
ANALYSIS OF 2.8 kVA GENERATOR NOISE LEVEL USING MATLAB/SIMULINK

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ABSTRACT

Noise is all around us in all sorts of forms. In the common use of the word, noise refers to sound. However, noise can more accurately be thought of as random variations that are always present in one or more parts of any entity such as voltage, current, or even data. Growth of standby generators and power installations resulting from epileptic power supply, design engineers have focused their attention in understanding how generator set noise is propagated and controlled. The high cost of retrofitting a site for noise reduction makes it imperative to assess noise performance requirements early in the on-site power system design stage. By applying the principles, power system designers and end users alike will be able to more easily control unwanted noise from their on-site power system.

Key words: Power quality, Noise, noise-peak-ratio, Noise Emission Criteria, r.m.s-noise-to-peak-signal-ratio, clipping noise

INTRODUCTION

Power quality (PQ) problems of energy distribution is not new until recently, the impact of these problems have create public awareness. Advance in technology of semiconductor devices has led to a revolution in electronic technology over the past decade and have more tendency in future. However rise in the PQ problem is due to power equipment which include adjustable-speed motor drives (ASDs), electronic power supplies, direct current (DC) motor drives, battery chargers, electronic ballasts. The distortion in the current is due to nonlinearity of the resistor. These nonlinear loads are constructed by nonlinear devices, in which the current is not proportional to the applied voltage [1].

Many industrial facilities place poor power quality at the top of the list of inefficiency factors responsible for losses due to reduced productivity and lower power quality. Optimal electrical power utilization

becomes a challenge, as well as a necessity to keep up with ever increasing energy demand without drastic increases in energy costs.

Rather than thinking of noise only as an acoustic term, it should be thought of more as a random signal. Noise can be the inherent fluctuations in some part in a system (i.e. temperature at a given point) or it can be the unavoidable interference on a measurement from outside sources (i.e. vibrations from a nearby generator blur measurements from a pressure transducer). The static interference on radio, the 'snow' on television, and the unresolved peaks on an infrared spectroscopy report are all examples of noise [2].

Defining noise

Sound is what the human ear hears; noise is simply unwanted sound. Sound is produced by vibrating objects and reaches the listener's ear as pressure waves in the air or other media. Sound is technically a

variation in pressure in the region adjacent to the ear. When the amount of sound becomes uncomfortable or annoying, it means that the variations in air pressure near the ear have reached high amplitude [3].

Noise Emission Criteria

The World Health Organization recognizes that adverse health affect due to community noise levels occur above 45dB. In otherwise, quiet environment however, noise level below this threshold can be intrusive and are often the cause of complaints. This is particularly evident when noise sources are not 'anonymous' or transient, like traffic, but are identifiable as the result of a neighboring activity [4].

At very low noise level, however, even in comparison with lower background conditions, the lower extent of the human dynamic range is approached and the benefit of further reductions becomes increasingly marginal.

This is recognized in the (British Standard BS4142) which states in its scope that '*background levels below about 30dB and rating levels below about 35dB are considered to be very low*' [5].

Sources of generator set noise [6, 7]

- i. Engine noise – This is mainly caused by mechanical and combustion forces and

typically ranges from 100 dB to 121 dB, measured at one meter, depending on the size of the engine.

- ii. Cooling fan noise – This results from the sound of air being moved at high speed across the engine and through the radiator. Its level ranges from 100dB to 105 dB at one meter.
- iii. Alternator noise – This is caused by cooling air and brush friction and ranges from approximately 80dB to 90dB at one meter.
- iv. Induction noise – This is caused by fluctuations in current in the alternator windings that give rise to mechanical noise that ranges from 80dB to 90dB at one meter.
- v. Engine exhaust – Without an exhaust silencer, this range from 120dB to 130dB or more and is usually reduced by a minimum of 15dB with a standard silencer.
- vi. Structural/mechanical noise – This is caused by mechanical vibration of various structural parts and components that is radiated as sound.
- vii. An expression is in the context of very high noise level emissions, wherein comparisons with background conditions are less important than absolute levels, and in extreme cases the potential for noise induced hearing loss.

