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Harvesting Energy from Human Walking and Health Monitoring System

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Abstract

This paper is presented in the context of generating renewable energy using the piezoelectric module to harvest kinetic energy from human walking. The electronic system has developed using 32 piezoelectric modules situated at the shoe sole and thereby energy will be harvested and stored whenever the user walks or runs. The harvester circuit is able to produce an average of 2.941 V and 0.171 mA per step by the person with a weight of 80 kg. In addition, IoT (Internet of Things) based health monitoring system has built with the aim of using the harvested power to power up the system. The microcontroller in the monitoring system able to work with the harvested power of 279mW per hour. It is observed that the battery of the system will last around 1.6 days under the no-load condition. The energy harvester enables the battery to get a full charge with a walking speed of 30 steps/minute, which will take 12.26 hours. At the walking frequency of 30 steps per minute for an 80 kg weighted person, the system generates the power of 905.23 mW and hence the power efficiency of 30.8% is accomplished by the harvester system.

***Keywords:** Energy harvester; monitoring system; piezoelectric; energy from human walking; IoT.*

I. INTRODUCTION

The demand for wearable and portable devices has been rapidly increasing as IoT is turning more popular among society. Energy is one of the vital factors, which will limit the growth of these wearable and portable devices technology. The energy storage and supply is a major concern in the wearable devices since the system complexity and overall weight of the deploying element into the gadgets [1]. The energy crisis is a very big issue around the world as most of our production lines and factories are depended very much on energy. The majority of the energy comes from natural resources which take millions of years to get in this form [2]. So, the government of all developed and developing countries is trying to harvest energy from other methods as the natural resources are going to be finished in the near future and thereby the new method of energy has been introduced, such as renewable energy.

Now solar energy and wind energy are already in use but it’s not enough to accomplish the current demands and hence some other alternative energy harvesting system is the part of requirements [3]. The well-known renewable energy such as solar and wind energy takes a lot of land place and also required a lot of new technologies, which indirectly increase the cost of deployment. So, the researchers are very keen on developing a new form of energy harvester designs. One of the latest ideas is harvesting energy from human walking using integrated electronic devices [4]. As the human body converts its energy in another form of energy and most of the time it gets wasted as there is no such device to convert human kinetic energy into electricity. This method of energy

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harvesting will be a good standby to boost up the efficiency as well as environment-friendly [5].

This work aims to address this issue by implementing an environment-friendly energy harvester. This harvester will convert human walking energy into electricity without using any harmful substance for the environment. It is more cost-effective and affordable, which can play a key role in the energy harvesting sector in the near future. It also aims to monitor a person's health using the Internet of Things (IoT) [6].

In recent days, most of the elements are becoming smart with the help of the latest technologies. The objects like clothes, shoes and other outfits are becoming smarter. People attach sensors and microcontrollers on those outfits to collect data from surrounding and analyze them with IoT [7]. Most of the leading technology companies have already launched smart wearable gadgets where Apple Watch is the most popular example along with Google Glass. As for wearable and portable devices, energy efficiency is always a big challenge. Wearable devices are always expected to be rechargeable most of the time by other devices [8]. Since the gadget consumes a reasonable amount of electrical energy even though it's not serving its main functionality. This is the main reason why gadgets have to be frequently recharged [9]. In particular, some specific locations such as thick forests and mountain climbing, charging a battery is not feasible and very difficult. Thus, the users will definitely be benefited when a battery has the ability to recharge itself. It is very curious that to make the battery with long-lasting capacity or no need to be charged rottenly [10]. So, there is a demand to produce sustainable energy to evade recharging the battery rottenly.

II. LITERATURE REVIEW

Zhao & You (2014) have researched a shoe-embedded piezoelectric energy harvester for wearable sensors that harvests the mechanical energy from human motion and convert this energy to electrical energy to supply power for wearable sensors. The researcher has used Photovolatile material to harvest human motion energy and able to produce an average output power of 1mW with a walking frequency of 1Hz. The super-capacitors are used as a storage unit to store the energy produced during human motion [11].

