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AC CHOPPER DESIGN AS UNIVERSAL MOTOR DRIVER BASED ON FUZZY LOGIC CONTROLLER

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The electric motor has the function is converting electrical energy into mechanical energy. Based on supply, the electric motor is divided into two kinds of supply that are alternating current and direct current. The universal motor is an alternating current motor, the construction, and characteristics of a universal motor are the same as a direct current motor. Fuzzy Logic Controller is combined with AC Chopper circuit as a universal motor driver to control the motor universal speed at the stability of 1000 RPM and uses LM393 Optical Encoder sensor that will give a feedback signal to the fuzzy system as input. This research purpose is to implement AC Chopper as a universal motor driver to get more stable speed control combined with Fuzzy Logic Controller as feedback. In this study, the author uses the experimental method. With variable control are setpoint at 50% duty cycle and 1000 RPM speed reference of motor universal. Which is using 10 types of duty cycle values to get the average of driver efficiency and then using 2 kinds of load conditions for the controller test. The result of the driver test is to get speed control while without load condition has a period of 3 – 5 seconds to reach 1000 RPM. Then, when the load shedding condition has an overshoot value of up to 1193.33 RPM and reaches 1000 RPM in the range of 2 - 3 seconds. In this study, got the result of average driver efficiency is 85.41%.

Keywords: *Speed Control, AC Chopper, Driver, Motor Universal, Fuzzy Logic Controller*

1. INTRODUCTION

Universal motors are mostly used and have controlling devices that function to control the speed of the universal motor [1-4]. AC Chopper is a circuit that is used to convert a fixed AC voltage input source into an AC voltage output source that can be controlled or regulated [5]. Power semiconductor components used like SCR, transistors, and MOSFETs that operate as a regulator [6]. The universal motor needs a controller with good efficiency as a speed controller. The sensor is needed on the motor whose output is the feedback to determine the universal motor actual speed produced for a good controller [7-8]. A fuzzy logic controller is one commonly used for feedback control methods. In this case, the Fuzzy control method was chosen to get a good motor speed control. With LM393 optical encoder sensor as feedback to motor driver that will read resulting motor speed and will be adjusted by the fuzzy logic controller by mapping a specified input to output [9 – 11].

This study aims to design and implement a basic and synchronous AC chopper circuit using MATLAB software to produce voltage intercepts based on the ignition angle as well as a dimmer circuit. Using four rectifier diodes connected to an IGBT for a basic AC chopper circuit that does not affect the resulting frequency [12]. However, previous research is just focused on producing intercept voltage using IGBT as well as a dimmer circuit without a closed-loop control system[13]. Whereas research in the design of AC-AC chopper as a universal motor driver based on fuzzy logic controller, using MOSFET as a signal trigger and implementing it for a universal motor driver and adding fuzzy logic as feedback with close loop controller system to make motor speed remain stable [14 – 16]. This research is the implementation of speed control of universal motor which has unstable speed while on loaded and load shedding condition.

The author uses an experimental method in this study, with three kinds of variables that are independent,

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dependent, and variable control. Voltage input and change of duty cycle are independent variables that will affect dependent variables like voltage output and actual speed. Then using setpoint at speed and duty cycle as a variable control. With a specified parameter, it can be the basis to conduct speed testing for the universal motor.

2. DESIGN SYSTEM

2.1 Block System

This research is a combination of an AC chopper as the main device, a universal motor as a controlled device, a fuzzy logic controller as a close-loop controller, an LM393 optical encoder sensor as a speed sensor, and Arduino Uno as a microcontroller which is processing place for fuzzy logic controller based on sensor data.

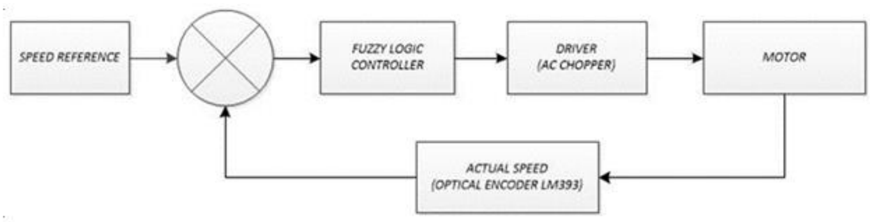

Figure 1: Block **s**ystem design.

The system can start by giving a reference speed to the fuzzy program used, FLC will affect the duty cycle value of the AC chopper. It will then affect change in voltage which affects speed change. The speed sensor will read the actual speed of the motor which will be sent back to the Arduino Uno microcontroller.

