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Performance Investigation of a 650W Domestic Portable Electric Power Generator using Ethanol as an alternative Fuel

W. C. Solomon [1], M. U. Bonet [2], S. U. Mohammed [3]

[1, 2, 3] Department of Mechanical Engineering, Nigerian Defence Academy, P. M. B. 2109, Kaduna, Nigeria.

Abstract
This paper investigates the performance output of a 650W gasoline powered portable domestic electric generator (Tiger TG950) through an experimental application of a variety of ethanol-gasoline blends as fuel contrary to the use of the regular gasoline (petrol) as originally designed. It examines the potential use of ethanol as an alternative fuel for operating domestic electric generators for local powering of small households and businesses. The research forms part of an on-going global effort of reducing exhaust gas emissions associated with the use of fossil fuels in Internal Combustion Engines. Electric bulbs with a capacity ranging from 100W to 600W were used to apply a lighting load while physically observing the variation of the voltage and alternating current being generated and the ability of the generator to provide adequate lighting to meet the demand. The performance of the baseline fuel was first assessed before advancing to use the different starting from 10% before up to 100% ethanol. In each case, the investigation was continued by the application of an initial load of 100W and increasing it by the same margin up to 600W. The results demonstrate that locally manufactured ethanol can be a viable alternative to fossil fuels for powering domestic portable electric generators in small households and businesses both in our urban centres and rural areas.

INTRODUCTION
Electricity plays a very vital role in the socio-economic and technological development of any nation and in Nigeria, the demand for electric power is on the rise due its significance to improving the standard of living for the people. It has been established that the Kilo-Watt hour (KWh) consumption of electricity per head of human population is a measure of the people's material well being [1]

Ours is a country with a population of well over 170 million people [2] endowed with several energy resources, especially natural gas with proven reserve estimates of 260 trillion cubic feet as at 2008 [3] which makes her the seventh largest gas endowment in the world and the largest in Africa. Despite her enormous energy resources, the country is still struggling to stabilize its power generation and distribution networks for a reliable electric power supply system. The problem is characterized by frequent blackouts and load shedding. Complimented by the National Integrated Power Projects (NIPPS) and Independent Power Plants (IPP), the grid supply is principally done by the Power Holding Company of Nigeria (PHCN). Quite less than forty percent of the entire population is connected to the grid and are shot of power supply sixty percent of the time [4]. As a consequence, most of the people are forced to augment their electric power demands through the frequent use of a variety of portable power generators.

Notwithstanding their complimentary role, the noise and exhaust gases emitted by this localized form of electric energy supply has been a source of concern due to its contribution to the toxic exhaust pollutant emissions and damage to the environment especially when a battery of them are simultaneously operated within the same vicinity and on every street of every urban centre and rural area of the country. Globally, pollutant emissions from fossil fuel combustion have been identified as the primary cause of environmental degradation and global warming, acid rain, ozone layer depletion and climate change. As a result of this, stringent environmental legislations have been put in place by many nations in order to tackle the menace. In line with global best practices and in accordance with the Kyoto protocol [5] therefore, the government of Nigeria is contributing its quarter by establishing Institutions that are saddled with the responsibility of drawing up policies aimed at reducing the exhaust gas pollutant emissions in the country. One of such policies is the 'Biofuel Policy and incentives' in which a blending of fossil fuel (gasoline or petrol) with up to 10% ethanol to be known as E10 consisting of 10% ethanol and 90% gasoline [4] has been mandated. Commercial use of E5, E10, E25 for conventional engines has been reported in the United States of America, Europe and Brazil [6,7] while the E85 blend has also been in use on flexible fueled engines [8].

Ethanol is a biodegradable and renewable fuel and is the same as the alcohol found in alcoholic beverages and 98% free of such pollutants that are normally found in fossil fuels [9, 10]. Its sources in Nigeria include sugar cane, cassava, sorghum, maize, millet, molasses, Nipa palm, rice, sweet potato, [11, 12]. The use of ethanol fuel in reciprocating engines dates back to the days of Henry Ford's Model T engine which was originally designed to run on ethanol [13, 14]. Earlier records also show the use of ethanol in reciprocating engines between 1824 and 1826 but in 1860, Samuel Morey and Nicholas Otto built engines to run on ethanol [8].