The reciprocal of k is the rms-noise-to-peak-signal-ratio, and the rms noise loading level is defined as $1/k$ expressed in dB.

$$\text{RMS Noise Loading Level} = 20\log_{10}(1/k) = -20\log(k) \quad (1)$$

The derivation for theoretical noise-peak-ratio (NPR) can be broken into two parts; the first part derives the theoretical quantization noise power of an ideal n-bit ADC, while the second part derives the "clipping noise" power due to the limiting ADC [8, 9, 10].

The quantization noise component (expressed as the square of the actual quantization noise voltage to yield noise power) can be shown as

$$N_Q = q^2 / 12 \tag{2}$$

where,

q is the weight of the least significant bit (LSB).

Recall, $q = 2V_0 / 2^n$ therefore from (2)

$$N_Q = q^2 / 12 = \left[\left(\frac{2V_0}{2^n} \right) / 12 \right]^2 = V_0^2 / 3 * 2^{2n} \tag{3}$$

However, $k = V_0 / \sigma$; therefore $V_0 = k\sigma$ and substituting for V_0 in (3) yields

$$N_Q = \left[\left(k^2 \sigma^2 \right) / 3 * 2^{2n} \right] \tag{4}$$

Now the clipping noise power is given by the following general expression:

$$N_C = \int_{-\infty}^{+\infty} e^2 * (x) P(x) dx \tag{5}$$

$$e(x) = x - V_0 \quad \text{for} \quad x \geq V_0 \tag{6}$$

Therefore

$$N_C = 2 \int_{-\infty}^{+\infty} (x - V_0)^2 P(x) dx \tag{7}$$

Where $P(x)$ is the Gaussian probability density function and is given by

$$P(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-x^2 / 2\sigma^2} \tag{8}$$

Substituting $V_0 = k\sigma$ and combining (8) with (7), yields

$$N_C = 2 \int_{k\sigma}^{\infty} (x - k\sigma)^2 * \frac{1}{\sigma \sqrt{2\pi}} e^{-x^2 / 2\sigma^2} dx \tag{9}$$

The final results of the integration yields

$$N_C = 2\sigma^2 (k^2 + 1) [1 - N(k)] - k\sigma^2 \sqrt{\frac{2}{\pi}} e^{-k^2 / 2} \tag{10}$$

Where $N(k)$ is the Normal Distribution function the function $[1 - N(k)]$ can be represented by the following expressions:

$$N(k) = \int_{-\infty}^k \frac{1}{\sigma \sqrt{2\pi}} e^{-t^2 / 2} dt \tag{11}$$

For calculation purposes,

$$1 - N(k) \approx \frac{1}{k\sqrt{2f}} e^{-k^2/2} \left[\begin{aligned} &1 - \frac{1}{(k^2 + 2)} + \frac{1}{(k^2 + 2)(k^2 + 4)} - \frac{5}{(k^2 + 2)(k^2 + 4)(k^2 + 6)} \\ &+ \frac{9}{(k^2 + 2)(k^2 + 4)(k^2 + 6)(k^2 + 8)} \\ &- \frac{129}{(k^2 + 2)(k^2 + 4)(k^2 + 6)(k^2 + 8)(k^2 + 10)} \end{aligned} \right] \quad (12)$$

The total noise N_T can now be calculated by adding (4) and (10)

$$N_T = N_Q + N_C = \frac{k^2 \dagger^2}{3 * 2^{2n}} + 2 \dagger^2 (k + 1) [1 - N(k)] - k \dagger^2 \sqrt{\frac{2}{f}} e^{-k^2/2} \quad (13)$$

$$\frac{N_T}{\dagger^2} = \frac{k^2}{3 * 2^{2n}} + 2(k + 1) [1 - N(k)] - k \sqrt{\frac{2}{f}} e^{-k^2/2} \quad (14)$$

$$NPR = 10 * \log \frac{\dagger^2}{N_T} = -10 * \log \frac{N_T}{\dagger^2} \quad (15)$$

