# Power Generation Using Bicycle Mechanism as an Alternative Energy Source

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**Abstract -** *In this paper importance of human poweras an alternative energy source is investigated, since beginning to present state and its future scope. Natural fuel use is increased due to industrial development and these sources oil, coal and natural gas reservoirs are limited. Energy crises need to search for alternate source of energy that is specifically renewable energy. Human power credit is more because of health benefit as a source of energy. More effective use of human power could be achieved through properly designed mechanisms. Human power as prime mover used to operate working unit is termed as human powered machine. Design considerations for bicycle mechanism are discussed in this paper. Owing to appropriate and most effective technology to use human power efficiently is bicycle technology. In bicycle technology operator uses mostly pedal to operate machine and transmits power through crank, chain and freewheels to the working unit. Bicycle is the main mode of transportation for many Indian villagers. Most of these villages are unelectrified. Power generated by pedaling can be converted from mechanical to electrical energy by using either dynamo or alternator.*

**Keywords:** Human Power machine, BicycleTechnology, Pedal ,Generator

## I. INTRODUCTION

Energy is the driving force of modern societies, and generation and utilization of energy are essential for socioeconomic development. Per-capita energy consumption levels are often considered a good measure of economic development. In recent years, energy scarcity has become a serious problem due to depletion of non-renewable energy sources, increasing population, globalization of energy intensive economic development, environmental pollution, and global warming [3].

In this context, the field of renewable energy represents a new frontier for the academic and research community, due to the following factors:

• Depletion or unreliability of non-renewable energy sources, e.g., oil

• Environmental pollution, e.g., due to coal use

• Needs of increasing population, especially in resource-scarce developing countries

• Global Warming/Climate changes

• New applications in modern, high-tech settings – e.g., wearable computing and portable consumer electronics

While in developed countries the energy problem is one of short-term scarcity or optimum use, an estimated 40% of the world's population – or, 2 billion people mainly in the less developed countries – do not have even have access to electricity. Moreover, this number is expected to double by the year 2050.

The reasons for this limited access to electricity in developing countries are the lack of energy sources such as coal, oil, or nuclear energy, and – even where such sources exist – the lack of expensive capital to exploit existing resources. While the costs of renewable energy sources such as solar and wind energy are falling gradually, these technologies are still far too expensive for developing countries, where about half the population has incomes of less than two dollars a day.

In recent years, there have been many interesting developments in the field of human power conversion. In the present paper, a method of harnessing the power of children's play in playgrounds and public places, on devices such as the seesaw, merry-go-round, and swing is proposed.

Data for 24 people, aged from 16 to 61 years old, riding a bicycle for 17 km (10 miles) were recorded and analyzed. During data logging procedure the average power of a biker varied between 215W to 375W. The graph in Fig. 1.1 shows the maximum duration of human effort for different levels of power. From this graph one can observe that healthy humans|| can sustain approximately 75W (0.1hp) for a full 8-hour period, while —first class athletes|| can sustain approximately 300W (0.4hp).

And that is for a single (stationary) bike; they are 20 times larger for a medium-sized gym with 20 bikes. We believe these numbers are promising and justify an attempt to harvest (part of) this energy efficiently [1].

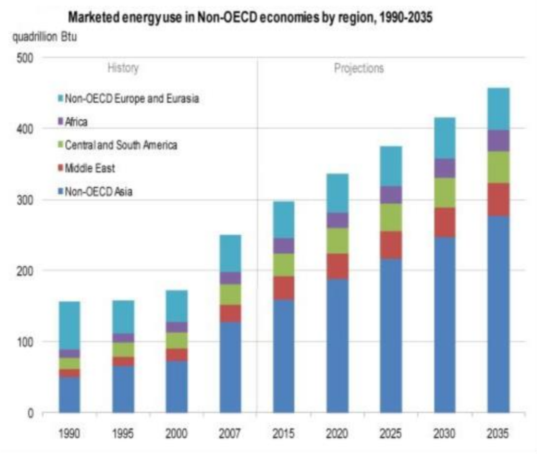


Fig. 1.1: Energy Consumption Projections by Non-OECD economies
Source: OECD Economy Thesis

