Implementation of Fuzzy Logic Control on Automatic Voltage Regulator for 3 Phase Synchronous Generator

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Abstract. The ever-changing use of electrical energy can affect the generator terminal voltage, this condition can result in a decrease in the reliability of the generator system. To maintain the reliability of the generator system, it is necessary to install a device capable of regulating the size of the terminal voltage or commonly called an auto voltage regulator (AVR). In this research, an AVR with Fuzzy Logic Control (FLC) method has been created which is able to regulate the generator terminal voltage. The results showed that the generator response with a 220V reference has a delay time = 0.45 s, rise time = 0.72 s, settling time = 1.15 s with a very small steady state error. AVR is able to improve the terminal voltage within ± 8 s when the generator is given a resistive load, and ± 6 s when the generator is given an inductive and capacitive load.

Keywords: Auto voltage regulator, Fuzzy logic control, Synchronous generator, Excitation, Electrical energy.

1. Introduction

Synchronous generator is one of the main components in power generation. Called synchronous because the speed of rotation of the magnetic field is synchronous with the rotation of the rotor. The importance of the use of synchronous generators in the generation of electrical energy also makes us have to always maintain the safety of the generator. One of the indicators of the quality of the electric power system is the stability of the frequency and voltage [1].

One of the factors that can disrupt the stability of the generator is a change in load. Changes in load is always exist and with a time that can not be determined with certainty. This can causes the terminal voltage to always change from it nominal value. An increase in load can decrease the terminal voltage, otherwise a decrease in load can increase the terminal voltage. This can cause instability of the entire generating system, therefore an Automatic Voltage Regulator (AVR) is needed.

AVR is a device that can adjust the excitation output to be connected to the rotor so that a terminal voltage is generated whose magnitude is directly proportional to the excitation current. The use of the AVR to adjust the excitation appropriately is able to stabilize the terminal voltage.

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The AVR also requires a control system where the system must supply Direct Current excitation automatically when the load increases or decreases. One of the control methods that can be used is Fuzzy Logic Control (FLC).

In this research, we will create an AVR device using FLC as a method of regulating the excitation output, so that the results are in the form of a generator terminal voltage that can stabilize the terminal voltage of a 3-phase synchronous generator.

2 Materials and methods

2.1 Research Tools and Materials

Table 1. Tools and Materials.

No	Tool	Materials
1	Laptop	Microcontroller
2	Matlab Software	AC Voltage Sensor
3	3 Phase Synchronous Generator	Excitation circuit
4	Solder	Rectifier circuit
5	Multimeter	-

2.2 Simulink Design

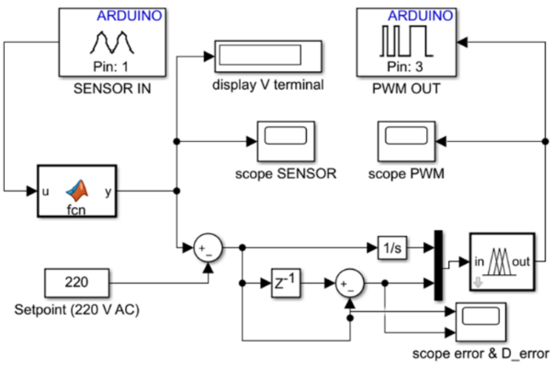

Fig. 1. Simulink design.

2.3 Fuzzy Logic Control

The FLC process consists of 3 processes, fuzzification, modification of membership values/rule base, and defuzzification [2]:

Fig. 3. Block diagram FLC.

In the first stage, the crisp input that enters the fuzzy is first transformed into the form of a fuzzy set. Then determine the degree of membership. In the second stage, the input value in the fuzzy set is entered into several rules, which are generally in the form of IF-THEN. Then the system will process the input according to the entered rule. In the third stage, the fuzzy set value that has been processed will be converted back into a crisp set so that it can be used for the next control stage.

