Energy Harvesting System Design for Converting Noise into Electrical Energy

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Energy Harvesting System Design for Converting Noise into Electrical Energy

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Abstract

This research aims to convert noise becomes electrical energy using an energy harvesting system. The noise around us is a form of wasted energy. The sound (acoustic) energy can be utilized to produce electrical energy. In this study conducted a test using generator function with a variation of frequency and result obtained in simulation and then compared to result. The research used loudspeaker conversion used manifold buzzer piezoelectric ceramic treble rectangle audio speakers with a size of 8.6 cm x 8.6 cm x 7.2 cm as a conversion to the energy harvester system. Test results using the sound source of the function generator at a frequency of 60 – 80 Hz. The highest response occurred at a frequency of 69 Hz with a voltage value of 3.2 Volt, current 3.2 mA and power 10.24 milliwatt in and testing with a variation in frequency 60 – 500 Hz response highest occurred at a frequency of 70 Hz with a voltage value of 1.68 Volt, current 1.68 mA and power 2.8224 milliwatt. The maximum sound pressure level in this study was 90 dB. The output voltage of the converting loudspeaker is measured at 1 kΩ resistor. Research the two sound sources using subwoofer speakers. The maximum sound pressure level in this study was 103 dB. The output voltage of the converting loudspeaker is measured at 100 Ω resistor. Results of experiments on the converting loudspeaker result in an electrical voltage of 5.56 volt for 10 hours.

Keywords: *energy harvesting, system design, noise, electrical energy, sound*

1. Introduction

The increase in population, economic growth and increasing technological developments each year resulted in an increasing need for electricity benchmark. The fulfilment of electrical energy today is still based on coal usage. The energy crisis has become a world problem. Energy is something that is inseparable from life and is eternal. The increasing number of people, the higher the amount of energy needed. While sources of fossil energy such as petroleum, natural gas, and coal, are a non-renewable source of energy. As an alternative to the limitation of fossil energy, humans try to utilize renewable energy by creating some energy harvesting. In recent years, researchers interested in conducting research and development of energy harvesting from the environment is increasing [1]. A form of energy that can be harvested from the environment is the acoustic energy (sound) which is usually noise. The acoustic energy harvesting can be described as the process of converting waves, a strong sound wave and the interface of the environment into electrical energy by using an acoustic transducer [2].

The energy obtained is subsequently stored in the form of a battery or capacitor for later use when needed. Big cities usually have a wide range of sound energy that was wasted with a considerable level of power. For example, the noise on the highway at peak times has a sound pressure level of about 80 dB – 90 dB, a handheld drill that generates sound with a 98 dB SPL, and the aeroplane's jet engine produces sound with an SPL of around 140 dB at a distance of 100 m [1]. Another example, noise at the site of several types of industrial plants has an SPL of about 100 dB to 136 dB [3]. Noise demonstrates the potential to utilize this wasted and disruptive energy as an environmentally friendly

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alternative energy source. Although until now the energy gained in this case is relatively small, that is a maximum of only tens of milliwatts [1, 4].

Most acoustic transducers (i.e. components that convert sound energy into electrical energy) used in acoustic energy harvester (acoustic energy wheat) are piezoelectric material, while others use magnetic which is mounted on a membrane that vibrates around a coil when it was charged by sound waves [1, 3]. The piezoelectric material is widely used in this regard because the price is cheap, can produce electrical energy with a large energy meeting, and its size is small so it is easy to be integrated with the system that will be powered by power [4]. On the other hand, the loudspeaker can also convert sound energy into electrical energy. However, so far the new loudspeaker is used in thermoacoustic power plant tools, which are tools that generate electrical energy from thermal energy through thermoacoustic effects [5]. Acoustic transducers in acoustic energy harvester are usually equipped with an acoustic resonator that serves as an acoustic energy collector and is useful for enhancing the amplitude of sound wave pressure at certain frequencies to be received OLE The acoustic transducer. The form of resonator used can be a straight-quarter resonator of the wavelength, or the resonator Helmholtz [6].

