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# Integrated Kineto-Voltaic Foot Platforms through Performance Evaluation and Feasibility of Voltage Generation in Valenzuela City People's Park

Alegre, Chrisneil C.[*], Barberan, Mae L[†], Dogma, Zebastian Troy G. [‡], Medrano, Hannah Gwyneth E.[§], Teodoro, Adrian B.[¶], and Kishimoto, Ryuichi T.[*]
Department of Electrical Engineering, Pamantasan ng Lungsod ng Valenzuela
Valenzuela, Philippines

**Abstract:- The main focus of Electrical Engineering endeavors all has to do with the ability of humanity and industrial progress to advance energy generation and storage. With the ecological problems being imminent and inevitable, the use of innovative technologies with the goal of harnessing electricity is becoming extensive. Piezoelectric Transducers are one of these extensive technologies that are still studied to become a progressive part of renewable energy generation. The system of providing these technologies to Green Parks such as that of the Valenzuela City People's Park through an original and durable platform design makes it so that the aim of voltage generation to be interactive and available can be attained even with newer technological applications like that of Piezoelectric Transducers connected in meticulous electrical networks that enables high generation with high efficiency of production to be possible and assess its capability that can challenge current technology as progressive renewable energy.**

***Keywords:-*** *Voltage Generation, Piezoelectric, Renewable*.

## I. INTRODUCTION

In the Philippines, the energy sector is one of the factors that contribute to environmental damage due to the location of the country and its resource activity throughout the years. In this regard, renewable energy has been tested time and time again to undergo tests for integration in the power generated society present in this age. Valenzuela City, a city located in the National Capital Region in the Philippines has its fair share of factories that contribute to the GHG emission each year with over fifteen (15) factories running solely on coal generated energy. In Valenzuela City, a city located in the National Capital Region, Barangay Malinta holds one of its most popular leisure parks called the "Valenzuela City People's Park" (VCPP) that pushes clean-and-green advocacy with its nature-esque design. These leisure parks accommodate heavy foot traffic due to the visitors present, according to the events handler as of 2022 and the joint-cooperation of the Valenzuela City Health Office, the average attendees of VCPP is approximately 1100 civilians, 40 Valenzuela City Vaccination (VC-Vax) Administrators, and 40 VCPP employees including the office clerks, park rangers, and sanitary workers. Considering the vicinity being in the middle of streets and avenues, thus theoretically implying an applicable measure to implement a working build of Piezoelectric Energy Harvesting (PEH) platforms that generates electricity becoming the future of energy generation as assistance for the distribution of power and establishing renewable energy projects.

With the goal of sustainable energy generation and implementation of renewable energy sectors in society, the study directs its motive towards the integration of PEH units to contribute towards the future of clean power generation through human activity inclined with electricity.

The conceptual framework follows an input and output process model as seen in the diagram below:

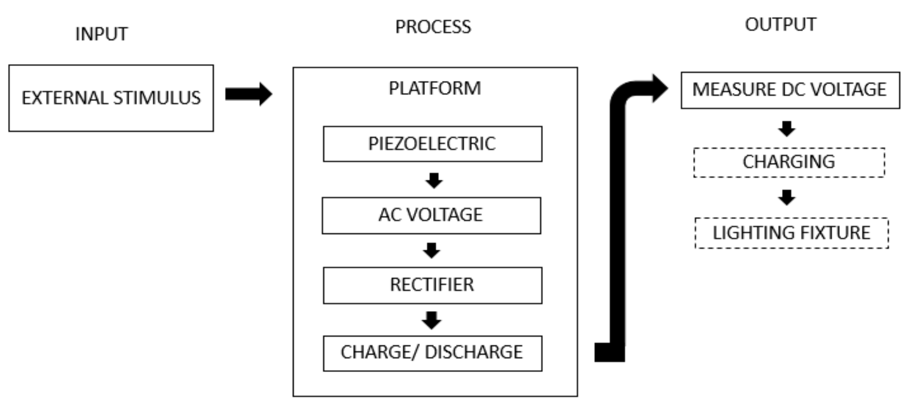


Fig 1 Conceptual Framework of harnessing, developing, and generating electrical energy.

The source is where the external stimulus happens as the mechanical stress is applied to the device allowing vibration to take effect as the variable measured by piezoelectric transducer model installed. This raw mechanical energy generated through footsteps, wheels, or mechanical stress will then be sent towards a rectification model effectively converting it into a feasible electrical energy producing device (Ragupathy, 2017).

