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Noise Level Investigation and Control of Household Electric Power Generator

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Abstract
Electric power generator is an essential household facility particularly in developing countries. It exists in various capacities and makes in shops, offices, workshops and factories. The attendant environmental risks of this source of power supply are major challenges to users both at household and industrial level. Efforts through research and development are still on-going to mitigate the prevailing health hazards. This study investigates noise level of typical portable generator (2 kW/220 V) and the sound absorbance capacity of an acoustic enclosure developed from a multilayer panel made of locally sourced galvanized metal sheet (0.90 mm), Polyurethane acoustic foam (7.50 mm), Particle board (35.0 mm) and plywood (10.0 mm). The noise produced by the generator when on load and no load were considered for cases of it being placed inside and outside the enclosure and compared with acceptable OSHA safe thresholds noise level for the school environment where the study was carried out. The result shows a significant reduction of noise produced indicating a shift from very laud threshold (average of 86.23 dB (A)) for no load and no enclosure to moderately low region (average of 69.34 dB (A)) for the case of no load using enclosure. Likewise considering loaded scenario similar trend was recoded with average acoustic capacity of the enclosure of 23.20 dB (A). The effect of the enclosure is positive and the potential benefits of improved noise absorption panels to enhance better performance of the developed enclosure for office and household generators was established.
Keywords: Electric Generator, Enclosure Panel, Noise control, Load, Household.

1. Introduction

Electric power is a major driver of any nation economy which opens viable and veritable investment opportunities to government, corporate bodies and private individual (Sambo 2009, Onawumi *et al* 2016). A novel product of engineering invention developed to provide continuous electric power is a device known as electric generator. The machine combines the knowledge, skills and training of mechanical, electrical and chemical engineering disciplines to develop a fossil fuel based engine which convert the chemical energy to mechanical energy and then to electrical energy. The bye products of the operation of this devise are emissions in the form of CO gas and noise which create environmental hazards and constitutes challenging global menace such as greenhouse effect and disability in man (Stanley 2010). Efforts are then geared towards minimising the pollutions and other negative contributions of the human invention called electric generator and to make life safer for mankind. This work considers the development of enclosure for common portable generating set used in small scale business and small households also known as "*I pass my neighbour*".

Fossil fuel energy sourced electric generator is a common household and industrial facility found in shops, homes, offices and business centres. It is a major requirement for the establishment of both service and manufacturing enterprise. This technological system comes with benefits and adverse effects on human life with the emission of toxic fumes and noise which constitute pollution to the environment possess health challenges and decreases in worker's efficiency. Noise which happens to be a significant product of most mechanical or mechatronic devices has been define as undesirable or excessive sound (Tandon *et al* 1998). Research efforts are being made to reduce the noise produced by technological activities, equipment, machine and large industrial facilities to the barest threshold level established by existing standard organizations and noise regulatory bodies. In Nigeria, portable power generators are the common and affordable sourced electrical power during power outage and prevents discontinuity of business activities. It is used in many cottage businesses like barbing and air dressing salon, photo studios, business centres, electrical accessory shops and other small scale one-man business outfits. It is also found in homes and hostels being used by individual tenants. The effect of noise from many units of this small sized power generator could annoying, disturbing and counterproductive particularly when they operate near schools, libraries, residential apartment, conference room, class room, examination venue, banks, small and private offices, court room, Radio and TV studio and hospitals,

Power availability has been a major challenge in Nigeria with individuals and organization always in the search for safe, reliable and economic source of energy to power their machines and appliances. The introduction of 1KVA capacity in to the market brought lot of relieves to low income earners in Nigeria as could afford the purchase of the generator and its capacity is sufficient for their essential business or household activities. However, the noise level it generates with age increases with more concern just as it is the case with other electric power generators of higher capacities. The inclusion of enclosure in the design of electric generator is known with heavy duty generator used in many corporate and industrial organizations but no consideration was given to portable generator which are found more popular among low income earners in Nigeria. 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. 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 *et al,* 2012) or by redesigning the cooling fan.

