Design and Simulation of Washing Machine using Fuzzy Logic Controller (FLC)

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N Wulandari* and A G Abdullah

Department of Electrical Engineering Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 207, Bandung 40154, Indonesia

*wulandarinur67@student.upi.edu

Abstract. This paper aims to design and simulate Fuzzy Logic control system in washing machine. Washing machine is one of the main machines in the household. Therefore it is necessary to control the washing machine system to facilitate the user, reduce the time, electricity consumption, and water in washing water. Fuzzy Logic is an efficient approach in complex control systems compared to conventional approaches. In this paper, Fuzzy Logic control is used to determine the value of washing speed based on 4 different inputs and the stability of motor speed of washing machine based on 3 inputs. The stability setting of the motor speed of the washing machine is controlled to have a constant speed despite the load changes. In the washing speed control system, the output is the value of washing speed. Based on the value of the output, the input value is a reference speed that will be processed on the motor stability control system. The output generated on this system is a control voltage for the inverter, which in case of input changes in the other two inputs will not affect the output value. In paper in, the washing machine control system is designed and simulated using Fuzzy logic toolbox in Matlab.

1. Introduction

One of the main machines in the household is the washing machine. In the early development of washing machine technology all motor control operations are set manually by operating timer [1]. Timer is used to determine the time the machine will work. With the ever-evolving technology, the use of microcontroller is being applied in the washing process based on predetermined time [2], [3]. In addition, the technology of using sensors in washing machines started to be applied [2], [3].

Currently, the washing machine control system has started using Fuzzy Logic as its controller [4]-[8]. The use of Fuzzy Logic controls is easier to implement than conventional controls such as PID [4], [5], and [9]. The weakness of the PID control is difficult to determine the constant value of P, I, and D in order to obtain the desired result [10]. The use of Fuzzy Logic controls is also applied to the control of the induction motor [10] - [13] commonly used in washing machines especially the 1 phase induction motor. The speed of an induction motor is affected by changing the load given. In addition, the speed control performance of the washing machine is also influenced by the effects of mechanical and electrical subsystems [14].

This paper aims to design and simulate a washing machine control system using Fuzzy Logic. The controlled parameters are washing speed based on the weight input of clothing, the type of defilement, the level of dirtiness, and the sensitivity of clothing. What distinguishes this research from others is that the output value of the speed control system washes into the motor stability control system. The value

becomes input as reference value of motor speed. In this system there will be 2 other input that is error and derror. The output value of motor stability control system will not affect the value of error and derror given. Where the system output is the control voltage to be supplied to the inverter to run the motor.

Fuzzy Logic controls are smart system controls. Fuzzy Logic controllers have the ability to solve problems on complex systems that are not owned by conventional controllers [10]. The basic structure of the Fuzzy Logic system is shown in Figure 1.

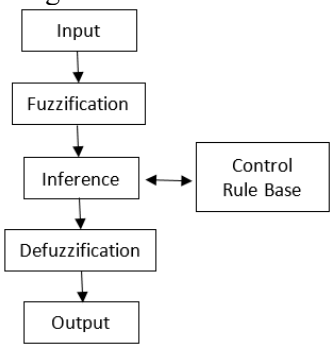

Figure 1. Fuzzy Logic system structure.

In the fuzzification process, there is a conversion of crisp input values into fuzzy values through mapping techniques of input variables into membership functions and truth values. Membership function is a curve showing the mapping of data input points into membership values that have intervals between 0 and 1 [15]. Membership function sets the function to declare membership of a value. There are several forms of membership functions such as triangular, trapezoidal. Each rule on fuzzy will relate to another fuzzy relation. Generally fuzzy rules are expressed in the form of IF-THEN logic. Evaluate fuzzy rules to generate the output of each rule. The input of the defuzzification process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a number in the fuzzy set domain. So if given a set fuzzy within a certain range, then it should be taken a certain crisp value as output.

2. Method

In this research is to make the control system simulation and make the design of Fuzzy Logic system using Fuzzy Logic Controller Simulink on software MATLAB. Figure 2 shows the proposed system design.