## II. LITERATURE REVIEW

### 1 Short History on Pedal Powered Machines

Throughout human history, energy has generally been applied through the use of the arms, hands, and back. With minor exceptions, it was only with the invention of the sliding-seat rowing shell, and particularly of the bicycle, that legs also began to be considered as a "normal" means of developing power from human muscles (Wilson, 1986). Over the centuries, the treadle has been the most common method of using the legs to produce power. Treadles are still common in the low-power range, especially for sewing machines. Historically, two treadles were used for some tasks, but even then the maximum output would have been quite small, perhaps only 0-15 percent of what an individual using pedal operated cranks can produce under optimum conditions. However, the combination of pedals and cranks, which today seems an obvious way to produce power, was not used for that purpose until quite recently.

It was almost 50 years after Karl von Krais invented the steerable foot-propelled bicycle in 1817 that Pierre Michaud added pedals and cranks, and started the enormous wave of enthusiasm for bicycling that has lasted to the present. Ever since the arrival of fossil fuels and electricity, human powered tools and machines have been viewed as an obsolete technology. This makes it easy to forget that there has been a great deal of progress in their design, largely improving their productivity.

The most efficient mechanism to harvest human energy appeared in the late 19th century: pedaling. Stationary pedal powered machines went through a boom in the turn of the 20th century, but the arrival of cheap electricity and fossil fuel abruptly stopped all further development (Kris, 2011). Otto Von Guericke is credited with building the first electrical machine in 1660. This form of electricity precedes electromagnetic energy which dominates today. The landscape for today's electricity usage practices bloomed from 1831 to 1846 with theoretical and experimental work from Faraday, Weber and Gauss in the relationship of current, magnetic fields and force. These theories enabled the design modern motors and generators. From 1880 to 1900, there was a period of rapid development in electrical machines. Thus this section reviews the works that has been done on human power generation.

### 2 Early Development

[1] Studies in power generation shows that bicycling is one of the most efficient forms of power generation known, in terms of energy expended per person. McCullough, (1977) gives us an insight into the test conducted by Stuart Wilson using a 24V (at 1800rpm), 20A generator to charge a 12V car battery. A belt-drive was used to connect a 15.5” diameter bike flywheel to a 2.5” diameter pulley that turned the generator. During this test, an average cyclist produced 75W of sustainable electrical power 12V (900rpm) for a period of one hour.

[2]In 1980, Carl Nowiszewski a mechanical student at the Massachusetts Institute of Technology worked with Professor David Gordon Wilson on a design of a human powered generator which when built will serve as an auxiliary control function in a sail boat in an Atlantic crossing. The energy storage was primarily for automatic steering while the pilot sleep and the pedaling was a way of keeping warm and avoid boredom. The overwhelming problem in the design was the cramped quarters which Nowiszewski eventually solved. And then in 1988, George Alexander Holt III designed a human powered generator using recumbent bicycle technology for use in a sail boat using 6061-T6 aluminum; he built a light weight foldable apparatus. The human power requirement was 120watt at 75rpm (George, 1988).

### 3 Recent Development

[3] Mohd and others (2013) discussed charkha device in India, stated that spinning wheel horizontally could be rotated by a cord encircling a large, hand-driven wheel where the fiber is held in the left hand and the wheel slowly turned with the right. Holding the fiber at a slight angle to the spindle produced the necessary twist.

[4] Jansen and Slob (2003) improved the power generation system known as “Better Water Maker” (BWM) water disinfection system. The BWM was designed for use where water is unsafe for drinking and electricity is scare. The BWM utilizes a Manual hand crank to provide power to its pump. They also studied one hand cranking and found that 50w of power could be sustained for up to 30 minutes, which is more than double the 17w required by the BWM. As early as 2007, fitness facilities around the world have begun researching applications for converting human power to electricity. The California Fitness facility in Hong Kong was one of the first gym establishments to incorporate human

powered machines. Started by French inventor Lucien Gambarota and entrepreneur Doug Woodring, the gym began a program called "Powered by YOU" in which the excess energy generated by members on 13-step cycling and cross training machines is diverted and converted to power lighting fixtures in the gym (Gerard, 2008).

