Empowering Remote Area of Bangladesh Using Pedal Generator

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***Abstract*—Now-a-days, Bangladesh is facing a problem with shortage of natural resources especially in gas sector.A large number of population in Bangladesh do not have the facilities of electricity. Besides that the people of remote area are normally far from modern facilities such education, health, online services etc. In general, they use kerosene as fuel for lighting purpose and it is hard for them to access modern technologies such as mobile, computer, internet, e-health. Pedal generator, a flywheel driven by human and coupled with an electric generator. may be an alternative solution in these situations. The efficiency and the performance was good. It can be operated in a standalone mode or may be used with PV module as a hybrid system. Though, the research has been done with respect to Bangladesh, this can be applicable everywhere. This will provide an easy, cheap, handy and pollution free source of energy by means of pedal generator.**

***Keywords*—pedal Generator, rotational energy, secondary energy.**

I. Introduction

Electricity is a secondary type of energy. Primary energy is defines as the energy that is available enough in nature such as energy is reserved in gas, coal etc as comical energy. On the other hand secondary energy is the energy that is derived from primary energy such as electricity can be derived from gas by means of mechanical rotation or from light by means of Photo Voltaic panel. Human power is basically as old as mankind. As long as people are used their muscles to pick up, carry and handle things. Human began making small tools which are the first examples of Human powered products. The first human powered product to convert human work into electricity was the Philips dynamo torch [1]. The pedal power [2] transfers the energy from a human source through the use of a foot pedal and crank system. This technology is most commonly used for transportation [3]and has been used to propel bicycles [4], [5] for over a hundred years. Less commonly pedal power is used to power agricultural citedavid and hand tools [6] and even to generate electricity [7], [8]. Some applications include pedal powered mobiles [9], pedal powered grinders [10]and pedal powered water wells [11].

Most of the power plant in Bangladesh uses gas as fuels. Few of the power plants are High Speed Diesel (HSD) based and few are renewable energy based. However, only around 40% of people in Bangladesh have the facilities of electricity. Rest of the population does not have electricity. Besides that the people of remote area are normally far from modern facilities such education, health, online services etc. Normally they use kerosene as fuel for lighting purpose and it is hard for them to access modern technologies such as mobile, computer, internet, e-health. Somewhere people use Solar Photo Voltaic (PV) module to meet the purpose. However, it is quite costly and some times and somewhere sunlight is not available and has some bad effect on environment due to cutting long trees. Pedal generator may be an alternative solution in these situations. We have shown in this research works that the pedal system power generation is suitable for the remote area of Bangladesh. It can be operate in a standalone mode or may be used with PV module as a hybrid system. Specific objective of this research project is to have an easy, cheap, and handy and pollution free source of energy by means of pedal generator.

II. Energy and Efficiency

Electricity can be generated by several types of converter with single or multi-stage conversion. Most common type of generation is obtained from mechanical energy. Mechanical energy is also some times, secondary types of energy. The rotational energy or angular kinetic energy is the kinetic energy due to the rotation of an object and is part of its total kinetic energy [12]. Rotational energy of any object around an object's axis of rotation me be represent as:

$$E_r = \frac{1}{2} \times I\omega^2 \tag{1}$$

Where, ω is the angular velocity, I is the moment of inertia around the axis of rotation, E_r is the kinetic energy.

The mechanical work required for / applied during rotation is the torque times the rotation angle. The instantaneous power of an angular accelerating body is the torque times the angular velocity. For free-floating (unattached) objects, the axis of rotation is commonly around its center of mass. The close relationship between the result for rotational energy and the energy held by linear [12] (or translational) motion:

$$E_t = \frac{1}{2} \times mv^2 \tag{2}$$

The electric energy is defined as the total work done or energy supplied by the source of e.m.f. in maintaining the current in an electric circuit for a given time [13]:

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$$Electric\ Energy = electric\ power \times time = Pt \tag{3}$$

$$Electric\ Power = Voltage \times Current = Vi \tag{4}$$

Thus the formula for electric energy is given by:

$$Electric\ Energy = P \times t = V \times i \times t$$
$$= i^2 \times R \times t = \frac{V^2 t}{R} \tag{5}$$

The S.I. unit of electric energy is joule (denoted by J) where,

$$1joule = 1watt \times 1second = 1volt \times 1ampere \times 1second$$

The commercial unit of electric energy is kilowatt-hour (kWh) where,

$$1kWh = 1000Wh = 3.6 \times 10^6 J$$
$$= One\ unit\ of\ electricity\ consumed.$$

The number of units of electricity consumed is

$$n = \frac{total\ wattage \times time\ in\ hour}{1000}$$

The cost of electricity consumption in a house

$$= No.\ of\ units\ consumed \times per\ unit\ cost\ of\ electricity.$$

In electricity generation, an electric generator is a device that converts mechanical energy to electrical energy [14]. A generator forces electric current to flow through an external circuit. The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, compressed air, or any other source of mechanical energy. Generators provide nearly all of the power for grids. The reverse conversion of electrical energy into mechanical energy is done by an electric motor, and motors and generators have many similarities. Many motors can be mechanically driven to generate electricity and frequently make acceptable generators [14].

Mechanical efficiency measures the effectiveness of a machine in transforming the energy and power that is input to the device into an output force and movement. Efficiency is measured as a ratio of the measured performance to the performance of an ideal machine.

$$Efficiency = \frac{Measured\ Preformance}{Ideal\ Performance}$$

The flywheel produces electric power by losing its rotational energy. The losing energy is mainly supplied by the paddler. The power of the paddler could be measured by the energy equation of the fly wheel every second. Although, the unit of flywheel energy is $Joule$, the power of the paddler is calculated from the energy supplied to the flywheel every second by the paddler.

$$Efficiency, \eta = \frac{Vi\ Watt}{\frac{1}{2} I\omega^2\ Joule/sec} \tag{6}$$

III. Pedal Power Generator

The pedal power generator consists of an iron frame. The pedal is mounted securely to this frame and the rear tire position to turn that has been custom fit over the generator shaft. The amount of electrical power that can be generated by the pedal power generator is determined by the energy available from pedaling. The stronger the user, the higher the production of electrical power. It is not essential but wonderful is that the pedal power generator output may be directly connected with a load such as water pump, light and 12V battery for charging etc.

A. Structure For Energy Conversion

It has 2.5 feet of iron (1.5 inches angle structure) and 20 inches shaft made by iron stick and fixed with each other as fall a general frame. After that, shaft are re-size from work shop and attached with 2 pieces bearing and balance wheel and 14 inches pulley (around the flywheel) fixed with shaft. A gear box attached is on the right side of pedal frame and a stand is attached with the gearbox. Then 2 inches pulley attached with alternator shaft. Now pedal machine pulley and alternator pulley attached by 88 inch belt. Then the pedal generator is installing by done pedaling and fixed load box from alternator output.

Regular rpm of the generator is about 1800. The generator was aimed to have a rated rpm of 1800 for production of electricity having 50 Hz line frequency. However, a generator of 3000 rpm was used. Both AC and DC generator has been coupled with the structure an the performance has been checked. These are shown in Fig. 2 and Fig. 1.

Fig. 1: Complete setup of the Pedal Generator system with DC generator, Storage and Light bulb

B. Debug And Finalize Of The Design

Several types of structure have been thought such as the pedal based knife sharpener, pedal based paddy separator machine, the oil extractor pulled by animal. Finally a similar structure close to the paddy separator machine is chosen as more acceptable. Then paddy separator machine was build in work shop. However, most of them were professional and they need exact design. Before finalizing the complete design, the process went through a lot of trial and error method. It was done in a remote area of Pabna, a district of Bangladesh where cost was lower and it was easier to be involved in the

