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Implementation Joule Thief Buck-Boost Converter in A Neodymium Wind Power Plant

Tedi Lasmara[1], Syaid Al Idrus[1], Muhamad Riyad Ariwibowo[1]

Abstract: Wind power generation is gaining popularity as an environmentally friendly renewable energy source. However, the output voltage of a wind generator usually varies according to the wind speed, requiring a power converter to produce a stable DC voltage. The author of this research aims to implement a Joule Thief Buck-Boost Converter on a neodymium wind power generation system. Joule Thief is a DC-DC converter that has the ability to convert a low input voltage into a higher output voltage, and can maintain a relatively stable output voltage despite changes in the input voltage. In this study, a Joule Thief buck-boost converter is used to regulate the output DC voltage of the neodymium wind generator to remain stable despite the changing wind speed. System testing is done by measuring the output voltage of the neodymium wind power plant. The test results show that the Joule Thief Buck-Boost Converter can maintain the output DC voltage at a stable value of 14V at input voltages above 3V, so the implementation of this converter in neodymium wind power plants is proven effective in producing a stable DC voltage. This research is expected to contribute to the development of a more efficient and reliable wind power generation system.

Keywords: Wind power generation, Joule Thief buck-boost converter, Neodymium generator, Stable DC voltage, Renewable energy

1. Introduction

Wind power generation is gaining popularity as an environmentally friendly renewable energy source. However, the output voltage of a wind generator usually varies according to the wind speed, thus requiring a power converter to produce a stable DC voltage [1-2]. Joule Thief is a DC-DC converter that has the ability to convert a low input voltage into a higher output voltage. The Joule Thief buck-boost converter is used to regulate the output DC voltage of the neodymium wind generator to remain stable despite the changing wind speed [3].

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Muhamad Riyad Ariwibowo
riyad_ariwibowo@ugj.ac.id

[1]Department of Electrical Engineering, Universitas Swadaya Gunung Jati, Cirebon - 45132, Indonesia.

Increased development of electrical and electronic systems in various study programs including telecommunication systems, electric power distribution, control system, and system used in medical engineering, navigation system, and others as required [4].

DC-DC converters are widely developed in various applications because they have various advantages, among them is a more compact form and has high efficiency [5-6]. DC-DC converters have experienced rapid development since the 1940s. In addition to its high growth rate DC-DC converters are undergoing dramatic changes as a result of two major trends in the world electronics industry namely high voltage and high-power density. Production of DC/DC converters in the world market is much higher than AC/DC converters. In many technical applications, it is required to convert a certain fixed DC input into a variable output voltage and for that used type certain converters called DC-DC converters [7-8]. By applying the joule thief buck boost converter to this wind power plant, it is expected that the overall efficiency of the system can be optimized. Joule thief buck-boost

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converter (JTBBC) will condition the output voltage of wind turbine to match the needs of the load or energy storage system.

This research aims to implement a Joule Thief Buck-Boost Converter on a neodymium wind power generation system, and can maintain a relatively stable output voltage despite changes in the input voltage. The JTBBC was chosen because it has a simple structure, low cost, and fairly high efficiency [9-10]. The research conducted includes applied research, with experimental research methods, where this approach is applied to system design and data analysis. The test results show that the JTBBC can maintain the output DC voltage at a stable value of 14V at an input voltage above 3V, so the implementation of this converter in a neodymium wind power plant is proven to be effective in producing a stable DC voltage.

The major contributions of this work are as follows

- Increases the input voltage of the generator and stabilizes its output voltage.
- When the generator input is low, the boost converter has the role of increasing the low voltage to a high voltage.
- Provide experimental results that validate the effectiveness of JTBBC in generating stable DC voltage for wind power systems.
- Contribute to the development of more efficient wind power generation systems.
- Applying Joule Thief Buck-Boost Converter (JTBBC) on neodymium wind power generation system

The remaining paper is organized as follows. Section 2 presents the literature survey, Section 3 about the methodology and materials, Section 4 about the results and comparisons and lastly the conclusions are drawn in Section 5.

