Quantum Electricity of Human Body for Micro Power Generation: A Review.

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Abstract- It is an undisputable fact that power is highly essential in all areas of human existence. Energy which is simply defined as the ability to do work is held to be fundamental to every existential element on earth and even beyond by both the science and the orthodoxy. Human activities on earth in the form of research, experiment and accidents, across centuries had led to the discovery and consequent categorization of power which is a derivate of energy, into different forms such as Electrical, Mechanical, Chemical etc. powers. Basically, energy is the building block, upon which power is constituted, and by quantum theory of matter, all elements, things or object stems from a conglomeration of several individual particles each having a given amount of energy subject to its mass and momentum

Indexed Terms- Quantum, Electricity, Human Body, Micro Power generation

I. INTRODUCTION

One of the big question in this context is, *"Is human body mass of energy particles?"* The simple but disputable answer is YES.

According to physics, the smallest quantity of any physical entity (physical property) involved in an interaction is termed quantum (plural quanta). The basic idea that a large mass can be broken down into smaller particles or "quantized" is known as "the hypothesis of quantization", according to Wiener (1966). This entails that the magnitude of the entity can take on discrete or isolated values consisting of integer multiples of a single particle or quantum.

For example, a photon is a single quantum of light or any other electromagnetic radiation. In the same vain, the energy of an electron bound within the atom is quantized and can exist only in certain discrete energy levels. This is why atom and matters generally are stable. Quantization of energy and its effect on how energy and matter relate referred to as quantum electrodynamics, is part of the fundamental structure upon which nature principles can be understood and described.

II. THE CONCEPT OF HUMAN BODY ENERGY QUANTA

The fundamental principle of energy conservation which is embodied in the first law of thermodynamics, states that energy cannot be created or destroyed but can be transformed from one form to another, Van Ness (1983). Hence power generation processes and energy sources involve the conversion of energy from one form to another, rather than the creation of energy from nothing, LaBonta (2014). Metabolism is one example of the first law of thermodynamics in action in the human body. This is the breakdown of food molecules to produce energy that is utilized by the body to perform several activities. By adaptation of the first law of thermodynamics, the human body heat can be converted into useful energy.

The average human being at rest, produces around 100 watts of power, and in the case of very short burst of energy such as sprinting, jumping etc., humans can output over 2,000 watts of energy, Ozcanli (2010). The bulk of this energy is required for vital tasks, such as cardiovascular operations (heart functions) and physiological operations (muscle actions), but a lot of it is wasted, primarily as heat. According to Starner (1996), almost all of this wasted energy could be captured and turned into electricity. Furthermore, this process could then augment the use of batteries in certain micro power devices. Success in this research area could result to wearable computers: computers wrapped around human wrist, embedded in their shoes, or woven into their clothes. To achieve this, only a few watts of power from the human body would need to be captured; a negligible amount that would probably have zero effect on the body, LaBonta (2014).

Analogically put, the human body can be compared to a complete power system in this form; thinking of the heart as the GENCOS or generating stations, the brain and the spinal cord as the TRANSCOP or transmission system, comprising of substations and high tension transmission lines whereas the rest of the nervous system including the neurons as well as the blood vessels as the distribution network or DISCOS. The various organs and subsystems in the body such as the eyes, ears, nose, etc., represents the consumer unit.
The fuel which powers the entire system is derived from various food items consumed by the human from where glucose, protein, vitamins and other essential minerals responsible for proper operation of the system are obtained.

III. MICRO ELECTRICITY GENERATION FROM HUMAN BODY

The idea of transforming human body heat into electricity has been an ongoing process for scientists for years. For instance, in Sweden, Stockholm Central Station uses heat exchanges to convert commuter body heat into hot water, which is then piped to an office building next door; an approach that can easily be replicated in shopping malls, Hinchey (2011). Researchers have been attempting ways to power small devices, such as cellphones and laptops, when there is no conventional and accessible energy sources. One of such research conducted at the University of Wisconsin, research engineers created a shoe that utilizes reverse electro-wetting to produce as much as a kilowatt of energy, just by simply taking a walk, Popular Science (2009). Similar approach but by piezoelectric effect, had a basketball pitch powered from the kinetic energy of the team during a game session.

