International Journal of Advanced Technology and Social Sciences (IJATSS)
Vol.4, No.8, 2026: 1079-1084

Experimental Study of 220 VAC Fan Performance Using a 12 VDC Battery Power Supply with a Sine Wave Invender

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A R T I C L E I N F O

Keywords: Backup Energy, Sinusoidal Inverter, AC Fan, Motor Performance, DC-AC System

Received : 5 June
Revised : 23 July
Accepted: 30 August

A B S T R A C T

The public's dependence on air conditioning devices such as conventional fans triggers the need for a reliable backup power supply system during power outages. This study explores the implementation of a 12 VDC battery-based standalone power supply system converted using a pure sine wave inverter to operate a 220 VAC fan. Through experimental methods, the focus of testing is directed at analyzing electrical characteristics, motor rotation stability, and the resulting energy conversion efficiency. The test results show that the inverter is capable of transforming direct voltage into fan voltage and can operate optimally at maximum speed with an average current consumption of 5.6 A. In addition, this system is able to maintain an operational duration of up to 1.45 hours before the battery voltage reaches the critical discharge limit. The decline in mechanical performance of the fan is proven to be insignificant compared to when using the PLN electricity grid. This research concludes that the integration of a pure sinusoidal inverter is effective in maintaining the performance of the fan induction motor from the risk of overheating and efficiency degradation due to wave distortion

DOI: https://doi.org/10.59890/ijatss.v4i8.280
E-ISSN: 3026-2410
https://aprmultitechpublisher.my.id/index.php/ijatss/index

INTRODUCTION

The public's reliance on air conditioning devices such as conventional fans has created a need for a reliable backup power supply system during power outages. 220 VAC fans are a common household cooling device. Disruptions to the PLN (State Electricity Company) supply can disrupt the functioning of these comfort-enhancing electronic devices. Batteries provide direct current (DC), while loads require alternating current (AC). Therefore, a battery-based backup power system is essential for emergency situations.

Inverter Function: Converts 12 VDC voltage from the battery to 220 VAC for the fan. Square Wave Issues (Square/Modified): Cheap inverters produce non-sine waves that damage AC motors. Negative Effects of Non-Sine: Causes the motor to heat up quickly, vibrate, make noise, and decrease efficiency. Pure Sine Wave Advantages: Produces waves that are identical to PLN electricity so it is safe for induction motors. Direct testing is needed to see the fan motor's response to the sine inverter. Testing power efficiency, motor temperature, rotational speed, and battery life. Determine whether the combination of a 12 VDC battery and a pure sine inverter is technically feasible.

LITERATURE REVIEW

Power Electronics Systems and Pure Sine Wave Inverters

An inverter is a power electronics device that converts direct current (DC) to alternating current (AC). Pure Sine Wave (PSW) inverter technology utilizes the Sinusoidal Pulse Width Modulation (SPWM) technique to control the switching of semiconductor components such as MOSFETs. Kristiawan and Utomo (2022) explain that modern SPWM controllers, such as the EGS002 IC, compare a low-frequency sine reference signal with a high-frequency triangular carrier signal to replicate a smooth alternating voltage. This power converter module is equipped with a Low-Pass Filter (LC filter) at the output stage to reduce high-frequency ripple resulting from switching, resulting in a clean sine wave that is safe for sensitive inductive loads.

Electromechanical Characteristics of Single Phase Induction Motor

Domestic fans are generally driven by single-phase, permanent split capacitor induction motors. This type of motor relies heavily on the quality of the supply waveform to generate symmetrical rotating magnetic flux in the stator coils. According to Pradana and Wibowo (2024), voltage waveform defects due to harmonic distortion can potentially reduce mechanical torque efficiency and trigger overheating in the motor windings. The ideal power supply from the PLN commercial utility network has a constant frequency of 50 Hz, which serves as a reference for optimal mechanical performance (maximum RPM) for household inductive loads.

