, and e[k] is the error of the kth sample. The error e[k] is calculated as e[k] = nRef-na[k], where na[k] is the converted digital value of the kth sample of the speed, and Ref is the digital value corresponding to the desired speed $\sum_{i=0}^{k} e[i]$ Is the sum of the errors and {e[k]-e[k-1]} is the difference between the error of the kth sample and the error of the (k-1) sample. The block diagram for the difference equation 1.

2.4 Fuzzy Logic Controller and Its Operational Methodology

Different from conventional control, fuzzy control is based on the expert knowledge of the system. Fuzzy control provides a formal methodology to represent and implement a human's heuristic knowledge about how to control the system. A block diagram of a fuzzy control system is shown in Figure. 4.

A fuzzy controller contains four main components:

i. The fuzzification interface that converts its inputs into information that the inference mechanism can use to activate and apply rules.
ii. The rule base which contains the expert's linguistic description of how to achieve good control.
iii. The inference mechanism that evaluates which control rules are relevant in the current situation.
iv. The defuzzification interface which converts the conclusion from the inference mechanism into the control input to the plant.

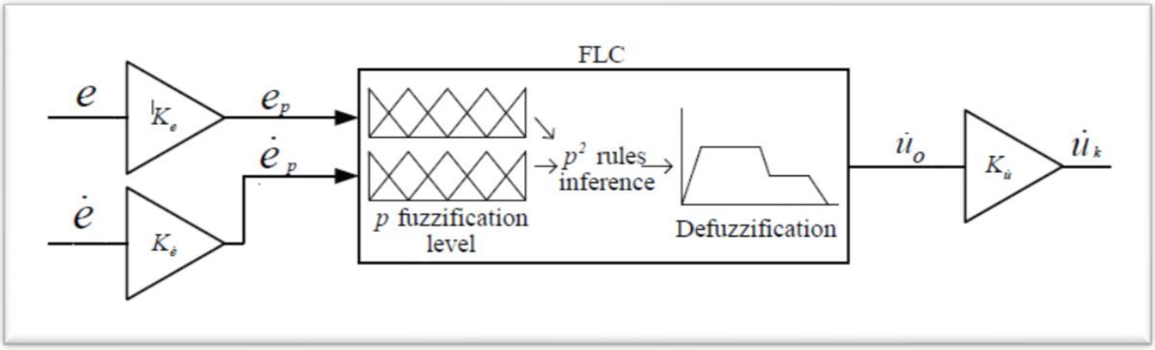

Figure 4: Block diagram of fuzzy control system

v. The performance objectives and design constraints are the same as those for conventional control. Design of fuzzy controllers involves the following procedures,
vi. Choose the fuzzy controller's inputs and outputs.

2.4.1 Fuzzification

First, the linguistic values are quantified using membership functions. Each universe of discourse is divided into fuzzy subsets. There were 3 fuzzy subsets in the fuzzy controller for the AC-DC converter: N, Z, and P, where N indicates negative, Z represents zero, and P indicates positive. The membership functions for e[k] and e[k-1] are shown in Figures (5,6 and 7). The variables μe(e[k]) and μche(e[k-1]) 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 all subsets are positive parts.

The number of fuzzy subsets was determined based on the experimental results of AC-DC converters.