Hassan et al [7] made the acoustic energy harvester system using a piezoelectric generator. In an experimentation piezoelectric type cantilever generator is used to extract the sound energy from the loudspeakers from various distances and then turn this energy into electrical energy. The results showed that a maximum output voltage of 26.7 mV was obtained with a sound intensity of 78.6 dB. Khan et al [8] made the acoustic electromagnetic energy harvester system to convert acoustic energy and use the resonator, Helmholtz. The harvester performance was analyzed in both the laboratory and the real environment. In a laboratory at a sound pressure level of 100 dB generates a peak load voltage of 198.7 mV, when performed on a real environment produces a maximum voltage of 25 mV when exposed to acoustic noise of a motorcycle and produces an optimal voltage of 60 mV. Garg et al [9] stated that speakers were used to altering the resulting noise into electrical energy.

Vibrations created by noise can be transformed into electricity through the principle of electromagnetic induction. The result at a sound pressure level of 90 dB is generated voltage valued at 1.62 V. Attia, et al. [2] used the piezoelectric generator of the lead zirconate (PZT actuator) is used to extract the sound energy from the loudspeakers from various distances and then transform this energy into electrical energy. The optimum voltage was generated by the piezoelectric generator occured when the resonant frequency operates near the frequency of the sound. The results showed that a maximum output voltage of 28.8 mVrms was obtained with a sound intensity of 80.5 dB of Resonance frequency 65 Hz at a distance of 1 cm in the first mode. In the second mode, a maximum output voltage of 94 m Vrms is obtained with a sound intensity of 105.7 dB at a frequency of 378 Hz at a 1 cm higher than the first mode [10].

2. Materials and Method

2.1 Testing with Frequency Generator Function of 60-80 Hz

The research was conducted experimentally in laboratories. The sound source used is a function generator. The first test by measuring uses the sound source of the function generator with different frequency variations – unlike the frequency range between 60 – 80 Hz. Sound loudness level represented by sound wave pressure (sound Pressure level, SPL) was measured by using a sound level meter (SLM) Digital Lutron Model SL-40, expressed in sound meter (dB) units with a reference value of 20 µPa. On a distance of 20 cm from the maximum SPL, sound source can be generated by the generator function and the woofer speaker loudspeaker as the source is 90 dB. The converting loudspeakers used in the study were the buzzer piezoelectric ceramic treble rectangle, audio speaker, with a size of 8.6 cm x 8.6 cm x 7.2 cm.

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In this experiment, sound sources are received by the converting loudspeaker, which converts it into alternating current – which is passed to resistance (R) 1 kΩ. The resulting voltage and current were measured by using a digital multimeter MASDA model DT830D. This experiment was conducted by measuring the voltage in the resistor at 90 dB SPL.

2.2 Test with the Frequency Generator Function of 60 – 500 Hz

The research was conducted experimentally in laboratories. The sound source used is a function generator. The first test by measuring uses the sound source of the function generator with different frequency variations – unlike the frequency range of 60 – 500 Hz. Sound loudness level represented by sound wave pressure (sound Pressure level, SPL) was measured by using a sound level meter (SLM) Digital Lutron Model SL-40, expressed in sound meter (dB) units with a reference value of 20 µPa, at a distance of 20 cm from the maximum SPL, the generator function can generate sound source and the woofer speaker loudspeaker as the source is 90 dB. The converting loudspeakers used in the study were the buzzer piezoelectric ceramic treble rectangle, audio speaker, with a size of 8.6 cm x 8.6 cm x 7.2 cm.

In this experiment, sound sources are received by the converting loudspeaker, which converts it into alternating current which is passed to resistance (R) 1 kΩ. The resulting voltage and current was measured by using a digital multimeter MASDA model DT830D. This experiment was conducted by measuring the voltage in the resistor on SPL of 90 dB.

2.3 Testing with subwoofer speakers

The second test was used as a subwoofer speaker (Figure 1). The loudness level represented by sound wave pressure level (SPL) is measured using a sound level meter (SLM) Digital Lutron Model SL-40, expressed in sound meter (dB) units with a reference value of 20 µPa at distance of 20 cm from the maximum SPL sound source that can be generated by the woofer speaker loudspeakers as the source is 103 dB. The sound source is received by the converting loudspeaker which converts it into alternating current which is passed at a resistance (R) 100 Ω. The resulting voltage is measured using a digital multimeter MASDA model DT830D. This experiment was conducted by measuring the voltage in the resistor at 103 SPL.

