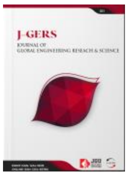

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Design and Hardware Implementation of Buck Converter Solar Charge System Using PID Controller

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ABSTRACT

Nowadays, energy sources in the world at the end until now tends to be filled using fossil fuels. It is estimated that the world energy consumption until 2025 is still dominated by fossil fuels, namely oil, natural gas and coal. The Ministry of Energy and Mineral Resources said that petroleum dominates 54% of energy use in Indonesia. One way to overcome the use of fossil energy sources is to replace them with renewable energy especially photovoltaic. Therefore, this paper presents solar charge system using Buck Converter PID Controller for Spotlight load. Buck Converter with PID Controller is used to produce a smaller and more stable output voltage from solar panels of 14.4 Volts for charging the battery. The PID parameter values obtained after performing calculations using the Analytic Tuning method and tuning are Kp = 0.0307, Ki = 58.20 and Kd = 0.000263. The expected result of this research is to design and implement a solar charge controller as a producer of electrical energy from environmentally friendly energy.

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1. INTRODUCTION

The electrical energy demands continues to increase every year due to population growth and increasing economic growth [1]. The use of fossil energy is still the main energy source in producing electrical energy. However, this fossil fuel will be depleted every year. Therefore, it is necessary to optimize the use of new renewable energy such as solar energy, wind energy, hydro energy [2]–[4]. Photovoltaic is one of the renewable energy sources that is widely used in software and software development processes due to the use of solar panels that are easy to use. The use of photovoltaic tends to be more expensive than the use of conventional energy, but the use of new and renewable energy is one of the environmentally friendly energies [5], [6].

Photovoltaic produce electrical energy that varies based on the intensity of the sun. This will cause the power (voltage and current) generated by the solar panel to unstable. Therefore, it need a DC-DC Converter that can convert a variable DC voltage into a constant DC voltage, one of the DC-DC Converter circuits is the Buck Converter. Buck Converter is used to convert a higher input voltage into a lower output voltage [7]–[9]. Recently, there are several techniques that have been used to produce a stable output voltage on the DC-DC Converter such as fuzzy logic control [10]–[12], fuzzy Takagi-Sugeno [13] and PID [14].

The main contribution from this research to design, simulate, and hardware implementation of buck converter that convert solar energy from photovoltaic to electrical energy using PID Controller for spotlight load. The mathematical model of Buck Converter is presented and the PID Controller is designed and tuned based on Analytic Tuning Method.

2. METHOD

Buck converter is a converter that convert DC variable input voltage to lower DC output voltage. The buck converter consists of two conditions, namely the duty cycle is on (Don) and the duty cycle is on cycle off ($Doff$), which basically has a differential equation that serves to determine the current in the inductor and the output voltage. When the switch (MOSFET) is on and the diode is off, the DC source will flow to the inductor and load. When the switch (MOSFET) is off and the diode is on, the DC source will be disconnected from the load circuit. For get a lower voltage than the input, buck converter using switching components to adjust performance (duty cycle). The switching component can be a thyristor, MOSFETs, IGBTs and more. The DC-DC buck converter circuit is shown in Figure 1 which is consists of a DC power supply, MOSFET transistor, output capacitor C, inductor L, ultrafast diode D, and resistor load R. Equation 1 is to obtain the output voltage, Equation 2 is to obtain the inductor value, and Equation 3 is to obtain the capacitor value are required to design a boost converter.

