ENERGY HARVESTING THROUGH PIEZOELECTRICITY

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ABSTRACT
In this digital era, techniques of wireless transmission of data are frequently employed in many electronic devices. To power the connection, there needs to be the supply of power through wires as the medium; similarly, the power can also be supplied by batteries. Batteries require maintenance efforts such as charging and cleaning. For instance, in setups such as remote villages, areas near the borders, jungles and hilly or mountainous areas, where it is generally suitable to deploy devices that are remote controlled, regular charge replenishment for microcells may not always be possible if a person is heavily reliant on conventional methods of charging. Therefore, it is highly advisable to develop alternative ways to keep the microcells charged all the time and to eliminate the necessity for other sources of external energy to charge up the microcells. To resolve such challenges, the harvesting of energy technology is perceived as a feasible alternative. A wide array of techniques to harvest energy is existent although the mechanical procedure of harvesting energy is more popular than the rest. The mechanical technique exploits piezoelectric constituents where deformations generated through different means are directly turned into electrical charge through what is referred to as the piezoelectric effect. Eventually, the electricity can be used or stored for use in the future. The main content of this paper endorses Piezoelectricity as an alternative source of energy. The motive for harvesting energy through piezoelectricity is to obtain an energy source which is clean and to utilize the energy that would otherwise be wasted. This paper major on two critical techniques upon which energy can be harnessed; the first one is Increased Bandwidth Piezoelectric Crystal while the second one is energy via Piezoelectric Windmill. The paper will also illustrate the principle of piezoelectric crystal as well as deviant vibration sources for the piezoelectric crystal.

***Index Terms* - Piezoelectricity, increased bandwidth, piezoelectric crystal, energy harvesting, and energy storage**

I. INTRODUCTION

Energy harvesting by utilization of different means has been a subject of deliberation as well as research for decades intensifying in the 21st century. With an increasing global population, the demand for energy needs is ever escalating, thereby precipitating the urge for the exploitation of more and more sources of energy. The process of energy harvesting refers to the derivation of energy from external sources and availing it to the machine that requires the energy in real time or storing it for utilization in the future. There are standard modes of harvesting energy which include farms for wind, solar, tidal energy utilizing farms and et cetera. With the advancements in technology, the science of energy harvesting has been finessed to levels never thought of before especially with the advent of piezoelectric energy harvesting. This is a relatively new way of energy harvesting which can be very useful to individuals who own devices that consume energy on a small to medium scales such as drones and other related equipment. Research on this method of energy harvesting is yet to be undertaken to desired levels so that the full potential of piezoelectricity can be realized. Energy harvesting by use of piezoelectricity is existent largely in general form, but the science behind it proves beyond doubt that it is functional and can be executed in real life. The use of piezoelectric crystals in harvesting energy yields minimal voltage values; hence the method can only power low voltage devices. This is the reason why Piezoelectric Energy Harvesting is categorized as an energy harvesting scheme at a microscale level. Through this paper, the principle behind the concept will be explained by studying how a piezoelectric crystal works. After that, the proposed idea of merging energy several piezoelectric crystals to gain higher voltages will be explained later in the paper. Specific methods of crystals implantation on different platforms will also be addressed in the paper.

