DETERMINATION OF ACTUAL DISTANCES FOR INSTALLATION OF A 100 kVA NON-SOUNDPROOF POWER GENERATOR AT RESIDENTIAL AREAS

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ABSTRACT

Power generators should be professionally sited from the residential areas as noise from them demeans the superiority of our living. This work therefore presents determination of actual distances for installation of a 100 kVA non-soundproof power generator at residential areas. Measurements of noise levels with respect to distance, x from the generator were taken and linear regression method was used to analyse the data obtained. Environmental noise models were developed by using the relevant displayed parameters such as the maximum noise level of the generator, the attenuation coefficient and the coefficient of determination. The results obtained from the models developed, L(modelled) were compared with the results obtained from the physical measurements, L(measured) and there was insignificant difference between them. The results reveal that the distances, xc in metres in which its adverse effects covered in the residential areas were $0 \leq x_c \leq 67$, while the distances, xs in metres at which it can be sited from the residential areas were $68 \leq x_s \leq \infty$. With the existence of x, the models developed in this work are recommended to be used as more reliable tools for environmental noise impact assessments.

Keywords: Actual Distances; Determination; Installation: Linear Regression; Power Generator; Residential Areas.

1. INTRODUCTION

Residential noise is described by World Health Organisation (WHO) as community noise or environmental noise or domestic noise [1]. The most important sources of community noise comprise air, rail and road traffic, neighbourhood, municipal work, and the construction plant, among others. Usually, noise from neighbourhood originates from building and installations associated with the food preparation business like cafeterias, restaurant, and discotheques; from recorded or live music; from playgrounds and car parks; from sporting events including motor sports; and from household animals for example barking dogs. The major sources of indoor noises include aeration systems, home appliances; office machines, and neighbours [2].

In the United States of America, the Environmental Protection Agency (EPA) identified noise as a hindrance since in the 1970s [3]. Then, the agency carried out a main study of noise and has continued to bring up to date its results. This means that the study of noise is a continuous phenomenon. As with all pollutants, noise demeans the value of our environment and is known to produce various negative effects both on structures and on humans. Noise has escalated to the point where it is currently the most important peril to the superiority of our existence. This increase in noise can be attributed to the ever-increasing number of people in the globe and the growing levels of economic affluence [4].

In this context, noise is defined as unpleasant sound [5]. However, noise can be described as the unwanted sound in the unwanted location at the unwanted occasion. The degree of "unwantedness" is usually a psychological issue since the effects of noise can range from temperate irritation to everlasting hearing loss and may be rated in a different way by special observers [2]. For this reason, it is often exigent to establish the benefits of dropping a specific noise. Noise does affect the inhabitants, humans, fauna, etc, in the natural environment. Some definite places influence noise contacts; so, it is invasive that it became difficult to run away from it. The public opinion polls almost constantly rank noise in the list of the most bothersome residential irritations. General noise sources are industry, neighborhoods and traffic. The industrial noise is one of the most annoying sources of noise complaints [6]. Elevated noise levels of adequate exposure time can result in short-term or permanent hearing damage. This is generally related to those working in industrial plants or operating machinery but can also take place at discotheques or near to aircraft on the ground if the duration is long enough. However, measurable hearing loss from many industrial sounds involves daily exposure for a number of years. On the other hand, community noise intrusions like traffic noise can obstruct speech communication, interfere with sleep and relaxation and disturb the capacity to perform difficult tasks [7].

In 1993, a study carried out by Cornell University indicated that children exposed to noise during classes experienced problem with various cognitive developmental delays in addition to words discrimination. Specifically, the writing learning mutilation called dysgraphic is usually related to stress on environment during classes [8] and [9]. Noise has been connected to vital cardiovascular health risks. In 1999, the WHO drew a conclusion that the existing evidence shown predicted a weak relationship between hypertension and long-term exposure to noise beyond 67 – 70 dBA [10]. More current studies have recommended that noise levels of 50 dB(A) at night may also increase the risks of myocardial infarction by constantly enhancing production of cortisol [11].