2. Literature Survey

The Joule Thief is a simple circuit that can increase the voltage of a power source that has a low voltage [11]. The Joule Thief circuit is operated using a MOSFET as a switch to regenerate voltage and current in units of time and then distributed to the load [12-13]. Power for the boost converter can come from DC sources such as batteries, solar panels, and DC generators. The converter is highly favored for its ability to produce a constant voltage output [10][2], [14].

Joule thief is not a new concept. The basis is the voltage oscillation booster [15-16]. Power for the boost converter can come from DC sources such as batteries, solar panels, and DC generators [17]. The basic operation of a buck-boost converter is that the current in an inductor is controlled by two switches (usually a transistor and a diode). In an ideal converter, all components are considered perfectly. Specifically, switches and diodes have zero voltage drop when on and zero current when off and inductors have zero series resistance. Furthermore, it is assumed that the input and output voltages do not change during the cycle.

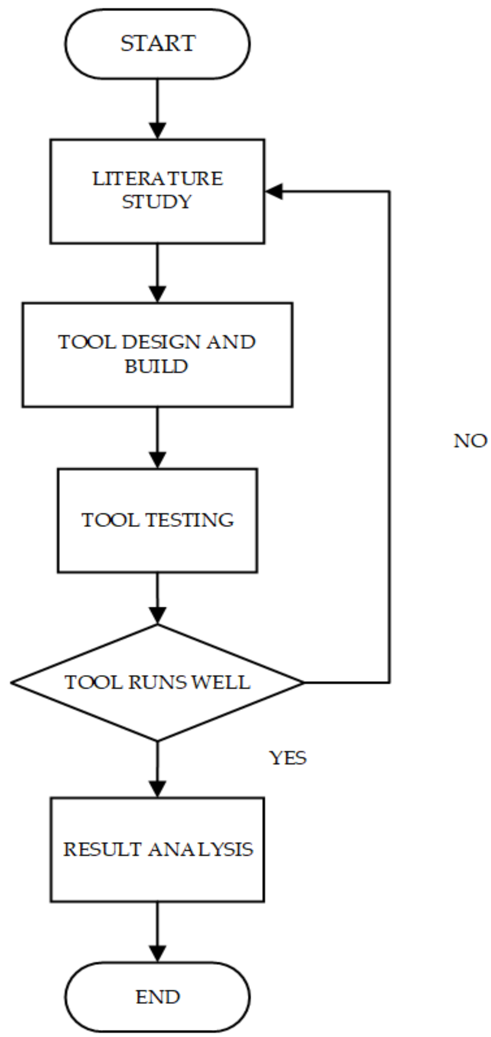

Fig. 1: Research flowchart

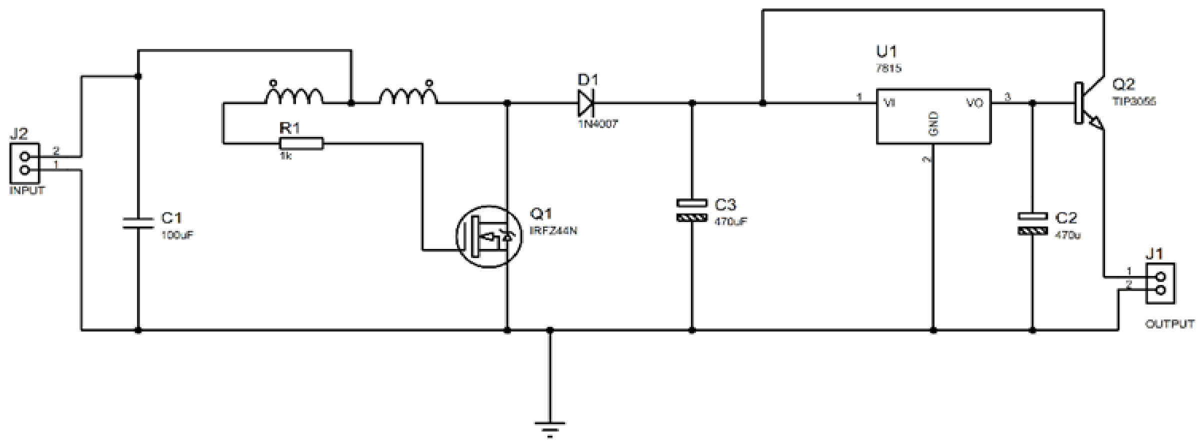

Fig. 2: Joule thief buck-boost converter circuit using Proteus 8 software

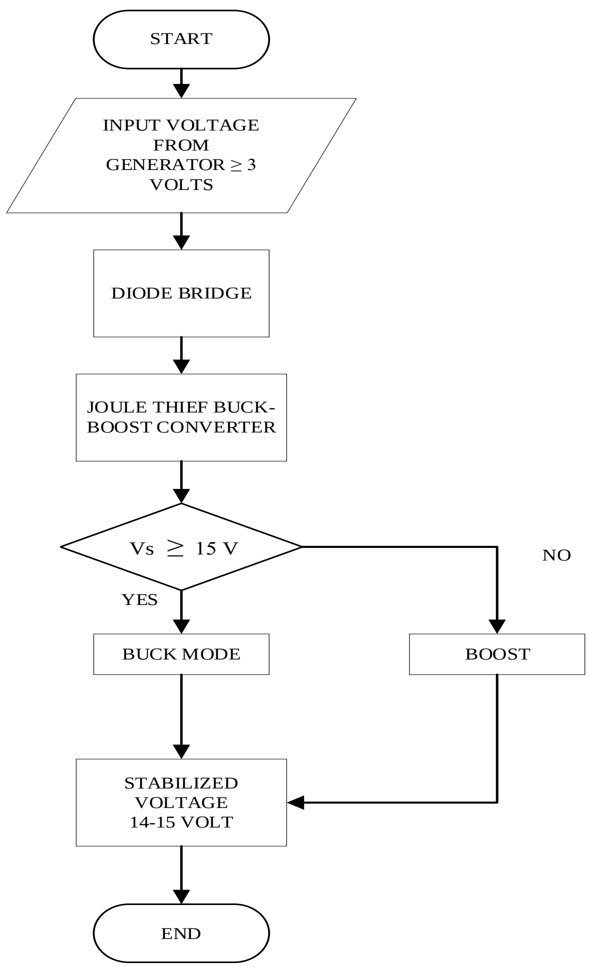

Fig. 3: Flowchart of the tool working system

3. Materials and Methods

3.1 Methodology

The research conducted includes applied research, with experimental research methods, where this approach is applied to system design and data analysis. The results will be compared with data from simulation data. Fig. 1 shows how the stages of this research were carried out, starting with conducting a literature study, tool design and design, tool testing, data collection and analysis. The hardware design is done by assembling all the components used according to the wiring diagram in Fig. 2. Then the next step is to collect data and analyze the data whether the resulting system has stabilized 14V at an input voltage above 3V. Testing on the generator output voltage, getting results that are in accordance with the author's expectations or not verified using Fig. 3. Where for generator outputs above 3V, the output voltage produced by the Joule thief buck-boost converter does not exceed 14V. This states that the tool that the author tested is in accordance with expectations.

3.2 Hardware design

Based on Fig. 4 shows the results of the hardware design of the JTBBC. This Fig. 4 shows the physical implementation of the components needed to build the JTBBC system. The description of the numbering in Fig. 4 is as follows.

1. Cable Input
2. Capacitor
3. TIP3055
4. Cable Output
5. IC LM7815
6. Diode 1N4007
7. MOSFET IRFZ44N
8. 1k resistor
9. Potentiometer 20K
10. Inductor

