Performance Evaluation using FLC to Optimize the Output Power PV

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Keywords: Fuzzy Logic Controller, Solar Cell, Zeta Converter.

Abstract: The role of renewable energy is needed to support the necessity of electricity. One of the renewable energy is solar power. Solar power is converted into electrical energy using a solar panel that produces DC electrical energy. The unstable of the power is cause by the intensity of the sun and temperature on the surface that fluctuate. The solution to the problem is needed a system to stabilize the power of the solar cell. A converter with a controller in the circuit of a power stabilizer. In this paper, the selection of the converter is based on the load requirements. The load requires a converter like a buck-boost converter. Zeta converter is the converter that's chosen in this paper. Zeta converter is a DC-DC converter that can produce increasing and decreasing output voltage. But, the output voltage of zeta converter is unstable. Thus, the zeta converter requires good control. In this paper is using Fuzzy Logic Controller. When the system is controlled by a fuzzy logic controller the average error obtained from the system is 0.05% with the average efficiency is 99.44% and the average time to achieve a steady state is 0.234 s. in addition to the test, this paper is comparing the performance of the fuzzy controller with the PI controller. The error that's obtained when the system is controlled using a PI controller the average error of the system is 0.0026% with an average efficiency is 93.86% and the average time to achieve a steady state is 0.593s.

1 INTRODUCTION

Along with the times, electronic technology is growing rapidly. But in reality, the more sophisticated technology causes the consumption of electrical energy that's needed also increasingly large. The increase in electricity consumption is not comparable to the availability of fossil fuels. So, it needs renewable energy to support the electrical energy. Renewable energy has a lot of advantages. One of them is friendly to the environment. Renewable energy can also reduce waste. There are many types of renewable energy. One of them is solar power (Sudiharto I, 2018). A component that's used to convert solar power into electrical power is the solar panel. Solar panel changes solar power into DC electrical power. Factors that influence the power of solar panels include the irradiation of the sun and the temperature of the solar panel. Because the output power is produced depends on the magnitude of the sun's intensity, so when the intensity of the sun fluctuates the power that's produced also fluctuates (Farid Dwi Murdianto, 2018). So from the problem is needed a system to stabilize the output power. The converter with the controller is a circuit of a power stabilizer. The converter is used based on the type of load. The load requires a converter like a buck-boost converter. Zeta converter is the converter that's chosen in this paper. A zeta converter is a converter that converts electrical energy DC into electrical energy DC with the value of the output voltage can be higher or lower than the input voltage. This zeta converter will transfer and stabilize the output power of the PV (Soedibyo, 2015).

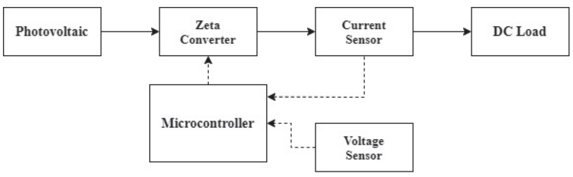

Figure 1: Block diagram system.

Figure 1 shows the overall system that is going to be discussed in this paper. From the block diagram, it can be seen that the zeta converter is controlled by the Fuzzy Logic Controller. The fuzzy logic controller is used to stabilize the output voltage of the zeta

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converter. This paper is comparing the performance of the Fuzzy controller with the PI controller. When the system is controlled by the fuzzy logic controller the average error obtained from the system is 0.05% with the average efficiency is 99.44%. then, when the system is controlled using a PI controller of 0..26% with an average efficiency is 93.68% (Indhana Sudiharto, 2019).

2 SYSTEM MODELLING

2.1 Photovoltaic Module

The solar panel is a semiconductor component that changes solar energy into DC electrical energy. The solar panel has a working principle which is when the sunlight hits the surface of the solar panel, electrons, and holes will emerge (M. Z. Efendi, 2017). Electrons and holes that arise around the p-n junction move towards the n layer and towards the p layer. So that the movement of electrons and holes arise potential differences in the load and also arise an electric current that flows through the load (S. Islam, 2014; S. Siddiqua, 2016). When the solar panel gets the sun's light the electricity that's generated from the ability of the solar panel device to produce voltage when it is given a load and current through the load. Factors that influence the output voltage of the solar panels other than sunlight are solar radiation and the angle of incidence of sunlight (Sattianadan D., 2017).

