Modification of High Noise Electric Power Generator for Low Sound Generation

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ABSTRACT

Aims: The noise emanating from high sound power electric generators has adverse effects on human health. In this view, this paper reports a modification that can be done to reduce this high levels of noise to a permissible noise limit

Place and Duration of Study: This study identified the major source and levels of noise emission from selected electric power generators sampled in Ile-Ife, Osun-State, Nigeria. Also determined the controlling parameters of the identified source and modified the identified parameters for low noise generation.

Methodology: Noise assignment was carried out on Four (4) medium size electric power generating sets using ATP: MODEL MT- 901A sound measuring instrument at distance of about one centimeter. The major sources of noise emission were investigated on the four selected generating sets. The source of noise from these generating sets was further analysed to identify the major controlling parameters of the identified source. Theoretical modification was done based on these identified parameters for low noise generation.

Results: The results of the findings showed that at silencer length of 46.5, 44.0 and 41.2 centimeter, the total sound power levels of the sampled generating sets will be 50, 55 and 60 decibels respectively which is within the permissible noise limits of World Bank.

Keywords: Generators, Noise, Pollution, Mitigation

1. INTRODUCTION

Energy has a major impact on socio-economic development of citizens of a nation. Its inadequate supply limits advancement in all areas thereby causing depreciation in the quality of life among citizens (Juliet, 2014). In Nigeria, it's a phenomenon such that as soon as there is shortage of power supply, a substitute called fuel or diesel generator is being used. In homes, offices, churches, mosques, social gatherings and even market area, it has become a norm for everyone to use electric power generator due to unreliable power supply system from the national grid in the country (Juliet, 2014). These generators emit high levels of noise in addition to noxious gas emission (Parvathi *et al.,* 2003). The noise may be generated by aerodynamic effects or due to force that result from combustion process or may result from mechanical excitation by rotating engine components ((Heywood, 1988). These need to be investigated for effective control.

Noise pollution interferes with the ability to comprehend normal speech and may lead to a number of personal disabilities, handicaps, and behavioral changes. These include problems with concentration, fatigue, uncertainty, lack of self-confidence, irritation, misunderstandings, decreased working capacity, disturbed interpersonal relationships, and stress reactions. Some of these effects may lead to increased accidents, disruption of communication in the classroom, and impaired academic performance (Standsfeld and Haines, 2000; Yusuf *et al.,* 2012).

The effects of noise on the environment have been documented in various studies (Azido and Babatude, 2013). There are several sources of noise pollution which ranges from industrial through non-industrial to mechanical sources. Most of the studies on noise pollution have focused on noise pollution around industrial centres paying more attention to noise from the industrial source (Onawumi *et al.,* 2018). The fact that human residence are usually far from these industrial centres cannot be overemphasized leading to less human concentration around those areas and hence reduced exposure of large people to the effect of noise. The erratic electricity generation and distribution in Nigeria has necessitated the massive use of electricity generators as alternative measure for domestic and commercial activities (Andrew, 2007). Generators are mechanical appliances that generate noise and the harness of them by individual households and commercial centres with large human concentration may lead to great exposure to the effect of noise. Little has been known about the major sources of noise from these generator sets and studies of noise pollution from them are scarce. It is against this backdrop that this study investigated the sources of noise in the generator set and how they can be modified for ecologically friendly noise level.

1.1. Generator Noise Pollution in Nigerian Cities

Generator noise pollution in Nigerian cities has been the subject of investigation and germinal literature for some time now. Ana *et al.* (2014) assessed work environment noise levels and risk locations in two selected commercial areas, the study was at Agbowo and Ajibode areas of Ibadan, Nigeria and found that the noise pollution levels exceeded the limits prescribed by WHO guide line limits (65-70 dBA) and NESREA permissible noise limits (50-60 dBA) . The researchers also reported incidence of hearing loss among residence of the areas, which appeared to be noise-induced. Nkeleme and Udoh (2014) carried out a study of randomly selected generators, find out if any relationship exists between the generator's age and its level of noise pollution. The researchers observed that generators installed in 2004 have lower noise pollution level than those installed one year earlier, and concluded that age was a factor in the noise level produced by the generators. Also, Anomohanran (2013) studied noise pollution levels in Abuja, the capital of Nigeria. For the purpose of the study, the author divided the city into seven zones. The findings showed that five out of the seven zones exceeded the noise pollution limits during the day, while all the seven zones were below the noise threshold at night.

