 ISSN: 3107-6513

Design, Construction and Evaluation of 1.5 kVA, Fuel-Less Generator by Self Induction

Idah N. N. P.,[#1], Ubeku E. U.,[*2], Eyenubo, O.J.[*3] & Otuagoma S. O.[*4]
[1,2,3,4]Department of Electrical/Electronic, Delta State University, Abraka Oleh Campus, Delta State, Nigeria.
[1]idahpaulson18@gmail.com, [2]ojeyenubo@delsu.edu.ng

Abstract:
This project is aim at the design, construction and evaluation of 1.5 kVA, fuel-less generator to produce 1.5KW of electricity. which of cause is to mitigate in-secant power outages and total black out which of course is a major problem in Nigeria, that increases downtime, high cost of productions of goods and services. The aim of this project was achieved by directly connecting a 1.5Hp, 12V, 4250rpm, Brushed Direct Current (BDC) motor via a shaft to a 1-ф, 1.5 kVA, 3000rpm, 220V and 50Hz rotor of an alternator, using a 12V battery as the energy storage unit (Energy Bank). The BDC motor was connected to a 12V DC rechargeable battery and a DC switch by a 4mm red and black DC cables. The switch when powered on would cause the 12V battery to excite the BDC motor and the BDC motor will prime the rotor of the alternator through a rotatory motion at a higher speed greater than 3000rpm to produce 220V of electricity. The battery is automatically recharged by connecting the 20V, 8.3A part of the alternator coil with a bridge diode, a 470μF capacitor, a 1kΩ resistor and a red LED. The charger produces a smooth sine wave AC (rectifier) that is converted to a DC current to charge the battery at the same rate of discharge (DoD) causing the generator to run continuously when the rate of discharge id equal to the rate of charging the battery. A frame was fabricated to house the electrical components of the generator. Meanwhile, when the generator was powered on, a torque was produced, analyzed and evaluated. The resultant time obtained when a DC motor torque (T_m) of 3.4Nm was used to drive (Acceleration) the motor (T_m) at no load speed from 0 - 3000rpm was 0.334sec and to drive (Deceleration) the alternator (T_L) from (3000 - 0) rpm was 0.235sec. The generator was found to have an average stability performance of 74.6% and it is advised that the maximum load should not be more than 500W for a better performance. The research has significantly achieved the UN SDG.7 which is to access an affordable, clean and noiseless energy and UN SDG13 which is focused on climate change

Keywords; Fuel less generator, Brushed Direct Current Motor, Zero Carbon Emission and Greenhouse gasses.

1. INTRODUCTION

A fuel-free generator is a power-generating equipment that does not require any combustible fossil fuel for it operate. meaning no carbon output, it is also categorized as renewable energy. Fuel less generator is a renewable source of energy and it is categorized into two; Static fuel less generator (SFLG) and dynamic fuel less generator (DFLG). [5].
Static fuel less generator (SFLG); these are energy systems that does not has any rotating parts e.g., inverters and solar photovoltaic panels while dynamic fuel less generator (DFLG) are energy system that duly requires some rotatory components to generate electricity e.g dynamic self-induced fuel less generator. [5].
In the world today, energy is the center piece of every major challenge and opportunity. Access to a clean, reliable and affordable energy has caused limitation to the standards of lives in developing countries, small and medium enterprises. Energy is required for the total eradication of poverty, adaptation to climate change, food security, quality health, education, sustainable cities, jobs and transport etc. At the advent of Covid 19, about 789 million people lacked clean and affordable electricity, Noise and green gas emission rose in 2018 globally by 1.69% to 33.1GT. Also, the CO_2, emission from the power sector increased abruptly to about two third of the growth rate [56]. Over the last few decades, the availability of energy has helped to transform over 70% of the standard of human life, as newer sources of energy is being harnessed, beginning with fossil fuel, then the diversification of renewable energies e.g Solar, Wind, Nuclear and hydro-power and now the evolution of bio technology with better quality and quantity for energies. [29].
[61] revealed that by extrapolation, the energy access data for some less developed countries like Afghanistan, Bhutan, Kiribati, Solomon Island, Timor-Leste, Tuvalu, etc., people over 550 million, being two third of the world population still lives without clean and adequate supply of energy(electricity). [62] also speculated that over 690 million of the world population never had grid access till 2030, 670 million people might still remain without electricity, the report also has it that due to the COVID of 2019, 2.4 billion people now cook with fossil fuel (fire wood and coal etc.) which causes pollution to human health and its environment. Also noted was that Africa is characterized by a low electrification rate over 568 million people living without electricity[40] Research has further shown that Indoor air pollution from the use of combustible fuels for household energy has contributed adversely to the emission of greenhouse gasses e.g., CO, CO_2, SO and SO_2 which caused 4.3 million deaths in 2012 with women and girls accounting for 59%, [40]. The accumulated concentration of these greenhouse gasses has led has led to the depletion of the

 ISSN: 3107-6513

earth's ozone layer (17th SDG). Thus, leading to a sporadic tapping into renewables from 0.24% to almost 17.5% in four years (2012 – 2016), owing to rapid grow in hydro-power, wind and solar. [40].

Statistics has it that the world largest energy consuming countries include; Norway, Canada, The United States, Oman, Saudi Arabia and Qatar where an average person consumes over 85% of the energy generated, [29]. Since independence Nigeria has been struggling to meet up with her energy needs, in spite of the privatization of the power sector in 2013 that was in line with the electricity power sector reform act of 2005, leading to the separation of PHCN into 6 power generating companies (Gen-cos) and 11 distributing companies (Dis-cos) with the federal government retaining the ownership of the transmission company (Trans-com), [43]. Nigeria as at present has an average of twenty-three (23) power generating plants being managed by generating companies (Gen-cos,), independent power producers (IPP) and Niger Delta Holding Company (NDHC) with a capacity to generate 11,1654MW of electricity. Interestingly, PHCN in 2012, where not able to distribute up to 4,999 MW of electricity out of 40,000 MW: the energy challenge of Nigerians, as a result of poor load shedding, power grid failures, leading to power failures, gas happens to be over 84% of the sources of our energy generation, while hydro-power and other sources accounts for the remaining 16% [10]. In the first quarter of 2024 alone, Nigeria experienced four major National Grid Collapse [28]. Plunging the nation into total darkness and also devastated the economy. While, in 2022 alone the National grid collapsed twice in one week that caused Nigerians to depend more on the use of generators set as alternative source of energy. In 2008, the geometric raise on the use of generators as alternative source of power generation rose to 6,000MW [10].

Presently in Nigeria, electricity generation is currently inadequate with a per capita usage of approximately 24.7245kwh in 2023. Between 1971 - 2009, the power plants operated below optimal capacity (29.3545 kwh)., some electricity generated were lost during transmission as a result of factors affecting transmission causing the power generated fall from 12,500MW to as low as 4630MW [6]. The hydro powered plants (Shiroro, Kainji and Jebba) have in contrast, gas-powered plants were hampered by infrastructure and maintenance issues, vandalism of power generation plant, uneven transmission and distribution, corruption, lack of training and retraining of man power as well as poor planning methods were some of the reasons Nigeria has been producing sub-optimal supply of electricity. In Nigeria the mean indoor power line is usually between 220V and 240V at 50Hz [39].

2. LITERATURE REVIEW

This chapter is aimed at reviewing relevant literature on the topic Fuel less generator. The term and history of the generator will first be conceptualized followed by early and recent developments of the fuel-less generator. Similarly, this chapter will also focus on the various types and works done by different researchers on the same topic and notably compare the gaps that may be found in the various work.

Fuel-less generator is a power generating device that operates without use of fuel to power electrical equipment. The generator produces an alternating current AC and it is operated by a direct current from a rechargeable battery or a renewable energy source, like wind turbines or solar panels. The device is designed to recharge battery while in operation. The battery stores a Direct Current (DC), process of operation is by converting a chemical energy (Chemical reaction) in the battery to an DC electrical energy in DC motor (by excitation) then again from electrical energy to mechanical by the shaft (prime mover) to an AC electrical energy in alternator. Most electrical appliances need AC power to run, so generator is necessarily to convert power into a usable form. The wave form of generator is a pure sine-wave. In a sine-wave, voltage rises and falls smoothly and same with phase angle. Polarity changes instantly when it crosses 0 Volts. Fuel-less generators are required to power delicate electronics that needs high quality waveform with little harmonic distortion. Furthermore, they offer temporary overload capacity, allowing for brief periods above rated wattage. Which is the reason while power motors can start easily by draw up to seven times their rated wattage during startup operation. Virtually any electronic device will operate with the output from a pure sine fuel-less generator. In this research, the battery is the energy storage device which do not explode when overloaded, on like use of flywheel which may explode when over loaded but has High power density; Long life cycle; easily estimated state-of-charge and No degradation over time.

The use of batteries to store energy is not a new technology. Basic batteries such as lithium batteries are known to store high amount of energy. Batteries has under gone through industrial revolution to improve on their standards the same way flywheel; use of batteries increased significantly when dollar economy became stronger and harder. The greatest milestone in fuel less generator development in 1970's when applications for backup-power and electric vehicles were proposed. During this period fuel-less, generators made of composite material was proposed and built. The development continued during 1980's when magnetic bearings were introduced. Recent developments in materials, magnetic bearings, microcomputers and power electronics have made it possible to consider fuel less as competitive option for electric energy storage [21].

Meanwhile, in line with the continuous search for better, affordable and alternative source of energy, desire to convert direct current (DC) to alternating current (AC) came into play obviously between mid-19th and 20th centuries before it was eventually achieved by use of motor generator (M-G) set [49]. At that time, switch of inverter system was made up of vacuum tubes and gas filled tubes [49] This process also gave rise to the term inverter system, through the process of electromagnetic conversions. AC to DC converters were usually synchronous or induced AC motor that were connected directly to dynamos or generators. The dynamo commutates and reverses its connection to produce DC as output. This concept was later developed to produce AC from DC [25];[28]. A synchronous converter whose dynamo and winding combined in an armature with slip rings that commutes at the opposite end having just one field was developed and was also used to produce AC from DC inputs.

Fuel-less generator was first envisaged by Nikola Tesla in early 20th century (Barkel, 2000), when he invented a system that generated a free, clean and limitless supply of electricity. This made it unusual for many engineers in their conference and paper presentation, support the ideas of Tesla on fuel-less generation till resent times and small-scale models created. Though prototype for industrial mass production for populace has not been achieved [3];[2]. Within the last decades, many researchers have ventured into the production of fuel-less generators giving rise to recent developments of fuel-less generators.

The fuel-less engine operates independently of the power grid. Even so, idea to mass produce fuel-less generators from the prototype remains an intriguing option. More than a hundred paper presentations have been written on possibility of building such an engine based on work of Tesla. At most conferences and seminars, it is not unusual to find researchers who speak in support of the idea of Tesla's fuel-less discovery from then till date.

Within last two decade, the designs, construction and performance of fuel less generator has improved tendentiously; mainly because a number of the anisotropic materials used have become readily available and has significantly improve on their quality.

No one knows the exert nature of electricity although investigation has shown that it consists of small negative charge called Electron, when this electron is standing still, it is said to be static electricity" and when they are forced to travelled either from the anode to the cathode or vise advice they are called "Dynamic electricity." Power generation, transmission and distribution has been an indispensable factor in the growth and development of an economy, ranging from manufacturing industries, banking, media, health care, aviation, etc. (Ulaby, 1999). Power is defined as the rate of doing work (Knight, 2004); It therefore means that the productivity of a Nation largely depends on the availability of quality and quantity of power available in that country.

