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Generation Of Electricity By Means Of Footsteps: A Review

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Abstract—In this review paper I intend to discuss how piezoelectric effect enables us to convert the kinetic energy produced by the human footsteps to electrical energy that can be used for various applications. The energy produced can be stored in a capacitor to be used at a later stage. These systems can be fitted in the busy places like railway stations, malls, cinema theatres etc. where huge crowds pass every day.
Keywords— Piezoelectricity, harvesting energy, power generation by footsteps, d_{33} coefficient, advantages.

I. INTRODUCTION

Piezoelectric transducers are a form of a transducer that converts the mechanical energy produced into electrical energy and vice versa.We should be aware that currently the electricity available serves only 65% of the population in India. We are often subjected to power failures. According to a survey, to supply continuous elelctricty, we require to produce 81,08,76,150 MWh/yr. But as a matter of fact, the total elecricity production is 60,06,49,000 MWh/yr. In order to achieve continuous electricity supply without power cuts we need 210227150 MWh/yr is required. We are in need of alternative sources to meet our demand [14]. Energy harvesting is the forthcoming technology to produce power. Energy harvesting is constructive as in a system the whole effectiveness is boosted.

II. PIEZOELECTRICITY: A MEANS OF ENERGY HARVESTING METHOD

Piezoelectricity has arose as a way to harvest energy. The array of piezoelectric crystals are laid under the pavements. The voltage produced can be utilized to charge batteries. It is to be noted that scientist at the Hull University worked on converting motion in to electrical energy. Japan has installed piezoelectric tiles in Tokyo's busiest stations. They noted that the footsteps of an average person whose weight is 60 kg is able to yield 0.1 watt/sec [4].

It has also been reported that there is a 3×5 feet panel a product of Digital Safari Greenbiz Company which is capable of producing 17.5 watts/step [16].

III. PIEZOELECTRIC PRINCIPLE

When stress is applied to a piezoelectric crystal an electrical energy is produced across the material. There are two kinds of piezoelectric effect, namely direct effect and indirect piezoelectric effect.

When mechanical stress is applied and electric potential is developed it is termed as the direct piezoelectric effect on the other hand when due to the application of electrical field there is deformation in the material it is termed as the indirect piezoelectric effect.when an electric field is applied [12]. The examples of some piezo materials are Quartz, PZT, $PbTiO_3$, PLZT, PVDF, $BaTiO_3$, $PbZrO_3$, etc.

IV. VARIOUS FORMS OF PIEZOELCTRIC ENERGY HARVESTERS

The piezoelectric energy harvesters can be categorised in three sets on the basis of size namely the mesoscale, MEMS (Micro electro mechanical systems) scale, and NEMS (Nano electro mechanical systems) scale.

The best examples of mesoscale are devices that includes manual assembly and bonding. The devices fabricated by photolithography practises are on the scale of MEMS. Piezoelectric nanowires are on the nano scale [15].

V. VARIOUS ENERGY HARVESTING SOURCES

According to the literature survey, the power density and efficiency of various energy harvesting sources are stated below in the tabular form [13].

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TABLE I

Power Density And Efficiency Of Various Energy Harvesting Sources

Serial No.	Sources of Energy	Power Density (mw/cm^3)	Efficiency in Percentage
1.	Photovoltaic	500-5000	5-40
2.	Piezoelectric	0.001-90	25-60
3.	Thermoelectric	50-500	0.1-10
4.	Electromagnetic	0.1-50	30-40

Piezoelectric effect is the result of electrical and mechanical energies as shown below [5].

$$S = s^E T + dE$$

$$D = dT + \varepsilon^T E$$

Where S is the strain, T is the stress, s the strain, d is the piezoelectric strain E is the field strength, D is the dielectric displacement and ε is the permittivity of the medium.

VI. THE d_{33} COEFFICIENT

When an electric field is applied to a piezoelectric the material dimension change in all 3 axes under the stress free condition. By literature study d expresses the amount of charge developed relative to the stress applied along a specified axis.

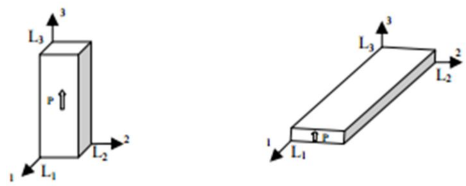

Fig 1: The d_{33} and the d_{31} mode of a piezoelectric crystal [9]

TABLE II

The d_{33} coefficient of various piezoelctric materials [1]

Serial No.	Piezoelectric Material	d_{33} (10^{-12} C/N)
1.	Quartz	2.3
2.	$BaTiO_3$	90
3.	$PbTiO_3$	120
4.	PZT	560
5.	PZN-9PT	2500

The d_{33} coefficient implies that when 1 N of force is applied then it produces 560×10^{-12} C of electrical charge. [1]. According to the literture survey, the amount of the electricity produced is directly proportional to the amount of the force or pressure applied which implies that the speed or frequency of vibration is the main determining factor of the amount of electric current yielded.

