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Generating Electricity Using Produced Mechanical Energy In A Gymnasium

D.K.A.Induranga
Department Of Engineering Technology
Sabaragamuwa University
Belihuloya, Sri Lanka
Ashaninduranga@Outlook.Com

G.D.K.V.Maduwantha
Department of Engineering Technology
Sabaragamuwa University
Belihuloya,
Sri Lanka
infokaveendra@gmail.com

H.G.N.A.Sirisooriya
Department of Sport Sciences a Physical Education
Sabaragamuwa University
Belihuloya,
Sri Lanka seeashan@gmail.com

W.S.M.Fernando
Department of Computing and Information Systems
Sabaragamuwa University Belihuloya,
Sri Lanka sachithfernando599@gmail.com

P.P.Weerakkodi
Department of Sport Sciences and Physical Education
Sabaragamuwa University Belihuloya
SriLanka pathump9@appsc.sab.ac.lk

H.D.C.N.Gunawardena
Department of Engineering Technology
Sabaragamuwa University Belihuloya, Sri Lanka
niroshangunawardane@gmail.com

K.R.Koswattage
Department of Engineering Technology
Sabaragamuwa University Belihuloya,
Sri Lanka koswattagekr@appsc.sabac.lk

***Abstract*—The way of using exercise equipment to generate electricity has attracted considerable research attention since the energy produced through such a human movement is clean, renewable and sustainable as well as which will be a solution for extraordinary increase in global energy demand.**

This study focuses on converting the mechanical energy released through a human workout in an exercise machine and converting to electrical power. It is identified that a considerable amount of electricity can be generated through the process which could be used for simultaneous operation of any suitable electrical device.

Here the experimental effort has mainly dedicated to developing a system to convert the above-mentioned kinetic energy produced in a stationary (exercise) bike to electrical energy using reusable parts of an abandoned exercise bike.

The system consists of an electrical circuit consists with an alternator which is fixed to exercise-bike to produce electricity during the paddling. Then generated electrical energy is stored in a portable power bank. In the machine, revolutions per minute (RPM) obtained during the workout and number of calories burned can be estimated based on formula which is defined for the particular machine through a pilot data analysis. This particular exercise machine will fascinate users to achieve goal-based approach to exercise since the machine gives details of the calories burnt during the workout as well as give the details of harvested electrical energy.

Keywords—Human Energy Harvesting, Green Energy, Energy Conservation

I. INTRODUCTION

In Sri Lanka, the energy demand will be increased to 20242 GWh per year, in 2024 (1, which is nearly 1500 GWh energy consumption larger than the current energy generation of a year. Humans need to extend their power generation methods to fulfill the energy demand of the future world. Further, the energy demand should be satisfied with renewable energy sources for a sustainable future where it has been reported huge negative environmental impact from currently existing non renewable energy sources. As an example, 2014, 41% of the total CO2 emission in Sri Lanka, produced by electricity generation (1).

As a result, there are several energy sources that can be proposed and mainly the developed countries have invested a lot of money to explore suitable candidates to satisfy future their energy demand.

On the other hand, researchers seek different ways to harness human power so called human

energy to produce renewable energy. The concept of sustainable gym is one way to generate renewable energy during the workout at exercise machines which will be a great benefit for developing countries currently struggling to invest money to find alternate renewable energy sources through high technological research works.

During the exercising, human energy that is stored as chemical energy which is then converted into kinetic energy. During this energy conversation via exercise, fat stored in human body burns to produce kinetic energy. But during the workout at exercise machine, this produced kinetic energy is transformed

to mechanical energy through the exercise machine. Thus, this research focuses a method to convert the produced mechanical energy in the gymnasiums to electrical energy using a cost-effective way. This type of a cost-effective and multifunctional machine will help to fulfill the increasing energy demand.