According to [33], he stated that major problems facing Nigeria could be stemming from nation's unstable power grid, however, so many activities and businesses have been paralyzed due to poor and erratic power supply. The nonavailability and unstable nature of Nigeria's power supply has poses so much threat on the economy, thereby reducing capacity of industries to increase productivity. More so use of fossil fuel to generate power has led to environmental pollution and degradation or depletion of ozone layer. Other problems associated with power generation using fossil fuel includes land and water pollution, noise pollution, increase in price of fossil fuel periodically, among others.

Researchers like Tai-Ran, (1999) design and fabricate fuel-less generator, he analyzed that industrial partners are committed to developing technology of their respective drives. His prototype generator has demonstrated feasibility of fuel-less generators in both grid-connected and autonomous power systems, as well as relative merits of two FESS configurations.

Moreover, Ulaby (2009) from his results in from blueprint to building fuel-less generator analyzed that flywheel is a promising technology for replacing conventional lead acid batteries as energy storage systems for a variety of applications, including automobiles, economical rural electrification systems, and stand-alone, remote power units commonly used in telecommunications industry. Only recently, mechanical characteristics of composites have been observed to rekindled interest using inertia of a spinning wheel to store energy. The rate of charge of the flywheel can easily be measured, since it is given by rotational velocity. The first rotation of flywheel rotors is suitable for direct generation of high voltage. It could obtain (100%) extra electrical output as free energy from project. Harnessing flywheel power, our AC generator delivered 3.7 kW of electricity with a 1.5 HP motor. This innovative setup offers a game-changing advantage: generating energy without extra equipment, with potential applications in electric cars and beyond

David (1980), designed, constructed and analyzed his fuel-less generator, study revealed that flywheel and bearings combination created a functional energy storage system, highlighting feasibility of flywheel technology for home energy storage. The system was designed to accept conventional as a single-phase, 115-V, 60-Hz power (from a conventional wall socket), he converts it to three-phase, variable-frequency power, and apply it to an electric induction motor. Induction motor, which is contiguous to flywheel shaft, spins up flywheel to its design rotational speed (14,300 rpm). The electronic controls then cause motor to operate as an electric generator which, being driven by flywheel produces electrical power that is reconverted to steady-state 115 V at 60 Hz. This flywheel-stored power has been used successfully to run typical household appliances.

[2], successfully tested and demonstrated company's 6.25 kW, 25 kWh flywheel systems. Field demonstrations confirmed that the flywheel system met major design specifications, and investigators and researchers have agreed on an effective set of operational and cost targets for a four-hour flywheel system. This system met with meets utility customer needs and is practical and cost-effective to manufacture. The researchers have also developed a commercialization plan to bring to market a commercially viable four-hour fuel-less generator. The product development and conclusion are ongoing.

[9] also compared load and efficiency of 1kVA power inverter and a fuel-free 1kVA generator; appraisal after about three trials each showed that power inverter was more efficient than fuel-less generator, a 12/24V battery were used as energy bank, DC motor used had a speed of 9000rpm and alternator used had a speed of 6000 rpm. Using same load 100W and 600W respectively, fuel-less generator on 100W had 89.1% and on 600W had 50.4% while power inverter had 96.3% and 73.5% respectively. Hence, they recommended that power inverter was more efficient for use. And concluded that max load of 400W at 71.5% was best for 1kVA fuel-less generator. (IEEE standard of 1 - 0.7, [8].[5] focused on renewable energy as best power source to reduce effect of CO_2, SO_2 and other poisonous gasses and their effect on the ozone layer depletion. Hence, they designed, developed and evaluated a 2kVA fuel-less generator with a 12V, 199Ah battery, 12V DC motor, using direct connect. On evaluating the loads 0W - 2kW, it was observed efficiency was reduced with increased load. (W), the fuel-less generator was noiseless, eco-friendly and low cost of maintenance cost. Others who also designed and fabricated fuel-less generator were the likes of [51] who engineered a locally-sourced, fuel-less power generation system like 12volts, 1hp DC motor to spine the alternator of 0-95KW and generated an output of 1KVA of electricity meanwhile, the battery was the power bank and was recharged by the alternator through a rectified diode.Esom et al (2020), Electrical and Electronics Engineering Department, Enugu State University of Science and Technology, developed a 5kVA self-induced Harnessing Local Resources for Fuel-Free Power Generation in Nigeria.

Construction consisted of a 12VDC motor, 12volts, 100Ah battery, as part of output electrical energy was fed back to charge batter [8] constructed a 2.5kVA self-induced fuel-less generator using a self-induced engine as against conventional fueled generator. Items used included a charging panel, an alternative voltage regulator (AVR), a DC motor, an alternator and 12V, 100Ah rechargeable battery. He also conducted the performance evaluation on fuel-less generator with loads raging between 0 – 250 kW each at 5mins periodic evaluation. He went further to recommend that a similar experiment should be performed using brand new items for comparison.

2.2 GAP IN LITERATURE

An exhaustive literature review has revealed that project works on fuel-less generator has been a success and can help render solution to electric power instability in the country. However, past work has not laid much emphasis on the economic cost reduction factor in producing various types of fuel-less generator, and to evaluation performance of 1.5KVA Fuel less generator, and calculate torque required to start and stop generator and time it will take drive to accelerate motor from 0 to 3000rpm and decelerate same drive from 3000rpm to 0.

III MATERIAL AND METHOD

Creating a fuel-less generator: design, build, and assess was carried out by directly coupling of the Alternator with a shaft to a DC motor. The 12V battery excites DC motor and the DC motor primes the synchronous alternator causing it to actuate rotationally to the required speed in other to produce the specified AC voltage output (220V). The alternator works with the principles of Faraday and Lenz's laws of electromagnetic inductions as well as Fleming left hand rule.

3.1 METHODOLOGY/CONCEPTUAL DESIGN.

From concept to reality: building a fuel-less generator of 1500W power generator included BDC motor, alternator, 12V/100Ah battery, coupling, charging panel key components include a 20V coil sourced from an alternator, a diode, a capacitor, and a precision-fabricated framework. The frame and motor mount were constructed using Steel Square pipes, angle steel and wire gauze linking shaft was precisely fitted into the DC motor through a threaded interface. The crank casing of the alternator was fabricated and inserted; the armature of the alternator was fixed as such that the frame provided rigid support. Electrical connections were established between the BDC motor terminals and the battery. The fuel-less generator is basically divided into five units as shown in the block diagram, figure 3.1 below. which is the power supply (Battery) unit, a conversion (BDC), control (Switch), output (Alternator) and battery charging unit. Power supply unit includes a 12 volts battery which is used for initial start-up of the system by supplying an induce EMF to the BDC motor. The battery also stands as the power storage unit. The control unit is the power switch of the generator, The Alternator has two coil windings of a 20V and 220V AC respectively. Where the 20V coil serves as a transformer in the alternator, its voltage is converted to DC by connecting it's two terminals to a diode, capacitor, resistor and an LED indicator to serve as the 12V battery charging unit, it aids the removal of ripples, and rectification of output
Basically, in some fuel-less generators, DC motor is connected to alternator by gear, pulley or belt depending on design. While, in this particular design a direct coupling method of the BDC to alternator was used.
The battery excites DC Motor which is a prime mover that actuates alternator by rotary motion to obtain an average speed of 3000 rpm required alternator to produce 220V of electric city. Though some energy may be lost due to heat and friction, DC motor must attain speed greater than that of alternator for it to supply current following the principles of Faraday and Lenz' Laws of electromagnetic induction.

Faraday's Law states that induced voltage E depends on magnetic field strength B, length L of conductor and volt V across field lines.

$$E = BL \qquad (3.1)$$

Lenz's Law also states that induced current flows as to oppose charge (motion) producing it. When Lenz's law is considered and combined with Faraday's law, it is expressed mathematically as

$$E = -\frac{N\Delta\Phi B}{\Delta t} \qquad (3.2)$$

[53]; [57] and [5].

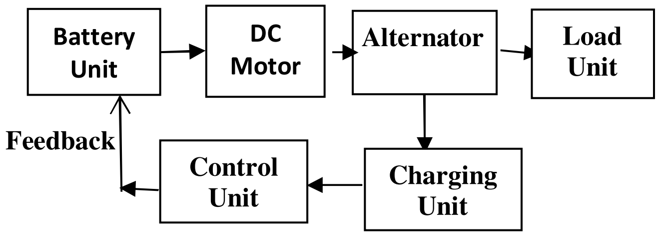


Fig 3.1 A Block Diagram of a Fuel-less Generator.

3.2 DETAILED COMPONENTS OF A FUEL-FREE POWER GENERATING SET

The five major component units of a fuel less generator includes the following; power, conversion, control, output, and charging units

3.3 POWER SUPPLY SECTION

A 12-volt, 100 ampere-hour battery was utilized as the power source for the DC motor, facilitating electromotive force induction and serving as a DC power storage unit for the generator."

3. "The DC motor was powered by a 12V, 100Ah battery, which induced an electromotive force and functioned as a DC power bank for the generator. Lead acid battery is highly recommended for DC generating system.
4.

3.3 POWER SOURCE

This unit distinguishes the DC generator from the fossil fuel generating set. The unit is made up of the DC motor, which is a prime mover that actuates alternator to produce the required 220V AC.

3.4 CONTROL MODULE

This unit handles DC-AC conversion, ripple suppression, and rectification

3.5 CRANK SHAFT

A critical component, the crankshaft connects the DC motor to the alternator, allowing for the efficient transfer of mechanical energy and generation of electric current.

3.6 OUTPUT UNIT

Given alternator's output specifications, generating set's capacity can be calculated based.

Mathematically; $P = IV \cos \Phi$ (3.3)

Where

P = Power output (watts) =?

V = Voltage (Volts) = 220

I = Current (ampere) = 8.5A

$\cos \Phi = 0.85$

Thus, generating set's capacity is

$P = 8.5 \times 220 \times 0.85 = 1589.5W$

3.7 THE FABRICATION AND ASSEMBLING PROCESS.

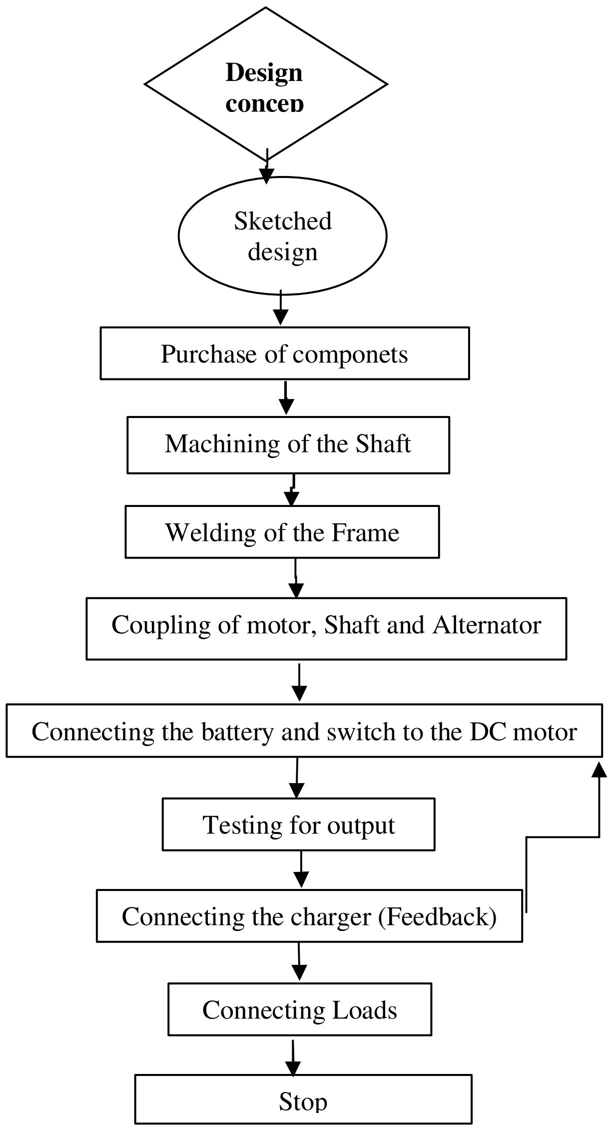


fig 3.2 the construction flow chart.