Fairly characteristic road levels of noise are adequate to reduce arterial blood flow and cause elevated blood pressures; in this situation it seems that a specific part of the populace is more vulnerable to vasoconstriction. This may occur because the noise bother leads to high adrenaline intensity to activate vasoconstriction (a reduction of the blood vessels) or separately through reactions from medical stress. Additional impacts of elevated levels of sound are high rate of vertigo fatigue, stomach ulcer and headaches [6]. The British Columbia Work's Compensation Board (WCB) has set 85 dB as its highest tolerant level in the workplace. Above this limit hearing protection should be used. It states that the threshold of pain is attained at 120 dB and it classifies 140 dB as excessive hazard level. WHO safety noise levels are similar while EPA of Nigeria tends to have even a stricter standard of 70 dB as a maximum safe level of noise in workplace. They gave the safe level around home to be 50 – 55 dB [12].

Researches have shown that constant noise above 55 dBA causes serious annoyance and above 50 dBA moderate annoyance at home (WHO, 2007). In a non-workplace and for health and safety purposes, 55 dBA is set as a safety noise level for outside and 45 dBA inside. Hospital and school permissible levels of noise are 35 dBA [1]. In Britain, the current and advanced Ministry of Agriculture regulations established in January 2002 state that propane cannons can be no closer than 150 metres from residential areas, and 100 metres from other kinds of noise makers. These machines generate noise at levels between 115 and 130 dB. At 100 meters the noise generated is above 80 dB, and greater than 75 dB at 150 metres, which is much greater than specified safe levels for around the residence. In fact, beyond 80 dB is near to the level at which ear protection should be used [3]. Noise beyond harmless levels leads to numerous health impacts which include high blood pressure, annoyance, sleep loss, stress, hearing impairment, loss of productivity and the ability to concentrate, among others [2].

Hence, the study of noise is highly imperative so as to create awareness on the impacts of noise on the environment for the betterment of our society. In this research, the determination of actual distances for installation of a 100 kVA non-sound proof power generator at residential areas and the development of models for predicting and controlling environmental noise pollution from this kind of generator shall be carried out.

2. MATERIALS AND METHODS

2.1. Physical Measurements

All the noise measurements were made using the sound level meter (SLM), modelWensnWS1361 with ½ inch electret condenser microphone. This model has both A and C weightings and 0.1dB resolution with fast/slow response. It has a measuring range 30 to 130 dBA or 35 to 130 dBC. Also, it is equipped with a built in calibration check (94.0 dB) and tripod moving. It has an accuracy of ± 1.5 dB. It has AC and DC outputs for frequency analyser level recorder, Fast Fourier Transform (FFT) analyser, graphic recorder and others. It also has electronic circuit and readout display and a weight of 308 g. The microphone senses the small air pressure variations related to sound and converts them into electrical forms. These signals are then passed to the electronic circuitry of the instrument for processing. The readout displays the processed sound levels in dB. The sound level meter picks the sound pressure level at one instance in a certain location. Measurements were taken by adjusting the sound level meter to A-weighting network in all the sampling locations. The sound level meter was calibrated. The manufacturer's manual gave the calibration procedure. During the noise level measurements, the microphone of the sound level meter was positioned at a distance of above 5 m from the generator at a height of 1.2 m above the ground and windshield was always used for accuracy. Slow response was used for comparatively stable noise measurement. For instance, workplace noise level measurements were taken on slow response. Here, the response rate is the time period over which the instrument averages the sound level before displaying it on the readout. Measurement of workplace sound pressure was made in the uninterrupted noise field in the workplace, with the microphone located at the position normally occupied by the ear exposed to the highest value of exposure [14].

2.2. Noise Level with Distance Measurements

In this case, a workshop with a 100 kVA non-soundproof power generator was identified Measurements of noise levels from it as they vary with distance were taken. All noise level measurements were carried out using the sound level meter stated earlier, while distance measurements were made using a measuring tape. Lastly, L_{eqs} for them were evaluated and the results are presented in section 3.