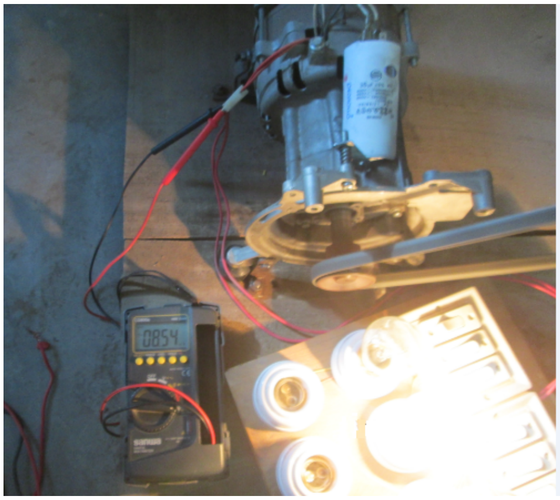

Fig. 2: Complete setup of the Pedal Generator system with AC generator and light bulb running directly

workshop. Then it was carried to Dhaka city. This structure was modified for several times. Major portion of the expense was in this field.

C. Generator Coupling

The coupling generator with the prime mover was another challenge. The structure was finally fitted on a wooden board. Necessary equipment for the project has been revised, the most needed equipment were an AC generator at least of 600 W, a 2 feet x 4.5 feet wooden board and some types of ranches. The necessary materials were collected from different places in Dhaka within two or three weeks. The AC generator was an one horse power with two stroke petrol engine. The petrol engine and the generator were separated with care. Then it was brought to a workshop at Gabtoli, Dhaka to attach the shaft with pulley and it was done. Next step was to send it to a workshop to set up the generator and iron structure (modified paddy separator) to wooden board. This machine and generator were connected to strong bolt with the wooden board.

D. Producing Electricity

The most challenging part was to generate electricity. Several markets and workshop were searched to manage a suitable generator as per the design. A generator was chosen with 3000 rpm whereas the design was 1800 rpm. The rpm varied 1000 to 2100 which mainly depends on the man working behind the pedal, whereas, the speed of the prime mover was around 180 rpm to 385 rpm. Two person, pedaling continuously, were able to keep the rpm just over 1800. Several design was tried to increase the rpm of the structure by changing the size of pulleys. For an rpm of 1800 of the generator pulley, the the rotation of the fly wheel was 330 rpm. All of the calculations shown here are based on a generator speed of 1800 rpm and prime mover speed of 330 rpm. However, the rpm used to change rapidly. At the lower rpm the output was not enough to provide electricity to a small bulb. Finally capacitor and other internal structure were changed. Thus, the produced electricity was enough to lighten up a 200W AC bulb with a 100W and a 60W bulb more. However, voltage was very low. A capacitor with higher value was also tested. It was quite better. This same experiment was also done by a DC generator and its experience is better than AC generator. In both cases, charged battery and UPS was connected to the system to run computer and other equipment.

IV. Calculation Of Prime Mover Design

The pedal generator is installing by done pedaling and fixed load box from alternator output. The summary of the calculation is provided bellow.

Here,

$\rho = 6.98\ gcm^{-3} = 6.98 \times 10^3\ kgm^{-3}$

$r_1 = 1.5\ cm = 0.015\ m$

$r_2 = 15.25\ cm = 0.1525\ m$

$r_3 = 17.5\ cm = 0.175\ m$

$r_4 = 11.5\ cm = 0.115\ m$

$r_5 = 3.75\ cm = 0.0375\ m$

$t_1 = 49\ cm = 0.49\ m$

$t_2 = 1.75\ cm = 0.175\ m$

$t_3 = 5\ cm = 0.05\ m$

A. Determination of Moment of Inertia

All the dimensions mentioned above are shown in Fig. 3 to Fig. 7. These Figures contain a common straight line (having sloop around 35^0 which is the axis of rotation for each measurement. The radius of the pulley which was connected with the generator is (not shown in the illustration).