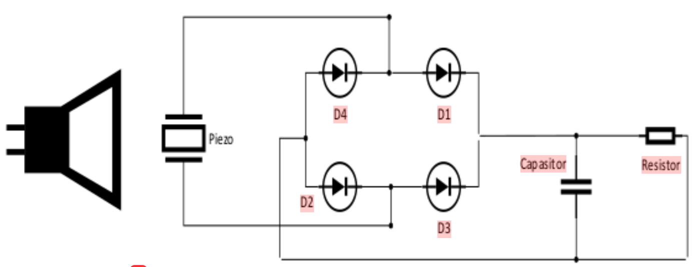

Figure 1: Testing with subwoofer speakers

2.4 Tests with Load of 1.8 V LED Lamp

The testing used was a subwoofer speaker loudspeakers. The loudness level represented by sound wave pressure level (SPL) is measured using a sound level meter (SLM) Digital Lutron Model SL-40, expressed in sound meter (dB) units with a reference value of 20 µPa, at distance of 20 cm from the maximum SPL sound source that can be generated by the woofer speaker loudspeakers as the source is 103 dB. The sound source is received by the converting loudspeaker which converts it into alternating current which passed at a resistance (R) 100 Ω. The resulting voltage is measured using a digital

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multimeter MASDA model DT830D. This experiment was conducted by measuring the voltage in the resistor at 103 SPL. In this test, the output side is connected to the LED lamp (Figure 2). This test observes the active and non-active LED at the time the inputs are given.

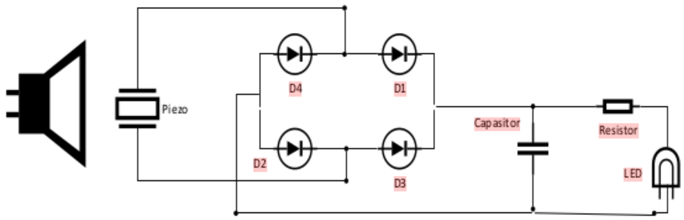

Figure 2: Tested with LED lamp of 1.8 V

2.5 Testing with Industrial Machinery

Testing was conducted on high-noise industrial machines with different SPL values. The loudness level represented by sound wave pressure level (SPL) is measured using a sound level meter (SLM) Digital Lutron Model SL-40, expressed in sound meter (dB) units with a reference value of 20 µPa, at distance of 20 cm from the maximum SPL sound source that can be produced by industrial machinery. The sound source is received by the converting loudspeaker which converts it into alternating current – which is passed at a resistance (R) 100 Ω. The resulting voltage is measured using a digital multimeter MASDA model DT830D. This experiment was conducted by measuring the voltage in the resistor at 103 SPL.

3. Results and Discussion

3.1 Testing with Frequency of 60 – 80 Hz

This test (Table 1) was conducted to see the maximum response of the voltage, power and current resulting from the variation of the frequency given by the generator function on the design of the acoustic energy harvester system (Figure 3). The network uses a load 1 kΩ.

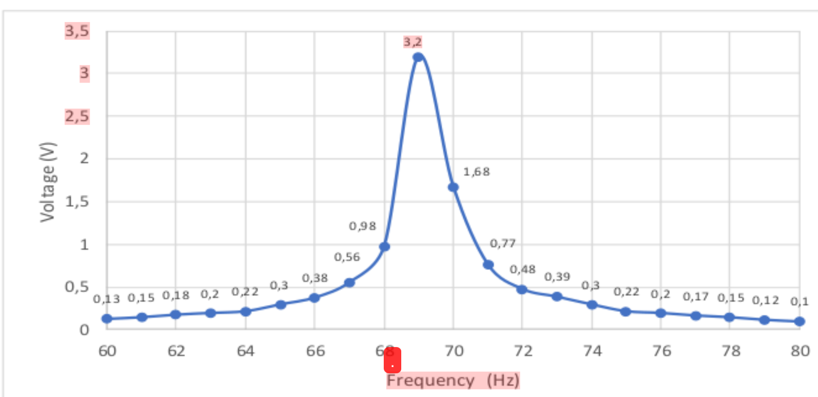

Figure 3: Voltage Response on Frequency of 60 – 80 Hz

Table 1: Voltage, Current and Power Response on Frequency of 60 – 80 Hz

Frequency (Hz)	Voltage (V)	Current (mA)	Power (mW)
60	0.13	0.13	0.0169
61	0.15	0.15	0.0225
62	0.18	0.18	0.0324
63	0.20	0.28	0.0728
64	0.22	0.22	0.0484
65	0.30	0.30	0.0900
66	0.38	0.38	0.1444
67	0.56	0.56	0.3136
68	0.98	0.98	0.9604
69	3.20	3.20	10.240
70	1.68	1.68	2.8224
71	0.77	0.77	0.5929
72	0.48	0.48	0.2304
73	0.39	0.39	0.1521
74	0.30	0.30	0.0900
75	0.22	0.22	0.0484
76	0.20	0.20	0.0400
77	0.17	0.17	0.0289
78	0.15	0.15	0.0225
79	0.12	0.12	0.0144
80	0.10	0.10	0.0100