Similarly, an investigation was carried out on the impact of generator noise on the health of the residents of Obantoko in Ogun State, Nigeria. Azido and Babatope (2013) found that residents who were constantly exposed to high noise levels experienced hearing impairment, sleep deprivation, negative social behavior, and cardiovascular problems. Yesufu *el al*. (2013) studied generator users in two commercial communities in Ibadan, Nigeria to understand their knowledge and perception of generator noise and associated health hazards. The researchers found that the users have low knowledge of the dangers of generator noise to their health. The recurring theme throughout the literature reviewed revolves around the high level of noise pollution and knowledge of the harmful effects of generator noise in Nigeria.

1.2. Generator Noise Mitigation

Mitigation is said to be the measures taken to reduce the effects of noise or the noise levels on a receptor. Adverse noise effects generated by a facility can be avoided or reduced at the point of generation thereby diminishing the effects of the noise at the point of reception (Tandon, 1998). The priority of noise monitoring and control is to reduce the noise at the source by engineering means once the main noise source has been verified. Noise reduction in electric motors can be achieved by the use of an absorptive silencer (Sehrndt, 2012) or by redesigning the cooling fan.

Reddy and Prakash (2016) worked on design and fabrication of reactive muffler. The findings aimed at optimizing noise level of engine and reduce back pressure. Based on new muffler design parameters, a model was fabricated and tested. The result showed that a noise level of 16.2 dBA at maximum of 3500 rpm was achieved.

Ibhadode *et al.* (2018) studied Assessment of noise-levels of generator-sets in seven cities of South-Southern Nigeria, this study aims to determine the Sound Pressure Levels (SPLs), Sound Power Levels (LW) as well as Noisiness of sixty different models with various Power-ratings from fourteen generator brands, commonly used in homes/offices in seven cities covering South-Southern Nigeria. The results obtained between January 2013 - December 2015 showed that for nearly all generator brands, models and ratings, the values of SPL were above the Permissible Noise Exposure Limits (PNELs) recommended by WHO, USEPA and EN of 90 dB(A), 75dB(A) and 70dB(A) respectively for 8hour daytime safe human exposure. The study concluded that decibel-ratings of majority of these generator-models are evidently hazardous. Also Nicholas and John (2016) worked on development of a soundproof device for 950 Watt rated portable generators. Performance evaluation of the soundproof device was carried out, and the sound pressure level of the generator was reduced by 7.64, 6.24, 6.82, 8.72 and 8.68 decibels at distances of 0.70, 1.40, 2.10, 2.80 and 3.50 meter from the generator respectively. Also Parvathi and Gopalakrishnan (2003) carried out a study on control of noise from portable power generator. Experimental studies on the assessment and control of indoor and near-field noise levels due to the operation of a portable power generator were undertaken at the Centre for Environmental Studies (CES), Anna University. Noise control was studied employing ant vibration mounts (made up of rubber, coir, polyurethane foam, thermocole, wool–felt and sand bed) and enclosures (made up of cardboard, thermocole and a sandwich of cardboard and thermocole). The results shows that sand beds of 32mm thickness (containing sand particle size 0.5 mm) with an air gap of 5 cm between sandwich enclosure walls, among anti-vibration mounts and enclosures, respectively, were found to be most effective in controlling noise due to the generator operation. The researchers concluded that among the anti-vibration mounts used in the study, the maximum reduction was due to the sand bed of thickness 32 mm (particle size 0.5 mm) which reduced noise by 10 dB(A).

2. MATERIAL AND METHODS

2.1 Study Area

The study was carried out at a commercial electronics store in Iremo, Ile- Ife. Ile-Ife is a major town in Osun State, southwest Nigeria. Its latitudes lies between 7°29'3"N and 7°29'5"N and longitudes 4°33'12" and 4°33'15"E (Figure1). This electronic store is one of the biggest electronics shop in iremo, Ile-Ife. It is a place where different types of electrical appliances such as fan, fridge, freezer, Iron, ceiling fan, Air conditional, generators of different capacities can be purchased. This electrical store was used as the study area due to accessibility of different brands of generators for the research study.