[5] Maha and Kimberly (2010), in the Proceedings of ASME 2010 4th International Conference on Energy Sustainability made us to understand that other gyms in the United States began to harness human power as well. The Dixon Recreation Center at Oregon State University (OSU) is one of the many facilities retrofitted between

The years 2008 and 2009 by the Clearwater, Florida based company known as ReRev. The company retrofitted 22 elliptical machines at OSU so that the excess energy generated by patrons was diverted to the electric grid. According to the company's website, "An elliptical machine in regular use at a gym using ReRev technology will generate one kilowatt-hour of electricity every two days."

[6]Dean (2008) revealed that human legs are up to four (4) times more powerful than human arms. On average, a human can sustain about 100W of power through pedaling for an hour but only hand crank about 30Ww of power in an hour. Wilson (2004) demonstrates that a person's oxygen consumption, and consequently their potential power output, decreases with age, with the peak of potential power output being between 20-40 years of age.

[7] According to Jamie and Aaron (2012), Wind stream, Convergence Tech and Magnificent Revolution have manufactured stationary pedal powered generators. Typical design included a back-wheel stand that elevates the bicycle and causes the back wheel to come in contact with a smaller wheel that is hooked up to a "bicycle dynamo "and a large battery.

## III. Our Innovation: Power from Daily Activities

The motion from everyday tasks can provide low-cost electricity for lighting and other Appliances in rural households. Incorporating electricity generation into the daily routine can reduce the time, effort, and cost burden of the user. We feel that harnessing daily tasks to Provide electricity is more acceptable than isolated stationary human power generation because people who have already worked all day may not want to work again to power a light at night. There are many possible motions for electricity generation, such as walking or running, riding a bicycle, and even the motion of animal, running of two-wheeler or three-wheeler.

## IV. POWER LEVELS

The power levels that a human being can produce through pedaling depend on how strong the peddler is and on how long he or she to pedal. If the task to be powered will continue for hours at a time, 75 watts mechanical power is generally considered the limit for large, healthy no-athlete. A healthy athletic person of the same build might produce up to twice this amount. A person who is smaller and less well nourished, but not till, would produce less; the estimate for such a person should probably be 50 watt for the same kind of power production over an extended period. The graph in fig. 2.1 shows various record limits for pedaling under optimum condition. The meaning of these curves is that any point on a curve indicated the maximum time that the appropriate class of person could maintain the given average power level [2].

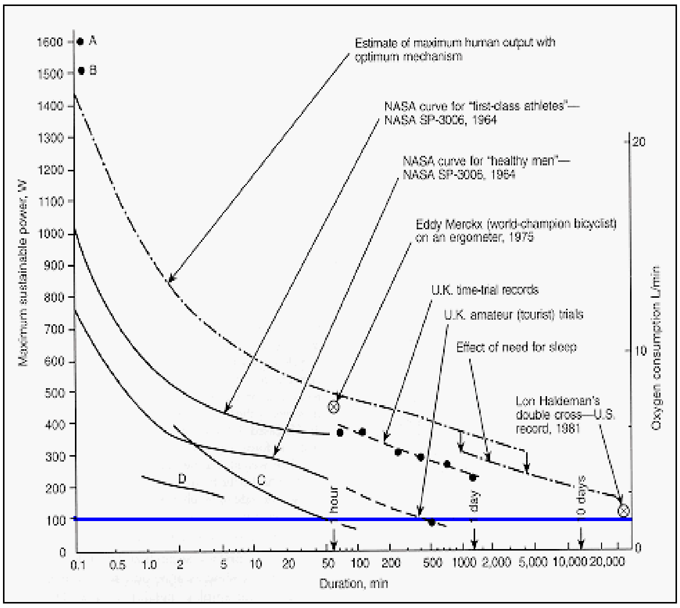


Fig.2.1 Human Power Output Pedaling
Source: tenderness.co/power output

Power levels are also directly related to the environment of the person doing the pedaling. To be able to continue pedaling over an extended period, a person must be able to keep cool whether because the ambient temperature is low enough or because there is adequate breeze.