A research work done at the Louisiana State University, Center for Advanced Microstructures and Devices, Taher, Orhan, and Choi (2018), present the development of a solution-processed photovoltaic structure designed to convert human body thermal radiation into electricity. This device is used to harvest infrared energy from human body thermal radiation and convert it into electrical energy. It takes advantage of quantum dots made of lead sulfide and couples multiple electronic excitations between mid-gap states to span the optical band-gap.

In a research published in National Library of Medicine, National Center for Biotechnology Information, an investigation of human body potential measured by a non-contact measuring system was carried out by Ichikawa (2016). The result demonstrated that the voltage of a human body wearing antistatic clothes and shoes or light clothes and slippers exceeds a malfunctioning voltage of a microelectronics device when the body walks on floors.

It is no more news that the human body can be charged up under certain conditions, given rise to electrostatic discharge effect (ESD), which oftentimes interfere with normal operation of electronic equipment, Honda (1989). In the experimental setup described below, it's observable how these human body potentials buildup and how they can be harnessed for better use.

In this experiment, a human body wearing antistatic clothes, shoes, light clothes and slippers are made to moves on an experimental floors, having different surface resistances on an ungrounded metal plate. According to Honda (1989), the relation between the voltage of a charged human body and the induced voltage generated on the ungrounded metal plate is studied experimentally by using the non-contact measuring system. The results show that the charged human body in this situation can be determined by the system, and the voltage build up in the body, exceeds the voltage at which electronic equipment malfunctions.

Figure 1 shows the arrangement of the experimental setup. The experimental setup consists of an experimental floor, a direct measuring part for the voltage of a human body, and measuring instruments, Honda (1989).

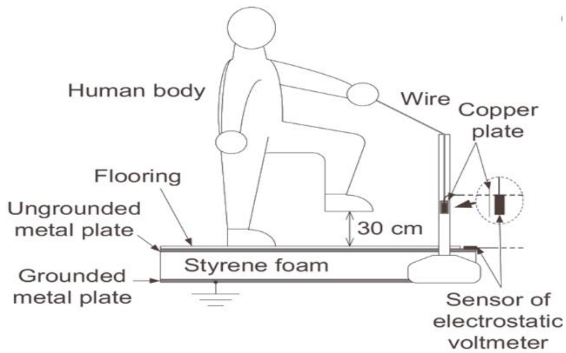

Figure 1: Arrangement of experimental setup, source: Ichikawa (2016).

This floor consists of a grounded metal (copper) plate, styrene foam, an ungrounded metal (copper) plate, and a floor. A sensor for the surface voltmeter (Model 347, Trek Co.) is arranged on the ungrounded metal plate. The experimental floor represents the floor in a room. Four floors are used with a Poly (methyl methylacrylate) - PMMA plate, a multi-layer vinyl floor sheet, carpet, and a polyvinyl chloride sheet. The surface resistances of the four floors are shown in Table 1.

Table 1: Surface resistance of flooring used in experiments, Source: Ichikawa (2016).

Type of flooring	Surface resistance (Ω)
PMMA plate	1.18×10^{12}
Multi-layer vinyl floor sheet	5.24×10^{11}
Carpet	3.30×10^{8}
Polyvinyl chloride sheet	1.53×10^{9}

In the experimental setup of figure 1, the measuring instruments consist of two surface voltmeters, an oscilloscope, and a notebook computer with the PC Link Software installed. The induced voltage generated on the ungrounded metal plate of the experimental floor and the human body's voltage are measured by using two surface voltmeters with sensors. The two surface voltmeters connect the oscilloscope and the notebook computer enabling the induced voltage on the ungrounded metal plate generated by the walking motion of the human and its body voltage to be measured automatically.