Despite the extensive generation of noise in urban areas of Nigeria, surprisingly little research and documentation exist on the nature and extent of noise generation activities, their accompanying impacts and the implication for urban communities and their residents. In order to achieve sustainable urban development in Nigeria there is need to combat the main sources of noise pollution in Nigerian urban areas both at Local Government level and Federal Government level (Atolagbe and Tanimowo, 2006, and Evelyn and Thomas, 2013). Figure 1 below shows typical noise levels associated with various surroundings and noise sources (Richard, 1991).

Noise from electric power generators can be traced to the two major units of the power systems (Mechanical and Electrical Units) and further investigation reveal specific noise sources as Alternator, mechanical/combustion in the engine, cooling fan, structural/mechanical system, induction, and exhaust (Jack *et al* 2009, Dennis 2016, and Danley 2015).

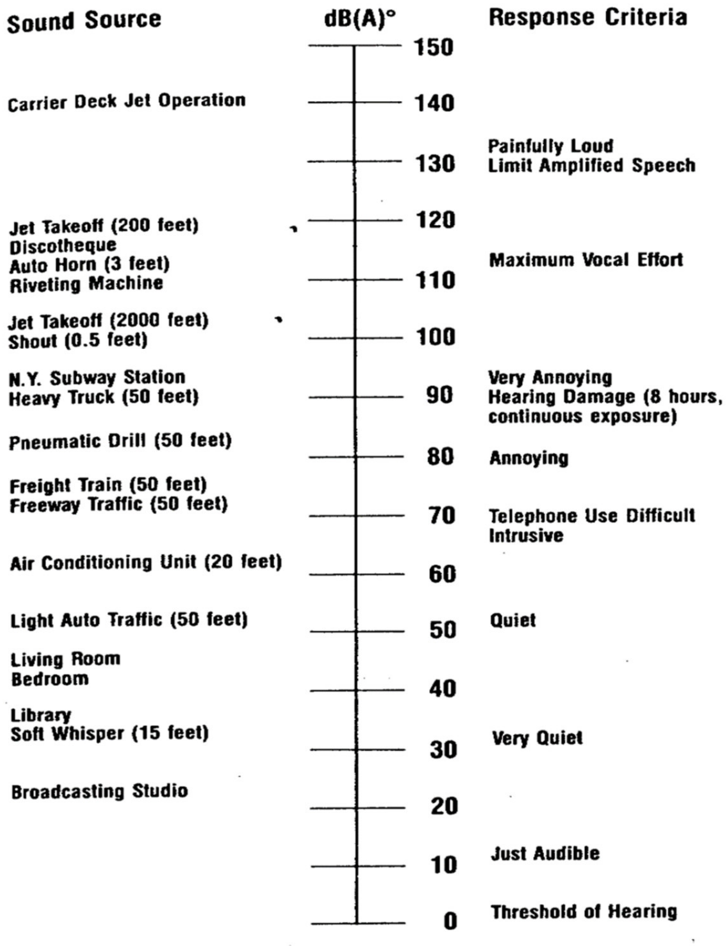

Figure 1: Typical noise level (OSHA, 1980)

Several studies have considered the noise levels of electric generator and its control using enclosures padded with different absorbents (Tandon *et al*, 1998). Sound absorbing capacity of different material suggest the potential application in construction of walls or sound barriers. Reflective and absorbing materials such as fuzzy, porous, soft, and or thick fibre, wood, textile are potential choices for building sound barriers, panels and sound prove walls. The absorbing capacity of the developed panels made of different composites varies and these form the basis for growing research in the field acoustic material development. In this work practical approach was employed with the selection of acoustic materials which were developed into a panel for the walls of the enclosure. Design consideration observed also include the heat capacity and absorption of the material and the critical components of the generating set, weight minimization of enclosure to enhance portability and cost reduction in other to ensure affordability. For the enclosure in this study, locally available acoustic materials was used and tested for performance rating.

2. Materials and Method

The enclosure is made of panels which were designed to insulate the noise from the outside environment at minimum weight and cost. The degree of reduction is enhanced by the use of the panel on all sides of the enclosure. The heat is dissipated through the vents created on the right and left sides of the enclosure. The selected materials for panel with thickness values include galvanized metal sheet (0.90 mm), Polyurethane acoustic foam (7.50 mm), Particle board (35.0 mm) and plywood (10.0 mm) (Figure 2). Materials for the components of the panel were sourced locally with the aim of enhancing availability and improve affordability. Likewise the material used are workable using the available workshop machine tools at LAUTECH. Mechanical Engineering workshop.

