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Development and Evaluation of Fuel-less Power Generator

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Abstract*: *The erratic power supply has been a growing cause for concern in developing countries. It becomes more challenging to supply adequate energy in countries with a high population due to the increased demand and this has led to load shedding and spreading in Nigeria. Also, emissions from power plants, impacts of hydroelectric development, and risks associated with nuclear energy use have been targets for political action due to the recent pursuit of sustainability development. Also, evidence of depletion of the protective ozone layer and its impact on the environment have urged the need for rapid development of alternative power generation method void of causing adverse environmental impact.

This paper, therefore, discusses the design and evaluation of a self-starting fuel less power generator using DC motor as the prime mover to generate electrical energy from an alternator. The alternator armature shaft was coupled directly with DC motor powered by a rechargeable battery. The DC motor rotates the armature of the alternator in the field coil at high speed when activated from the starting switch, which results in alternating current output voltages of 220V.

Keywords*: *Free energy, Portable Generator, Sustainable power.

I. INTRODUCTION

Despite technological advancement in power and energy production, access to constant electricity in some countries is almost not achievable despite billions of dollars spent by the government in the electrification projects across the country. Furthermore, other places with power can depend on sporadic, unpredictable, and unacceptable electric power [1]. Insights demonstrate that 67% of the developing world has no accessible domestic power [2]. In Africa, a French consulting firm has begun a vitality program that quickens the structure of rustic frameworks for providing electrical capacity to the most remote areas. Another initiative has been the push for instituting sustainable power source frameworks, for example, wind, sun oriented, and geothermal generators to control provincial African territories [3]. The objective of these is to make a substantial and minimal effort energy program.

The pace of development and industrialization of any nation relies upon their capacity to deliver satisfactory electric power and ensure viable distribution to power homes, ventures, banks, media, health care, aviation, etc. [4] and this is profoundly evident in Nigeria as the power sector has over the years struggled to meet load demand [5] regardless of its bounty of sustainable power source, for example, biomass, wind, hydro control and so on whose exploitation and utilization are negligible [6] [7] [8].

This inconsistent power supply has caused a surge of the search for alternative forms of power generation with minimal operating costs. Industries adapted the use of natural gas generators as much saving was made compared to the traditional petrol or diesel-run generators. However, with the increasing demand for gas, the price subsequently went up [9]. Also, gasoline generators emit toxic fumes and pollutants like carbon monoxide and particulate matter.

Based on the Faraday electromagnetic induction principle of electromagnetic force induction (EMF), power generators convert mechanical energy [10] into electrical energy [11]. It comprises a magnetic field, slips rings, an armature, resistive load, and brushes. The magnetic field is typically an electromagnet while the armature is any number of conductive wires in loops that revolve in a circular motion through the magnetic field. At the point where the armature turns through the magnetic field, it produces voltage which in turn induces the flow of current. Slip rings are joined to the armature and pivot with the armature. Carbon brushes ride against the rings of the slip to direct current from the armature to the resistive load. The significant components of a generator are the magnetic field and the movement of the conductor in the magnetic field. Figure 1 below demonstrates the schematics of a generator.

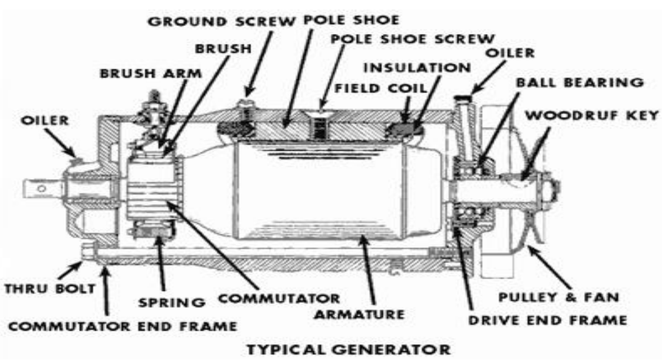

Fig. 1.The Schematics of a Generator [12]

