Journal of Advances in Science and Engineering, ISSN: 2636-607X
Volume 2 Number 2 (2019): 37-44

Journal of Advances in Science and Engineering (JASE)

Efficiency Analysis on Small Sized Generators in Nigeria

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Abstract

In this paper, efficiency analysis of small sized generators in Nigeria was considered. Experimental analyses were carried out on two (2) different samples of generators tagged "S" and "T" at different loading conditions (20%, 40%, 60% etc. of ratings) to ascertain the generators' efficiencies as well as the maximum true power that could be drawn out from the generators. The experimental results are compared with the manufacturers ratings specified on the name plate of the generators. The results indicated an average efficiency of 44.9% and 55.7% for "T" and "S" respectively an indication that generator "S" is more efficient that "T". The results also showed that the values of the power factor indicated on the generators are inaccurate as none of the generators could give the maximum power as indicated on their name plates based on the experimental analysis carried out. The generators selected were able to provide adequate power to the selected loads with efficiencies not up to 100% of the expected rated value of the generators. For generator "S" it was observed that the efficiency decreases from the highest rating to the lowest rating. Conclusively, this result suggests that portable generators dealers are taking advantage of the energy crises to importing generators not up to specifications to the Nigerian market at the expense of naïve customers. This paper recommends that proper standards and measures be put in place and enforced by the relevant authority for conformity of standards to all imported generators to save guard and protect the interest of potential customers and Nigerians.

Received 28 November 2019; Revised 29 December 2019; Accepted 30 December 2019; Available online 31 December 2019.

Keywords

Efficiency;

Energy;

Generators;

Nigeria;

Power.

1. Introduction

In Nigeria, generator has provided nearly all the electric power needed both at residential and industrial usage (Airoboman & Tyo, 2018; Airoboman *et al*., 2016). But, a bright future lies ahead. The main idea is to concentrate on how the power supply can be improved since efficiency of private generators and off grid generators have fallen short of the required capacity, which is running into several megawatts. Energy has a major impact on every of our socio-economic life (Okundamiya & Omorogiuwa, 2015). It plays an important role in the economic, social and political development of any nation with Nigeria inclusive. Supply of energy inadequacy impedes socio-economic activities, limits economic growth and adversely affects the quality of life.

Despite Nigeria's reliance on electricity from the national grid for high productivity; Nigeria's electricity market has been dominated on the supply side by the state-owned Power Holding Company of Nigeria (PHCN) formerly called National Electric Power Authority (NEPA) and still has been incapable of providing minimum acceptable

Citation: Airoboman, A. E., Jibrin, M. A. S., Ademola, J. O., Oladokun, J., Ahmed, S., & Edu, M. O. (2019). Efficiency analysis on small sized generators in Nigeria. *Journal of Advances in Science and Engineering, 2*(2): 37-44. DOI: https://doi.org/10.37121/jase.v2i2.66

international standards of electricity service reliability, accessibility and availability for the past 30 years (Oyedepo, 2012). This has made electricity consumers resort to the use of generators for their regular source of power instead of it been used in cases of emergency as obtainable in many countries of the world.

A generator converts mechanical energy into electrical energy. It works on the principle of Faraday's law of electromagnetic induction, which states that "if a conductor is placed in a varying magnetic field, an emf is induced into the conductor which is equals the rate of change of flux linkage". When a relative space or relative variation in time between the conductor and the magnetic field exists between the conductor and magnetic field an emf is induced into the conductor. A generator has two important elements in its working; these are magnetic field and motion of conductor in magnetic field. They basically consist of electric conductor coils, normally copper wire that are tightly wound round onto a metal core and are mounted to turn in the inside of large magnets. The movement of an electric conductor through the magnetic field causes an interface with the electrons in the conductor to induce an electrical current flow inside it (Elprocus, 2019).

Energy efficiency of generator can be referred as an improvement in generator practices as well as products that reduce the energy necessary to provide services. Energy efficiency products essentially, are put in place to help do more work with invariably less energy and less cost. It essentially provides certain services using less energy. It can also be thought of as a supply of resource - often importantly, cost-effective supply option. Added economic value can be obtained by conserving the resource base (particularly combined with pollution avoidance technologies) and mitigating environmental problems (Oyedepo, 2012). Energy efficiency improvements have lots of merits that include the efficient exploitation of natural resources, level of air pollution reduction, and consumers lower spending on energy-related expenditure. Investments in energy efficiency have long-term benefits, which includes reduced energy consumption, local environmental enhancement, and overall economic development (Rosen, 2002; Uyigue, 2007).