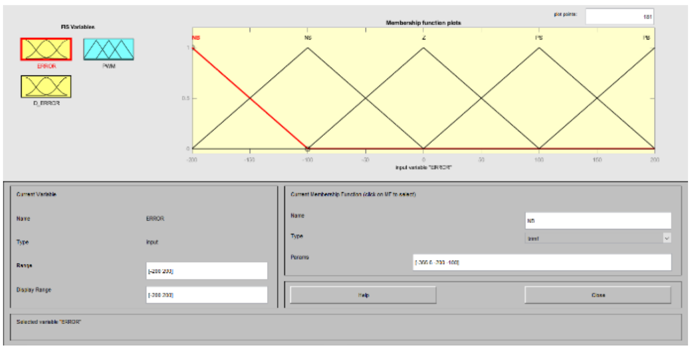

Fig. 4. Membership function input error

Figure 4 shows the membership function of input 1 named Error. The range of this error input is set with a lower limit of -200 and an upper limit of 200. It has 5 memberships, each of it is triangular in shape.

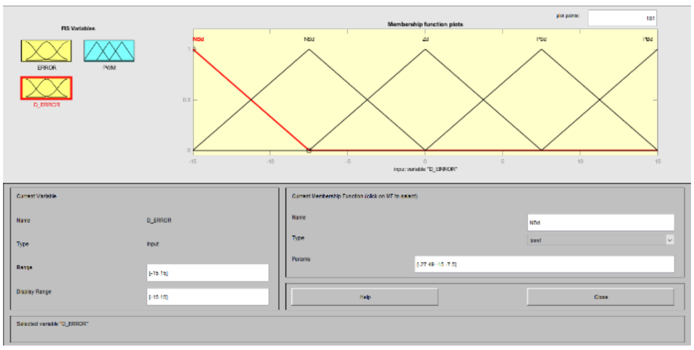

Fig. 5. Membership function input delta error.

Figure 5 shows the membership function of input 2 named Delta Error. The range of the input delta error is set with a lower limit of -15 and an upper limit of 15. It has 5 memberships, each of it is triangular in shape. **Figure 6** shows the membership function of output named PWM. The range of this output is set with a lower limit of 0 and an upper limit of 255 adjusted to the range of values that can be generated by PWM. Like the previous 2 inputs, this output also has 5 memberships, each of it has a triangular shape.

Table 2 can be seen that the input and output of this FLC have 5 membership functions symbolized by Negative Big (NB), Negative Small (NS), Zero (Z), Positive Small (PS), and Positive Big (PB). As for the number of rules in Table 2 can be determined from the result of multiplying the number of 2 membership inputs, each of which has 5 memberships so that the results are 5x5 = 25 rules.

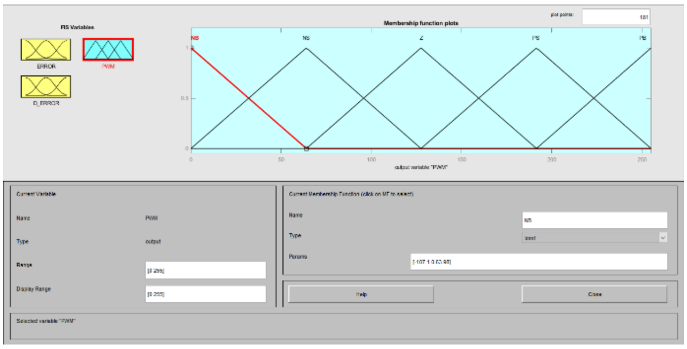

Fig. 6. Membership function output PWM.

Table 2. Rule Base.