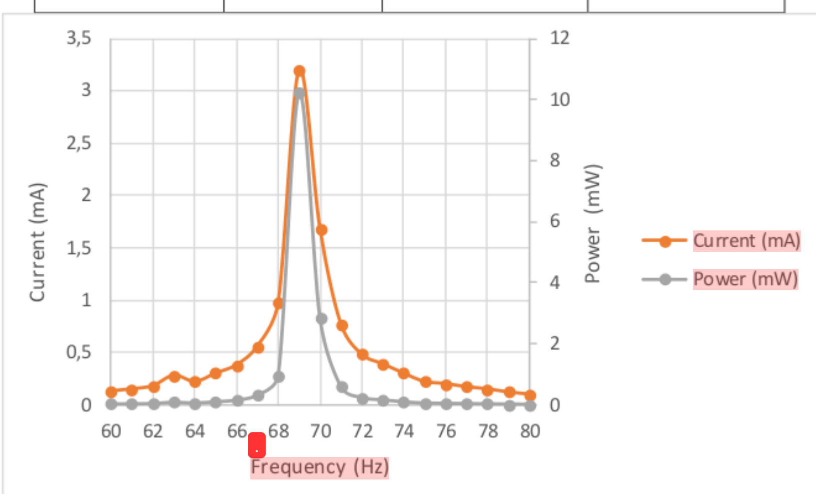

Figure 4: Current and Power Response on Frequencies of 60 – 80 Hz

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At this test (Figure 4) obtained the highest response at a frequency of 69 Hz, where the voltage, current and power are generated sequentially as follows. The voltage was obtained at 3.2 Volts, with a current of 3.2 mA and a power of 10.24 mW in with a resistor load of 1 kΩ.. The result was compared with the input to a simulation with the same parameters that used a resistor 1 kΩ at a frequency of 60 – 80 Hz, the result can be seen in Figure 5.

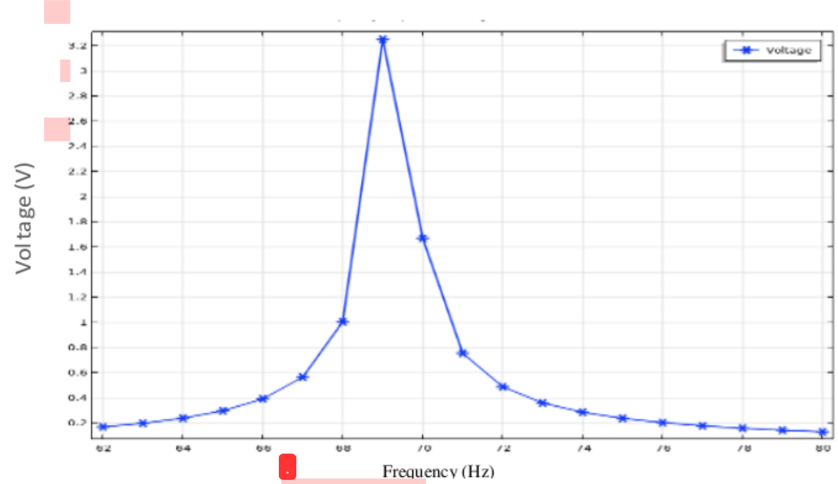

Figure 5: Voltage Response from Simulated on Frequency of 60 – 80 Hz

Live test results and results in simulations do not have distant corporation. Results in live testing can be said to be almost similar in simulation results if both charts are merged can be seen in Figure 6.

