Journal of Energy Technology & Environment
www.nipes.org

Study of an Environmentally Friendly Generator for Sustainable Energy Generation

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Article information

Article History
Received 31 December 2024
Revised 26 January 2025
Accepted 03 February 2025
Available online 13 March 2025

Keywords:
Energy consumption, Environmentally friendly, Fuel-less generator, Loads variation

OpenAIRE
https://doi.org/10.5281/zenodo.15019911

https://nipesjournals.org.ng

Abstract

Nigeria faces a significant challenge due to its unreliable electricity supply. Despite a potential generating capacity of 12,522 MW, daily generation falls short at around 4,650 MW. This shortfall forces homes and industries to rely heavily on internal combustion engine generators, contributing to air pollution (CO2 emissions) and climate change. This project presents the design, construction, and performance evaluation of a sustainable, locally sourced fuel-less generator. This aim of the research is to develop a system that utilizes a flywheel for energy storage and recovery. The system includes a 12V, 100Ah battery powering a 12V DC motor, which drives a 3.5 kVA alternator through a coupling mechanism. A custom charging system, including a transformer, diode, and capacitor, ensures continuous operation. The generator is capable of handling loads from 0W to 1kW, with efficiency optimized for different load levels.

1. Introduction

Electricity is a fundamental aspect of modern society, driving economic growth and development across various sectors such as manufacturing, banking, media, healthcare, and aviation [1]. The quest for knowledge and technological advancements has led to significant strides in power generation, with electricity playing a pivotal role in enhancing productivity and fostering socio-economic progress.

Traditional power generation methods (household generators), especially those using fueled generators, causes noise pollution, the smoke from the exhaust causes environmental pollution and the cost and the current cost of fuel is a major challenge [2]. Additionally, the environmental impact of conventional generators (household generators) is severe. To address these issues, there is increasing interest in alternative, renewable energy sources like fuel-less generators, which present a promising solution to reduce the negative effects of traditional power generation [3]. By utilizing electromechanical devices powered by batteries to drive an alternator, fuel-less generators pose to offer a sustainable and efficient means of electricity generation [4]. The fuel-less generator concept aligns with the global shift towards renewable energy sources and sustainable development goals. There are different kind of household generators, in this research a household generator of 3.5kW was employed , a fuel-less generator employs a 3.5 kW, 24V direct current (DC) motor as its driving mechanism. This motor serves as the primary power source and is propelled by a 12V battery, providing the necessary energy to initiate the electricity generation process. The battery supplies power to the DC motor, initiating its rotation. As the motor gains momentum, it drives a 3.5 kW alternator, which serves as the primary electricity-generating component. The alternator produces electricity at a standard voltage range of approximately 220/230V. Electricity generated by the alternator is channeled through a sophisticated full-wave rectifier system. This system ensures the conversion of alternating current (AC) into direct current (DC), thereby facilitating the efficient recharging of the battery.

The aim of the research is to develop a system that utilizes a flywheel for energy storage and recovery. The recovered energy will be used to power the systems internal components and potentially provide a limited amount of surplus electricity to an external power supply.

2. Methodology

2.1 Materials

The system designed and fabricated in this project utilizes a 12V/100Ah battery to power a 1hp DC motor of 220v, and other parameters is shown in table 1. which serves as the prime mover for a 3.5 kVA alternator. This system operates without the need for fossil fuels, a significant departure from traditional generators that rely on internal combustion engines, as noted by Adewumi and Adelekan (2016) [3]. The driving mechanism involves a DC motor powered by the battery, facilitating continuous electricity production without external fuel sources [5].

Table 1: Design Input Parameters

S/N	PARAMETER	VALUE	SYMBOL	UNIT
1.	DC Motor Rated Voltage	90V	Vdc	Volts
2.	DC Motor Rated Power	1HP	Pdc	Watts
3.	DC Motor Rated Speed	162	Ndc	RPM
4.	Alternator Rated Capacity	220V	Pac	KVA
5.	Alternator Rated Voltage	3.5	Vac	Volts
6.	Alternator Rated Speed	3000	Nac	RPM
7.	Battery Voltage	12V	Vbat	Volts
8.	Battery Capacity	100	Ah	Amp-hours

A construction diagram for the final concept is shown in the Figure 1. This concept was selected due to several key advantages, which are the elimination of fossil fuels in the power generation process, the absence of a combustion engine results in a much quieter operation, a notable improvement over traditional model and the use of a 12V battery and lightweight materials for the frame suggests a design that is more portable than bulky, fuel-powered generators.

