Vol. 16. No. 01, Januari 2025: 46-51
http:// publikasi.mercubuana.ac.id/index.php/jte
p-ISSN: 2086-9479 e-ISSN: 2621-8534

UPS With Half-Bridge Converter Based On Type-2 Fuzzy Logic Controller

David Benny Setiawan[1], Moh. Zaenal Efendi[1], Rachma Prilian Eviningsih[1]*

[1]*Department of Electrical Engineering Politeknik Elektronika Negeri Surabaya, Surabaya, Indonesia*
*rachmaevin@pens.ac.id

Abstract— ***Electricity is one of the most important needs. There are many electronic devices that support and facilitate human. Electrical disturbances are an inseparable part of the existence of electrical energy and we often encounter power outages with very fast and sudden time lags. The sudden disconnection of the power source can cause various losses, one of which is damage to the electronic equipment used or the loss of important data. Losses resulting from an abrupt power source failure can be effectively managed and reduced by incorporating a UPS (Uninterruptible Power Supply) unit between the power source and electronic devices. The converter and method used in this journal is the Half-Bridge Converter with the Type 2 Fuzzy Logic Controller method which functions to control the output of the Converter to be stable. The PLN source or input will be rectified with the Rectifier and lowered by the Half-Bridge Converter which will later be used to charge the battery. The output of the Half-Bridge Converter will be controlled using the Type 2 Fuzzy Logic Controller method. When the PLN source is still there, the battery will be in a charging position, and after the PLN source is lost or extinguished, the static switch will change the load source from the PLN source to a battery source. The output from the battery will be forwarded to the inverter and directly to the load. In this journal, the results of each simulation carried out are appropriate and close to the value of the plan. From the tests that carried out with Fuzzy Type-2, the average voltage value was 13.802V with an average error value of 0.055%, which is close to the planning and the error obtained is relatively small.***

Keywords*— *DC-DC Converter, Fast Switching, Fuzzy Type 2, Half-bridge Converter, UPS

DOI: 10.22441/jte.2025.v16i1.008

I. INTRODUCTION

Energy is the most important area of the industrial sector and the world economy in general [1]. Nowadays, the demand for digital technology and electronic equipment is increasing along with advancements and modernization in economic activities, industry, medical fields, and transportation systems with ensure reliable power supply to high-tech enterprises [2]. Digital technology and electronic equipment are often highly sensitive to disturbances, including issues as harmonics, overvoltage, undervoltage, transients, and power outages. These disturbances can significantly impact the performance of electronic devices and systems [3]. Unstable voltage or frequent voltage fluctuations over a long period and with high intensity can cause fatal damage, including damage to electronic equipment, malfunction of critical loads, and loss of unsaved data, resulting in significant losses across various sectors including industrial production [4], [5], [6]. Based on data in 2019, the number and duration of power outages in Indonesia increased. This causes a high possibility of equipment damage which is detrimental to companies and individuals. The main goal of the electric grid complex is to guarantee a consistent flow of electricity to consumers. This reliable and uninterrupted supply of electricity is crucial for the effective operation of numerous electronic devices and systems that are essential to modern society. [7].

In order to reduce the potential dangers caused by power interruptions, Uninterruptible Power Supply (UPS) systems are frequently installed at equipment locations. These UPS systems are designed to guarantee that the equipment can still operate even without external power, offering a crucial level of safeguard against power failures and other disturbances. [8]. So, when a power outage occurs, the load supply will automatically move from main source to the battery in the UPS without turning off electronic equipment using static transfer switch [9]. Meanwhile, when main source electricity is supplied again, the battery in the UPS is in charging mode. However, the increasing number of sensitive loads in information technology, communications systems, industry and health equipment means it is necessary to develop an UPS system.

In this research, the UPS is designed using a Half-Bridge Converter with the Type 2 Fuzzy Logic Controller method with battery capacity around 36 Ah [10]. Half-bridge cascading configurations facilitate synchronized power transfer from the input stage to the output stage in a single switching cycle, enabling efficient energy utilization. [11]. Apart from that, the output voltage of the Half-Bridge Converter (a half of the input voltage) is considered more efficient in reducing voltage as a battery charger [12].