$e/\Delta e$	NB	NS	Z	PS	PB
NB	PB	PB	PB	PS	Z
NS	PB	PB	PS	Z	NS
Z	PB	PS	Z	NS	NB
PS	PS	Z	NS	NB	NB
PB	Z	NS	NB	NB	NB

2.2 AVR Schematic

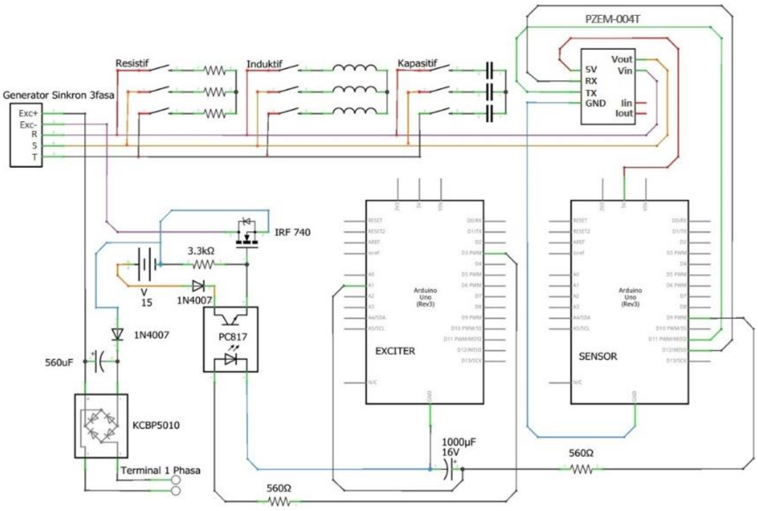

Fig. 7. AVR circuit schematic.

Figure 7 shows the test series of AVR circuit schematic using load aims to evaluate the AVR as a whole by automatically using a feedback system and adding load. This test also shows the ability of FLC to correct errors caused by additional loads, be it resistive loads, capacitive loads, or inductive loads.

3. RESULT

3.1 AVR with Resistive Load

Figure 8 below shows 2 system responses when a resistive load is given, namely systems that do not use FLC and those that use FLC. For testing systems that do not use FLC, when the terminal voltage reaches a value of 220 V then it is given a resistive load at t = 2 s* and makes the generator terminal voltage decrease to 203 V and is unable to improve the system response back up to the setpoint of 220 V.

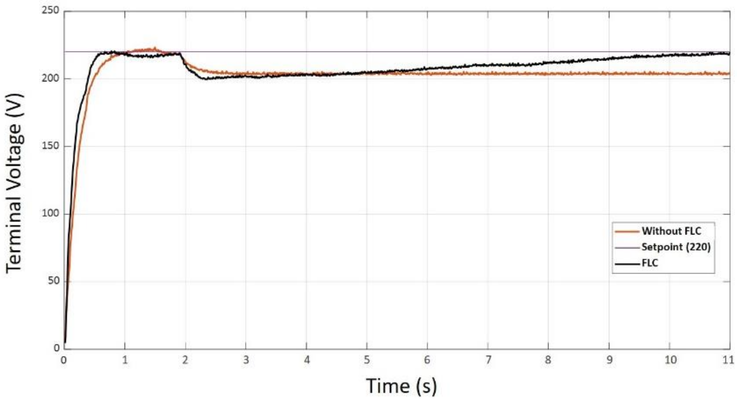

Fig. 8. AVR with resistive load.

As for testing the system using FLC, when the terminal voltage starts to touch 220 V then a resistive load is given so that it can be seen at t = 2 s* the terminal voltage decreases to 199 V and rises again until it reaches the setpoint at t = 10 s*. From these tests, it can be said that the FLC method takes ±8 seconds for the AVR to improve the response when given a resistive load.

3.2 AVR with Inductive Load

Figure 9 shows 2 system responses when given an inductive load, namely systems that do not use FLC and those that use FLC. For testing systems that do not use FLC, when the terminal voltage reaches a value of 220 V then it is given a resistive load at t = 2 s* and makes the generator terminal voltage decrease to 194 V and is unable to improve the system response back up to the setpoint.