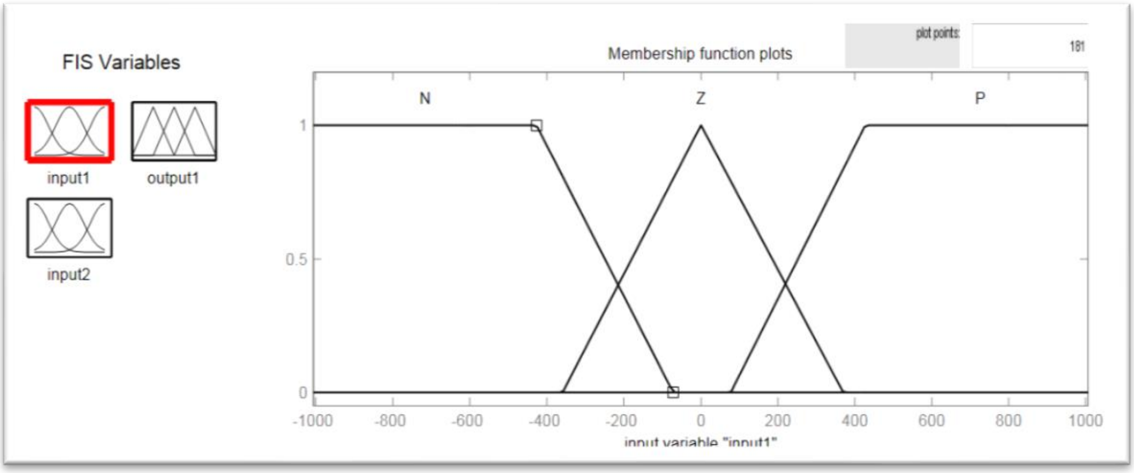

Figure 5: Membership functions of the inputs e[k].

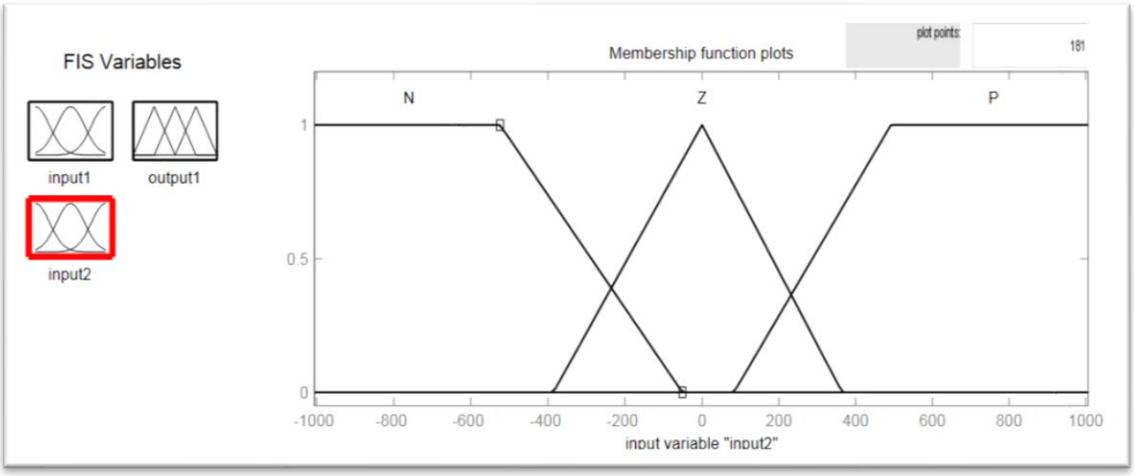

Figure 6: Membership functions of the inputs e[k-1].

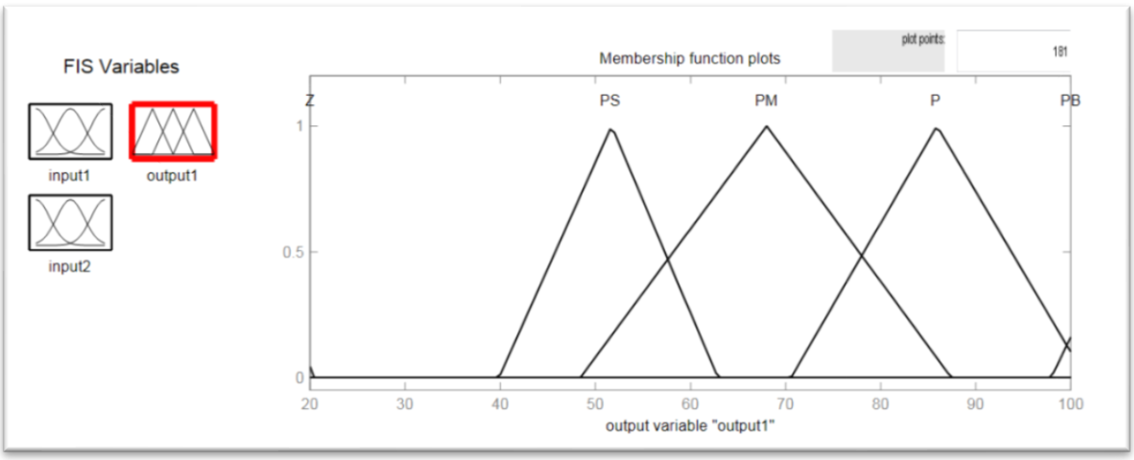

Figure 7: Membership functions of the output δd[k].

