IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 3, June-July, 2014
ISSN: 2320 – 8791 (Impact Factor: 1.479)
www.ijreat.org

'Piezoelectric Charger': Energy Harnessing Technique

Arun kumar Gangwar[1], Farheen Chishti[2]

[1]Assistant Professor, Electrical Engineering Department, Invertis University, Bareilly, India

[2]Assistant Professor, Electrical Engineering Department, Shri Ram Murti Smarak Women's College of Engineering & Technology, Bareilly, India

Abstract

In the present era, batteries require charging, replacement and other maintenance efforts. 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. So, some alternative methods needs 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. To resolve such problems, energy harvesting technique is proposed as the best alternative. There exists variety of energy harvesting techniques but mechanical energy harvesting happens to be the most prominent. This technique utilizes piezoelectric components where deformations produced by different means are directly converted to electrical charge via piezoelectric effect. Subsequently the electrical energy can be regulated or stored for further use. The proposed work in this research recommends 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 a setup is being proposed that contains few piezoelectric sensors which will be able to generate sufficient amount of voltage by the application of strain on them. The aim is to design a system such that its application will be user friendly, flexible and can be versatile.

Keywords: Energy harvesting, piezoelectric effect, charging

1. Introduction

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 [4]. When viewed on a large scale, energy harvesting schemes can be categorized as shown in Table 1.

Table-1

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

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

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 ($AlPO_4$), Bone, Tendon, Silk, Enamel, Dentin, Barium Titanate ($BaTiO_3$), Lead Titanate ($PbTiO_3$), Potassium Niobate ($KNbO_3$), Lithium Niobate ($LiNbO_3$) etc.[6]. 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 Fig.1

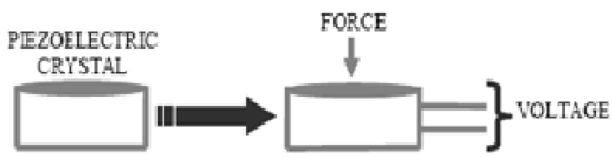

Fig 1: Principle of direct piezoelectric effect

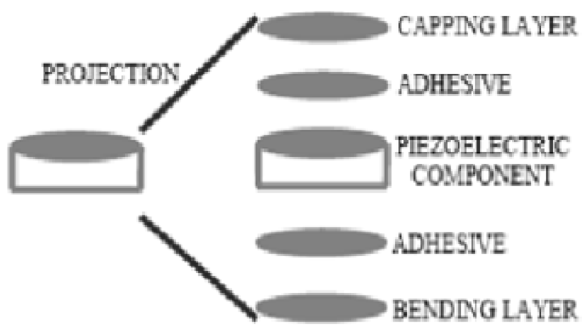

Fig 2: Structure of Piezoelectric component

Fig.2 shows the structure of a piezoelectric component being used for energy harvesting. The output voltage obtained from a single piezoelectric crystal is in millivolts 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 [6].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. In the next 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 by us.

3. Sources of Vibration for Crystal

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 from the array can be used to charge the chargeable Lithium batteries, capacitors etc.

3.2 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 equipment's of the night clubs [3].

3.3 Vehicles Passing Speed Breakers

Speed breakers installed at locations where there is mass movement of vehicles can be used as a source of energy by the application of piezoelectric devices.

3.4 Rail Tracks Can Be Made A Source.

By proper measurement of force and balancing it, rail tracks can be used as a medium to provide high fluctuations of force to piezoelectric crystals. This can be done by using proper force absorbers.

4. Proposed Concept

4.1 Piezoelectric Charger

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. So by the use of translatory motion of vehicles or objects, the developed force can be used for charging batteries.
The piezoelectric charger consists of an array of crystals that are arranged in a unique fashion. Arrangement is shown in Fig 3 .This arrangement is made such that it satisfies the current and power rating of the battery that is being charged. Here we focus our aim to charge a mobile battery. The application of force on the crystal

arrangement generates a sufficient amount of force which produces alternating voltages at discrete interval of times. These voltages are utilized by using them to charge the battery.

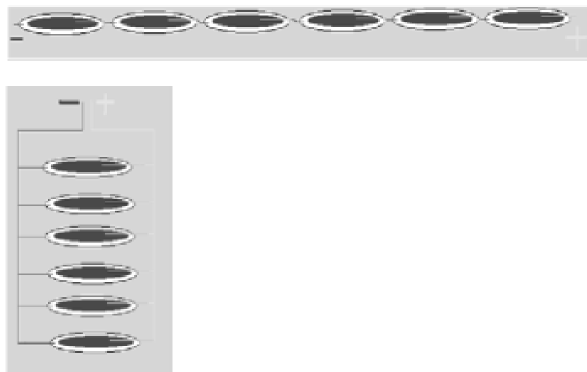

Fig 3: Series and parallel combination of crystals

4.2 Source Specifications & Improvement in Design

To obtain suitable amount of output we require the piezoelectric source that gives good amount of output. By analyzing the availability and cost effectiveness, PZT (Lead Zirconium Titanate) is the best available source in the market with good efficiency. It has crystal structures belonging to the perovskite family with the general formula AB03. In the Fig. 4 the ideal, cubic perovskite structure is shown. PZT crystallites are centro-symmetric cubic (isotropic) before poling and after poling exhibit tetragonal symmetry (anisotropic structure) below the Curie temperature [2].