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The concept of fuel less power generation is not new. When a conductor is turned in a magnetic field, voltage is induced in the conductor. This is due to the variation of flux. However, some losses are experienced in the core and winding of the rotor and stator. This design, therefore, consists of the power supply unit, conversion, and control unit, output, and charging units. The components parts include 12V battery, D.C motor, alternator, connecting shaft, bolts and nuts, transformer, diode, and noise damper. From R.J [13] analysis of the internal combustion engine based self-induced generator which recycles the electricity generated by the alternator, mechanical energy was generated by the combined motion of the engine while the electrical unit includes amateur, field coil, diode, AVR, capacitor, etc. which produces and regulated the produced energy. Bala [14] however, designed an isolated fuel less engine power generation system without the use of a secondary engine in producing mechanical energy. The system focuses on the use of fuel less engine as an option for detached power from sustainable power sources because of its preferred financial position, low upkeep cost, and development strategy. Abatan and Dipali [15] [16] also worked on economic, noiseless, emission-free, and uninterrupted alternative Self-Charging Inverter's Constant Electricity Generation. The system was designed such that a built-in battery charger recharges the batteries at the same rate as the DC discharges the battery when drawing battery current. Their study revealed that the system could be designed to any limit, contingent upon the capacity of the planned load and the setup required no form of maintenance. This helps in reducing the cost of acquiring the fuel less generator. Subramanian [17] portrays the impression of the load controller of a self-energized asynchronous generator with a steady power generation using MATLAB/Simulink software. Furthermore, Sreenivasula and Rajaendra's study [18] [19] showed the modelling and simulation of the asynchronous generator with AC/DC/AC converter fed RLC series circuit in an isolated power generation system. Their objective was to simulate a self-excited asynchronous generator (SEASG) feeding RL load together with an AC/DC/AC converter which was subsequently fed to the RLC series circuit connected at a common point. The acquired outcomes demonstrated that the impact of the RLC series circuit at the point when worked at variable frequency influences the generated voltage profile. This mirrors an extra capacitance, or inductance impact is conceivable to infuse when the RLC is worked at a frequency lower or higher than the resonance frequency. Adewumi [20] designed a 2.5KVA self-induced power generator as a feasible solution to isolated power generation from renewable energy sources owing to their low price, low maintenance costs, and reliability. The construction characteristics include an alternator, DC motor, 12V 100Ah battery, AVR panel, and charging panel. Power transmission was carried out by direct coupling technique and V-belt technique. The self-induced generator assessment was performed by charging for a period of 300s for each load with variable loads ranging from 0 to 2000W bulbs. The research disclosed that for reliability and better system efficiency, the self-induced energy-generating set must make use of a new direct current engine and alternator for future study.

II. METHODOLOGY

The design and performance evaluation of this 1000W power generator included DC motor, 12V/60Ah battery, alternator, coupling, charging panel (Transformer, diode, and capacitor), and frame. The frame and motor mount were constructed using Steel bars and angle steel while the connecting rod was suitably fitted into the DC motor with a threaded hole for bolting. The crank casing of the alternator was inserted, and the armature of the alternator was fixed such that the frame provided support and rigidity. The terminal of the DC motor was connected to the battery. The design of the fuel-less power generator includes five basic units which are the power supply unit, a conversion unit, control unit, output unit, and battery charging unit. The power supply unit includes a 12 volts battery which is used for the initial start-up of the system by supplying energy to the D.C motor to induce EMF. It also stands as the power storage point. The control unit, however, converts direct current (DC) to alternating current (AC), aid the removal of ripples, and rectification of output energy. The block diagram describing the component and circuit arrangement of the system is shown below.

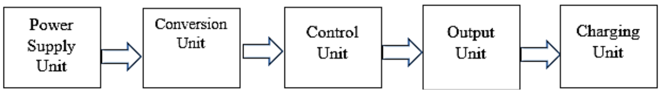

Fig. 2.Block Diagram

Similarly, the Conversion Unit distinguishes the DC generator from the popular fuelled generating set. The unit use of DC motor, which will be responsible for all voltage, current, and power conversion. The circuit diagram in figure 3 shows the schematic layout designed using Proteus. This enables proper circuit simulation to ensure that a proper connection.