A portable 2KVA electric power generator rated 950 W/220 V, 18 kg weight and 370×330×320 mm dimension (L×W×H) was considered. Six walls made of designed acoustic panel were constructed for the enclosure. A slider was introduced at the base to serve as the base to ease the placement of the generator inside the enclosure. Sufficient clearance was provided between the generator and the enclosure for necessary circulation of air. This is assisted by four bores that were created on the slider to accommodate the shoes to fix the generation in a position and minimise movement of resulting from vibration. To avoid the risk of explosion and fire hazard that could result from excessive heat exposure during the operation of the generator the fuel (gasoline) tank was isolated for the generator and mounted on the top of the enclosure. Vents were made on the sides of the enclosure to convey heat away from the enclosure. An extension pipe was designed and made to serve as passage for exhaust gases from the enclosure. The outside dimension of the enclosure is 440×440×440 mm (Figure 3). To enhance heat absorption, the inner galvanised sheet metal was coated with black paint.

The noise level measurement was carried out using calibrated Sound Level Meter HD600 (IEC 61672-1) by Extech Inc. USA. The meter which has dimension of 278×76×60 mm and powered by either 9V battery or AC power adaptor can measure, display and data log sound pressure level (SPL) from 30 -130 dB(A) with 1.4 dB(A) accuracy (Figure 4). The meter was directed towards noise source and located from 1.0 m distance.
For evaluation of the effectiveness of the enclosure sound level were measured and recorded for

1. Ambient condition,
2. Generator noise without enclosure and
3. Noise with generator inside the enclosure.

Three different times of the day (7-9 am, 1–3 pm, 8–10 pm) were considered to monitor the contributions of environmental noise due to other activities taking place around the location of the generator. The effect of loading on the noise level variation were also recorded for on and off loading at all the time frames considered for the experiment.

Figure 3: Enclosure and 2KVA Electric Power Generator

Figure 4: Sound Level Meter HD600 (IEC 61672-1) by Extech Inc. USA.

Thermal conditions of the enclosure through the monitoring of the heat generated in the inside during the operation of the generator were also considered. A resistant thermometer was used to measure heat in the enclosure for the 45minute experiment. The experiment was repeated three times to obtain average values for the temperature.

3. Results and Discursions

The allowable noise is accepted by the National Environmental Standard and Regulation Enforcement Agency NESREA (2009). The minimum noise level was measured to be 34.5 dB(A), at ambient noise condition in the morning as shown in Table1.

Table 1: Ambient Noise Measurements

Time	Minimum dB(A)	Maximum dB(A)	Average dB(A)
7a.m- 9a.m (Morning)	34.5	49.9	42.3
1p.m – 3p.m (Afternoon)	43.9	54.5	47.0
8p.m – 10p.m (Evening)	45.4	50.5	46.6

Figures 5 and 6 showed the significant decrease in the noise level of the generator when placed in the fabricated enclosure at no load and on load conditions respectively. Noise level from the exposed single sourced generator (without load) under study ranges between 81.3 dB and 82.3 dB within a day. When the generator is placed inside enclosure the noise level dropped from the annoying threshold to near quiet range of 64.5 – 68.8 dB (A). When load is place on the exposed generator the noise levels measured ranged between 82.1 and 82.9 dB (A). With the generator properly secured inside the enclosure the noise dropped near quiet range of 66.1 – 66.5 dB (A). The ambient noise range between 42.3 and 47.0 dB (A) with maximum noise level of 47 dB (A) which occurs in the afternoon.