In this system, the Half-Bridge Converter is controlled using a Fuzzy Logic Controller Type 2 because it has a better dynamic response than the PID method when large disturbances occur[13], [14], [15], [16]. The simulation outcomes and certain real-world control challenges demonstrated that an interval type-2 fuzzy controller delivered superior control performance compared to a type-1 fuzzy controller or a PID controller. [14], [17]. This method can also handle more parameter variations compared to the PID method. Integrating type-2 fuzzy sets into clustering algorithms provides increased flexibility in managing uncertainties related to membership concepts induced by a noisy environment. [18].

The advantage of this UPS is that it is able to control the output of the converter using type-2 fuzzy logic so that the converter output value is much more stable and the battery life time is longer. The use of type-2 fuzzy logic can also overcome things that affect the output in reaching the set point, such as temperature or environmental changes. For example, the change in voltage on the battery when charging for the battery itself is around 110-115% of the battery voltage.

For battery design in this research, a capacity of 36 Ah is used which lasts for 2 hours with a load of 200 W because this research is on a prototype scale. The aim of this research is to test the load conditions when the main source goes out (switching supply) when using an UPS system with a Half-Bridge Converter based on the Type-2 Fuzzy Logic Controller. This is to determine the suitability between the system design and the implementation of the journal created.

This research shows that by using Fuzzy Type-2 in Half-Bridge Converter can be developed for optimization purposes. However, there is currently still no research on the use of Fuzzy Type-2 in Half-Bridge Converter for a better voltage balance in Battery charging. This research opportunity could significantly contribute to the progress of Voltage balancing in Converter.

II. RELATED RESEARCHES

Creating a UPS using a half-bridge converter controlled by a type-2 fuzzy logic controller has not been attempted yet, although there have been various similar studies conducted previously. In the journal that explained about another UPS Technique [3]. The objective of this research was to develop an online Uninterruptible Power Supply (UPS) system incorporating a double conversion technique. The system was designed and simulated using MATLAB software, allowing for a detailed analysis and evaluation of its performance under various conditions. All simulation results of the converters, achieved using MATLAB SIMULINK R2015, are both desirable and ideal. The rectifier designed in this study efficiently transforms the AC waveform into a smooth DC waveform with minimal voltage loss and ripple. This ensures stable and reliable DC power supply for the UPS system, contributing to its overall effectiveness in maintaining power continuity for critical equipment. Furthermore, the SMC boost converter demonstrates robustness to input voltage fluctuations, consistently maintaining output voltage level of 24V. The inverter simulation successfully generates a 24V pure sine wave with a frequency of 50Hz. The performance analysis of the UPS system indicates compliance with relevant standards, such as IEEE standard 159 for THD, thereby ensuring the power quality is suitable for supplying critical loads.

This paper [19] introduces a transformerless single-phase online UPS featuring a novel half-bridge doubler-boost converter with switched-capacitor operation. The UPS supports both AC and DC input sources, ensuring high power efficiency and a unity power factor for optimal performance in line voltage applications. Experimental validation with a 2.5 kW prototype shows efficiency levels up to 94.9%, highlighting its practical feasibility and effectiveness.

In this journal [20], the study investigates about reducing harmonics in UPS outputs connected to nonlinear loads. It employs a Hybrid Active Power Filter (HAPF) with a Fuzzy Logic Current Controller (FLCC) to achieve significant harmonic reduction. The FLCC generates PWM signals in a single-phase half-bridge HAPF, studied under steady and transient conditions. The research compares various power filter topologies and reference current extraction methods to optimize UPS performance with nonlinear loads, demonstrating a THD reduction to 1.09%, meeting IEEE-519 standards.

Another journal [17] discussed about a detailed overview of Type-2 Fuzzy Logic Systems (T2FLS) and their successful applications in pattern recognition, classification, and control. It also includes a comparison with Type-1 Fuzzy Systems (T1FS) to illustrate the differences and strengths of these two fuzzy logic systems. The paper provides a succinct overview of Type-2 Fuzzy Logic Systems (T2FLS) and their prominent applications in pattern recognition, classification, and control, comparing them with Type-1 Fuzzy Systems (T1FS). Emerging in the early 2000s, T2FLS evolved from traditional Type-1 FL concepts to better model uncertainty and handle noise. Type-2 Fuzzy Logic (T2FL) has become increasingly popular due to its capacity to handle elevated levels of uncertainty and vagueness compared to traditional fuzzy logic systems. This enhanced capability makes T2FL a valuable tool in various applications where precise modeling of complex and uncertain systems is required. The reviewed papers highlight various successful applications of T2FL and discuss its potential in solving complex problems amidst vast information.