$r_{generatorpulley} = 3.2\ cm = 0.032\ m$

Figure 3 is showing calculation of I_1 can be found by

$I_1 = \frac{1}{2} t_1 \rho \pi {r_1}^4$

$I_1 = 2.7198 \times 10^{-4} kgm^2$

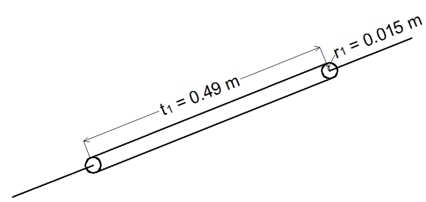

Fig. 3: Illustration for calculation of I_1

Figure 4 is showing calculation of I_2 can be found by

$I_2 = \frac{1}{2} \times \rho\pi \times t_2({r_2}^4 - {r_1}^4)$

$= \frac{1}{2} \times 6.98 \times 10^3 \times 3.1416 \times 0.175 \times (5.4085 \times 10^{-4} - 5.0625 \times 10^{-8})$

$= 0.1037653\ kgm^2$

Figure 5 is showing calculation of I_3 can be found by

$I_3 = \frac{1}{2} \times \rho\pi \times t_3({r_3}^4 - {r_2}^4)$

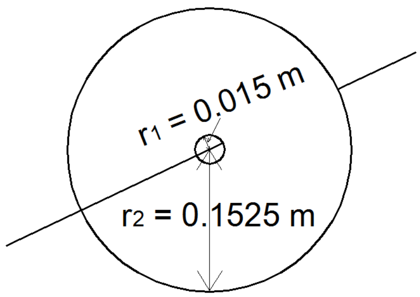

Fig. 4: Illustration for calculation of I_2

$= \frac{1}{2}6.98 \times 10^3 \times 3.1416 \times 0.05 \times (9.3789 \times 10^{-4} - 5.4085 \times 10^{-4})$

$= 0.2176591\ kgm^2$

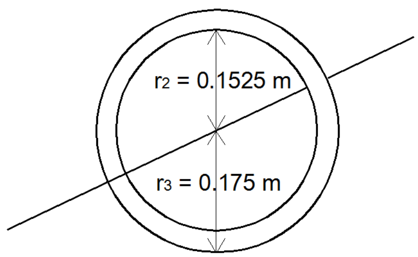

Fig. 5: Illustration for calculation of I_3

Figure 6 is showing calculation of I_4 can be found by

$I_4 = 3 \times (\rho \pi {r_5}^2 \times t_2 {r_4}^2 + \frac{1}{2} \rho \pi {r_5}^4 \times t_2)$

$= 3(6.98 \times 10^3 \times \pi \times 1.406 \times 10^{-3} \times 0.175 \times 0.01322) + (\frac{1}{2} \times 6.98 \times 10^3 \times \pi \times 1.9775 \times 10^{-6} \times 0.175)$

