iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** V **Month of publication:** May 2017

DOI:

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Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Piezoelectric Energy Harvesting in Roadways and Railways

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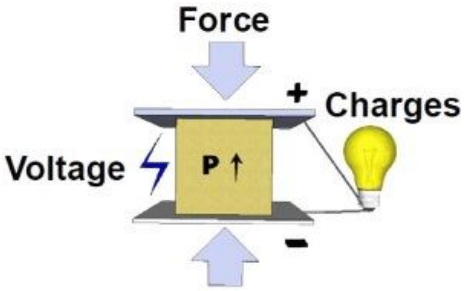
Abstract*: Electricity has become major need nowadays and everyday a new research is conducted to find alternate sources of energy mostly focussed on non-conventional sources of energy. Nearly every aspect of our lives relies on using energy .Energy consumption is a huge part of our daily life and almost everything starts with energy .But, the sources which provide energy in present time are going to be depleted in next 50-100 years so we need alternative energy resources . Since the population is expanding at fast rate and traffic on roads has become impossible to handle, it can be taken as an opportunity to generate energy in the form of electricity from piezoelectric materials .This paper emphasis on electricity generation using piezoelectric materials .These materials produce electricity when stress is applied on them.
Keywords— piezoelectricity, population , electricity, non-conventional , alternative

I. INTRODUCTION

It is very difficult to imagine a life without electricity, so alternative energy becomes very important as fossils fuels are going to run out one day. We use energy faster than it can be produced. Coal , oil, and natural gas takes thousands of years for formation but get consumed very rapidly .Energy we use are mostly non-conventional and constitute 80% of the daily energy consumption and these are going to last only for 50-100 years. So to overcome these challenges we need to design a system that generate electricity for a very long time as well it should be a cleaner source of energy. The proposed system is based on piezoelectric materials .These materials have very unusual and interesting properties .As photovoltaic materials generate electricity with the application of light , thermoelectric materials generate electricity with the application of heat , so as these piezo materials generate electricity when applied stress. In other words, when a mechanical stress is applied on these materials, electricity is produced and voltage produced is directly proportional to stress that is greater the force , larger the electricity. The technology which is emphasized in this paper is very promising and it will help in overcoming Global's energy demand. Some piezomaterials are suitable for micro harvesting applications while others are suited for bulk harvesting and power production.



Electricity generation when applied stress

II. HAT IS PIEZO

A. History of Piezo

Piezo is derived from Greek word means to press or squeeze. Piezomaterials were discovered in 1880 by Pierre Curie and Jacques Curie. They experimentally found out that when stress is applied on Rochelle salt , tourmaline , quartz, topaz, and cane-sugar ,voltage is produced and voltage produced is directly proportional to applied stress .It has also converse effect that when voltage is applied across these crystals there is change in shape of crystals .It was first used in World War 1 ,in piezoelectric ultrasonic transducers.

B. Overview

The basic principle behind piezo is that when a force or pressure is exerted on these crystals the crystals get deformed .The neutral crystal gets changed into dipole and it causes to develop charge between them. But when force or pressure is removed crystal gets

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back to its original state .Examples of piezomaterial are Rochelle salt , topaz, quartz , all these are naturally occurring.$GaPO_4$(Gallium orthophosphate) $La_3Ga_5SiO_{14}$(Langasite) are manmade piezo materials.

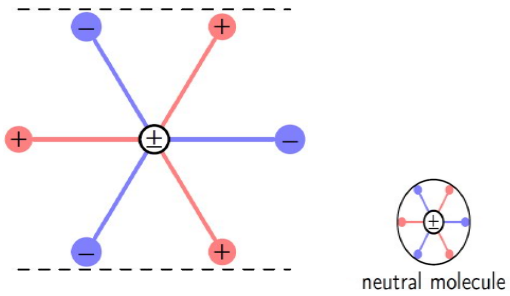

Fig .1 No external force

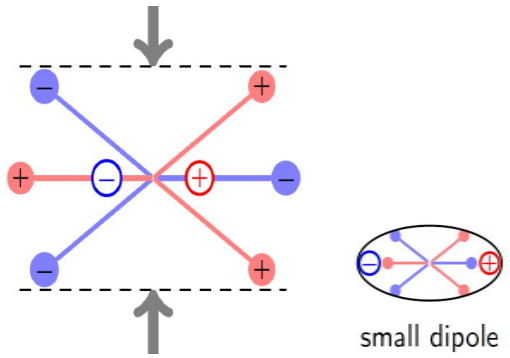

Fig .2 External force applied

C. Mathematical Equations:

Piezoelectricity is the combination of materials dielectric behaviour and Hook's Law