III. RESEARCH METHODOLOGY

The planning of a UPS system with a half-bridge converter based on a type-2 fuzzy logic controller is presented in the following block form in Figure 1:

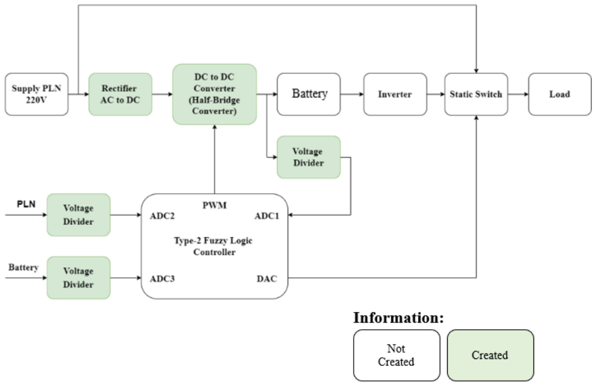

Figure 1 Flowchart of UPS system with a half-bridge converter based on a type-2 fuzzy controller

The system begins with a single-phase AC mains supply (220 V), which is then converted to DC voltage using a full-wave rectifier. The rectifier's output voltage is reduced with a DC-DC half-bridge converter and then used as a battery charger. The output from the converter also goes to a voltage divider, which is then processed using a type-2 fuzzy logic controller method to control the PWM and stabilize the converter's output. When the mains power (PLN) fails, a static switch changes the power source from the mains to the battery. The battery voltage is then processed with an SPWM inverter to produce AC voltage, which can be used to supply the load.

A. Battery Capacity Method

The AH size of the battery must be taken into account because this system must be able to last for 2 hours. Determining the battery current required by the UPS system with a 200 W load and 90% efficiency, Equation 1 is used:

$$I_{in} = \frac{P_{out}}{\eta \times V_{DC}} \quad (1)$$

Using an emergency time of 2 hours, the battery capacity in ampere-hours (Ah) is determined using Equation 2 as below:

$$Ah = I_{in} \times t_{emergency} \quad (2)$$

Based on the calculations from Equations 1 and 2, a battery with a capacity of 36 Ah has been selected, as it aligns with the commercially available options. For more comprehensive information about the parameters of the Battery Capacity, please consult Table 1.

Table 1. Parameters of Design Battery Capacity

Parameter	**Value**
Battery Input Current	18.51 A
Battery Capacity	36 Ah

B. Fuzzy Type-2 Logic Algorithm Programming Method

The programming method for the Type-2 Fuzzy Logic Algorithm uses the toolbox in MATLAB software as a simulation planning medium. In this simulation, input variables, output variables, rule bases, and the type reducer in the Type-2 Fuzzy algorithm are declared. The flowchart for the Type-2 Fuzzy Logic to control the duty cycle in the converter is as follows.

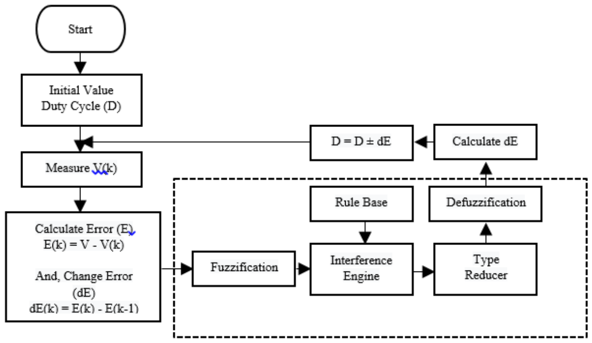

Figure 2 Flowchart Fuzzy Type-2 Logic Algorithm

The flowchart in Figure 2 initiates with the initialization of the initial duty cycle in the system. The initial declaration is the mid-value duty cycle between the maximum and minimum [0 – 0.45], which is 0.25. Next, the output voltage from the converter is measured using a voltage sensor or voltage divider. The measured parameter is declared as V(k). The program then calculates the values of E(k) and dE(k) from V(k). The input variables in this type-2 fuzzy method are Error and delta Error. Error (E) is obtained by subtracting the Set Point from V(k), and delta Error (dE) is the difference from the previous Error.