3.8 CONSTRUCTION/DESIGN PROCEDURES

To build the fuel-less generating set, we followed these procedural steps:

Step 1; Involves fabricating a shaft and boring reasonable holes on both ends that would conveniently fit into DC motor and the Alternator.

Step 2; Involves fitting fabricated shaft in DC motor.

Step 3; Involves fitting fabricated shaft in alternator.

Step 4; Involve boring holes on frame to firmly fit DC motor and alternator on frame of machine using nut and bolts.

Step 5; Involves connecting battery and switch to DC motor using red and black 4mm electric wires.

Step 6; Involves connecting the terminals of 12volts DC fan to battery to cool battery and the DC motor.

Step 7; Involves connecting 20V AC terminals of alternator to a bridge diode, 470µf capacitor, a 1kΩ resistor and a red LED (Charger).

Step 8; Involves connecting the 220volts AC terminal of the alternator to the 13amps sockets.

Step 10; Involves connecting charger to the terminals of battery.

Step 11; Involves connecting circuits breakers between alternator and 13amps sockets as well as between battery and DC motor (Switch).

Step 12; Involves welding of perforated and non-perforated metal sheets on fabricated frame to allow cooling and prevent water from entering the system.

Step 13; Involves testing of machine.

Step 14; Involves fixing of four rollers at the base of frame to ease movement of machine.

3.9 MATERIAL SELECTION

Before embarking on the project design, adequate material selection should be ensured in other enhance the functionality of the generator. The following are key areas of consideration.

- Reliability.
- Complexity.
- Ductility.
- Tensile strength.
- Resistance to corrosion.
- Available of materials.
- Machinability.
- Weight Reduction

.

TABLE 3.1: BREAKDOWN OF COMPONENTS AND MATERIALS USED

Component	material	Justification
Main frame	Structural steel	Cheaper and has high tensile strength
Shaft	Mild steel	High resistance to breakage
Bearing	Alloy steel	Hardness and high strength
Bolts, nuts and screws	Alloy steel	Hardness and high strength

DC motor was powered by a 12V battery, which induced electromotive force. Lead-acid batteries are highly recommended for DC generating systems due to their efficacy in storing direct current and providing excitation current.

Battery chargers restore energy to rechargeable batteries by forcing an electric current through them. They play a crucial role in fuel-less generators, with three primary tasks.

To restore battery capacity, often as quickly as possible

To ensure a continuous current generation cycle.

To maintain capacity by compensating for self-discharge.

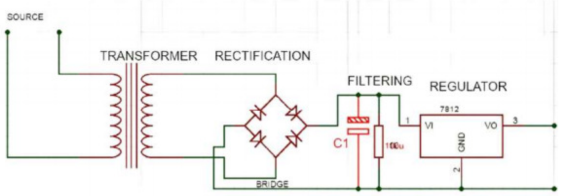


Fig 3.4 A Charging Unit [5],

A key factor in prolonging battery life and obtaining optimum performance from it is proper charging environment. This is only possible if charging current and voltage are properly controlled and matched to battery temperature.
Major circuit component to recharge batteries in a fuel less generator is a rectifier.

3.10 CHEMICAL REACTION IN BATTERY

Lead accumulator, or car battery, features sponge-like lead plates and lead oxide (PbO2) with sulfuric acid as the electrolyte [16].

As current flows, hydrogen ions migrate to positive plate and sulfate ions to negative, causing plate degradation and formation of lead sulfate.

Chemical reaction at negative plate is:

$$Pb + SO_4^2 \rightarrow electron \rightarrow PbSO_4 \quad (3.4)$$

Positive plate reaction is given by:

I. $PbO_2 + 2H^+ + 2electron \rightarrow PbO + H^2$ (3.5)
II. $PbO + H_2SO_4 + H_2O$ (3.6)

To become

$PbO_2 + H_2SO_4 + 2H^+ + 2electrons \rightarrow PbSO_4 + 2H_2O$(3.7)
Know that H_2SO_4 molecules break down into ions in solution $2H^+$ and SO_2 Equation 3.8 becomes
$PbO_2 + SO_4^{2-} + 4H^+ + 2electrons \rightarrow PbSO_4 + 2H_2O$(3.8)
In the above discharging reaction water, (H2O) is former

In the above discharging reaction water, (H2O) is former and sulphuric acid is consumed. The concentration of the acid therefore weakens and reduces its density.

A DC motor served as prime mover by rotating the alternator with a fabricated shaft to produce a required electrical energy on reaching a required rotation as specified for the alternator (e.g., 3000rpm). Hence rotation causes a conversion from mechanical energy to electrical energy. There are three major types of DC motor design which are based on the magnetic field of rotor; (i.e., Separately-excited DC motor, Self-excited DC motor and Permanent-magnet DC motor or generator),
The DC motor used in this project is a Self-excited DC motor with the following specification; 2.26 Ω, 5.30 amps, 2.2 kg, 13 cm long, a diameter of 10.80 cm, 1.5 Hp, 12V, 50Hz and a speed 0f 4250 rpm when load is not attached. where 1hp is equal to 746 watts. [5].

The DC electric power motor, 1hp = 746watts
Therefore, 1.5hp =1.5x746
= 1,119watts or 1.12kW.

$$\text{Therefore, } e_b = \frac{\emptyset \, x \, Z \, x \, N}{60} \quad (3.9)$$

$$\text{Were, } W = \frac{2\pi \, x \, N}{60} \quad (3.10)$$

w = angular speed and

k_e = Voltage Constant and the armature voltage V, consists of two; Back e.m.f (e_b) and the voltage drops across the armature resistance (I_BR).

$$V = I_B R + e_b \quad (3.11)$$

$$V_{ia} = I_a^2 R + e_{bia} \quad (3.12)$$

Where, V_{ia} = Electric power supplied to the armature,
$I_a^2 R$= Power loss due to armature resistance,
e_{bia}= Mechanical Power (P) developed by the DC motor.

$$\text{Torque (T)} = \frac{P}{W} = \frac{Mechanical\ Power}{Angula\ Speed} = \frac{e_{bia} \, x \, 60}{2\pi \, x \, N} \quad (3.13)$$

$$= \frac{\emptyset \, x \, Z \, x \, N \, x \, P \, x \, ia}{2\pi \, x \, N \, x \, C} \quad (3.14)$$

The effective torque which overcomes first rotational torque at current I_a is; This, therefore, implies that
Practically, $T_f \approx 0$,
Eqn (3.15) This describes speed (angular) of a DC motor based on power supplied to it. The electric power supplied to the armature was evaluated.
Let Armature Speed be equal to;

$$N \text{ (rpm)} = \frac{N}{60} \text{ (rpm)} \quad (3.15)$$

Recall, 1 revolution = 2π and 1 minute = 60 seconds. Armature speed during one revolution then gives you your Angular Speed (ω) is given by,

$$\frac{N}{60} \text{ (rpm)} = \frac{N}{60} \left(\frac{2\pi \, radian}{seconds}\right)$$

$$= \frac{2\pi rN}{60} \left(\frac{radian}{seconds}\right) \quad (3.10)$$

Work done in 1 revolution (w.d) is given by multiplying force(F) by distance traveled in 1 revolution (2πr) as shown in Equation 3.18

$$w.d = F \times 2r\pi \quad (3.16)$$

Recall that Power developed (P) in watts is shown in Equation 3.20 by diving work done (w.d) by time

$$\text{(t) } t = \frac{60}{N} \quad (3.17)$$

$$P = \frac{F \, X \, 2\pi r}{t} \quad (3.18)$$

Using Equation 3.20, the Power Developed (P) in watts is shown during I revolution is given by Equation 3.7.

$$P = \frac{F \, X \, 2\pi r}{\frac{60}{N}} = \frac{2FN\pi r}{60}$$

$$P = F \text{ x r x } \frac{2\pi N}{60} = \frac{T_g 2N\pi}{60} \text{ (watts)} \quad (3.19)$$

Where T_g is the gross Torque developed in armature While Angular Velocity?

$$(\omega) = \frac{2\pi N}{60}.$$

Therefore. the Power Developed (P) in watts can also be given as in Equation 3.23 below.

$$P = \tau \, x \, \omega \quad (3.20)$$

The expression of DC Motor Voltage is given by Equation 3.24.

$$V = E_a + I_a R_a \quad (3.11)$$

Where V is voltage supply to DC motor (V), E is emf induced in the armature (V), I_a is armature current (A), R_a is armature resistance (Ω). Multiply Equation 3.22 through by I_a to get Equation 3. 24

$$VI_a = E_a I_a + I_a I_a R_a$$

$$VI_a = E_a I_a + I_a^2 R_a \quad (3.12)$$

Where the Electrical power input (VI_a) is equivalent of mechanical power ($E_a I_a$), armature and copper Loss is $I_a^2 R_a$ recall that mechanical power developed (watts) $E_a I_a$ (3.21) there after let (3.19) equals equation 3.21.

i.e.,

$$\frac{T_g 2\pi N}{60} = E_a I_a (\text{watts}) \quad (3.22)$$

Also recall that, $E_a = (\frac{\emptyset ZN}{60} x \frac{P}{A})$ (3.23)

I.e. $E_a = (\frac{\emptyset ZNP}{60A})$

Where, Ø = Flux (Wb), Z = No of conductors (Turns and always fixed), N = armature speed (rps), P = No of motor poles also fixed, A = area, substitute E_a in Equation 3.26 into equation 3.25 and make T_g the subject.

$$\frac{T_g 2\pi N}{60} = \frac{\emptyset ZNP}{60A} \text{ x } I_a \quad (3.24)$$

$$T_g = \frac{\emptyset ZNP}{60A} \text{ x } I_a \text{ x } \frac{60}{2\pi N}$$

$$T_g = \frac{\emptyset ZNP I_a}{2\pi A} = \frac{\emptyset ZNI_a}{2\pi} \text{x} \frac{P}{A}$$

$$= 0.159\emptyset ZNI_a \text{ x } \frac{P}{A} (\text{Nm}) \quad (3.25)$$

Note; Torque of a DC motor is proportional to flux/pole and armature current.