In this paper is using solar panel 100 WP. So we should know the specification solar panel 100 WP. Here are the specifications of the solar panel 100 WP that will be used

Voltage at Maximum Power	: 17.8V
Open Circuit Voltage (V_{OC})	: 21.8V
Current at Maximum Power (I_{mp})	: 5.62A
Short Circuit Current (I_{SC})	: 6.05A
Maximum Power (P_{max})	: 100WP

From the specification, it can be calculated the component of the zeta converter.

2.2 Topology Zeta Converter

Zeta converter is one of the isolated DC to DC converter that's operated in CCM. Zeta converter has a positive output voltage that operates like a buck-boost converter (Falin, 2018). The following is a picture of the working principle of zeta converter when MOSFET is in "On" and "Off" conditions.

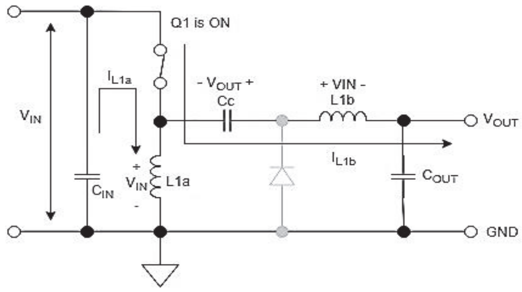

Figure 2: When MOSFET is "On State".

Figure 2 shows that the MOSFET is in "On state". When the MOSFET "On state" diode is open, the output voltage that's connected in series with inductor L_{1b} will charge the capacitor coupling. The value of the voltage across the inductor is $+V_{IN}$, and the voltage across the diode is V_{IN} + V_{OUT} (Ahana Malhotra, 2016).

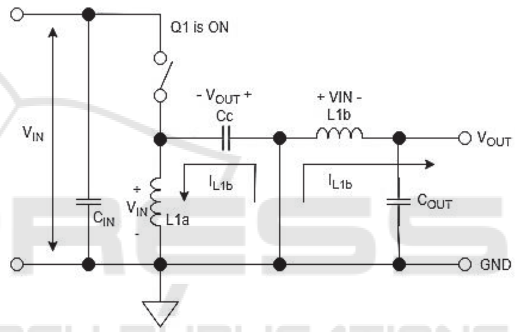

Figure 3: When MOSFET is "Off State".

Figure 3 shows that the MOSFET is in "Off state". When the MOSFET is in "Off state", the diode will be closed, so the voltage that passes through the inductor L_{1b} is the output voltage that's connected in parallel with the output capacitor. When the output voltage fills the output capacitor, the voltage that will pass through the MOSFET at "Off" condition is V_{IN} + V_{OUT}. The voltage that's through in the inductor L_{1a} is the relative output voltage of the negative drain's MOSFET (Antonio M.S.S. Andrade, 2015).

From the circumstances which are when the MOSFET "On state" and "Off state" can be obtained equations that are used to determine the value of duty and component values on the converter. Following is the equation for calculating the duty value and converter component value (Ashvini Admane, 2018; U. Jayashree, 2017).

$$D = \frac{V_{out}}{V_{in} + V_{out}} \quad (1)$$

$$\Delta I_{L(pp)} = K \times I_{in} \quad (2)$$

$$L_{1a(\min)} = L_{1b(\min)} = \frac{1}{2} \times \frac{V_{in} \times D}{\Delta I_{L(pp)} \times f_{sw}} \quad (3)$$

$$C_{in(\min)} = \frac{D \times I_{in}}{\Delta V_{C_{in}} \times V_{in} \times f_{sw}} \quad (4)$$

$$C_c = \frac{D \times I_{in}}{\Delta V_{C_c} \times V_{out} \times f_{sw}} \quad (5)$$

$$C_{out(\min)} = \frac{D}{8 \times \Delta V_o \times f_{sw}} \quad (6)$$

D : Duty cycle (%)
V_{in} : Input voltage (v)
V_{out} : Output voltage (v)
ΔI_L : inductor current ripple (A)
f_{sw} : switching frequency (kHz)
I_{in} : input current (A)
$L_{1a\,(min)}$: inductor 1 (uH)
$L_{1b\,(min)}$: inductor 2 (uH)
C_{in} : input capacitor (uF)
ΔV_{cin} : input capacitor voltage ripple (V)
C_{in} : input capacitor (uF)
ΔV_{cc} : voltage ripple capacitor coupling (V)
C_C : coupling capacitor (uF)
ΔV_o : output voltage ripple (V)
C_{OUT} : output capacitor (uF)

From equation 1 until 6 can be calculated the value of the component zeta converter. Here's the calculation component of the zeta converter.