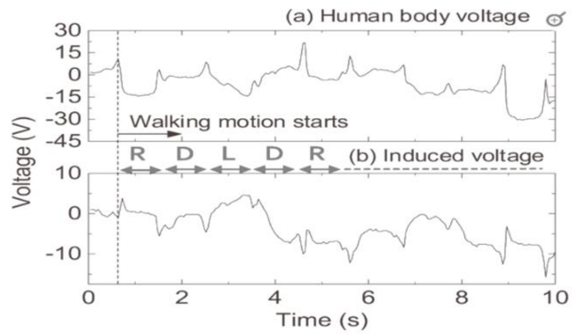

Figure 2: HBV and induced voltage for PMMA plate, Source: Ichikawa (2016).

The result of the experiment is shown in Figure 2 for a PMMA plate on the experimental floor. In these figures, the symbol of "R" implies that the human body raises a right foot, "D" the body downs the foot, and "L" the body raises a left foot. As can be observed, the human body's voltage (HBV) is −14 V when the right foot rises and it decreases when the foot is lowered. The HBV is seen to change when the walking motion repeats. Note that the induced voltage is directly the opposite of the HBV owing to the fact that action and reactions are equal and opposite.

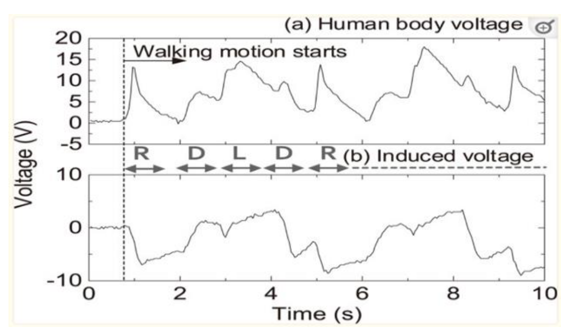

Figure 3: HBV and induced voltage for multi-layer vinyl floor sheet, Source: Ichikawa (2016).

Figure 3 shows HBV when the human body walks on the multi-layer vinyl floor sheet on the experimental floor. The HBV increases when the right foot rises, and its peak value is 13V. It decreases and increases immediately to 7 V when the right foot is lowered. The largest potential recorded in this experiment is 17 V.

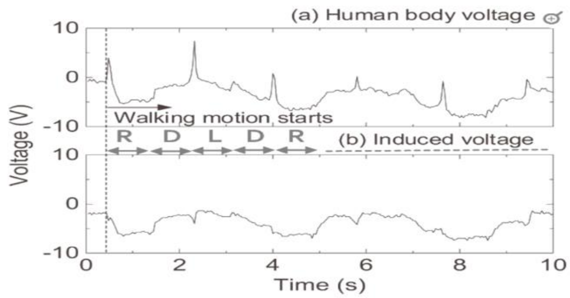

Figure 4: HBV and induced voltage for multi-layer carpet, Source: Ichikawa (2016).

Figure 4 (a) shows the HBV when the human body walks on carpet. The HBV changes when the right foot rises, and its negative peak value is −5 V. It decreases to −1 V when the right foot is lowered. The human body potential decreases rapidly even though the induced voltage increases positively when the height of the left foot increases.

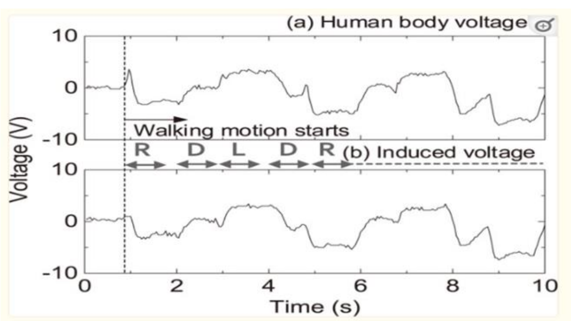

Figure 5: HBV and induced voltage for polyvinyl chloride sheet, Source: Ichikawa (2016).

