A review on electricity production by non-conventional means

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***Abstract*— Energy is the basic need for the development of the modern world. For meeting up the regular demand of energy we need to design a system that will produce electricity without destroying the nature. Energy can be transformed among a number of forms that may each manifest and be measurable in differing ways. The total energy of a system can be calculated by simple addition when it is composed of multiple non-interacting parts or has multiple distinct forms of energy. In this paper, A detailed review is conducted on production of electricity from piezo-electric material. First generation of electricity from speed breaker is discussed. Then generation of electricity from human body heat and movement and finally electricity from dance floor is presented. All the previous works published related to these topics are covered in this paper.**

Index Terms*— Stress, Energy Conversion, Uncertain Energy, Renewable Energy.

I. INTRODUCTION

HUMANS are a rich source of energy. An average-sized person stores as much energy in fat as a 1000-kg battery. People use muscle to convert this stored chemical energy into positive mechanical work with peak efficiencies of about 25%. This work can be performed at a high rate, with 100 W easily sustainable. Many devices take advantage of human power capacity to produce electricity, including hand-crank generators as well as wind-up flashlights, radios, and mobile phone chargers. In most of these conventional methods users must focus their attention on power generation at the expense of other activities, typically resulting in short burst of generation. For electrical power generation over longer durations, it would be desirable to harvest energy from everyday activities such as walking, running, cycling or even dancing. However, to produce substantial energy from these activities is not trivial. For reduction of carbon dioxide emission, renewable energies are considered as proper alternative energy. Renewable energies mainly refer to the wind, solar, biomass and marine currents which are less harmful to environment, attracting a wide attention of researchers in design and development of renewable energy conversion systems. Although improvement of renewable energy converters is in a fast rate, the systems to extract the wasted energy in conventional energy conversion systems are not developed as much as its technologies. In many systems and processes, dissipation of energy is inevitable whatever renewable or conventional energy was used. For instance, as a car passes over a speed-breaker, most of car kinetic energy will be wasted as heat in it.

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II. ELECTRICITY FROM FOOTSTEP AND DANCE FLOOR

Every day, a normal person takes 3000-5000 steps [1].At the time of walking or dancing significant amount of energy is wasted in the form of vibration, it is possible to generate electricity from this waste energy using piezo-electric crystals. The piezo-electric materials absorb mechanical energy and convert it to electrical energy.

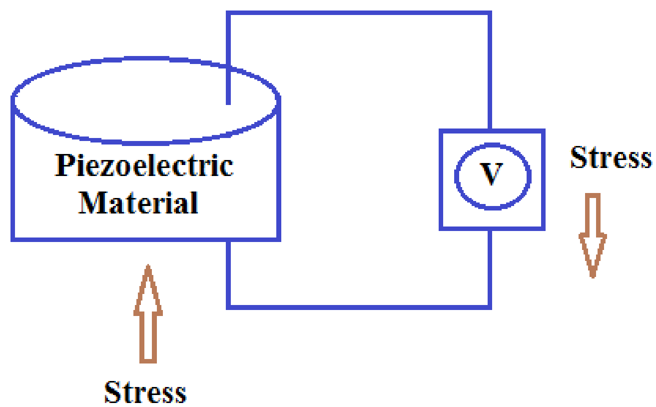

Fig.1.Diagram of piezoelectric effect

When piezoelectric materials are placed under mechanical stress, negative and positive charge shifting take place in the material which results in an external electric field. When reversed, an outer electrical field either stretches or compresses the piezoelectric material. Figure 1 shows the diagram of piezoelectric effect. Crystalline materials with asymmetric unit cells possess piezoelectric effect. Due to mechanical force the unit cells shift towards a different pattern- one that is generally more aligned and regular. Because of this, dipole effects build up, and a potential difference is generated across the crystal [2, 3]

The effect can be seen as a combination of Hooke's law, which governs the relationship between stress and strain, and the electric displacement field, which relates dielectric permittivity and electric field. Piezoelectric materials also show opposite effect where the application of an electric field creates mechanical deformation in the crystal [4, 5].

