Energy Harvesting via Piezoelectricity

Tanvi Dikshit¹, Dhawal Shrivastava², Abhijeet Gorey³, Ashish Gupta⁴, Parag Parandkar⁵, Sumant Katiyal⁶

¹,²,³,⁴,⁵ChameliDevi Institute of Technology and Management, ⁶School of Electronics, DAVV, Indore
¹tanvi.d27@gmail.com, ²shrivastava.dhawal@gmail.com, ³abhijeetgorey2006@gmail.com, ⁴ashishgupta72@rediffmail.com, ⁵p_paragp@yahoo.com, ⁶sumant578@yahoo.com

ABSTRACT
In the present era, although wireless data transmission techniques are commonly used in electronic devices, but they still suffer from wires for the power supply or from batteries which require charging, replacement and other maintenance. For example, in the applications such as villages, border areas, forests, hilly areas, where generally remote controlled devices are used continuous charging of the microcells is not possible by conventional charging methods. Thus there should be some alternative to keep the batteries full time charged and to avoid the need of any external energy source to charge these batteries. Thus energy harvesting is an essential issue that should be undertaken to resolve such problems. There are many energy harvesting techniques but one of the most promising techniques is mechanical energy harvesting e.g. by piezoelectric components where deformations produced by different means is directly converted to electrical charge via direct piezoelectric effect. Subsequently the electrical energy can be regulated or stored for further use. This research paper proposes Piezoelectricity as an Alternate Energy Source. The motive is to obtain a pollution-free energy source and to utilize and optimize the energy being wasted. In this paper we have mainly concentrated on two techniques to harness the energy, that are Piezoelectric Windmill and Increased bandwidth piezoelectric crystal. In this paper, we have also described the working principle of piezoelectric crystal and various sources of vibration for the crystal.

KEYWORDS
Energy Harvesting, Piezoelectricity, Piezoelectric Windmill, Increased bandwidth piezoelectric crystal.

1.0 INTRODUCTION
Energy harvesting has been a topic of discussion and research from around three decades. With the increasing energy needs, finding and exploiting more and more energy sources has become a need of the day. Energy harvesting is the process by which energy is derived from external sources and utilized to drive the machines directly, or the energy is captured and stored for future use. Some traditional energy harvesting schemes are solar farms, wind farms, tidal energy utilizing farms, geothermal energy farms and many more. With the advent of technology, utilization of these sources has increased by leaps and bounds [5]. When viewed on a large scale, energy harvesting schemes can be categorized as shown in Table I.

<table>
<thead>
<tr>
<th>Types of Energy Harvesting Schemes</th>
<th>Energy Source</th>
<th>Solution</th>
<th>Ultimate Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro</td>
<td>Renewable sources like solar, wind, tidal etc.</td>
<td>Energy Management solutions</td>
<td>Reduce oil dependency</td>
</tr>
<tr>
<td>Micro</td>
<td>Small scale sources like vibration, motion, heat etc.</td>
<td>Ultra-low-power solutions</td>
<td>Driving low energy consuming devices</td>
</tr>
</tbody>
</table>

Piezoelectric Energy Harvesting is a new and innovative step in the direction of energy harvesting. Not many researches have been carried out till now in this field, hence it is a challenging job to extract energy from piezoelectricity. Through this research paper, we will describe the basic working of a piezoelectric crystal. Then later in the paper, we have proposed the idea of combining energy from a number of piezoelectric crystals to obtain higher voltages. Certain ways of implanting the crystals at different places have also been sited in the paper. Piezoelectric crystals can be utilized to obtain voltages of very small values and hence can drive low voltage devices. Hence, Piezoelectric Energy Harvesting comes under the category of Micro scale energy harvesting scheme.