## V. EXISTENCE OF HUMAN

## POWERED OPERATED DEVICES

Interest in human power conversion declined in the early 20th century due to several technological developments and researches:

- Availability of cheap, abundant electrical energy Use of compact, powerful, and versatile electric motors and lights
- Availability of cheap, disposable batteries for portable use

In recent years, human power conversion is making a comeback due to a variety of economic, environmental, and technological factors:

- Applications in less-developed countries and remote locations of developed countries (e.g., camping)
- Use in portable computing, where progress in battery technology lags behind developments in laptop PCs
- Use in wearable computing and communication devices, where absence of batteries or usable energy in remote locations such as battle fields hinders their continuous use
- Energy shortage and high cost of solar/wind power
- Use in emergency situations, e.g., earthquakes and hurricanes
- Energy conservation – e.g., to minimize energy requirements in power assist devices for elderly and disabled
- Environment friendly – batteries are energy intensive to produce and are non-biodegradable
- Advances in actuators, materials, and energy storage techniques
- Technological challenges – e.g., human-powered flight, with spin-off benefits

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### *A. HUMAN POWERED MACHINES*

These are the human power magnification units driven manually, the units may be driven by hand or foot. Thus, the human powered machines can be categorized as:

1. Hand Operated Human Powered Machines: These machines are operated by hand and are available in the following forms

i. *Hand Crank with Gear Transmission Unit:* Rotary motion of crank is transmitted throughgear train. Gear train may be used to rise speed and/or torque, e.g. Sugarcane Juice extractor.

*Hand Crank with Chain Drive:* Rotarymotion of crank is transmitted through crank and chain drive as in bicycle, e.g. Tri-cycle for orthopedically handicapped person.

2. Foot Operated Human Powered Machines: These machines are operated by foot and following two basic forms of foot operated human powered machines are available

i. *Treadle Powered Unit*: To drive treadle powered unit operator uses one foot to pedal the machine. These machines are available with following mechanical arrangements,

Treadle Powered Unit with Crank, Connecting Rod: The oscillating motion of pedal is converted in to rotary motion through crank and connecting rod and then is transmitted to processing unit. Chain and crank or belt and pulley may be used for further transmission, e.g. Sewing Machine

ii. *Bicycle Technology*: The rotary motion of foot pedal is transmitted through crank, chain and sprocket to the processing unit. In this paper we are mainly focusing on the single bicycle electricity generation

## VI. DESIGN OF BIKE-POWERED ELECTRICITY GENERATOR

The intention of this paper is to build a straight forward human powered generator from a used bicycle and to use it to power light bulbs, blenders, cell phones, laptops, and other small appliances. Following is the general design procedure of the single bike electricity generator.

***Parts Tools:***

- Diode
- Battery
- Hammer or Screwdriver
- Inverter
- Tape Measure
- Wire
- Screwdriver
- Motor (12-V or higher)

Design the base which should support a motor with the shaft facing the wheel. Attach the motor i.e. Generator to the base and calculate the gear ratios to figure out what size pulley would be most suitable for the application. For more efficient production a flywheel should be placed on the motor (like in the picture) or if an exercise bike is used the wheel should already be a flywheel. To measure the rpm and the speed attach a tachometer/speedometer to the bike.