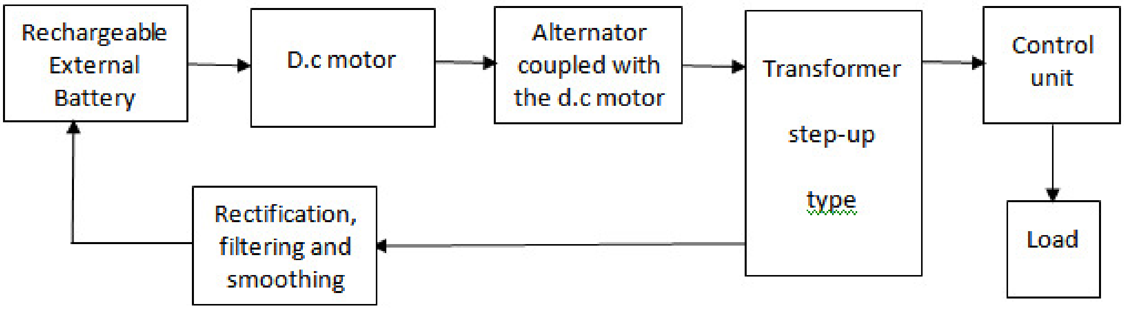

Figure 1. Construction Diagram for Final Concept Design

This design was chosen due to its practicality, as it offers a potential solution to specific low power needs. The generating unit comprises of the following components:

i. Power Supply Unit
ii. Generating Unit
iii. Control Unit
iv. Transmission Unit

2.1.1 Power Supply Unit

The power supply unit consists of a 12V lead-acid battery. Lead-acid batteries are well-suited for this application due to their ability to deliver high currents and their relatively low self-discharge rates.

2.1.2 Generating Unit

The generating unit consists of the 3.5KW alternator. The unit is responsible for the conversion of mechanical energy into electrical energy.

2.1.3 Control Unit

The control unit performs crucial functions such as converting DC to alternating current (AC), removing ripples, and rectification. The alternator's size determines the generating set's capacity.

A. *Ripple Removal*: The raw AC output from the alternator may contain unwanted ripples or fluctuations in voltage. The control unit incorporates capacitors or filtering circuits to minimize these ripples and provide a cleaner AC waveform.
B. *Rectification (Optional):* Depending on the specific inverter design, rectification might be necessary if the inverter does not produce a pure sine wave output. A rectifier circuit can convert any residual DC component in the AC waveform to pure AC.

2.1.4 Transmission Unit

The system’s transmission unit incorporate bearings, shafts, and flanges which play a crucial role in supporting and facilitating the movement of various components.

2.2. Methods

2.2.1 Capacity Calculation:

The capacity of the generator can be determined mathematically using Equation 1, assuming the efficiency of the gearbox and motor-to-generator conversion is incorporated into the overall system efficiency (η):

$$P = VI\cos(\varphi)\eta \qquad (1)$$

Where:

P = Power output (watts)
V = Voltage (volts) = 220
I = Current (amperes) = 5.35A (provided value)
cos(φ) = Power factor = 0.85 (assumed value for typical appliances)
η = System efficiency

$$Efficiency\ (\eta) = \frac{Output\ Power}{Input\ Power}\ x\ 100 \qquad (2)$$

$$Efficiency\ (\eta) = \frac{2358.7}{2910.5}\ x\ 100$$

Therefore, Efficiency (η) of the generator = 81%.

2.3 Structural Components

2.3.1 Alternator

A salvaged 3.5kV alternator from a gasoline generator was used, with a power rating factor of 0.85. A permanent magnet alternator was chosen for its efficient design. The high-speed shaft from the transmission unit spins the alternator's shaft, inducing AC current in its windings. The control unit then receives this AC output and might regulate voltage, remove fluctuations, or rectify the signal (depending on the design) before delivering usable electricity to power appliances, as shown in the figure 2 below.

Figure 2. An AC Alternator

2.3.2 Electric Motor

The fuel-less generator relies on a single electric motor to convert battery power into rotation for the electricity-generating alternator. This motor functions like a reversed generator, using electromagnetic fields to create a spinning/rotating effect. A 1HP DC electric motor with high efficiency and consistent speed, with an input voltage of 12V, and input current of 62.142A was chosen for this research, as shown in the figure 3 below.

Figure 3. A Pictorial view of Electric Motor

2.3.3 The Flywheel

Essentially, it acts as a linkage converting the rotational motion generated by the DC motor into the necessary mechanical force to drive the alternator.

2.3.4 Frame

In designing objects like the fuel-less generator, understanding service load history is crucial. Steel emerges as the preferred frame material for its cost-effectiveness, durability, and ability to withstand cyclic loading. Steel's versatility allows for customization to specific design requirements, ensuring structural integrity and reliability over the generator's lifespan.

v. Cables

Various lengths of insulated wires are employed to transmit electric current from the generator to power household electrical appliances. These cables serve as conduits for the flow of electricity, ensuring that power is efficiently distributed to the intended devices. A 2.5mm thick and length of 10m cable wire was used as shown in figure 4 below.