$= 0.0225486\ kgm^2$

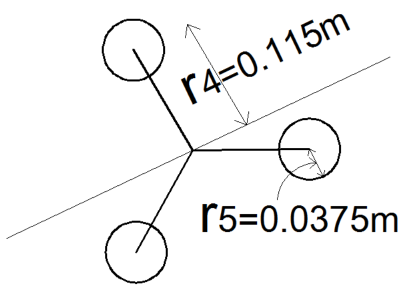

Fig. 6: Illustration calculation of I_4

Figure 7 is showing calculation of I can be found by

$I = I_1 + I_2 + I_3 - I_4 = 0.2991477\ kgm^2$

B. The Angular Velocity and the Kinetic Energy

The angular velocity ω is found as

$\omega = 2\pi \frac{rpm}{60}\ rad/sec$

$\omega = 2\pi \frac{330}{60}\ rad/sec = 34.5575\ rad/sec$

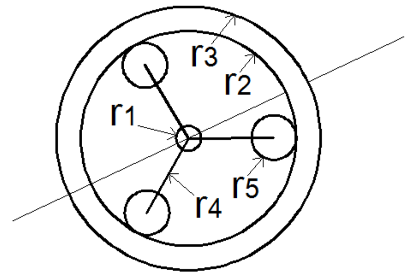

Fig. 7: Illustration for calculation of I

Now, $E_k = \frac{1}{2} I \omega^2$

$= \frac{1}{2} \times 0.2991477 \times 34.5575^2 = 178.62442\ Joule$

C. Efficiency

Output of the system is varied rapidly as the speed was changing quickly. However, the measurement was taken when the speed of the prime mover was around 330 rpm. The voltage and current with a load of 360 W (1 x 200W + 1 x 100W +1 x 60W) tungsten light bulb varied around 118 Volt and 854 mili Ampere. The output power thus, was measured to be around 100 W. It is true that the output fluctuated very much and thus only approximate measurement of voltage, current and speed was possible. Hence, the efficiency could be measured by equation 6.

$Efficiency, \eta = \frac{100\ Watt}{178\ Joule/sec}$

$Efficiency, \eta = 56.18\%$

The losses were incorporated mainly with the huge friction at the bearings of the prime mover. The sound loss was also significant. Finally, the loss of the generator due to under frequency operation decreased the efficiency.

V. Conclusions

This is a useful machine at places where many people gather and stay together (meetings, residential schools). It is easy to maintain and make. This project was extremely challenging, consuming huge amounts of time, energy and resources. However, the knowledge and experience obtained was tremendously valuable and has given confidence to work with more complicated electrical projects. The efficiency of the developed system is quite good. It would be more than the achieved value if the frictional loss of the rotary parts could be minimized. Installation of this machine in a remote area for where it was designed, is necessary to get field level data. This installation will also provide deep and clear information about the durability, reliability, feasibility, ease of use as well as farther modification of the system.

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REFERENCES

[1] M.W. Nasim, “Pedal Power Generator”, Published by: Sultangetin on May 02, 2013, Copyright: Attribution Non-commercial.

[2] Renewable Energy: Pedal Power, http://www.foodshare.net/files/www/Roots_to_Rooftops/2-6-8_Ren_energy_pedal_power_supptg_mats.pdf

[3] David Weightman, “The use of pedal power for agriculture and transport in the developing countries”, Published by Lanchester Polytechnic, May 1976.

[4] Electric Bicycles, https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/presto_fact_sheet_legislation_en.pdf

[5] Rajesh Kannan Megalingam, Pranav Sreedharan Veliyara, Raghavendra Murali Prabhu and Rocky Katoch, “Pedal Power Generation”, International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11 (2012).

[6] Human and Animal Power Tools and Transmission Systems, http://www.fastonline.org/CD3WD_40/JF/424/Human & animal power tools & transmission systems.pdf, accesses on 24th August 2015.

[7] R. Subash, C.M. Meenakshi, K. Samuel Jayakaran, C. Venkateswaran, R. Sasidharan, “Fabrication of Pedal Powered Hacksaw Using Dual Chain Drive” International Journal of Engineering & Technology, 3 (2) (2014) 220-223.

[8] R. Singh, D.C. Sharma, “Experimental Study of Home Automation by Bicycle Pedal Power Using of Different Sprocket”, International Journal of Engineering Trends and Technology (IJETT) Volume 8 Number 2- Feb 2014.

[9] Thad Starner and Joseph A. Paradiso, “Human Generated Power for Mobile Electronics”, Low Power Electronics Dsign, CRC Press, Fall 2004.

[10] G.S. Pinson, “A Pedal-Operated Grain Mill”, Rural Technology Guide, No. 5, 1979, Published byTropical Development and Research Institute (TDRI).

[11] Atul P. Ganorkar, K.S. Zakiuddin and H. A. Hussain, “An Experiment on Development of Pedal Operated Water Pump”, IOSR,e-ISSN:2278-1684,(2014).

[12] en.wikipedia.org/wiki/Rotational_energy, accessed at 20th of July, 2015.

[13] http://www.web-formulas.com/Physic_Formulas/Electric_Power.aspx, accessed at 20th of July, 2015.

[14] en.wikipedia.org/wiki/Electric_generator, accessed at 20th of July, 2015.