2.4.2 Rule Base

The rule matrix is used to describe fuzzy sets and fuzzy operators in form of conditional statements. The rule base is derived from general knowledge of AC-DC converters and adjusted based on experimental results. There is a tradeoffs between the size of the rule base and the performance of the controller. A 3*3 rule base was also designed and implemented for the AC-DC converter. Experimental results indicate that the fuzzy controller with a 3*3 rule base exhibited less oscillation during steady state. 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.

A small 3×3 rule base for the fuzzy logic controller is shown in Table 3.1 for illustration purposes. In the table for the input three groups: N: negative, Z: zero, and P: positive. And for the output five groups; Z: zero, PS: positive Small, PM: positive medium, P: Positive area and PB: Positive Big and its parameter.

Table 2: 3×3 Rules base for error and change of error.

		Error		
		N	Z	**P**
Change in Error (Che)	N	PB	P	**pm**
	Z	PB	PB	**Z**
	P	P	PS	**Z**

2.4.3 Inference Mechanism

The results of the inference mechanism include the weighing factor wi and the change in duty cycle ci of the individual rule. The weighing factor wi is obtained by Mamdani's min fuzzy implication of µe(e[k]) and µche(e[k-1]), where wi = min{µe(e[k]), µche(e[k])} and µe(e[k]), µche (e[k]) are the membership degrees [14]. ci is taken from the rule table (3.1) . The change in duty cycle inferred by the ith rule, zi is written in (3)

zi = wi×ci = min{ µ (e[k]), µ (e[k-1])} × ci (3)

2.4.4 Defuzzification

The center of average method is used to obtain the fuzzy controller's output δd[k], which is given in (4). When using triangle-shaped membership functions, there are at most four rules that are effective at any one time; therefore,

$$\delta d[k] = \frac{\sum_{I=1}^{N} w_{i*c_i}}{\sum_{i=0}^{N} w_i} \quad (4)$$

3.1 Operational the Fuzzy logic Control for AC-DC Boost Converters

A fuzzy controller for a AC-DC converter has two inputs. The first input is the error in the output voltage e[k] = nRef-na[k], where na[k], is the converted digital value of the kth 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 kth 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 firing angle δd[k]. It is scaled by a linear gain h. The scaling factors g0, g1 and h can be tuned to obtain a satisfactory response.

In this method it to calculate the new firing angle from the fuzzy controller's output δd[k]. The output of the fuzzy logic controller, scaled by the output gain h, is added to the previous sampling period's firing angle d[k-1], which is written in (5).

$$d[k] = d[k-1]+h*\delta d[k] \quad (5)$$

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 equation (3.5) to calculate the firing angle d[k] is shown in Figure 3.7. Since the change in firing angle is accumulated every sampling period, the firing angle 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 firing angle may even occur if h is relatively large compared to the firing angle 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 firing angle [3].

The flowcharts of the fuzzy controllers are shown in Figure 8 shows the flowchart of the fuzzy controller using the method to calculate the new firing angle, which corresponds to the Simulink model in Figure 8