$D = €E$

$S = sT$

D: electric displacement €: permittivity, E: electric field strength, S: strain, s: compliance, T: stress

$S = s^E T + d^T E$; (Converse Piezoelectric effect)

$D = €^T E + dT$; (Direct piezoelectric effect)

III.PRESENT SCENARIO

Fossil**s** fuels are non –renewable and require finite sources which are dwindling because of high cost and environmental damaging. India has 1% of total energy of world but it has 16% of total's world population.

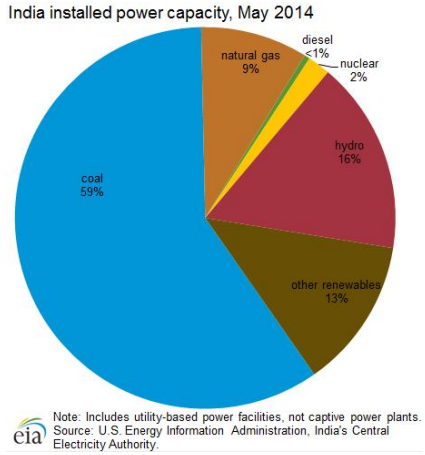

Fig. 3 Energy distribution in India

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IV. METHODOLOGY

A. Roadways

Piezoelectric sensors are placed beneath the road surfaces which in turn will generate electricity due to moving vehicles .These materials when embedded at traffic signals or road junctions , moreover a whole road can be embedded with these materials then these materials capture energy in the form if vibration and convert it into electricity. Smart roads has been introduced in this area to harness energy of vehicles moving on roads. These smart roads can generate up to 400kw of energy from a1km road enough to generate power for 40 houses. The concept behind this is when a vehicle passes over a road , the road deflects vertically and this deflection is transformed into piezoelectricity. These sensors are best placed in areas having high traffic flow rates .In this paper the main focus is given only on roadways because in railways this concept is not introduced on macro scale .The piezo units are installed in the roadbed and epoxy is used as filler to permanently affix the units in place . 5 cm of asphalt is overlaid .Channels are given for connections .Some energy is absorbed by surroundings therefore efficiency decreases .According to Israel institute of technology, these piezomaterials can produce 200kwh ,while a four lane highway can produce about 1Mwh of electricity to provide power to 2500 households .This energy produced can also be given to power traffic lights , street lights and for ice melting on roads. Various factors which affects the cost of energy are : 1. Weight of vehicle 2. Speed of traffic 3. Traffic volume 4. Capital cost of technology and installation 5.spacing between vehicles 6. Maintenance and other operational cost .Innowattech is the most notable company in piezo based energy harvesting on bulk.

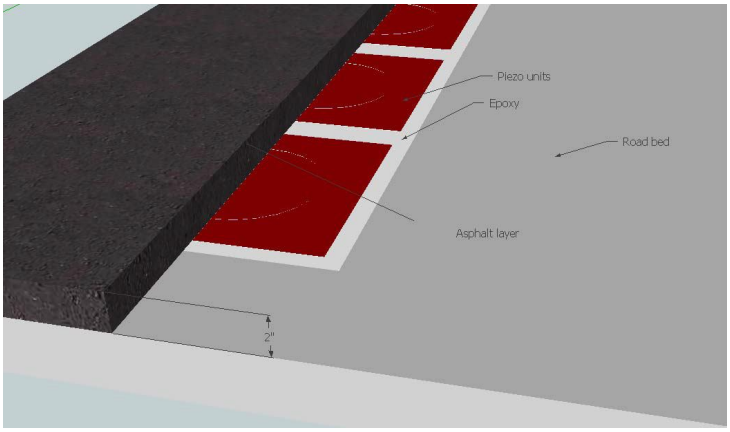

Fig.4 a road fitted with piezo units

B. Railways

Installation cost of railways is lesser than roadways. It can be installed between the rail tie and steel rail and doesn't require excavation. Moreover rail is rigid and less elastic than roadways therefore it imparts more stress on piezo unit. Efficiency is greater because there is 100% chance of train to contact the piezo units .The units are also easily accessible for maintenance also requires thinner units ,it ultimately lowers the capital and labour cost and increases overall efficiency.