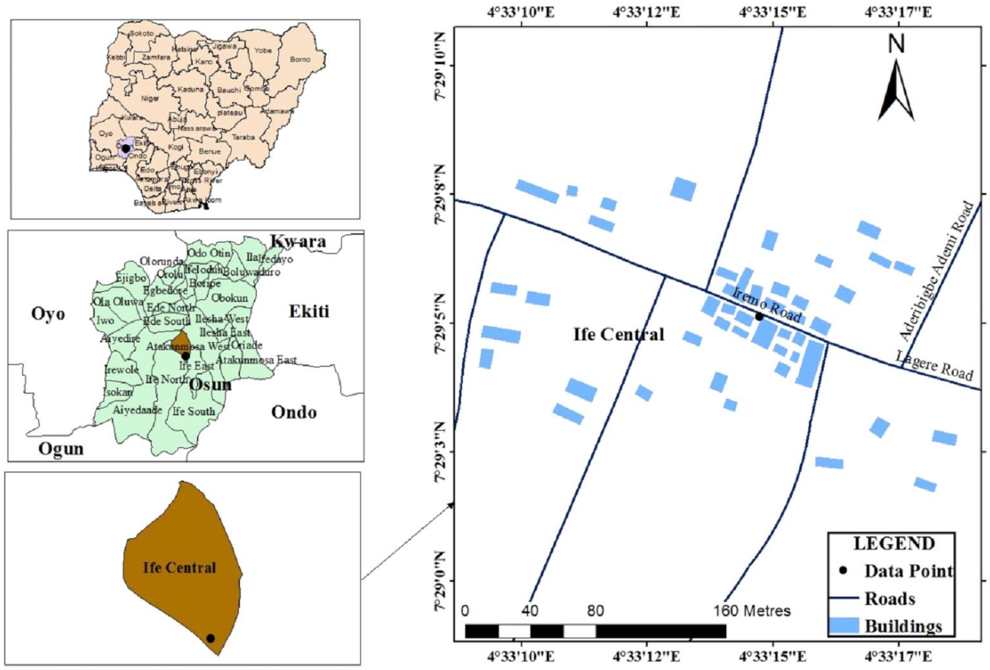

Figure 1: The Study Location

2.2 Experimental procedure

Measurement of these generators noise levels was carried out where there were no other generators running. For each generator, the reading position was first at 1cm distance from the source and later varied at distances of 100, 200, 300, 400 and 500 centimeter respectively. The procedure for the measurement using the sound level meter types, ATP: MODEL MT- 901A was commenced with the installation of the 9 volt battery and the power of the meter switched on. The meter level was put on slow and the A – weighting was selected. The desired level was put to 'low' for level range 30 – 100dB and was put to 'high' for level range 60 – 130dB and the level meter's microphone was pointed at the generator and held steadily and as far away from the body. The 'maximum hold' mode was selected to capture the maximum noise level and this was also recorded. At the time the noise measurements was carried out, the sky was clear, temperature was in the mid 22 ˚C, wind speed was light and variable. The measurement were repeated to confirm that noise level had remained unchanged. Four (4) sampled generating sets was considered for this study. This include; (Elepaq, Lutian, Tiger and Tigmax) within the engine capacity range of (2.5-2.9kV).

2.3 Identification of Major Noise Source and levels of Noise from Sampled Generating Sets

This study employed literature support on the major sources of noise and hence make use of ATP: MODEL MT- 901A noise meter to determine the levels of noise from these electric power generating sets. This is in line with the findings of John and Dewan, 2015; Nicholas and John, 2015; Ekata, 2016; Olamijulo *et al.,* 2016. Noise levels measured in these generating sets was compared with the World Bank, (1998) permissible noise limits standard to determine the levels of noise emission from the understudied generating sets.

2.4 Controlling Parameters Determination

There are several controlling parameters identified in the literature, for instance engine capacity, power rating, maximum speed (RPM), length and the exhaust diameter of silencer exhaust (Shubham *et al.*, 2014; Nasir *et al.*, 2016; Reddy and Prakash, 2016). Due to instrument availability, the exhaust length and the exhaust diameter were measured in this study. Venier scale was used to measure the exhaust length and exhaust diameter of each of the sampled generating sets.

2.5 Procedure for Modification of Identified Parameters

The major parameters considered in this study were the lengths and the exhaust diameter because of the single cylinders possessed by the generators considered, also, their Revolution per Minute (RPM) are also fixed and cannot be modified. These major modifiable parameters were used in computing the silencer volume of each of these generating sets using the formula in equation 2.1.