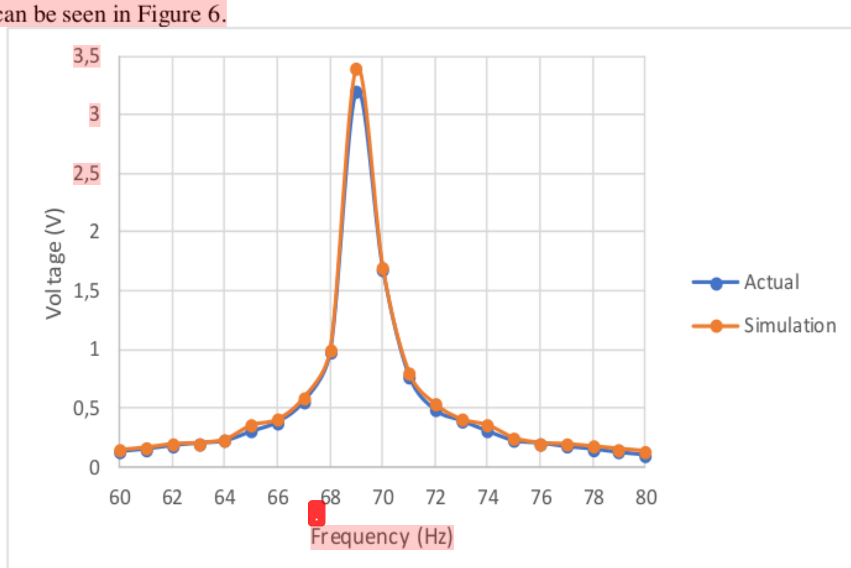

Figure 6: Comparison of live test results and simulated results

3.2 Testing with Frequency of 60 – 500 Hz

This test (Table 2) was conducted to see the maximum response of the voltage, power and current resulting from the variation of the frequency given by the function generator up to 500 Hz on the design of the acoustic energy harvester system (Figure 7). The network uses a load 1 kΩ.

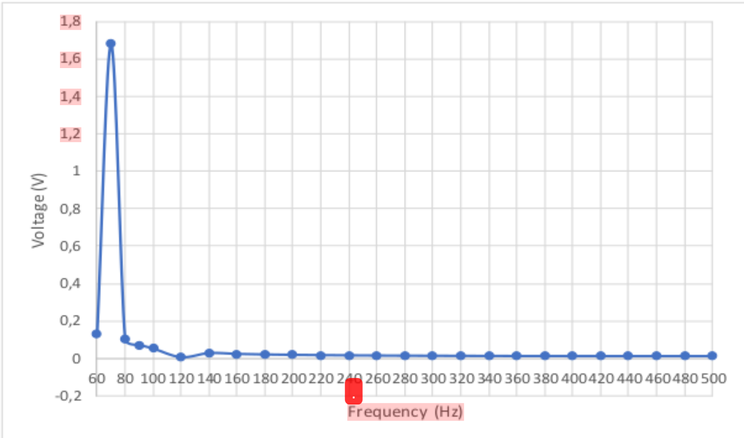

Figure 7: Voltage Response on Frequency of 60 – 500 Hz

Table 2: Voltage, Current and Power Response on Frequency of 60 – 500 Hz

Frequency (Hz)	Voltage (V)	Current (mA)	Power (mW)
60	0.13	0.13	0.0169
70	1.68	1.68	2.8224
80	0.10	0.10	0.0100
90	0.07	0.07	0.0049
100	0.05	0.05	0.00225
120	0.0033	0.033	1.09E-03
140	0.0255	0.0225	6.50E-04
160	0.0210	0.0210	4.41E-04
180	0.0180	0.0180	3.24E-04
200	0.0160	0.0160	2.56E-04
220	0.0145	0.0145	2.10E-04
240	0.0133	0.0133	1.77E-04
260	0.0124	0.0124	1.54E-04
280	0.0115	0.0115	1.32E-04
300	0.0111	0.0111	1.23E-04
320	0.01055	0.0106	1.11E-04

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340	0.0102	0.0102	1.04E-04
360	0.0098	0.0098	9.60E-05
380	0.0097	0.0097	9.41E-05
400	0.0095	0.0095	9.03E-05
420	0.0095	0.0095	9.03E-05
440	0.0094	0.0094	8.84E-05
460	0.0094	0.0094	8.84E-05
480	0.0094	0.0094	8.84E-05
500	0.0094	0.0094	8.84E-05