Relating loss Torque (T_{loss}), armature torque (T_a) and shaft torque (T_{sh}) = T. Recall Equation 3.25

$$T_g = \frac{\emptyset ZNP\ I_a}{2\pi A} = \frac{\emptyset ZNI_a}{2\pi} \text{ x } \frac{P}{A}$$

$$= 0.159\emptyset ZNI_a \text{ x } \frac{P}{A} = \frac{E_a I_a}{2\pi \frac{N}{60}} (\text{Nm}) \quad (3.26)$$

Therefore, motor power output in watts is given by Equation 3.16. motor power output = 2πN 60 × Tsh (3.27)

$$\text{Motor power output} = 2\pi \frac{N}{60} \text{ x } T_{sh} \quad (3.27)$$

$$T_{sh} = \frac{\text{Motor Power Output}}{2\pi \frac{N}{60}} (\text{Nm}) \quad (3.28)$$

Simplify Equation 3.28, Torque (T or Tsh) when power is in watts is given by Equation 3.29

$$= \frac{9.55 \text{ x Motor Power Output (watts)}}{N(rpm)} \quad (3.29)$$

Where Constant $9.55 = \frac{60}{2\pi}$ after simplification of Equation (3.27), Torque (T) when power is in kilowatts is given by Equation 3.30

$$= \frac{9550 \text{ x Motor Power Output (kilowatts)}}{N(rpm)} (\text{Nm}) \quad (3.30)$$

Where constant $9550 = \frac{60 \text{ x } 100}{2\pi}$ after simplification of equation 3.27

[8]

Meanwhile, power of the DC motor was determined by using a multimeter to measure the voltage across motor terminals and current being drawn by motor during an open circuit test. The values of the measures were observed and recorded simultaneously as 11.98V, 5.3A, and 4250rpm for voltage, current, and speed respectively. This was used to verify the figures on the nameplate of the DC Motor. Using Equation (3.30) substitue the measured values to obtained, the applied Torque to the drive.

$$\text{DC Motor Torque (Nm)} = \frac{9550 \text{ x } 0.063}{4250} = \frac{601.65}{4250} \quad (3.30)$$

$$\frac{601.65}{4250} = 0.14\text{Nm}$$

The alternator used was gotten from a 1900 Fireman Generator at an affordable price, it has a copper coil rotor windings and permanent magnet stator both recovered in good condition. The carbon brushes were also in good condition with the attached automatic voltage regulator (AVR)unit. The alternator is made up of two major components; The rotor and stator assembly, these two components convert the mechanical energy of the brush direct current motor (BDCM) motor to electrical energy. Alternator is engine room of power generation. It generates power at a specified frequency 50/60Hz depending on the standard of location and can be referred to as a synchronous machine (generator). It produces AC power through electromagnetic induction following the principles of Faraday and Lenz' Laws of electromagnetic induction. The alternator turns alongside the BDCM due to the mechanical coupling. Thus, during rotation, the alternator's magnetic field rotates with respect to the coil and at the same time, the rotor produces rotating magnetic flux which rotates alongside to induces an AC Electromagnetic field across the armature winding. The BDCM is excited by 12V, 100AH battery. BDCM was coupled directly to rotor of alternator by a fabricated shaft and BDC motor is powered by a rechargeable battery, the BDCM when excited, primes the rotor(armature) in alternator to a required angular speed (synchronous) and rated current when activated from starting switch, to produce an alternating current output voltage of 220V

The speed of the alternator was derived using given parameters and some standard engineering formulas as shown in the Equations below. Recall that the equation of a synchronous speed (N_s) is given by

$$N_s = \frac{120f}{P} \quad (3.31)$$

Given that; frequency(F) = 50Hz, No of Poles = 2 poles,

Therefore, $N_s = \frac{120 \text{ x } (50)}{2} = \frac{6000}{2} = 3000rpm$

Where rpm is revolutions per minute, the S.I Unit for synchronous speed of a machine.

Secondly, currents were determined for two different power factors. Recall the single-phase power formula as shown in Equation 3.25 Power = Voltage × Current × Power Factor

$$\text{P} = \text{VI} \cos \emptyset \quad (3.3)$$

Making the Current in Equation 3.3 as shown in Equation 3.36.

$$\text{Therefore} \quad \text{I} = \frac{\text{P}}{\text{V} \cos \emptyset} \quad (3.4)$$

Where P = power in Watts (W), V = supply Voltage (V),
I = current in Amperes (A), Cos θ
= power factor. Given the following alternator parameters;
P = 1500W, V = 220V.

At 0.8 pf, the input value in equation 3.5

$$\text{Therefore} \quad \text{I} = \frac{\text{P}}{\text{V} \cos \emptyset}$$

$$= \frac{1500}{220 \text{ x } 0.8} = 8.5A$$

And at 1pf, input value in equation 3.4 also becomes

$$\text{I} = \frac{\text{P}}{\text{V} \cos \emptyset}$$

$$= \frac{1500}{220 \text{ x } 1} = 6.8A$$

The alternator recovered from salvaged generator had an AVR in its housing unit with a carbon brush compartment. AVR is required for voltage or power stability during generation. It controls and maintains output terminal voltage of a generator or alternator within a set value. Whenever load connected to alternator or generator increases, speed of alternator also decreases. The speed of an alternator is proportional to frequency which will cause a decrease in output terminal voltage. More so, as soon as output terminal voltage decreases below set value, the AVR will increase rotor field current (I_f) to adjust output terminal voltage back to its set value. Output terminal voltage of alternator is high above set value, AVR reduces rotor field current (I_f) to reduce output terminal voltage back to its set value. In summary, AVR senses output voltage,

 ISSN: 3107-6513

compares it with set value, and adjusts output voltage to keep it within a set value.

3.11 THE MOTOR SEAT

A piece of 1.5mm angle iron bar was welded to form the frame and was padded 1900 generator seating.

3.12 A FRAME DESIGN

In choosing the materials for the design for the frame of the fuel-less generator, the firmness and stress resistance of the electrical and load components are highly considered. Hence one inch square metal pipe, iron wire gauze and metal sheet were chosen for the construction of the frame. The frame work as shown in figs 3.10 - .3.13 below with the following dimensions; 20.75 x 11.50 x 11.50 inches, provides a structural frame work, support and ground to the electrical components. The iron wire gauze and perforated metal sheets on the frame allows for natural cooling of the system as shown in frames figs 3.10 - 3.13 respectively. The structural frame also has rollers to ease its movement and a handle for the direction of movement, dimensions 20.75 Inc x 11.50 Inc x 11.50 Inc

Fig 3.10 .Real View

Fig 3.11 Bottom View of Frame.

Fig 3.12 Top View

Figs 3.10, 3.11 and 3.12and their dimensions 20.75 Inc x 11.50 Inc x 11.50 Inc.

\

Fig. 3.13 Side View of a Cased FLG.

A flat metal sheet without perforation is to prevent liquid and direct contact (Side view).As show in Figs 3.10 - 3.13 welding and fabrication are the main manufacturing process and they were adopted in the project manufacturing process. The required dimensions of metal pipes, wire gauze and metal sheets were cut to specification using precision tools and then welded together to produce the metal frame which is the foundational base to mount the alternator, battery and DC motor.

Testing stage.

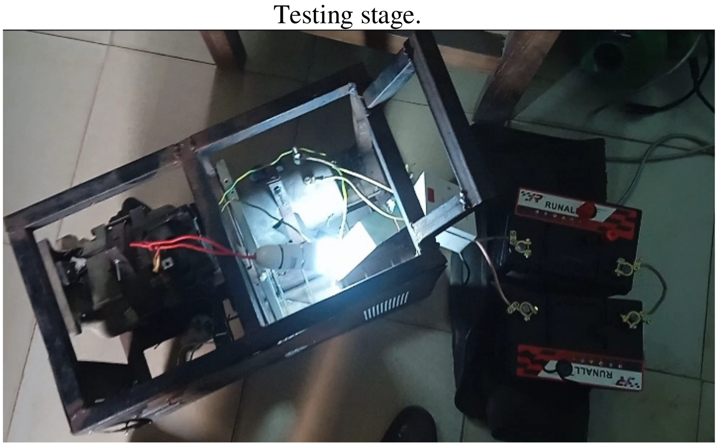


Fig 3..14 Uncased Fuel Less Generator

.

 ISSN: 3107-6513

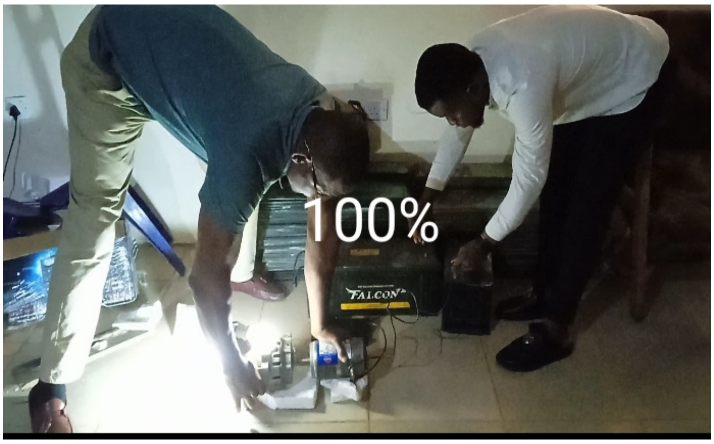


Fig 3..15 Testing a Coupled DC Motor and Alternator.

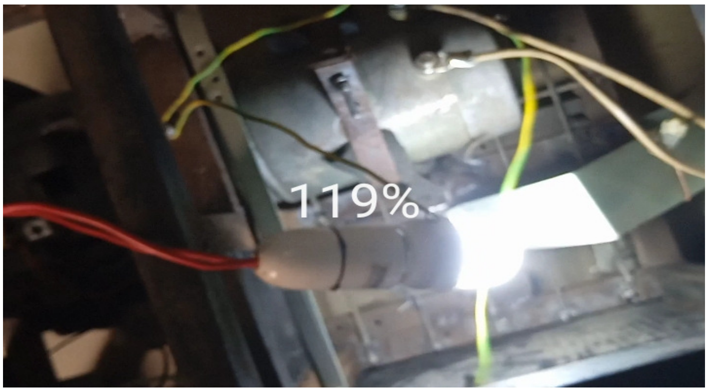


Fig 3..16 Working Fuel less Generator.

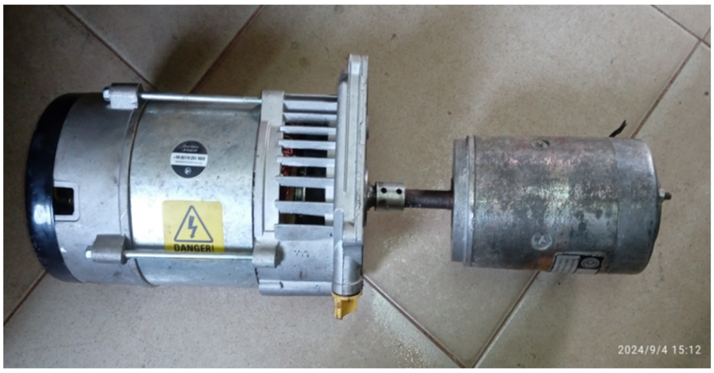


Fig 3..17 Coupled DC Motor and Alternator.

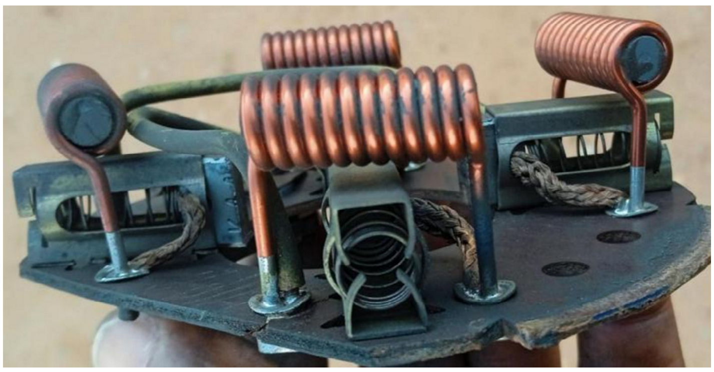


Fig 3.18 Side View of a Brush DC Motor.