Figure 4. Generic Gauge 10M Cable Wire

3. Results and Discussion

This section provides an overview of the input and output data analysis, which stems from evaluating the analysis presented in the methodology and the design.

3.1 Input Parameters

The input parameters, detailed in Table 1, constitute the foundational values upon which the overall design was predicated. These parameters encompass critical factors such as the operational speed of the alternator, sourced from the specifications of the DC motor procured for the research.

3.2 Output Parameters

Table 2 shows the results obtained from the evaluation of the analysis in the methodology, it shows the summary of the output data of the analysis of the system.

3.2.1 Machine Evaluation

During the evaluation process, various electrical devices are used as loads to assess the performance of the fuel-less generator, including a 10-watt bulb, 24-watt bulb, 60-watt bulb, and a 45-watt fan. Table 2 depicts the fuel-less generator testing results.
Following construction, the fabricated system underwent performance testing as shown in figure 5 below. A multimeter was used to measure the voltage output, while a tachometer determined the rotational speed at which this voltage was produced. The test results indicated that the system generated a voltage of 220V at a current of 12A, with the motor operating at a speed of 2900 rpm. Based on these measurements, the system's output power calculated as shown using equation (2), and the overall efficiency was estimated to be 81%.

Table 2: Experimental results

Trials	Load(W)	Input Voltage (V)	Input Current (A)	Output Voltage (V)	Output Current (A)	Input Power (VA)	Output Power (W)
1	0	13.26	4.55	220	13.30	2926	2450
2	10	12.84	4.52	220	12.60	2801	2373
3	24	12.77	4.46	220	12.87	2929	2472
4	45	12.57	4.29	220	13.10	2901	2373
5	60	12.55	4.28	220	12.92	2920	2352
6	70	12.50	4.27	220	12.98	2900	2273
7	80	12.44	4.22	220	12.77	2939	2370
8	100	12.37	4.21	220	13.30	2926	2341
9	140	12.30	4.20	220	13.20	2930	2341
10	180	12.70	4.31	220	13.29	2933	2242

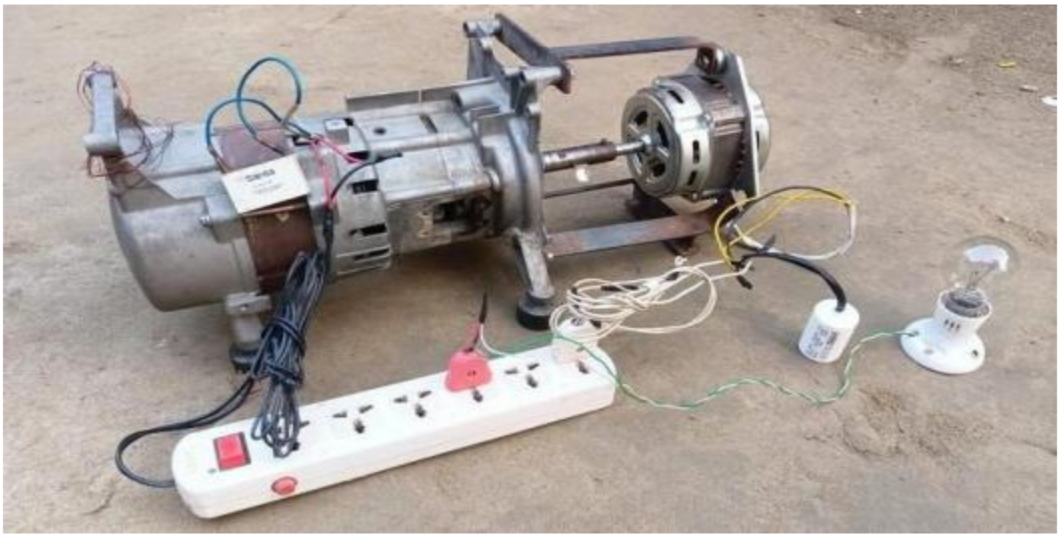

Figure 5: Fuel-less Generator after completion

4. Conclusion and Recommendation

The findings from the trials of the constructed environmentally friendly generator reveal a consistent output of 220V across varying loads, with the input voltage fluctuating between 12V and 13V, and the input current remaining within the 4-5A range. The output power observed ranges from 2242W to 2472W, while the calculated efficiency of the system stands at 81%. These results indicate that while the concept of a fuel-less generator shows promise in delivering substantial output power, the system's efficiency and reliability could benefit from further refinement.

Given the challenges in achieving sustainable energy generation without fuel, this project highlights the potential and limitations of such technology. The concept of harnessing energy through alternative means, such as flywheel generators, offers a compelling direction for future exploration. The results of this study lay a foundation for continued experimentation and development in the pursuit of sustainable energy solutions.

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