Several kinds of exercise equipment with different mechanisms can be found in the gymnasium. The stationary bike is a common exercise equipment. It has a suitable mechanism that can be used for energy conservation purposes. The study aims to discuss a certain context of reusing both energy and materials. Since, the instrument with circuits were mainly cost effective, and the machine is completely made with reused materials from disposals. The electronic circuit is implemented to display the number of calories burned by the user and the amount of the electrical energy produced during exercising time. The electricity is generated using a simple alternator which is attached to the flywheel of the bike. This generated AC power is converted to DC power using a rectifier circuit. Rest of the circuit is designed to store this electric energy in a portable power bank.

I. LITERATURE REVIEW

A. Energy Sources

According to the long-term generation expansion plan 2020 – 2039 of Ceylon Electricity Board (CEB) there will be a yearly energy demand increment of around 5 % - 6.8 % in Sri Lanka (1). To generate this excess energy requirement, there should be research on finding alternative energy sources. Meanwhile, to reduce the greenhouse gas emission, Sri Lanka Energy Authority and CEB plans to increase the renewable energy share up to 50% in the total energy generation capacity (1). Thus, the researchers need to be focused more on renewable energy sources considering the alternative methods for power generation.

If we consider a country's power system, Electrical energy generation varies according to the energy demand because traditional power systems don't contain energy storage methods. However, considering the world's new trends of power generation, there are new methods to store energy in effective ways producing renewable energy sources for on demand use. There are certain specific goals has been identified for energy storage such as Department of Energy US set a target of 6 wt% hydrogen storage for on board hydrogenation energy applications and proposed materials at nanoscale as one of the promising candidates (2).

Pump storage method is another example for energy storing. During off peak times power systems can generate excess power and utilizing the excess power, water can be pumped from a lower to an upper reservoir. During the peak hours, hydro – electricity can be generated via the pumped water (3).

B. Human Energy Harvesting

Now a day, Human energy harvesting for a sustainable future is an interesting field for many researchers focused on since human energy is a green energy. Considering the human energy harvesting process, researchers mainly focused in gymnasiums since a large amount of kinetic energy production through human workout. There are several gymnasium instruments that can be used for energy harvesting with different mechanisms like stationary bike, treadmill, upright bike etc. It has been reported average person can produce kinetic power between 215 W to 375 W with a stationary bike (6).

Human energy harvesting is not only limited to gymnasiums. Humans generate kinetic energy during their day to day activities and the energy can also be harvested with suitable methods such as using piezoelectric materials in people's walking lanes (8).

II. METHODOLOGY

A. Methodology of the power generating exercise bike

The machine is made up of three main parts.

1.Exercise Bike

2.Electronic Circuit

3.Software

1) Exercise bike

Fig. 1*: Stationary Bike (left – isometric view & right – side view)*

A stationary bike is used here as the exercise machine. Stationary bike is a common exercise machine in the gymnasium where it helps to gain muscles and the strength of legs. Training on a stationary bike is ideal for toning legs, thighs and buttocks, as well as the arms, abdominal and back where, stationary bike can be considered as a full body exercise machine. A low level of resistance is useful for warming up and enhancing endurance. Stationary bike is a great instrument for the people who enjoy repetitive solo workouts. Also, stationary bikes are designed with a better mechanism that can be modified for energy harvesting.

Mainly the stationary bike consists of a handle, flywheel, chainwheel, paddles and stabilizers. The stationary bike for this study was made out using recycled materials.

In the bike, the alternator is connected to the flywheel and the alternator starts to rotate with the movement of the flywheel. Due to the rotation

mechanical energy is flowed to the alternator through the flywheel. The alternator can generate an AC voltage up to 12 V where the output voltage varies with the rotating speed of the alternator. The rotating speed of the flywheel varies with the gender, weight, muscle strength and experience of the human performing the workout on the bike. Hence the instrument needs a proper pathway to control the output voltage at a constant value for further uses. Since the system has to be implemented in a way that the above criteria are satisfied.