Input Voltage (V_{IN})	: 78 V
Switching Frequency (f_{SW})	: 100 kHz
Input Capacitor (C_{IN})	: 42.57 uF
Inductor Current Ripple ($\Delta IL_{(PP)}$)	: 6 A
Inductor 1 (L_{1a})	: 47.97 uH
Coupling Capacitor (C_C)	: 22 uF
Inductor 2 (L_{1b})	: 47.97uH
Output Voltage Ripple (ΔV_{OUT})	: 0.025 V
Output Capacitor (C_{OUT})	: 36.9 uF
Output Voltage (V_{OUT})	: 204.9

2.3 Modelling of Fuzzy Controller

There are several methods in the fuzzy logic controller. In this paper is using Sugeno's method. The output of the fuzzy logic controller is a linear equation (Indhana Sudiharto S. F., 2018).

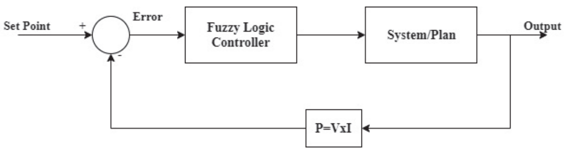

Figure 4: Block diagram fuzzy logic controller.

Figure 4 shows a block diagram of the fuzzy logic controller. There is a process tabulation of data in the fuzzy logic controller. In the process of fuzzy, there are stages in the planning consisting of fuzzification, rule base, and defuzzification (Narendiran S., 2016). The first stage determines the membership function using 2 inputs, namely error, and delta error.

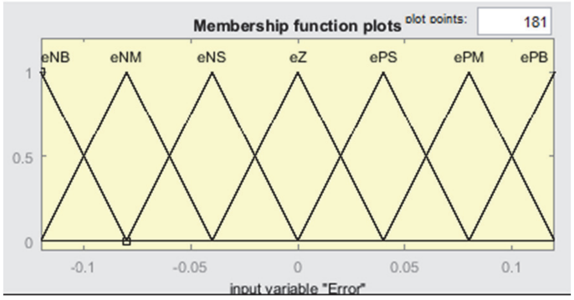

Figure 5: Design of membership function input "error".

Figure 5 shows the design of membership function input "error" using 7 membership functions.

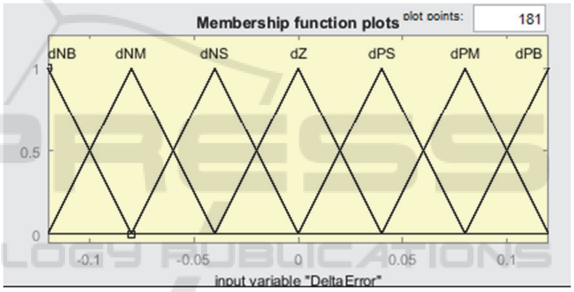

Figure 6: Design of membership function input "delta error".

Figure 6 shows the design of membership function input "delta error" using 7 membership functions.

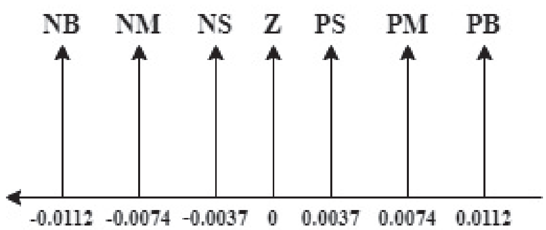

Figure 7: Design membership function output fuzzy controller.

Figure 7 is the design of the membership function output fuzzy controller which will be used to determine the results of the IF-THEN rules structure.

After designing the membership function input error, delta error, and output the next is designing a rule base. This rule usually uses a statement if then that describes as action in response to various fuzzy inputs. The rules are written in the membership function linguistic table pattern. The table consists of two inputs is error and delta error as well as one output (Epyk Sunarno, 2019). These rules can be written in the form of a matrix as shown in Table 1.

Table 1: Design of rule base fuzzy.

e/Δe	eNB	eNM	eNS	eZ	ePS	ePM	ePB
dNB	oNB	oNB	oNM	oNM	oNM	oNS	oZ
dNM	oNB	oNM	oNM	oNM	oNS	oZ	oPS
dNS	oNM	oNM	oNM	oNS	oZ	oPS	oPM
dZ	oNM	oNM	oNS	oZ	oPS	oPM	oPM
dPS	oNM	oNS	oZ	oPS	oPM	oPM	oPM
dPM	oNS	oZ	oPS	oPM	oPM	oPM	oPB
dPB	oZ	oPS	oPM	oPM	oPM	oPB	oPB