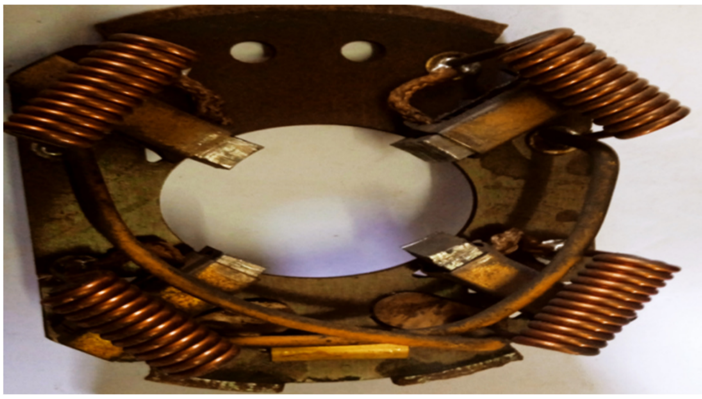


Fig 3.19 Top View of a Brush

Fig 3.20 Magnets and Rotor of a DC Motor

.

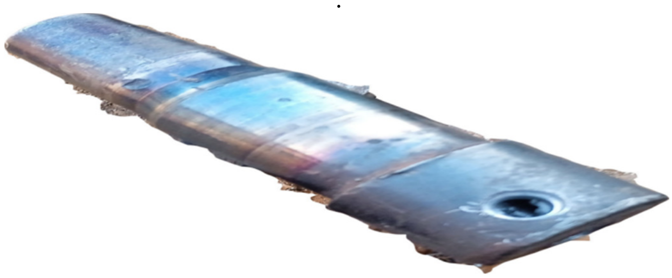
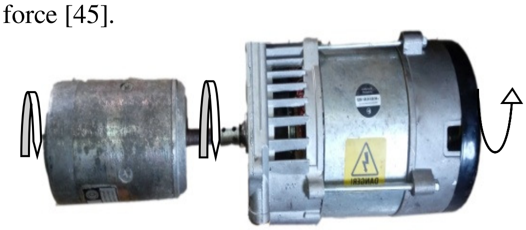


Fig 3.21 Fabricated Shaft

3.13 FUNDAMENTAL TORQUE EQUATIONS

The dynamic relations involve in all types of motors and loads, which is also known as dynamic or transient condition. These conditions appear during starting, braking and speed reversal of the drive. A motor generally drives a load (machine) through some transmission system. While the motor always rotates, the load may rotate or undergo a translational motion. However, to represent the motor-load system by an equivalent rotational system as shown in fig 3.22, the DC motor and AC alternator are connected directly to shaft as shown below. [63]; [23]. This could be best explained using Newton 1st law thus; A body remain in its initial state of motion unless it is acted upon by an external force [45].



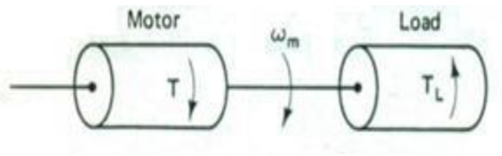


Fig 3.22: Motor–Load System

[63]; [23]

THE FOLLOWING NOTATIONS ARE ADAPTED:

J = polar moment of inertia of the motor-load system referred to the motor shaft, $kg - m^2$
ω_m= instantaneous angular velocity of the motor shaft, rad/ sec
T_m = developed torque of the motor, N-m
T_L = the load (resisting) torque, referred to the motor shaft, N-m
Any motor-load system can be described by the following fundamental torque equation;

$$T_m - T_L = \frac{d}{dt}(J\omega_m) = J\frac{d\omega_m}{dt} + \omega_m\frac{dJ}{dt} \qquad (3.32)$$

This equation is applicable on variable inertia drives such as mines winder, industrial robots etc. because, their moment of inertia changes with time.

For the drives with a constant inertia $\left(\frac{dJ}{dt}\right) = 0$ (3.33)

Becomes $T_m = T_L + J$ (3.34)

(Newtons 2nd Law of rotational motion)

Motor torque is offset by load torque and dynamic torque $J\frac{d\omega_m}{dt}$. The dynamic torque is only present during transient operations Acceleration or deceleration depends on whether T_m is greater or less thanT_L plus dynamic torque in order to overcome drive inertia.
It is seen from the equation (3.32) that, when

$$T_m > T_L i.e.\ \ J\frac{d\omega_m}{dt} > 0 \qquad (3.35)$$

The drive will be accelerating, picking up speed to reach rated speed.

$$T_m < T_L i.e.\ \ J\frac{d\omega_m}{dt} < 0 \qquad (3.36)$$

The drive will be decelerating coming to rest,

$$T_m = T_L i.e.\ \ J\frac{d\omega_m}{dt} = 0 \qquad (3.37)$$

(Newtons 2nd Law of rotational motion)
The motor will continue to run at the same speed, if it were running or will continue to be at rest,
.[63]; [23]

3.12 STABILITY:

a. Steady State Stability
b. Transient State Stability or Dynamic Stability

3.13 CRITERIA FOR STEADY STATE STABILITY:

The motor-load speed-torque curve is at equilibrium (steady state).

Disturbances change the equilibrium states. The disturbances are of two types. Such as

1. The effects of rotating mass inertia and inductance are considered negligible in dynamic studies due to their relatively small contribution.
2. Inertia and inductance effects are crucial when analyzing dynamic systems with sudden changes.

Steady-state stability deals with small-signal disturbances, whereas dynamic stability addresses large-signal disturbances.
At equilibrium, let the torques and speed be represented by T_m, T_L and ω_m. When system is in equilibrium, without any perturbation $T_m = T_L$ (3.38)
Let a small change occur in the load torque then we have

$$\Delta T_m = \Delta T_L + J\frac{d\Delta\omega_m}{dt} \qquad (3.39)$$

With small increments, we can approximate them as linear functions of speed deviation

$$\Delta T_m = \frac{dT_m}{d\omega_m}\Delta\omega_m \qquad (3.40)$$

$$\Delta T_L = \frac{dT_L}{d\omega_m}\Delta\omega_m \qquad (3.41)$$

Where $\frac{dT_m}{d\omega_m}$ and $\frac{dT_L}{d\omega_m}$ indicates derivatives at point of equilibrium. Substituting these relations in equation 3.39 and rearranging, we have

$$J\frac{d(\Delta\omega_m)}{dt} + \left[\frac{dT_L}{d\omega_m} - \frac{dT_m}{d\omega_m}\right]\Delta\omega_m = 0 \qquad (3.42)$$

$$\Delta\omega_m = (\Delta\omega_m)_0 e^{-\tau/2} \qquad (3.43)$$

Where: $$\tau = \left(\frac{J}{\frac{dT_L}{d\omega_m} - \frac{dT_m}{d\omega_m}}\right) \qquad (3.44)$$

is called mechanical time constant

$$\Delta\omega_m = (\Delta\omega_m)_0 \qquad (3.45)$$

is initial value of deviation in speed

Based on the value of exponent there are three cases

1. Exponent greater than zero: the speed deviation will increase with time and system will move away from equilibrium which results in an unstable system
2. Exponent less than zero: the speed deviation will decrease with time and system will move towards equilibrium which results in a stable system
3. Exponent equals zero: the equiton insufficient to discuss about stability

The exponent will always be negative if

$$\frac{dT_L}{d\omega_m} - \frac{dT_m}{d\omega_m} > 0 \qquad (3.46)$$

3.13 TRANSIENT STATE STEADINESS:

Thus, the equation of motion in terms of power, can be written as

$$P_m = P_{dyn} + P_L \qquad (3.47)$$

Where P_m ,$P_{dyn}$and P_L represents motor power, dynamic power, and load power at shaft. Dynamic power is determined by angular acceleration. Let's define δ as angular position of shaft relative to a reference rotating at synchronous speed. When load suddenly increases, the rotor slows, resulting in negative angular acceleration and corresponding dynamic power $P_{dyn} = -P_j\frac{d^2\delta}{dt^2}$ (348)

Where $P_j = \frac{j2\omega}{p}$ (3.49)

 ISSN: 3107-6513

p is the number of poles

The electromagnetic power P_m can be decomposed into two components, namely damping power, which exhibits a linear relationship with $\frac{d\delta}{dt}$ from synchronal speed and (ii) synchronous power, which is determined by load angle δ. Thus,

$$\frac{d^2\delta}{dt^2} + P_d\frac{d\delta}{dt} + P(\delta) = P_L \quad (3.50)$$

Where P_d is damping power. Assuming no damping and a smooth rotor then, we have

$$\frac{d^2\delta}{dt^2} + P_m \sin\delta = P_L \quad (3.51)$$

$$\text{Where } P_m = \frac{VE}{X_s} \quad (3.52)$$

$$\text{Now, } \frac{d^2\delta}{dt^2}\frac{P_m \sin\delta - P_L}{P_j}$$

(3.53)

Multiplying through by $\frac{d\delta}{dt}$ we have

$$\left(\frac{d\delta}{dt}\right) = \left(\frac{P_m \sin\delta - P_L}{P_j}\right)\left(\frac{d\delta}{dt}\right) \quad (3.54)$$

$$\frac{d\delta}{dt} = \sqrt{\int_{\delta_0}^{\delta}\frac{2(P_L - P_m\sin\delta)}{P_j}d\delta}$$

(3.55)

Where δ_0 is the load angle before the disturbance, i.e., at time $t = 0$. So, for the machine to be stable at the synchronous speed $\frac{d\delta}{dt} = 0$. Hence

$$\sqrt{\int_{\delta_0}^{\delta}\frac{2(P_L - P_m\sin\delta)}{P_j}d\delta} = 0 \quad (3.56)$$

$$\sqrt{\int_{\delta_0}^{\delta}(P_L - P_m\sin\delta)\,d\delta} \quad (3.57)$$

With the motor initial load P_{L1} , the operating point is at A corresponding to point δ_0 . As the load is suddenly increased to P_{L2} , the power angle swings to δ_f at which the speed is again synchronous. When the system is stable

$$\int_{\delta_0}^{\delta_i}(P_{L2} - P_m\sin\delta)\,d\delta + \int_{\delta_i}^{\delta_f}(P_{L2} - P_m\sin\delta)\,d\delta = 0 \quad (3.58)$$

Where δ_i is the power angle corresponding to new load P_{L2}.

The equation can finally be written as

$$\int_{\delta_0}^{\delta_i}(P_{L2} - P_m\sin\delta)\,d\delta = -\int_{\delta_i}^{\delta_f}(P_{L2} - P_m\sin\delta)\,d\delta = \int_{\delta_i}^{\delta_f}(P_m\sin\delta - P_{L2})\,d\delta \quad (3.59)$$

And as demonstrated in Fig 3.14 $areaA_1 = areaA_2$. Equal area criterion is used to assess transient stability.

