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Current Change of 12 Volt DC to 220 Volt AC Using Inverter Circuit

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ABSTRACT

The need for reliable alternative sources of electricity continues to increase, especially in areas that are not yet reached by PLN's network and in renewable energy systems based on solar panels and batteries. Inverters play a key role in such systems because they convert DC voltage into AC that household appliances need. This study aims to design and test a simple inverter circuit capable of converting 12 Volt DC voltage into 220 Volt AC voltage. The inverter was designed using a 12V battery source, D313 transistor as an electronic switching component, and a center tap transformer as a step-up transformer. The research method used was an experimental method through stages of circuit design, assembly, testing, and analysis of inverter performance using LED lamp loads of 5 Watt, 10 Watt, and 15 Watt. Parameters measured included input voltage, input current, output voltage, output current, and output frequency. The test results showed that the inverter was able to produce AC output voltages of 219 Volt, 216 Volt, and 211 Volt respectively with frequencies close to 50 Hz. The increase in load caused a slight decrease in output voltage and frequency due to increased current and power losses in the circuit. Overall, the inverter succeeded in converting 12 Volt DC into AC voltage close to household electricity standards and was stable enough for light electrical loads.

Keywords: inverter; DC ke AC; transformator CT; transistor D313; switching

INTRODUCTION

The need for electrical energy continues to increase along with the development of technology and the use of electronic devices in daily life. Most household electronics use an AC (Alternating Current) voltage source of 220 Volts, while alternative energy sources such as batteries and solar panels produce DC (Direct Current) voltage with relatively low voltage levels. These differences in characteristics lead to the need for a power electronics device that is able to convert DC voltage into AC voltage so that DC energy sources can be used to operate household electrical appliances (Trihasto, 2020).

Based on the International Energy Agency (IEA, 2023) report, global electricity consumption continues to increase by an average of 2.5% per year, with the largest contribution coming from the household and small industry sectors. In Indonesia, the Ministry of Energy and Mineral Resources (EMR) noted that the national electrification ratio will reach 99.63% in 2023, but there are still remote areas that have not received a stable and reliable electricity supply from PLN. This condition encourages the use of renewable energy sources such as solar panels and batteries that generate DC voltage, so the need for DC-to-AC inverter devices becomes increasingly relevant and urgent (Rihar et al., 2024; Roy, He, Zhao, & Singh, 2022; Yao, Lu, Taghizadeh, Bai, & Seagar, 2023).

Inverter is one of the power electronics devices that functions to convert direct current (DC) into alternating current (AC) with a certain voltage and frequency. The working principle of inverters is carried out through an electronic switching process using transistors or MOSFETs that produce alternating waves on the primary side of the transformer (Ferdiansyah, & Syamsuddiin, 2025). Inverters are widely used in solar power systems, backup power sources, electric vehicles, and a variety of other electrical applications that require the conversion of DC to AC energi (Bangsa & Bangsa, 2021).

Inverters play a crucial role in renewable energy conversion systems because they are the bridge between the DC source of solar panels or batteries and the AC load on the consumer side (Blaabjerg, Yang, Kim, & Rodriguez, 2023). The development of inverter technology in large-scale and small-scale energy generation systems continues to progress rapidly as the penetration of renewable energy into the electricity grid increases (Mathew & Naidu, 2024). The development of research on inverters has been carried out with various methods and types of components used (Ivanovic & Knezic, 2022; Maulana, 2023; Suwitno, Gukguk, & Hamdani, 2022).

Research by Amrullah & Herwandi, (2021) successfully designed a 12 Volt DC inverter to 220 Volt AC using an automatic switching system with quite good efficiency. Other research conducted by Simanullang, (2025) using CD4047BE IC as PWM signal generator on a single-phase inverter to produce more stable output waves. Although the study has shown significant progress, there are gaps that need to be systematically addressed. First, research Amrullah & Herwandi, (2021) does not provide an in-depth analysis of the percentage of voltage error against PLN standards. Second, the IC PWM-based approach by Simanullang, (2025) requires additional components that increase complexity and cost. Although various inverter studies have progressed well, most previous studies have used relatively complex components, higher design costs, and required additional control systems.