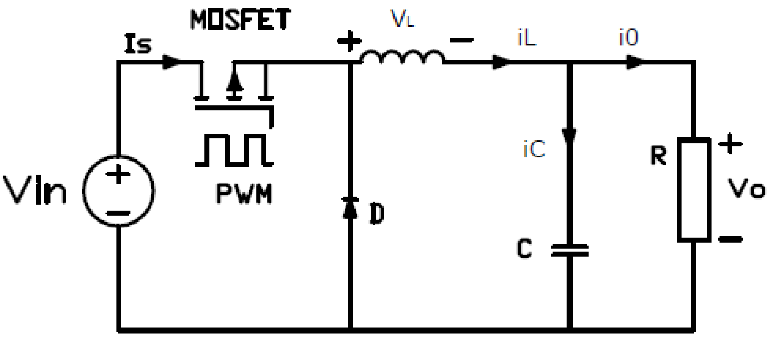

Figure 1. Buck Converter Circuit

$$Vo = VS \ x \ D \tag{1}$$

$$L = \frac{Vin - Vout}{2 \ x \ \Delta I_L} \ x \ DT \tag{2}$$

$$C = \frac{\Delta I_L}{8 \ x \ \Delta V} \ x \ TS \tag{3}$$

PID (Proportional Integral Derivative controller) is a controller to determine the precision of an instrumentation system with the characteristics of the presence of feedback on the system. PID controller is a conventional controller that is widely used in industry. The PID controller will give action to the Control Valve based on the size of the error obtained. The control valve will act as an actuator that regulates fluid flow in industrial processes that occur. The desired voltage level is called the Set Point. Error is the difference between Set Point and actual voltage level. The PID Block Diagram is depicted on Figure 2.

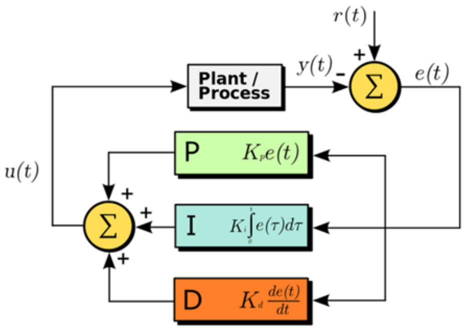

Figure 2. PID Controller

Figure 3 present a block diagram of solar charge system that consists of photovoltaic 150 WP that used for the main energy source to convert solar energy into the electrical energy, buck converter to convert DC variable input voltage into lower output voltage, battery 12 V 32 Ah as electrical energy storage, voltage input sensor to measure the input voltage from photovoltaic, voltage output sensor to measure the charging voltage, LCD to display the data, Arduino Uno arrange all of the controls work as well as the control of PWM buck converter using PID Controller and spotlight 12 V 20 W as the load.

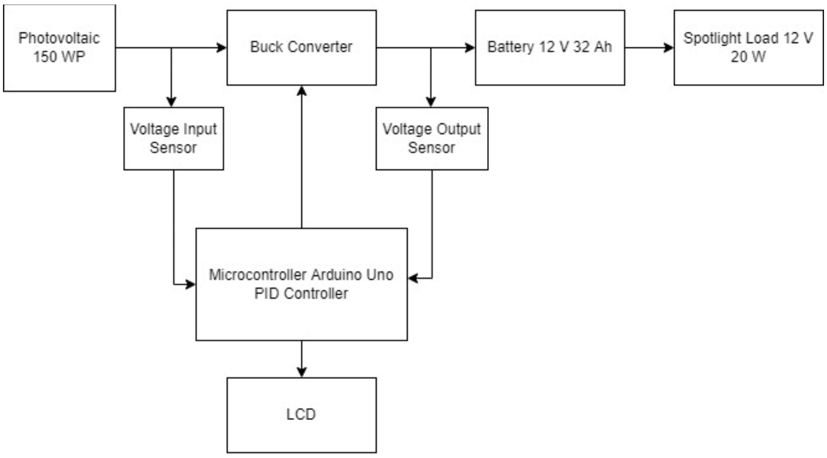

Figure 3 Blok Diagram System

3. RESULTS AND DISCUSSION

The 150 WP photovoltaic has a maximum output voltage of 22 Volts, which is the input voltage reference (Vin). For the charging voltage, it is obtained from the calculation of the battery voltage capacity, which is 12 Volts of which there are 6 2 Volt battery cells, then the charging voltage used is 2.4 Volts per cell, totaling 14.4 Volts for 6 battery cells. For the charging current, it is obtained from the calculation of the current capacity of the battery, which is 32 Ah, then the charging current used is 20% of the current capacity of the battery, which is 6.4 A. Based on the formula in equation 1, equation 2 and equation 3, the capacitor and inductor values are obtained in the table 1.