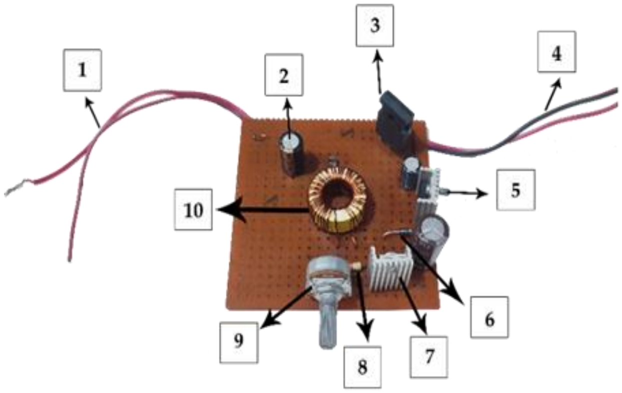

Fig. 4: Hardware design

3.3 Hardware Implementation

Based on Fig. 5, the implementation of the JTBBC is connected from the generator output connected to the diode bridge, then connected to the input of the joule thief buck-boost converter and voltage measurements can be made from the output of the hardware that has been designed.

To find the duty cycle value and system voltage can be calculated using the following equation 1.

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

Description
D = Duty cycle
Vout = Output voltage
Vin = Input Voltage

To find out the output voltage, it can be done with equation 2 using the results of the duty cycle value that has been calculated using the previous formula. Equation to determine the output voltage.

$$V_{out} = \frac{(V_{in} \times D)}{1 - D} \quad (2)$$

Description
Vout = Output voltage
Vin = Input voltage
D = Duty Cycle

The absolute error of a number, measurement, or calculation is the numerical difference of the true value with the approximate value given, or obtained from the calculation or measurement results. this can be formulated with the Monte Carlo simulation method, which is as follows. Then in equation 3 to determine the error value of direct measurement comparison with measurement using simulation:

$$Error = \left| \frac{V_{out}\ field - V_{out}\ Simulation}{V_{out}\ Field} \right| \times 100 \quad (3)$$