The theoretical framework of the system comes from the scientist Michael Faraday discovery that when a magnet is given a movement inside the coil of wire, there can be a flow of electric current. The theoretical framework of the study follows the Electromagnetic based Generators using Faraday's Law of Electromagnetic Induction where the vibration of an external stimulus creates energy to that of an electromagnetic inductor through the energy passing through its cores. It also follows the theoretical studies of Renewable Energy and Application of Lund (2005), and the theory of power generation through human footsteps by Gawad, A. A. (2015).

The input, being the movement of people who walk on the platform, creates a mechanical stress or vibration and will be processed through the transducer module with varying mechanical stress and strain causing the piezoelectric module to respond with electricity generation (Abramovich et al, 2003). The generated voltage is AC and will undergo rectification turning the AC to DC voltage. The electrical energy that is rectified will pass through a capacitor, where the capacitor will act as smoothing agent. It will then be stored by the use of a storage device that connects to the output, a lighting fixture.

*A. Objective of the Study*

➢ *General Objective*

The study aims to integrate an Electrical Energy Harvesting platform made with Piezoelectric Transducers in an electrical circuitry capable of producing voltage and storing it on a high-capacity voltage battery that will in turn distribute the said stored electrical energy towards lighting systems. The objective of the study is to assess the capability of the system to become a fully integrated platform for distributive use of lighting fixtures and to assess the feasibility of installing the platform in Valenzuela City People's Park

➢ *Specific Objective*

The research aims to specify objectives in accordance with the effectiveness of the platform in the production of electricity with a feasible number of people applying force towards the system. This will be done through assessing the capacity of production made by the piezoelectric transducer platform. Obtaining a viable measure for system yield and application feasibility. Evaluating the stored electrical energy in its capability to distribute towards circuit layouts of small capacity load fixture application in Valenzuela City People's Park. Associating the platform device into innovative technology for renewable energy advancement. Providing a quality Piezoelectric Energy harvesting unit through rigorous testing and maintenance checks producing the most optimal piezoelectric design.

*B. Significance of the Study*

Providing an innovative renewable energy generation device can be a breakthrough in the field of energy generation that tackles the mitigation of environmental effects non-renewable energy generation brings to society. Renewable Energy Distributors, Local Government Units, the Society, Future Researchers, and even Students can harness the full potential of this study to look into the capability of newer and reliable energy generation through different means if it deems necessary and essential.

## II. REVIEW OF RELATED LITERATURE

*A. Issues in Renewable Energy*

Renewable energy is a development of the century and the proper answer for maintenance problems, environmental, and lower reliance on foreign energy sources. Such foreseen problems can provide a lens of reflective use to the effects of renewable energy and its application in day-to-day lives (Nocera, 2009), which in turn can help to understand the true capabilities of Renewable Energy and its application. According to the peer study done by Kerry Thouborron (2018) about the Advantages and Disadvantages of Renewable Energy, collectively indicating intermittency and sustainability as primary problems.

*B. Piezoelectric Sensors*

A study from Venkatesh et al. (2019), said that the piezoelectric effect is employed to create power in this technique that when pressure and strain are applied to a material that exhibits the piezoelectric effect, an electrical charge can be generated and in this study presents the design of power generation using footstep based on piezoelectric sensors

*C. Power Generation through Human Walking*

Arvind et al. (2016) claimed that human walking could be used to generate energy. It generates electricity by installing a circular piezoelectric transducer in pedestrians, which is then used to power streetlights. Ghosh et al. (2013) conducted another study and proposed employing footstep to generate electrical power for urban energy applications. They are using human motion to press the gear and shaft to create electrical energy using rotational motion and the faraday law notion in this study.

*D. Conversion of Kinetic Energy to Electrical Energy*

As per Arvind Ragupathy (2017) experimental article, the Piezoelectric Transducer gives a discontinuous or alternating output when tapped repeatedly. As a result, it must be rectified in order to be storable or usable DC. The stress or applied pressure and strain to the piezoelectric transducer has something to deal with its output. The application of strains and stress in the systems provides an actuation graph where the max point of the stress applied in the beams also correlates with the piezoelectrics voltage and charge factor meaning that the pressure is directly proportional to the applied strain (Elka et al., 2003).

*E. Platform Model*

In Batangas State University, there was a study and prototype conducted. It is a 0.6 by 0.8-meter portable power generating floorboard that works by steps made on it. The supply generated by the device was rectified to produce DC output and then stored on a 12-volt battery bank. According to Balansay, Banaag, Ilagan and Maputi (2019), the weight of the person who steps on the floorboard is proportional to the output of the device. Meaning it generates more electricity and charges faster when heavier and more frequent weight is applied on it.

