Energy collection via Piezoelectricity

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Abstract. In the present days, wireless data transmission techniques are commonly used in electronic devices. For powering them connection needs to be made to the power supply through wires else power may be supplied from batteries. Batteries require charging, replacement and other maintenance efforts. So, some alternative methods need to be developed to keep the batteries full time charged and to avoid the need of any consumable external energy source to charge the batteries. Mechanical energy harvesting utilizes piezoelectric components where deformations produced by different means are directly converted to electrical charge via piezoelectric effect. The proposed work in this research recommends Piezoelectricity as a alternate energy source. The motive is to obtain a pollution-free energy source and to utilize and optimize the energy being wasted. Current work also illustrates the working principle of piezoelectric crystal and various sources of vibration for the crystal.

1. Introduction

Energy harvesting has been a topic of discussion and research for three decades. With the ever increasing and demanding energy needs, unearthing 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 [1]. When viewed on a large scale, energy harvesting schemes can be categorized as shown in Table 1.

Table 1. Types of Energy Harvesting Schemes.

Type of Energy Harvesting	Energy Source	Solution	Ultimate Goal
Macro	Renewable sources like solar, wind, tidal etc.	Energy Management solutions	Reduce oil dependency
Micro	Small scale sources like vibration, motion, heat etc	Ultra-low- power solutions	Driving low energy consuming devices

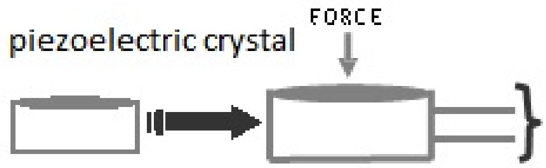

Figure 1. Principle of direct piezoelectric effect.

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 cited 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. Working principle of piezoelectric energy harvesting

The piezoelectric effect is a special material property that exists in many single crystalline materials. Examples of such crystalline structures are Quartz, Rochelle salt, Topaz, Tourmaline, Cane sugar, Berlinite ($AIPO_4$), Bone, Tendon, Silk, Enamel, Dentin, Barium Titanate ($BaTiO_3$), Lead Titanate ($PbTiO_3$), Potassium Niobate ($KNbO_3$), Lithium Niobate ($LiNbO_3$) etc.[2]. There are two types of piezoelectric effect, direct piezoelectric effect and inverse piezoelectric effect. The direct piezoelectric effect is derived from materials generating electric potential when mechanical stress is applied and the inverse piezoelectric effect implies materials deformation 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 figure 1, figure 2 shows the structure of a piezoelectric component being used for energy harvesting.The output voltage obtained from a single piezoelectric crystal is in milli volts 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 cascading manner, that is, 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. Sources of vibration for crystal previous work

In this section , 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.

3.1. Power generating sidewalk

The piezoelectric crystal arrays are laid underneath pavements, sidewalks and other high traffic areas like highways, speed breakers for maximum voltage generation. The voltage thus generated

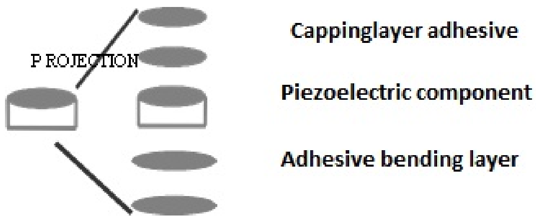

Figure 2. Structure of a piezoelectric component.

from the array can be used to charge the chargeable Lithium batteries, capacitors etc. These batteries can be used as per the requirement [3].

3.2. Power generating boots or shoes
In United States Defense Advance Research Project Agency (DARPA) initiated a innovative project on Energy harvesting which attempts to power battlefield equipment by piezoelectric generators embedded in soldiers' boots [3]. However, these energy harvesting sources put 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.

3.3. 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.

3.4. Mobile keypad and keyboards
The piezoelectric crystals can be laid down under the keys of a mobile unit and keyboards. With the press of every key, the vibrations created can be used for piezoelectric crystal and hence can be used for charging purpose [4].

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

3.6. 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].

4. Proposed work
In this section , we propose two methods.

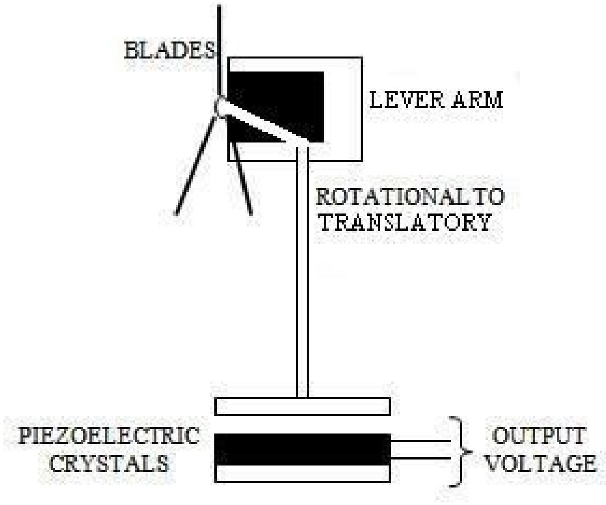

Figure 3. Piezoelectric wind mill.