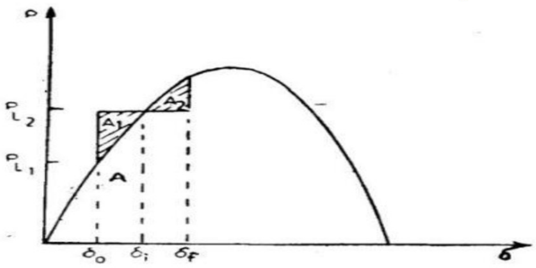


Fig 3.23: Stability graph

In conclusion:

- If area $A_1 > A_2$, the drive is stable
- If area $A_1 = A_2$, the drive is just stable
- If area $A_1 < A_2$, the motor loses synchronism [63]

4. RESULTS AND DISCUSSION

The data obtained from the input and output of the 1.5kVA fuel-less generator during evaluation were tabulated in tables 4.3a to 4.3c and their mean values on table 4.3 was used to plot chart as shown in figures 4.1 - 4.5 respectively.

4.1 PERFORMANCE EVALUATION.

In evaluating the performance of generator using suitable equipment, A multi-meter was used to measure currents in ampere, voltages in volts and a tachometer were also used to measure speed in rpm when loads of tungsten bulbs ranging from 0 - 800W were applied relatively. Each trial was carried out in 120 seconds and repeated trice, the mean of each parameter noted as shown in tab. 4.3

4.2 MECHANICAL EVALUATION.

The mechanical evaluation was calculated as ratio of the output power to input power multiply by 100.

Mathematically, $\textbf{Efficiency} = \frac{\textbf{OutputPowerx 100}}{\textbf{InputPower}}$ **(4.1)**

4.3 CONTINUITY TEST:

This was carried out on the DC Motor, Alternator and the frame of the generator before and after coupling to make sure that each of the components was not reading to ground (Bridging). i.e., DC 2.26Ω, AC 10 Ω and 0 to ground.

4.4 OPEN CIRCUIT TEST:

This was carried out by connecting the volt meter and ammeter to the input (battery;$11.98V$, 5.30A) and output (alternator; 0V, 0A) of the generator as no Watt-load was connected and the generator was switched off.

4.5. SHORT CIRCUIT TEST:

This was also carried out by connecting the voltmeter and ammeter to the input (Battery) and output (alternator) and different tungsten bulb Watt-load applied were applied to the generator on switched on mode, the mean readings of the different trials is shown on table 4.3 and the different trials is shown on tables 4.3a - 4.3c.

4.6 NO-LOAD TEST AND LOAD TEST

A No-Load test was conducted on the BDC motor and its results are shown in Table 4.1. The FLG after assembling was tested and Table 4.2 gives the result in detail. No-load test carried out on FLG lasted for 3 minutes: 30 seconds. Load test of FLG was conducted alongside no-load test and a total of nine trials was reached, all lasting not less than 3 minutes 30 seconds and results as can be seen are in Table 4.3. These readings were obtained from the DC Ammeter, DC Voltmeter, and AC Meter.

4.7 SPEED TEST

The speed of the BDC motor (FLG) was noted throughout the test. Table 4.4 shows the results as observed on the Tachometer and the Output frequency was observed on the Energy Meter.

 ISSN: 3107-6513

4.8 BATTERY CHARGE TEST RESULT.

The battery charger was tested with a Digital Multimeter and the value of the charging current and voltage when it was powered by an external AC power source. A 12V battery that was drained to 9V was used to test the charging rate and the results are shown in Table-4.5.

4.9 PARAMETER FOR THE ANALYSIS.

Table 4.1 OPEN AND SHORT CIRCUIT TABLE

Item	Input (Battery)		Alternator (Output)	
Open Circuit	11.98V	5.3 A	0V	0A
Short Circuit	12.97V	6.0 A	228V	8.5A

Table 4.2 INPUT PARAMETERS FOR THE ANALYSIS

/No rial	Load (W)	Input Voltage (V)	Output Voltage (V)	Input Current (A)	Output Current (A)	Input Power (W)	Output Power (W)	Speed (rpm)	Efficiency (%)
1	0	12.97	228	6.0	8.5	77.82	1938	3540	0
2	100	12.74	220	7.36	0.38	93.77	83.60	3200	89.10
3	200	12.78	218	7.82	0.40	99.94	87.20	3499	87.30
4	300	12.80	200	7.26	0.39	92.93	78.00	3215	83.90
5	400	12.76	170	8.20	0.46	104.6	78.20	2724	74.70
6	500	12.74	168	7.79	0.44	99.24	73.92	2688	74.50
7	600	12.51	130	6.76	0.38	84.57	49.40	2042	58.40
8	700	12.46	100	5.36	0.32	66.79	32.00	1565	47.90
9	800	12.40	87	4.62	0.28	57.29	24.00	1355	41.80

Table 4.2 INPUT PARAMETERS FOR THE ANALYSIS.

S/N	PARAMETER	VALUE	SYMBOL	UNIT
1.	Generating power rating	1.5	Pa	KW
2.	Motor power rating	1.5	Pa	HP
3.	Rotational speed of	3000	ω_a	RPM
4.	generator	4250	ω_m	RPM
5.	Rotational speed of motor	10	M	Kg
6.	Mass of alternator	2	M	Kg
7.	Mass of motor	5	M	Kg
8.	Mass of battery	12	⊣⊢	V
	Voltage of battery			

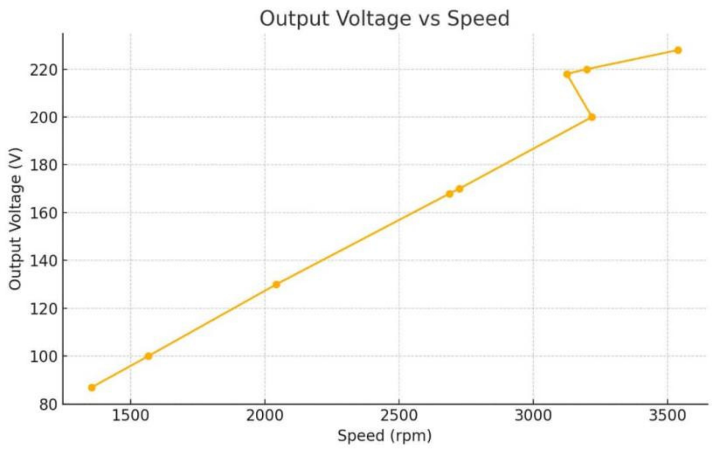


Fig 4.1 GRAPH OF OUTPUT VOLTAGE AGAINST SPEED.

RELATIONSHIP BETWEEN THE GENERATOR VOLTAGE AND SPEED PRODUCED

Figure 4.1 shows the computation and analysis carried out, it was observed that voltage output and speed of generator have a linear relationship. Varying the size of tungsten bulbs connected to generator ranging from 0 - 800W will have an effect on amount of speed and voltage produced and also amount of work done on system. Thus, increasing the voltage will result to an increase in speed of generator.

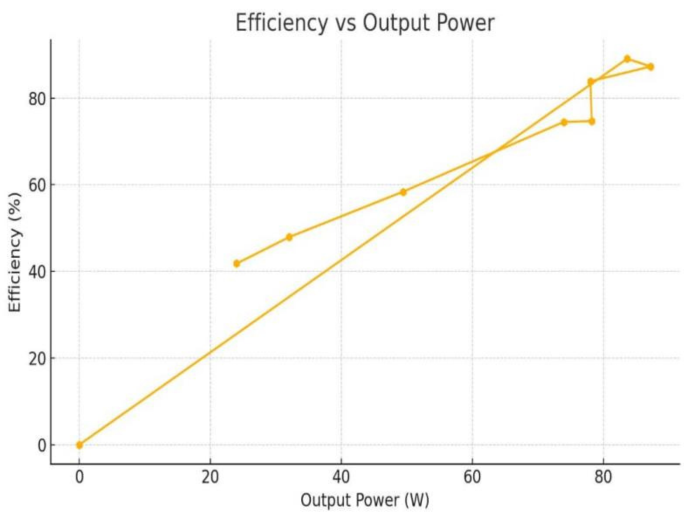


Fig 4.2 GRAPH OF EFFICIENCY AGAINST OUTPUT POWER.

RELATIONSHIP BETWEEN THE EFFICIENCY AND OUTPUT POWER

By carefully taking measurements of current and voltage of each trial, efficiency and output power of each trial was calculated and plotted against each other. Plot identified that efficiency only increases with a corresponding increase in output power as shown in Figure 4.2.

Fig 4.3 GRAPH OF EFFICIENCY AGAINST LOAD TRIALS

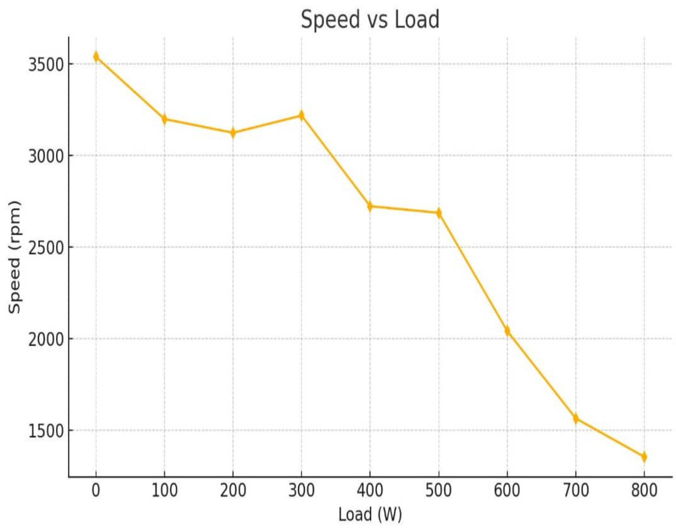


Fig 4.4 GRAPH OF SPEED AGAINST LOAD TRIALS

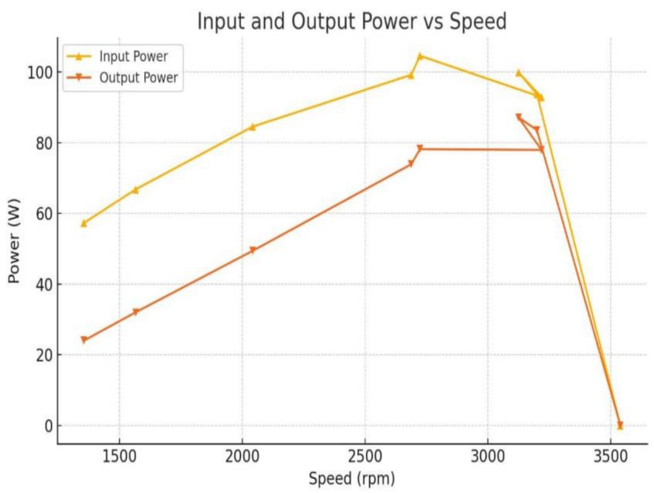


Fig. 4.5 GRAPH OF INPUT & OUTPUT POWER AGAINST SPEED

RELATIONSHIP BETWEEN GENERATOR POWER AND SPEED PRODUCED

From the analysis, it was observed that power produced by electric generator increased as rotational speed of generator increased. Therefore, to harness a great power output from generator, speed of generator is needed to be kept at its maximum intensity. It was also observed that to keep generator running at high speed, fuel less generator needs to rotate at a very high speed. Conclusively, increasing rotational speed, will subsequently lead to increasing speed of generator which analogously mean increases in electrical output and the efficiency of the generator.