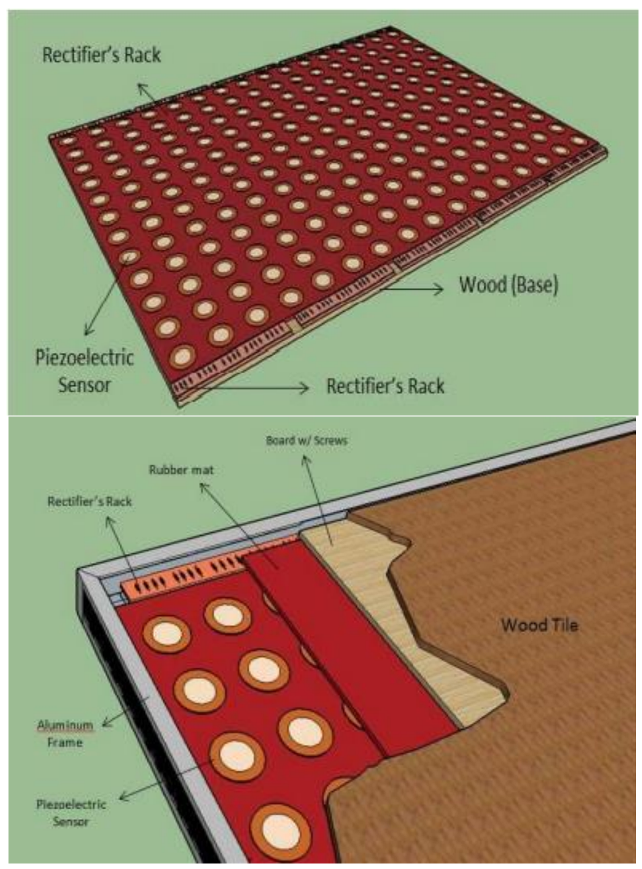


Fig 2 Cutaway view and the internal view of the portable power generating floorboards.

## III. RESEARCH PROCESS

*A. Research Design*

The researchers employ manual creation of the Piezoelectric Transducer platform and ensure that the system is provided with the sturdy chassis and cohesive circuitry design capable of providing voltage generation while being viable through the creation of a strong chassis that is able to withstand high instantaneous force application and even continuous force application simultaneously. The data recording will work within two weeks of deployment and all data gathered will be treated by the corresponding data analysis treatment to verify system response, storage, and other parameters for feasibility. The research follows this methodological approach as represented in the workflow chart of the system:

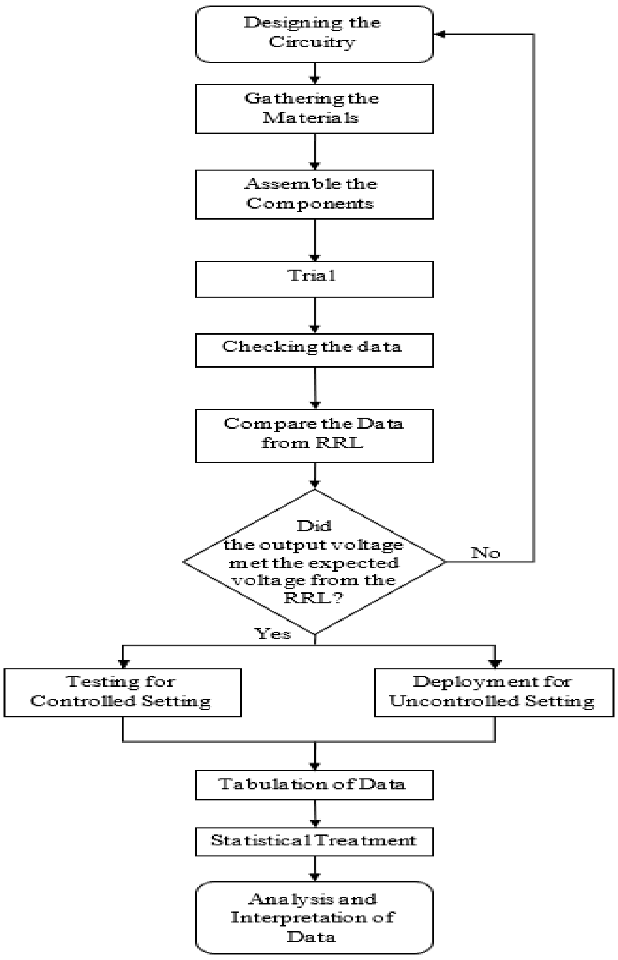


**Fig 3.1** Process Flow chart for the Methodology

*B. Research Locale*

The study was conducted within the Valenzuela City People's Park, all of which have dense population presence due to being public areas for leisure and gatherings situated near neighborhoods, homeowners and small-scale subdivisions, as well as the city's main City Hall and government establishments. The most optimal location for placement is on the entrance of the Picnic Ground connecting the Ampitheatre Catwalk and the rightmost side of the area. Since it connects the inner street of A. Pablo, Malinta to the main hi-way of McArthur bound towards north and south outside of Valenzuela thus commuters use the VCPP as a linking avenue.