2.0 WORKING PRINCIPLE
The piezoelectric effect is a special material property that exists in many single crystalline materials. Some such crystalline structures are Quartz, Rochelle salt, Topaz, Tourmaline, Cane sugar, Berlinitre (AlPO₄), bone, tendon, silk, enamel, dentin, Barium Titanate (BaTiO₃), Lead Titanate (PbTiO₃), Potassium Niobate (KNbO₃), Lithium Niobate (LiNbO₃) etc.[4] There are two types of piezoelectric effect, direct piezoelectric effect and inverse piezoelectric effect. The direct piezoelectric effect is for materials generating electric potential when mechanical stress is applied and the inverse piezoelectric effect implies materials deform when an electric field is applied. The energy harvesting via Piezoelectricity uses direct piezoelectric effect. The phenomenon will be clear from the diagram shown in
The output voltage obtained from a single piezoelectric crystal is in millivolt range, which is different for different crystals. And the wattage is in microwatt range. So in order to achieve higher voltages, the piezoelectric crystals can be arranged in series. The energy thus obtained is stored in lithium batteries or capacitors. This is the working principle behind piezoelectric energy harvesting system. Now the extreme engineering lies in optimization of piezoelectric energy, which is done in various ways. A lot of studies are being carried out in order to know which crystal will be the best to obtain maximum output voltage, what should be the structure of piezoelectric component, which type of circuit should be used at the output terminals of piezoelectric crystal in order to have maximum wattage [3]. In the section ahead, we have mentioned a number of sources of vibration which are already being used for piezoelectric energy harvesting and a new idea in this direction has been proposed by us.

3.0 SOURCES OF VIBRATION FOR CRYSTAL

3.1 PREVIOUS WORK

A. POWER GENERATING SIDEWALK

The piezoelectric crystal arrays are laid underneath pavements, side walks and other high traffic areas like highways, speed breakers for maximum voltage generation. The voltage thus generated from the array can be used to charge the chargeable Lithium batteries, capacitors etc. These batteries can be used as per the requirement.[4]

B. POWER GENERATING BOOTS OR SHOES

An idea is being researched by DARPA in the United States in a project called Energy Harvesting, which includes an attempt to power battlefield equipment by piezoelectric generators embedded in soldiers' boots. [4] However, these energy harvesting sources by association have an impact on the body. DARPA's effort to harness 1-2 watts from continuous shoe impact while walking were abandoned due to the discomfort from the additional energy expended by a person wearing the shoes.

C. GYMS AND WORKPLACES

Researchers are also working on the idea of utilizing the vibrations caused from the machines in the gym. At workplaces, while sitting on the chair, energy can be stored in the batteries by laying piezoelectric crystals in the chair. Also, the studies are being carried out to utilize the vibrations in a vehicle, like at clutches, gears, seats, shock-ups, foot rests.

D. MOBILE KEYPAD AND KEYBOARDS

The piezoelectric crystals can be laid down under the keys of a mobile unit and keyboards. For the press of every key, the vibrations being created can be used for piezoelectric crystal and hence can be used for charging purpose.[6]

E. FLOOR MATS, TILES AND CARPETS

A series of crystals can be laid below the floor mats, tiles and carpets which are frequently uses at public places.

F. PEOPLE POWERED DANCE CLUBS

In Europe, certain nightclubs have already begun to power their night clubs, strobes and stereos by use of piezoelectric crystals. The crystals are laid underneath the dance floor. When a bulk of people use this dance floor, enormous amount of voltage is generated which can be used to power the equipments of the night club [5].

3.2 PROPOSED WORK

A. PIEZOELECTRIC WIND MILL

In order to energize low power consuming devices, microcells are invariably used. But these microcells need to be charged once they get discharged. Hence if the devices are placed at remote places like villages, border areas, forests, hilly areas, then continuous charging of the microcells is not possible by conventional charging methods. In such cases, we have options like solar energy and wind energy. But cloudy days and rains restrict the use of solar energy. So, wind energy seems to be a better option. [1] The idea about a Piezoelectric Wind mill will be clear from Fig.3. The piezoelectric wind mill that we have proposed consists of a fan with three blades to effectively capture the wind flow. A lever arm is connected to the windmill fan rotor and a translator is connected with this lever arm to convert rotational motion into translatory motion. A disc is connected at the lower end of translator, such that whenever it moves upwards and downwards, it compresses the piezoelectric crystals. Hence for different speeds of wind also, that is for different frequencies, the Piezoelectric Wind mill may function. Hence, it has higher workable bandwidth. The constant compression of piezoelectric crystals causes a huge amount of energy to be
generated, which can drive the remotely placed low power consuming devices. [2] Hence, the concept of Piezoelectric Wind mill can be used to harness piezoelectric energy very efficiently and effectively.

