International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No. (03), January 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

POWER HARVESTING FROM VIBRATION USING PIEZOELECTRIC MATERIALS

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ABSTRACT

Dynamic- The way toward procuring the vitality encompassing a framework and changing over it into usable electrical vitality is named control collecting. Over the most recent couple of years, there has been a surge of research in the zone of energy gathering. This expansion in investigate has been expedited by the cutting edge progresses in remote innovation and low-control hardware for example, microelectromechanical frameworks. The advances have enabled various ways to open for control reaping frameworks in reasonable true applications. The utilization of piezoelectric materials to benefit from the surrounding vibrations encompassing a framework is one technique that has seen a sensational ascend being used for control reaping. Piezoelectric materials have a crystalline structure that furnishes them with the capacity to change mechanical strain vitality into electrical charge also, the other way around, to change over a connected electrical potential into mechanical strain. This property furnishes these materials with the capacity to ingest mechanical vitality from their environment, normally surrounding vibration, and change it into electrical vitality that can be utilized to control different gadgets. While piezoelectric materials are the significant strategy for gathering vitality, different strategies do exist; for instance, one of the customary techniques is the utilization of electromagnetic gadgets. In this paper we talk about the exploration that has been performed in the region of energy collecting and the future objectives that must be accomplished for control collecting frameworks to discover their way into ordinary utilize.

Keywords:- power harvesting, energy scavenging, energy generation, piezoelectric.

I. INTRODUCTION

With the current advances in remote and microelectromechanical frameworks (MEMS) innovation, the interest for convenient hardware and remote sensors is developing quickly. Since these gadgets are convenient, it winds up plainly fundamental that they convey their own particular power supply. By and large this control supply is the customary battery; notwithstanding, issues can happen when utilizing batteries in light of their limited life expectancy. For convenient gadgets, supplanting the battery is risky in light of the fact that the hardware could kick the bucket whenever also, substitution of the battery can turn into a repetitive errand. In the instance of remote sensors, these gadgets can be put in exceptionally remote areas, for example, auxiliary sensors on an extension or on the other hand worldwide situating framework (GPS) GPS beacons on creatures in nature. At the point when the battery is smothered of all its control, the sensor must be recovered and the battery supplanted. On account of the remote situation of these gadgets, acquiring the sensor basically to supplant the battery can move toward becoming an exceptionally costly errand or even unthinkable. For example, in common framework applications it is regularly attractive to implant the sensor, making battery substitution unfeasible. On the off chance that encompassing vitality in the encompassing medium could be acquired, at that point it could be utilized to supplant or charge the battery. One technique is to utilize piezoelectric materials to acquire vitality lost because of vibrations of the host structure. This caught vitality could then be utilized to drag out the life of the power supply or in the perfect case give interminable vitality to the electronic gadgets life expectancy. Therefore, the measure of investigate committed to control collecting has been quickly expanding. In this paper we audit and detail a portion of the subjects in control collecting that have been getting the most examine, including vitality collecting from mechanical vibration, natural frameworks, and the impacts of energy collecting on the vibration of a structure.

II.MECHANICAL VIBRATION

One of the most effective methods of implementing a power harvesting system is to use mechanical vibration to apply strain energy to the piezoelectric material or displace an electromagnetic coil. Power generation from mechanical vibration usually uses ambient vibration around the power harvesting device as an energy source, and then converts it into useful electrical energy, in order to power other devices. The re-search in the following three sections has made use of mechanical vibration in order to quantify the efficiency and amount of power capable of being generated, as well as to power various electronic systems, ranging from digital electronics to wireless transmitters. Williams and Yates (1996) proposed a device, which generated electricity when embedded in a vibrating environment. For their evaluation, an electromagnetic transducer was chosen. A harmonic analysis of the generator was performed in order to evaluate the viability of the device and to optimize the design. It was determined from the analysis that the amount of power generated was proportional to the cube of the vibration frequency. This illustrated that the generator was likely to perform poorly at low frequencies. It was also determined that a low damping factor was required to maximize power generation, therefore the design must allow for large deflections of the mass. For a typical device the predicted power generation was 1 2W at an excitation frequency of 70 Hz, and 0.1MW at 330 Hz (assuming a deflection of 50 2m).