2.3. Calculating the Equivalent Continuous Noise Level (L_{Aeq})

The L_{Aeq} is the steady noise level over a certain period of time that generates very similar quantity of A-weighted energy as the varying level over identical period. It is presented in equations (1-2) and it is measured in dBA.

$$L_{Aeq} = 10\log_{10}[\frac{1}{T}\int_0^T \frac{P(t)^2}{{P_0}^2}dt] \quad 1$$

$$L_{Aeq} = 10\log_{10}(\frac{1}{T}\int_0^T 10^{0.1L_i}\,dt) \quad 2$$

Where,
T = time period over which L_{Aeq} is determined
P(t) = the instantaneous A-weighted sound pressure
P_o = the reference sound pressures (20 μPa)
L_i = noise level in the ith sample

Formula used for calculating the equivalent continuous noise level L_{eq} of a noise source, *N* at a particular distance, x is presented in equation (3) [7].

$$L_{eq} = 10\log_{10}\{\frac{1}{T}\{10^{0.1L_N}\Delta T_N + 10^{0.1L_B}\Delta T_B\}\} \quad 3$$

The noise level of a noise source, L_N is presented in equation (4) [15]; [7] and [16]

$$L_N = 10\log_{10}(10^{0.1L_{TOTAL}} - 10^{0.1L_B}) \quad 4$$

Where,
T =Time period over which L_{eq} is determined
ΔT_N =Time period over which noise level of a noise source is measured
ΔT_B =Time period over which background noise level is measured
L_N =Noise level of a noise source in dBA
L_B =Background noise level in dBA
L_{TOTAL} =Total noise level in dBA.
and,
T = 5 minutes, ΔT_N = 2 minutes, ΔT_B = 3 minutes

2.4. Noise Modelling

The data obtained were analysed and the linear regression method was used. Hence, linear fitting models were developed for it by using the relevant displayed parameters such as the maximum noise level of the generator, the attenuation coefficient and the coefficient of determination. Finally, a general model for evaluating, controlling and predicting environmental noise pollution from a source of this type was developed. The results are presented in sections 3.

3. RESULTS AND DISCUSSIONS

3.1. Analysis of Noise Levels and Distance Measurements from A 100 kVA Non-Soundproof Power Generator

The results of the survey (Table 1 and Fig.1) show that when the 100 kVA non-sound proof power generator is put to use, the total noise level (noise level with generator) at a distance of 65 metres is approximately equal to 55.4 dBA instead of a safety noise level of 55 dBA. This can cause serious annoyance. Moderate annoyance can occur between 70 – 75 metres if the generator is operated at night. Considering the L_{eq} the power generator adversely affects the residents up to distances of 55 metres with the L_{eq} approximate value of 55.34 dBA. Here, moderate annoyance may occur between distances of 60 – 65 metres if the generator is switched on at night. The levels of the background noise (from x = 5 metres to x = 100 metres) show that the area is conducive in the absence of the power generator. At a distance of 65 m from the generator, the noise level of the generator is 55.34 dBA instead of the WHO tolerant level of 55 dBA for residential areas.

Table 1: Noise levels and distance measurements from a 100 kVA non-soundproof power generator

Distance, x (m)	Background noise level (dBA)	Noise level with generator (dBA)	Generator noise level (dBA)	Equivalent continuous noise level (dBA)
5	35.5	85.3	85.29995	81.32062
10	35.0	83.2	83.19993	79.22063
15	35.2	81.9	81.89991	77.92065
20	36.1	78.5	78.49975	74.52072
25	35.8	75.7	75.69956	71.72082
30	38.3	73.6	73.59872	69.62124
35	39.0	70.0	69.99655	66.02232
40	40.2	66.6	66.59004	62.62557
45	39.1	64.8	64.78830	60.82644
50	37.7	61.2	61.18056	57.23029
55	39.4	59.3	59.25533	55.34276
60	37.9	57.1	57.04747	53.14663
65	36.9	55.4	55.33822	51.45116
70	38.0	53.0	52.86045	49.08873
75	37.6	51.7	51.52767	47.80427
80	38.9	49.0	48.55340	45.22778
85	39.0	48.3	47.75720	44.56851
90	38.9	46.6	45.79170	42.97455
95	40.4	44.9	42.99685	41.62986
100	38.5	42.1	39.60882	38.97799

