APPLICATION OF ENERGY HARVESTING IN THE FIELD OF MECHANICAL VIBRATIONS

Naga Sudha Rani Behara¹, Prof. Putti Srinivasa Rao²

¹Research Scholar, Dept. of Mechanical Engg, Andhra University College of Engg (A), Visakhapatnam-530003, AP, INDIA. &Asst. Professor, Dept. of Mechanical Engg, Dhanekula Institute of Engineering and Technology, Vijayawada, AP, INDIA. nsrani@gmail.com
²Professor, Dept. of Mechanical Engg, Andhra University College of Engg (A), Visakhapatnam-530003, AP, INDIA.

Abstract. Energy harvesting (EH) is the most upcoming technology which is defined as a process where the environmental energy sources such as load, mechanical vibrations, temperature changes, light energy, wind energy etc. are captured and transformed to acquire quite small levels of power within the of range of Nano Watts - Milliwatts. This method is used to power an installed system by accumulating energy from ambient sources such as solar, wind, thermal and radio frequency waves. It is also called Energy Scavenging. The purpose of energy harvesting is to power electronic devices where there are no conventional power sources. The energy harvesting device has design goals and the three main elements are energy Source, Energy harvesting IC, Energy storage. In particular the energy harvesting used in charging of rechargeable batteries on site, low power electronic devices like traditional and super capacitors. Common energy harvesting systems include a lot of applications in many remote locations, distant locations, undersea where batteries and conventional power are not in used practically. In this paper the research that has been carried away in the field of energy scavenging of vibration analysis was discussed. In this scenario different type of energy harvesting methods like Thermo electric harvesting, Piezo electric energy harvesting, Pyro electric Energy Harvesting, PVDF Films are studied and focused on the method which is relatively used to enhance the performance and transformation efficiency in the analysis of vibrations. From all the above methods the piezo electric energy harvesting is the one which is suitable for analysis of vibration since the deflection of a specimen using piezo electric material results in an electric displacement. This electricity can be used in storage of power in batteries or used to power portable devices.

1. Introduction
Harvesting of energy is one of the productive ways of responding to the shortage of energy and to produce feasible power sources from the environment. The energy scavenging technology accumulate electrical energy from scavenged sources of energy, that always exist in surrounding environment, such as in light, wind, fluids, vibrations. Energy scavenging systems was first investigated by integrating into a biological environment by Hausler and Stein in the year 1984, who published a paper suggesting the
use PVDF films to integrate the implantable physiological power supply. Vibration of a system cannot be destroyed but can be reduced or converted to energy using appropriate methods considerable amount of work had been carried out by various investigators on energy harvesting. Some of these attempts are discussed below:

Priyanka Guin et al [1] performed Investigation on the Load Characteristics of Piezo film-based Energy experimental based. Abhishek Mallick et al [2] proposed a method for converting mechanical vibration in to electrical energy. In this an unnatural vibrator is fabriceted and modeled to simulate and analyze the ambient vibrations. They suggested a method which generates highest power from the parallel combination of films, indicating that a Piezo film vibrator acts as a source of power from their study on varying load characteristics. Henry A sodana et al [3] suggested and reviewed power harvesting from vibration using Piezo electric Materials. Majid Tabash et al [4], proposed a device using a piezoelectric bimorph which is made up of a composite namely Macro Fiber Composite (MFC), from an oscillating motion it can generates electricity. The device consists of a fan blade, which adjusts with the direction of the wind and moves a rod in vertical direction. Robert Andosca et al [5] proposed a mathematical analysis with the mass loading which is combined with the experimental confirmation on a multi-morph cantilever PZEH in detail. Min-Gyu Kang et al [6], In this survey paper, gives an overview of PZT which is a metallic oxide based piezoelectric material and the energy harvesting devices in their advanced progress. Ashwani Kumar et al [7], reviewed the vibration energy harvesting from different model configurations. and also, they have brushed up some papers in order to examine the various techniques through which efficiency of a piezoelectric energy harvester can be bettered. Dhananjay Kumar et al [8] proposed the prototype and designed an energy harvester and the circuit-based power conditioning. The extracted power out of the piezoelectric tile has been optimized in this presentation. Action Nechibvute et al[9] presents a review on how to power wireless sensors as a renewable energy resource by using the micro generators and nano generators made up of piezoelectric materials. Renato Calio et al [10] they focus on harvesting techniques using piezoelectric motion. Ashok K.Batra et al [11] proposed an energy harvesting devices for industrial and biomedical applications. Junlei Wang et al [12] proposed a method by investigating the installment direction of the proposed bluff bodies and understand the system performance by the effect of the bluff body’s in upwind direction. This consideration including the performance comparison, parametric study, and physical insight explanation in order to improve the effectiveness which makes them to perform comprehensive wind tunnel experiments and to study computational fluid dynamics (CFD). An innovative wind energy harvesting technology is proposed, through their study for structural health monitoring the low-power sensor can be applied.