Table 1: Details of the Fuel Blends investigated

Serial Number	Designation of the mixtures	Ratio of Ethanol to Gasoline	
		Ethanol (%)	Gasoline (%)
1	Gasoline	0	100
2	E10	10	90
3	E20	20	80
4	E40	40	60
5	E50	50	50
6	E100	100	0

In an earlier investigation of a 4-stroke spark ignition internal combustion engine powered by ethanol blends but designed to run on 100% gasoline, the results for a 10% ethanol blended fuel showed reduced carbon monoxide emissions without any degradation in thermal efficiency. However, 20% increased the fuel conversion efficiency and brake power as well as a reduction in carbon monoxide emissions [15]. Similarly the influence of isobutanol blend in spark ignition engine performance and pollutant emissions was investigated [16] in which it was observed that blending unleaded gasoline with isobutanol and ethanol led to the increase of brake power, volumetric and thermal efficiencies and fuel consumption with reduced carbon monoxide (CO) and unburned hydrocarbon (UHC) emission concentrations. A comparative performance investigation between hydrous ethanol and Gasoline-ethanol blends was conducted [17] in which higher hydrous ethanol was found to generate higher power at high engine speeds while producing about the same power at low engine speeds. Abundant literature on this subject shows that tremendous progress has been made in reducing the use of unleaded gasoline through the application of ethanol blends.

A further experimental investigation of a gasoline powered Yamaha TG 650 model using an ethanol-gasoline blend of E50 investigated the specific fuel consumption and engine power output at varying loads. Though the result recorded maximum engine power output using 100% petrol as fuel, the overall performance did not show any significant changes when E50 was deployed. Also when the electric load was increased, the specific fuel consumption increased.[17] More recently too, another investigation was carried out to determine the performance characteristics of a similar portable power generating set (FERMA brand - model SPG 650) and very little difference in performance was observed with the use of E10 compared to the use of 100% gasoline. With the E20 blend however, the fuel consumption increased particularly with increased electricity load in a much similar way to the results of earlier investigations [9].

The objective of this paper therefore is to investigate the possibility of using different blends of gasoline-ethanol as an environmentally-friendly alternative to the regular gasoline by assessing the performance of a Tiger TG 950 domestic portable generator through a selective variation of the electric load in each case.

MATERIALS AND METHODS

The different blends of ethanol and gasoline prepared for the purpose of the investigation are outlined as detailed in Table 1. While gasoline is commercially available as Premium Motor Spirit (PMS or simply petrol) at any Fuel filling station, the ethanol (with a concentration of 96%) is locally available in the open market. It started by mixing the two different fuels at a ratio of 10% ethanol to 90% gasoline and later rose to 20% and from where it progressed to 40% and 50% as can be seen in Table 1. The comparison was also conducted with 100% gasoline as well as 100% ethanol, designated as G100 and E100 respectively.

The above blends were then used as the fuel for powering the Tiger TG 950, a very small portable electric power generator that is driven by a single cylinder two stroke spark ignition engine, originally designed to run on unleaded gasoline and to generate an installed output of 650W of electricity for use in small households and businesses as outlined in Table 2.

Table 2: Technical Details of the investigated Portable Generating Set

S/N	Parameter	Specification
1	Engine Model	Tiger TG 950
2	No. of cylinders	1
3	Cooling method	Air-cooled
4	AC Voltage output [V]	220
5	AC Current output [A]	30
6	Rated Power output [W]	650
7	Frequency [Hz]	50
8	Power factor	1

The simple design and portable nature of this generator has made it to be easily affordable among low income earners which has earned it the popular name of "*I pass my neighbour*" among its numerous users. It is locally used for the supply of electricity in small homes and small scale commercial ventures both in urban centres and rural areas during periods of blackout. Its technical details are as outlined in Table 2 as demonstrated in Figure 1. Other materials that form the experimental platform include a burette, a retort stand, a hose and clip, an ammeter, a voltmeter and a stop watch.

Figure 1: Experimental platform of the investigation.

In order to feed the selected quantity of blended fuel for the investigation, the fuel tank of the portable power plant was bypassed through the use of a calibrated burette and was connected directly to the carburetor via a rubber hose. With the engine started and running at full power for the generation of electricity, the lighting power was progressively tested by the installation of the bulbs in steps of 100W up to 600W in order to observe the intensity of illumination for about 5 minutes as illustrated in Figure 2. The voltage and alternating current output were both read off from the voltmeter and the ammeter respectively and their values were recorded against each value of the lighting load at each point of the exercise. The same procedure was repeated for every grade of the fuel blends under investigation as illustrated for G100 to E100 from Figure 3 to Figure 8. While the voltage and the alternating current values were read off directly from the voltmeter and the ammeter respectively, the power generated by the engine could only be obtained through computation by using the power factor contained in Table 2 and the corresponding values of the voltage and alternating current in the basic equation found in literature [18] as follows:

$$\mathbf{P = I \times V \times Cos\ \theta} \qquad (1)$$

where
P = power generated by the generator
I = Alternating current generated
$\mathrm{Cos}\ \theta$ = Power factor (Manufacturer's handook)