$V = h$ since the exhaust pipes are cylindrical in nature.

$$V = h \quad (2.1)$$

But in this case, h=L. and:
L= length of the exhaust of silencer in cm
r = radius of the diameter where d= 2r (Taking pi to be 3.142).

Line graphs of noise level against silencer length and also a graph of silencer volume against noise level were plotted for these medium generators using linear regression modelling. Parameters modification was achieved from the two models for low sound generation.

2.6 Statistical Analysis

The field work data collected from the generating set measurement along with the measured lengths and exhaust diameters of these generators were subjected to Inferential and descriptive statistics using Microsoft Excel 2010. Measures of central tendencies, specifically the mean and range (minimum and maximum values) were utilized in summarizing the noise level generated by the sampled generating sets. Furthermore, regression analysis was conducted in modelling the identified controlling noise parameters. Graphs as well as tables were used to present result in a manner that could be easily understood.

3. RESULTS AND DISCUSSION

3.1 Major Noise Source

The major sources of noise emission from the investigated generating sets were identified based on literature support gathered from the study. The electric power generating sets considered in this study were Elepaq, Lutian, Tigmax, and Tiger. These electric generating sets were within the capacity range of (2.5-2.9kV), speed range of (3000- 3,600) RPM, power rating of 5.5- 6.5 hp with single cylinders. Evidence from literature sources revealed that generator noise sources include: Engine, exhaust, cooling fan, alternator, induction and vibration noise source (Aaberg, 2007; Jack *et al.,* 2009; Bloxsom, 2013; Danley, 2015). This study found out that of all these sources, three major sources generates noise mostly and these include, engine, exhaust and mechanical/structural noise source. Krishna and Wegrzyn (1999) and Foster (2012) have also asserted this claim. The exhaust noise of an internal-combustion engine, with a high sound pressure level and low frequency is the main output noise source of generating sets. The treatment for exhaust noise will affect the overall performance of noise control (Nailong *et al.*, 2008). Therefore the exhaust system is seen as the major source of noise and a modification of this part can reduce the total sound power level of the sampled generating sets.

3.1.1 Levels of Noise Emission

Table 1 shows the descriptive summaries of the noise level of the sampled generating sets. The results showed that the mean noise level were between 72.97 for Tigmax and 84.73 for Lutian. These values were found to be above the standard permissible noise limit. Table 2 presents the summary of noise levels measured at various distances from the source of noise (generators). The noise levels from these generating sets varies from distance of 1cm to 500 centimeter respectively. It further shows the effect of distance on noise level from the generating sets. It also shows that the noise level of each of these generators was higher from the source (93.30, 82.40, 93.50, and 88.50 decibels) for (Elepaq, Tigmax, Lutian, and Tiger) generating sets. These noise levels were higher than the noise permissible standard laid down by the World Bank which is 55 dBA and all the National regulatory bodies and hence can be detrimental to human health when continuously exposed to such levels.

Table 1: Descriptive Summaries of the Noise Levels of the Sampled Generator Set

Generator Type/Band	**Minimum Value (decibels)**	**Maximum Value (decibels)**	**Mean Value (decibels)**
Elepaq	79.9	93.3	84.45
Tigmax	67.11	82.4	72.97
Luitan	77.2	93.5	84.73
Tiger	73	88.5	79.30

Source: Author's work (2019)

Table 2: Measured Noise Levels during the Study

S/N	Generator	Noise Level (dBA)						Capacity (k
	Type/Brand	1	100	200	300	400	500	
	(cm)							
1	ELEPAQ	93.30	87.50	83.40	82.10	80.50	79.90	2.5
2	TIGMAX	82.40	76.60	73.50	70.00	68.21	67.11	2.9
3	LUITAN	93.50	89.30	86.40	82.50	79.50	77.20	2.5
4	TIGER	88.50	83.40	80.20	77.50	73.20	73.00	2.5

Source: Author's work (2019)

3.2 Controlling Parameters of the Sampled Generating Sets

Table 3 is the result of the length and diameter of the exhaust silencer measured in the study. A reason for the importance of these sub-parts of the exhaust silencer is due to the fact that the shape of the exhaust is cylindrical in nature and in order to determine the volume of the cylindrical pipe, these two parameters are salient. Both the length of the exhaust and the diameter were used in turn to compute the volume of the exhaust silencer using equation 2.1 (Taking pi to be 3.142). This Table further revealed that there is an inverse relationship between noise level (in decibel) and length, diameter and the newly calculated silencer volume. The result revealed that TIGMAX recorded the highest value of volume and hence the lowest emitted noise level, and Lutian with the least volume recorded, has the highest noise level and a modification of these identified controlling parameters can be modified for effective performance and low sound generation.