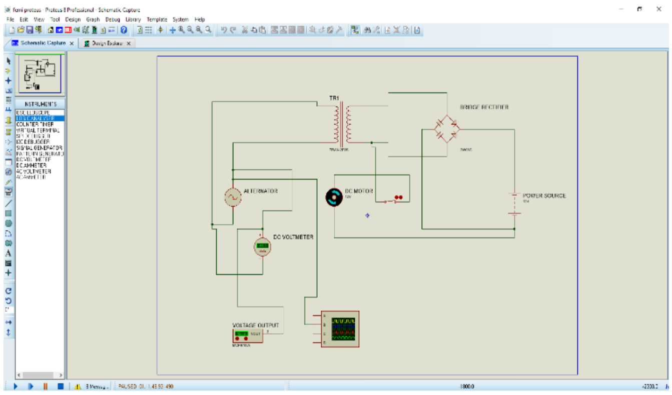

Fig. 3.Fuel less Generator Circuit Diagram

The choice of construction material was based on strength, cost, and availability. The frame was made of mild steel due to its strength, durability, resistance to breakage, and ease in weldability.

A. Mathematical Modelling

The generator was built by the direct coupling of a 50W alternator with a 30W DC motor that acts as a prime mover to the synchronous generator. The DC motor was powered by an external rechargeable DC voltage battery for separate excitation of both the field coil and the rotor winding of the DC motor at the first phase.

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The alternator works on the principle of Faraday's Laws of electromagnetic induction to produce an induced electromotive force (EMF) at whatever point the attractive motion connected with a circuit change [21].
The rotor (conductor) placed in the magnetic field of the stator which was linked together by magnetic flux. The rotational force was applied to the rotor by the prime mover.
Mathematically

$$Induced\ e.m.f = \frac{N\Phi2 - N\Phi1}{t}$$

Where, NΦ1 and NΦ2 is the initial and final flux leakage, with N being the coil number of turns and t being time.
The DC motor was designed based on the related principle of electromagnetic induction, but instead of generating an induced EMF, DC voltage was supplied to the rotor winding in the field coil (stator winding) which was linked together through the magnetic flux. This, in effect, causes the rotational motion of the rotor winding in the field coil. During the DC motor operation, a back EMF (eb) was experienced; an induced voltage in the coil of DC motor due to the generator effect. The back EMF as quantified in (3) opposes the externally applied voltage to the coil; as a result, it tends to reduce the motor current

$$e_b = \frac{\phi \times Z \times N \times P}{C \times 60}$$

Where C = Number of parallel paths of the conductor in the armature, Z = Number of conductors in the armature, N = Speed of shaft rotation in rpm, Φ = Flux Density, p = Number of poles.
For a Lap Wound DC motor, C = p

$$\text{Hence } e_b = \frac{\phi \times Z \times N}{60}$$

$$e_b = k_c w$$

$$Where, w = \frac{2\pi \times N}{60}$$

w = angular speed and k_c = Voltage Constant
The armature voltage V, consists of two; Back e.m.f(e_b), and the voltage drop across armature resistance ($i_b R$).

$$V = i_a R + e_b \qquad (3.12)$$

$$V_{ia} = i_{a^2} R + e_{bia}$$

Where, Vi_a = 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.