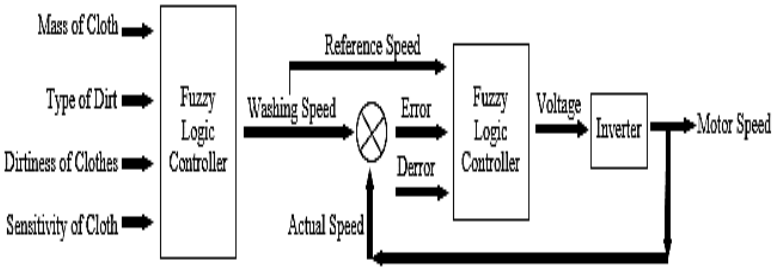

Figure 2. Proposed System.

In this design have 2 different systems. The first fuzzy logic control system is used in determining the washing speed with 4 inputs. These 4 inputs can be provided manually or automatically by using the corresponding sensor. After the first system produces the output the system then performs a process whereby the output on the first system is defined as the reference speed at the second system input. The second system runs the process of regulating motor speed stability with 3 inputs. Two other inputs

include error is the difference between the reference speed with the actual speed and the current error difference derror with the previous error.

The first step in using Fuzzy Logic system is to determine the input and output. In this model the desired output is obviously the washing speed. But for more details can be show in Figure 3. This membership function is based on the analysis of several related journals [4] - [6].

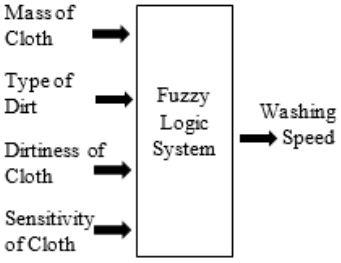

Figure 3. Fuzzy Logic Control for washing machine.

Each linguistic input and output is set into the membership function. The membership function used is the triangular membership function. It can be seen in figures 4 and 5 show the membership functions of input and output and also lower and upper limits.

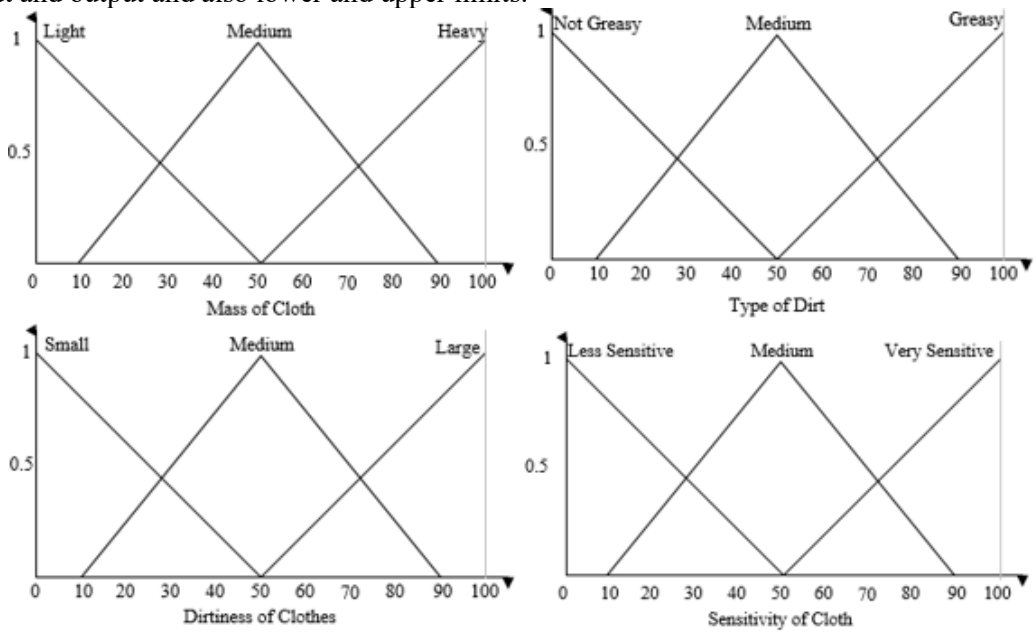

Figure 4. Input membership function.