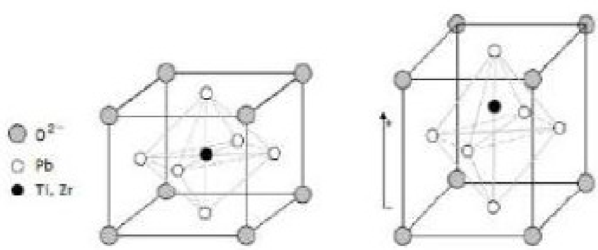

Fig 4 Lattice structure of PZT

Before poling, a piezoelectric ceramic material consists of small grains (crystallites), each containing domains in which the polar direction of the unit cells are aligned. These grains and domains are randomly oriented; hence the net polarization of the material is zero, i.e. the ceramic does not exhibit piezoelectric properties. The application of a sufficiently high DC field (called poling process) will orient the domains in the field direction and lead to a polarization of the material [5].

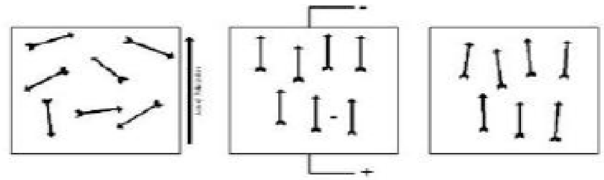

Fig 5 Polarization effect

In order to increase the workable bandwidth, that is, 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 internal structure of such type of crystal.

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.

5. Circuit Implementation

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 DC signal. This is done with the help of AC to DC converter.

A simple diode rectifier is used to convert AC to DC. This is followed by a capacitor, which gets charged by the rectifier up to 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. The addition of DC-DC converter has shown an improvement in energy harvesting by a factor of 2 or even more.

The DC-DC Convertor in the circuit is modified such that it need not require any external energy source as it was required for the functioning of switching operation.

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 [1].This is the concept used behind the assembly. The basic block diagram is shown in Fig. 6.

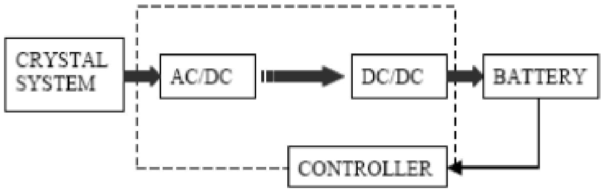

Fig 6 Basic Block diagram of System

For implementing the hardware of the charger it was supposed to simulate the above idea and hence we assumed a voltage source of 3V (a.c supply) to ease our understanding. The simulation is done in LTSPICE and the results were promising. The circuit diagram of dc-dc convertor is shown in Fig 7.

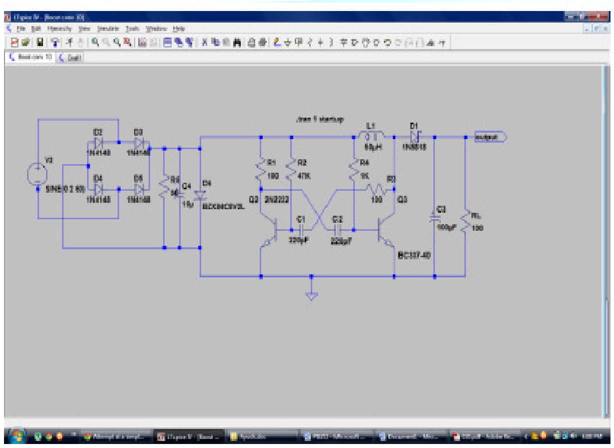

Fig 7 Equivalent circuit model

The output waveform of dc-dc convertor is shown below.

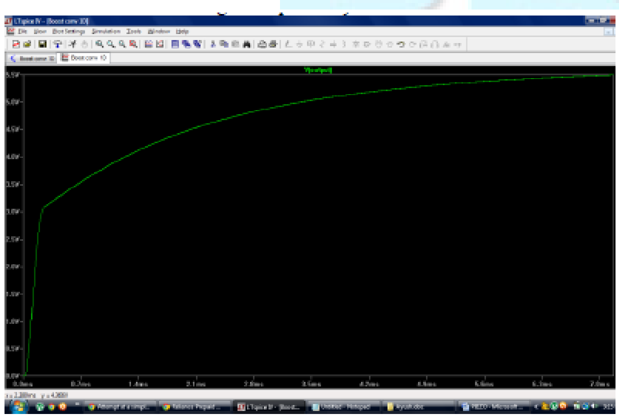

Fig 8 Output of System

6. 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. 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 focuses on the practical work carried out in this field of Piezoelectric Energy Harvesting. The idea of Piezoelectric Charger will solve the problem of continuous microcell discharging in the devices being used at remote places or in rough terrains. We are making efforts in improvement of design by enhancing the voltage regulation of rectifier. So the concept can be very useful in harnessing energy.

References

[1]. E. P. EerNisae, C, E. land, and J. B. Snelling, Sandia Laboratories, Albuquerque, NM 87U5

[2]. Proceedings of the Institute of Radio Engineers, Volume 18, Number 123 ,December 1980 Summary Of Piezo-Electric Crystal Conference, held by U. S. Navy department, December 3-4, 1929

[3].Steven R. Anton and Henry A. Sodano, A review of power harvesting using piezoelectric materials (2003-2006), Smart Materials and Structures 16 (2007).

[4].U. K. Singh and R. H. Middleton, “Piezoelectric power scavenging of mechanical vibration energy” Australian Mining Technology Conference, 2-4 Oct. 2007, pp. 111-118.

[5]. R. D’hulst, and J. Riesen ,k.u.leuven, esat-electakasteelparkarenberg 10, 3001 leuven, belgium, “Power Processing Circuits For Vibration-Based Energy Harvesters “

[6]. C. S. Brown, b.sc, R. C. Kell, b.sc, a.inst.p., associate member, R. Taylor, m.a.,ph.d., b.sc, f.inst.p., f.i.m., and l. A. Thomas, b.sc, f.inst.p., associate member. “Piezoelectric Materials (A Review Of Progress)”.