$$= Error\%$$

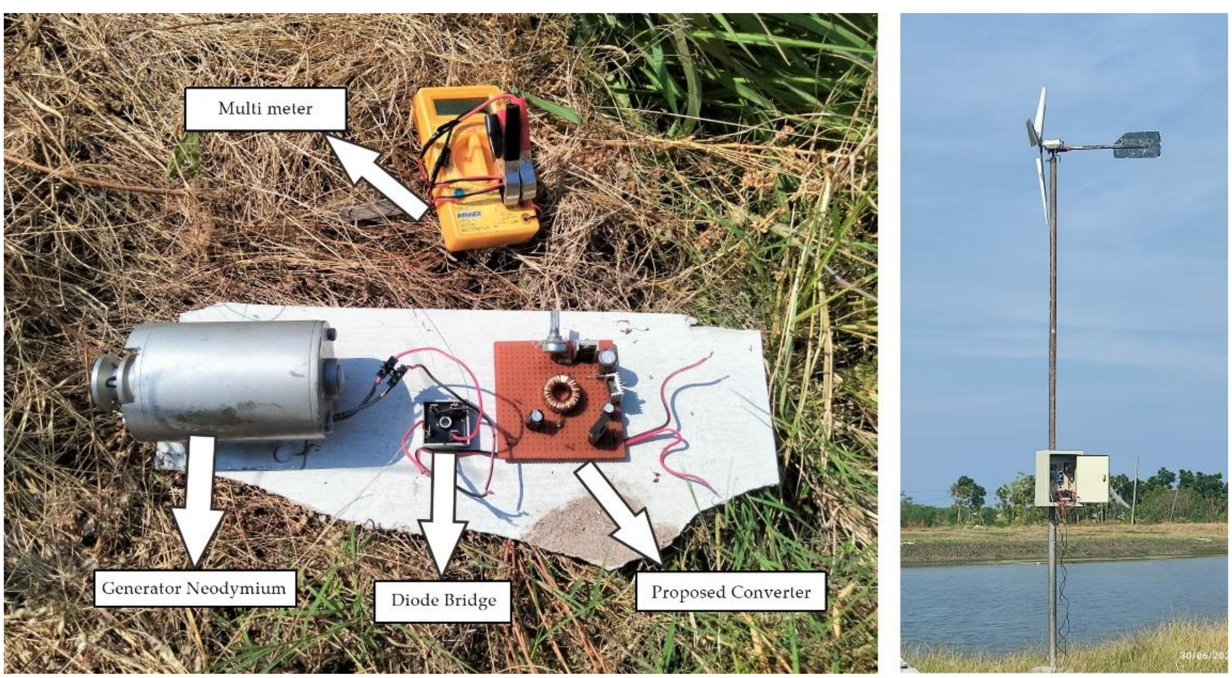

Fig. 5: Hardware implementation from generator to output

4. Results

Research: "Joule Thief Buck-Boost Converter" was conducted from June 27 to July 01, 2024, while for the location of this research was carried out on Jalan Empang Kertayasa RW 02 Jatimerta Village Gunungjati District Cirebon Regency West Java Province zip code 45151 (-6.670729,108.551801).

4.1 *Measurement Results*

The test results were carried out for five days, then the data collected from the five days was recapitulated into one and the following average data was obtained:

Table. 1: Average measurements in 5 days of testing

Hours AM/PM	Wind Speed (m/s)	Input (Volt)	Output JTBBC (Volt)
8 AM	2,20	5,00	14,00
9 AM	2,93	4,59	13,67
10 AM	4,00	6,38	14,00
11 AM	3,10	5,44	14,00
12 PM	3,23	6,80	14,00
1 PM	3,30	5,97	14,00
2 PM	4,14	7,54	14,00
3 PM	3,76	6,27	14,00
4 PM	3,40	5,62	14,00
5 PM	2,65	4,64	13,75

Based on Table. 1, the average measurement of the lowest input voltage is in the measurement at 9 PM, where the Input from the generator reaches 4.59 V and for the buck boost converter output reaches 13.67 V with Wind Speed reaching 2.93 m/s. And for the highest from the average table above, namely in measurements at 2 AM, where the input from the generator reached 7.54 V and for the buck boost converter output reached 14.00 V with Wind Speed reaching 4.14 m/s. Furthermore, the test results were carried out with a simulation using proteus software and obtained the following results

Table. 2: Output voltage testing results using proteus 8 simulation according to average data

Input from the generator	Output JTBBC on proteus simulation
5,00	14,70
4,59	14,70
6,38	14,70
5,44	14,70
6,80	14,70
5,97	14,70
7,54	14,70
6,27	14,70
5,62	14,70
4,64	14,70

From Table. 2, it can be seen that the output voltage from the simulation using Prroteus software shows a stable voltage at 14.70V with the same input as the average input when measuring the generator output.

Table. 3: Comparison of measurement results and proteus simulation results

Hours	Input	Output JTBBC	Output of JTBBC on Proteus Simulation	Error
8:00 AM	5,00	14,00	14,70	5,00 %
9:00 AM	4,59	13,67	14,70	7,00%
10:00 AM	6,38	14,00	14,70	5,00 %
11:00 AM	5,44	14,00	14,70	5,00 %
12:00 PM	6,80	14,00	14,70	5,00 %
1:00 PM	5,97	14,00	14,70	5,00 %
2:00 PM	7,54	14,00	14,70	5,00 %
3:00 PM	6,27	14,00	14,70	5,00 %
4:00 PM	5,62	14,00	14,70	5,00 %
5:00 PM	4,64	13,75	14,70	6,00 %

Based on Table. 3, the highest error value of 7% is obtained at 09.00 AM.

4.2 *Measurement Documentation*

Based on Fig. 6 are the results of waves measured using an oscilloscope from direct measurements and using simulations using Proteus software, from the results of the measured waves both are in the form of horizontal straight lines. This is because the voltage output produced by the Joule Thief Buck-Boost Converter is a DC voltage that has a constant value without any change in polarity or current direction.

