# LOW WIND PROFILE ENERGY HARVESTER USING ROTOR AND PIEZOELECTRIC

by

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AC | Alternating Current |
| ANSYS | Analysis System Software |
| DC | Direct Current |
| EMF | Electromagnetic Field |
| FEA | Finite Element Analysis |
| LCD | Liquid Crystal Display |
| PFEH | Piezoelectric Flow Energy Harvester |
| PZT | Piezoelectric |
| RCC | Resistor Capacitor Circuit |
| RF | Radio Frequency |
| RPM | Revolution Per Unit |

# LIST OF SYMBOLS

| | |
|---|---|
| $B_{av}$ | Average Flux Density |
| $C$ | Capacitor |
| $D$ | Dielectric Displacement |
| $E$ | Field Strength |
| $f$ | Frequency |
| $F_c$ | Force on Single Conductor |
| $I_a$ | Armature current |
| $L$ | Conductor Length |
| $n$ | Revolution Number |
| $P_{conv}$ | Converted Power |
| $r$ | Harmonic force Frequency |
| $R$ | Resistance |
| $S$ | Strain |
| $T$ | Torque |
| $W$ | Work |
| $\varepsilon$ | Permittivity of a Process in a Specific Medium |

**Profil Tenaga Penuai Angin Rendah Menggunakan Rotor Dan Piezoelektrik**

# ABSTRAK

Baru-baru ini, usaha-usaha dalam menyediakan sumber tenaga alternatif telah Banyak kajian dijalankan dengan pertimbangan untuk melanjutkan permohonan mereka mengikut ciri-ciri sumber tenaga. Walau bagaimanapun, penuaian tenaga getaran adalah antara sumber yang paling menjanjikan percuma memerangkap tenaga. Dalam perkembangan projek ini, satu sistem yang menjana kuasa dari DC generator, bagaimanapun, penjana kuasa biasanya menghasilkan sisa tenaga getaran. Oleh itu, pembangunan akhir, memberikan sebagai kaedah alternatif untuk menuai tenaga getaran sisa dan menukar tenaga getaran ini menjadi tenaga elektrik menggunakan bahan piezoelektrik. Projek ini telah dibangunkan pada MATLAB Simulink manakala fokus kajian utama mengenai kombinasi pemutar dan peranti piezoelektrik. Dalam senario ini, model mesin DC telah dipertimbangkan untuk reka bentuk rotor dan bahan Piezoelektrik (PZT) yang telah dianggap sebagai bahan piezoelektrik. Keputusan akhir menghasilkan voltan output piezoelektrik, DC voltan penjana, kesan damping sistem manakala beberapa cara yang digunakan untuk memperbaiki sistem telah dicadangkan.

**Kata kunci:** piezoelektrik, bahan, Generator, Getaran, Daya, Kelajuan, Frekuensi, Dam

**Low Wind Profile Energy Harvester Using Rotor And Piezoelectric**

# ABSTRACT

Recently, efforts in providing alternative energy sources have been widely explored with the consideration of extending their application according to energy source characteristics. However, vibration energy harvesting is among the most promising source of free energy scavenging. In this project development, a system that generates power from Direct Current (DC) generator, however, power generators usually produced waste vibration energy. Therefore, the final development, providing as an alternative method for harvesting the waste vibration energy and convert this vibration energy into electricity using piezoelectric material. The project has been simulated in MATLAB Simulink while the main study concern about the combination of rotor and the piezoelectric device. In this scenario, modeling of DC machine has been considered for rotor design and the Piezoelectric (PZT) material has been considered a piezoelectric material. The final result provided piezoelectric output voltage, DC generator voltage, effects of damping of the system while few ways used to improve the system were suggested.

**Keywords:** Piezoelectric, Material, Generator, Vibration, Force, Speed, Frequency, Damping.

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The current efforts for providing alternative energy sources include biomass energy, wind energy, solar energy and a lot have been widely researched with the consideration of extending its application according to the characteristics of each. Wind energy, solar and vibration energy are among the most commonly used sources for certain circumstances (Cammarano, Alessandro, Petrioli, Chiara, & Spenza, Dora., 2012).