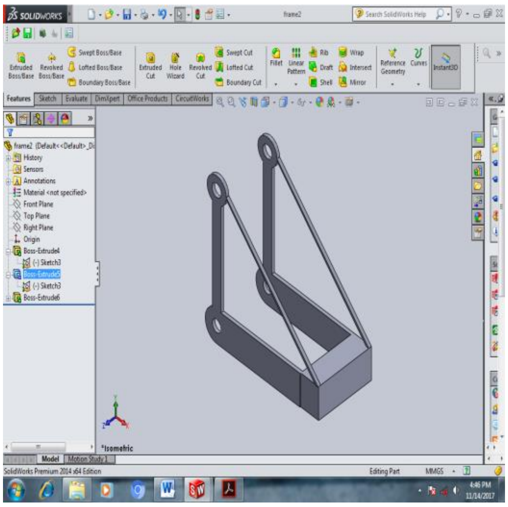

Fig.4.1: Base (Home Trainer) attached to bike-Solidworks Software

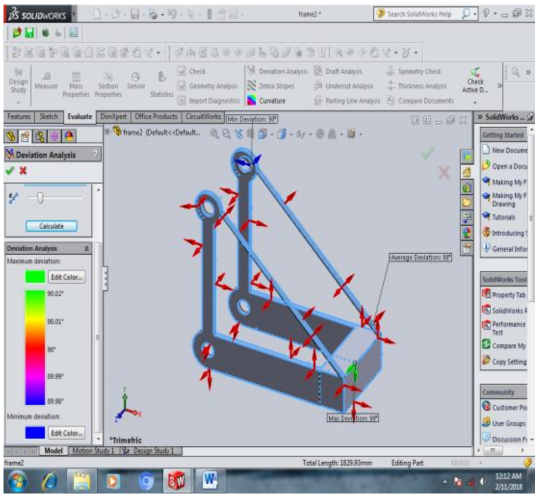

Fig. 4.2: deviation analysis of frame-Solidworks Software

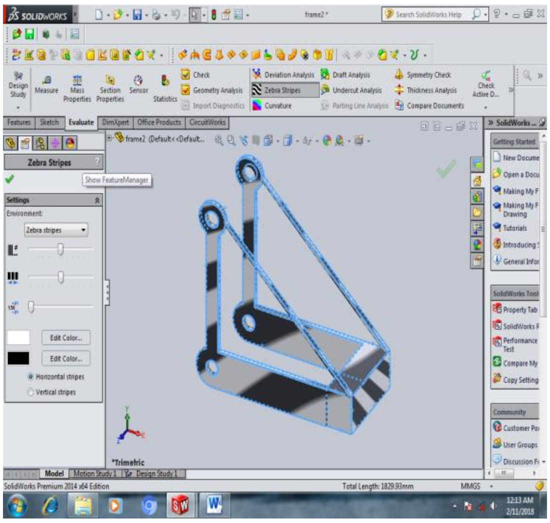

Fig. 4.3: Zebra strips analysis of frame-Solidworks Software

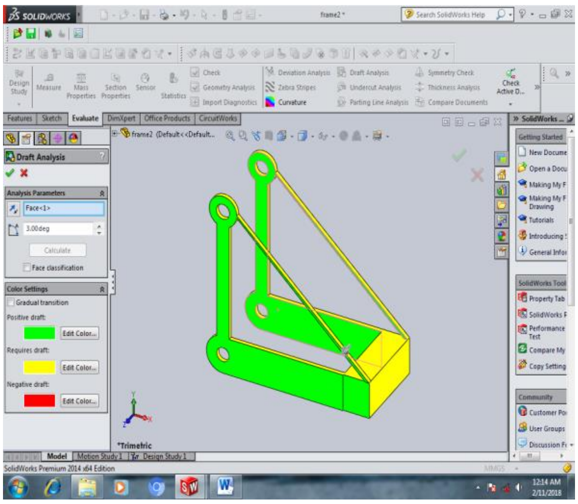

Fig. 4.4: Draft analysis of frame-Solidworks Software

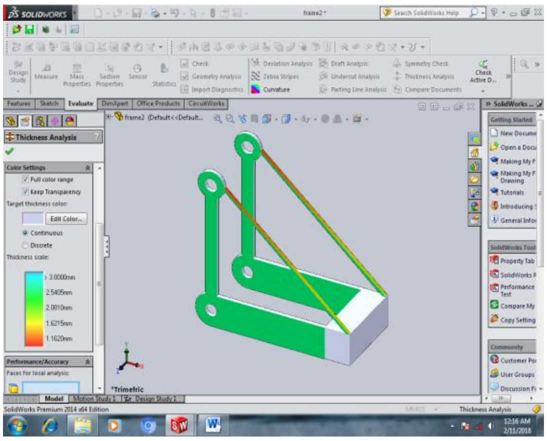

Fig. 4.5: Thickness analysis of frame-Solidworks Software

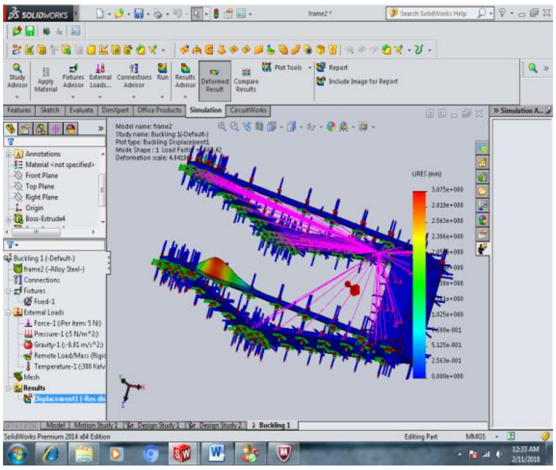

Fig. 4.6: Force analysis of frame-Solidworks Software

Fig. 4.7: Motor or Generator

Attach the Volt meter and the ammeter to be able to take measurements.