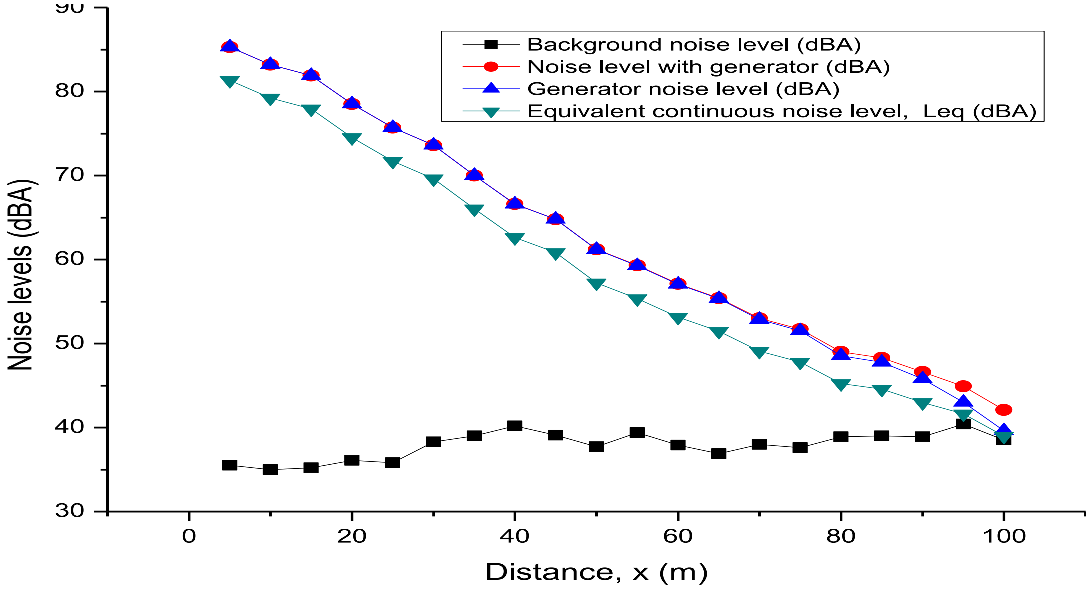

Figure 1: A 100 kVA non-soundproof power generator noise levels against distance

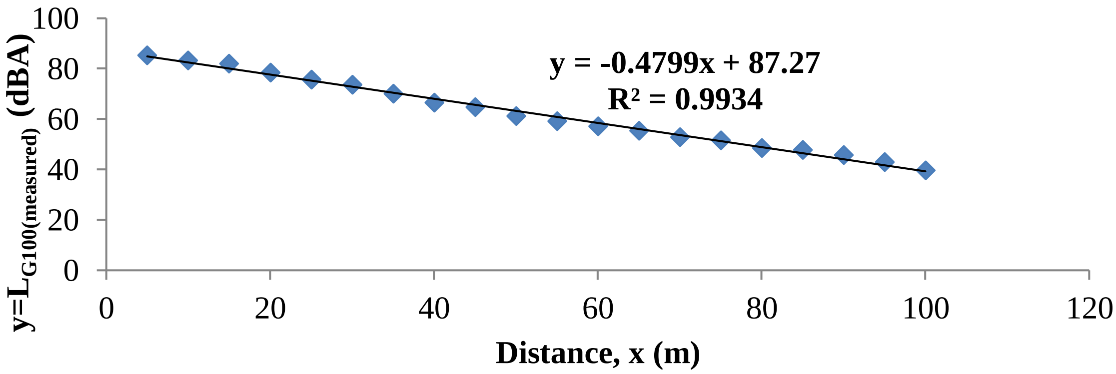

Figure 2: The characteristics of the 100 kVA non-sound proof power generator measured noise level