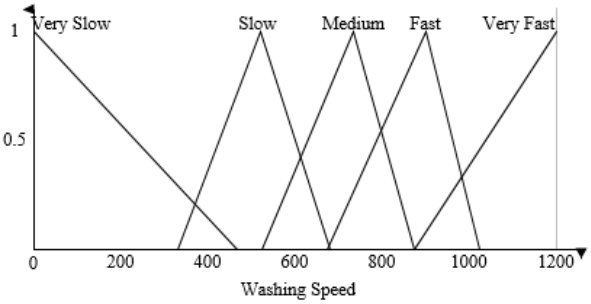

Figure 5. Output membership function.

After determining the membership function and upper and lower limits for the input and output parameters, the total IF-THEN rule base required is 81 rules. Rules can be seen in table 1. The rule setting obtained results from the analysis of several related journals [4] - [6].

Table 1. If-Then Rule base required is 81 rules.

No	MoC	ToD	DoC	SoC	WS
1	Lt	NG	S	VS	VS
2	Lt	NG	S	M	S
3	Lt	NG	S	LS	M
4	Lt	NG	M	VS	S
5	Lt	NG	M	M	M
6	Lt	NG	M	LS	F
7	Lt	NG	Le	VS	M
8	Lt	NG	Le	M	F
9	Lt	NG	Le	LS	VF
10	Lt	M	S	VS	S
…	…	…	…	…	…
81	H	G	Le	LS	VF

Notes: Lt=Light, M=Medium, H=Heavy, NG=Not Greasy, G=Greasy, S=Small, Le=Large, LS=Less Sensitive, VS=Very Sensitive, VS=Very Slow, S=Slow, F=Fast, VF=Very Fast.

The inference system used is the Mamdani Method. In this method the implication function used is Min that is in implies a rule takes its minimum value.

As for the method of defuzzification used the method of Center of Gravity (CoG) or another name centroid. In this method the crisp output value is obtained by enchanting the center point (z *) fuzzy area. The output on this system will be forwarded to the next system.

The input and output for Fuzzy Logic Modeling of Induction Motor Speed can be seen in figure 6.

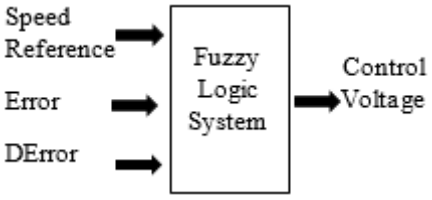

Figure 6. Fuzzy Logic Control for induction motor speed.

In this model the input parameters are reference speed, error, and derror value. The reference speed is obtained from the previous system output. Error is the difference between set point speed and actual speed. Derror is the current error increment with the previous error. While output is a voltage (volts) that will be given to the inverter as a control voltage to run the motor. Membership functions used are triangle and trapezium.

The membership function used can be seen in figures 7 and 8. And the rules required as many as 125 rules shown in table 2. Rules are based on several journals [11] - [13].

The method used is Mamdani Method with Min implication function and defuzzification method using CoG.