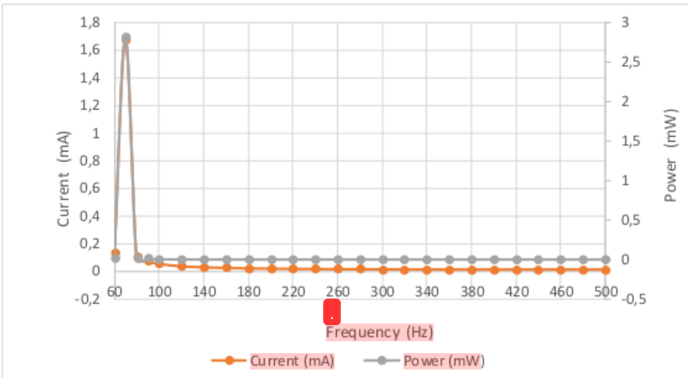

Figure 8: Current and Power Response on Frequency of 60 – 500 Hz

At this test with a frequency variation of 60 – 500 Hz (Figure 8) obtained the highest response at a frequency of 70 Hz, where the voltage, current and power are generated sequentially as follows. The voltage was obtained at 1.68 V, with a current of 1.68 mA and a power of 2.8224 mW in with a resistor load of 1 kΩ. The result is then compared with the input to a simulation with the same parameter that is used 1 kΩ resistor at a frequency of 60 – 500 Hz, the result can be seen in Figure 9.

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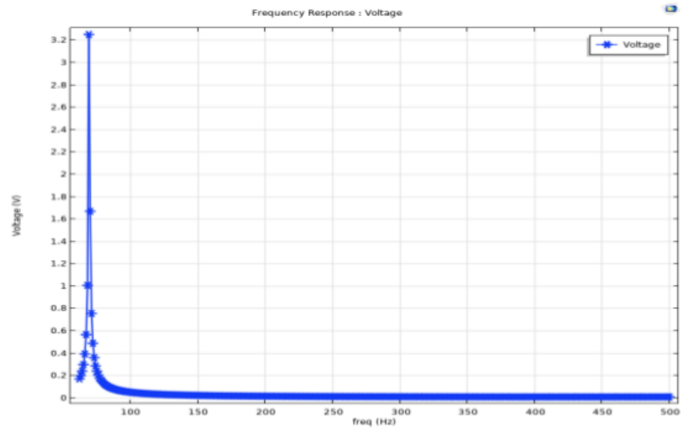

Figure 9: Voltage Response from Simulation on Frequency of 60 – 500 Hz

Live test results and results in simulations do not have distant corporation. Results in live testing can be said to be almost similar in simulation results if both charts are merged can be seen in Figure 10. In tests with frequencies 60 – 500 Hz, the higher the frequency given the result of the resulting voltage response does not add the resulting voltage to the highest response remained at 70 Hz.

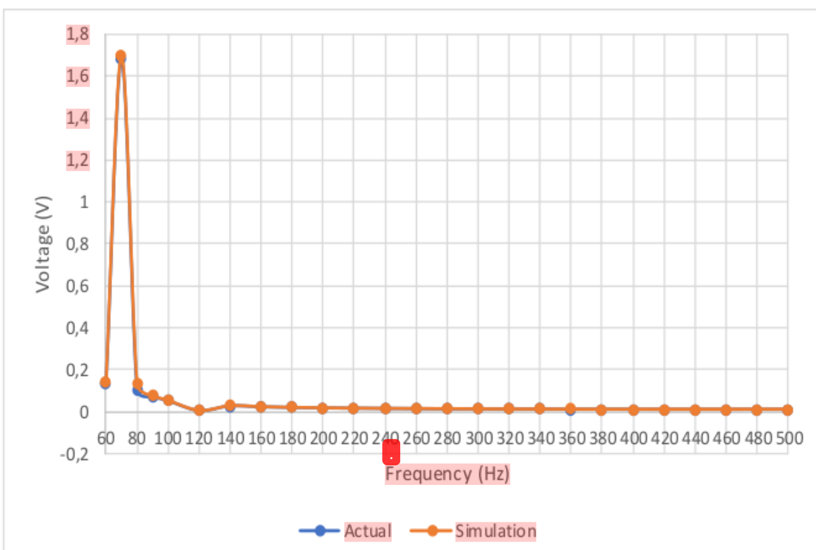

Figure 10: Comparison of Live Test and Simulation Test

3.3 System test results with Subwoofer speakers

Results from the testing of energy harvester systems in laboratories with a value on SPL of 103 dB. Here is the result of the testing of energy harvester systems (Table 3).