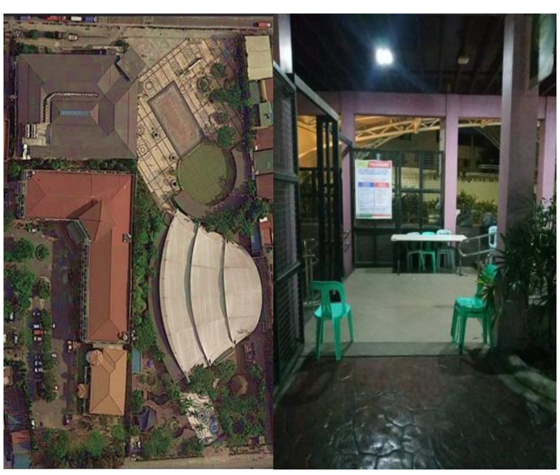

**Fig 3.2** Valenzuela City People's Park. *Source: Google Earth and Google Street View*

*C. Construction of the Platform*

The researchers designed a newer platform that is able to comply with the necessary parameters of the design and ensure that the system can becomes as efficient as possible. The construction of the platform follows the workflow charting below:

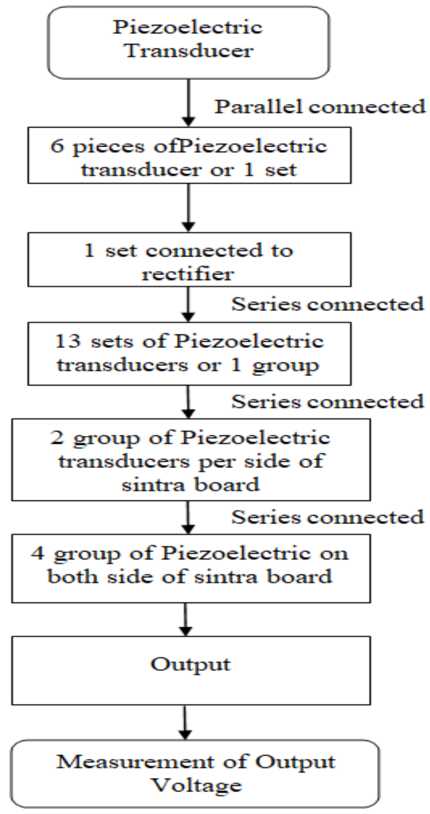


**Fig 3.3** Process Flow chart of Piezoelectric Transducer

The platform circuitry and design for the rectifier and the final output of the system through Computer Aided Drawing (CAD) and 3D rendering shows the system applying a Parallel-Series-Series Circuitry system that enables consistent voltage output even with damaged piezoelectric pieces, higher voltage output, and consistent circuit efficiency.

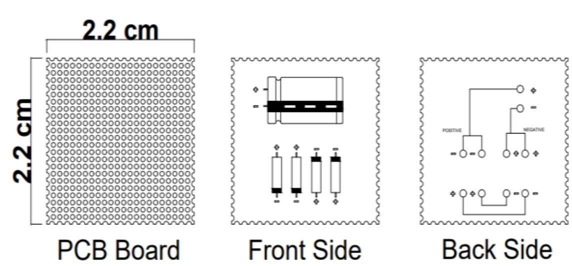


**Fig 3.4** Rectifier circuit on Printed Circuit Board (PCB)

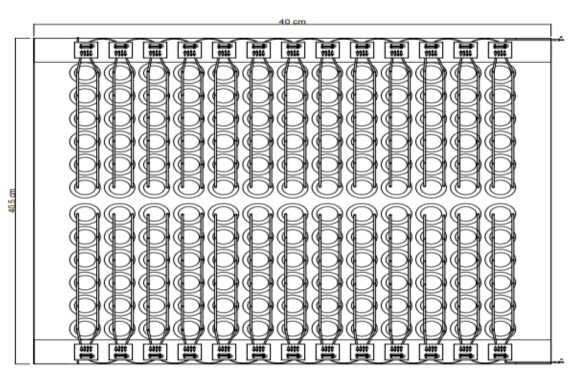

**Fig 3.5** Piezoelectric transducer circuitry with rectifiers.

**Fig 3.6** Cross-sectional eye level view

*D. Data Gathering Forms*

The data gathering forms are made with careful consideration of the parameters that can be inferred with the platform interaction as it respond with the stimuli of force application. The aforementioned parameters will be verified through related study analysis and make a controlled environment testing that can eliminate the unnecessary responses that will make not affect the system once deployed in the research locale.