4.10 TESTING AND EFFICIENCY

Upon completion of fabricated system, it was tested using a multi-meter and tachometer to measure voltage produced and speed at which generator is producing that voltage respectively. It was found to produce a voltage of 170V and 8.2A at a speed of 2724 rpm. It was from this basis the output power was calculated and hence overall efficiency of the system estimated 74.7%.

4.11 ANALYSIS

1. Given that alternator has 170V, 8.2A and power factor of 0.83,

Mathematically,

Real Output Power $P = VA\cos\Theta$ (4.2)

$$P = 220\ x\ 8.2\ X\ 0.85$$

$$P = 1{,}533\ \text{kVA}$$

Hence, capacity of the generator is 1,533W

Reactive power $P = \text{VASin}\Theta$ (4.3)

(Where $\Theta = 28.36$) $Sin\Theta =$

$$\sqrt{1-\text{Cos}^2\,\emptyset} = 0.4750$$

$$P = 220\ \text{X}\ 8.2\ \text{X}\sqrt{1-\text{Cos}^2\,\emptyset}$$

$$P = 220\ \text{X}\ 8.2\ \text{X}\sqrt{1-(0.85)^2}$$

$$P = 220\ \text{X}\ 8.2\ \text{X}\ 0.4750$$

$$P = 856.9\text{VA}$$

Hence, reactive power = 856.9VA power lose during operation

Note. $Real\ Power^2 + Reactive\ Power^2 = Apparent\ Power^2$

$$Apparent\ Power\ x = \sqrt{Real\ Power^2 + Reactive\ Power^2}$$

$$Apparent\ Power\ x = \sqrt{1{,}533^2 + 856.9^2}$$

$$Apparent\ Power\ x = \sqrt{2350089\ + 734277.6}$$

$$Apparent\ Power\ x = \sqrt{1615811.4}$$

$$Apparent\ Power\ x = 1{,}271.14$$

$$Apparent\ Power\ x = 1271.14\text{VA or } 1.27\text{kVA}$$

(Sylvester et al (2021) ; Tunji et al (2023).

2. Consider a DC drive with a 1.5 kW rating and 4250 rpm speed, powering a load with a constant component $T_L = 3.2$ Nm. Drive system has an inertia of 0.15 kg.m^2. If drive develops rated torque during the acceleration phase, time it would take to accelerate load from zero to 3000 rpm is?

Rated speed= $4250\ rpm$

Rotational speed $\omega = \frac{n_s}{60} \times 2\pi = \frac{4250}{60} \times 2 \times \pi$

$$= 445.1\ rad/s \quad (4.4)$$

Rated torque $T_m = \frac{P_{rated}}{\omega} = \frac{1500}{445.1} = 3.4\ Nm$ (4.5)

$$= T_m - T_L = J\frac{d\omega_r}{dt} = 3.4 - 3.2 = 0.2\ Nm$$

$$T_a = J\frac{\Delta\omega}{\Delta t}$$

$$\Delta t = J\frac{\Delta\omega}{T_a}$$

$$\Delta\omega = (3000 - 0) \times \frac{2\pi}{60} = 314.3\frac{rad}{s}$$

$$\Delta t = 0.15 \times \frac{314.3}{0.2} = 235.7\ ms \text{ or } 0.2357\text{sec}$$

If 235.7ms (0.2357sec) was used to drive the machine from 3000 - 0rpm

While, drive also drove from 0 - 3000rpm by

$$\Delta t = 235.7\ m \times \frac{4520}{3000} = 333.9ms\ or\ 0.3339sec.$$

Given that 3000rpm = 314.3rad/s, change in angular speed is;

$$\Delta\omega = \omega(final) - \omega(initial) \quad (4.6)$$

$$\Delta\omega d = (314.3rad/s - 0)\text{(Deceleration)}$$

$$= -314.3rad/s \quad (4.7)$$

$$\Delta\omega a = (0 - 314.3rad/s)\text{(Acceleration)}$$

$$= 314.3rad/s \quad (4.8)$$

Therefore, angular speed is same for both direction ($\pm$)

Also given that change in time for deceleration was 235.7ms and acceleration was 333.9ms, that goes to show that time taken to accelerate from $(0 - 314.3rad/s)$ is more that time taken to decelerate from $(314.3rad/s - 0)$. The difference in time (Δt) was due to; The difference in applied torque, power supply limitations, efficiency and load characteristics.

In comparing relationship between change in speed ($\Delta\omega$) and change in time (Δt) using Kinematic formula;

$$\alpha = \frac{\Delta\omega}{\Delta t} \quad (4.9)$$

For deceleration;

$$\alpha = \frac{-314.3}{0.2357} = -1.3335rad/s^2 \quad (4.10)$$

Required Torque to drive the machine from (3000 - 0) rpm was

$$Tm = I\alpha \quad (4.11)$$

$$0.15\ kg.m^2 \times -1.3335rad/s^2 = 0.200025Nm$$

For acceleration;

$$\alpha = \frac{-314.3}{0.3339} = 940.9rad/s^2 \quad (4.12)$$

Required Torque to drive machine from (0 - 3000) rpm was Tm = Iα

$$0.15\ kg.m^2 \times 940.9rad/s^2 = 141.135Nm \quad (4.13)$$

(Ehimetalor et al, 2017).

4.12. RESULTS AND DISCUSSION

Generator design utilized direct coupling with tungsten bulb resistive loads (100W-800W). Measurements were taken using a multimeter (current, voltage) and tachometer (speed), with time intervals recorded via stopwatch. Input and output powers and their efficiencies were calculated using mean values obtained after each set of three repeated trials. The following observations were made. From fig.4.1 the output voltage is proportional to speed of generator and when a load is between 400W and 500W were applied, it was observed that generator had steady stability due to small change in speed and voltage; voltage drop was 2volts (170V – 168V) that could also be seen on efficiencies of generator 74.70% and 74.50% which is within IEEE standard of 1 - 0.7% [8]. Fig 4.2 shows that any load more than 500W would cause generator to be inefficient and mechanical evaluation would be less than 74.5%. In figs.4.3 and 4.4, it is evidently clear that load should not be more than 500W in order to obtain a better performance (steady stability) of generator. While, fig 4.5 also clearly shows that input and output powers were function of speed, thus giving rise to steady and transient state stability of generator. Meanwhile, from analysis given on section 4.8 pages 28 and 29 shows that time difference was due to difference in angular acceleration of $-1.3335rad/s^2$ and $940.9rad/s^2$ as well as difference in their applied torques; *0.200025Nm and 141.135Nm.* The power supply and efficiency of generator is limited by friction (e.g., static and dynamic frictional force) and load characteristics.

5.1 CONCLUSION/RECOMMENDATIONS

Conclusively, a fuel less generator can be produced by connecting a 12V battery to exist a DC motor that primes an AC motor which is connected via a shaft. And alternator is also connected to a 12V battery charger which keeps battery charging and the DC motor run. If rate of charge is equal to rate of discharge, generator will remain running. The generator was at maximum speed when no load was added (NO load speed) and had a speed of 3540rpm that produced an output voltage of 228V with an input of 12.97V. And when load was added, it was seen that increase in load led to a considerable decrease in speed of machine as shown in fig4.4. Meanwhile From fig.4.1 it was deduced that output voltage is proportional to speed of generator hence, when speed of generator is reduced, output voltage is reduced. Fig 4.2 shows that the machine was stable when output power(W) was between 78.20V and 73.92V result of a slight change on output power of about 4.28V and their efficiency were 74.40% and 74.50% which is within IEEE standard of 1 - 0.7% [8]. fig4.3, shows that at fifth and sixth trials, efficiencies were slightly different 0.20 which make it slightly stable. Hence it is recommended that maximum load should not be more than 500watts. Fig 4.5. explains that input and output powers are proportional to the speed of generator. All of above best explains steady and transient state stability of drive system. DC motor speed rating should be higher than alternator rating in other to obtain maximum speed. Fuel-less generator is eco-friendly and cost effective and can serve as a backup uninterrupted power generator to prevent down time (loss of time and man hours) which could be caused by incessant power outage. At steady state speed of motor is

 ISSN: 3107-6513

approximately equal to speed of load and machine continues to run when sum of current leaving battery is equal to sum of current entering battery. The alternator obeys Faraday, and Lenz' Laws of Electromagnetic inductions.

5.2. RECOMMENDATION

1) Further research can be carried out using a 24V DC motor and 3 - 10kVA (30,000 - 100,000) alternator, same method may by applied.
2) Incorporation of inverters in subsequent project would further enhance the sustainability of the products.
3) The project is subject to further research in order to improve on its limitations.
4) Mass production and adoption of fuel-less generators could provide a viable power solution for rural areas.

5.3 CONTRIBUTION TO KNOWLEDGE.

This study explores carbon-neutral energy technology, aiming to design and build a prototype fuel-less generator by coupling a DC motor with an alternator. The impact of the DC motor on the brushless fuel-less generator was verified through design, build, and testing. Torque requirement determination is a pivotal aspect of DC motor selection, and this research effectively tackled this challenge. This research provides a framework for designing and retrofitting fuel-less generators, with a focus on hybrid cooling systems for DC motors. Potential applications of fuel-less generators include:
in the course of this research. Other areas were fuel less generator can be exploit includes

I. Fuel-less generating set can be achieved with greater performance by increasing size of both DC motor with a speed that is over 3500rpm and the alternator with a higher capacity (kVA), provided the speed of the DC motor is higher than that of the alternator.
II. Fuel-less generator can be combined with an inverter to generate stable and higher capacities of electricity.
III. The power output can also be cascaded to generate up to100 kVA of electricity. etc.,
IV. The importance and determination of required torque play a major role in selecting a DC motor and this was discovered and addressed in this research.
V. The fuel-less engine can used to replace diesel engines
VI. Petrol and diesel engines used in air planes can be replaced with fuel less engines.
VII. Fuel less engines can replace high-speed engines that are used to power yachts, ships and lines along the high seas.
VIII. Fuel less engines can also replace diesel powered engines that are used by mining and mineral extraction sector
IX. Fuel less engines can replace emergency backup generators that must be made available for any major medical health care facilities due to critical nature of work
X. Fuel less engines can be used to power computers, heart of today's industry. When servers and systems go down, communication can be lost,