Table 3: Subwoofer Speaker System Test

No	Time (hour)	Voltage (V)
1.	1	1.65
2.	2	2.03
3.	3	2.43
4.	4	2.78
5.	5	3.18
6.	6	3.59
7.	7	4.21
8.	8	4.71
9.	9	5.15
10.	10	5.56

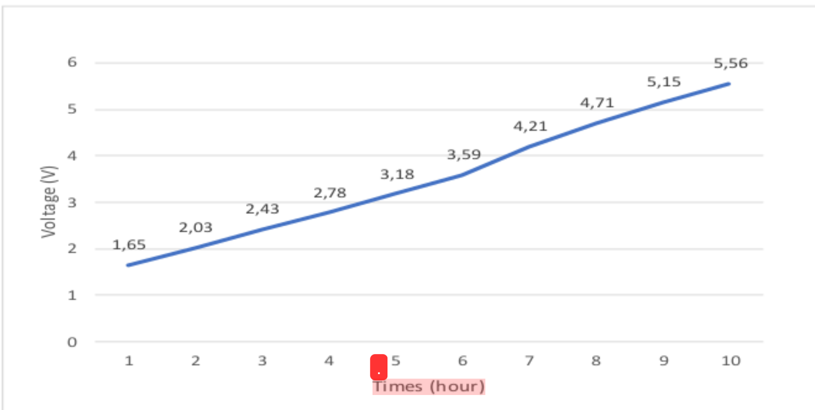

Figure 11: Energy Harvester System on SPL of 103 dB

Based on the Table 3 and the Figure 11, the acoustic energy harvester system tested, has fulfilled the design criteria and has good quality. The energy harvester system can respond well to acceptable sound sources. This means the components of the energy harvesting system are working properly. The energy harvester system means charging quite well but takes a very long time, it shows that it takes more than one sound converting instrument to be electrically and made in parallel, and then in connection with a resonator to the received sound source can be centered at one point, so that the sound vibrations received is greater bias and the converted amount is greater.

3.4 Test result with LED load

The result of system performance data retrieval is 1.8 V LED status on load testing. Load test data retrieval on 1.8 V LED at charging duration for 10 hours is shown in Table 4 where data is retrieved every hour.

Table 4: Load Test Data on LED of 1.8 V

No	Voltage (V)	Status LED
1.	1.65	Off
2.	2.03	On
3.	2.43	On
4.	2.78	On
5.	3.18	On
6.	3.59	On
7.	4.21	On
8.	4.71	On
9.	5.15	On
10.	5.56	On

Based on the Table 4 above the energy harvester system tested with the load in the form of LED 1.8 V obtained the status of LED that can be lit, although only a few moments. This phenomenon proves that the tested energy harvester system can deliver the output to the test load, i.e. LED.

3.5 System Test on Industrial Engine Noise Source

The retrieval of system testing data in a real environment is by testing the harvester energy system directly in places that have a noise source. This test was conducted by taking the source of noise from the machine-production machines in the factory. Test results and data can be seen in Table 5.

Table 5: System Test by Industrial Engine Noise Source

No	Sound Source	SPL (dB)	Voltage (V)
1.	Dust Collector	84	0.60
2.	Chiller	87	0.70
3.	Genset	115	2.70
4.	Vacuum Pump	97	1.74
5.	Fitzmill	97	1.70
6.	Ultrasonic Bath	93	1.65
7.	Trucking Washing	92	1.58
8.	Labelling Machine	87	0.70
9.	Shredder Machine	90	1.62
10.	King Counter	93	1.64

Based on the Table 5 above the energy harvester system which is tested directly with the noise source of the machine-the production machine can also work well, but the output result is still not very large, it also indicates that the system acoustic energy harvester does require an additional tool of resonator so that the received sound source can be captured at one point through the resonator so that the results can be more optimal.

4. Conclusion

It has been designed an acoustic energy harvesting system using a buzzer-type loudspeaker with a piezoelectric ceramic treble rectangle of audio speakers. The tool can convert acoustic energy into electrical energy. It is seen from the value of voltage, current and power generated during the harvester operating system. The test results in this study showed that sound or noise can be used as electrical energy and convertible loudspeakers could also be used as an acoustic transducer to convert sound energy into electrical energy by harvesting energy system. Energy potential wasted from noise can be used as alternative energy. It is seen from the energy power value generated if the power is stored in large quantities and in super capacitors.

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