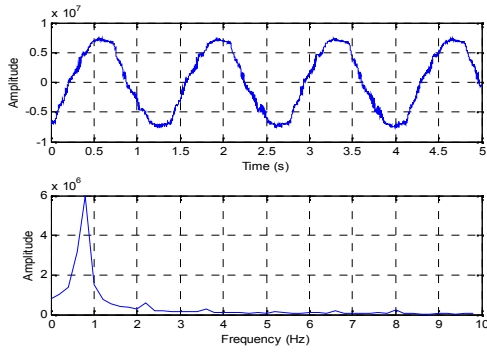
It is important to remember that the NPR obtained when the input signal noise occupies the full Nyquist bandwidth, dc to $f_s/2$. For the case of oversampling, where the signal bandwidth, BW is less than $f_s/2$, the correction factor of $10 * \log * [(f_s/2 * BW)]$ often referred to as process gain, must be added to the NPR given in (15).

$$NPR = 10 \log \frac{\dagger^2}{N_T} + 10 * \log \frac{f_s}{2 * BW} \quad (16)$$

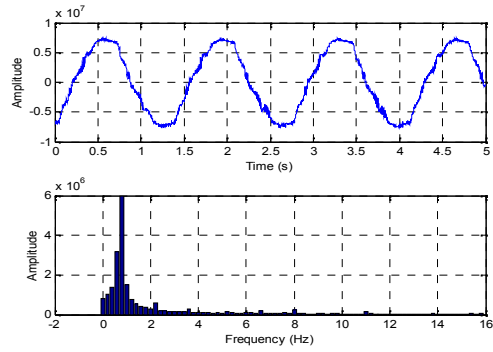
In multi-channel high frequency systems, there is little or no phase correlation between channels, NPR can be used to measure the distortion and noise caused by a large number of individual channels. An ideal ADC will only generate the theoretical value of quantization noise; however, a practical one has additional noise components due to additional noise and distortion caused by ADC imperfections. Notice that the NPR is about 60.8dB compared to 62.7dB theoretical [11, 12].

RESULTS

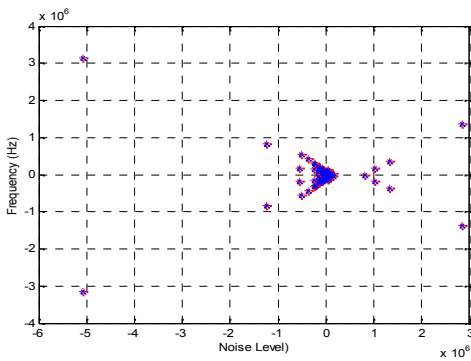
From Figure 1: (a) shows a power waveform that is sinusoidal clean-looking, unaltered waveform and the FFT that power generators produced, (b) shows the spectrum of harmonic contents in the generator, (c) shows the noise level display from the generator reduced to zero level, while (d) shows a rectified sinewave.



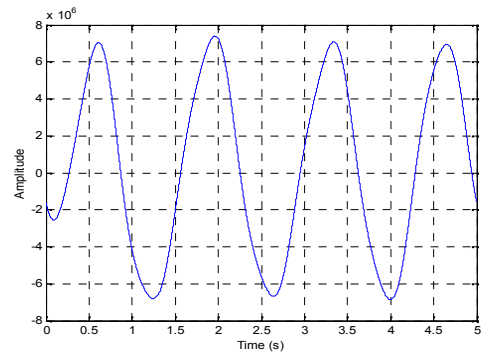
a



b



c



d

Table 1: Noise levels from a 2.8 kVA Single – Phase Generator, the signal and time

Noise levels from waveform produced from generator				
N	n_i	noise	signal	time
1	-0.022	0.188	0	0
2	0.6183	-0.4533	0.3387	0.01
3	1.8659	-0.6201	0.6374	0.02
4	0.0819	-1.9254	0.8607	0.03
5	1.608	-1.4255	0.9823	0.04
6	-0.3807	0.268	0.9877	0.05
7	-1.2996	-0.3626	0.8763	0.06
8	-0.724	-0.9841	0.6613	0.07
9	-0.565	1.365	0.3681	0.08
10	0.6217	0.867	0.0314	0.09