The Error and Delta Error values will be used as input parameters for the Type-2 Fuzzy system and processed into membership functions of Type-2 Fuzzy. The membership functions consist of Upper and Lower. These memberships are given a Rule Base as specified in Table 2. The parameters of these membership functions will be processed based on the Type-2 fuzzy calculation method using the Karnik-Mendel type reduction method.

Table 2. Rule Base Fuzzy Type-2

dE **E**	**NB**	**NS**	**Z**	**PS**	**PB**
NB	NB	NS	NB	NS	NB
NS	NS	Z	NS	Z	NS
Z	NS	Z	Z	Z	PS
PS	PS	Z	PS	Z	PS
PB	PB	PS	PB	PS	PB

The crisp values from the Type-2 fuzzy output will be in the form of dD values, which are then added to the Initial Duty Cycle. After calculation, the result of this Duty Cycle is compared to the Triangle signal emitted from the microcontroller, yielding respective high and low PWM signals.

C. *Half-bridge Converter* Method

Under normal conditions, the load is supplied by PLN, so there is a charging process on a 12 V battery. The required charging voltage is 115% of the battery voltage (Vo) which is 13.8 V. With the input of the rectifier output (Vs) of 311V, it requires a voltage drop using a half-bridge converter. By using a duty cycle (D) of 0.45, the transformer ratio of the half-bridge converter is determined by Equation 3.

$$V_{out} = V_{in} \times \frac{N_s}{N_p} \times D \quad (3)$$

Then determine the inductor value as a filter from the output of half-bridge converter through Equation 4 with switching frequency (fs) value of 40 kHz.

$$L = \frac{(V_s\left(\frac{N_s}{N_p}\right) - V_o)D}{\Delta i_L f} \quad (4)$$

With the inductor current value (iL) equal to output current value of the battery charging current (0.1 of the 18.51 A battery current) and the current ripple (riL) of 20%, the ΔiL value is calculated with Equation 5.