4.1. Piezoelectric wind mill

In order to energize low power consuming devices, microcells are invariantly 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, alternative options like solar energy and wind energy can be utilized. But cloudy days and rains restrict the use of solar energy. So, wind energy comes out to be the best alternative [6]. The idea about a piezoelectric wind mill will be clear from figure 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 comfortably 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.

4.2. Increased bandwidth piezoelectric crystal

In order to increase the workable bandwidth, that is, in order to use piezoelectric crystals over a wide range of vibrations, we are propose 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. figure4 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.

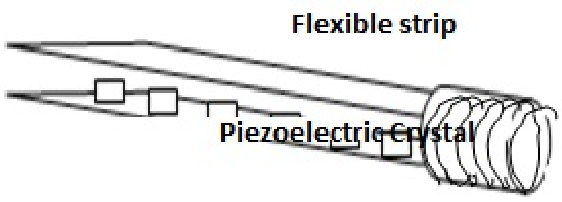

Figure 4. Piezoelectric crystals and electromagnetic energy.

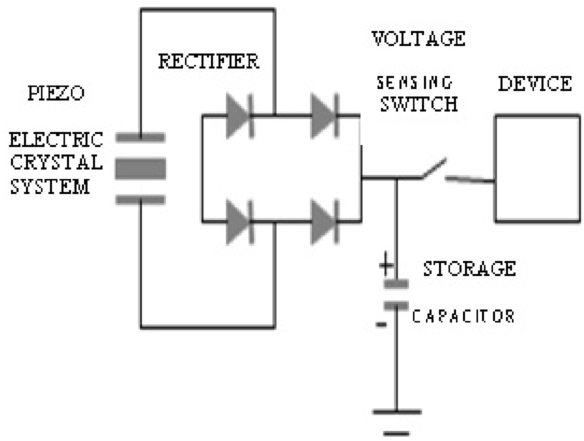

Figure 5. Bridge rectifier type AC to DC converter.

5. Output stage of piezoelectric energy harvesting system

The output of a piezoelectric crystal is alternating signal. 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 figure 5. Figure 5 shows a simple diode rectifier to convert AC to DC. This is followed by a capacitor, which gets charged by the rectifier upto a pre-decided voltage, 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 figure 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. Figure 7 shows the SSHI technique [6].

6. Implementation

Experimentation has been done on a Piezo-crystal and it is tested with a Light Emitting Diode (LED). The two terminals of the LED are connected with the two terminals of the crystal. Choice

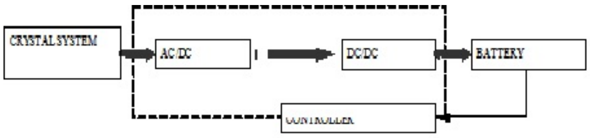

Figure 6. Energy harvesting circuit.

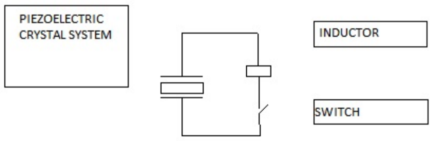

Figure 7. SSHI (Synchronized switch harvesting on inductor) technique.

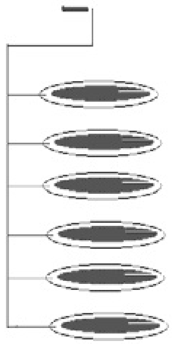

Figure 8. Series and parallel combination of crystals.

of Blue LED is being made for experimentation. Single stroke on the crystal blows blue LED with full intensity. Measured values of output voltage and current from the crystal come out to be 3.5 Volt and 100 milliamps. The only shortcoming of this using a single crystal and a LED was that both the voltage and current obtained exists instantaneously. To increase the range of voltage and current output, an assembly of 6 crystals in series and 6 such series has been put in parallel. When number of voltage sources are put in series, then the net voltage increases, while when a number of voltage sources are put in parallel, then the strength of signal, that is, current increases. This is the concept used behind the assembly. The output of parallel connection is fed to the current amplifier for signal strengthening and the output of series connection is fed to the amplifier for biasing purpose and also to the voltage amplifier. The assembly has been put under a doormat and the output obtained from amplifier has been very encouraging which was around 6 V voltage and 1 ampere current. This magnitude of voltage and current can be certainly used to charge a battery. Figure 8 shows the assembly used in our system.

7. Cost effectiveness

The assembly developed using series and parallel combination of piezo-crystals is very cost effective. A single crystal costs around 23 - 25 Rupees, and hence the cost of whole assembly is very less. It is very encouraging to get a good voltage and current at such a low cost at the same time is utilized.

8. Conclusion

The method used to perform 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 of batteries as power supplies for these wireless electronics. As the battery has a finite lifespan, recharging needs to be done once discharged. 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. Implementation aspects focus on the practical work carried out in this field of piezoelectric energy harvesting. The idea of piezoelectric windmill will solve the problem of continuous microcell discharging in the devices being used at remote places or in rough terrains. The concept of combining two energy sources piezoelectric energy and electromagnetic energy has been proposed in the paper. So these two ideas can greatly help in harnessing the piezoelectric energy thereby improve the results of the system.

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