Vibration energy harvest is among the most promising source of free energy scavenging. While the major approach of scavenging this energy is the application of piezoelectric (PZT) devices. PZT device typically converts mechanical energy into electrical energy such as converting the rotation of a rotor which produces vibration into usable electricity.

However,  the main concept behind the use of energy harvesting using low wind profile has been developed lately as a way for providing sufficient energy source. Thus, combining other energy methods such as PZT has been one of the well-utilized methods which mainly aim at transforming mechanical energy into electrical energy.

This is due to the ongoing needs for providing sufficient remote power electrical sensor networks. However, providing and examining such networks require substantial extraction of electrical energy from the operating environment in accordance with its settings (Krishnan, S Harihara, Ezhilarasi, D, Uma, G, & Umapathy, M, 2014). Despite this, global warming problems and related factors have raised the needs for providing a lower energy profile which as a result led to the consideration of other alternatives.

Primarily, the process associated with the consideration of certain energy harvester usually depends on the cost effectiveness and reliability of the solutions (McCarthy, JM, Watkins, S, Deivasigamani, A, & John, SJ., 2016). Thus, a number of harvesting methods were proposed in order to offer potential solutions based on the profile of solar, electromagnetism, capacitive methods and others.

This research work discusses the modelling of a system that generates power from a rotating power generating machine. Since most power generator produces waste vibration energy, project modelling focuses on the development of a system that could harvest the generator waste vibration energy and convert it into electricity.

The design and theoretical principle of a mass spring for vibration, bimorph cantilever PZT type, internal voltage generated by piezo and also discuss power generation from synchronous or induction machine.

## 1.2 Problem Statement

There have been many novel ideas for vibration-based PZT energy harvesters, device ideas in conjunction with design technology are likely developed but real applications of the vibration-based energy harvesters are still limited. There are different sources of vibration such as cantilever type, cymbal type, and shell type. Hence, generating sufficient vibration from rotor required any one of these vibration sources stated but the selection of the vibration source type method could also be challenging. Another concern is the usage of voltage generated from the piezo electric device. These also required some certain steps to be followed for the conversion, such as voltage rectification, voltage boosting and power analysis while all this need to be implemented as a circuit base rather than the mechanical structure base.

However, vibration harvester would also require a full and better understanding of a produced mechanical oscillation in the environment, it was set up before power output can be maximized. Using a cantilever type gives more suitable, but the choice of cantilever would also depend on the main vibration frequency of vibration energy produced by rotating rotor. Therefore, there is a good reason to analyze data collected from environmental vibration. The current issues related to the ambiguity of energy availability generated from other sources have led to the consideration of providing energy-efficient power solutions. The harvesting practices of energy sources were processed by applying sophisticated methods to generate energy intake either by using certain energy predictors. However, such practices comes with various limitations in terms of articulating the behavior of energy sources produced in short and medium periods (Carli, Davide, Brunelli, Davide, Benini, Luca, & Ruggeri, Massimiliano, 2011).

As such, the lack of gaining more insights about potential energy predictors of harvesting sources will result in an under-performing system. This includes slowing down the process related to nodes, planning in order to manage the transferred energy (Bansal A, Howey DA, & Holmes AS., 2009).  On the other hand, the problem with this study is that the frequency appears to be not stable when PZT harvest the energy. This reason could be that the turbine state is changed due to certain environmental conditions. Thus, this study considered the potential of combining rotor with current properties of PZT as an efficient and practical method of harvesting energy from the  wind energy.



## 1.3 Research Aims and Objectives

### 1.3.1 Aims

The rotation of the rotor can be utilized as a Direct Current (DC) power generator, the rotor also produces some waste vibration energy. Therefore, the primary aim of the project is to convert this waste vibration energy into electricity.

### 1.3.2 Objectives

The objectives of this study are:

1. To model the turbine generator using MATLAB Simulink environment.
2. To evaluate the effect of rotor and PZT in providing the harvested energy of low wind.
3. To harvest a waste vibration energy of a DC machine for power optimization.

## 1.4 Scope of Research

This study is mainly concerned with combining rotor and PZT in order to provide a low wind profile. Simulation based on MATLAB has been carried out in this study. The standard specifications of PZT have been considered in this study. The rotor was applied to the PZT when turbine began vibrate.