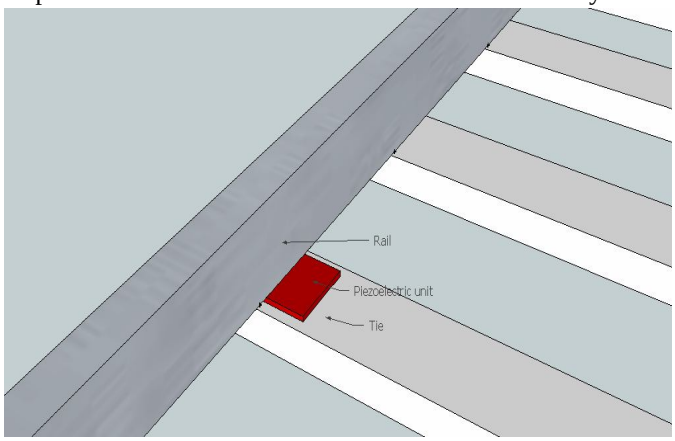

Fig.5 a rail fitted with piezo units

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V. EXPERIMENTAL OBSERVATION

Vehicles per hour	600
Vehicle speed	45 mph
Power generated (1km)	150 kw
Number of harvesters	9800
Installation cost per km	$ 650,250

A test conducted by Innowattech

The above test was conducted by Innowattech to measure power generated from 1km of road . Another company named Digital Safari Greenbiz has claimed that 3×5 feet piezo panel can produce 17.5W every hour. According to Innowattech ,total cost of installation of piezounits in roadways is $650000 per km but it can be reduced to two third in coming years.

VI. OTHER APPLICATIONS

A. Piezo Floors

London club Surya and Rotterdam Watt have piezofloors which harvest energy from dancers .It provide 60% of club's energy needs. Each person can produce 5-20 watts. A company named Piezopower sells the piezo tiles $1.50 per ft square .The material is Rochelle salt and it comes in 3'×5' tiles

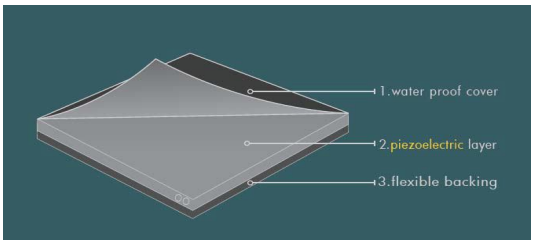

Fig.6 Piezo floor

B. Piezo Shoes

Generation of electricity just by walking or jogging .Piezo sensors are placed in the sole of shoes ,and whenever a person walks these gets pressed and electricity is generated . A piezo based mobile charger is trending nowadays. It can simply charge your mobile phone just by walking miles. According to experiments ,a 400 mAh Li-ion battery can be fully charged by jogging continuously for 8 hrs.

Fig.7 Piezo shoe

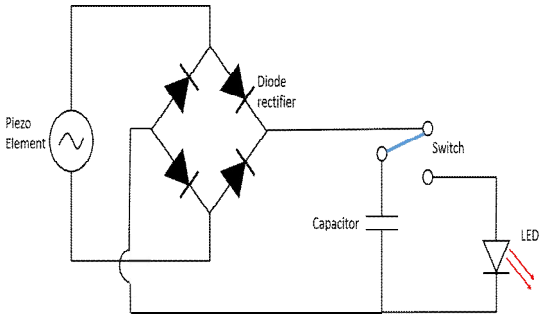

Fig.8 Basic electrical circuit for piezoelectricity

VII. CONCLUSION

There is never ending demand of energy requirement and even a small step is a very great step. This method is very good to produce electricity on small as well as large scale and a unique approach in the field of electricity . Though it is very difficult to make roads embedded with piezo because cost of installing piezo materials is very high and it is not efficient as other renewable resources. But still it has the potential like other renewable resources after optimizing this technology. Vibration energy is still untapped. Since movement is everywhere, this energy would be a significant advancement toward greater efficiency and cleaner energy production.