Table 3: Controlling Parameters of the Sampled Generating Sets

S/N	**Generator Type/Brand**	**Noise Level (dBA) at 1cm**	**Silencer Length**	**Exhaust diameter cm**	**Volume of Silencer (cm$^{3)}$**
1	LUTIAN	93.50	22.0	18.50	5914.422
2	ELEPAQ	93.30	22.50	20.0	7069.50
3	TIGER	88.50	26.0	20.5	8582.76
4	TIGMAX	82.40	28.0	22.0	10645.10

Source: (Author, 2019)

3.2 Modification of Identified parameters

Figure 2 and 3 presented the various modifications that was proposed. These Figures shows a visual understanding of the relationship between noise and the controlling parameters. These Figures further shows that there is a negative relationship between noise level and length of the exhaust silencer, also same relationship exist between noise level and the silencer volume of these generating sets. From the forgoing, it follows that for efficient noise level reduction, the volume of the exhaust silencer can be modified. To ensure this modification, the length of the exhaust and the diameter was considered. In order to modify these parameters for desirable noise limits, regression model for noise level and silencer length was determined and it showed that for every change in the distance of the silencer, there is a 1.778 decrease in the noise level for each of the generating sets that is been considered (Figure 2). The regression model of the noise level and silencer volume was utilized for various noise levels which were within the standard of World Bank permissible noise limit. To have a generator of maximum noise value of 55 and 60 decibels, the silencer length should be between 44.0 cm and 41.2 cm respectively (Table 4). Also, that of the noise level and volume of silencer showed that at 1 cm^3 increase in the volume of the silencer, the noise decreases by 0.0025 dBA (Figure 3). Furthermore, Table 4 shows the various silencer lengths that are proposed to have a lower desirable noise limit while Table 5 depict the results of all the parameters modified including the newly proposed silencer volume in order to achieve those permissible noise limits. From Table 5, we can see that there is a pronounced changes between the silencer length and silencer volume when compared to that of the controlling parameters (Table 3) but since the two parameters measured initially were the length and exhaust before volume was calculated, This shows that the silencer length played a major role in noise reduction compared with the volume and exhaust diameter.

Figure 2: Noise Level of Sampled Generating Sets against varying Silencer Length

Figure 3: Noise Levels of Sampled Generating Sets against Varying Silencer volume

Table 4: Expected Noise Values with Different Silencer Length

S/N	Expected Noise Value (dBA)	Recommended Length (cm)
1	50	46.5
2	55	44.0
3	60	42.1
4	65	38.4
5	70	35.5
6	75	32.7
7	80	29.9

Source: (Author, 2019)

Table 5: Values for the Modified Parameters at various Noise levels

Noise Level (dBA)	Length	Diameter Cm	Vo1 cm^3
50	46.5	25.50	23792
55	44.0	25.10	21792
60	41.2	24.73	19792
65	38.4	24.30	17792
70	35.5	23.80	15792

Source: (Author, 2019)

4. CONCLUSION

The use of electric power generator is unavoidable as it is the readily available, affordable and alternative energy source for developing economies like Nigeria with insufficient power supply from the national grid. The noise pollution levels from these generators is a major contributor to environmental noise pollution. This results from this findings shows that, the major source of noise from electric power generator is the exhaust system while the major parameters of this part include: exhaust length, exhaust diameter and volume of the silencer. The study therefore concluded that for low sound generation which will help to reduce ambient noise pollution the exhaust component of the electric power generating set should be designed with increased length of the exhaust silencer as it played a major role in noise reduction.

Recommendations

1. Noisy machines should be located away from main areas of activity. That is, Maximizing distance between area of activity and noise source.

2. Silencers with long pipe should be fixed to combustion engines and also ensure they are in good condition and work effectively

3. Electric Power generators should be kept in sound absorbent location to reduce the noise

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