Senthamilarasi et al., (2018) have researched on a smart patient health monitoring system using IoT. The researcher Arduino Uno microcontroller with a WIFI module and three different sensors which are pulse sensor, temperature sensor and EEG shield sensor for monitoring a patient's health. The WIFI module enables Arduino to connect with the internet for sending the sensor data on the IoT platform [12]. In order to send a signal from sensors to Arduino, it is used the amplifier circuit and signal controlling unit (SCU) because the gain of the sensor signal is very low [13]. After receiving the signal from these sensors, Arduino then sends the data to the cloud database with the aid of a WIFI module. The limitation of this research is using Arduino Uno and WIFI module where instead of these two components, this same work can be done with the help of NODEMCU which have an in build WIFI module and it works as a microcontroller which is also economical compared to Arduino Uno and WIFI module [14].

Narendra Swaroopa (2019) have researched about health monitoring system using IoT. Two sensor units are used such as temperature sensors to monitor the patient's health and pulse sensors to monitor the heart rate. They have used Arduino to collect the signals from the sensors and ESP8266 module for wireless transmission of the signal data to the IoT platform [15].

Zhang et al., (2018) have researched long-distance medical monitoring systems based on the internet of things. The researcher has designed a medical health monitoring system with the aid of CC2432 microcontroller where they have designed a sensor node circuit and a coordinator node circuit for collecting medical signals [16].

III. METHODOLOGY

The block diagram of the energy harvester system is shown in Figure 1. The foot strike of a person is applied to the piezoelectric module on the shoe sole. The piezoelectric module converts the kinetic energy of the foot strike into electrical energy. The electrical energy which is produced by the piezoelectric module is AC voltage. This AC voltage is converted to a DC voltage with a full-wave bridge rectifier. Then this DC

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voltage is used to charge the energy storage which is in this project a 3.7 V LIPO battery.

This energy storage is used to power up the IoT based health monitoring system. This health monitoring system has a heart rate sensor and a temperature sensor which helps to monitor the health of the user. In addition, a voltage sensor is also placed to monitor the battery life of the health monitoring system. The health monitoring system will also notify the user when an alert is triggered. The notification will be done via email and on the phone using the notification window.

The system uses a total of 32 piezoelectric disks that are placed at 8 in 1 set with a total of 4 set to maximize the pressure on the energy harvester to produce more energy. Moreover, piezoelectric produces AC voltage but the system required is DC voltage. For the conversion of AC voltage to a DC voltage, a full-wave bridge rectifier is used. A voltage indicator has been placed to indicate the voltage level of the battery. This is very significant to measure the amount of voltage generated from footstep for efficiency calculation and hence digital voltmeter has been used. Along with that, the charging module has been implemented to charge up the battery.

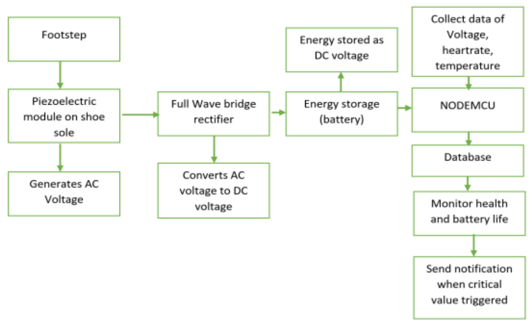

Figure. 1

Furthermore, from the battery, NODEMCU ESP8266 is getting charge which is used to power up the health monitoring system. A switch is also placed in-between the battery and NODEMCU to turn on the system whenever it needed or when the person is walking using the system. A total of 3 sensors such as voltage sensor, heart rate sensor and temperature sensor LM35 are incorporated into the system for data acquisition.

The NODEMCU ESP8266 has only one analog input port and thereby an analog multiplexer CD74HC4067 has been used to multiplex the inputs from three sensors. For the health monitoring system, it uses 3.72 V 75 mA from the battery. The capacity of the battery is 3.7V 3000mAh. As we know, the power of the battery is, P=VI

$$P = 3.7 \times 3000 = 11100\text{mW} \quad (1)$$

The power consumption of the system is,

$$P= 75\text{mA} \times 3.72\text{V} = 279 \text{ mW} \quad (2)$$

So, the system will last without charging the battery is = (11100/279) = 39.78 Hour or 1.6 days.