The main goal was to develop a simple and modular system that can be used both in gyms and at home without special mechanical or electrical skills. The basic idea is to connect a bicycle to a static system capable of transforming the rotation of the pedals into electric energy. The system that converts mechanical energy into electric energy consists of two blocks:

A. Mechanical Block – has the role to transfer the rotation movement of the pedals and adapt it to the generator requirements.

B. Electric Block – has the role to convert the energy provided by the mechanical block into electric energy.

### *A. Mechanical block*

The mechanical block was designed starting from the following assumptions:

1. Use available components that should not change their functionality. In other words, every part of the mechanical block is an independent device that can be further replaced with better or cheaper versions.

2. Use recycled and refurbished components. The "age" of the components does not matter as long as their initial functionality is not altered or damaged.

3. Use low-budget equipment. Assuming that the system will be replicated for many fitness devices, its cost should be as low as possible. 4. 4.

4. Individual components must allow fast and safe connectivity and operation

### *B Electric block diagram*

The electric block diagram is presented in fig.4.6.

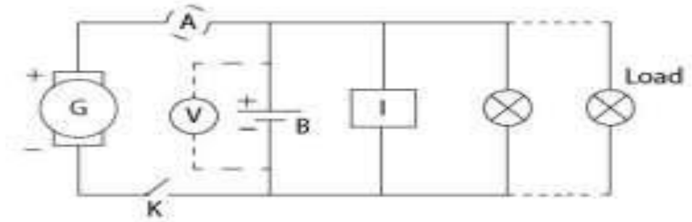


Fig. 4.6: Electric block diagram

Where:

G – Generator
B – Group of lead–acid rechargeable batteries I – Inverter
A – Ammeter
V – Voltmeter
K-Switch

There were three options for choosing the generator: car alternator with an integrated voltage regulator, car alternator with an external voltage regulator and a permanent magnet alternator. The three criteria used in choosing the generator were:

1. The generator output voltage should comply with the battery charging conditions. For this reason, the output voltage should be between 14.2V and 14.8V. [1]

2. The connections between the components should be very simple.

3. Embedded regulator into alternator chassis would be preferred since it may help save space, reduce wiring demands and the system would be less susceptible to mechanical damages due to error in handling or even during regular use.

The generator (G) that meets all above requirements is the automotive alternator with integrated voltage regulator. The availability on the market, the variety of shapes, sizes and outputs have been other advantages that have been taken into consideration when choosing this unit for prototype implementation. Furthermore, the working principle was validated, over many years, by the automotive industry, where more severe challenges (extreme temperatures, humidity, high revs) are met. To temporarily store the harvested energy a group of 12V lead – acid batteries (B) was used. In order to deliver the stored energy into the (local or regional) power network we also use a 300W, 12Vcc/220Vca inverter (I). The voltmeter

(V) and the ammeter (A) have a double significance: they are used during the experimental stage but they are replaced with transducers for the batteries management in the final solution.

## VII. SYSTEM FUNCTIONALITY

The equation that calculates the generator pulley speed, as a result of pedals rotation movement is:

$$N(t) = Nsped(t) \cdot m1 \cdot m2 \cdot m3 \quad (1)$$

with:

$$m1 = ci / sj; \; m2 = dr / dc; \; m3 = dpt / dg \quad (2)$$

Where:
N – Generator pulley speed [RPM]
Nspeed – Pedals speed [RPM]

ci – Chain ring dimension [teeth]
sj – Sprocket dimension [teeth]
dr – Rear wheel diameter [cm]
dc – Home trainer cylinder diameter [cm]
dpt – Pulley home trainer diameter [cm]
dg – Pulley generator diameter [cm]

## VIII. GENERAL DESIGN CONSIDERATIONS

Generally, the design of this system depends primarily on the ratings of the DC permanent magnets which produce the DC and the required output power. The output power to be produced affects the dimensioning as well as the input parameters like torque, speed, etc. In light of the above constraints, the following design considerations and assumptions has been made for this project design;

1. **Sizing and economic considerations**:This system is design to compact in consideration of the power requirement as well as reduction in the cost of fabrication. For affordability, the device is relatively small.