Figure 5 shows the HBV when the human body walks on a polyvinyl chloride (PVC) sheet. The HBV is −3 V when the right foot of the body rises. The human body's voltage decreases to approximately zero when the right foot is lowered. The largest human body potential recorded in this experiment is −7 V.

IV. HUMAN BODY ENERGY TECHNOLOGY BREAKTHROUGH

The human body is an incredible piece of biology. It can do many impressive things, including producing small amounts of electricity. According to sites like extremetech.com, the human body creates a surprising amount of electrical energy, even when at rest, McFadden (2020).

"The average human, at rest, produces around 100 watts of power. This equates to around 2000 kcal of food energy, which is why your recommended daily intake of calories is around 2000 kcal."

The human body does emit electricity, Plante (2016). In fact, most living animals do, to some extent, Conger (2022). The human body has various bodily functions that rely on the flow of charged ions like the muscles of the body and heart. However, one of the organs that has a lot of electrical activity is the brain. This vital organ has somewhere in the region of a hundred billion electrically conductive biological wires, kwon as neurons, McFadden (2020).

In reality, the human body produces between 250 and 400 BTUs of power, depending on its state of consciousness. In other words, when the body is asleep, it produces less." Some of the devices developed so far in this regard includes:

I. Flexible Thermoelectric Generator

A South Korean team of researchers at The Electronics and Telecommunications Research Institute (ETRI), have created a lightweight, flexible thermoelectric generator that uses the temperature difference between a human and the surrounding air to generate electricity which they hopes could be revolutionary for wearable technologies in the future, Eurek (2019).

"When a patch-like structure is attached upon the thermoelectric device which is 5 cm in width and 11 cm in length, a temperature difference occurs between the skin and the structure, imitating the sweat glands structure. This core technology is called *"biomimetic heat sink."* It increases the output of the thermoelectric module by five times that of conventional products, maximizing the energy efficiency."

Initial tests of the device were able to generate 35 microwatts per square centimeter. This is around 1.5 times higher than results obtained by other researchers working on similar tech in the U.S.

II. Biological Tattoo

Researchers at the Jacobs School of Engineering, University of California; San Diego have created a small temporary tattoo that incorporates enzymes that produce an electrical current from human sweat, Labios (2017).

These enzymes strip electrons (oxidize) from lactate in sweat to produce small amounts of electricity whenever the wearer sweats (like during exercise). They produce enough electricity to power small electronics like LEDs and even Bluetooth radios.

"The biofuel cells generate 10 times more power per surface area than any existing wearable biofuel cells so far developed. The devices could be used to power a range of wearable devices such as wrist watch, electronic glass, hearing aid etc.

The epidermal biofuel cells are a major breakthrough in the field which has been struggling with making the devices that are stretchable enough and powerful enough. Engineers from the University of California; San Diego were able to achieve this breakthrough thanks to a combination of clever chemistry, advanced materials, and electronic interfaces that allowed them to build a stretchable electronic foundation by using lithography and screen-printing to make 3D carbon nanotube-based cathode and anode arrays."

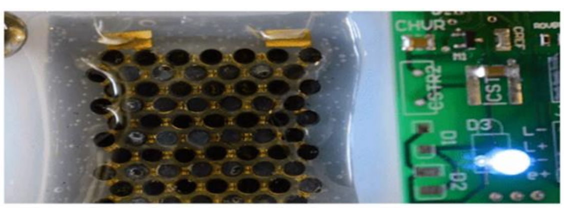

Plate 1: Biological tattoo. Source: Jacobs School of Engineering, source: Labios (2017).

III. In 2011, a team of researchers at the Joseph Fourier University of Grenoble created an implantable piece of tech that can generate electricity from the human body. The biofuel cells draw power from substances that are freely available in the human body: glucose and oxygen. Each cell consists of two special electrodes that perform separate functions. The first oxidizes (strips electrons from) glucose, the other donates electrons (reduces) to molecules of oxygen and hydrogen, Limer (2011). When both electrodes are connected in a circuit, they produce a flow of electrons from one electrode to the other, thus generating a handy electrical current that could be tapped to power wearable or other implanted tech (like pacemakers).