With each of the fuel blends made available and with the experimental platform in place, an assessment of the engine performance of this portable power plant was conducted to determine the viability of each fuel blend turn so as to assess their feasibility of serving as an alternative to the regular fossil fuels. The determination and variation of power output, the electric current and voltage generated according to the electric load depended on the number of bulbs connected and tested

Figure 2: A physical observation of power generated by the portable power plant.

For the purpose of ensuring optimum performance results, the generator under investigation was properly serviced before the conduct of the investigation was launched.

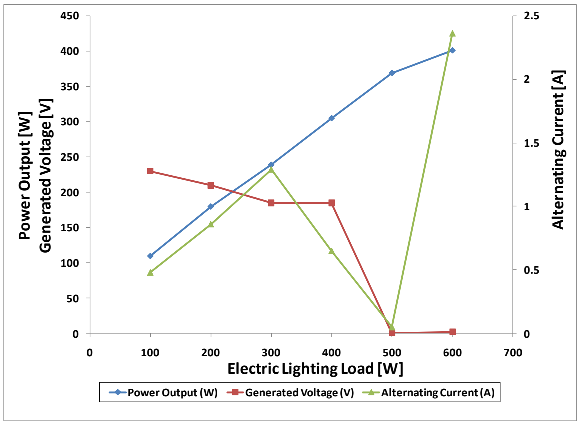

Figure 3: Generator performance results when 100% unblended Gasoline was used

Results and Discussion

In order to articulate a basis for the comparative analysis of all the blends carefully prepared for the investigation, the unblended 100% gasoline (designated as G100) was first used to power the plant and the results are plotted in Figure 3, showing an availability of 110W minimum power generated and a maximum of 401W. A physical observation of this showed how the regular unblended gasoline can brightly light up a small household or business concern as originally designed. The variation of the voltage was seen to steadily drop from about 230V to 185V at a load of 400W but it continued with a sharp decline to as low as 0.65V at a load of 500W and gradually rose again to a value of 2,36V at 600W of loaded power. In the case of the alternating current generated, it alternated between the loaded points of 100W and 600W with a zigzag profile hitting a lowest value of 0.05A at 500W and the highest value of 2.36A at 600W of loaded power. The plotted result for the unblended G100 gasoline was therefore used as the basis for further investigating the other blends of selected fuels.

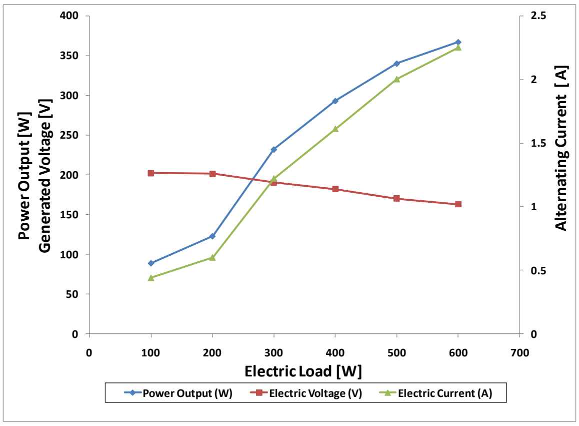

Figure 4: Generator performance results when E10 was used.

In contrast to the result obtained when G100 was used, the curves for the E10 blend (10%) as illustrated in Figure 4, shows that only a power output of 89W can be generated at a load of 100W and about 367W at 600W respectively giving a current of between 0.44A and 2.25A while the voltage output remained fairly steady.

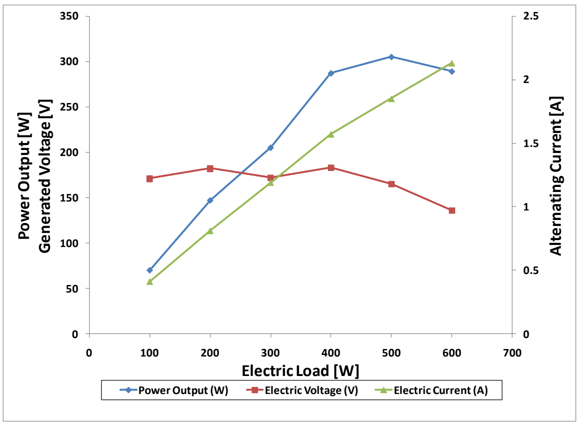

Figure 5: Generator performance results when E20 was used

A further investigation led to the use of the E20 blend (20% ethanol) in which the power output for loading a 100W bulb of electricity dropped to 70W and could only attain a maximum of 305W when the demand became 500W. This figure later declined to a value of 289W when the machine was loaded with a power demand of 600W as contained in **Error! Reference source not found.**. 0.41A and 2.31A of electric current with a fairly steady voltage output observed between the two points under consideration.