2.2 AC Chopper

AC Chopper circuit in Figure 2 which will be a universal motor driver has speed control which is affected by the output voltage of the AC Chopper [15]. It becomes a universal motor input voltage. The output voltage will be affected by PWM with the MOSFET gate which voltage has been increased with the Bootstrap MOSFET.

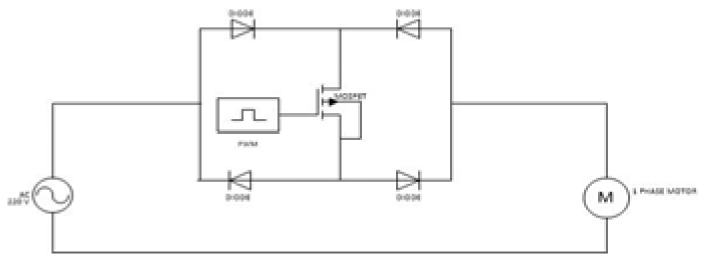

Figure 2: Basis AC chopper circuit.

AC chopper circuit consists of four rectifier diodes with a type of Ultra-Fast Recovery Diodes HER307 which has a maximum voltage of 700 V and maximum current of 3 A and one IRF730 MOSFET with maximum VDS of 400 V and VGS 15 V as PWM signal switching which will regulate the output voltage. It will be connected directly to a 220 V AC source and the universal motor load is a permanent magnet Synchron generator.

2.3 Fuzzy Logic Controller

In this Fuzzy Logic control, a fuzzy model used is closed-loop control. Clearer blocks of control used, can be seen in Figure 3.

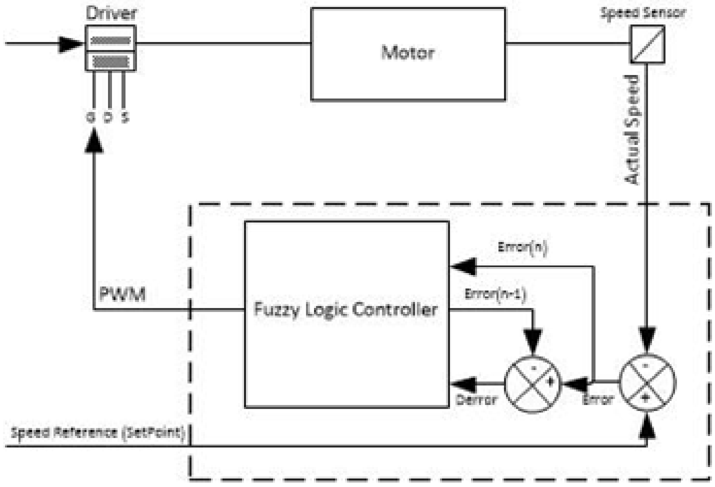

Figure 3: Controller diagram block.

Input from FLC (Fuzzy Logic Controller) system is the actual speed and speed reference of the universal motor which is processed with Equation 1 to get the Error value and Equation 2 to get the Deltaerror value [11]. The membership input function in this control is shown in Figure 4. Whereas for output of this system is a PWM signal to control the MOSFET gate [17]. The membership output function is shown in Figure 4 with the actual system output control value obtained by Equation 3 and the rule used is shown in Table 1.

$$Error = Actual\ Speed - Speed\ Reference \quad (1)$$

$$Derror = Error\ (n) - Error\ (n-1) \quad (2)$$

Where:

Error = error

Derror = delta error

Error (n) = error in n time

Error (n-1) = error in n-1 time

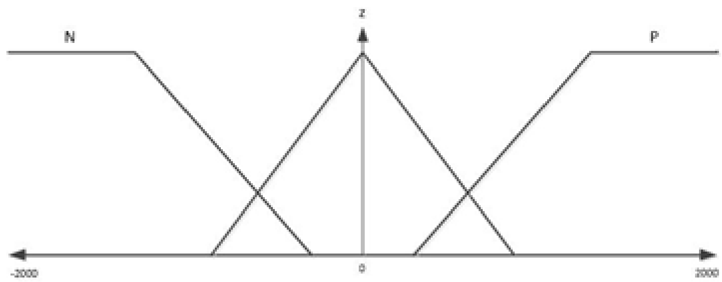

Figure 4: Error and derror membership input function

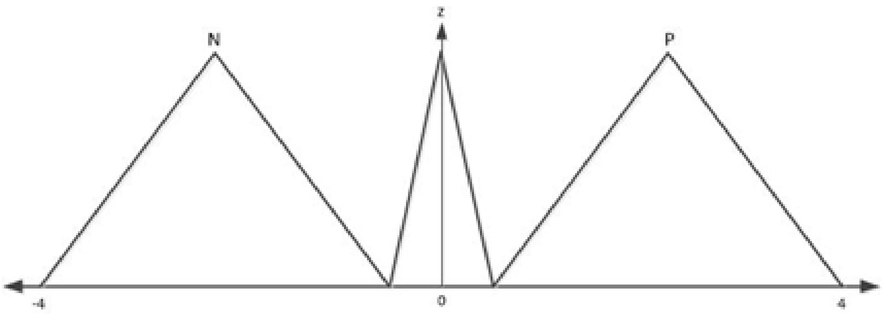

Figure 5: Membership output function.

Membership functions on FLC input and output are divided into 3, N (Negative), Z (Zero), and P (Positive). From 2 inputs and an output, 9 rules will determine the addition or reduction of the duty cycle to achieve a stable motor speed at 1000 RPM.

Table 1: Rule of fuzzy logic controller

	N	**Z**	**P**
N	P	P	N
Z	P	Z	N
P	P	N	N

$$PWM = PWM\ (Fuzzy)\ \times\ 255 \quad (3)$$

Where

N = negative

Z = zero

P = positive

3. METHOD

Researchers used experimental methods with the initial step of determining the independent variable, dependent variable, and control variable for the testing that the control work well. The researcher used the input voltage of the driver and duty cycle as an independent variable, the output voltage and actual speed of the motor as a dependent variable, and reference speed (setpoint) as a control variable. Researchers carried out two kinds of testing scenarios, efficiency, fuzzy control with load, and without load conditions.

3.1 Scenario 1

The first scenario is to input 10 different types of independent variables with the condition of a motor being loaded with a permanent magnet Synchron generator.

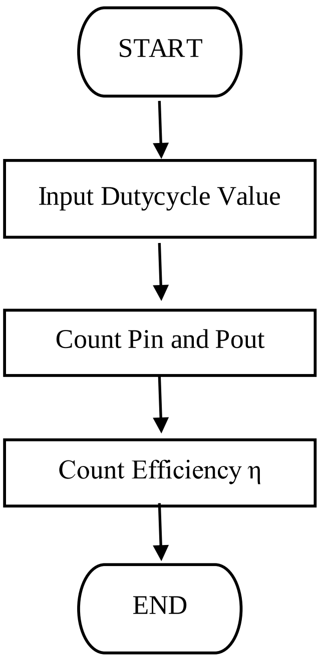

Figure 6: Scheme of scenario 1.

The scheme of scenario 1 starts with 10 kinds of duty cycle values. From 52% to 71% duty cycle to get efficiency value with equation (4) and equation (5) to get average of efficiency.

3.2 Scenario 2

The second scenario is a test of fuzzy control. The test was conducted when the motor was without load and given a permanent magnet Synchron generator as a load, both of which started at speed of 0 RPM (scenario 2a). Then the test was carried out with a load of 2 15W / 220V AC lamps with load giving and load shedding scenarios. Both have a 1000 RPM variable control.

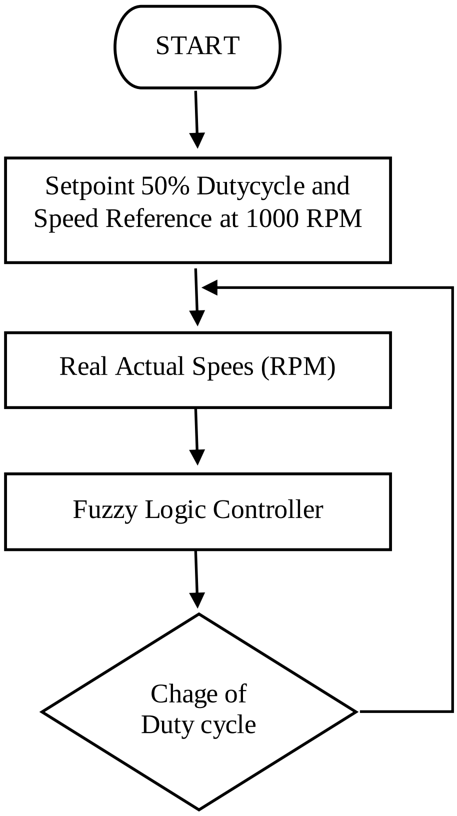

Figure 7: Scheme of scenario 2.