Table 3.1 summarizes the voltage production sheet as it is deployed in the research locale.

| MORNING INTERVAL RECORDING | | | | |
|---|---|---|---|---|
| TIME (30 min. Int.) | Voltage(V) | Previous Reading | Highest Voltage/Int. | Time of Highest/Int. |
| 8:00 AM – 8:30 AM | | | | |
| 8:30 AM – 9:00 AM | | | | |
| 9:00 AM – 9:30 AM | | | | |
| 9:30 AM – 10:00 AM | | | | |
| 10:00 AM – 10:30 AM | | | | |
| 10:30 AM – 11:00 AM | | | | |
| 11:00 AM – 11:30 AM | | | | |
| 11:30 AM – 12:00 NN | | | | |

| AFTERNOON INTERVAL RECORDING | | | | |
|---|---|---|---|---|
| TIME (30 min. Int.) | Voltage(V) | Previous Reading | Highest Voltage/Int. | Time of Highest/Int. |
| 12:00 NN – 12:30 PM | | | | |
| 12:30 PM – 1:00 PM | | | | |
| 1:00 PM – 1:30 PM | | | | |
| 1:30 PM – 2:00 PM | | | | |
| 2:00 PM – 2:30 PM | | | | |
| 2:30 PM – 3:00 PM | | | | |
| 3:00 PM – 3:30 PM | | | | |
| 3:30 PM – 4:00 PM | | | | |
| 4:00 PM – 4:30 PM | | | | |
| 4:30 PM – 5:00 PM | | | | |

**Table 3.1** Data Sheet of Voltage Tabulation Produced by the technology.

The duration of the test will be 12 days all done from Sunday to Saturday in the first week as foot traffic in the locale is more abundant due to people attending classes and getting to work and Tuesday to Saturday in the second week. The following test sites will have two researchers administering the experimentation at exactly 9 hours from 8:00 AM to 5:00 PM. Two researchers will administer the experiment at the following test sites for exactly 9 hours, from 8:00 AM to 5:00 PM, where the time frame is the exclusive time considered by the locale's administration.

The experimentation is expected to experience malfunctions and manual repairs as it is subjected to the 9-hour deployment mark. Thus, maintenance reports describing the design specifications where damage or malfunction occurs will be reported each day and the time stamp such repairs are executed. Table 3.2 shows the maintenance report sheet for the system for monitoring.

| ENCOUNTERED PROBLEMS | Time of Maintenance | Solution | Time It Took to Fix |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Table 3.2** Daily Maintenance Report Table

The following are the necessary data gathering forms for the measurement of the parametric nature of the system's response. These data are considered for accuracy and feasibility.

*E. Data Interpretation*

The *mean* of the data in the voltage production of the platform is necessary to observe the average trend of voltage production yielded by the Piezoelectric Transducer circuitry in the platform. The recorded voltage will be tallied every hour after the initial deployment until its end and goes by the formula:

$$V_{ave} = \bar{x} = \frac{Sum\ of\ Voltage\ per\ day}{Number\ of\ Voltages\ Recorded\ per\ day}$$

(Eq. 3.1)

$$\mu = \frac{Sum\ of\ Voltage\ for\ the\ entire\ data}{Total\ number\ of\ Voltage\ recording}$$

(Eq. 3.2)

*Standard Deviation* analysis will be employed in the data to provide dispersion data of the voltage collected per week. This can determine where the extremities lie within the data set and whether they highly deviate in an environment reflective of a controlled variant nature. Since there is little to no way of measurement to the population count of forces applied to the system, it is highly recommended to apply a standard deviation procedure to measure dispersion count. It is given with the formula:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \qquad \text{(Eq. 3.3)}$$

Where: s = sample standard, n = sample size, $x_i$ = each value from the sample, $\bar{x}$ = mean sample

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \qquad \text{(Eq. 3.4)}$$

Where: $\sigma$ = population standard, N = population size, $x_i$ = each value from the population, $\mu$ = mean population

$$CV = \left(\frac{s}{\bar{x}}\right) = \left(\frac{\sigma}{\mu}\right) \quad \text{(Eq. 3.5)}$$

Finally, the data will be treated in a "*Chi-Squared Test*" manner due to the nature of the data being comparable measure from an expected value. This statistical data treatment considers an ideal data formation in accordance with ideal voltage production and the average of its yield to the total average in voltage production of each time interval compared to natural interactions.