Table 1. Data Spesification of Buck Converter

f	Vin	Vout	L	C	R
40 kHz	22 V	14.4 V	3.97 mH	560 uF	2.25 Ohm

After getting the value of the inductor and capacitor components, next step is to simulate the open loop buck converter circuit in the PSIM application. Buck Converter circuit simulation which is used to reduce the solar panel voltage to the battery charging voltage is depicted in Figure 4. This simulation uses an open loop system so there is no output voltage feedback to the control system. The duty cycle is produced by comparing the ratio of DC voltage to the triangular voltage using the comparator component. If the DC voltage is greater than the triangular voltage then the mosfet in the buck converter circuit will be on, while the DC voltage is less than the triangular voltage then the mosfet in the buck converter circuit will be off.

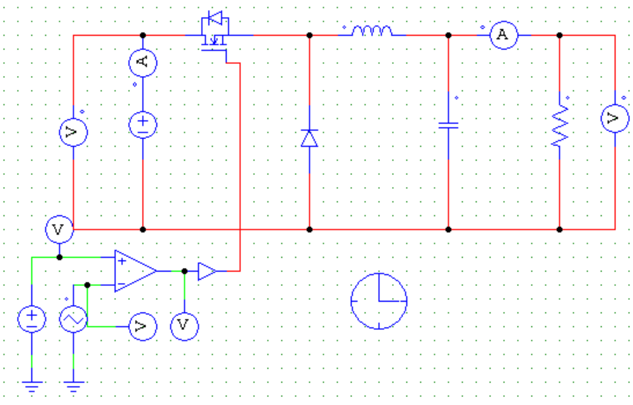

Figure 4. Buck Converter Simulation using PSIM

Figure 5 shows the output voltage waveform of the buck converter. It can be seen that the output voltage from the buck converter is still quite bad, which is shown from the output voltage response waves such as tp = 0.0231 s, Mp = 13.9V, ts = 0.0686 s, tr = 0.01004 s and ess = 2%. So the PID control is used to control the duty cycle which will improve the output voltage response of the buck converter. From the results of the output response above, the parameters Kp, Ki

and Kd can be searched using analytical methods. This tuning analytical method is used to find the Kp, Ki and Kd parameters by using an open loop output response.

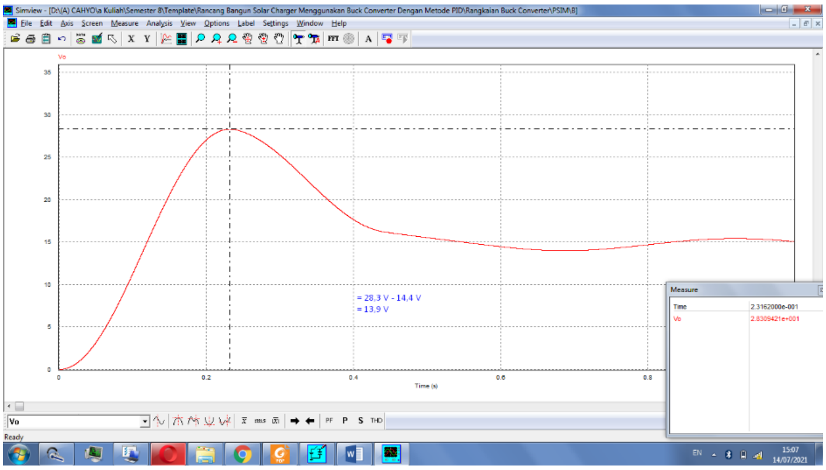

Figure 5. Open Loop Output Voltage Response

Simulation was done to simulate the control output voltage of Buck Converter with PID controller using matlab simulation. The purpose of carrying out PID control with analytical calculations is to minimize the overshoot of the output response of the output voltage and reduce the steady state error value Figure 6 present the Simulink block that contained reference voltage input, PID control, buck converter plant that was already modeled and scope, Figure 7 is a PID control parameter, and Figure 8 is a controlled output voltage response. There are 2 waveform namely the blue waveform as the reference voltage and the green waveform as the output voltage with the PID control. It can be seen that the output response produced is Tp = 0.0231 s, Mp=13.9V, Ts = 0.0686 s, Tr = 0.01004 s and ess = 2%. It can be seen that the resulting output response is quite good but trial and error must be carried out to produce a better output response so that the settling time is faster and the overshoot is not too large.