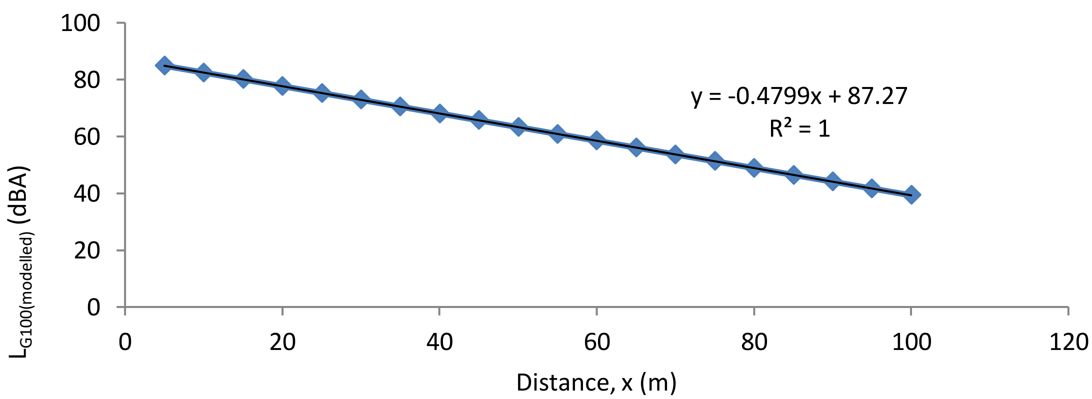

Figure 3: The characteristics of the 100 kVA non-sound proof power generator modelled noise level

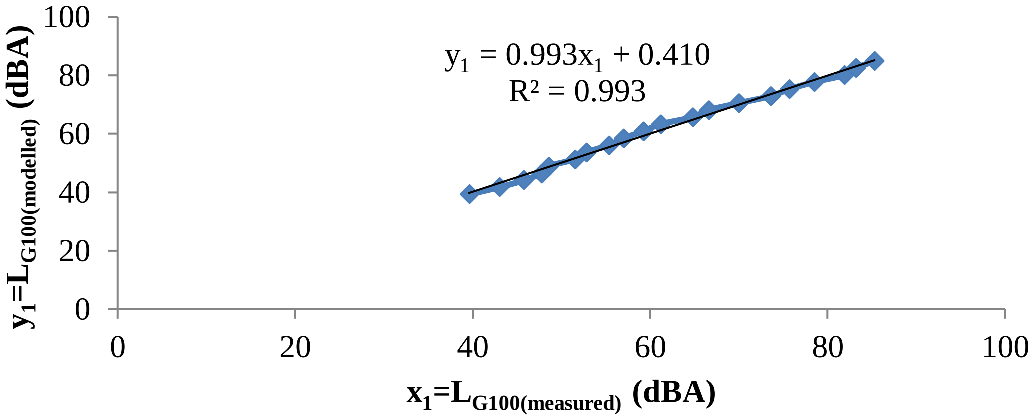

Figure 4: Comparism of modelled noise levels, $L_{G100(modelled)}$ and measured noise levels, $L_{G100(measured)}$ of a 100 kVA non-sound proof power generator

3.2. Model Development for Noise Levels and Distance Measurements of A 100 kVA Non-Sound Proof Power Generator

The results of the analysis of a 100 kVA power generator noise levels, L_{G100} show that the noise levels of the power generator and distance, x are strongly correlated with the coefficient of determination, R^2=0.99301. Hence, a linear fitting model in dBA for the generator noise levels is presented in equation (5).

$$L_{G100} = 87.27031 - 0.47992x \quad (5)$$

Considering the error term, $\in_{G100}$, equation (5) becomes

$$L_{G100} = 87.27031 - 0.47992x + \in_{G100} \quad (6)$$

In equation (5), if $x = 0$, the noise level of the power generator at source is:

$$L_{G100} = 87.27031 \text{ dBA} \quad (7)$$

The intercept or the maximum noise level (87.27031 dBA) has a standard error of 0.55303 dBA. The model has a slope of –0.47992 $dBAm^{-1}$ with a standard error of 0.00923 $dBAm^{-1}$. Comparing the measured noise levels, $L_{G100(measured)}$ with its predicted noise levels of the power generator, $L_{G100(modelled)}$ (Table 2 and Figs. 2-4) show that there is no significant difference between them. This simply shows that they are strongly correlated. Hence, equation (5) or (6) is recommended to be used as a model for evaluating, predicting and controlling environmental noise pollution from a noise source of this kind. The following conditions satisfy the model presented as equation (5):

$0 \leq x_c \leq 67$; at $x_c = 67\ m$, $L_{G100} = 55.11567$ dBA

$68 \leq x_s \leq \infty$; at $x_s = 68\ m$, $L_{G100} = 54.63575$ dBA

Condition (II) implies that the adverse effects of the noise from the 100 kVA non-sound proof power generator cover distances from 0 m (point of its installation) to 67 m. This is because at a distance of 67 m from the power generator, its noise level is 55.11567 dBA instead of the WHO tolerant level of 55 dBA for residential areas. The distance at which the adverse effects covered is denoted by x_c in metres. Condition (II) means that the 100 kVA non-sound proof power generator should be installed or sited from the residential area at a distance of 68 m and above. This is because at the distance of 68 m, the noise level of the power generator is 54.63575 dBA, which is less than the WHO recommended level of 55 dBA. Here, x_s is the distance it can be sited in metres (m).