In present paper, a comprehensive study of various energy harvesting methods and devices has been reviewed and proposed the method which is suitable for vibration analysis, present and future applications of energy harvesting are also discussed

2. Energy Harvesting Through Mechanical Vibrations

This paper deals with initially the sorts of Energy Harvesting, The essential components of energy harvesting and strategies. Later deals with the Mechanical Vibrations and the last targeted on how will the primary one associated with the later. Coming back to the primary the subsequent are varied means of energy harvesting.

The main design goals of energy harvesting are

a) Choose terribly tiny power electronics

b) Accumulate energy and store energy with efficiency
3. Elements of Energy Harvesting

The basic elements of energy harvesting method are

3.1 Source of Energy
As there are many ambient energy sources for energy harvesting method one can apt anyone of the energy sources based upon their harvesting system. Wind energy, solar energy, Radio frequency waves, thermal energy are some of the examples of ambient energy sources.

3.2 Integrated Chip
This Integrated chip transforms ambient energy into some form of energy which may be accumulated in energy storage devices. Mechanical stress transforms into electrical signal, temperature into electrical voltage are some of the examples how this integrated chip works.

3.3 Storage of Energy
Energy can be stored in the form of rechargeable batteries and lower power electronic devices like capacitors, super capacitors etc by various ways. Smaller size, higher efficiency, high capacity are the
characteristics of Super capacitors. Memory, actuators, communication interface, sensors, processing and control device such as microcontroller etc are the other components of energy harvesting device.

4. Energy Harvesting Methods

The different types of energy accumulating/harvesting methods are Thermoelectric or photo voltaic Method.
- Piezoelectric Method.
- Radio Frequency Method.
- Wind energy Method.
- Pyro Electric Method.

4.1 Thermoelectric Energy Harvesting or Photo Voltaic Method

In this harvesting method the ambient solar energy transforms the temperature differences into an equivalent electric voltage or electric current over the material. One can notice the difference in temperature on both sides i.e warmer and colder sides of crystal which causes voltage across the crystal device. When difference in temperature remains, unchanged steady voltage is available. To generate tiny amount of energy any light source can be used. For example, other than solar energy any artificial lights produce along with photons a 60 HZ signal. Photovoltaic devices usually are made up of silicon which transforms solar radiation into electric current where solar radiations are generated from sun energy. Examples of thermo electric energy harvesting systems are equipped with Cars, trucks and Lorries which have good amount of fuel savings.
4.2 Piezoelectric Method

In this method mechanical stress is transformed into electrical Signal. The charge gets accumulated in solid materials by applying the mechanical strain and the converse mechanical strain will also accumulated in solid materials when subjected to electrical field. Low frequency vibrations, acoustic noise, human motion etc are the common sources that have been utilized by Piezoelectric harvesting which are usually harvested by Piezo electric materials. Piezo electrical floor tiles, Automobile Car tire sensors or monitors, Battery less devices are some of the examples.

4.3 Radio Frequency Method

In this Radio frequency waves/ electromagnetic waves imparted from varied diverged wireless sources like TV, radio, cellular towers into an equivalent electric voltage. This methodology employs the ambient RF waves reached due to radiations from mobile base stations, satellites, TV and radio broadcasting stations. By using matching and rectifier circuits this Electromagnetic harvester transforms Radio Frequency energy into Direct Current energy for storage.
4.4 Wind Energy Method

In this Vibration energy which depends upon amplitude and frequency is transformed into electric signal which includes wind power also. As vibrations are made up of number of fundamental frequencies and their harmonics the mass of harvesting device is equivalent to mass of vibrating system. This phenomenon is utilized in different ways which includes piezoelectric conversion used in materials like PZT, BaTiO₃, PVDF, Electrostatics conversion using parallel plate capacitor and electromagnetic conversion using electromagnetic field and coil.

4.5 Pyroelectric Method

In this temperature difference is transformed into an equivalent electric charge. It produces electric charge when the temperature of crystal material changes and when temperature remains constant no charge is accumulated. This method is used in certain sensors and thus it is preferable to harvest low grade thermal energy at low temperatures.