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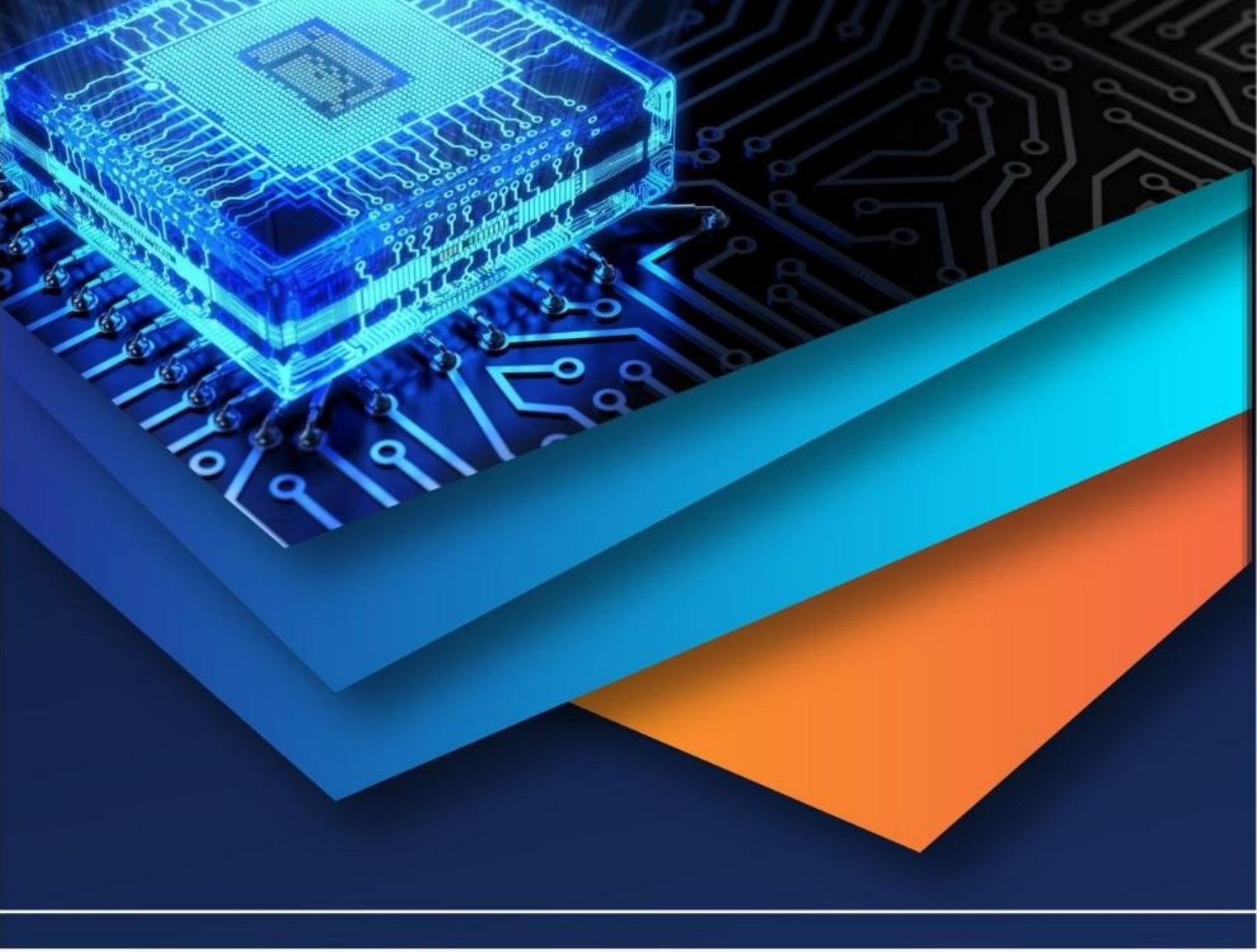

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