Table 2: Comparison of modelled noise levels, $L_{G100(modelled)}$ and measured noise levels, $L_{G100(measured)}$ of a 100 kVA non-sound proof power generator

Distance, x (m)	$L_{G100(measured)}$ (dBA)	$L_{G100(modelled)}$ (dBA)	$L_{G100(difference)}$ (dBA)
5	85.3000	84.8707	0.4293
10	83.1999	82.4711	0.7288
15	81.8999	80.0715	1.8284
20	78.4998	77.6719	0.8279
25	75.6996	75.2723	0.4273
30	73.5987	72.8727	0.7260
35	69.9966	70.4731	-0.4765
40	66.5900	68.0735	-1.4835
45	64.7883	65.6739	-0.8856
50	61.1806	63.2743	-2.0937
55	59.2553	60.8747	-1.6194
60	57.0475	58.4751	-1.4276
65	55.3382	56.0755	-0.7373
70	52.8605	53.6759	-0.8154
75	51.5277	51.2763	0.2514
80	48.5534	48.8767	-0.3233
85	47.7572	46.4771	1.2801
90	45.7917	44.0775	1.7142
95	42.9969	41.6779	1.3190
100	39.6088	39.2783	0.3305

3.3. Development of A General Model for Evaluating, Predicting and Controlling Environmental Noise Pollution from A 100 kVA Non-Soundproof Power Generator

Generally, it is observed that all the models developed in this work are of the forms in equation (8) and equation (9).

$$L_N = -\theta x + \alpha \qquad 8$$

$$R^2 = \delta \qquad 9$$

Where,
θ is the slope representing the attenuation coefficient of the noise from the 100 kVA non-sound proof power generator and it is measured in $dBAm^{-1}$. α is the intercept or the maximum noise level signifying the noise level at source (i.e at x = 0) in dBA. x is the distance in metres (m) and δ is the coefficient of determination. Substituting equation (8) into equation (3), gives equation (10).

$$L_{eq} = 10\log_{10}\{\frac{1}{T}\{10^{0.1(\alpha-\theta x)}\Delta T_N + 10^{0.1L_B}\Delta T_B\}\} \qquad 10$$

Equation (10) shows that when θ and α for the 100 kVA non-soundproof power generator are known, L_{eq} of the noise source can be determined at any distance, x with the consideration of the background noise level, L_{B} at that point. Hence, with the introduction of the distance of measurement, x equation (10) can be used as a more scientific and reliable general model for evaluating, predicting and controlling environmental noise pollution from the 100 kVA non-soundproof power generator. Therefore, this model can be applied in environmental noise impact assessment. L_{eq} is the equivalent continuous noise level. It is measured in dBA.

4. CONCLUSIONS AND RECOMMENDATIONS

It is concluded from the findings that the maximum noise level the 100 kVA non-soundproof power generator is (87.27±0.55) dBA. The results indicate that the distances, x_c in metres at which the adverse effects of the generator covered in the residential areas are are $0 \leq x_c \leq 67$, while the corresponding distances, x_s in metres in which it can be installed from the residential areas are $68 \leq x_s \leq \infty$. The results of the findings show that the models developed in this work can be used in evaluating and predicting the exact distance at which adverse effects of noise from this generator can cover and in controlling environmental noise pollution from a generator of this kind. The models require less cost, less manpower and less time than physical measurements. They can be used by the manufacturer of the generator to reduce its maximum noise level. Hence, the models are recommended to be used as reliable tools for environmental noise impact assessment as the results show insignificant difference between the measured noise levels, $L_{(measured)}$ and the modeled noise levels, $L_{(modelled)}$.

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