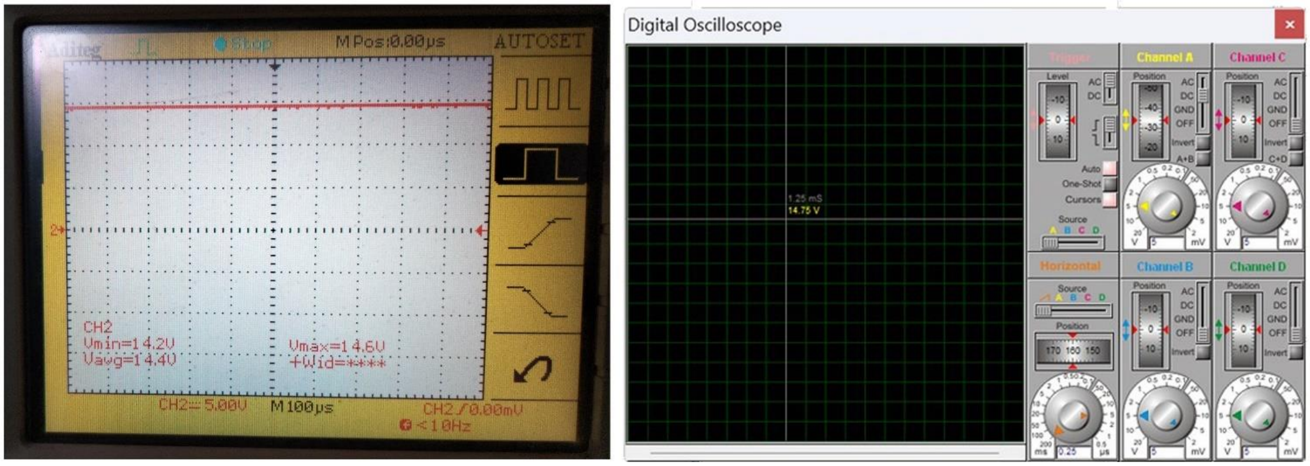

Fig. 6: Documentation of waveforms using an oscilloscope

Fig. 7: Voltage measurement documentation

Based on Fig. 7 when the wind speed is 2.9 m/s, the generator voltage is above 3 V, the output generated by the joule thief buck-boost converter is 14V on average, the output voltage is stable at 14V and the maximum voltage is 15V. This shows that the designed device is in line with expectations to produce a stable voltage.

5. Conclusions

Based on the results of the research that has been done, it can be concluded that the implementation of the Joule Thief circuit as a buck-boost converter on a wind power generation system has proven effective in increasing efficiency and output power as expected. Through testing, it was found that the Joule Thief circuit was able to increase the output voltage of the wind generator from just over 3V to 14V DC. This increase in voltage allows for more efficient charging of batteries and operation of electrical loads that require higher voltages. In addition, the Joule Thief circuit was also shown to work well. This proves the reliability and flexibility of the system in utilizing wind energy with frequent speed variations at the installation site.

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Conflict of interest

The authors declared 'No conflict of interest'.

References

[1] H. Tao, A. Kotsopoulos, J. L. Duarte, and M. A. M. Hendrix "Transformer-coupled multiport ZVS bidirectional DC-DC converter with wide input range", *IEEE Transactions on Power Electronics*, Vol. 23, No. 2, pp. 771–781, 2008. https://doi.org/10.1109/TPEL.2007.915129

[2] F. Zishan, A. Barmakh, and O. D. Montoya-Giraldo "A non-isolated synchronous buck DC-DC converter, ZVS topology under CCM and DCM conditions," *Results in Engineering*, Vol. 23, art, no. 102440, September 2024. https://doi.org/10.1016/j.rineng.2024.102440

[3] Y. Du, S. Lukic, B. Jacobson, and A. Huang, "Review of high power isolated bi-directional DC-DC converters for PHEV/EV DC charging infrastructure", *IEEE Energy Conversion Congress and Exposition: Energy Conversion Innovation for a Clean Energy Future*, pp. 553–560, 2011, https://doi.org/10.1109/ECCE.2011.6063818

[4] D. Nayanasiri and Y. Li "Step-Down DC–DC Converters: An Overview and Outlook," Electronics, Vol. 11, No. 11, art. no. 1693, 2022. https://doi.org/10.3390/electronics11111693

[5] V. Mummadi and M. R. Khuntia "Design and analysis of two-switch-based enhanced gain buck–boost converters", *IEEE Transactions on Industrial Electronics*, Vol. 69, No. 4, pp. 3577-3587, 2021. https://doi.org/10.1109/TIE.2021.3071696