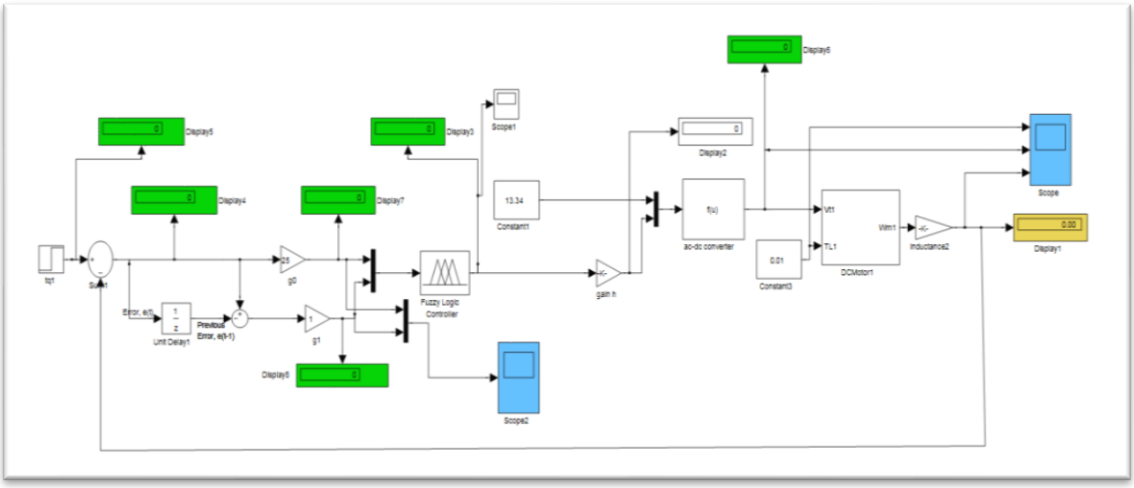

Figure 8: Simulink Model of the Fuzzy Logic Controller for the Boost Converters

Result and analyses

4.1 Analysis for AC-DC Converter

For simulation, input voltage was set at 13.34V and the speed reference was set at various values. The other values of parameters are setting same like the previous section. The simulation result has compared between the AC-DC converter closed loop by PID controller and the AC-dc converter closed loop with fuzzy logic controller.

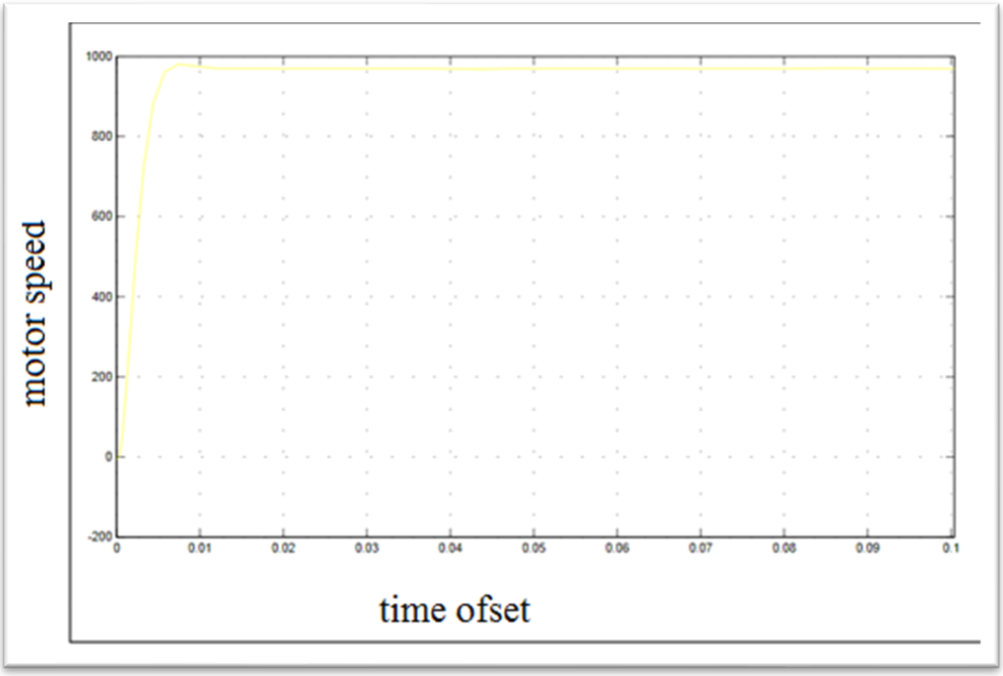

Figure 9: Speed motor result for open loop circuit of AC-DC converter.

4.2 Analysis for Boost Converter with PID Controller

The simulation results of the motor speed driven by the AC-Dc converter with PID controller have shown in Figures 10 and 11. From the simulation result the value of the motor speed is follows the reference speed.