2. **Safety Considerations:** This system is design in such a way that women and children can use it for sustained period of time. It preserves the safety of our immediate environment from noise and air pollution because it's noiseless and smokeless. Stability of the unit was also considered to ensure that the equipment remains upright at all time, i.e. it should not drift or bend to one direction and it should remain stationary.

3. **Ergonomics:** The ergonomics aspect has to do with optimizing the physical contact between human and the equipment. Four important areas of bike ergonomics are usually considered:

- The strain of the arm and shoulder
- The muscle support and the position of the lower back
- The work of proper pedaling
- The crank length

4. **Technological consideration:** The design of this system is well considered in such a manner that it can be produced within the technology of our immediate environment and sustainable at the same time so that our future generation can also make use of this.

## IX. FINDINGS FROM LITERATURE REVIEW

The main goal of this study is to demonstrate that the energy from stationary bikes is worth scavenging by showing that the energy produced is not negligible. Therefore, to determine the characteristic of generated energy versus generator speed (determined by pedals speed) as a functional characteristic of the system. Owing to the linear dependence of energy with Ig (considering the voltage Vg rather constant), the generated current (Ig) can be used as a measure of the energy produced by the system. The measuring process consists of two indirect procedures: calculus of the generator speed and evaluation of the produced energy. We calculate the generator speed using equation (1), starting from the speed of the rear wheel measured with a bike computer. The produced energy is evaluated using a set of bulbs (having different powers - 8W, 15W, 25W, 40W,75W) as the generator load.[1] We have used an increasing load, determining the values of speed corresponding to each load value: we increase the speed until p bulbs (totalizing P watts) light up, and we log the data point as the speed necessary to generate P watt. We could still determine the system functional characteristic starting from the generated current values, knowing that theoretical characteristic of the generator is unique. Therefore, we built the pairs (Ig, Nalternator) presented in Table 6.1; the resulting characteristic is presented in Fig. 6.1. Overall, our results show that the designed system is capable to scavenge (some of) the energy produced by the biker on a stationary bike but the collected energy heavily depends on the losses in the system before reaching the collection point. Some of these losses do not appear in professional gym equipment but need to be addressed for home use systems like the one proposed in this paper. Minor improvements at the mechanical block (as indicated above) should increase the generator's Speed and, consequently, the output current.

| N | N{alternator} | $I_g$ |
|---|---|---|
| 2111 | 1084 | 0.65 |
| 2322 | 1097 | 1.25 |
| 2856 | 1122 | 2.08 |
| 2980 | 1129 | 2.75 |
| 3187 | 1386 | 3.35 |
| 3676 | 1146 | 4.58 |
| 4160 | 1180 | 5.41 |
| 4901 | 1213 | 6.25 |

Table: N{alternator} vs I{generator}
Experimental Data

where:
$N_{alternator}$ – Actual generator speed [RPM]
Ig – Generated current [A]
N – Calculated generator pulley speed [RPM]

## X. CONCLUSION

In conclusion human power there is vast scope in economical use of Bicycle mechanism as an alternative energy Source thereby renewable energy generation as well as exercising for good health cause. In this paper an energy scavenging system built with recycled, independent components and targeted at energy consumed while exercising is presented. The amount of harvested energy is more than sufficient to motivate us not to let it be wasted into heat or other forms of un-useful energy. While building the scavenging system authors observed a couple of problems related to both interconnections between mechanical and electrical systems, as well as interconnection between the scavenging system and the electrical network. Solutions for these problems are reviewed. Economical perspective shows vital utility due to the recycled components, the system is affordable. All the components can still be used separately.

## XI. ACKNOWLEDGEMENT

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