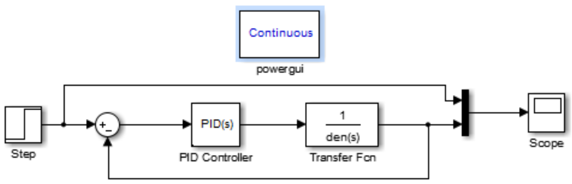

Figure 6. Buck Converter Closed Loop Simulation (analytic method)

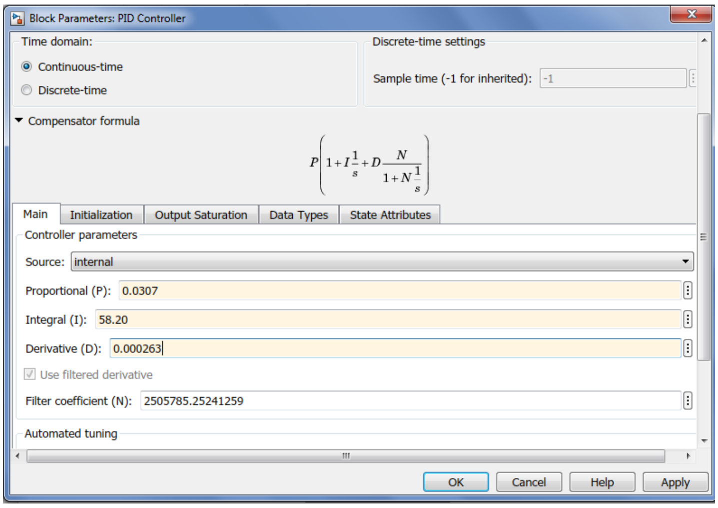

Figure 7. PID Controller Parameter Simulaton (Analitic Method)

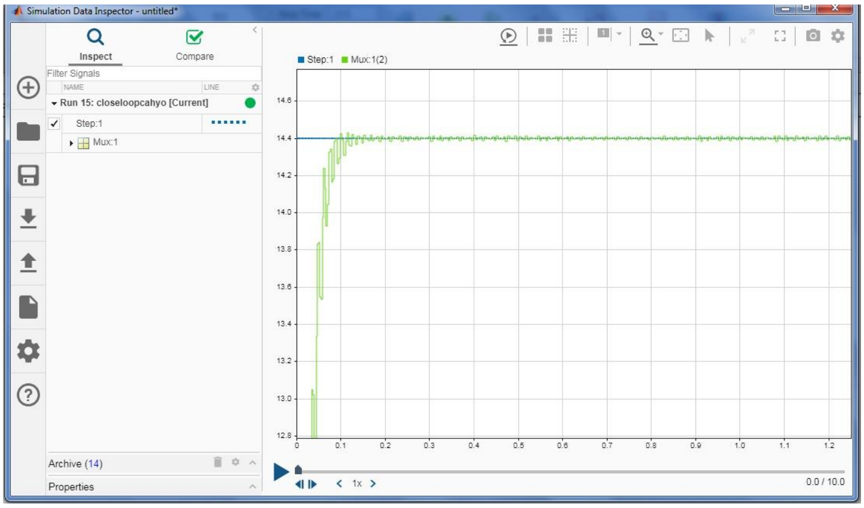

Figure 8. Output Voltage Response Closed Loop System (Analytic Method)

The last step is to make a hardware circuit of solar charge controller which includes Buck Converter, optocoupler, arduino uno, input and output voltage sensors which can be seen in Figure 9. Arduino uno contains related programs for reading input and output voltage sensors, displaying the readings on the LCD, and PID control for duty cycle settings. While the optocoupler used to separate the power circuit (Buck Converter) and control circuit (Arduino Uno), also increase the output voltage from the Arduino Uno into the MOSFET.