The linear electric behavior of the material:

$D = \epsilon E,\ D_i = \epsilon_{ij}E_j$ (1)

Where, ε is permittivity (free-body dielectric constant), D is the electric charge density displacement (electric displacement), E is electric field strength.

$\Delta . D = 0,\ \Delta * E = 0$ (2)

Hooke's Law for linear elastic materials:

$S = sT,\ S_{ij} = s_{ij}klT_{kl}$ (3)

Where, S is strain, s is compliance under short-circuit conditions, T is stress. These may be combined into so-called coupled equations, of which the strain-charge form is:

$S = sT + \delta^{t}E,\ S_{ij} = s_{ijkl}T_{kl} + d_{kij}E_k$

$D = \delta T + \epsilon E,\ D_i = d_{ijk}T_{jk} + \epsilon_{ij}E_j$ (4)

In matrix form:

$\{S\} = [S^E]\{T\} + [d^t]\{E\}$

$\{D\} = [d]\{T\} + [\epsilon^t]\{E\}$ (5)

Where, [d] is the matrix for the direct piezoelectric effect and [d^t] is the matrix for the converse piezoelectric effect. The superscript E indicates a zero, or constant, electric field; the superscript T indicates a zero, or constant, stress field; and the superscript t stands for transposition of a matrix. Seth Winger [5] discussed about Rotterdam nightclub Watt which generates part of its power from the dance moves of its patrons. Each module generates 20 W of power while an adult dance on it. In that club 160 modules are wired together; this entirely generates 3200 W electricity. For four hours of dancing floor will generate approximately 4.6 × 107 J of energy. Pratibha Arun et al. [6] implemented the model on a miniature project and got 25 V from a single piezo chip. This estimates that a single human can flicker a 60 W bulb for approximately 1 sec. The authors also discussed about implementing piezoelectric method below the keypad of mobile and laptop keyboard. The vibrations created by the pressing of button will create electricity and can be stored directly in the system battery using a rectifier. Rupendra Kumar Gohite et al. [7] discussed Generation of electricity thorough PZT materials with the help footfall stress. The author discussed about the installation parameters and environmental effect of the system. In this paper, different potential and challenges are discussed including dance floor and human footstep. J.J.H. Paulides et al. [8] developed Human-Powered Small-Scale Generation System for a Sustainable Dance Club. In this paper, different systems are analyzed and implemented that generates electricity from dancing floor. It was shown that power's exceeding walking can be extracted from the system, i.e., maximum 80-100 W or an average of 20-30 W over a time of 10 s.

ELISABETH ROSENTHAL [9] discussed about different night clubs which develops energy from dance floor. In this paper, the author mentioned about different night club like Watt, Greener, Still etc. In Watt, energy is harvested from musical equipment's and dance floor. In still night club about 10% of total power is generated from the dance floor. S French [10] designed an illuminated floor panel. A safe, reliable yet temporary electrical system to give electrical energy to all lighting components is fundamental. The floor must have the capacity to be immediately gathered or dismantled, by unskilled manpower, while withstanding weight and vibration when being used, without interruption of the mechanical couplings or the electrical system connections. The system used a low voltage source and wiring was such that it did not affect the utility of the floor.

III. Electricity from Speed Breaker

When a vehicle passes over a speed breaker energy is wasted, this energy can be recovered or convert it to electrical energy by some technological means. Several mechanisms can be used for converting this kinetic energy into electrical energy.

1. Spring coil mechanism
2. Rack-pinion mechanism
3. Crank shaft mechanism
4. Roller mechanism

In the last few years several works have been done on this topic. This method of generating electrical energy by speed breaker was first implemented in South Africa. They used this method to light up small villages in the highway.