2) Electronic Circuit

Fig. 2*: Electronic circuit diagram*

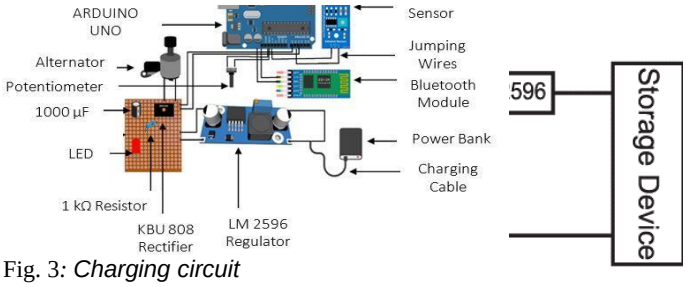

Fig. 3*: Charging circuit*

ddling. This AC power is varying with the paddling speed. Since the generated AC voltage is converted to DC power using KBU 808 single phase rectifier and a 1000 µF capacitor.

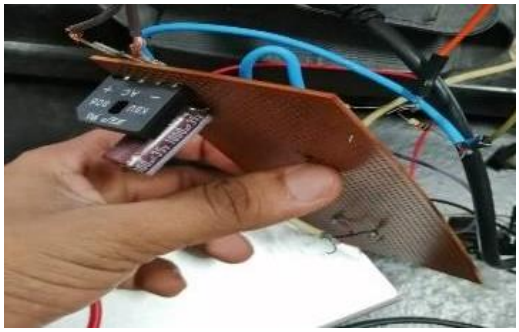

Fig. 4*: KBU 808 Rectifier, 1000 µF capacitor*

Energy Harvesting system is modified for satisfying a low-level energy requirement where the DC output voltage should be adjusted for 5V. Thus, a LM 2596 buck converter (DC – DC Converter) is connected to reduce the voltage to 5V.

ARDUINO UNO is connected to the output terminals of the alternator for the voltage measuring purpose and to IR sensor for measuring the RPM rate of the flywheel.The measured rpm rate is converted to the relevant rpm value for the chain wheel according to the ratio between the number of serrations. The 16x2 LCD displays the RPM value of the chain wheel. Bluetooth module is used for the remote controlling of the calculating procedure. An android application is created to communicate with the circuit via a Bluetooth module.ARDUINO UNO is programmed to display the number of calories burnt and the produced electrical energy throughout the time.

3) Software

A. A. ARDUINO UNO Program

ARDUINO application is designed to calculate the number of calories burnt as well as the electrical energy production by the user during the exercising time. However, the program is designed to accumulate produced electrical energy, only if the RPM values higher than 60. The data acquire rate is determined to be 1 Hz to the program for proper data acquisition. It doesn't require to increase the data acquiring rate, since the rpm rate isn't changed rapidly.

The 16x2 Display is selected to display the number of calories burnt and the amount of electrical energy produced since those are the most useful values for an athlete. These values are shown to motivate the athlete.

Fig. 5*: LCD Display*

B. B. Bluetooth switch

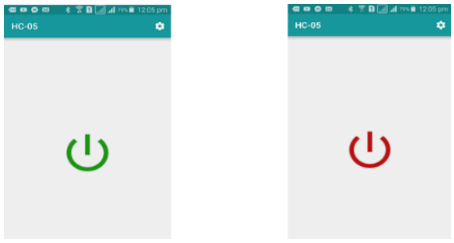

Fig. 6: *Graphical User Interface of the Android Application*

This ANDROID application is designed to control the ARDUINO IDE program via Bluetooth. This ARDUINO application is used to switch on and off the circuit, the green virtual button represents the on state and the red represents the off state.

III. Calculation Of The Number Of Calories Burned (CB)

The machine has to be calibrated in order to provide output values of burned calories and energy production. There are two main methods namely Metabolic Equivalent of Task (MET) based and graphical method [10]. In the (MET) weighted method it defines a difficulty value for the exercise. Depend on the MET value, the mass of the cyclist and the exercise time, the amount of CB can be calculated. Since the proposed system consists with unassigned and unknown MET values which restricts the use of the MET method. However, average MET value for the proposed system can be derived using MI4 health band which gave the CB values of the person workout.