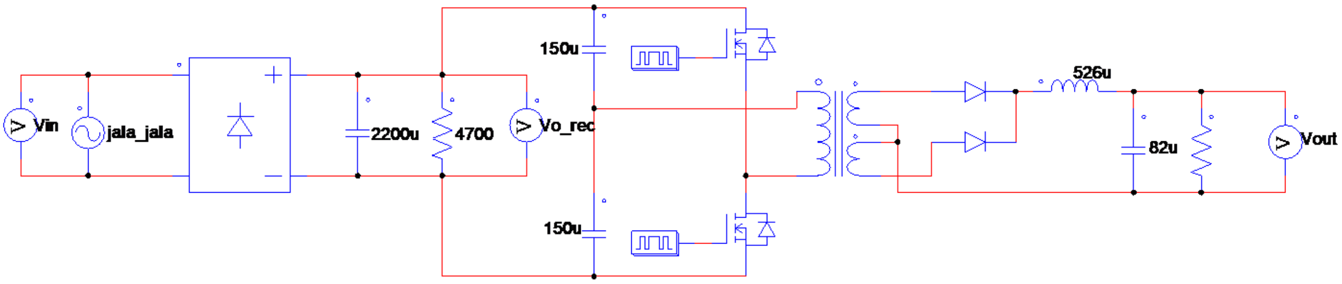

Figure 3. Open Loop System Integration Simulation Suite

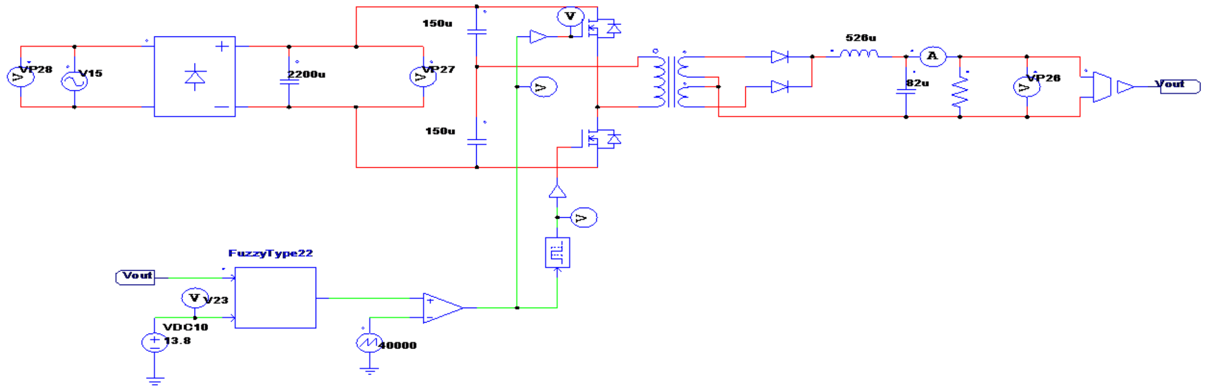

Figure 4. A Series of System Integration Simulations with Fuzzy Type-2

$$\Delta i_L = ri_L \times i_L \qquad (5)$$

Next, determine the value of the capacitor as a filter from the output of the half-bridge converter with an output voltage ripple (rVo) of 0.1% through Equation 6.

$$C = \frac{1-D}{8L_x rV_o f^2} \qquad (6)$$

Meanwhile, to determine the capacitance value of the capacitor on the half-bridge converter side using the input voltage value (Vs). Because the function of these 2 capacitors as input voltage divider, the voltage of each capacitor is half of the input voltage which is about 100 V. So, it uses 100 µF 100 V capacitors as on the market. For more comprehensive information about the parameters of the Half-Bridge Converter, please consult Table 3.

Table 3. Parameters of Design Half-Bridge Converter

Parameter	Value
Δi_L	0.37 A
Inductor	526.01 μH
Capacitor	81.68 μF
Switching Frequency	40 kHz

IV. RESULT AND ANALYSIS

This chapter contains data on the results of several tests carried out on all parts of the system. The system design is simulated via PSIM software, to determine the output results.

The simulation circuit is shown in Figure 3 and the simulation results are shown in Figure 5.

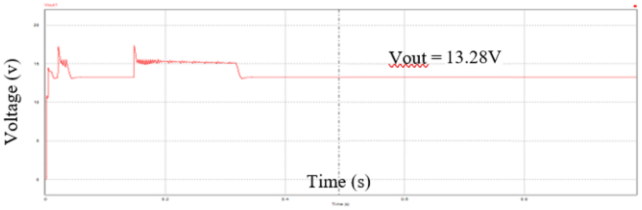

Figure 5 Open Loop integration system simulation results

From Figure 5 it can be seen that the output voltage value of the integrated system is 13.28 V with quite high voltage ripple. The results of the output value in the Open Loop integration system simulation are slightly close to the output value which should be 13.8 V. Without using Fuzzy Type-2, the Half-Bridge Converter in the simulation does not produce optimal output, so Fuzzy Type-2 is needed so that the output results are good. The result is more stable and optimal.

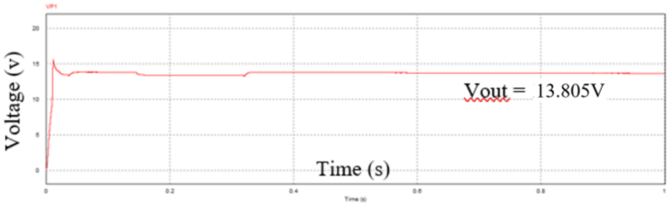

Figure 6 Simulation results of system integration with Fuzzy Type-2

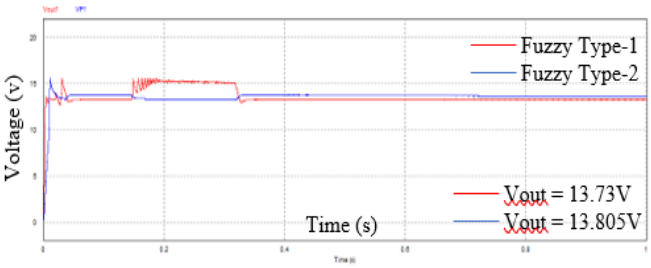

Figure 7 Comparison of Fuzzy Type-2 with Fuzzy Type-1

From Figure 4 and Figure 6 we can see the circuit and simulation results from integrated simulation testing using fuzzy type-2. In Figure 1.6 we can see the decrease in voltage ripple values in system testing using Fuzzy Type-2 compared to Open Loop system testing. Fuzzy Type-2 makes the voltage value more stable by referring to the set point that has been set. In Figure 7 you can see a comparison of the simulation results when compared with Fuzzy Type-1. The difference in output and set point will create a difference in value which requires Fuzzy Type-2 to calculate and set the Duty Cycle value on the MOSFET to the duty value it should be. The output value in the simulation results with Fuzzy Type-2 shows a value of 13.805V which is close to the design value in planning.