In this scenario, used a 50% duty cycle and set speed reference 1000 RPM as a set point. Then while loaded or under load shedding conditions, the speed sensor sends the actual speed reading to Arduino as feedback. The fuzzy Logic Controller will have the resulted output as a change of duty cycle. This algorithm work in a close loop system.

4. RESULT AND DISCUSSION

By carrying out the test by what has been stated in the Method section, the results of 2 test scenarios are obtained as follows:

4.1 Scenario 1

This test uses 10 different types of duty cycle variables with an input voltage of 63.57 VAC and gets the efficiency value calculated by Equation (4) and the average efficiency got from the calculation of Equation (5).

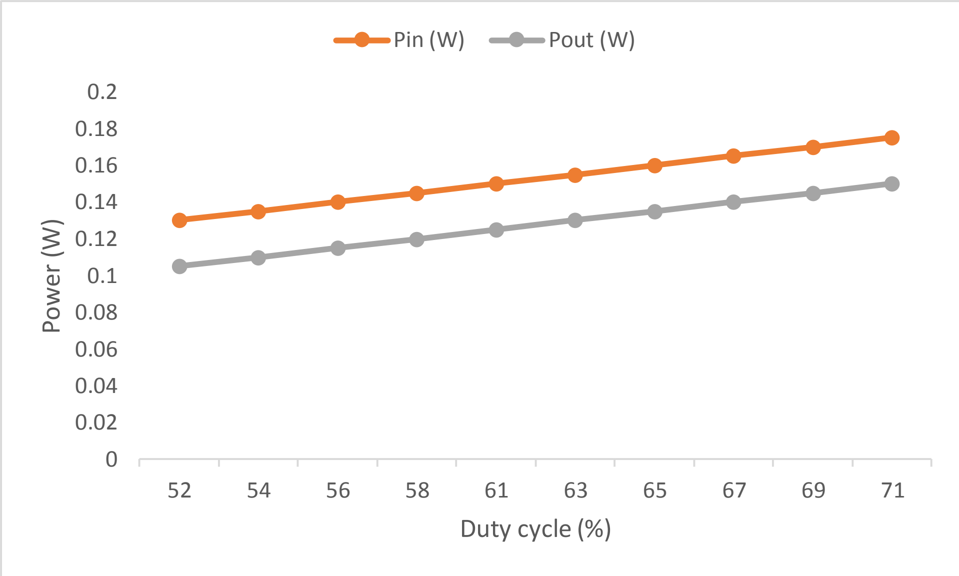

Figure 8: Efficiency of universal motor driver.

$$\eta(\%) = \frac{Pout}{Pin} \times 100\,\% \qquad (4)$$

Where :

η = efficiency (%)

Pout = power ouput (W)

Pin = power input (W)

Then average efficiency is obtained from:

$$average\,.of\,.\eta\,(\%) = \frac{\sum \eta\,(\%)}{\sum variable\ duty\ cycle} = \frac{854.12}{10} = 85.41\,\% \qquad (5)$$

From the efficiency test, the average efficiency value is 85.41%. These results prove that an AC chopper can be good voltage control as a universal motor driver with good efficiency.

4.2 Scenario 2

Scenario two is performed without load and loaded conditions. This test uses a 50% duty cycle as a setpoint. The load that the research used is a permanent magnet Synchron generator (scenario 2a) and two 15W /220VAC lamps connected to generator output (scenario 2b). When scenario 2b, without load condition setpoint, is when lamp 1 is on and lamp 2 is off. While the condition is loaded when both lights are on. In figure 9, activating lamp 2 means giving a load, and deactivating lamp 2 means load shedding. From the two scenarios, the following results were obtained.