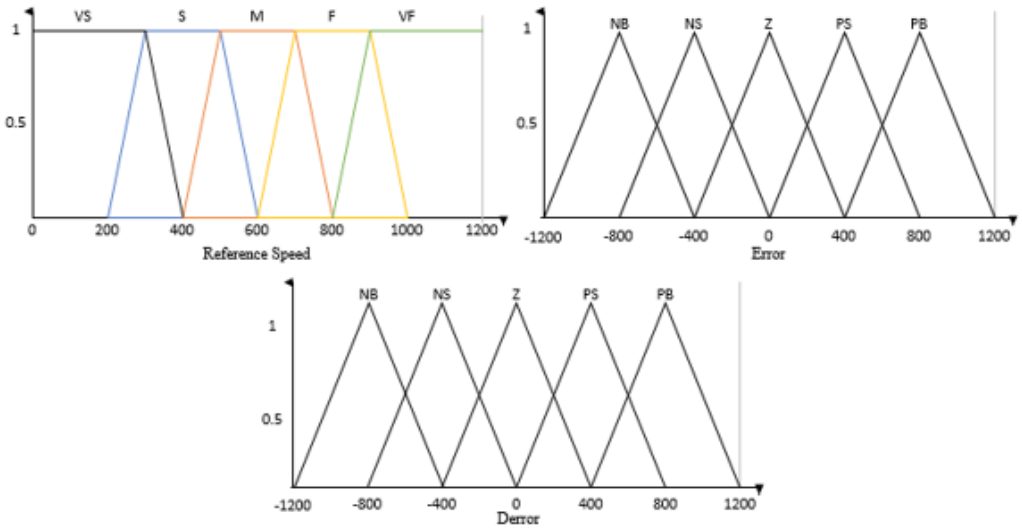

Figure 7. Input membership function used are triangle and trapezium.

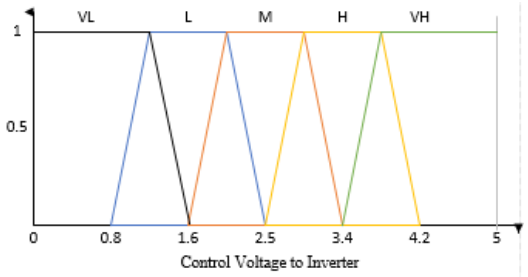

Figure 8. Output membership function used are triangle and trapezium.

Table 2. If-Then Rules.

No	RS	E	DE	VC
1	VS	NB	NB	VL
2	VS	NB	NS	VL
3	VS	NB	Z	VL
4	VS	NB	PS	VL
5	VS	NB	PB	VL
6	VS	NS	NB	VL
7	VS	NS	NS	VL
8	VS	NS	Z	VL
9	VS	NS	PS	VL
10	VS	NS	PB	VL
…	…	….	…	…
125	VF	PB	PB	VH

Notes: VS=Very Slow, S=Slow, M=Medium, F=Fast, VF=Very Fast, NB=Negative Big, NS=Negative Small, Z=Zero, PS=Positive Small, PB=Positive Big, VL=Very Low, L=Low, H=High, VH=Very High.

From a combination of 3 inputs it can be concluded that the rule at VS reference speed will output VL, S yields output L, M produces output M, F produces output H, and VF produces output VH. Although there is a change in the input error and derror.

3. Results and Discussion

Using Fuzzy Logic controls can result in different washing rates according to different inputs on the weight of clothing, the type of impurity, the level of impurities, and the sensitivity of clothing. For example, the case on the first system will be given 40 inputs on the weight of the clothing, 20 on the type of clothing defilements, 20 on the level of clothing defilements, and 30 on the clothing sensitivity. The data is influenced by 8 rules, after doing the implications on the rule is taken minimum value. Once we get the implication function of each rule in use Max method to do the composition between all rules. So, get the output area can be seen in Figure 9.

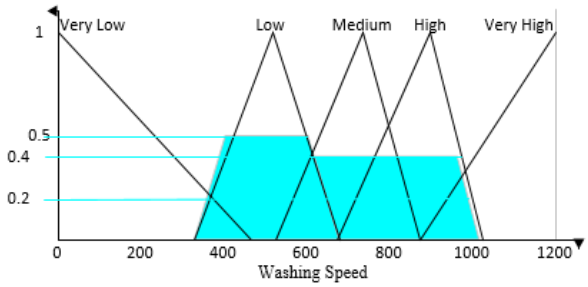

Figure 9. Graph of the Composition of the Rules (The data is influenced by 8 rules).

From picture 9 done defuzzification with method of centroid hence generated output value equal to 600 rpm.

While in the second system to stabilize the speed of the induction motor, the output voltage value to be given to the inverter will remain the same according to the reference value of the speed. Where previously been done to initialize for motor speed with control voltage. Despite the change in input error and derror values. For example, given the reference value of the speed of the first system output value of 600 rpm, error = 100 and derror = 100. The data is influenced by 4 rules, after doing the implications of the rule is taken the minimum value. Once we get the implication function of each rule in use Max method to do the composition between all rules. So get the output area can be seen in Figure 10.