Strategies for reducing noise in generators are as follows: [13, 14]

1. **Acoustic barriers** – Rigid materials with significant mass and stiffness reduce the transmission of sound. Examples include sheet steel typical of enclosures and concrete- or sand-filled block walls or solid concrete walls typical of indoor generator room installations. It is also important to eliminate sound paths through cracks in doors or walls, or through access points for exhaust, fuel or electrical wiring.
2. **Acoustic insulation** – Sound-absorbing materials are available for lining air ducts and covering walls and ceilings. Directing noise at a wall covered in sound absorbing material can be very effective. Select materials that are resistant to oil and other engine contaminants. Fiberglass or foam may be suitable, based on factors such as cost, availability, and density, and flame retardance, resistance to abrasion, aesthetics and cleanability.
3. **Isolation mounts** – Vibrating equipment creates sound pressure waves (noise) in the surrounding air. Anything that is physically connected to a generator set can cause vibrations to be transmitted to the building structure. These connection points include skid anchors, radiator discharge air ducts, exhaust piping, coolant piping, fuel lines and wiring conduit. Fitting these connections with flexible joints effectively reduces noise transmission. Mounting a generator set on spring type vibration isolators effectively reduces the vibration and noise that are transmitted through the floor.
4. **Cooling air attenuation** – Inlet and outlet air attenuation baffles can help reduce the noise

produced by the cooling air as it moves across the engine and through the radiator. Noise from the movement of cooling air is significant because of the volume required – about 20 cubic meters per second for a generator set with a 50-liter diesel engine. Alternatively, the radiator can be remotely located to a roof, for example, to eliminate this noise source or direct it up and away from people or the property line. Also, making air travel through a 90-degree bend in a duct reduces high-frequency noise.

5. **Maximizing distance** – When there are no reflecting walls to magnify the noise produced by the generator set, the noise level will decrease by approximately 6dB every time the distance is doubled. If the property line is within the near field of a generator set, however, the noise level may not be predictable. A near-field environment is any location within twice the largest dimension of the noise source (generator set).
6. **Exhaust silencers** – Generator sets are almost always equipped with an exhaust silencer (muffler) to limit exhaust noise from the machine. Exhaust silencers come in a wide variety of types, physical arrangements and materials. Silencers are generally grouped into either chamber-type silencers or spiral type devices. The chamber-type devices tend to be more effective, but the spiral-type devices are more compact and may provide sufficient attenuation for many applications. Silencers can be made of cold rolled steel or stainless steel. Stainless steel is the preferred material for use outdoors when corrosion is a concern. Silencers are available in several different noise-attenuation “grades,” commonly referred to as “industrial,” “residential” and

"critical." Industrial silencers reduce noise from 12 to 18dB; residential silencers reduce noise from 18 to 25dB; critical silencers reduce noise from 25 to 35dB. In general, the more effective a silencer is at reducing exhaust noise, the greater the level of restriction on the engine exhaust. For long exhaust systems, the piping itself will provide some level of attenuation.

CONCLUSION

Most generators are labelled with a decibel rating. For every increase of 10dB, the sound level is 10 times more powerful, but will only sound twice as loud to the ear. A generator that runs at 100 dB is twice as loud as a generator that runs at 90 dB. However, generators are renowned for their quiet operation. In conclusion, with maximum noise levels permitted at a property line that range from 52 dB(A) to 72 dB(A), depending on location and zoning, and untreated generator set noise levels that approach 100 dB(A) or more, it is clear that generator set noise mitigation is a subject of great importance. Furthermore, the high cost of retrofitting a site for noise reduction makes it imperative to assess noise performance requirements early in the on-site power system design stage. Working closely with local regulators, the generator set manufacturer, consulting engineer or acoustic specialist will allow you to achieve your project's sound-attenuation goals.

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