In Nigeria, a lot of wastage in energy is being observed because households, private and public offices along with industries utilise more energy than is actually required to fulfil their needs. A typical example is the use outdated and inefficient tools and production processes. Unwholesome practices can also lead to energy wastage. The pervasive and indiscriminate nature of its usage has pose a lot of health challenges in the form of pollution (noise, sooth, smoke, etc.). The cost implication on the consumers is increasingly high due to frequent use. Furthermore, energy efficiency involves conserving a limited resource; improving the technical efficiency of energy generation, conversion, transmission and end-use devices; substituting more expensive fuels with cheaper ones; and reducing or reversing the negative impact of energy production and consumption activities on the environment. Hence, it recommends a feasible means of achieving four goals that should be of high priority in any nation that desires quick and sustainable growth economically and national development. These include economic competitiveness, scarce capital utilisation for development, quality of environment, and energy security (Oyedepo, 2012).

Energy efficiency enhances the competitiveness of the industries in the world markets by reducing production cost. It optimises the use of capital resources by directing lesser amounts of money in conservation investment as compared with capital-intensive energy supply options. It protects the environment in the short run by reducing pollution and in the long run by reducing the scope of global climate change (Okundamiya *et al*., 2014). It strengthens the security of supply through a lesser demand and a lesser dependence on petroleum product imports. Energy conservation is a decentralised issue and is largely dependent on individual, distinct decisions of energy supply, which are highly centralised. The car driver, the housing developer, the house owner, the boiler operator in industry, and every other individual who consumes energy in some form or another are required to participate in energy-saving measures. It calls for a collective endeavour and is dependent upon the actions of people in diverse fields although the people involved may not be sufficiently informed or motivated to conserve energy (Uyigue, 2009).

2. Review of Related Literature

In most countries, energy has been behind the machinery of economic development and this trend has persists for long. Many countries that are today great and economically prosperous have judiciously used energy for its social and overall human development. Unfortunately, two major setbacks have sufficed as a resultant factor of how energy has been sourced, produced and its nature holistically. These setbacks are the overall energy system problem, which has been very inefficient; and the major local and global environmental, social and health problems that has been connected with the energy system generation and usage (Davidson, 2002). This unfolds challenges in the improvement in efficiency of energy conversion, management of sustainable environment and the consumption of energy from the view point of energy efficiency.

Nigeria is blessed with a vast amount of resources of energy. According to the OPEC annual statistical bulletin (2019) accessed from the internet (https://www.opec.org/opec_web/en/about_us/167.htm; accessed on 20th October 2019). Nigeria proven crude oil reserves and natural gas are 36,972 million barrels and 5,675 billion cubic metres, respectively. Despite these huge energy reserves, which should have translated into cheap, affordable and reliably constant power supply many Nigerians now own power generating sets for their electricity; with an annual operating cost of approximately ₦1.56tr ($13.35m) on fuel as quoted in ECN (2005). According to Oniwon (2011), fifteen percent of natural gas produced in Nigeria is being flared while only twelve percent is utilised locally between industrial and power sectors. Nigerian industrialists and other stakeholders have decried bitterly the pathetic situation of the Nigerian power sector. For instance, manufacturers who operate under different trade associations like the Manufacturers Association of Nigeria (MAN) and Nigeria Association of Small Scale Industries (NASSI), once complained that the major problem bedevilling the manufacturing sector is the lack of power, explaining that the volume of daily diesel combustion in Nigeria was currently put at between 12 million and 13 million litres (Adedeji & Badmus, 2012).

Uyigue (2009) carried out energy efficiency survey in Nigeria. The focused was on the management of electricity, involving how efficient other forms of energy have been. The study identified commercially and behaviourally low-cost ways of reducing energy consumption in the residential, public and private sectors in Nigeria. In addition, renewable energy potential in different regions of Nigeria was identified. The proposal was that an energy efficiency policy document applicable in Nigeria should be drafted.