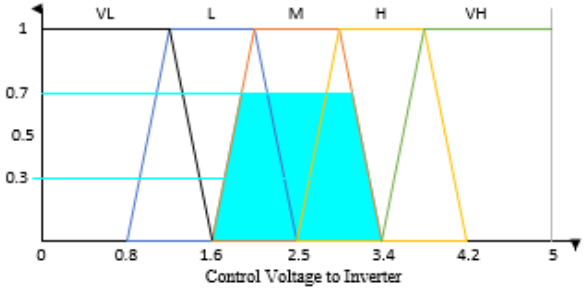

Figure 10. Graph of the Composition of the Rules (The data is influenced by 4 rules).

It can be seen in Figure 11 shows a surface response relationship between input and output on the case of washing speed. Figure 12 shows the response surface of the relationship between the input and output on the stability control system of induction motor speed.

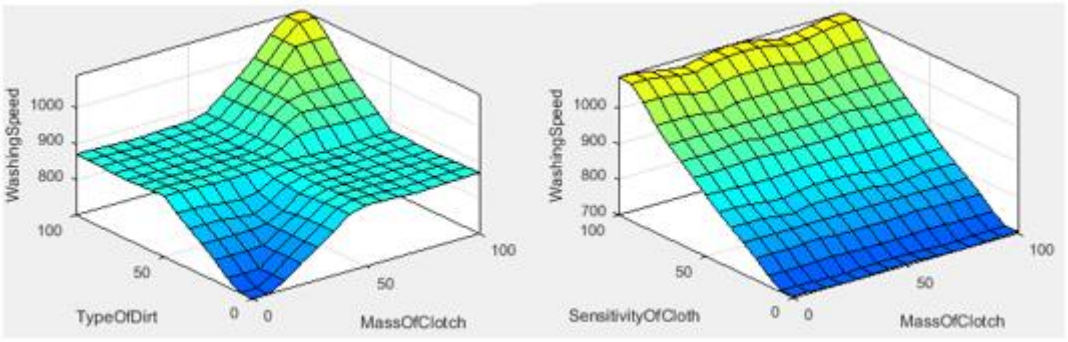

Figure 11. Surface response relationship between input and output on the case of washing speed.

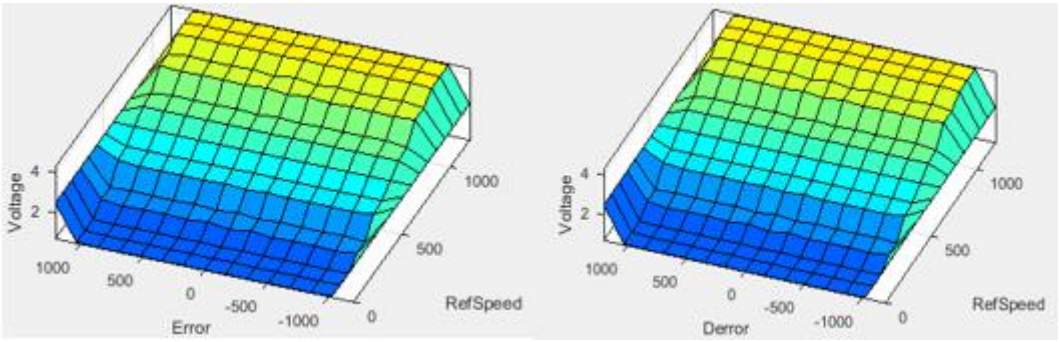

Figure 12. Surface response relationship between input and output on the stability control system of induction motor speed.

4. Conclusions

In this paper, developing fuzzy logic for washing machines can help improve automation systems in washing machines and reduce electricity, water and time consumption. Based on the weight of clothing detected by the weight sensor, while other input parameters are given externally as well as with related sensors. The parameters can determine the appropriate washing speed. The results of the washing speed can enter the next control system to stabilize the motor speed despite any changes in load. Looking at the surface graph obtained from the combination illustrates the desired operating achievement. Using a fuzzy logic system is easier to implement into complex systems than conventional controls.

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