5. Mechanical Vibrations

Now the discussion will be focused on Vibrations analysis. Vibration of a system cannot be destroyed but can be reduced or converted to energy using appropriate methods. Vibration is the measure of oscillations over a period about a point which is in equilibrium. One should be alert to vibrating...
systems such as structural elements like beams, waves in strings, plates and streams, vibration isolation, critical speeds, rotating and reciprocating machinery balancing. Vibrations can be caused by one or more factors at any given time, the commonly imbalance, misalignment, wear and looseness, Forces. Mechanical Vibrations are classified into three types, depending on the nature of the vibrations: Torsional Vibration, Axial or Longitudinal Vibration, Lateral Vibration. The vibration characteristics are based on to what extent (amplitude or intensity), and to what speed (frequency) the object moves helps in determining its vibration characteristics. Frequency, amplitude and acceleration are the terms used to describe the vibration movements. To sense and measure the level of vibrations a typical vibration measurement system is considered. An accelerometer is a sensor which measures the acceleration of a physical device dynamically as an electric voltage. The different ways to reduce and control the vibrations

Minimize them.
Accommodate them.
Determine the disturbing frequencies.
Determine the system inertia.
Determine the maximum allowable natural frequency
Determine the required coupling spring rate.
Select the appropriate coupling.

By considering the Mechanical vibrations in this paper focussed on how can Power harvesting applied in the field of vibrations. This leads in search of research that has been carried away on the recent progress in wireless technical devices and low-power electronic devices such as micro electromechanical systems. The advances for energy harvesting systems allowed in practical applications in real world. Out of all the various types discussed above the use of piezo electric materials found to be the one which is to exploit on the ambient system that has seen a substantial rise in use of harvesting of energy.

5.1 Piezo Electric Materials

Piezoelectric materials are the solid materials which have a crystalline structure that gives them with the flexibility to transform the accumulated mechanical strain energy in the specimen into electrical charge and, piezo electric materials have opposite effect that to transform an accumulated applied electrical charge into mechanical strain. This property makes these materials with the flexibility to acquire the ambient mechanical energy, usually deflection by applied mechanical stress, and transforms into voltage that can be used to power different devices. The effect of piezo electric materials has two main domains:

the primary is that the direct piezoelectric effect which is defined as the ability of materials to transform the applied mechanical stress into an electrical charge.the second kind is that an opposite effect, that is the ability to transform an accumulated applied electrical charge into mechanical strain energy. As a method of accumulating energy from the environment the almost misuse of electricity materials takes place in many cases and it becomes necessary that the generated energy which was stored be reused. If not scavenging a big quantity of energy, the facility of harvesting the energy system will not be a possible power source for power electronics. During this paper focuses on the analysis work that has been exhausted the realm however the power harvesting associated with vibration analysis Williams and Yates (1996) planned a tool that generated electricity once installed during a vibratory setting. For their analysis, an electromagnetic force transducer was chosen. Umeda et al. (1997) continued their investigation on piezo generator with a bridge rectifier and electrical condenser and studied the various characteristics of energy storage. by a. Kasyap et al. (2002) proposed a lumped element model (LEM) victimization constant circuit model to explain the facility generated from cantilever beam with a piezoelectric component connected by inducing forced vibration. If one considers the damping effect that plays a distinguished role in vibration analysis that once a power
harvesting system is interpreted into a structure in which energy was removed within the form of an electric charge. As a result of energy is far from the structure, it should see some impact on its dynamics.

6. Result & Discussion

The excellent study of Energy harvesting in the field of vibration analysis determines that the amount of power accumulated in the harvesting devices was proportional to the cube root of the vibration frequency. It is applicable to all or any machine elements so as to convert frequencies to the amount of power generated by using the piezo electric device which acts as energy harvesting device.

\[ P = \sqrt[3]{F} \]

7. Conclusion & Future Scope

As avoiding of vibrations in any device or machine is impossible task one can reduce the vibrations and those can be accumulated and transformed into an electric charge. As it is application of energy harvesting in the field of vibration analysis what are various methods of harvesting and how it can be transformed were discussed in this paper. The future scope of energy harvesting technology is its application to various structures like beams, machines, automobiles, turbines etc., analyze how can be energy stored and can be scavenged. The future goals of energy harvesting are as follows

- Self-Powered Electronics
- Rechargeable Batteries
- Portable Electronics
- MEMS.

Limitation

Power generated by piezoelectric materials is used for low power electronics.

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Acknowledgement:

As it is an application of energy harvesting in the field of vibration analysis I thank and acknowledge the authors of above references for their ideas which creates an interest to select this upcoming technology as my research area.