$$Torque\ (T) = \frac{p}{w} = \frac{Mechanical\ power}{Angular\ speed} = \frac{e_{bia} \times 60}{2\pi \times N}$$

$$= \frac{\Phi \times Z \times N \times P \times ia}{2\pi \times N \times C}$$

The effective torque which overcomes first rotational torque at current i_a is;

$$T = K_{Tia} - T_f \qquad (3.21)$$

This, therefore, implies that

$$V = \frac{T + T_f}{kT} R + k_c w$$

Practically, Tf ≈ 0,

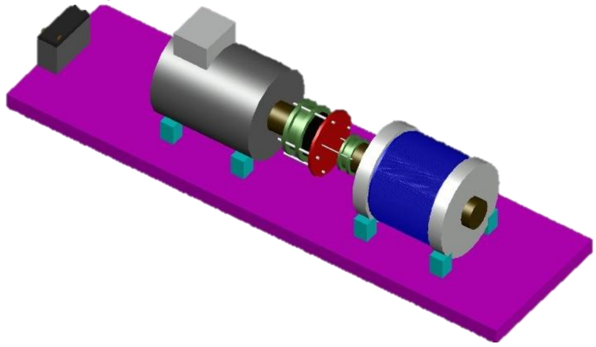
$$w = \frac{kT \times V) - (T \times R)}{(kT \times k_c)} \qquad (3.39)$$

This describes the speed (angular) of a DC motor based on the power supplied to it. The electric power supplied to the armature was evaluated from [22] to calculate the mechanical power developed by the DC motor with the power loss to the armature resistance. However, the batteries used as the source of power to the DC motor will be recharged automatically as it is being used simultaneously, just like the electrical system of an automobile system. In determining battery capacity, power calculations were evaluated, as shown below.

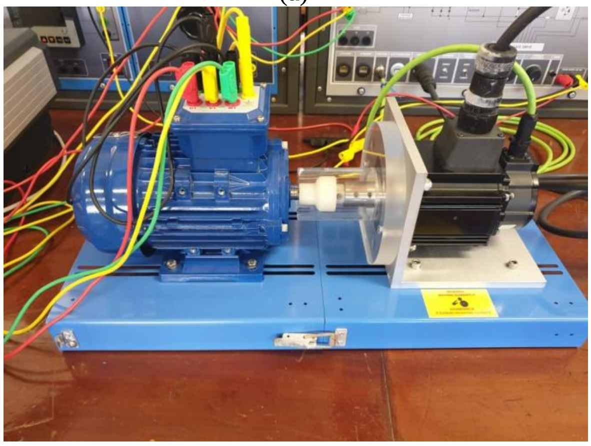
$$p = IV$$

$$W = VA \times \cos\phi$$

Where $\cos\phi$ is the power factor of 0.85.



(a)



(b)

Fig. 4.(a) AutoCAD model, (b) constructed prototype

III. RESULTS AND DISCUSSION

The direct coupling technique was implemented during the development of the fuel-less power-producing set and light bulbs were utilized as the load, connected to the extension wire. A stopwatch was utilized to record the time an interim of 20 seconds for five distinct runs, while the multi-meter was utilized to peruse the voltage yield, current and the mean voltage with the current outcome.
Output efficiency was calculated using the data obtained after testing, during which the load capacity used ranged from 0 watts to 200 watts. The speed of the motor utilized was 3000 rpm whereas the alternator's speed was 500 rpm. This implies that there is the direct coupling of the motor and the alternator since the speed is in ratio 1.5: 1. The power factor was kept consistent (Φ = 0.85), as the standard range from IEEE is between 1 – 0. Each test was imitated five times. The evaluation of the efficiency is given by;

$$Efficiency = \frac{output\ power}{input\ power} \times 100 \qquad [23]$$

The performance evaluation establishes the conversion efficiency between the input source and output. This includes response to variations in input power, the input and output voltage, ambient temperature as revealed by [24].
Moreover, it can be seen that while the load is amplified gradually from no load to full load (200W) at an incremental step of 50W, as shown in figure 5, the input power requirement from the battery varied slightly but remained relatively constant. This fluctuation is due to varying current demand and internal resistance.