III.POWER HARVESTING EFFICIENCY

The two papers in this section investigate the efficiency of a piezoelectric generator. The first paper looks at the efficiency of a piezoelectric vibrating in the –31 direction and the second paper tests a stack that operates in the –33 direction. It is important to quantify the efficiency of the power harvesting medium in order to allow the device to be designed to function optimally in its intended environment. Umeda et al. (1996) carried out an investigation concerning the fundamentals of a generator, which transformed mechanical energy to electrical energy using a piezoelectric vibrator and a steel ball. They also investigated the effect of the various characteristics of the piezoelectric vibrator. To simulate the generation mechanism, they introduced an electrical equivalent model. The fundamental modes of bending vibration for two models were calculated: model A (the transducer with the steel ball) and model B (the transducer only). The admittance characteristics of each model were measured and they found that it was clear that the peak frequencies corresponded to the vibration modes. It was seen that the calculated waveforms of the output voltage were similar to the measured ones; therefore, the model provided an accurate simulation of the output voltage. An efficiency curve was drawn for various input mechanical energies, and they determined that as the potential energy of the ball increased the maximum efficiency decreased. A large part of the applied energy was returned to the steel ball in the form of kinetic energy causing it to bounce off the plate. It was concluded that the energy generated would be large if the steel ball did not bounce off after an impact but rather vibrated with the piezoelectric plate. This case was simulated and it was determined that a maximum efficiency of 52% could be obtained. The effects of the characteristics of the piezoelectric vibrator were investigated and it was determined that the efficiency increased if the mechanical quality factor increased, the electromechanical coupling coefficient increased and the dielectric loss decreased.

Goldfarb and Jones (1999) have analyzed the efficiency of the piezoelectric material in a stack configuration for the purpose of electric energy generation. An analytical model is presented and suggests that the fundamental problem in generating electrical power from the piezoelectric material is that it stores the majority of the energy produced and returns it to the excitation source that initially caused the charge to be generated. They state that this occurrence is particularly problematic when the piezoceramic is placed in parallel with a capacitor that is in series with the load. Therefore, it is suggested that the maximum efficiency of power generation can be achieved by minimizing the amount of energy stored in-side the piezoelectric material. The efficiency of the model was determined across a spectrum of frequencies and resistive values. It was found that, at frequencies above 100 Hz, the efficiency of the stack actuator was negligible and that the highest efficiency was obtained at 5 Hz. This frequency is far lower than the first mechanical and electromechanical resonances of the stack, which occur at approximately 40 and 60 kHz, respectively. The authors state that the frequency of maximum efficiency occurs so low because of the energetic structure of the stack. In addition, it is found that the efficiency of the stack is most strongly dependent on the frequency of excitation, with the load resistance providing a lower effect on it.

IV.POWER STORAGE AND CIRCUITRY

When using piezoelectric materials as a means of gathering energy from the surroundings, in most cases it is a necessity that a means of storing the energy generated be used. Without accumulating a significant amount of energy, the power harvesting system will not be a feasible power source for most electronics. The following research has made use of circuitry to either store the energy generated by the piezoelectric material or to develop circuits that allow the energy to be removed from the piezoelectric in a more efficient way al-lowing more power to be generated.

Umeda et al. (1997) continued their investigation with a study into the characteristics of energy storage by a piezo generator with a bridge rectifier and capacitor. As in their previous research, the piezo-generator consisted of a steel ball and a piezoelectric vibrator, and with the introduction of a bridge rectifier and capacitor they were able to determine the energy storage characteristics both theoretically and experimentally. To simulate the generation and storage mechanism they employed an equivalent circuit model, where the input mechanical energy was translated into an initial electrical energy. Changing the parameters of the circuit simulated the separation of the vibrator and the ball. After examining the storage characteristics for the first impact they determined that as the capacitance increased the electrical charge increased due to an increased duration of oscillation. They also deter-mined that for each value of capacitance as the initial volt-age increased the stored electric charge decreased, and the efficiency increased. When considering the overall storage characteristics for multiple impacts they determined that, for each value of capacitance, the first impact gave the largest electric charge. The overall storage characteristics were ob-served when the initial voltage was changed; as the initial voltage increased, the electric charge decreased for each value of capacitance, while the efficiency increased. Their proto-type achieved a maximum efficiency of 35%, over three times that of a solar cell.