Table 1 shows the design results of the rule base

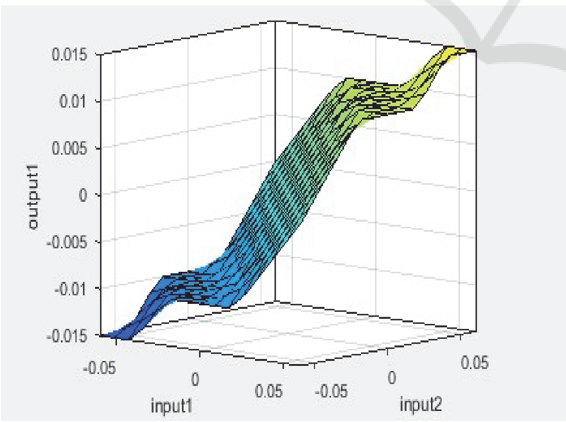

Figure 8: The surface of the results rule base fuzzy.

Figure 8 shows the surface that gets f/rom the design rule base fuzzy logic controller.

3 SIMULATION AND DISCUSSION

The performance of the Fuzzy Logic Controller is tested using simulation. The simulation of the zeta converter with a fuzzy logic controller is shown in Figure 9.

In this paper, the zeta converter is simulated using Powersim Simulation (PSIM) software.

This simulation uses a solar cell as a source of converter. Each solar cell has a power of 100WP. This system requires 12 solar panels with 4 solar panels is connected in series and 3 solar panels is connected in parallel. So the amount of the input power is 1.2 kW with the output voltage 78 V.

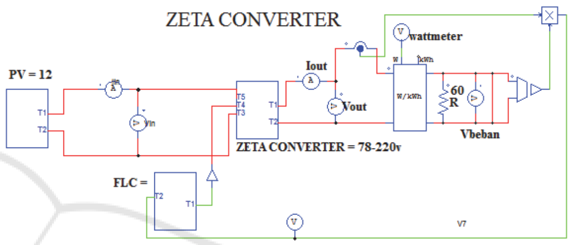

Figure 9: Simulation of zeta converter with Fuzzy Logic Controller.

Figure 9 shows the zeta converter that has been simulated with a fuzzy controller using 12 solar panels. In the sub-circuit, there are 3 solar panels which is 1 solar panel represents 4 solar panels that are connected in series. The voltage at maximum power (V_{mp}) is 17.8 V and the maximum power (P_{max}) is 100 Watts. After being simulated it can be seen the response of the system when using controls without disturbance or with disturbance. Besides that, it can also be seen the comparison of responses to the system when it is controlled using a fuzzy controller and PI controller. In this paper, the load uses the power setting. So, it uses the set point of power.

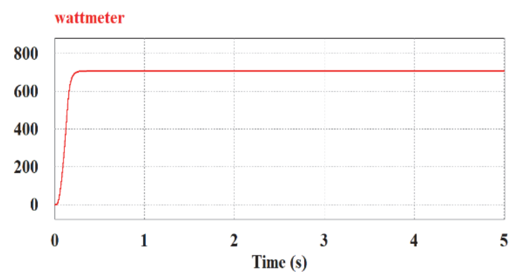

Figure 10: Response system when without control or using duty manual 72.4%.

Figure 10 is the response when without control or using duty according to the calculation that is 72.4%. it can be seen that at 72.4% duty, the output power is 707.49 watts. So it must be set manually according to the set point that's used. Figure 10 has been simulated with the output power is 301.5 watts, 397.6 watts, and 501.3 watts. The results of this simulation can be seen in the Table 2.

Table 2: The results of the simulation open loop system.

Duty (%)	V_{in} (V)	I_{in} (A)	V_{out} (V)	I_{out} (A)	P_{in} (W)	P_{out} (W)	Time to Steady (s)	Efficiency (%)
48.5	79.7	4.31	134.4	2.24	343.5	301.5	0.29	87.7
57.4	78.3	5.88	154.4	2.57	460.4	397.6	0.3	86.3
66.5	76.1	7.1	173.5	2.89	540.3	501.3	0.32	92.7
Average							0.3	88.9

Table 2 is the results of the simulation when the system is in an open-loop or without control. This open-loop condition was initially carried out by calculating the amount of duty when the output power was 300 watts, 400 watts, and 500 watts. After knowing the value of duty through the design, then it is simulated to validate whether the value of the duty is according to the output power. If it is not appropriate the value of duty is changed manually by estimating the value.