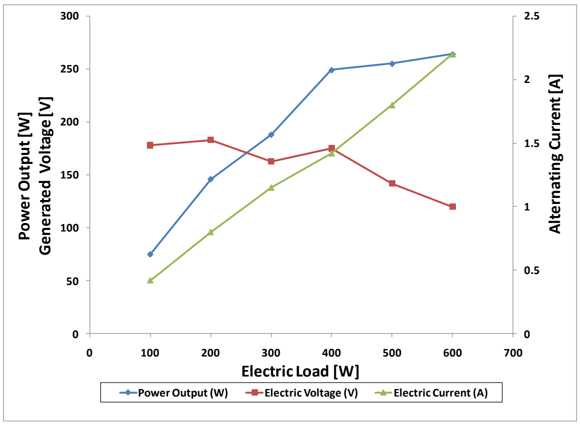

Figure 6: Generator performance results when E40 was used

To further observe the effectiveness of ethanol as a viable alternative fuel, its percentage in gasoline was raised to 40% as plotted and illustrated in Figure 6, revealing a generated power of 75W to light up a bulb of 100W and as high as 264W to light up 600W bulb with the current steadily growing from 0.42A to 2.2A respectively.

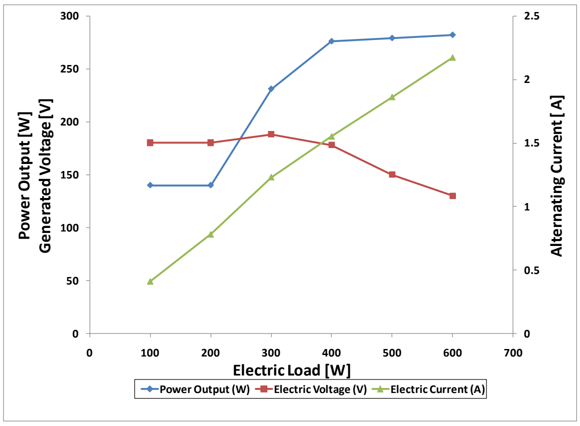

Figure 7: Generator performance results when E50 was used

Since this research is aimed at determining the viability of ethanol as an alternative option for powering small-scale portable electric power generators for homes and businesses, it was necessary to further blend the gasoline at a 50-50 percentage rate with the ethanol as represented by the result illustrated in Figure 7. This particular test revealed an interesting result that showed the generator producing a power of 140W for the 100W bulb of electricity and 282W to power the 600W bulbs. It generated 180V output for a load of 100W and steadily rose and fell to 130V at 600W of lighting power.

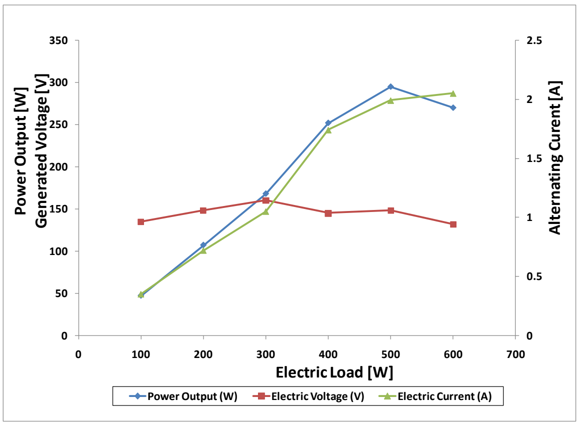

Figure 8: Generator performance results when E100 was used

An ultimate conclusion could not be arrived at without powering the generator with a 100% (E100) pure ethanol as illustrated in Figure 8. In this case, the results revealed that the engine can generate 47W to power a 100W bulb and 270W when 600W of electric load was connected. It was however capable of generating a maximum of 295W at 500W of load for the illumination of a house and whereas the voltage fluctuated satisfactorily between a minimum of 132V and 165V, the alternating current output on the other hand showed a steady ascension from 0.35A to 2.05A within the range of load under consideration. From experience, it is sufficient to conclude that the maximum power output of 270W recorded from the use of this category of blend is capable of sufficiently powering a small household when energy saving bulbs are used in place of the regular ones available in the market.