[6] A. Pedro, A. N. Alcaso, F. Bento, and A. J. M. Cardoso "Buck-Boost DC-DC Converters for Fuel Cell Applications in DC Microgrids—State-of-the-Art", *Electronics*, Vol. 11, No. 23, art. no. 3941, 2022. https://doi.org/10.3390/electronics11233941

[7] J. K. A. Mohamed, Y. Sukhi, N. Anjum, Y. Jeyashree, A. F. Ahamed, S. Debbarma, G. Chaudhary et al "PV-based DC-DC buck-boost converter for LED driver", *e-Prime-Advances in Electrical Engineering, Electronics and Energy*, Vol. 5, art. no. 100271, 2023. https://doi.org/10.1016/j.prime.2023.100271

[8] W. C. Hsiang, K. H. Huang and C. Y. Wu "Enhanced power supply circuitry with long duration and high-efficiency charging for indoor photovoltaic energy harvesting internet of things end device", *IET Power Electronics*, Vol. 17, No. 5, pp. 663-674, 2024. https://doi.org/10.1049/pel2.12683

[9] E. Mahesh, M. Deguchi and Y. Y. Lim "A self-powered H-Bridge joule theory circuit for piezoelectric energy harvesting systems", *Power Electronic Devices and Components*, Vol. 3, art. no. 100015, 2022. https://doi.org/10.1016/j.pedc.2022.100015

[10] W. A. Oktaviani and A. Maulana "Design and Build of 1000 V Joule Thief Inverter by Utilizing Pineapple as an Energy Source", *Journal of Robotics and Control (JRC)*, Vol. 3, No. 1, pp. 55-61, 2022. https://doi.org/10.18196/jrc.v3i1.10198

[11] H. Shayeghi, S. Pourjafar, and F. Sedaghati, "A buck-boost converter; design, analysis and implementation suggested for renewable energy systems", *Iranian Journal of Electrical and*

Electronic Engineering, Vol. 17, No. 2, pp. 1–14, 2020. https://doi.org/10.22068/IJEEE.17.2.1862

[12] L. M. A. Rodríguez, F. J. P. Pinal, A. I. B. Gutiérrez, C. A. H. Ramírez and J. C. N. Perez "A Reconfigurable Buck, Boost, and Buck-Boost Converter: Unified Model and Robust Controller", *Mathematical Problems in Engineering*, Vol. 2018, No. 1, art. no. 6251787, 2028. https://doi.org/10.1155/2018/6251787

[13] A. Ali, H. Ardi and A. Farakhor "Design, analysis and implementation of a buck–boost DC/DC converter", *IET Power Electronics*, Vol. 7, No. 12, pp. 2902-2913, 2014. https://doi.org/10.1049/iet-pel.2013.0874

[14] X. Weng, X. Xiao, W. He, Y. Zhou, Y. Shen, W. Zhao and Z. Zhao "Comprehensive comparison and analysis of non-inverting buck boost and conventional buck boost converters", *The Journal of Engineering*, Vol. 16, pp.3030-3034, 2019. https://doi.org/10.1049/joe.2018.8373

[15] M. Everson, A. M. S. S. Andrade, G. V. Hollweg, J. R. Pinheiro and M. L. S. Martins "A review of boost converter analysis and design in aerospace applications", *IEEE Latin America Transactions*, Vol. 16, No. 2, pp. 305-313, 2018. https://doi.org/10.1109/TLA.2018.8327380

[16] L. Y. Kang, J. T. Chen, C. Y. Lin, and S. Y. Ou "Improved control-to-output characteristics of a PWM buck-boost converter", *International Journal of Circuit Theory and Applications* Vol. 39, No. 2, pp. 203-209, 2011. https://doi.org/10.1002/cta.624

[17] A. Mohammadreza, O. Husev, and D. Vinnikov. "Single-stage buck–boost inverters: A state-of-the-art survey", *Energies*, Vol. 15, No. 5, art. no. 1622, 2022. https://doi.org/10.3390/en15051622

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