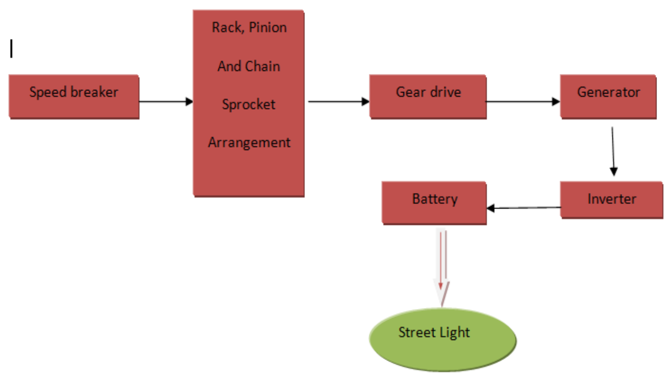

Figure 2. Block diagram of power producing from speed breaker

C.K das et al [10] developed energy from speed breaker by roller mechanism. The obtained electrical energy was sufficient to lighten the street and signal lights. In this research, a roller was fitted with the speed breaker and grip was provided so that when a vehicle passes over, it rotates the roller. Through this mechanism the kinetic energy is converted to rotational energy. By gear mechanism this rotational energy is converted into mechanical energy and through dynamo mechanism this mechanical energy is converted into electrical energy.

Figure 3. Production of electricity by roller mechanism from speed breaker

A.Padma Rao et al. [11] investigated Rack and Ratchet mechanism to extract energy from speed breaker. In this research, Authors used power hump method o extract energy. The power hump technology utilizes both mechanical and electrical techniques for power production. The Rack and ratchet mechanism is used to convert rotary to linear mechanism. In this research, from the developed mechanism 2.452 W electricity was produced by a 150 kg vehicle in one push. Syed Arslan Ahmed et al. [12] discussed about the principle of the system, its implementation and the advantages. The energy developed or extracted from the system was sufficient enough for lighting the streetlights during nights. The suggested model was a very eco-friendly method and much more efficient. Md. Saiful Islam et al. [13] developed a novel speed breaker generator for extraction of kinetic energy of vehicle flow in the street. The device can convert the kinetic energy into electrical energy. Plate was installed and the plate takes the stroke motion of the vehicle and converts it to mechanical energy and then through crank mechanism the plate generates electricity. Almost 15 W power was generated by an average weight vehicle. Mr. Amol Sheshrao Fawade [14] used air compression and rack and pinion mechanism to extract energy. In this research, the author produced electricity and air compression simultaneously. It works on a principle of reciprocating air compressor. Air volume is reduced by the compression of the compressor that has been isolated. Weight of the moving vehicle is used as a input to produce the reciprocating motion. Ch. Bhanu Prakash et al. [15] introduced powered bearing which force to rotate the shaft in one direction and itself rotates freely in other direction over the rollers. The return stroke is operated by a suspension system. The author operated 12-volt DC motor at 3000 rpm generating 70 W. The applied system was very much effective and got a system efficiency of about 40%. D. Venkata Rao et al. [16] designed the model of the system in Pro E. design using standard procedures. Crank shaft was used to convert the linear motion of the lever into rotary motion. The speed obtained is amplified by a set of gears. This amplified speed is utilized to produce electric power by turning the generator. In this research, Authors showed that by applying 200 kg load approximately 11.23 V voltage can be generated. Ankita et al. [17] developed an electrodynamics-based model for harvesting energy from speed breaker. But this model is very much expensive and evolved complicated mathematical calculations. Though this model is effective but cannot be used for mass production. Piyush Bhagdikar et al. [18] developed a system in which electricity is produced by the spinning of rollers which is connected to a generator. Rollers are fixed in a wooden ramp over which vehicles are passed. A chain drive mechanism is provided in this system which transfers the motion to the DC generator. The fabrication cost of the model is comparatively low.

IV. GENERATION OF ELECTRICITY FROM HUMAN BODY HEAT AND MOVEMENT

At normal conditions, Human body consistently maintains a temperature of 36 ^{o}C throughout the entire lifetime and releases an energy of approximately 100 W to the surroundings [19]. A maximum power of 5 watts which is equivalent to the needed power to operate portable smart electronic devices is available from human body. It has abundant energy sources in the form of motions, vibrations and heat for energy harvesting in practical life. Several works have been done and numbers of techniques have been invented for harvesting energy from human body in the last 2 decades.