This condition causes inverters to be less simple to be applied to basic needs of the community or basic level power electronics learning. In addition, research on simple inverters based on D313 transistors and center tap transformers is still relatively limited, especially in testing the stability of voltage and output frequency against light load variations. A study of the efficiency of single-phase inverters on various switching component structures shows that the selection of the right components has a significant effect on design performance and cost (Kong, & Lee, 2024). On the other hand, the development of simple component-based inverters with a minimal number of components is also a research trend in small-scale photovoltaic systems (Alaas, 2024; Díaz, & Rohten, 2023; Zhang et al., 2024). This shows that there is a research gap related to the development of a simple inverter that is cheap, easy to assemble, but still able to produce an output voltage close to household electricity standards.

The state of the art in this study lies in the use of the D313 transistor as the main switching component with a center tap transformer configuration to produce simple AC voltage without the use of a microcontroller system or digital PWM (Ivanovic & Knezic, 2022). This approach contributes to the development of a simple inverter at a more economical cost but still has a fairly stable performance in light load use. This study aims to design and test a simple inverter capable of converting a voltage of 12 Volt DC to 220

Volts AC using a D313 transistor and a center tap transformer, as well as analyzing the effect of load variation on the voltage stability and frequency of the inverter's output.

The urgency of this research is based on the real needs of people in remote areas or areas that experience power outages for alternative sources of electricity that are cheap and easy to assemble. Studies of renewable energy-based off-grid power generation systems show that the availability of reliable and affordable DC-to-AC conversion devices is a critical component in ensuring the success of electrification of remote areas (Mulenga & Shilongo, 2024). The D313 transistor based inverter and center tap transformer offer a practical solution as the components are easily available in the local market at an affordable price. In addition, this research has academic urgency in providing an empirical reference for basic level power electronics learning that can be applied in vocational high schools and technical colleges.

The benefits of this research include both theoretical and practical aspects. Theoretically, this study enriches the scientific literature on the performance of discrete transistor-based simple inverters at light load variations. Practically, the results of the research can be used as a guide for designing small-scale inverters for household electricity backup systems, especially in micro-scale solar energy systems. The implications of this study include the availability of technical references for power electronics practitioners and teachers in developing discrete component-based inverter learning modules, the opening of opportunities for the advanced development of simple inverters with the addition of a series of voltage regulations or harmonized filters to improve the quality of output waves and the potential application of household-scale renewable energy systems in remote areas that require low-cost solutions.

METHOD

The research method used in this study is the experimental method. The research was carried out through several stages, namely literature study, inverter series design, component assembly, system testing, data collection, and analysis of test results. The experimental method was chosen because the research focuses on direct testing of the performance of the inverter in converting DC voltage to AC at various load variations. This research was carried out at the Electrical Engineering Laboratory in the odd semester of the 2025/2026 academic year. The entire assembly, testing, and data collection process is carried out in the laboratory under the supervision of experienced instructors.

The initial stage of research was carried out with a literature review to obtain references related to the working principle of inverters, transistor switching systems, center tap transformers, as well as previous studies related to DC to AC inverters. Literature studies are obtained from scientific journals, power electronics books, as well as relevant research articles. The inverter design was carried out using a 12 Volt DC battery voltage source, two D313 transistors as electronic switches, a 10 kΩ resistor, a 12V CT center tap transformer, a heatsink, a connecting cable, and an LED light as the test load. The inverter circuit is designed using the alternating transistor switching method to generate alternating current on the primary side of the transformer.

The switching voltage is then raised by the transformer resulting in an output voltage close to 220 Volts AC. The specifications of the main components used are as follows: the D313 transistor has a maximum collector-emitter voltage (VCEO) of 60 V, a maximum continuous collector current (IC) of 3 A, a maximum power dissipation of 30 W, and a DC current gain (hFE) in the range of 40–320. The center tap transformer used has a primary voltage specification of 220 VAC and a secondary voltage of 12V-CT-12V with a power capacity of 30 VA. The DC voltage source uses a 12 V lead-acid battery with a capacity of 7 Ah.