## IV. RESULT AND DISCUSSION

*A. Interval Data Gathering Results*

The characteristics of interaction, generation, and the presented yield in the system are shown through the figures in graphical form to better understand its connection with one another.

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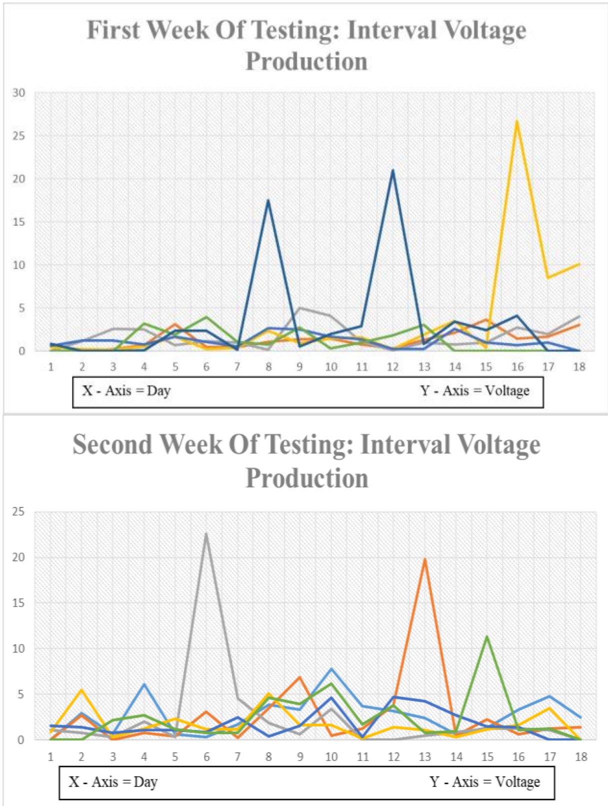


**Fig 4.1** Interval Voltage Production for the First and Second Week of Testing

In the overall first and second week comparison shown in Figure 4.1, the system provided with info graphics and proper platform guides have reflected a serviceable amount of data recording that is mostly varied due to the natural response of people that would either avoid the system or does not interact with them. The system responds averagely in the interval recording due to factors of being new and responsive towards only those that find the system worth checking. The system is on its third day of deployment, which shows the system adapting to the assessed problems present in both day 1 and day 2. The data shows an almost linear data count with two instances of maintenance that affects interval recording but still projects a more sustained interval count. The zero data outliers are the maintenance records and this reflects throughout the data in the highest peak consideration, as well as, the maintenance report.

*B. All-Time High (ATH) per Interval Data Gathering Results*

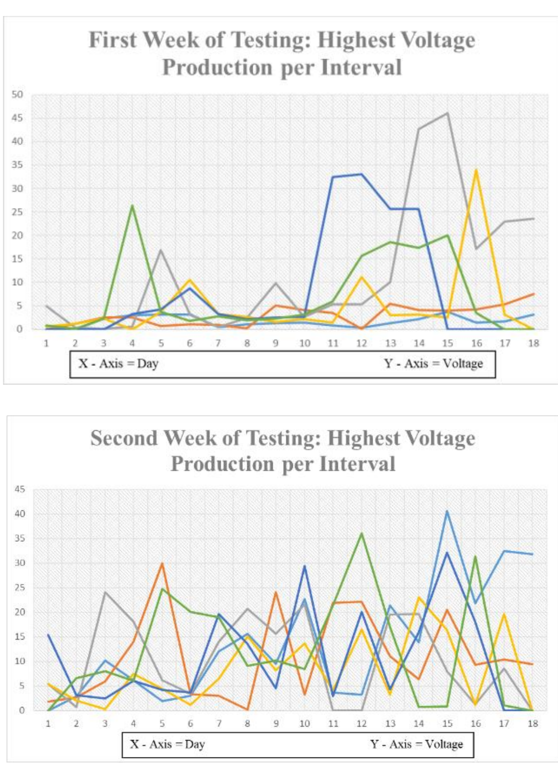


**Fig 4.2** Peak Voltage Production for the First and Second Week of Testing

The first 2 days, which is shown on figure 4.2, produced minimal peak voltage production because people are still unaware of the platform that causes them to avoid stepping on the platform. The peak voltage production on days 3 and 4 shows great peak voltages in late afternoon hours, which shows a great density of crowd visiting the park. In day 7 to day 12 shows great peak voltage production, although it shows volatility where Peak voltages do not appear on consistent timeframes. Peak voltages appear inconsistently but yields high voltage production because people on the park are accustomed to the platform and interact with it more frequently.