The energy harvester generates on average 2.941V and 0.171mA per footstep when an 80Kg weighted person walks on the system with a walking speed of 30 steps per minute which makes 1800 steps per hour. So, the power output of this system will be,

$$P= 2.941\times0.171 = 0.502911\text{mW per step} \quad (3)$$

$$P= 0.502911\times1800 = 905.23 \text{ mW per hour} \quad (4)$$

For fully charging the battery with a walking speed of 30 steps per minute, the energy harvester will take 11100/905.23=12.26 Hours. It means that the system will take approximately 22,000 steps to charge the battery by which the health monitoring system works smoothly without any interruption. An average human takes 10,000 steps daily. For charging the system fully, it will take approximately 2 days. The battery of the system will last without charging around 1.6 days. The efficiency of the system can be calculated through the ratio of the system uses 279 mW per hour which is the required amount at the output to the ideal value of energy generated by the proposed system. According to the calculations, the energy generated by the system with a walking frequency of 30 steps per minute is 905.23 mW as energy output. Hence, the efficiency of the system can be calculated by Efficiency=energy input/energy output = =279/905.23×100=30.8%. The efficiency of the system is around 30.8%.

The constructed prototype is depicted in Figure 2. In the designed harvester circuit, a total of 32 piezoelectric modules is used and are grouped into four sets. Each set contains eight piezoelectric modules in which four of them are connected together in parallel and another four modules also connected in parallel and then finally connected together in the form of series topology. This setup intended to boost-up the harvested voltage from the footsteps. It is observed that the voltage and current production of this system is 0.05V – 2V DC and 0.21 mA per footstep respectively.

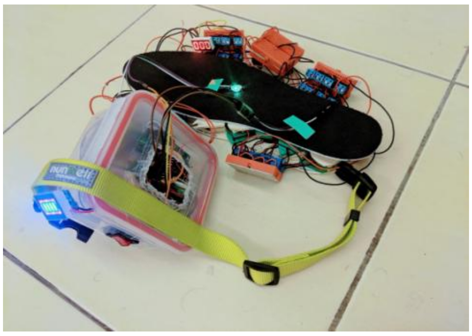

Figure. 2

The notification system also deployed into the harvester design to display the critical values of the physiological parameters. Whenever different sensors will reach its critical values, the system will indicate the parameter value and notify the respective person via the messaging facility. If the temperature of the user is below 40° C or more than 450° C, then the notification will be displayed. On the other hand, for the heart rate sensor, when the pulse rate is less than 30 BPM or more than 110 BPM then the notification system will be activated, and an alert message will be sent through the application. For the voltage sensor, when the voltage of the battery dropped to 3.21 V or its energies more than 4.21 V then the notification system will be activated and provides the instruction to the user for taking further action. The notification either will be on the phone display or send via email to the user. If the health of the user is very critical then the system will send the additional email to the immediate family member of the user. The system has the ability to produce a data report which is very convenient for the doctor to analyze the patient's health condition.

For the IoT platform, BLYNK is being used in this work to analyze the results. The GUI of the BLYNK application can be seen in Figure. 3 in which the voltage of the battery is displayed at the top of the GUI. The measurements are taken in real-time when the health monitoring system is working with sensors and controllers. As can be seen, the initial measurement of voltage is 3.89 V. This voltage will increase correspondingly when the number of users starts walking on the energy harvesting system. The pulse or heart rate measurement features also customized with the ability of temperature measurement in the designed system.

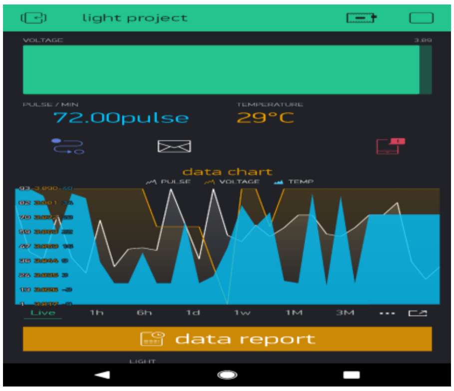

Figure. 3

IV. RESULT ANALYSIS

The amount of energy harvesting of the designed system mainly depends on the average weight of individuals. The first test has performed to analyze the relationship between energy generation and weight of individuals. The factors considered for this test are the weight of a person and the amount of energy generation by the harvester design is illustrated in Figure 4. There are five persons with different weights such as 55 kg, 65 kg, 75 kg, 85 kg, and 95 kg are used to test the developed prototype and measured its corresponding voltage generated at the output of the system. The piezoelectric energy harvester converts kinetic energy into electrical energy so that this system able to produce more energy when more weights are applied.