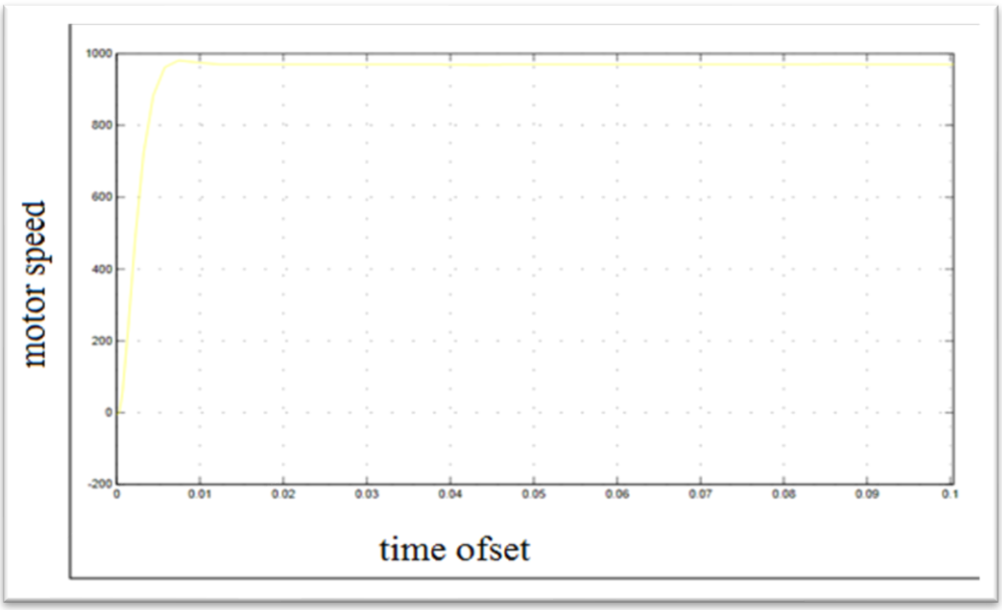

Figure 10: The result of speed motor change from 700 to 1200 rpm using PID controller.

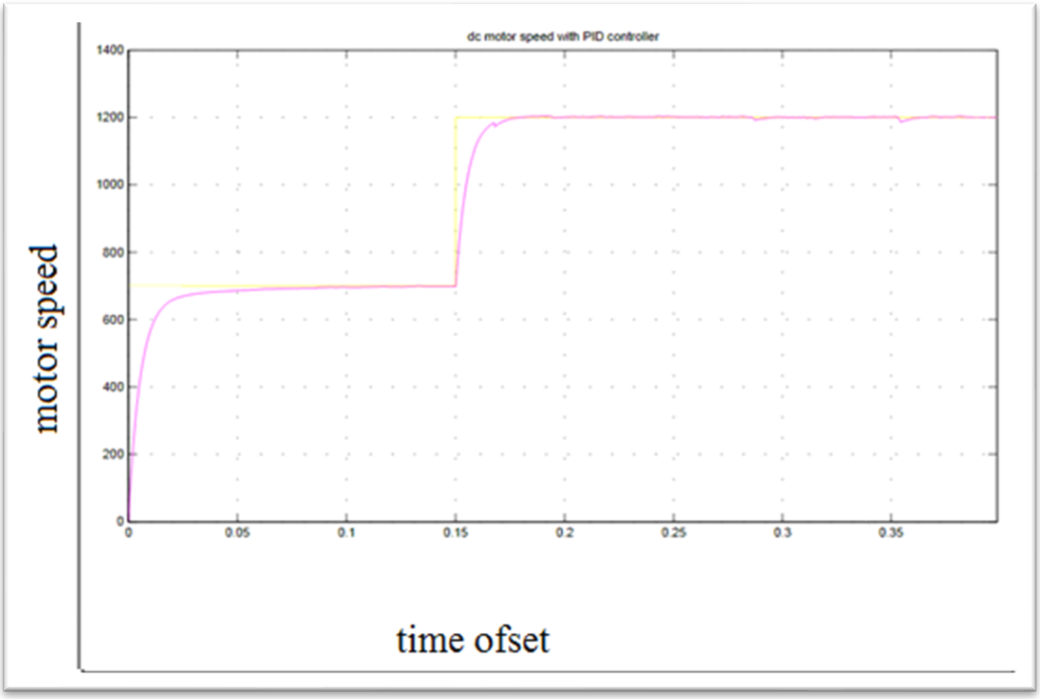

Figure 11: The result of speed motor change from 1200 to 700 rpm using PID controller.