Aderibigbe *et al*. (2017) expressed dissatisfaction with respect to pollutant coming out from generators; hence, the authors proposed retrofitting for a more environmental friendly environment. Amaize *et al.* (2018) focussed on assessment of renewables potential in Nigeria that could be used to address climate change. According to Medlock (2009), the geometric economic growth and major improvements in standards of living in general, over the last few decades are mainly due to the workforce replacement with mechanical power through technological progress. The gap in the socio-economic development obtainable in Africa in order to improve the standards of living, better use of technology through electricity may need to be an important point to note when planning for long term. The demand of energy is very vital in the sense that it affects the economy; consequently the wellbeing of the people (i.e. their income, health, happiness, and also their ability to meet the basic needs of life such as infrastructure, education). Access to electricity in particular is very crucial to human development, since in practice, it is indispensable because of the basic household activities, such as lighting and the running of household appliances, which cannot easily be replaced by other forms of energy (Kayode *et al*., 2015).

3. Method

Generators "S" and "T" brands with specific ratings were used with selected household loads connected to them. These generator brands used comprise seven (7) generators made up of four (4) brands of "S" and three (3) of "T". The specific power ratings of these generators are shown in Table 1. The power factor (PF) of each of the generator selected is unity (1). Each generator was turned on at a time and incrementally loaded in the order of 20% till shut down (full capacity). At each 20% load increase, the generator's efficiency deduced using Equation (1) was recorded. The results were analysed and compared with the corresponding rated values. Figure 1 shows the experimental process while Table 2 shows the different loading scenarios.

$$\text{Generator Efficiency, } \eta = \frac{P_{act}}{P_{rat}} \times 100 \tag{1}$$

Where η is the generator efficiency (%), P_{act} is the actual or tested power output (kW), and P_{rat} is the rated or running power output of the generator (kW).

Table 1. Power Ratings of Selected Generators

Generator Brands	**Power Rating (kW)**			
	Type A	Type B	Type C	Type D
S	6	4	2.5	1
T	2.3	1.2	0.85	-

PF = 1.

Figure 1. Pictorial view of the experimental process

Table 2. Different Loading Scenarios of Selected Generators

Brand	**Type**	**Rated Power** (kW)	**Maximum Power** (kW)	**Load Device (kW)**	
				Type (Rating)	Power
S	A	6	6.5	Pumping machine (0.75) and 3 light bulbs (0.3)	1.05
				Pumping machine (1.5); pressing iron (0.45); & 2 bulbs (0.2)	2.15
				2 air conditioners (1.49); pumping machine (1.5); and deep freezer (0.25)	3.24
				3 air conditioners (2.24); pumping machine (1.5); and 6 bulbs (0.6)	4.36
				Pumping machine (1.5); 2 air conditioners (3.0); 5 bulbs (0.5) & pressing iron (0.45) *	5.45
	B	4	4.5	Pumping machine (0.75)	0.75
				2 air conditioner (1.5)	1.5
				3 air conditioners (2.24)	2.24
				2 air conditioners (1.49) & air conditioner (1.5)	2.99
				Pumping machine (1.5); air conditioner (1.5); & electric boiler (0.75) *	3.75

* Loaded device up to shut down.

 ISSN: 2636-607X

Table 2. Different Loading Scenarios … (Continuation)

Brand	**Type**	**Rated Power** (kW)	**Maximum Power** (kW)	**Load Device (kW)**	
				Type (Rating)	Power
S	C	2.5	2.8	Pressing iron (0.45)	0.45
				Pumping machine (0.75) & 2 bulbs (0.2)	0.95
				Air conditioners (0.745); pressing iron (0.45); & 2 bulbs (0.2)	1.395
				Pumping machine (0.95); air conditioner (0.745); & fridge (0.15)	1.845
				Pumping machine (1.5); electric boiler (0.75); & bulb (0.1); *	2.35
	D	1.0	1.1	Fridge (0.185)	0.185
				2 bulbs (0.2) & fridge (0.17)	0.37
				4 bulbs (0.4) & fridge (0.17)	0.57
				3 bulbs (0.3) & pumping machine (0.45)	0.75
				1 pumping machine (0.75) & 2 bulbs (0.2) *	0.95
T	A	2.3	2.3	3 bulbs (0.3)	0.30
				6 bulbs (0.6)	0.60
				Pressing iron (0.95)	0.95
				Pressing iron (0.95) & fridge (0.25)	1.20
				Pumping machine (1.5) *	1.50
	B	1.2	1.5	Fridge (0.19)	0.19
				4 bulbs (0.4)	0.40
				6 bulbs (0.6)	0.60
				Pumping machine (0.75)	1.20
				Pumping machine (0.75) & 2 bulbs (0.2) *	0.95
	C	0.85	1.0	Fridge (0.15)	0.15
				Bulb (0.1) & freezer (0.19)	0.29
				3 bulbs (0.3) & fridge (0.15)	0.45
				3 bulbs (0.3) & 2 fridges (0.3)	0.60
				Pumping machine (0.75) *	0.75

* Loaded device up to shut down.