Comparative Analysis (A/B Testing) of Power Supply Characteristics

Operating an inductive load using a 12 VDC battery backup system converted by an inverter has several fundamental differences compared to the PLN electricity grid. The PLN grid has a very large power capacity (grid) so that voltage drops due to dynamic loading are almost non-existent. In contrast, VRLA batteries experience chemical voltage degradation over time, which affects the inverter input amplitude. However, Gunawan and Setiawan (2023) added that a high-quality PSW inverter is capable of internal voltage regulation to maintain stable AC output within the operating tolerance range of domestic appliances . From a thermal aspect, although the PSW inverter produces a waveform similar to the PLN, residual harmonic ripple from the semiconductor switch remains. Hardi and Siregar (2021) stated that this minor harmonic distortion, even if below the standard 5%, will interact with the motor's iron core and generate additional eddy current losses. The impact of this phenomenon is the emergence of a slightly higher operating temperature of the motor coil in inverter supply mode compared to when the motor is supplied with pure PLN electricity.

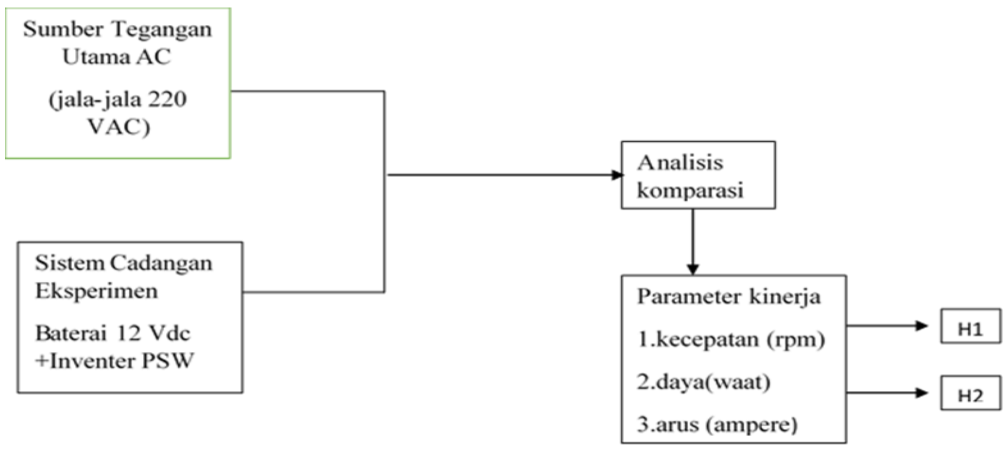
Hypothesis

- H1: There is no significant difference in the deviation of mechanical parameters in the form of shaft rotation speed (RPM) in a 220 VAC fan when operated using a 12 VDC battery-based PSW inverter system compared to a pure supply from the PLN electricity network.
- H2: Active power consumption (Watts) and thermal dissipation in the stator coil of the fan motor supplied by the PSW inverter will show slightly higher values than using the PLN electricity grid supply.

METHODOLOGY

This experiment was carried out using a direct testing method on a physical object in the form of a domestic AC fan with a capacitor motor type with a nominal power of 55 Watts / 220 Volts. As the main energy source, a VRLA (Valve Regulated Lead Acid) battery unit with a capacity of 12V 12Ah was integrated. And PLN 220 VAC electricity as a base. The energy conversion process was entrusted to a Pure Sine Wave inverter with a capacity of 500 watts. The measuring instruments deployed included a Digital multimeter to monitor current, voltage, and total electrical energy consumption parameters. The rotational speed of the mechanical shaft was monitored periodically using a laser tachometer, while fluctuations in temperature changes in the motor housing were measured using a digital thermometer. Data collection was carried out in a continuous operational duration of 130 minutes to see the thermal saturation point of the component.