4.3 Analysis for Boost Converter with Fuzzy Logic Controller

The simulation results of the Dc motor driven by AC-DC converter with fuzzy logic controller have shown at Figures 12 ,13 from the simulation result, the value of the motor speed is getting about the target speed.

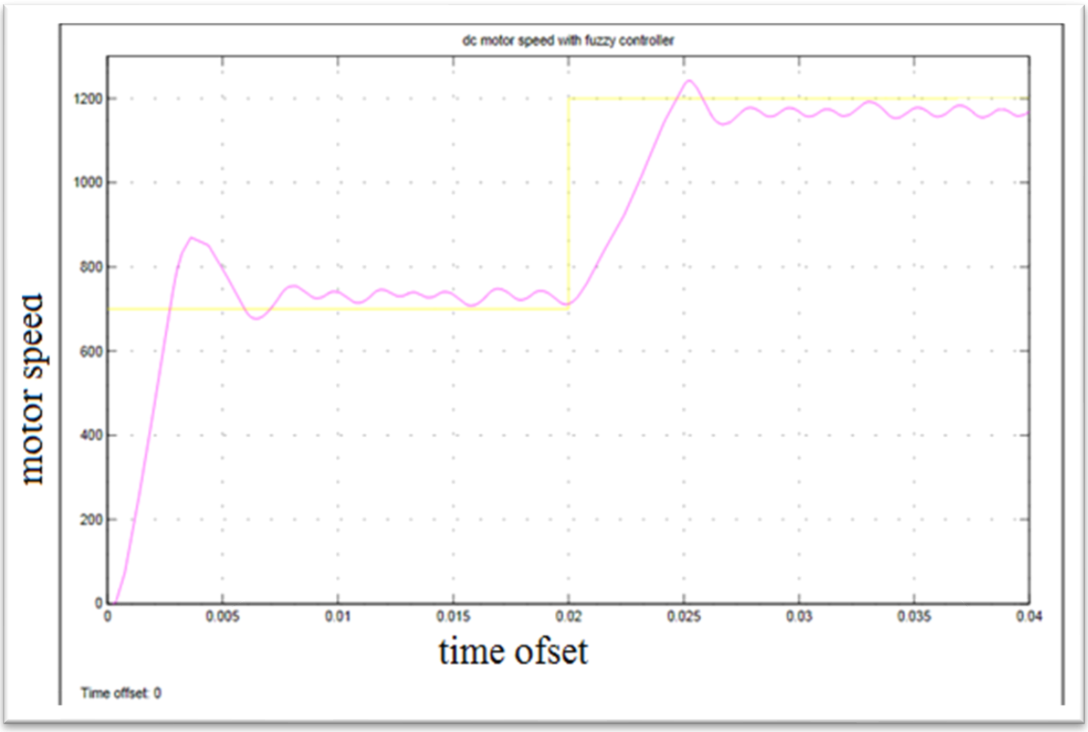

Figure 12: The result of speed motor change from 700 to 1200 rpm using fuzzy logic controller.

4.4 Comparison Analysis

The comparison analysis between the PID controller closed loop and the fuzzy controller closed loop were continue on the simulation result based on the settling time of the speed motor. This analysis is shown as Figure 13 where the reading on the settling time were taken.