Table 2 also presents efficiency without control. The resulting average efficiency value is 88.97% and the average time to achieve steady-state is 0.3 s. The resulting efficient value is not optimal so that the control is needed to be more optimal.

Because the output power in the simulation value is greater than the desired design, control is needed. This paper uses a fuzzy logic controller.

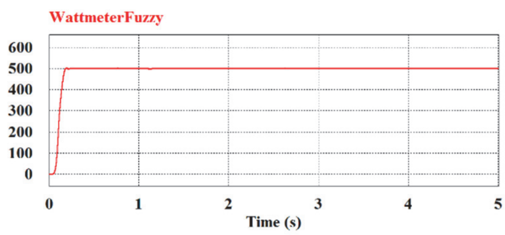

Figure 11: Response system is controlled by fuzzy at set point 500 watts.

Figure 11 is the response when the system is controlled by a fuzzy controller with the set point 500 watts. At the set point 500 watts, it turns out that the value of duty obtained is smaller than the value of design duty. So the output power on the system is according to the set point that's wanted.

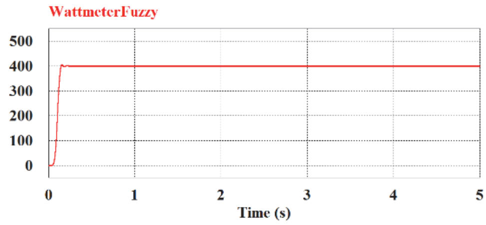

Figure 12: Response system is controlled by fuzzy at set point 400 watts.

Figure 12 is the response when the system is controlled by a fuzzy controller with a set point of 400 watts. It can be seen that the wattmeter shows the power is according to the set point that's wanted.

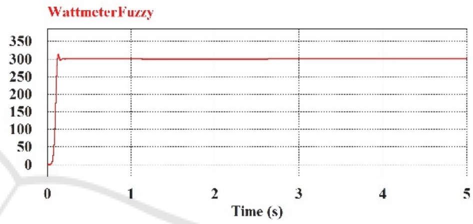

Figure 13: Response system is controlled by fuzzy at set point 300 watts.

Figure 13 is the response of the system when the system is controlled by a fuzzy controller with a set point of 300 watts. It can be seen the value of the response is according to the set point value that's given.

The results of the simulation from figure 11, figure 12, figure 13 can be seen in Table 3.

Table 3: Results of the simulation when closed-loop system or using fuzzy logic controller.

Set Point	V_{in} (V)	I_{in} (A)	V_{out} (V)	I_{out} (A)	P_{in} (W)	P_{out} (W)	Time to Steady (s)	Efficiency (%)
300	79.5	3.78	134.1	2.23	300.5	300.2	0.223	99.89
400	78.2	5.2	154.9	2.58	406.6	400.1	0.248	98.39
500	76.5	6.55	173.1	2.85	501	500.3	0.233	99.84
Average							0.234	99.37

Table 3 is the results of the simulation using a fuzzy logic controller. The working principle of this fuzzy controller is increasing duty if the power of the converter is smaller than the set point. And will reduce the duty cycle if the power of the converter is greater than the set point. In this case, the fuzzy controller is expected to optimize the output power so that the resulting efficiency is better than the open-loop system. It can be seen in the table the average efficiency values when using this fuzzy controller are 99.37%.

In the table 3, shows the time that's needed to achieve a steady-state. The average time to achieve a steady-state on this control is 0.234 seconds.

After the system is given control so that the value of the output system is according to the set point. Then the system is given a disturbance on the input side. Disturbance in the form of changes in solar irradiation. The purpose is to test the reliability of the control that's used. Reliability can be seen whether when the disturbance complete, the system can return to the initial set point.

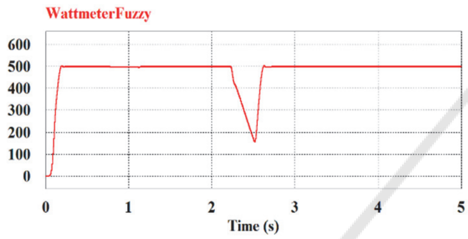

Figure 14: Response system is controlled by fuzzy when there's disturbance with set point 500 watts.

Figure 14 shows the response of the system with fuzzy control when there is disturbance. The set point of the system is 500 watts. Disturbance is given in seconds 2 to 2.5. So that after 2.5 seconds the system will return to the initial set point.