Table 4. Comparison of the output voltage results of Fuzzy Type-1 and Fuzzy Type-2

Input Voltage (V)	**Output Voltage with Fuzzy Type-1 (V)**	**Output Voltage with Fuzzy Type-2 (V)**	**Error Fuzzy Type-1 (%)**	**Error Fuzzy Type-2 (%)**
218	13.73	13.79	0.5	0.07
219	13.735	13.795	0.47	0.03
220	13.75	13.805	0.36	0.03
221	13.756	13.808	0.32	0.058
222	13.77	13.812	0.22	0.087

In Table 4 You can see the difference in the simulated voltage output of the Half-Bridge converter with Fuzzy Type-2 and Fuzzy Type-1. The converter output using Fuzzy Type-2 has an output value that is closer to the expected value with an average output voltage value of 13.802V with an average error value of 0.055% compared to Fuzzy Type-1 which has an average output value of 13.75V with an average error value of 0.37%. In the study, it was demonstrated that Type-2 Fuzzy Logic is more reliable in ensuring that the output value consistently approaches the set point. The reliability of Type-2 Fuzzy Logic was confirmed through a comparison between the converter output and the set point. This comparison allowed for the generation of a duty cycle value, which played a crucial role in adjusting the MOSFET to achieve the desired output. This duty cycle value is then utilized to adjust the MOSFET to generate the desired output, highlighting the effectiveness of Type-2 Fuzzy Logic in achieving precise control.

V. CONCLUSION

After carrying out the design and system creation stages and continuing with testing and analysis, several conclusions can be drawn. Are as follows:

1. In partial simulation using PSIM, the converter has worked according to design, namely converting a DC input voltage of 311 Volts with a duty cycle value of 45% to produce a DC output voltage of 13.8 Volts.
2. In the integration simulation using PSIM, the output results were slightly different compared to those during partial testing.

REFERENCES

[1] N. A. Testoyedov, I. A. Potapenko, N. M. Lugovaya, V. V. Kukartsev, and M. V. Karaseva, “Analysis of electric power technologies in industrial production,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 919, no. 6, p. 062006, Sep. 2020, doi: 10.1088/1757-899X/919/6/062006.

[2] South Ural State University, Chelyabinsk, Russia, I. Kirpichnikova, S. Shipilov, and Training aviation base, Chelyabinsk, Russia, “ENSURING UNINTERRUPTED POWER SUPPLY TO HIGH-TECH POWER ENTERPRISES,” *Bull. South Ural State Univ. Ser. Power Eng.*, vol. 22, no. 1, pp. 55–61, Mar. 2022, doi: 10.14529/power220106.

[3] Mohd. Z. Bin Daud and L. Kar Kuan, “Uninterruptible Power Supply (UPS) Using Double Conversion Technique,” in *2020 IEEE International Conference on Power and Energy (PECon)*, Penang, Malaysia: IEEE, Dec. 2020, pp. 159–164. doi: 10.1109/PECon48942.2020.9314492.

[4] S. Mgaya and H. Maziku, “Machine Learning Approach for Classifying Power Outage in Secondary Electric Distribution Network,” *Tanzan. J. Eng. Technol.*, vol. 41, no. 1, pp. 1–9, Jul. 2022, doi: 10.52339/tjet.vi.767.

[5] M. Ramachandran, V. Saravanan, and C. Raja, “An overview of Uninterruptible Power Supply Systems,” *J. Appl. Chem. Phys.*, vol. 1, no. 1, pp. 8–13, Dec. 2022, doi: 10.46632/jacp/1/1/2.

[6] Y. Zhu, W. Hu, Z. Wang, and X. Ma, “Single-phase on-line uninterruptible power supply with low load regulation,” in *2021 IEEE International Conference on Power Electronics, Computer Applications (ICPECA)*, Shenyang, China: IEEE, Jan. 2021, pp. 615–619. doi: 10.1109/ICPECA51329.2021.9362585.

[7] M. N. Polkovskaya and M. A. Yakupova, “Analysis of the Causes of Emergency Shutdowns on Electric Networks,” *J. Phys. Conf. Ser.*, vol. 2096, no. 1, p. 012130, Nov. 2021, doi: 10.1088/1742-6596/2096/1/012130.