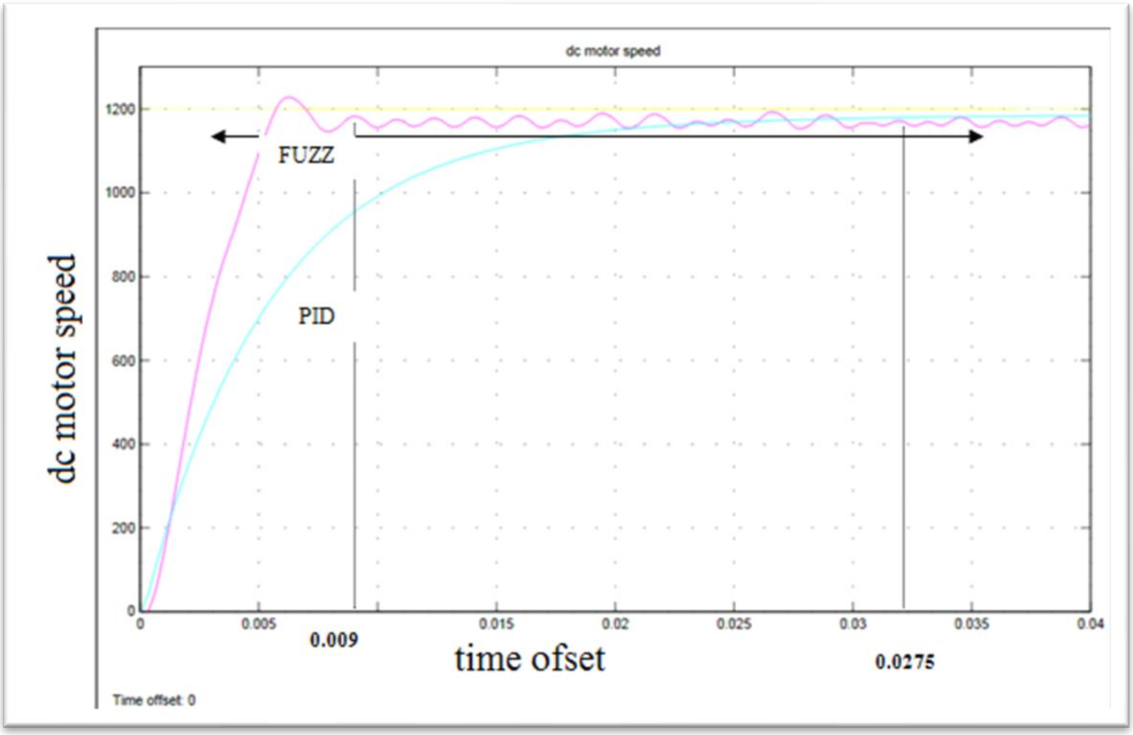

Figure 13: Response reading on the settling time.

Table 3 shows the reading of the Settling Time from closed loop for PID and FLC controllers for the AC-DC converter.

Table 3: The reading of the Settling Time.

Input voltage (v)	Reference speed (rpm)	PID		fuzzy	
		Actual speed (rpm)	Setting time	Actual speed (rpm)	Setting time (sec)
13.34	700	689	0.1	720	**0.007**
13.34	800	790	0.16	810	**0.009**
13.34	900	895	0.08	920	**0.009**
13.34	1000	990	0.08	995	**0.025**
13.34	1200	1190	0.03	1185	**0.009**

5.1 Conclusion

Design of the fuzzy logic controller for AC-DC converter to drive and control DC motor by using Matlab/Simulink has been successfully achieved. From the observation simulation result, the fuzzy controller could force the motor speed toward the desired speed. The best result of the fuzzy controller it can be achieved in this system by increasing the number of the membership functions and the appropriate selection of the fuzzy rules.

The fuzzy logic controller design is able to control of the output voltage of the AC-DC converter to suitable level to drive the load, that proved the fuzzy logic is better to use to control of the output voltage of the AC-DC converter. Besides that, fuzzy logic controller has improved the performances in term of settling time limitation system. Finally, we can conclude that the fuzzy logic controller is robust and better performance in system.

5.2 Recommendation

There has some recommendation be able to make controller performs can be better for future works of this project:

i. Add the rules of fuzzy logic. When more the rules of fuzzy logic, the output of fuzzy logic would more precise. For this project has used just 9 rules so for future works, 25 or 49 rules could be adopted.

ii. Compare with conventional controller such as PI controller with fuzzy logic controller to study the characteristic both of controllers. Then make the comparison which the better controller.

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