4.2.1 Scenario 2a

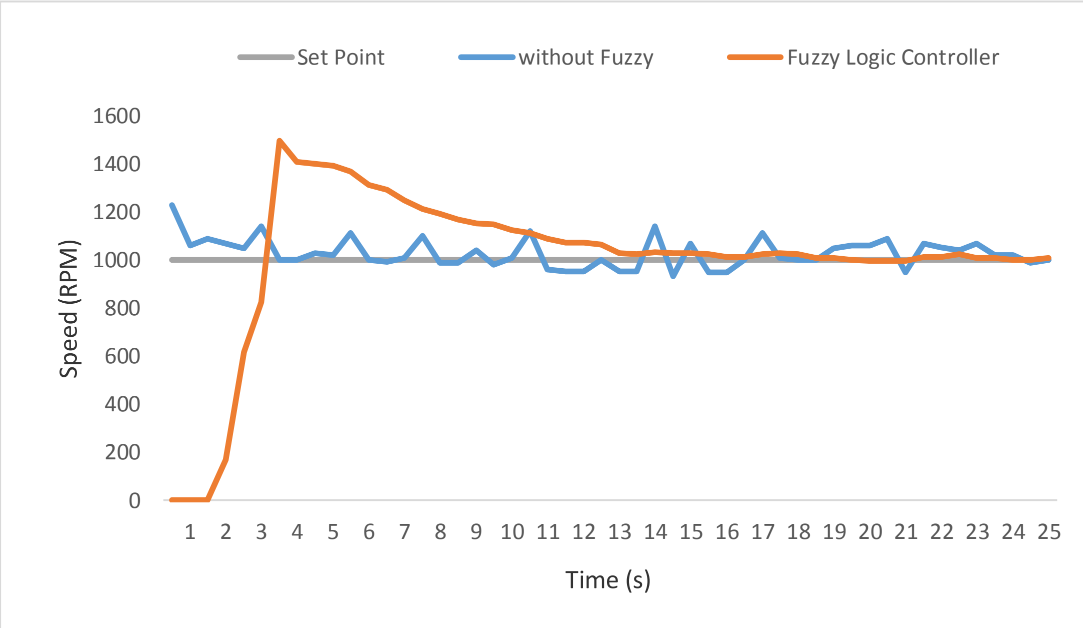

Figure 9: Speed testing without load condition.

In Figure 9, when using FLC, universal motor speed from 0 RPM to the 1000 RPM setpoint is obtained in 13 seconds and then stabilizes at 1000 RPM. Whereas when without FLC the motor speed is unstable at 1000 RPM even though it uses the same voltage value at the motor driver input.

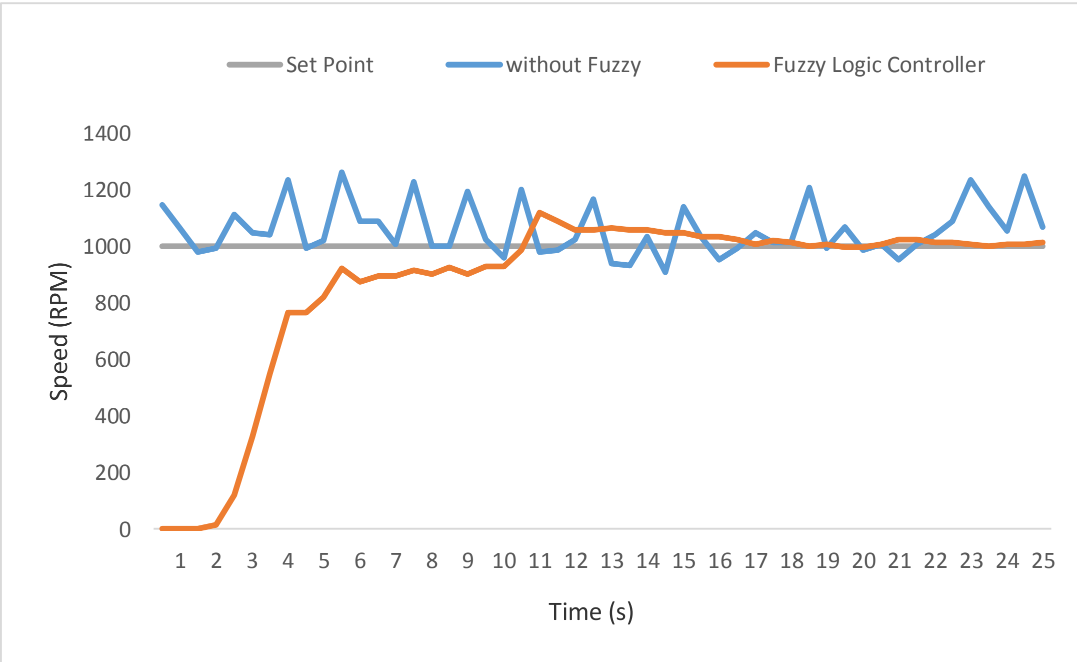

Figure 10: Speed testing loaded condition.