The noise reduction achieved in this project is significant when the absolute values of noise are compared with the acceptable noise level. It depicts that the domestic generator noise level category has been reduced from ‘Very Loud’ to ‘Moderately loud’. The reduction in the category of the noise level makes it gains importance in localities where legal noise limits may not allow operation of domestic generator with ‘Very loud’ categories and only for lower noise category generator. The area where the experiment was carried out was educational environment with ambient noise range of 42.3dB(A) – 47dB (A) which suggest quiet response criteria. The sound proof enclosure designed could efficiently reduce the noise level of the generator by approximately 20.1% which meets the required standard and allowable noise level in most countries. The efficiency of the sound proof enclosure is noticeably high, due to reduction in the noise level by approximately 22 dB (A). Due to the use of enclosure, the sound has decreased significantly, making the sound emitted to be at a comfortable zone and bearable to the people in the environs. The results obtained from the present study show a compliance to reportedly permitted noise level in North America where maximum noise levels range from 45 dB(A) to 72dB(A), depending on the location and zoning.

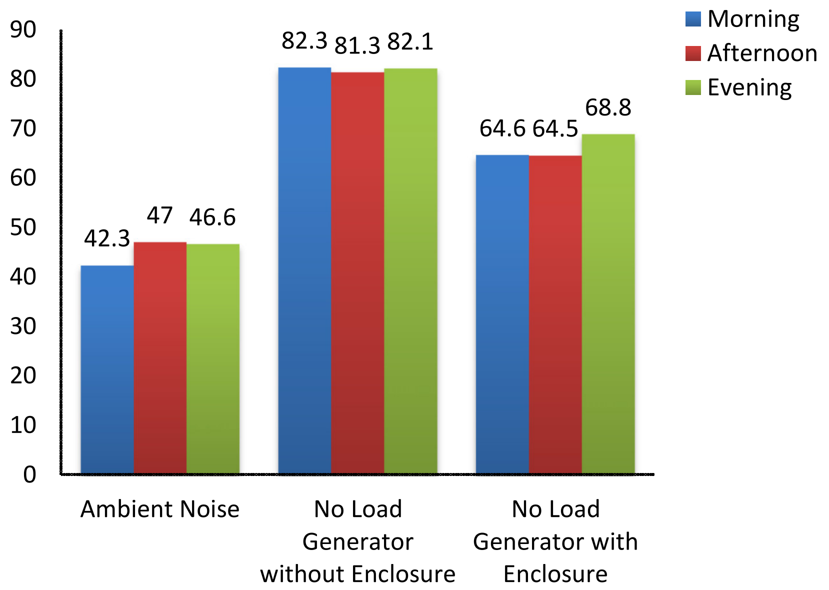

Figure 5: Sound levels distributions at no load conditions with and without enclosure

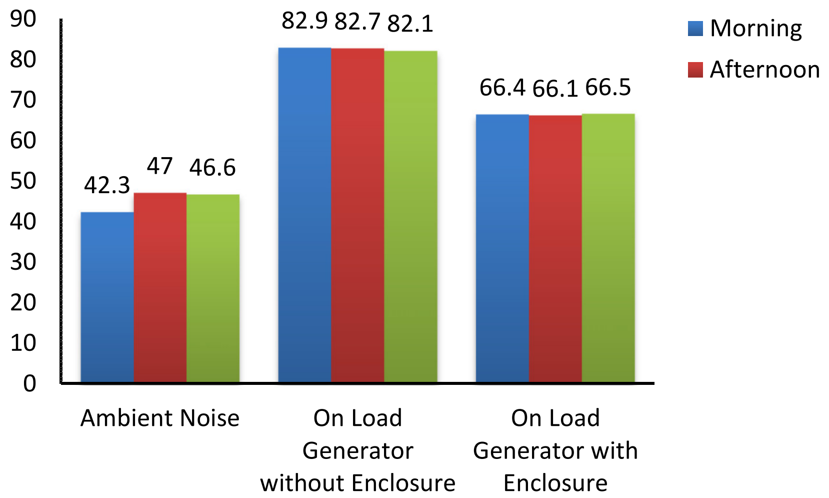

Figure 6: Sound levels distributions when loaded with and without enclosure

In an open-air environment where the environmental noise is minimal, the highest reduction were calculated which is approximately 17.7dB (A) (21.5%) in the morning at no load condition and 16.6dB(A) (20.1%) in the afternoon at on load condition as shown in Tables 2 and 3 respectively. Investigation revealed that a well-designed and relatively airtight enclosure has the capacity of reducing noise by as much as 30 dB to 40 dB which suggests that the study has achieved about 50% of the expected attenuation potential thereby explain the need for further improvement in the design and construction effort