Design and modelling was started by setting of the MATLAB environment based on the energy harvesting source. The researcher has considered a turbine model in which the wind load applied to it. By doing so, the vibratory movement of the turbine has been estimated based on the wind data collected. Then, the energy harvester was obtained by comparing it with different cases in accordance to the stiffness, mass and damping coefficient. Rotor and PZT was applied into the vibration in order to produce the low energy harvester. The design characterizes the energy output has been estimated to determine the effectiveness of the combination of rotor and PZT for providing a low wind profile based on the oscillation amplitude of the vibration as an indication of the potential energy that can be harvested.

## 1.5 Thesis Outlines

This thesis has five main chapters, introduction, literature review, methodology, result and conclusion.

**Chapter 2: Literature Review**

This chapter includes the development approach by other researchers, it also elaborates result from work done by other researchers, it is mostly content of related systems, method, result and limitation observe.

**Chapter 3: Methodology**

This chapter provides all idea and information regarding the system design and the functionality of the system, it comprises of design concept, mathematical equation involve and the system sustainable.

**Chapter 4: Result and Discussion**

This chapter provides the system model results and categorized them into three main different sections such as power generation from turbine generating machine, waste vibration generated from DC machine and conversion of waste vibration energy into useable electrical energy using PZT material.

**Chapter 5: Conclusion**

This chapter concludes the project, which reached the expected results of the study of the development of energy harvesting from rotor vibration in order to generate electricity. It also suggests further work needed for project improvement.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This section of the project reports evaluate different journals and works implemented by other researchers, review focus on researchers primary objective, method and result related information.

This chapter generally discusses  ways that could use to generate electrical energy from generating machine and vibration. Also describe the similarities of work done by different researchers. By the end of this section, possible method has been identified and limitation observed from previous researchers work served as a key point for this project improvement.



## 2.2 Energy Harvest Review

Harvesting of energy to generate electricity from vibration as an alternative source or support to conventional battery is becoming an important focus for researchers, adaptation of vibration energy into electrical energy is increasing daily. However, harvesting of electrical energy for consumption from vibration can be achieved using different methods, typical examples are PZT, electrostatic or electromagnetic.

The basic understanding of energy came from the process of collecting incoming energy sources and turns them into usable since. It helps provide shows about converting the external power sources into supplying energy to various applications (Yen Bernard C & Lang Jeffrey H., 2006). Nowadays, enhancing the current techniques for extracting electrical energy from the natural sources led many researchers to consider the potential of materials such PZT to enable the current extracting techniques.

In addition, the motivation for considering such materials comes from the global warming perspectives which imposed a remarkable challenge in lowering the carbon footprint (Soliman MSM, Abdel-Rahman EM, El-Saadany EF & Mansou RR, 2008). This as a result led scholars to seek alternative energy sources that come with lower wind profile.

However, the current customization of energy sources in a harvested form can be driven by the mechanical, solar, chemical, ambient-radical or the combination of them. There are two parts where the harvest kinetic energy can be extracted from the environment, the first is known as vibration mechanical system which is usually configured by considering the environmental motion along with the motion of power generator (Liao Yabin & Sodano Henry A, 2008). However, the second part consists of conversion mechanism which is utilized in order to convert the received energy source into electrical energy.



Understanding the design of these two parts drives researchers to try out the combination of different technique in an attempt to maximize the coupling effect of the kinetic energy source.

Despite this, the key issue associated with the design of harvester system is the voltage level produced by the generator along with the regulations of the vibration level used in a circuit. This is due to the fact that a generator produces an Alternating Current (AC) voltage that requires rectifier to be operated. In addition, it is evident from the literature that current vibrations typically use higher frequencies that are appropriate for such systems since its movement value is considered somehow high enough for real life vibration sources (Lefeuvre Elie, Audigier David, Richard Claude & Guyomar Daniel, 2007). Thus, PZT materials can be used to help solve the use of higher frequencies.

### 2.2.1 Piezoelectric Vibration Energy Harvest

There are many ways to get energy from nature, one of the recent ways is harvesting energy through PZT, proposed project to generate energy using a piezo sensor component that is useful for multiple applications.

Study focus on the development of a model of piezo material energy harvesting device for power generation, research also investigated on the behavior of plate made from piezoceramic wafer.