Tom Torfs et al. [20] developed a Wearable Autonomous Wireless Electro-Encephalography System Fully Powered by Human Body Heat. The system can produce up to 2 mW at 23 oC. Only 0.8mW is consumed by the whole system, at the time of sampling and transmitting 2 channels of 12- bit EEG data continuously at 256Hz.The author combined an ultra-low power EEG amplifier circuit and thermo-electric converter. Vladimir Leonov et al. [21] developed an electrocardiography system in a shirt powered by only human body heat. The system was integrated in an office style shirt. Thermo electronic generator was used to power the device that converts the body heat into electrical power. The whole system was composed of total 17 modules spread over the shirt. Hyeongwook Im [22] developed flexible thermocells for utilization of body heat. In this paper thermocells with aqeous potassium ferricynide electrolyte was examined as a source of energy harvesting. When the weather is cold the system generates short circuit current of density .39 A/m2 and at 30 oC temperature maximum power density of 0.46 mW/m2.This paper also did practical investigation on that when a person worn a T-shirt the thermowells are charged up.

S.E. Jo et al. [23] designed and examined flexible thermoelectric generator for human body heat energy extraction. In this paper, the thermoelectric generator which was proposed comprised a polydimethylsiloxane substrate and thermoelectric materials. The polydimethylsiloxane was added to provide flexibility to the generator. The device was very easy to construct and comparatively more flexible. At a temperature difference of 19 K the output power provided by the generator was obtained about 2.1 mW. Vladimir Leonov et al. [24] presented a discussion about what type of wearable devices can be charged by human body heat or energy. In this paper, the authors discussed about the existing wearable devices and new technologies of thermopiles. The discussion concluded that the thermopiles reduces the cost compared to other technologies in harvesting body energy. The authors also discussed about their fabrication and design parameters and techniques. Melissa Hyland et al. [25] designed an advanced thermoelectric generator to harvest energy from human body. TEGs are one of the enabling technologies which enabling and enhancing the mission of creating self-powered, wearable, health and environmental monitoring systems. The developed system was implemented in a T-shirt and power production was recorded for different human activities. The technology was further compared in implementing in different sections of body part. Thielen et al. [26] proposed a complete system optimization for wearable thermal harvesting from body heat to the application. The authors conducted simulation and experiments for the characterization of the harvesting performance. In this research, a case study was done to demonstrate the feasibility to supply multi sensor wearables only from body heat. Several DC-DC converters ae also classified and discussed in this paper.

Gael Sebald et al. [27] showed through investigation that a pyroelectric device may reach to an efficiency of about 50%

of Carnot efficiency. In this paper, an illustration is discussed which helped to estimate the output power that could be expected from natural time variations of temperature of wearable devices. Within a 24-hour investigation the power peak of 0.2m cm-3 were found and a mean of 1 μ Wcm-3 on average was determined. Rusen Yang et al. [28] developed a piezoelectric nanowire-based nano-generator that could produce electricity from human body movement like touching by finger or movement of arms. Inside the wire piezoelectric potential is created which tends to lead the flow of electron in the external circuit. Several single wire generators were integrated to increase the output voltage. A series connection of four single wire generators could produce up to 15 V. Sylvie Turri et al. [29] designed an electro-mechanical portable system for electricity generation using natural human body movements. In this research, electrochemical natural generator was designed which could generate power while walking. The article discussed about nature of human walk in terms of frequency and the displacement of hip. Combined mechanical and electrical study was conducted for the determination and measurement of recoverable power. Teahoon Park et al. [30] developed and designed highly conductive PEDOT tube to generate electricity by the touch of fingerprints. The system provided large power factor of about 1,270 μW m−1 K−2 and was able to produce flexible and cuttable thermoelectric films to generate electricity by fingertips.

V. CONCLUSION

Piezoelectric converters are prominent choice for mechanical to electric energy conversion because the energy density is three times higher as compared to electrostatic and electromagnetics. The electrical power generated is inversely proportional to the damping ratio which should be minimized through proper selection of the materials and design. The power is proportional to the square of the acceleration and reaches maximum at the resonance frequency. The resonance frequency of the piezoelectric transducer is dependent upon the configuration, size, and loading conditions. The efficiency (η) of the conversion process in resonance condition is dependent upon the coupling coefficient and mechanical quality factor of the piezoelectric. In the off-resonance condition, the product (d.g) is directly related to the energy density. As the progress in the development of the power harvesting continues it will be important to standardize the characterization methods so that a comparative study between the systems could be realized.

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