TABLE III

The D_{33} Characteristics Of The Most Common Piezoceramic Pzt [10]

Serial No.	Factors	Values
1.	Power	1 μW
2.	Frequency	13.9K Hz
3.	Power Density Estimated	37,037 μW/cm3
4.	Acceleration	10.8

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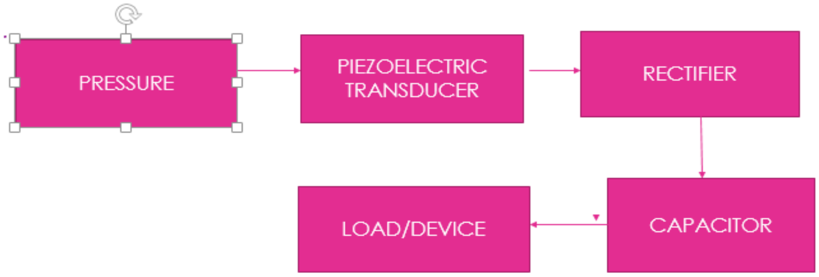

Fig 2: Basic block diagram of the power generation circuit [17].

VII. EXPLANATION

According to the literature survey, piezoelectric materials produce ac voltage. When the pressure is applied on the face of the piezoelectric element then it generates the ac voltage and is sent to the rectifier. Then the function of the rectifier is to achieve full-wave rectification. Thus transforming the ac voltage to dc voltage. The rectifier is a bridge circuit made by diodes. The dc voltage is stored in a capacitor in the subsequent stages. The stored energy can be effectively used for various applications. Sometimes a controller is also attached after the rectifier as it optimizes the power in input to the capacitor. Super capacitors can also be used in place of conventional capacitors [6]. The power can be directly applied to the electrical devices or can be a supplement of main power supply [14]. One can determine the effectiveness of a system by comparing the input energy to the output results .However, when the amount of output energy produced versus input energy is high then the level of efficiency is also high.

VIII. AMOUNT OF POWER GENERATION DETAILS

It is reported in literature, that when a piezoelectric tile is used for the flooring purposes then each slab is capable of producing 2.1 watts/hour in a football area if the stepping rate is 4-10 seconds. Based on testing it is found that walking 5 hours will generate enough electricity to lighting a bus stops continuously for over 12 hours. The energy produced is stored in Lithium Polymer Batteries. To light a low energy LED, 5% of the energy produced by a footstep is sufficient [8].

IX. METHODS TO INCREASE VOLTAGE OF THE CIRCUIT

The energy produced by piezoelectric elements is extremely low. The electrical energy produced by a piezoelectric crystal is about 2-3 volts. To increase the voltage we can use a boost converter circuit which enhances it to 12 volts. To feed it further to any device we can use an inverter circuit [3]. A boost converter or a step-up-converter is a is capable of converting high DC voltage from low DC voltage in input. It has two modes of operation, namely continuous and discontinuous mode [7].

X. CONNECTIONS OF THE PIEZOELECTRIC ELEMENT

The piezoelectric elements can be connected with each other by two ways. These are by series or parallel connection. Three piezoelectric elements are connected in series and parallel combination. The current versus voltage graphs can be drawn for each case and analysed. According to the literature study, it is observed that the in a series connection the voltage is good, but the current is poor while it was exactly the opposite in the case of the parallel connection i.e. the current was good and the voltage is poor. Thus, we can use both the series connection as well the parallel connection according to our application [2]. But in the series connection, the voltage does not increase in linear fashion may be owing to the non-linearity of the system's total internal impedance [8].

XI. ANALYSIS

When connected in series, then equivalent capacitance of 3 piezoelectric discs is as follows[2].

$$1/C_{eq} = 1/C_1 + 1/C_2 + 1/C_3$$

Again,

$$Q = C \times V$$

$$V_{eq}/Q = V_1/Q + V_2/Q + V_3/Q$$

Therefore,

$$V_{eq}= V_1+V_2+V_3$$

Also, the folowing formula is used to calculte the voltage of a piezoelectric material

$$V= S_v \times P \times D$$

Where V is the piezoelectric generated voltage (in Volts), S_v stands for voltage sensitivity of the material (Volt ×meters / Newton), P is the pressure (N/m^2) and D is the thickness of material (in meters) [14].

XII. ADVANTAGES

Energy harvesting with piezoelectricity is advantages as it is cost effectiveness, safe, no fuel needed, nonconventional, is reliable and the energy can be stored in a capacitor to be used at a later stage[8]. We can generate more power with the help of the the heat produced using the peltier effect. Thus, designing of a system for various applications through ac output is possible [6].

XIII. CONCLUSION

This method produces electricity with the help of piezoelectric elements that make use of the energy of human footsteps. The capacitor used in the circuit stores the charge for future applications. In order to increase the efficiency of the whole system if super capacitors are used in place of the conventional ones then more charge can be stored than the conventional ones. The super capacitors store and discharge energy without consuming much energy. Thus, the requirement of constant increase of power can be met by installing these systems in heavily packed places. This will undoubtedly not only overcome the energy crises but also build up a healthy surrounding.

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