Elvin et al. (2001) used a polyvinylidene fluoride (PVDF) piezofilm sensor attached to a simply-supported Plexiglas beam with an aspect ratio of 0.11 to generate an electrical sig-nal. The goal of this power harvesting experiment was to generate sufficient energy from the strain induced on the piezo-film by the bending beam to power a telemetry circuit. The energy generated from the PVDF patch was accumulated in a capacitor. A switch was added to the circuitry to allow the capacitor to charge to a predetermined value of 1.1 V, at which point the switch would open and the capacitor would discharge through the transmitter. Once the capacitor had discharged to a value of 0.8 V, the switch would close and the capacitor would be allowed to recharge and repeat the process. The operation of the power harvesting system was found to provide the required energy to power the circuitry and transmit a signal containing information regarding the strain of the beam a distance of 2 m. Kasyap et al. (2002) developed a lumped element model (LEM) using an equivalent circuit model to describe the power generated from the forced vibration of a cantilever beam with a piezoelectric element attached. It was found that the LEM provided results consistent with those generated using a finite element model from excitation frequencies ranging from DC through the first resonance of the beam. A similar result was found during a second model validation using experimental results. The goal of the study was to use a flyback converter to increase the efficiency of the power transfer from the piezoelectric patch to a power storage medium. The use of a flyback converter allows the circuit impedance to be matched with the impedance of the piezoelectric device. It was found that when using the flyback converter a peak power efficiency of 20% was achieved.

V.FUTURE OF POWER HARVESTING

The idea of carrying electronic devices such as a portable radio and never worrying about when the batteries will need to be replaced could be far closer than one would think. This thought has caused the desire for self-powered electronics to grow quickly, leaving only one limitation before these devices can become a reality. The one issue that still needs to be resolved is a method to generate sufficient energy to power the necessary electronics. However, with the advances in power harvesting that have been outlined in this paper the ability to obtain and accumulate the necessary amount of energy to power such devices is clearly possible. The major limitations facing researchers in the field of power harvesting revolve around the fact that the power generated by piezoelectric materials is far too small to power most electronics. Therefore, methods of increasing the amount of energy generated by the power harvesting device or developing new and innovative methods of accumulating the energy are the key technologies that will allow power harvesting to become a source of power for portable electronics and wireless sensors. One recent advance that shows great promise for power harvesting is the use of rechargeable batteries as a means of accumulating the energy generated during power harvesting. Much of the early research into power harvesting looked to the capacitor as a method of storing energy and powering electronics. However, the capacitor has poor power storage characteristics because of its quick discharge time, causing the electrical output of such circuitry to switch on and off as the capacitor charges and discharges. This aspect of the capacitor is not suitable for powering computational electronics. However, the rechargeable battery can be charged and then used to run any number of electronic de-vices for an extended period of time while being continuously charged by ambient motion. Innovations in power storage such as the use of rechargeable batteries with piezoelectric materials must be discovered before power harvesting technology will see widespread use. Furthermore, the efficiency of the power harvesting circuitry must be maximized to allow the full amount of energy generated to be transferred to the storage medium. The continuous advances that are being made in low-power electronics must be studied and utilized both to optimize power flow from the piezoelectric and to minimize circuit losses. Gains in this area are a necessity for the successful use of piezoelectric materials as power harvesting devices. Additionally, the intended location of the power harvesting sys-tem must be identified so that its placement can be optimized and the excitation range realized to allow for tuning of the power harvesting device. By tuning the power harvesting medium with the structure, the excitation can be made to maximize the strain of the piezoelectric material using the concept of resonance. Finally, practical applications for power harvesting systems such as wireless sensors and self-powered damage detection units must be clearly identified to encourage growth in this area of research, thus allowing the contributions and in flow of ideas to increase. With the advances in wireless technology and low-power electronics, power harvesting is the missing link for completely self-powered systems.

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Volume No.07, Special Issue No. (03), January 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

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