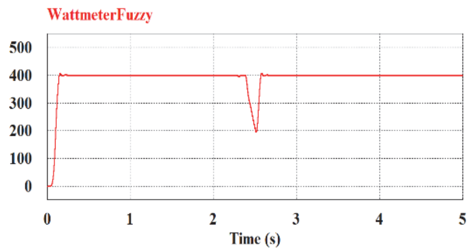

Figure 15: Response system is controlled by fuzzy when there's disturbance with set point 400 watts.

Figure 15 shows the response when it is controlled by a fuzzy controller when there is a disturbance. The set point of the system is 400 watts. At the set point 400 watts, the disturbance is smaller than the disturbance at the set point 500 watts.

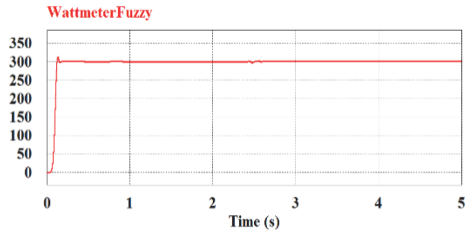

Figure 16: Response system is controlled by fuzzy when there's disturbance with set point 300 watts.

Figure 16 is the response of the system that's controlled by a fuzzy controller when there is a disturbance. The set point of the system is 300 watts. The resulting response is not so visible because the value of the input power system is greater than the desired output power.

In addition to testing the reliability of control by giving disturbance, the control that's used in this paper can also be tested by comparing when the system uses the PI controller.

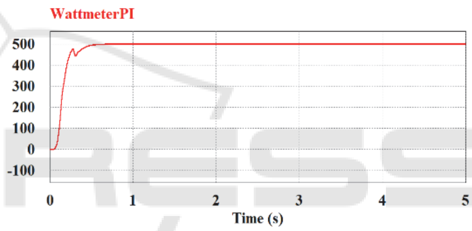

Figure 17: Response system when it's controlled by PI controller at set point 500 watts.

Figure 17 shows the response system when the system is controlled by the PI controller. The set point of the system is 500 watts. It can be seen in the response that the output power is stable at a value of 500 watts. And even though it's already stable, there's still an error.

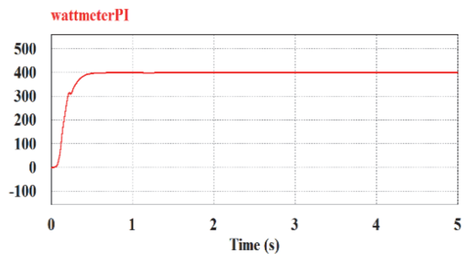

Figure 18: Response system when it's controlled by PI controller at set point 400 watts.

Figure 18 shows the response of the system when controlled by the PI controller. The second set point of the system is 400 watts. The set point is used to control the power to be stable. It can be seen the response system is stable at a value of 400 watts. Nevertheless, there is still an error.

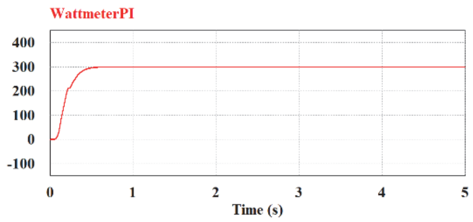

Figure 19: Response system when it's controlled by PI controller at set point 300 watts.

Figure 19 shows the response of the system when the system is controlled by the PI controller. The last set point of the system is 300 watts. From the set point, it can be seen that the output power is more stable at values close to 300 watts.

The results of the simulation from figure 17, figure 18, figure 19 can be seen in Table 4.

Table 4: Results of the simulation close loop system PI controller.

Set Point	V_{in} (V)	I_{in} (A)	V_{out} (V)	I_{out} (A)	P_{in} (W)	P_{out} (W)	Time to steady (s)	Efficiency (%)
300	79.8	4.1	134	2.23	327.18	299.99	0.62	91.68
400	78.4	5.4	154.8	2.58	423.36	399.99	0.57	94.47
500	76.6	6.88	173	2.88	527	499.99	0.59	94.87
Average							0.593	93.68

Table 4 is the results of the simulation when the close loop system. This close loop system is controlled by the PI controller. From the table can be seen the output power is according to the set point. Where the working principle of the PI controller is the same as the Fuzzy Logic Controller. When the output power is smaller than the set point, the control will automatically increase the duty cycle. And if the output power is greater than the set point, the control will automatically reduce the duty cycle. So that the output power is according to the set point and it is expected that the error value between the set point and the reference is small. From this small error, the average efficiency on the system is better than the average efficiency of the system in the open-loop condition but this efficiency of the system is smaller than the average efficiency in the close loop system using a fuzzy logic controller. The average efficiency of the close loop system that is controlled by the PI controller is 93.68%.