REFERENCES

1. **A Guild to the Nigeria Power Sector** (PDF) KPMG *Sept, 2016.*
2. Abass, W.O., (2013): Construction and Evaluation of a Power Inverter. Unpublished HND Project, Department of Agricultural Engineering, Federal College of Agriculture, Moor Plantation, Ibadan.
3. Abatan O.A & Adewale A.O, (2013) Electricity Generation from a Fuel-less Engine in an Isolated Power Generation System, IJETAE, Ibadan
4. Abonyi E.S, OKolie P.C and Emmanuel C.N. (2021) Design and Construction of a Fuel less AC Generator using Alternator interfaced with an Inverter of the creative common attribution. www.IJTSRD.Com. e-ISSN2456 - 6470
5. Adegoke A., Adebayo I., Babajide .D and Oladepo .O. (2021) Development and Performance Evaluation of a 2kVA Fuel-less Generator. LAUTECH Journal of Engineering and Technology 15 (1) 2021:146-153
6. Adegoke, A. (2020). Design and construction of a 2kVA fuel-less generator. An Unpublished B.Techproject, Department of Electronic and Electrical Engineering, Faculty of Engineering and Technology, LAUTECH.
7. Adelekan BA. Potentials of selected tropical crops and manure as sources of Bio-fuels, Bio-gas.
8. Adewumi I. (2016), "Development of 2.5 kVA Self Induced Power Generating Set," Sci-Africa Journal of Scientific Issues, Research and Essays, vol. 4, no. 1, pp. 890-894.
9. .Adewumi. I. O and Adelekan. B. A (2016) Fuel-less Generating set and Power inverter system. Analysis of Load and Efficiency Appraisal. Current Journal of applied Research and Technology. Pages 1-7.
10. Afroyanga Bootcamp. (2024), https://wiki media. org
11. Ajav, EA and Adewumi, I.O (2014) Fuel less generating set Design, Construction and Performance Evaluation, Proceeding of the 3rd International Conference on Engineering and Technology Research, August 5-7, Volume 3, ISBN: 978-2902-58-6, Pages 258-269\
12. Akwemoh .M.., Asikhia O.K., Idiata D.J., and Oriarewo E.E. The Necessity of a Paradigm Shift Towards Alternative Energy Sources in Nigeria: An Examination of Fuel-less Generators. www.ijrpr.com ISSN 2582-7421..
13. Al-Salaymeh A., Al-Hamamre Z. and Abdelkader M., (2010) Technical and Economical Assessment of the Utility System in Residential Buildings; Case of Jordan. Energy Conversion and Management, 51(*), 1719-1726.
14. Aremu, D.O (2009) Design, Construction and Performance Evaluation of motorized Maize Shelling Machine. Unpublished B.Sc Project, Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, 41-45.
15. Ashoro O. (2021), Design, Construction and Performance Evaluation of a 1500W DC Powered Inverter Unpublished Project work, Department of Electrical Electronics and Computer Engineering, Delta State University, Abraka, Oleh Campus. Pages 9-28
16. Atere (2009): Farm Electrification. Being a lecture note from Department of Agricultural Engineering, Federal College of Agriculture, Moor Plantation, Ibadan. Oyo-State Nigeria. 5 – 16

17. Babarinde O.O., Adeleke B. S., Adeyeye A, H., Ogundeji O. A., & Ganiyu A. L (2014). Design and Construction of 1KVA Inverter, International Journal of Emerging Engineering Research and Technology, 2(3), 201-212.

18. Beauchamp, K G (1997).“Exhibiting Electricity”.IET.p.90. ISBN 9780852968956.

19. Beck .K. (2018, April 30). Types of Electrical Loads, Retrieved 20 May, 2022 from Sciencing http://Sciencing.Com/types-electrical-Loads- 8367034.html.

20. Bhim. S., Murthy. S. S and Sushman. G, (2006), “Analysis and Design of Electronic Load Controller for Self-Excited Induction Generators” IEE transaction on energy conversion, India.

21. Bitterly, J.,(1997).“Flywheel technology past, present, and 21st Century projections”. Engineering Conference, Proceedings of the 32nd Intersociety,Europe.

22. Dipali S., Rutuja S., Shital M.(2017), "Fuel less Generator: Review," International Journal for Research in Applied Science & Engineering Technology (IJRASET) , vol. 5, no. VI, pp. 1375-1378, 2017.

23. Dudey G.K. (2024) Fundamentals of Electric Drive EEE 8601 Solid State Drive, Rohiri College of Engineering and Technology.

24. Ebruke. E, (2023).Technical Analysis of the New Power Sector, State’s Readiness and the Place of Engineers.

25. Ehikhamenle. M. and Okeke. R. O (2017), Design and Development of 2.5kVA Inverter Adopting a Microcontroller Based Frequency Meter. International Journal of Engineering and Modern Technology, 8(1), 1-13.

26. Erinle. T. J., Falana. A. B and Oladipupo. O.T., (2023).Design and Fabrication of Environmental Friendly Generator Harnessing Electric Motor and Alternator for Pollution-Free Power Generation, Department of Mechanical Engineering, Federal Polytechnic Ado-Ekiti, Nigeria..

27. Emmanuel .O, Eyenubo. J, Alele .J, Okpare .A, Oghogho I.(2025), Systematic Review of Barriers to Renewable Energy Intergration and Adoption. Delta State University, Abraka. Journal of Asian Energy Studies Vol. 9,

28. Eyenubo .O.J, & Oshevire P. Improvement of Power System Q uality Using VSC-BASED HVDC Transmission, ISSN:0331-8443.NIJOTECH, Vol36, No. 3, July 2017, pp 889-896.

29. Eyenubo .O.J, and Otuagoma S. O. (2016). Performance Analysis of a Self Excited Single -Phase Induction Generator.ATBU, JOSTEL; Vol4(4), December, 2025.

30. Farinde. O. E., Ehimetalor. H. E and Dada. S. K (2017). *Essential Physics for Senor Secondary School, Tonad Publisher Limited. ISBN 978-978-52654-7-7*

31. Gideon .A, *.www.nerc.gov.ng*. Retrieved 2024-01-09

32. Hannah. R and Max. R, (2018), Global Primary Energy Consumption Source, www. Researchgale.net

33. Hansan, H. J. (1989). Types of fuels for electricity generation. Electrical Energy in Agriculture,Henrik,M.I.(2000):“ThGlobalPowerInverter”http://www.05.abb.com/global/scot/scot271.nsf/369669d5dd6e6es1257ba5. Accessed 12/10/2011.

34. Knight, R.D (2004) “Physics for Scientists and Engineers: A Strategic Approach. San Francisco Maini, A.K. (1998) “Electronic Projects for Beginners” Pustak Mahal, 2nd Edition. An Indian Publication. 211 – 21.

35. Ibekwe B.E and Ezekiel N.A (2020). Development of Seif-Inducted Fuel less Generating Set for Sustainable Power Supply in Nigeria Using Local available materials, American Journal of Engineering Research (AJER), Vol 9 (07), 2020 pp 56-61.

36. IEEE(1999): Institute of Electrical Electronics Engineering.wwwiee.org Retrieved 2021-1-2

37. Losty, H.H.W & Lewis, D.L.(1973) Homopolar Machines. Philosophical Transactions for the Royal Society of London. Series A, Mathematical and Physical Sciences. 275 (1248), PP.69-75.

38. Iyappa. S. B., Dinesh G., kodeeswaran. R., Vidhya. K., Musthafa. P., (2014) Electricity Generation from a Fuel-less Engine in an Isolated Power Generation, International Journal of Research in Electrical and Instrumentation Engineering. Vol. 3 Special Issue 4. Pages 167 -170.

39. Mbokop D.E, Etim H.E and Essien A.F, (2019) Design and Fabrication of a Fuel-less generator. , Department of Mechanical Engineering, Akwa Ibon State University. Akwa Ibon State.

40. Muhammud, B., Abdullahi, H. and Muhammad S. (2015) A Design,Construction and Installation of 1000Watts Inverter Using Solar Power System. 2nd International Conference on Science, Technology and Management, 2860-2865 www.electricaleasy.com Retrieved 20 May 2022.

41. Murthy. S.S., Malik. O. P., Tandon. A. K., (2008),“Analysis of self-excited induction generators,” Proc. IEE.

42. "NERC Quarterly Reports". *www.nerc.gov.ng. 2022*. Retrieved 2023-01-09

43. *NESI.NERC Retrieved 2023 -03-30 > History > Generation > Transmission > Distributio.www.nercgov.ng and https//dailypos.ng 2023-01-08*

44. *Ogunlade C.A, Akinyele O.A (2022) Agricultural and Enviromental Sustainability in Nigerian a review of Challenges and possible Eco-friendly Remedies (Solar Crop Dryer).*

45. Okagbare G.O (2019). Mastering Senior Secondary School Certificate Physics.

46. Onochie, U., Egware, H., & Eyakwanor, T. (2015). The Nigeria Electric Power sector (opportunities and challenges). Journal of Multidisciplinary Engineering Science and Technology, 2(4), 494-502

47. Oseni (2011-12-01*). "An analysis of the power sector performance in Nigeria". Renewable and Sustainable Energy Reviews. 15 (9):4765 4774.* doi:10.1016/ j.rser. 2011. 07. 075 . ISSN 1364-0321..

48. Osogbue P. C., et al (2014),Design and Construction of 2.5KVA Inerter with Battery Control Unpublished Project work, Department of Electrical Electronics and Computer Engineering, Delta State University, Abraka, Oleh Campus.

49. Otuaguma. S. (2022) Lecture Material on Electrical Machine Design EE840, EEE Department, Delta State University, Abraka.

50. Otuaguma. S. (2022) Lecture Material on Synchronous Machine, EEE Department, Delta State University, Abraka.

51. Otulana. J. O., Akinwunmi. A. A, Awoyemi. J. A., Adeleke. M. B and Efunbote. M. I, (2015) Construction of a Fuel-Less Generator. International Journal of Recent Research in Civil and Mechanical Engineering (URRCME) Vol, 2 , Issue 1, pp: (285-289), Month: April 2015 –September 2015, Available at: www.paperpublications.org ISSN 2393-8471

52. Owen, E. L (January / February 1996). "Origin of the Inverter" IEE Industry Application magazine: History Department (IEEE) 2(1): 64-66 Doi: 10.1109/2943,476602.

53. Oyekola P,, Mohamed .A, Aforijiku O, and Oyekola E. (2019).Development and Evaluation of Fuel-less Power Generator ISSN: 2278-3075 (Online), Volume-9 Issue-1, November 2019

54. Perry I-Pei Tsao,(2008), "An Integrated Fuel-less generator with a Homopolar Inductor Motor/Generator and High-Frequency Drive", Thomas publishers, UK..

55. Peter O., Aezeden .M. Olufemi A. and Elizabeth .O. (2019) Development and Evaluation of a Fuel-less Generator. International Journal of Innovative Technology and Exploring (IJITEE) ISSN: 2278-3075 (Online), Volume-9 Issue-1, November 2019.

56. SDG Goal 7, (2022) Energy-United Nation Sustainable Development Retrieved 20 May 2022. https;//www.un.org>energy.

57. Singh, B., Murthy, S., & Gupta, S, (2006) "Analysis and design of electronic load controller for selfexcited induction generators.," IEEE transactions on energy conversion, vol. 21, no. 1, pp. 285-293.

58. Sunil. K., (Ed.); (2012) ISBN:978-953-51-0204-5, In Tech Available:http://www.intechopen.com/book Available:http://www.intechopen.com/books/biogas/potentials-of-selected-tropicalcrops-and-manure-as sources-of Bio-fuels

59. Swillas Engineering (2013).

60. Sylvester E. A., Okolie C.P., and Emmanuel C.N. (2021). Design and Construction of Fuel less AC Generator Using Alternator Interfaced with an Inerter. International Journal of Trend in Scientific Research and Development (IJTSRD) Volume 5, Issue4, May-June 2021, www.ijtsrd.com e-ISSN: 2456-6470

61. Takahashi, K., Kitade, S., Morita, H., (2002) "Development of high speed composite flywheel rotors for energy storage systems" .Adv. Compos publishers. India

62. Theraja B.I,. and .Theraja A. K. (2007)A T extbook of Electrical Technology 24th Edition, S Chand and Company Ltd New Delhil- 110055

63. Ubeku. E. U. (2024) Lecture Material on Electric Drives (DC Motor) EEE 814, Dept of Elect/Elect Faculty of Engineering, Delta State University, Abraka.

64. UNCTAD, (2019) Retrieved 20 May 2022. https://unctad.org>2019

65. United Nation (2022).

66. .https://www.electronics-tutorials.com

67. https://circultlab.com(www.electricaleasy.com.