[8] M. Ferraro, G. Brunaccini, F. Sergi, D. Aloisio, N. Randazzo, and V. Antonucci, “From Uninterruptible Power Supply to resilient smart micro grid: The case of a battery storage at telecommunication station,” *J. Energy Storage*, vol. 28, p. 101207, Apr. 2020, doi: 10.1016/j.est.2020.101207.

[9] A. H. Okilly, N. Kim, J. Lee, Y. Kang, and J. Baek, “Development of a Smart Static Transfer Switch Based on a Triac Semiconductor for AC Power Switching Control,”

Energies, vol. 16, no. 1, p. 526, Jan. 2023, doi: 10.3390/en16010526.

[10] G. Jiang, "Design of online uninterruptible power supply with AC output," *J. Phys. Conf. Ser.*, vol. 1754, no. 1, p. 012010, Feb. 2021, doi: 10.1088/1742-6596/1754/1/012010.

[11] K.-C. Tseng, V.-T. Liu, R.-Y. Chen, and R.-H. Hsieh, "An Integrated Buck and Half-Bridge High Step-Down Converter," *Electronics*, vol. 11, no. 17, p. 2666, Aug. 2022, doi: 10.3390/electronics11172666.

[12] C. Akgül, Y. ÇetiNceviZ, and E. ŞehiRli, "DESIGN AND APPLICATION OF AC/DC SWITCHING POWER SUPPLY WITH HALF BRIDGE DC/DC CONVERTER TOPOLOGY FOR BATTERY SYSTEMS of ELECTRICAL VEHICLE," *J. Sci. Rep.-A*, no. 052, pp. 149–173, Mar. 2023, doi: 10.59313/jsr-a.1213162.

[13] B. Arifin, B. Y. Suprapto, S. A. D. Prasetyowati, and Z. Nawawi, "Steering Control in Electric Power Steering Autonomous Vehicle Using Type-2 Fuzzy Logic Control and PI Control," *World Electr. Veh. J.*, vol. 13, no. 3, p. 53, Mar. 2022, doi: 10.3390/wevj13030053.

[14] J. Shi, "Structure Analysis of General Type-2 Fuzzy Controller and Its Application:," *Int. J. Fuzzy Syst. Appl.*, vol. 12, no. 1, pp. 1–20, Mar. 2023, doi: 10.4018/ijfsa.319813.

[15] H. Han, Z. Liu, H. Liu, J. Qiao, and C. L. P. Chen, "Type-2 Fuzzy Broad Learning System," *IEEE Trans. Cybern.*, vol. 52, no. 10, pp. 10352–10363, Oct. 2022, doi: 10.1109/TCYB.2021.3070578.

[16] B. Zhu and P. Ren, "Type-2 fuzzy numbers made simple in decision making," *Fuzzy Optim. Decis. Mak.*, vol. 21, no. 2, pp. 175–195, Jun. 2022, doi: 10.1007/s10700-021-09363-y.

[17] K. Mittal, A. Jain, K. S. Vaisla, O. Castillo, and J. Kacprzyk, "A comprehensive review on type 2 fuzzy logic applications: Past, present and future," *Eng. Appl. Artif. Intell.*, vol. 95, p. 103916, Oct. 2020, doi: 10.1016/j.engappai.2020.103916.

[18] X. Yang, F. Yu, and W. Pedrycz, "Typical Characteristic-Based Type-2 Fuzzy C-Means Algorithm," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 5, pp. 1173–1187, May 2021, doi: 10.1109/TFUZZ.2020.2969907.

[19] L. G. Fernandes, A. A. Badin, D. F. Cortez, R. Gules, E. F. R. Romaneli, and A. Assef, "Transformerless UPS System Based on the Half-Bridge Hybrid Switched-Capacitor Operating as AC–DC and DC–DC Converter," *IEEE Trans. Ind. Electron.*, vol. 68, no. 3, pp. 2173–2183, Mar. 2021, doi: 10.1109/TIE.2020.2970672.

[20] M. Kumar, M. A. Uqaili, Z. A. Memon, and B. Das, "Experimental Harmonics Analysis of UPS (Uninterrupted Power Supply) System and Mitigation Using Single-Phase Half-Bridge HAPF (Hybrid Active Power Filter) Based on Novel Fuzzy Logic Current Controller (FLCC) for Reference Current Extraction (RCE)," *Adv. Fuzzy Syst.*, vol. 2022, pp. 1–18, May 2022, doi: 10.1155/2022/5466268.