Table 3: Characteristic Parameters of the Investigated Blends

S/N	% of Blend	Power Generated [W]		Voltage output [V]		Alternating Current output [A]	
		Min	Max	Min	Max	Min	Max
1	0%	110	401	0.65	230	0.05	2.36
2	10%	89	367	163	202	0.44	2.25
3	20%	70	305	136	183	0.41	2.13
4	40%	75	264	120	183	0.42	2.20
5	50%	140	282	130	188	0.41	2.17
6	100%	47	295	132	160	0.35	2.05

The data contained in Table 3 outlines the maximum and minimum performance output values for each of the ethanol blends within the scope of the investigation. It seeks to draw a conclusion on which of the blends may be capable of realizing the most outstanding performance output in terms of the three parameters under consideration. When analyzed together with the curves in Figure 9 and Figure 10, it was deduce that the blend of 50% ethanol (E50) gives the best results when considering the minimum engine power output of 140W but it was only 282W at maximum. This minimum power output generated was computed to be 27% higher than that of the unblended gasoline (G100) while the maximum value turned out to be less by about 42%. even though the performance of G100 showed the voltage dropping to a very low value when loaded with 500W watts of power and above. A further analysis revealed the E40 as the next best ethanol blend after the E50 option.

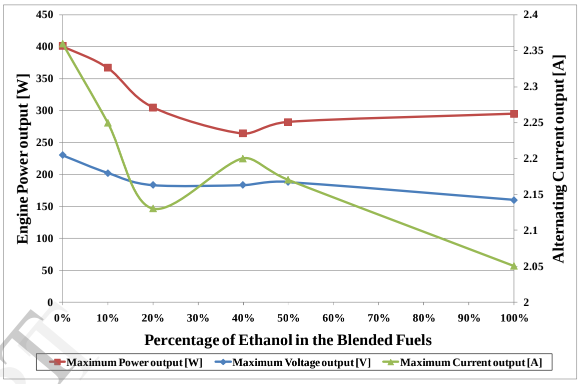

Figure 9: Comparative Maximum Performance curves for the investigated ethanol Blends

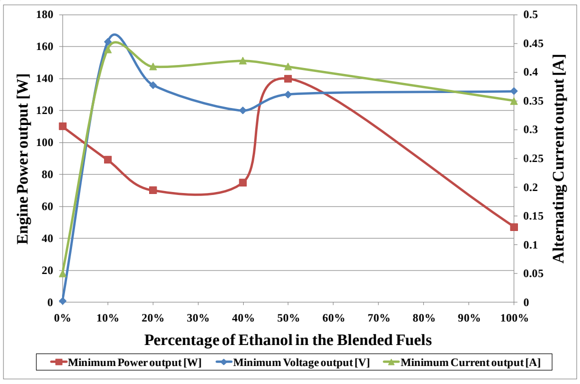

Figure 10: Comparative Minimum Performance curves for the investigated ethanol Blends

Conclusions and Recommendations

Although the potential for the mass production of ethanol that will make it commercially available as an alternative to fossil fuel is yet to be fully realized, this piece of research suggests that its application will significantly reduce the current environmental degradation caused by the emission of noise and harmful exhaust gases owing to the domestic use of portable electric power generators and thanks to the current power generation and distribution deficit in Nigeria. Although the performance of the engine using either of the blends was not generally found to be totally unacceptable especially in the case of

E100, that of the E50 blend appeared to be within a range of closely acceptable limits in comparison with the baseline unblended G100. Next to it may be the E40 whose results may be considered as acceptable thereby affording it a preferred status as well. As a direct consequence of the impact of the higher calorific value of gasoline, the results relating to pure ethanol (E100) recorded the lowest performance output parameters with the exception of the power output which continued to decline between10% and 40% blending but began an upward climb from 50%. Broadly speaking, the results obtained show a pattern of engine performance behavior that is similar to those of earlier research on the same subject leading to a further conclusion that it is possible to use locally produced ethanol as fuel for powering the TG950 portable generator and others in its category especially when energy-saving bulbs are used for lighting the home. It is note-worthy to mention the unsophisticated nature of the experimental platform for which the results obtained cannot be said to be totally devoid of human and material errors for which further work is being recommended.

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