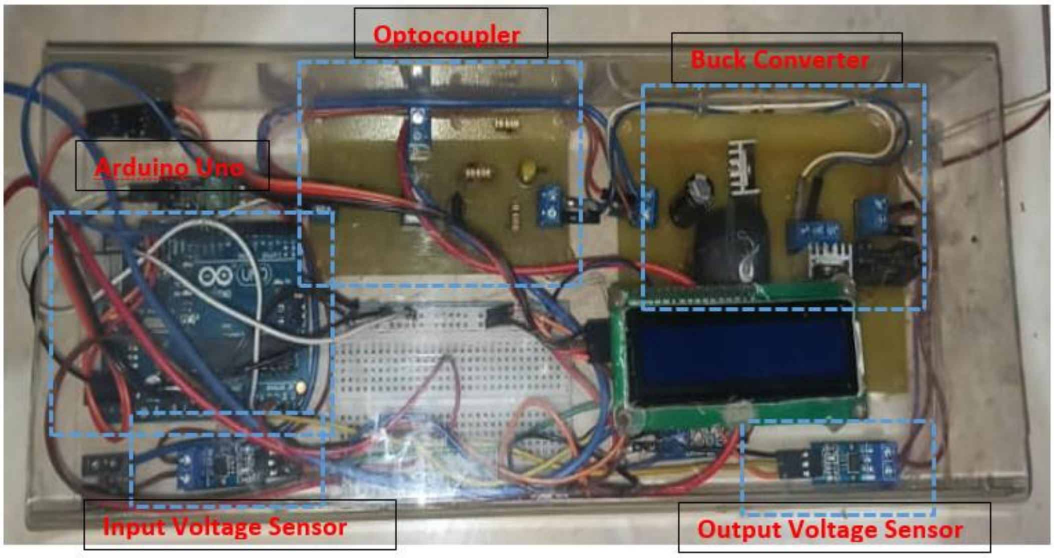

Figure 9. Solar Charge System using Buck Converter Hardware

Testing the system is done by connecting the solar charge system with photovoltaic. Testing is done with 2 methods, namely open loop and closed loop using PID Controller. Figure 10 shows the voltage response on the solar charge controller which shows that the Buck Converter has been successfully made by showing an output voltage with or without control which is smaller than the input voltage from the photovoltaic. And the voltage generated by the Buck Converter with the PID Controller is more stable, approaching the voltage setting point of 14.4 V compared to without control.

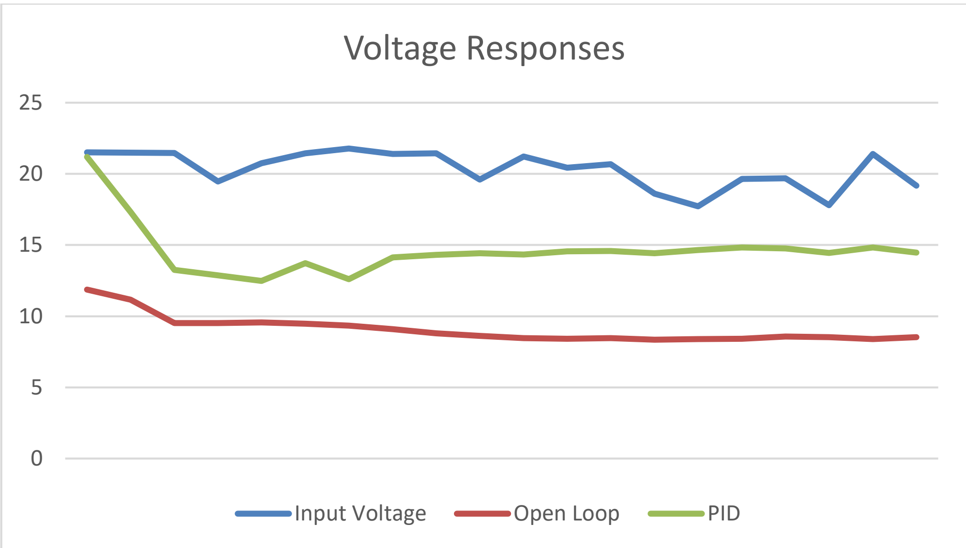

Figure 10. Voltage Responses of Buck Converter using Photovoltaic Input

4. CONCLUSION

The solar charge system using buck converter was successfully designed, simulated, built, and tested in this research. The buck converter succeeded in reducing the input voltage from the photovoltaic to a smaller voltage for charging the battery. This voltage was get lowered because the solar panel output voltage is around 17-22 volts, which will damage the battery if it is directly charged to the battery. The solar charge system is combined with a PID Controller as a buck converter output voltage regulator for battery charging which is set as much 14.4 Volts with PID control parameters, namely Kp = 0.0307, Ki = 58.20 and Kd = 0.000263. Solar energy utilization can reduce the use of fossil fuel sources for the generation of electrical energy on a small or large scale.

REFERENCES

[1] A. S. Paramita and S. Yohanes, "The Influence of Liquidity Toward Capital Structure," *J. Akunt.*, vol. 31, no. 11, pp. 2800–2911, 2018.