Table 2: Extent of Reduction in noise Levels due to Enclosure at No Load

Time	Measurement Condition		Extent of Reduction In Noise Level	
	No Load			
	Without Enclosure dB(A)	With Enclosure dB(A)	Reduction dB(A)	Percentage (%)
7a.m- 9a.m (Morning)	82.3	64.6	17.7	21.5
1p.m – 3p.m (Afternoon)	81.3	64.5	16.8	20.7
8p.m – 10p.m (Evening)	86.4	68.8	17.6	20.4

Table 3: Extent of Reduction in noise Levels due to Enclosure at On Load

Time	Measurement Condition		Extent of Reduction in Noise Level	
	On Load		On Load	
	Without Enclosure dB(A)	With Enclosure dB(A)	Reduction dB(A)	Percentage (%)
7a.m- 9a.m (Morning)	82.9	66.4	16.5	19.9
1p.m–3p.m (Afternoon)	82.7	66.1	16.6	20.1
8p.m –10p.m (Evening)	82.1	66.5	15.6	19.0

The temperature due to heat generated within the enclosure was observed to increase with time. The temperature-time curve shows that the heat within the enclosure is maximum (31.7^{O}C - 60.5^{O}C) in the afternoon and minimum (29.8^{O}C - 57.4^{O}C) in the evening. This explained the effect of atmospheric heat outside the enclosure on the system (Figure 7).

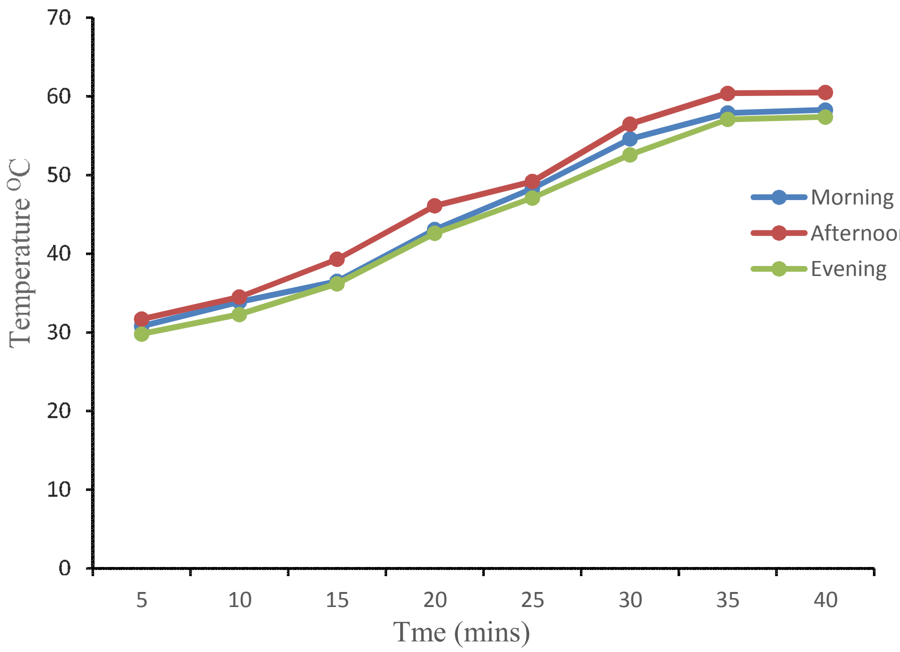

Figure 7: Internal Thermal Condition of the Enclosure

4. Conclusion

Noise from electric generator is considered repulsive and discouraging factor for its choice among other available power sources. Further effort directed towards the design of the sources of noise promised to provide higher efficiency in mitigating noise generated from generator. With continue interest in improving the quality of life by minimizing hazard associated with human inventions at minimal cost, each effort made in respect of improved design/re-design of enclosure is expected to yield encouraging result. Opportunities exist with the use of some sound absorbing wastes/scraps from textiles and other composite material in the development of acoustic panels which could improve the noise absorption propagation/dispersion.

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