Table 4 can also be seen that the average time the control to achieve a steady-state is 0.593 seconds. So for optimizing efficiency and also speed up time to achieve a steady-state, on the system need the control to be improved by using a controller that can produce smaller errors.

From table 2, table 3 and table 4 can be compared that the fuzzy controller can optimize output power and produce greater efficiency than the PI controller. And the time to achieve a steady-state on the fuzzy controller is faster than the PI controller. The comparison can be seen in the graphic.

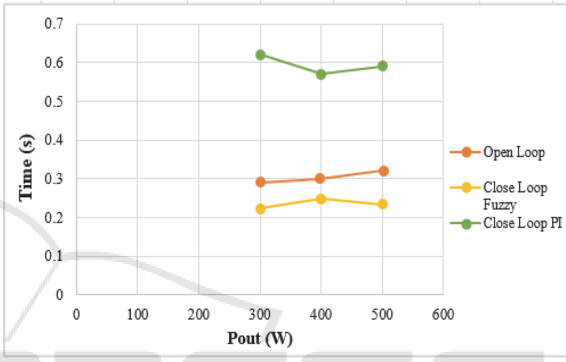

Figure 20: The graph of the comparison time to achieve steady-state when open-loop system, close loop system using FLC, and close loop system using the PI controller.

Figure 20 shows the comparison time to achieve steady-state when the open-loop system, close loop system using a PI controller, and close loop system using FLC. That graphic. From that picture, it can be seen that the fastest time to achieve a steady-state is a close loop system using FLC. And the longest time to achieve a steady-state is a close loop system using PI Controller.

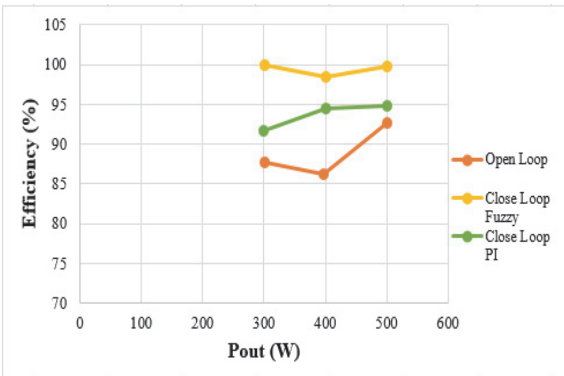

Figure 21: The graph of the comparison efficiency when open-loop system, close loop system using FLC, and close loop system using the PI controller.

Figure 21 shows the comparison efficiency when the open-loop system, close loop system using a PI controller, and close loop system using FLC. From that picture, it can be seen that the value of the biggest efficiency is a close loop system using FLC. And the value of the smallest efficiency is an open-loop system.

4 CONCLUSION

In this paper, the Fuzzy Logic Controller controls the zeta converter with the set points of 300 watts, 400 watts, and 500 watts. The results of the simulation indicate that the system is controlled by fuzzy works well. This can be compared when the system is without control. The value of the output power is not according to the calculation of output power. So the system is controlled to the output power is stable. When the system is controlled, it is necessary to test the reliability of the control. Control reliability testing is done by giving disturbance in seconds 2 to 2.5 s. After 2.5 s, the system will return to the initial set point. From the results of the simulation, it is shown that the fuzzy controller requires an average time to achieve the set point of 0.234 s. While in the PI controller, the time that's needed to achieve the set point was 0.593 s and the results of the simulation when the system without control requires an average time to achieve the set point of 0.3 s. The average error of the system that is controlled by fuzzy is 0.05% with the efficiency obtained by 99.37%. While the average error of PI is 0.002% with an efficiency obtained of 93.68%. And the last, the average error without control is 0.453% with an efficiency obtained of 88.97%. So the time is needed for the fuzzy controller to achieve a steady is faster than the time needed for the PI controller to achieve steady-state (Anjaly DAS, 2018)Also, it can be said that Fuzzy control is suitable for increasing the efficiency of the zeta converter.

REFERENCES

Sudiharto, Indhana; Sunarno, Epyk; Farid Dwi; Kurniasari, Desy Nanda (2018). Robustness Analysis of PI Controller to Constant Output Power with Dynamic Load Condition in DC Nanogrid System. IEEE 2018 *3rd International Conference on Information Technology*, 402-405.