[2] D. Hendrawati, A. Soeprijanto, and M. Ashari, "Optimal Power and Cost on Placement of Wind Turbines using Firefly Algorithm," in *2015 International Conference on Suistainable energy Engineering and application*, 2015, pp. 59–64.

[3] D. H. N. F. A. Suharta, Nadella Penny, "Analisis Perhitungan Optimasi Daya Panel Surya Panel Surya," vol. 1, no. November, pp. 846–855, 2021.

[4] Sahid *et al.*, "Rancangan Turbin Pelton Mikro untuk Penggerak Mula Pembangkit Listrik Memanfaatkan Potensi Mikrohidro Kawasan Wisata Semirang Desa GOGIK Kabupaten Semarang," 2019.

[5] D. Hendrawati, A. Soeprijanto, and M. Ashari, "High performance maximum power point tracking on wind energy conversion system," *Int. J. Power Electron. Drive Syst.*, vol. 8, no. 3, pp. 1359–1367, 2017, doi: 10.11591/ijpeds.v8i3.pp1359-1367.

[6] B. Widi Dionova, "RANCANG BANGUN SUPLAI HYBRID ENERGY DENGAN AUTO SELECTION SWITCHING UNTUK BEBAN CHARGER BATTERY PADA LAPTOP DAN COOLING PAD," 2020.

[7] W. He, M. M. Namazi, H. R. Koofigar, M. A. Amirian, and J. M. Guerrero, "Voltage regulation of buck converter with constant power load: An adaptive power shaping control," *Control Eng. Pract.*, vol. 115, no. January, p. 104891, 2021, doi: 10.1016/j.conengprac.2021.104891.

[8] D. Ounnas, D. Guiza, Y. Soufi, R. Dhaouadi, and A. Bouden, "Design and Implementation of a Digital PID Controller for DC-DC Buck Converter," *Proc. - 2019 1st Int. Conf. Sustain. Renew. Energy Syst. Appl. ICSRESA 2019*, pp. 4–7, 2019, doi: 10.1109/ICSRESA49121.2019.9182430.

[9] K. Swathy, S. Jantre, Y. Jadhav, S. M. Labde, and P. Kadam, "Design and Hardware Implementation of Closed Loop Buck Converter Using Fuzzy Logic Controller," *Proc. 2nd Int. Conf. Electron. Commun. Aerosp. Technol. ICECA 2018*, no. Iceca, pp. 175–180, 2018, doi: 10.1109/ICECA.2018.8474570.

[10] K. Behih, K. Benmahammed, Z. Bouchama, and M. N. Harmas, "Real-Time Investigation of an Adaptive Fuzzy Synergetic Controller for a DC-DC Buck Converter," *Eng. Technol. Appl. Sci. Res.*, vol. 9, no. 6, pp. 4984–4989, 2019, doi: 10.48084/etasr.3172.

[11] N. D. Bhat, D. B. Kanse, S. D. Patil, and S. D. Pawar, "DC/DC Buck Converter Using Fuzzy Logic Controller," no. Icces, pp. 182–187, 2020, doi: 10.1109/icces48766.2020.9138084.

[12] B. W. Dionova, M. N. Mohammed, S. Al-Zubaidi, and E. Yusuf, "Environment indoor air quality assessment using fuzzy inference system," *ICT Express*, vol. 6, no. 3, pp. 185–194, 2020, doi: 10.1016/j.icte.2020.05.007.

[13] M. H. Cervantes, M. F. Montiel, J. A. Marin, A. C. T. Anguiano, and M. C. G. Ramírez, "Takagi-Sugeno fuzzy model for DC-DC converters," *2015 IEEE Int. Autumn Meet. Power, Electron. Comput. ROPEC 2015*, 2016, doi: 10.1109/ROPEC.2015.7395109.

[14] Widjonarko, G. A. Rahardi, C. Avian, W. Hadi, D. W. Herdiyanto, and P. L. Satrio, "Driver for LED Lamp with Buck Converter Controlled by PID," *Proc. - 2021 Int. Semin. Intell. Technol. Its Appl. Intell. Syst. New Norm. Era, ISITIA 2021*, pp. 216–219, 2021, doi: 10.1109/ISITIA52817.2021.9502199.