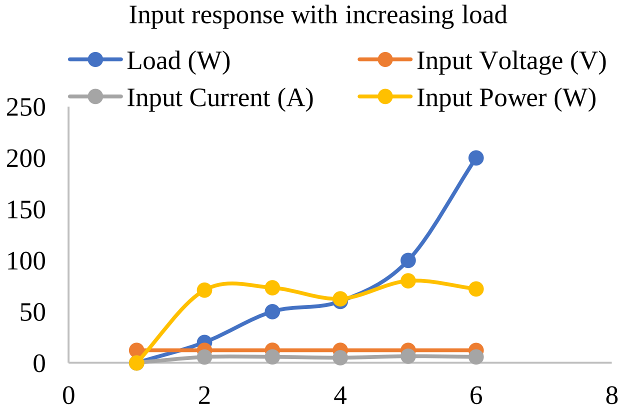


Fig. 5.Input parameter variation with changing load

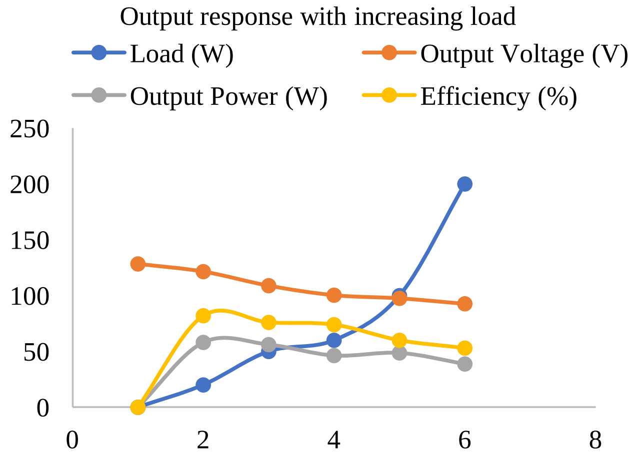


Fig. 6.Output parameter variation with changing load

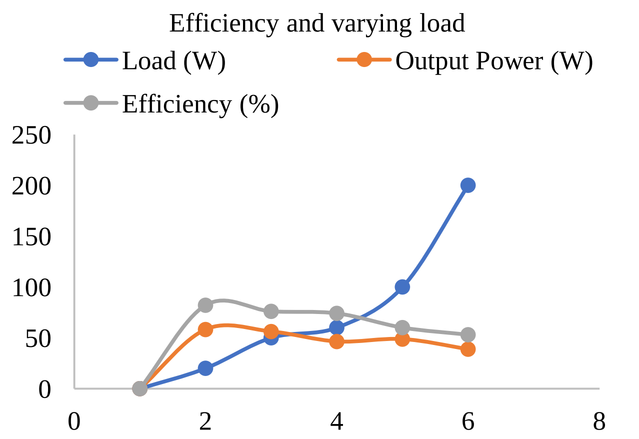


Fig. 7.Generator efficiency and output power

As seen in figure 7, efficiency holds reliability from zero (0) to a hundred (100) percent against a total of six (6) trials (test runs) which shows an upward trend with peak efficiency before slowly dropping with the increase in load.
Figure 5 and 6 also shows the connection between voltage and current at both input and output points. The efficiency of the generator diminishes with increment in the input load of the generating set. In this way, the maximum loading of the machine must be below 200 watts for an increased efficiency running the generating set. This outcome has affirmed that the most elevated proficiency recorded is at 82%, at a load of 20W. Additionally, it was also seen that a decrease in the output of the machine occurs when the input load increases.

IV. CONCLUSION

In the absence of utility power and other renewable sources of electricity, the fuel-less generating unit, which is driven from a battery supply through a DC motor, can be used to supply electric energy on a small scale. While this paper has presented a typical unit with only one battery, increasing the number of battery units in parallel connection, or installing a deep-cycle high-capacity utility battery to be recharged by a suitable charging unit and controller for voltage regulation, will deliver enormous power to the connected load. This certainly would increase the output power delivery and the overall efficiency of the generating set significantly. More so, all the generator parts were sourced locally and readily available for replication. The generator is compact, moveable, and easy to maintain such that any unskilled person could use it. Overall, it is a veritable resource replacement for grid electricity that is unreliable, and for other conventional fossil fuel generator counterparts that are susceptible to noise.
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