In this project, they transform mechanical energy into electrical power supply with piezo material configurations in a tile, this allow the system to achieve an optimum power.

System performance and evaluation were performed from a remote section while transferring was done via a wireless transition, power supply produces an AC signal was ripple to produce a Direct Current (DC) signal with a rectification circuit while receive signal such as power was display of user for monitoring with Liquid Crystal Display (LCD) (Sowmyashree M S,Naveen R, Naveen S, Manoj V and Shashanka M K, 2015).

Another research described the development of PZT for electrical power generation as challenging due to their low current, high voltage and high impedance output.

The research proceed to describe the theoretical analysis for power generation using PZT crystal material, paper describe that, if the potential difference apply to PZT device, the deformation will occur due to strain that is generated, however, if this phenomenon is reversed by apply strain to PZT, this will produce and electric field.

A research has also overcome the weakness that is related to cantilever mounted PZT device that commonly develops to use for mobile phone, this method, to the self-actuator connected in parallel while these are turned in order to resonate the frequency range derive from am ambient vibration, this have a similarity of same vibration that will produce by human foot stepping during walking while nickel battery with 40 to 80 mAh was recharged for result demonstration at 1.4 Hz frequency.

The result generated indicated to be enough to power a device for a long time and charging of battery found to be fast enough to use the system as an alternative way for power supply using a PZT device as vibration energy harvesting technology (Anil Kumar, 2011).

A research conducted by Raunaq Shah et al (2013). Generate power under a dynamic and quasi-static condition using PZT material, research indicated that PZT for power generation is more reliable, though, using this technology result in the low voltage generation in comparison to conventional battery.

Method approach to this project is dynamic and static method for exciting PZT generator while module consists of mechanical model that allow force to apply and electrical model that consist of RC circuit for power generation.

In this development, in Quasi-Static case, stress was used to produce an output voltage result into two opposite polarity peak, one peak occur one force apply, the other peak occurs once forcibly remove and an order of 100 ms force pulse length produce while dynamic is 10 ms force pulse length. Quasi-static method produce a 4.2 V and -4.5 V when PZT material use for experimentation purpose dynamic only, result to a positive voltage of 58.4 V that decay with time (Raunaq Shah, Rahul Khandelwal, Vishnukumar A, Prof Sudha R, 2013).

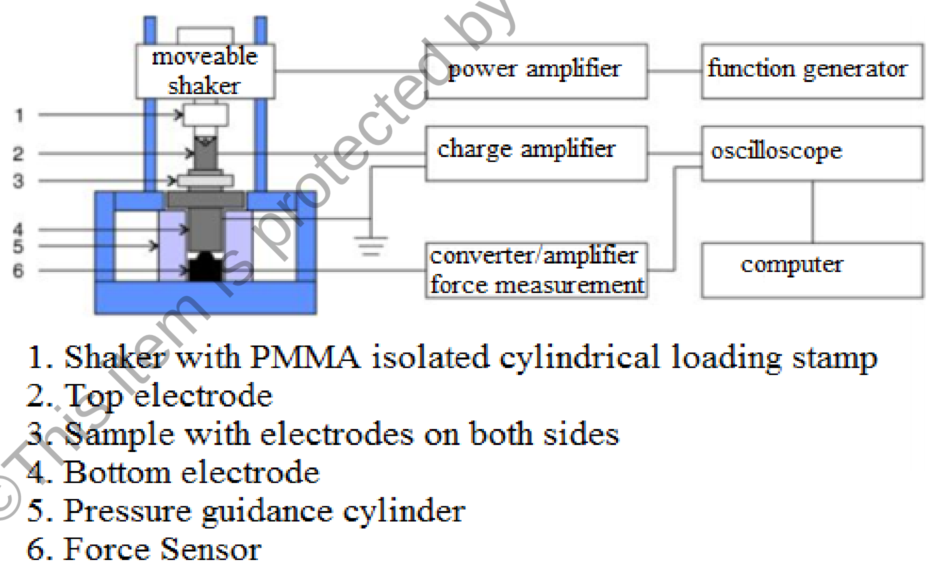


Figure 2.1: Power generating from a piezoelectric generator using piezoelectric generator.

(Raunaq Shah, Rahul Khandelwal, Vishnukumar A, Prof Sudha R, 2013)