The test was carried out using a variation of LED light load of 5 Watt, 10 Watt, and 15 Watt. Measurements are made using a digital multimeter and oscilloscope to determine the performance of the inverter at each load variation. The parameters measured include DC input voltage (VDC), DC input current (IDC), AC output voltage (VAC), AC output current (IAC), and inverter output frequency. The measuring instruments used include: (1) Sanwa brand digital multimeter type CD800a with DC voltage reading accuracy ±0.5% and current accuracy ±1.2%, and (2) Hantek brand digital oscilloscope type DSO5102P with a bandwidth of 100 MHz and a sampling rate of 1 GSa/s which is used to measure frequencies and observe the waveform of inverter output. Before use, both gauges are calibrated against the reference voltage source to ensure measurement accuracy. The multimeter calibration procedure is performed by comparing the readings to a standardized DC voltage source of 12.00 V, while the oscilloscope is calibrated using the device's built-in 1 kHz reference signal.

The calculation of the input power and output power of the inverter is done using the following equation:

Daya output inverter:

$$P_{out} = V_{AC}\ x\ I_{AC}$$

Daya input inverter:

$$P_{in} = V_{DC}\ x\ I_{DC}$$

The efficiency of the inverter is calculated using the equation:

$$\eta = \frac{P_{out}}{P_{in}} x\ 100\%$$

The test results data were analyzed using a comparative descriptive method by comparing the actual measurement results to the theoretical value of the household voltage of 220 Volts AC and the standard frequency of 50 Hz. The analysis was carried out to determine the level of stability of the inverter at various load variations and the effect of load addition on the voltage and frequency of the inverter output.

RESULTS AND DISCUSSION

Research Results

This research resulted in a simple inverter circuit capable of converting a voltage of 12 Volts DC to a voltage of 220 Volts AC using a D313 transistor and a center tap (CT) transformer. The test was carried out using a variation of LED light load of 5 Watts, 10 Watts, and 15 Watts to determine the stability of the voltage and frequency of the inverter's output.

The parameters measured in this study include DC input voltage (VDC), DC input current (IDC), AC output voltage (VAC), AC output current (IAC), and inverter output frequency. The test results were obtained through measurements using a digital multimeter and oscilloscope. Each test is carried out three times and then the average value is calculated so that the data obtained is more accurate and stable.

The results of the inverter test are shown in Table 1.

Table 1. Inverter Network Test Results

Load	VDC (Volt)	IDC (Ampere)	VAC (Volt)	IAC (Ampere)	Frekuensi (Hz)
0 Watt	12,30	0,15	220	0,000	50,00
5 Watt	12,27	0,59	219	0,0217	49,93
10 Watt	12,07	1,07	216	0,045	49,80
15 Watt	11,87	1,62	211	0,071	49,60

Source: Data processed

Based on the test results in Table 1, the inverter is capable of producing an AC output voltage close to 220 Volts at all load variations. The highest output voltage is obtained at a 5 Watt load of 219 Volts, while the lowest voltage occurs at a 15 Watt load of 211 Volts. In addition to the output voltage, the inverter's output frequency also decreases slightly as the load increases. At a 5 Watt load, the output frequency is 49.93 Hz, then drops to 49.80 Hz at a 10 Watt load and 49.60 Hz at a 15 Watt load. Despite the decline, the output frequency is still close to the standard frequency of PLN electricity, which is 50 Hz.

Based on the calculation results, the efficiency of the inverter has increased as the load increases. The efficiency of the inverter at a 5 Watt load is 65.6%, at a 10 Watt load is 75.3%, and at a 15 Watt load is 77.9%. A detailed calculation of efficiency is presented in Table 2 below. At 5 Watt load: Pout = 219 V × 0.0217 A = 4.75 W; pin = 12.27 V × 0.59 A = 7.24 W; η = (4,75/7,24) × 100% = 65,6%. At 10 Watt load: Pout = 216 V × 0.045 A = 9.72 W; pin = 12.07 V × 1.07 A = 12.91 W; η = (9,72/12,91) × 100% = 75,3%. At a load of 15 Watts: Pout = 211 V × 0.071 A = 14.98 W; pin = 11.87 V × 1.62 A = 19.23 W; η = (14,98/19,23) × 100% = 77,9%. The increase in efficiency as the load increases shows the characteristics of transformer-based inverters that have an optimal working point at a load close to its nominal capacity.