II. THE WORKING PRINCIPLE

The piezoelectric characteristic is a unique physical property existent in single crystalline materials such as quartz, topaz, sugar, belemnite among other substances. The piezoelectric effect is classified as the direct or inverse piezoelectric effect. The immediate piezoelectric effect is present in materials that generate electric potential when stress (mechanical) is applied while the opposite piezoelectric effect is realized when materials deform after application of the electric field. When harvesting energy through Piezoelectricity, the direct piezoelectric effect is exploited. The voltage output obtained from one unit of piezoelectric crystal is the range of millivolts, and it differs among the various crystalline materials. The wattage from a single crystal is in the microwatts range. This means that it is imperative to attain a higher voltage if anyone is going to use piezoelectricity in a meaningful way. To achieve voltage in ranges higher than millivolts, the piezoelectric crystals are aligned in a series. The energy obtained from the piezoelectric crystals used as it is generated or stored in capacitors or lithium-ion batteries. This is the functioning principle which is exploited in the piezoelectric energy harvesting system. Extreme engineering is dependent on optimization of this piezoelectric energy, which can be accomplished in several ways. Research is still ongoing to determine which crystal yields maximum voltage output, what the structure of piezoelectric component should be, what circuit variant should be deployed at the output terminals of piezoelectric crystal setup to have the highest wattage possible. The following section covers several sources for vibration which are currently being used in the process of piezoelectric energy harvesting.

III. SOURCES OF VIBRATIONAL ENERGY

A. ENERGY GENERATING PAVEMENTS

Materials such as quartz and topaz can be arranged beneath the upper layers of pavements, sidewalks other high traffic areas such as busy highways and pitches which can facilitate the generation of the maximum voltage. The energy in the form of electricity generated can be used for a wide array of activities such as street lighting or illumination of advertising boards which are close to the infrastructure generating energy utilizing the piezoelectric crystal. Storing of the energy can be an option although this can only be done on a small scale using lithium-ion batteries.

B. ELECTRICITY GENERATING BOOTS

The Defense Advanced Research Projects Agency is conducting a project whose aim is to exploit the power of the bodies of soldiers. By making use of thermodynamic as well as piezoelectric power generation capabilities, researchers are to provide sufficient energy which can be used by a soldier for a wide array of activities. This initiative exploits thermodynamic reaction; for instance, the deficit between the air and the soldier's body-more like how combat boots generate electricity which can be used to recharge gadgets. If the futuristic ideas of troops donning sensor-studded attire which monitor vital signs or computerized contact lenses ever come to fruition, the energy generating boots will come in handy.

C. WORKPLACES AND GYMS

In gyms, the activities of people who are working out such as running on treadmills, weight lifting, jogging, indoor cycling and many more generate high-intensity vibrations. These vibrations caused by human or machine activities at a place like a gym or any other establishment hosting a large number of active people can be exploited to generate energy. Piezoelectric crystals can be laid on the floor, on the furniture or any other piece of infrastructure which is prone to producing vibrations and the voltage generated could be channeled to other equipment which consumes electric energy. Apart from gyms and workplaces, vehicles of all types also provide, and piezoelectric crystals can be used to harvest energy which can be stored in the car battery.

IV. PIEZOELECTRIC WINDMILL

To power devices that consume power on a small scale, microcells are generally used. But these microcells get exhausted, and this raises the need for recharging them; more so if the devices are being used at places that are remote such as villages, jungle forests, border areas or mountainous areas, then continued energizing of the devices is impossible by the conventional methods of charging. In such cases, alternative options like solar energy and wind energy can be utilized. The use of solar energy is restricted by night, and cloudy weather: therefore, wind energy is a feasible alternative to solar energy. The utilization of wind power can be merged with the concepts of piezoelectricity in a piezoelectric windmill. A classical piezoelectric windmill should be comprised of a fan with three to five blades which can effectively capture the flow of wind. A lever is then connected to the fan rotor of the windmill with a translator being connected to this level in order to convert circulatory motion into motion that is a translator. This setup will then incorporate a disc connected to the inferior end of the translator, such that anytime when upwards and downwards movements occur, the piezoelectric crystals will be compressed. This arrangement will lead to energy generation in the form of electricity every time the wind blows at a certain speed; Hence, a bandwidth that is higher and more workable bandwidth can be achieved. The frequent compression of piezoelectric crystals during windy moments will generate some amount of energy, which can power electronic devices in areas of the world which have limited or no access to the electricity grid.