Farid Dwi Murdianto; Moh. Zaenal Efendi; Kukuh Widarsono; Miftahul Azizi (2018). Robustness Analysis of PID Controller Bidirectional SEPIC/ZETA for Energy Management in DC Nanogrid Isolated System, IEEE 2018 *3rd International Conference on Information Technology*, *Information and Electrical Engineering*, 406-411.

Soedibyo; Budi Amri; Mochamad Ashari (2015). The Comparative Study of Buck-Boost, CUK, Sepic, and Zeta Converters for Maximum Power Point Tracking Photovoltaic Using P&O Method, IEEE 2015 *2nd International Journal of Int. Conference on Information Technology, Computer and Electrical Engineering*, 327-332.

Indhana Sudiharto; Epyk Sunarno; Farid Dwi Murdianto; Eni Wulandari (2019). Robustness Analysis of PI Controller to Optimizing the Output Power for Energy Management in DC Microgrid System, IEEE 2019 *2nd International Conference on Applied Information Technology and Innovation*, 105-110.

M. Z. Efendi, F. D. Murdianto, and R. E. Setiawan (2017). Modelling and Simulation of MPPT Sepic Converter using Modified PSO to Overcome Partial Shading Impact on DC Microgrid System, IEEE 2017 *International Electronics Symposium on Engineering Technology and Application*, 27-32.

S. Islam, S. B. Azad, H. Fakir and R. Rahman, A. Azad (2014). Development of Electric Stove for the Smart Use of Solar Photovoltaic Energy, IEEE 2014 *International Journal of Region 10 Humanitarian Technology Conference*, 94-98.

S. Siddiqua, S. Firuz, B. M. Nur, R. J. Shaon, S. J. Chowdhury, and A. Azad (2016). Development of Double Burner Smart Electric Stove Powered by Solar Photovoltaic Energy, IEEE 2016 *International Journal of Global Humanitarian Technology Conference*, 451-458.

Sattianadan D., Roopam Jha, Deepak Kumar Nayak (2017). Maximum Power Point Tracking for a Grid Connected Photovoltaic System using Sliding Mode Control, IAES Core *International Journal of Power Electronics and Drive Systems*, Vol. 8, 1785-1792.

Jeff Falin (2014). Designing DC/DC Converter based on Zeta Topology, *analog application Journal Texas*, 121-128.

Ahana Malhotra, Shitiz Vij, Dr. Prerna Gaur, Charvi Malhotra (2016). Design, Analysis and Performance of Zeta Converter in Renewable Energy Systems, IEEE 2016 *International Conference on Computing for Sustainable Global Development*.

Antonio M.S.S. Andrade, Luciano Schuch, Mario L. da S. Martins (2015). Photovoltaic Battery Charger based on Zeta Converter : Analysis, Design and Experimental Results, IEEE 2015 *24th International Symposium on Industrial Electronics*, 379-384.

Ashvini Admane, Dr. Harikumar Naidu (2018). Analysis and Design Of Zeta Converter, *International Journal for Innovative Research in Multidisciplinary Field*, Vol. 4, 161-167.

U. Jayashree, R. H. Pearl Nightingale, S. Divya (2017). Implementation of basic MPPT techniques for zeta converter, IEEE 2017 *3rd International Conference on*

Science Technology Engineering & Management, 601-604.

Indhana Sudiharto, Sutedjo, Farid Dwi Murdianto, Epyk Sunarno, Syechu Dwitya Nugraha, Ony Asrarul Qudsi (2018). Design and Implementation Unipolar SPWM FullBridge Inverter Using Fuzzy Sugeno in DC Microgrid Isolated System, IEEE 2018 *3rd International Conference on Information Technology, Information Systems and Electrical Engineering*, 368-373.

Narendiran S., Sarat Kumar Sahoo, Raa Das, Ashwin Kumar Sahoo (2016). Fuzzy Logic Controller based Maximum Power Point Tracking for PV System, IEEE 2016 *3rd International Conference on Electrical Energy System*, 29-34.

Epyk Sunarno, Indhana Sudiharto, Syechu Dwitya Nugraha, Farid Dwi Murdianto, Suryono, Ony Asrarul Qudsi (2019). Design and Implementation Bidirectional SEPIC/ZETA Converter using Fuzzy Logic Controller in DC Microgrid Application, IOPscience 2019 *International Converence on Engineering, Technology and Innovative Researches*, 1-7.

Anjaly DAS, Khrisnakumari T. (2018). Comparison of PI Controller and Fuzzy Logic Controller for The Improvement of Power Factor In Smps, IEEE 2018 *2nd International Conference on Inventive Communication and Computational Technologies*, 1597-1602.