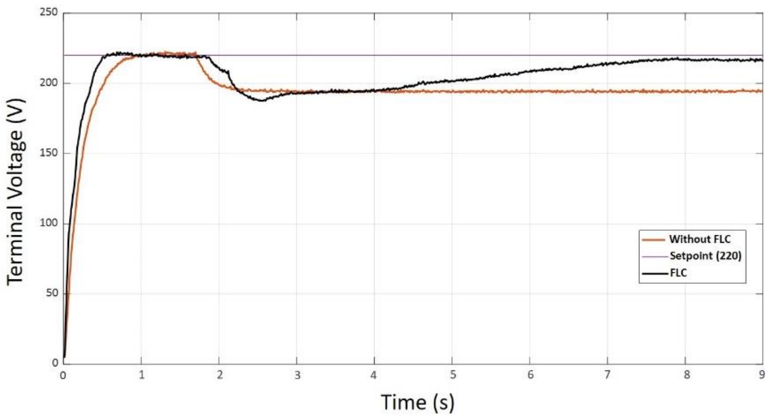

Fig. 9. AVR with inductive load.

As for testing the system using FLC, when the terminal voltage starts to touch 220 V then an inductive load is given so that it can be seen at t = 2 s* the terminal voltage decreases to 187 V and rises again until it reaches the setpoint at t = 8 s*. From these tests, it can be said that the

FLC method takes ±6 seconds for the AVR to improve the response when given an inductive load.

3.3 AVR with Capacitive Load

Figure 10 below shows 2 system responses when given a capacitive load, namely systems that do not use FLC and those that use FLC. For testing systems that do not use FLC, when the terminal voltage reaches a value of 220 V, it is then given a resistive load at t = 2 s* and makes the generator terminal voltage increase to 238 V and is unable to improve the system response back up to the setpoint of 220 V.

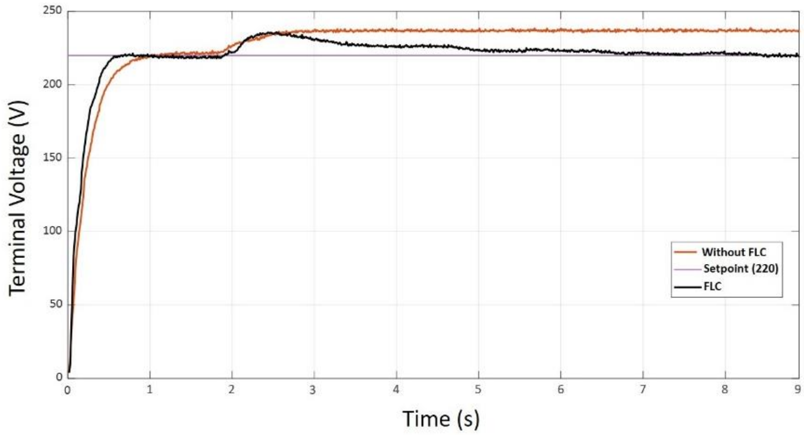

Fig. 10. AVR with capacitive load.

As for testing the system using FLC, when the terminal voltage starts to touch 220 V then a capacitive load is given so that it can be seen at t = 2 s* the terminal voltage rises to 234 V and falls back down until it reaches the setpoint at t = 8 s*. From these tests, it can be said that the FLC method takes ±6 seconds for the AVR to improve the response when given a capacitive load.

4 CONCLUSION

After the research was completed, namely designing the AVR with FLC then analyzing the test data so that conclusions were obtained : The excitation circuit is able to regulate the DC current that comes out according to the need to be supplied to the field coil of a 3-phase synchronous generator so that the terminal voltage can be controlled as desired. The AVR with the FLC method is able to stabilizing the terminal voltage of 220 V and able to correct the voltage within of ±8 seconds when the generator is given an resistive load, ±6 seconds when the generator is given an inductive and capacitive load.

References

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