4. Results and Discussion

The result of the experimental analysis is depicted in Table 3. As observed the efficiency tends to reduce as the size of the generators increases for the different brands of generator under study. However, none of the generators could account for 100% load efficiency. A comparative analysis of the sampled generators shows that Generator S tend to have a better efficiency than Generator T. Since none of the generators could carry the rated load as indicated on the transformer, one may therefore infer that the values of the power factor inscribed on the name plate of these generators are either fundamentally flawed or as a means to take advantage naive customers.

The average loading and efficiency of the different brands of generators are compared in Figure 2. The average efficiency of Generator S is approximately 56% while that of Generator T is 45%.

Table 3. Analysis of Generators' Load Capacity and Efficiency

Brand	Type	PF	Rated Power (kW)	Rated Power (kVA)	Loading (%)	Load Capacity (kW)	Efficiency (%)
S	A	1.0	6.0	6.0	20	1.05	18.75
					40	2.15	35.83
					60	3.24	54.00
					80	4.36	72.67
					100	5.45	90.83
	B	1.0	4.0	4.0	20	0.75	18.75
					40	1.5	37.50
					60	2.24	56.00
					80	2.99	74.75
					100	3.75	93.75
	C	1.0	2.5	2.5	20	0.45	18.00
					40	0.95	38.00
					60	1.39	56.00
					80	1.85	74.00
					100	2.35	94.00
	D	1.0	1.0	1.0	20	0.185	18.50
					40	0.37	37.00
					60	0.57	57.00
					80	0.75	75.00
					100	0.95	95.00
T	A	1.0	2.3	2.3	20	0.3	13.03
					40	0.6	26.08
					60	0.95	39.13
					80	1.2	52.17
					100	1.5	65.22
	B	1.0	1.2	1.2	20	0.19	15.83
					40	0.4	33.33
					60	0.6	50.00
					80	0.75	62.50
					100	0.95	79.19
	C	1.0	0.85	0.85	20	0.15	15.00
					40	0.29	29.00
					60	0.45	45.00
					80	0.6	60.00
					100	0.75	88.24

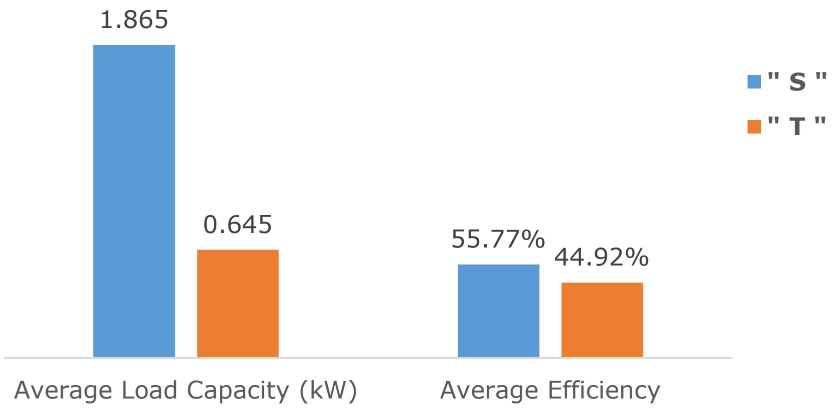

Figure 2. Comparison of Average Energy Efficiency of Generators Brands

5. Conclusion

In this paper, the efficiency analysis of seven portable generators sets of different brands has been analysed. The generators were loaded with basic domestic and household equipment in order to get their respective efficiencies. The objective was to ascertain if the quoted efficiency on the name plates of these generators are accurate. The result showed that the quoted efficiency may be fundamentally flawed; hence, urgent measures need to be taken by the appropriate authority at ensuring that standards are met before generators are allowed into the Nigerian market.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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