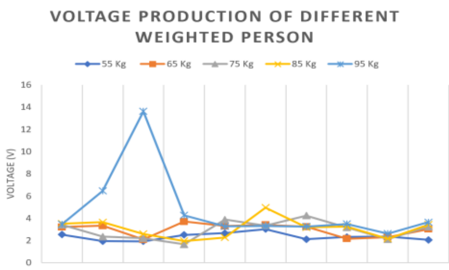

Figure. 4

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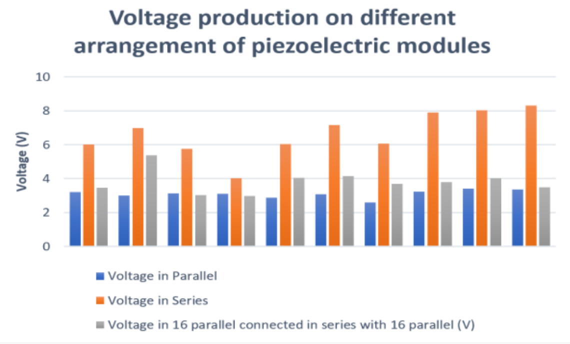

Figure. 5

Another significant test is to analyze the arrangement of piezoelectric transducers for voltage generation. The topology of transducers has the ability to change the percentage of energy production. Three topologies are being used in the transducer connectivity for the practical design. To test the ability of the designed system, piezoelectric sensors are connected in series, parallel and series-parallel arrangements and its resultant output voltages are measured and analyzed in the Figure. 5. It is observed that the output of series topology is higher than other topologies. This result analysis is very useful for the good design since the transducer arrangement will affect the energy generation and performance of the harvester circuit design.

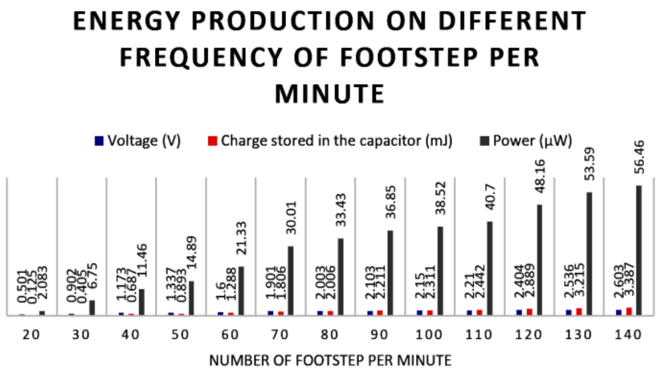

Figure. 6

Subsequently, the analysis of energy production on the different frequency of footstep per minute is performed and its interpretations are illustrated in Figure 6. This test will determine the suitable value of walking frequency for producing more energy so that it can be benefitted to the user. An average human has a walking speed in-between 20 – 140 steps per minute. This test provides the power generation on a different frequency of footsteps per minute for an average human being. It can be seen from the results that the value of voltage increases with the number of footsteps increasing. It is because the value of the capacitor increases the output voltage as it added the newly generated voltage together with the old voltage due to the previous footstep. As similar, the charge and power also increase simultaneously with the number of footsteps. For the analysis, there are 13 different sets of data were taken to prove that the energy generation increases with the number of footsteps. It is considered the average walking speed of between 20 to 140 steps per minute for the observation. The results and measurements are proved that the value of harvesting energy increases when the frequency of walking increases. It is obvious that increasing the number of footsteps on the system that generates more power.

V. CONCLUSION

The harvesting of energy from human walking is presented in this work. The electronic system has developed using 32 piezoelectric modules to harvest kinetic energy from human walking. The compact system has built and placed at the shoe sole for the energy generation whenever the user walks or runs. It is highlighted that the developed system has the ability to produce an average of 2.941 V and 0.171 mA per step with a weight of 80 kg. Subsequently, the IoT based health monitoring system has developed to utilize the harvested power for measuring the physiological parameters. The result analysis has revealed that the energy harvester enables the battery to get a full charge in 12.26 hours. The designed system has the capacity of producing the power of 905.23 mW with a power efficiency of 30.8%. Finally, it is concluded that this kind of power generation is very sustainable for many applications.

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