For the proposed system, instead of MET, graphical method is proposed to use due to the simplicity of the design perspective. By the time a

disadvantage was occurred in the form of outliers with higher degree of freedom owing to different factors that are irrepressible. Due to the limited number of samples we obtained from the population (n = 100) the variability of the real value of CB is much higher/lower than which is expected. But this can be easily reduced by increasing the number of samples. The graphical method focuses to build a relationship between RPM and CB with the help of regression. The preliminary relationship which is derived from the graphical method is as follows.

$$\text{CBs} = \text{slope of graph} \times \text{RPM} \quad (1)$$

It is assumed that there might be a certain degree of misinterpretation from the real situation due to the simple linear relationship of equation 1. It should be noted that this relationship can be modified to be highly accurate by using the values that are augmented while future usage.

IV. Data Analysis And Presentation

A. *Burnt calories*

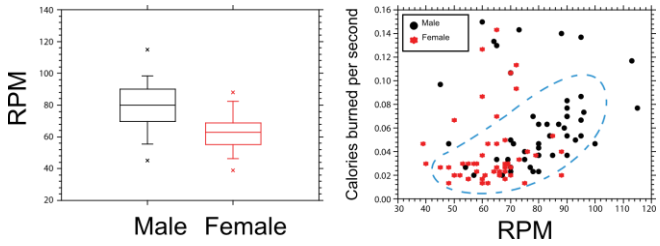

Fig. 7*: Box plot for two data groups (left) scattered plot of CB per second vs. RPM [red -female black – male] (right)*

By analyzing the data obtained for 50 males and 50 females for a constant time of 5 minutes at a constant friction level, we suggest several key factors that might be influenced calorie burning sporadically such as, gender difference, muscle strength, physical condition (tiredness) and muscular endurance. Further we should notice that, males were able to maintain a steady calorie-burning level with higher RPM, in contrast to a lower RPM of females. The relationship was built particularly considering the data region encircled in Figure 7. in blue color. Linearity of the regression is a mere hypothesis at this moment in time, somehow further measuring will tweak the correlation. Even though the system is designed to harvest wasted energy it is worthwhile to mention that this kind of achievement based exercising methods are known to be a source of motivation for users. Thus, it is an interesting method for use in achieving cardio and muscular endurance enhancement strategies.

V. Measuring The Efficiency

Considering the complexity followed by modifying the circuit to measure the efficiency, we decided to follow a distinct stage for measuring the efficiency of the machine using a sample size of 10 students by measuring the output current and voltage of the alternator. This stage resulted in a mere low average efficiency value of 0.596% which is comprehensible as the alternator itself produced < 3W at maximum thrust and frictional forces that transform usable energy into heat. Further we had to maintain the rectified voltage below 6V as a precaution to avoid any damage might occur to connecting devices. The important fact we had to consider is that this stage of measurements must be conducted at threshold RPM of 60 as lower RPM values do not contribute to usable amount of energy (in this case charge the power bank). Further this machine can produce usable electrical energy approximately is 5 Wh by exercising for an hour.

$$\text{efficiency} = \frac{\text{stored useful electric energy}}{\text{energy produced by the user}} \times 100\% \quad (2)$$

VI. Conclusions

In this paper we present the development of a cost-effective method to harvest electrical energy from human energy considering both the future world energy requirement and green energy concept. Even with very low efficiency (~0.6%) this possesses the ability to motivate users such as university students, with help of graphically interactive interfaces to promote and enhance the importance of doing exercises. However, human energy harvesting method has less efficiency compared with the other renewable energy generating methods that are already being used in the world. Since this human energy harvesting method is more suitable for fulfilling the normal household needs [7].

With the future developments of the research, energy conversion efficiency will be developed. Most importantly the current development can be modified to be compatible with any exercise machine that uses repeatable orbital motion.

VII. Recommendations

- Increase the number of test cases to obtain a more accurate function.
- The research can be developed to harvest energy from different exercise machines like treadmills [8],[9].
- Electrical system should be developed to harvest energy from several exercise machines simultaneously considering a real gymnasium environment.
- The system still lacks producing high efficiencies and a further development suggestion is to use an advanced alternator with high power output.

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