*C. Maintenance Report*

| Day | Maintenance Record | Minutes |
|---|---|---|
| 1 | 1 | 42 |
| 2 | 1 | 13 |
| 3 | 1 | 8 |
| 4 | 1 | 30 |
| 5 | 2 | 205 |
| 6 | 1 | 60 |
| 7 | 1 | 22 |
| 8 | 0 | 0 |
| 9 | 2 | 75 |
| 10 | 1 | 30 |
| 11 | 1 | 60 |
| 12 | 2 | 60 |

**Table 4.1** Maintenance Record with Time for the First and Second Week of Testing

The relative maintenance count of not higher than two maintenance check-ups and with most of the maintenance being done with the last instance of data recording, the Piezoelectric platform design shows reliable and durable reaction against high application of force.

*D. Mean Analysis*

The average value per day in the interval section of the data shows the trend in data accumulation. In the first day, the mean of day one provided the basis of the system when it comes to the projected data gathering.

| | | |
|---|---|---|
| **AVERAGE VALUES PER DAY** | 1st Day | 1.29 |
| | 2nd Day | 1.72 |
| | 3rd Day | 3.42 |
| | 4th Day | 1.18 |
| | 5th Day | 1.11 |
| | 6th Day | 3.36 |
| | 7th Day | 2.73 |
| | 8th Day | 2.73 |
| | 9th Day | 2.35 |
| | 10th Day | 1.68 |
| | 11th Day | 1.70 |
| | 12th Day | 2.33 |
| MEAN OF ALL DATA | | 2.13 |

**Table 4.2** Table of average values per day of interval data gathering and mean of all data

| | | |
|---|---|---|
| **Average of Peak Voltage per Day** | 1st Day | 1.68 |
| | 2nd Day | 2.93 |
| | 3rd Day | 11.91 |
| | 4th Day | 5.08 |
| | 5th Day | 7.96 |
| | 6th Day | 7.00 |
| | 7th Day | 14.06 |
| | 8th Day | 11.11 |
| | 9th Day | 10.40 |
| | 10th Day | 8.23 |
| | 11th Day | 10.86 |
| | 12th Day | 12.28 |
| Mean of all | | 8.63 |

**Table 4.3** Table of average values per day of peak data gathering and mean of all data

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In Figure 4.3, the average peak values reflected in the mean per day of the system's highest voltage inside each interval shows a gradual increase as exposure in the form of deployment days is formed. The quantitative aspect reflects a directly proportional inclination in the form of each average increasing as the day increases.

*E. Standard Deviation Analysis*

The application of the standard deviation will be related to both the sample mean and the population mean, which will produce a Coefficient of Variance where a system of higher value than one (1) would indicated high variance.

| | | |
|---|---|---|
| **STANDARD DEVIATION** | 1st Day | 1.10 |
| | 2nd Day | 1.48 |
| | 3rd Day | 6.45 |
| | 4th Day | 0.80 |
| | 5th Day | 1.34 |
| | 6th Day | 5.96 |
| | 7th Day | 2.10 |
| | 8th Day | 4.61 |
| | 9th Day | 5.19 |
| | 10th Day | 1.55 |
| | 11th Day | 1.48 |
| | 12th Day | 2.87 |

**Table 4.4** Table of standard deviation per day of interval data gathering

| | | |
|---|---|---|
| **COEFFICIENT OF VARIANCE (CV)** | 1st Day | 0.85 |
| | 2nd Day | 0.86 |
| | 3rd Day | 1.89 |
| | 4th Day | 0.68 |
| | 5th Day | 1.21 |
| | 6th Day | 1.77 |
| | 7th Day | 0.77 |
| | 8th Day | 1.69 |
| | 9th Day | 2.21 |
| | 10th Day | 0.93 |
| | 11th Day | 0.87 |
| | 12th Day | 1.23 |

**Table 4.5** Table of Coefficient of Variance (CV) per day of interval data gathering

| COEFFICIENT OF VARIANCE (CV) |
|---|
| 1.64 |

**Table 4.6** Coefficient of Variance (CV) of Interval Data Gathering Population

| | | |
|---|---|---|
| **STANDARD DEVIATION** | 1st Day | 1.16 |
| | 2nd Day | 2.22 |
| | 3rd Day | 14.05 |
| | 4th Day | 8.05 |
| | 5th Day | 12.00 |
| | 6th Day | 8.40 |
| | 7th Day | 12.05 |
| | 8th Day | 9.00 |
| | 9th Day | 8.71 |
| | 10th Day | 7.26 |
| | 11th Day | 10.00 |
| | 12th Day | 11.14 |