B. INCREASED BANDWIDTH PIEZOELECTRIC CRYSTAL

In order to increase the workable bandwidth, i.e. in order to use piezoelectric crystals over a wide range of vibrations, we are proposing a new method. If in place of a single energy source, we make use of more than one, then the efficiency of harvesting system will definitely increase. Hence, we are making use of two energy converting techniques, one is the piezoelectric crystal and other is the electromagnetically induced voltage. Fig. 4 gives the structure of such type of system.[7]

The system consists of a flexible strip, over which the piezoelectric crystals are mounted and at one end of the strip, a magnet is mounted. This magnet lies inside a stationary coil. At times, when intensity of vibration is high, voltage is obtained from piezoelectric crystals. Hence, at higher frequencies, piezoelectric crystals give the output. When intensity of vibration is less, the piezoelectric crystals do not give a considerable output. At lower frequencies, the magnet moves inside the stationary coil. This motion causes electromagnetic flux to be generated and hence an output voltage is obtained.

4.0 OUTPUT STAGE OF PIEZOELECTRIC ENERGY HARVESTING SYSTEM

The output of a piezoelectric crystal is AC. In order to use this voltage for low power consuming electronic devices, it has to be first converted into digital signal.[2] This is done with the help of AC to DC converter as shown in Fig. 5.

Fig. 5 shows a simple diode rectifier to convert AC to DC. The voltage obtained from piezoelectric device is analog, which is converted into digital by the rectifier. This is stored into a capacitor, which gets charged up to a pre-decided value, at which the switch closes and the capacitor discharges through the device. In this way, the energy can be stored in the capacitor, and can be discharged when required. But the energy harvesting capacity of this circuit is not appreciable. Hence, a DC to DC converter is used after bridge rectifier stage, which has been demonstrated in Fig. 6. The addition of DC-DC converter has shown an improvement in energy harvesting by a factor of 7.

A non-linear processing technique “Synchronized Switch Harvesting on Inductor” (SSHI) was also proposed in 2005 for harvesting energy[7]. It consists of a switching device in parallel with the piezoelectric element. The device is composed of a switch and an inductor connected in series. The switch is in open state except when the maximum displacement occurs in the transducer. At that instant, the switch is closed and the capacitance of the piezoelectric element and inductor together constitute an oscillator. The switch is kept closed until the voltage on the piezoelectric element has been reversed. This circuit arrangement of the output circuit is said to have a very high energy harvesting capacity. Fig. 7 shows the SSHI technique[6].
5.0 FUTURE SCOPE

Through this paper, we wanted to introduce the concept of Piezoelectric Energy Harvesting. Our future plan is to build a practically working model using this concept. We have planned about making a piezoelectric crystal. Later, we will carry out a study of a variety of piezoelectric crystals, and make a comparison between them, so that we get the best performing crystal. Using this crystal, we will design a circuit or a project, which will harness the output of this crystal.

6.0 CONCLUSION

One method of performing power harvesting is to use PZT materials that can convert the ambient vibration energy surrounding them into electrical energy. This electrical energy can then be used to power other devices or stored for later use. This technology has gained an increasing attention due to the recent advances in wireless and MEMS technology, allowing sensors to be placed in remote locations and operate at very low power.[7] The need for power harvesting devices is caused by the use batteries as power supplies for these wireless electronics. As the battery has a finite lifespan, once extinguished of its energy, it has to be recharged. Charging of batteries in order to provide energy to the electronic devices in the applications such as borders or hilly regions is a tedious job to do. Through this paper, we have proposed two new ways of harnessing the piezoelectric energy. Also, we have summed up in brief the work, which has been carried out till now in the field of Piezoelectric Energy Harvesting. The idea of Piezoelectric Windmill will solve the problem of continuous microcell charging in the devices being used at remote places or in rough terrains. The concept of combining two energy sources has been proposed in the paper. We have combinedly used the piezoelectric energy and electromagnetic energy. So these two ideas can greatly help in harnessing the piezoelectric energy.

7.0 REFERENCES