V. HIGH-BANDWIDTH PIEZOELECTRIC CRYSTAL

To utilize piezoelectric crystals over a variety of vibrations, it is essential to increase the available bandwidth. If a case scenario entails a single source of energy, this should be changed to two or more; by increasing the sources of energy, the efficiency of the energy harvesting system will increase in turn. In this case, the suitable energy converting systems should be the piezoelectric crystal and electromagnetically induced voltage. The method for increasing the workable bandwidth is made up of-of a flexible strip, which provides a surface for the attachment of the piezoelectric crystals; a magnet is mounted at one end of this flexible strip. This magnet is situated in a stationary coil. When vibration intensity is high, the piezoelectric crystals generate a voltage. Therefore, when the frequency is high, the piezoelectric output is given by the crystals. When vibration intensity is decimated, the piezoelectric crystals reduce voltage output; the magnet located inside the stationary coil moves to cause the generation of electromagnetic flux causing a voltage output.

VI. THE OUTPUT STAGE

An alternating signal is the output of a piezoelectric crystal. To deploy the harvested energy to low power-consuming electronics, the voltage has to be converted into a digital signal. The AC to DC converter can be used for this purpose. The converter is then connected to a capacitor, which is charged up by the rectifier until it reaches its maximum voltage, after which the rectifier switch closes making the capacitor discharge electric power through the electronic device. This setup helps in energy storage in the capacitor, which can be discharged at need. The deployment of an AC-DC converter has been proved to improve energy harvesting seven-fold. A Synchronized Switch Harvesting on Inductor is a non-linear technique energy harvesting which can serve a purpose similar to the AC-DC converter and associated accessories which are the rectifier and capacitor. The Synchronized Switch Harvesting on Inductor consists of a device for switching which is parallel with the piezoelectric array. It is made up of an inductor and a connected in series. If maximum displacement has not occurred in the transducer, the switch stays in an open state. The switch remains closed unless the piezoelectric component has been reversed. This circuit array has a relatively high energy harvesting capacity.

VII. IMPLEMENTATION

The effectiveness of the piezoelectric crystal in energy harvesting has been tested on LED (Light-Emitting Diode). Two terminals of the Light-Emitting Diode are connected with those of a piezoelectric crystal. A single stroke on the piezoelectric crystal ignites the LED to full intensity. Values of output voltage as well as current confirmed by measuring; from the crystal range between 4 Volts and 130 milliamperes. The only downside of using a LED in conjunction with a single crystal is that both the current as well as the voltage obtained exist simultaneously. To maximize the current output and the voltage range, six crystals are assembled in a series, and not less than six such arrays are put in parallel. When voltage sources are arranged in a series; the overall voltage increases. When several voltage sources are arranged in parallel, the current increases. These principles inspire the assembly described above. The output generated from the parallel connection is channeled to the amplifier for a stronger signal. The assembly can be put beneath a doormat, and the generated output can range from 6 V voltages to 1-ampere current. This amount of voltage and current can no doubt be used to charge a battery.

VIII. CONCLUSION

There are several methods which can be used to harvest energy is to via piezoelectric crystals which are capable of converting the vibration energy in the surrounding into electricity. The electrical energy can be for powering a wide range of low power-consuming devices, or it can be stored in lithium-ion batteries or capacitors for later use. This energy harvesting through piezoelectric crystals has gained an increasing focus due to the latest technological advances in wireless technology and MEMs. Through it, sensors can be deployed in desolate locations and operate at relatively low power without requiring to recharge. The necessity for energy harvesting technology is occasioned by the widespread use of microcells as sources of power for wireless electronics. Since all microcells have a limited lifespan, charge replenishment is necessary once discharged. Charging of microcells may be impossible in some environments due to lack of infrastructure and challenging terrain. This paper, however, has explored various ways through which piezoelectric energy harvesting can be undertaken. Power generating pavements, boots, gyms and workplaces, as well as windmills have illustrated in the paper. Methods on how voltage and wattage can be enhanced have also been deeply analyzed in the paper.

IX. REFERENCES

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