**Table 4.7** Table of standard deviation per day of peak data gathering

| | | |
|---|---|---|
| **COEFFICIENT OF VARIANCE (CV)** | 1st Day | 0.69 |
| | 2nd Day | 0.76 |
| | 3rd Day | 1.18 |
| | 4th Day | 1.59 |
| | 5th Day | 1.51 |
| | 6th Day | 1.20 |
| | 7th Day | 0.86 |
| | 8th Day | 0.81 |
| | 9th Day | 0.84 |
| | 10th Day | 0.88 |
| | 11th Day | 0.92 |
| | 12th Day | 0.91 |

**Table 4.8** Table of Coefficient of Variance (CV) per day of interval data gathering

| COEFFICIENT OF VARIANCE (CV) |
|---|
| 1.14 |

**Table 4.9** Coefficient of Variance (CV) of Peak Voltage Data Gathering Population

Through standard deviation, the data is noticeably erratic in nature and this due to the response of the application in the locale making it unstable. The Coefficient of Variance proves these parameters as volatile yet consistent in producing voltage since even if the deviation is high, the system itself produces higher voltages in correlation with the mean.

*F. Chi-Squared Testing Results*

The statistical treatment used in the research is the "Chi-Squared Test" as the data are compared towards an expected value for the system. The expected values are reflected as the needed value that either rejects or accepts the aim of the objective as its null hypothesis stand-in.

| Variables | P-Value | Level of Significance | Remarks |
|---|---|---|---|
| Voltage Interval | 0.242 | 0.05 | Accept Null Hypothesis |
| Voltage Peak | 0.233 | 0.05 | Accept Null Hypothesis |

**Table 4.10** Chi-Square Testing Table

The data mean in the chi-square test table is the recorded mean interval per day of the system, the expected value is written in the rightmost side of the data table and shows a 0.242 P-Value score for the system. Since the P-Value is above 0.05, the chi-test indicates an acceptance of the null hypothesis in the objective of determining feasibility in deployment of the Piezoelectric Platform System in the Valenzuela City People's Park. The null hypothesis is accepted and the day does not affect voltage generation due to the randomness of the voltage production and respondents. For the second chi-square testing, the chi-square test treatment of the study is provided with the P-Value indication of 0.223, which is higher than the alpha value of 0.05. Through the chi-square test treatment, the objective as null hypothesis is accepted since the correlation fails to be below 0.05, which implies failure in attaining the system for storage in a battery

## V. CONCLUSION

*A. Summary of Findings*

Overall, the findings reflected through data gathering in the natural setting as well as the controlled setting showed viable response data that proves the study to be successful in terms of feasibility in applying the technology in Valenzuela City People's Park. The Piezoelectric platform system together with its circuitry showing successful operation reflected by the yield and highest voltage accumulated by the system. Notable findings that should be considered is the prototype powering LED Modules, reliant on sustained and continuous foot traffic application, the interactivity, and establishing familiarity for the platform. Summarily, the findings provided better understanding in the accumulation of voltage and its implications and use for the aim of the study.

*B. Conclusion*

In the presented data, the methodological review, the statistical treatment, and the overall objective of the study, the feasibility of voltage generation through the use of kineto-voltaic platforms that is done through piezoelectric circuitry in the Valenzuela City People's Park is viable, highly effective, and successful through the means determined by the study. The integration of the piezoelectric platform shows phenomenal effectiveness as each interval shown in the data gathering method reflects accumulation of data where every time interval produces enough voltage that caps the expected voltage applied

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on each application. The platform durability is efficient and reliable for long-term exposure of the system to foot-traffic application. The voltage and current generation for the use of storage and supply as seen in renewable systems like solar and wind energy is still much to be desired. The careful consideration of current amplifying technologies and factors that affect the system's capability of storage should be considered since the system aims for the full technological advancement with renewable energy system being the stepping-stone of the study towards supply generation.

The objectives of the study were accomplished flawlessly through data analysis as it is proven that the system cannot store voltage due to the inconsistency of constant voltage and current production, which is needed in providing storage supply towards batteries. Due to high voltage yield, the system proves itself to light LED fixtures that can be integrated in the Valenzuela City People's Park's premises. This follows proper placement and component specifications to accomplish

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