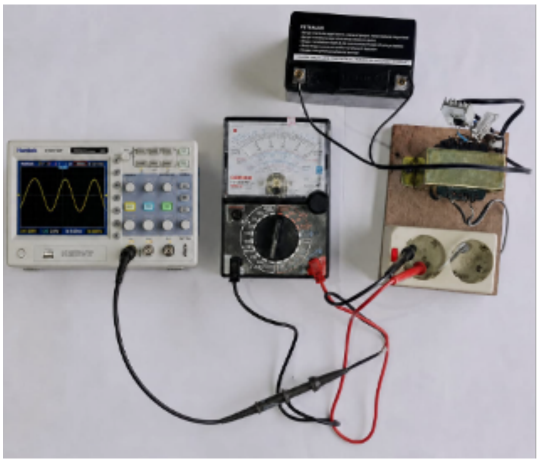

Figure 1. Inverter Circuit

Discussion

The results show that a simple inverter based on the D313 transistor and a center tap transformer is able to convert a voltage of 12 Volts DC into an AC voltage close to 220 Volts. The output voltage of the inverter decreases gradually when the load is increased from 5 Watts to 15 Watts. The decrease in output voltage occurs due to an increase in the current flowing through the inverter circuit as the load increases.

At a load of 5 Watts, the inverter produces an output voltage of 219 Volts AC with a frequency of 49.93 Hz. When the load is increased to 10 Watts, the output voltage drops to 216 Volts AC and the frequency drops to 49.80 Hz. Furthermore, at a load of 15 Watts, the output voltage drops again to 211 Volts AC with a frequency of 49.60 Hz. A decrease in output voltage from 219 Volts to 211 Volts indicates a power loss in the transformer and transistor switching due to an increase in load current.

The results of this study are in accordance with the transformer and inverter theory which states that an increase in load will cause the current on the primary side of the transformer to increase so that there is a decrease in output voltage due to power loss in electronic components (Ivanovic & Knezic, 2022; Yao, Lu, 2023). In addition, the increase in current also causes the transistor to work heavier thereby affecting the stability of the inverter's switching frequency. This research is in line with research Amrullah & Herwandi, (2021) which states that a simple inverter is still capable of generating a voltage close to 220 Volts despite a voltage drop as the load increases.

According to Simanullang, (2025) It also shows that the inverter switching system will undergo a change in frequency stability as the load current increases. However, this study uses a simpler configuration because it does not use a digital PWM system or microcontroller, so the design cost is lower and easier to apply to basic electronics learning (Maulana et al., 2023; Suwitno et al., 2022).

Analysis of the inverter's output waveform using an oscilloscope showed that the output wave generated by the D313 transistor with a push-pull configuration was close to a square wave. This is a common characteristic of inverters based on simple switching transistors without LC filters. Square waves have a higher harmonic content than pure sinusoidal waves, making them more suitable for resistive loads such as LED lamps than inductive or capacitive loads that are sensitive to wave distortion.

This condition is consistent with the findings Simamora and Simanullang, (2025) which states that unfiltered transistor-based inverters tend to produce box waves with higher total harmonic distortion (THD). Improving the quality of the inverter's output waves can be done through the application of the SPWM technique or the addition of harmonic filters on the output side (Díaz et al., 2023; Rihar et al., 2024; Zhang et al., 2024). To improve the quality of the output waves, further research can consider the addition of an LC filter array on the output side of the transformer.

Based on the results of testing and discussion, the designed inverter has been able to work quite well on light load use. The output voltage is still in the range of 211–219 Volts and the output frequency is close to 50 Hz so that the inverter can be used as a simple alternative power source for small power electronic equipment.

CONCLUSION

A simple inverter circuit based on the D313 transistor and center tap transformer successfully converts a voltage of 12 VDC into an AC voltage of close to 220 Volts with an output frequency close to 50 Hz. The output voltage produced at loads of 5 Watts, 10 Watts, and 15 Watts is 219 V, 216 V, and 211 V respectively, with frequencies of 49.93 Hz, 49.80 Hz, and 49.60 Hz. Inverter efficiency increases as the load increases, ranging from 65.6% to 77.9%. The percentage of output voltage error against the PLN 220 V standard does not exceed 4.09%, still within the power distribution tolerance limit of ±5%. The increase in load causes a decrease in voltage and frequency due to increased current and power losses in transformers and switching transistors. This study has limitations in resistive load testing only, a power range of 5–15 Watts, and THD measurements have not been carried out. Further research is suggested including inductive and capacitive load testing, addition of LC filters to improve wave quality, THD measurement using power quality analyzers, and development of larger power inverters using MOSFETs.

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