"Dr. Serge Cosnier and his team are the first ones to successfully prove this concept by implanting a prototype cell into a living being and having it function, Limer (2011). In 2010, an early model of the bio-cell was implanted in a laboratory rat where it stayed for 40 days, producing electricity without having any visible side-effect on the rat's health or behavior; a pretty promising success."

IV. Endoelectronics Ear implant chip

A team of researchers in Massachusetts Institute of Technology (MIT) produced a device back in 2012 that can harvest power from human inner ear. The ears of mammals contain tiny electric voltages called the endocochlear potential (EP) which helps convert pressure waves into electrical impulses before sending it to the brain.

This is a very tiny electrical potential at around one-tenth of a volt, but this is still strong enough to power, theoretically, hearing aids and other aural implants.

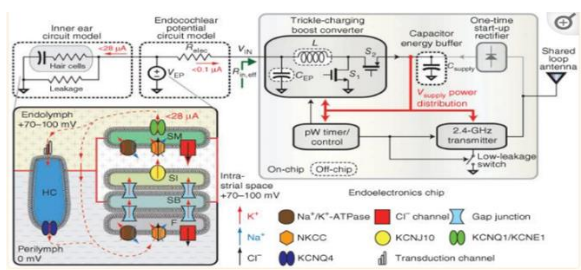

Figure 6: Schematic of the endoelectronics chip and equivalent circuit model of the endocochlear potential and inner ear tissues, source: Mercier et al, (2012).

A feat long thought unthinkable before the team created an *"energy harvesting chip"* the size of a thumbnail that can extract some of this electrical energy directly. "They tested the chip in a guinea pig, implanting it into the animal's inner ear where it generated enough electricity to power a radio transmitter. The minute electric power produced by the chip; about a nanowatt (a billionth of a watt), is still about a million times too low to power an electronic implant." Mercier et al, (2012).

V. nPowerPEG

Converting human kinematics into electrical energy is nothing new, but the nPowerPEG is a very innovative one. Developed almost a decade ago, it is a handheld tube-shaped device that clips onto a belt or backpack and generates electricity as the wearer moves around, Lasky (2012). It incorporates a magnet weight, spring, and induction coil that all work in harmony to generate power. The device cannot produce enough electricity to power laptops or tablets, but it could have great potential in the future for powering another wearable tech or smaller electronics like mobile phones.

Plate 2: nPowerpeg source: Lasky (2012).

V. APPLICATIONS OF MICRO ELECTRICITY

Scientific and engineering inventions of the past that harnessed human body electrical activities, such as Electrocardiogram (ECG), Electroencephalogram (EEG) machines etc., mostly focused on sensing these electrical signals and using it to provide vital information about the state of health of the human species being studied or monitored, thus assisting the medical personnel carryout an informed therapy.

But in recent times, there had been a paradigm shift towards harvesting these human body electrical energy and using it to power wearable devices such as wrist watches, hearing aids, electronic glasses etc., irrespective of its micro nature. Several researches are currently in progress, which are geared towards improving the magnitude of extracted human body electrical energy, through various means and possible applications to power low energy smartphones of the future.

VI. FUTURE RESEARCH

Not only can the human body heat be harnessed but also its motion and body electromagnetic waves. So far progress had been recorded in the area of human body heat, and kinematics to power conversion, but little or no research work had been recorded in the area of human body electromagnetic wave radiation direct capture and conversion. A possible probe into this area could be to develop a system which harvest this energy through the process of electromagnetic induction, and also improve on energy amplification.

CONCLUSION

While human body heat can be harvested in large scale as in the case of a shopping mall or moving train and channeled to heating chamber, it is still far from efficiency harvesting human body heat using wearable devices. However, it appears the future of human batteries are inevitable. It just a matter of time and research away.

With continued investment in research and technology geared towards developing sustainable energy, it’s apparent that the use of human body electricity will likely be used to power micro technology innovations of the future.

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