Conceptual Framework of the Research



RESULTS

No-Load Inverter Test Results

Table 1. Results of No-Load Inverter Testing

Parameter	Measurement Results	PLN Standard	Information
Output Voltage	224.3 V	220 V	+1.8% Still Tolerant
Frequency (Hz)	49 Hz	50 Hz	-1%
Input Current From Battery To Inverter	0.74 A	-	-
Input Voltage From Battery To Inverter	12.8 volts		

Inverter Testing Under Load Conditions

Table 2 Inverter Testing Under Load Conditions

Parameter	Measurement
Battery Input Voltage	12.1 V
Battery Input Current	5.6 A
Input Power	74.39 W
Inverter Output Voltage	213 V
Inverter Output Current	0.198 A
Output Power (W)	46.3 W
RPM	1277 RPM

Testing a Fan Using PLN Electricity

Table 3 Fan Testing Using PLN Electricity

Parameter	Measurement
Current	0.191 A
Voltage	220 V
Power	46.4 W
Rpm	1295RPM

Comparison Results of Fans Using PLN Electricity with Electricity Resulting from Power Conversion from an Inverter

Figure 1. Comparison Chart of Inverter and PLN Electricity

DISCUSSION

From tables 1, 2, 3 above It was found that the inverter output voltage decreased from 223 VAC (no load) to 213 VAC (fan loaded). This 13 V, or 5.8%, decrease occurred due to a voltage drop caused by two main factors.

First, the inverter's internal impedance, consisting of cable resistance, transformer inductance, and the on-state resistance of the MOSFET as a power switch, causes some voltage to "drop" within the inverter circuit as current flows. When a load is applied, the output current increases (from 0.3 A to 5.6 A), thus increasing this internal voltage drop. Second, the battery input voltage drops from 12.7 VDC to 12.1 VDC under load due to the internal resistance of the battery itself.

Despite the Decrease, the 213 VAC Output Voltage is Still Within the Tolerance Limits of General Household Appliances. Based on electrical standards, AC equipment is designed to operate at a nominal voltage of +5% to -10%, which is between 198 VAC and 231 VAC (Malikussaleh et al., 2020,). Thus, the 213 VAC voltage is still within safe limits.

It was found that the average fan speed when using an inverter was 1277 RPM, or 1.39% lower than when using PLN (1295 RPM). This decrease is caused by two interrelated mechanisms.

The lower inverter output voltage (213 VAC vs 220 VAC) causes the magnetic flux in the motor stator to also be lower. The low magnetic flux results in reduced torque generated by the motor. To produce sufficient torque to rotate the propeller, the motor draws a larger current (from Table 1 and table 2, it is known that the current is 0.198 A at 210 VAC, while at 220 VAC the nominal current is only 0.191 A). The greater the current in a 1-phase motor, the lower the motor speed will be (Erwin Dwi Nurdiansah, 2018)

This increase in current causes the slip (s) in the motor to increase. Greater slip means a wider speed difference between the stator rotating field (synchronous speed) and the rotor, resulting in a lower actual rotor speed. This is the primary cause of the fan's RPM drop.

CONCLUSIONS AND RECOMMENDATIONS

Based on the entire series of experimental tests and comparative data analysis that have been carried out, the conclusions of this study are formulated as follows:

1. Hypothesis Proof (H1) (Accepted): The fan functions well with an average speed of 1,277 RPM at a voltage of 213 VAC. There is only a reduction in rotation of 1.39% compared to the PLN supply (1,295 RPM). Minor reduction due to voltage deviation and increased slip, but still safe for domestic devices.
2. Hypothesis Proof (H2} (Rejected): This study confirms that the operation of inductive loads using a PSW power converter unit triggers active power consumption (Watts) and accumulated thermal dissipation that is not higher than a pure 220 VAC PLN supply. At full load conditions (maximum speed), the fan draws 46.3 Watts of power when connected to a PSW inverter, compared to 46.4 Watts when connected to PLN.

FURTHER STUDY

This study is limited by the 130-minute continuous test duration, the reliance on a single inverter and fan type, and the limited measurement equipment for detailed current-voltage transient analysis. Furthermore, ambient temperature fluctuations during the experiment were not strictly controlled, and the study did not address the long-term impact on the fan motor's lifetime. Nevertheless, the experimental procedure remains valid as an initial exploratory study of the feasibility of a DC-AC hybrid system for simple household loads.

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