When a loaded condition is a permanent magnet Synchron generator, the time for the motor to reach 1000 RPM is 15 seconds and then it is stable. Figure 10 also shows that the universal motor speed has a smaller overshoot value than without load conditions.

4.2.2 Scenario 2b

This test is performed with a motor speed setpoint of 1000 RPM and a 50% duty cycle when the first lamp is on and the second is off. Arduino program used delay is 500 ms, which means that every one second represents 2 data displayed on the serial monitor.

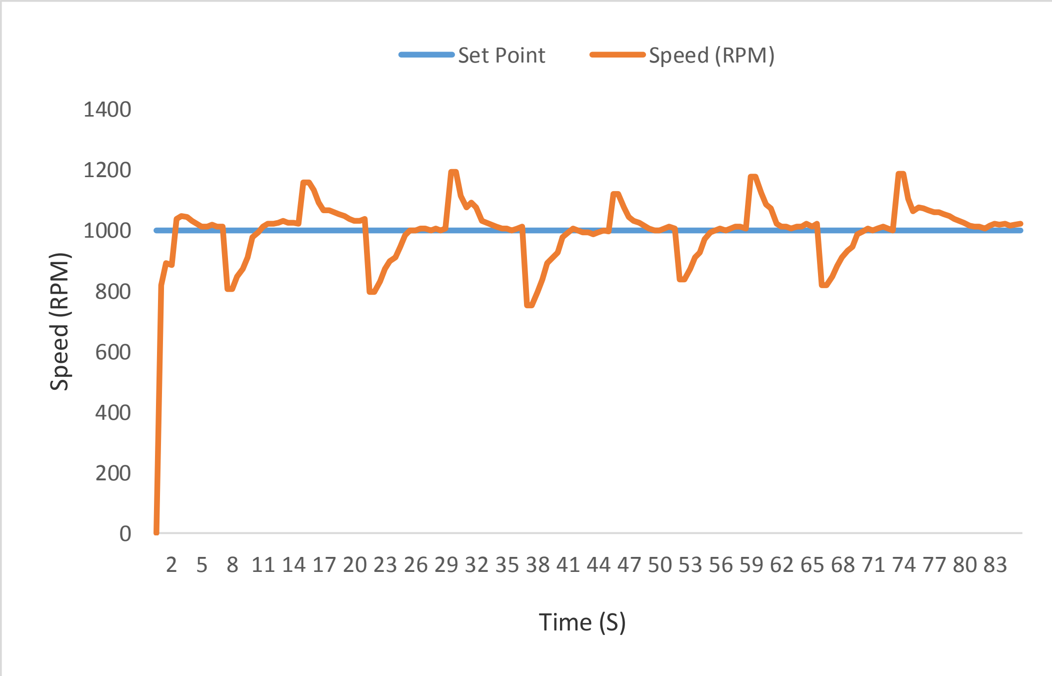

Figure 11 : Speed testing results by raising the setpoint while loaded and load shedding conditions.

Load giving and shedding is carried out five times. The lowest drop speed was obtained at the third load at 753.33 RPM, while the highest overshoot speed was obtained at the second load release at 1193.33 RPM. With highest duty cycle was 66% and the lowest was 48%. In scenario 2b, the time needed to reach a set point when given a load is 4 seconds, while to reach a set point when load shedding is 2 seconds.

In Scenario 2, the FLC function is to change voltage value to make universal motor speed stable at 1000 RPM through a change in duty cycle as an output of FLC. The addition of a duty cycle occurs when the actual speed is less than 1000 RPM, and the duty cycle will not change if the actual speed is in the 1000 RPM range, and if the actual speed exceeds 1000 RPM, a reduction in duty cycle will be carried out. There are two types of duty cycle changes mentioned that will loop until the actual speed is in the 1000 RPM range.

5. CONCLUSIONs

From the analysis and test results of the research, conclusions can be given that a universal motor driver designed using AC Chopper has a speed control through the duty cycle value of PWM which has an average voltage cut of 17.74 V and has a fuzzy design that functions as feedback which will result in the addition or reduction of duty cycles with a range of 7% - 94%. AC Chopper basic which is designed as a universal motor driver with fuzzy logic controller feedback control has an average efficiency value of 86.96%. Results of universal motor speed control when loaded conditions have a period of 3 - 5 seconds to reach 1000 RPM, while when the load shedding conditions have an overshoot value of up to 1193.33 RPM but can reach 1000 RPM in a range of 2 - 3 seconds.

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