Pedal Operated Power Generation

Shubham Dubey[1], Shubham Saraswat[2], Sumit Bagla[3], Tarash Tejwani[4]
D. Blandina Miracle
[1,2,3,4] Department of Electrical And Electronics Engineering
Krishna Institute of Engineering and Technology
Corresponding Author: *tarashtejwani@gmail.com*

Abstract

Our goal for this project is to design and implement a pedaling chair power generator for the rural areas are having the common problem of hardly any resource to power up their devices due to backwardness. The "Pedal Operated Power Generator" is an initiative to bring safe and reliable power to the billions of people around the world without electricity. This goal will be accomplished by designing a safe and sturdy human powered stationary pedaling chair that produces DC energy. The DC power generated can be stored via batteries and used by the local population to use for lights and other utilities that many take for granted on a daily basis. Pedaling chair Power Generators are not a new idea, with many created by hobbyist for residential use with small scale energy in mind, to charge batteries in case of a power outage or natural disaster. We are looking to expand upon these designs and build a DC generator that will convert human power into electrical power. The objective is to build a device that is safer and more power efficient. If our product design were to be built and shipped to people across the globe, it would be imperative that it meets all the safety specifications that any national commercial product entails.

Keywords: *Pedaling chair power generator, power generators, Pedal Operated Power Generator.*

I. INTRODUCTION

(1.1) Present Scenario

With the evolution of technology and increasing demand of power sources, it has become important to generate new power sources for the use of these appliances. With the depleting sources and highly polluting conventional generation, it is important to develop a new efficient and economical method of power generation.

(1.2) Problems with Conventional Method of Pedal Operated Power Generation

a) Low voltage generation.
b) Current generated is low.
c) High battery charging time.
d) Low power generation.
e) Low efficiency.

(1.3) Solution Proposed In This Paper

Solution to these problems is a system that uses an alternator which generates both high voltage and high current. Also to increase efficiency and to ensure less human effort is applied six speed gears are used. Human comfort is also very important and therefore comfortable seat and reclining position is chosen.

(1.4) Advantages Over Other Systems

This system is capable of generating high voltage and current resulting in high power generation followed by low battery charging time with increased efficiency of the whole system.

II. LITERATURE REVIEW

(2.1) Early Development

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. 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.

(2.2) Recent Development

Manoj Bhargava CEO Billions in Change have developed a bike that estimates to produce 50W to 200W of electricity through one hour of pedaling and the currently the pilot project is taking place in the rural areas. His project aims to provide electricity to the rural areas where there is totally no Electricity and it is difficult to provide electricity there. The typical design includes an alternator connected to the flywheel. The output of the alternator is directly given to the battery.

III. DESIGN ASPECT OF PEDAL OPERATED POWER GENERATOR

(3.1) Mechanism of Operation

The Pedal Operated Power Generator (POPG) is a type of generators in which the source of mechanical power is provided by the human effort while spinning a shaft, with its corresponding angular speed (ω_{human}) and torque (T_{human}). Usually, a sort of mechanical transmission system is needed to adapt these variables into the generator's required ones (ω_{gen} and T_{gen}). Then, this mechanical power is turned into electric power by the generator ($P_{out\ gen}$). Eventually, P_{outgen} is converted with the aim of being stored (P_{in} storage), without damaging the storage system. The principle of using your pedal motion to create the same motion as a motor can be translated to almost any device, and the parts needed are all the same, and in the case of the pedal powered electrical device, the components include:

- A pedaling bike, belt and pulley system, chain drive system, generator, blocking diode, fuse, battery and inverter system.

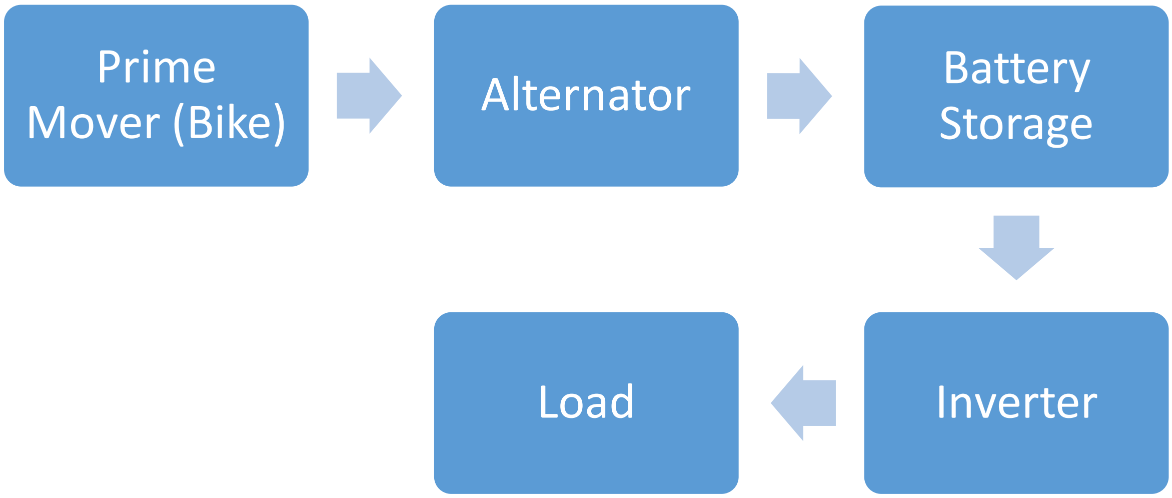

Figure 3.1 Block Diagram of the Generation System

(3.2) Energy Analysis

Heslin and Annette (2005) provided an insight into the average daily consumption of an average male as 2440kcal, this is about 119W of power in, 10.299MJ or 2861Wh of energy every single day. This is approximately the same amount of energy stored in the typical car battery (2400Wh). The primary fuel used in the production of human power is consumed food. The human body utilizes energy stored in the chemical bonds of consumed compounds such as carbohydrate, proteins, fats and fibre to fuel metabolic processes. These processes include basal metabolic function that sustain life, and advance metabolic function used during physical activities. Food energy is commonly measured in the empirical units of Kilocalories (Kcal) or food calories (C), 1Kcal is equivalent to 1C.In the metric system, is measured in Joules, where 1C is equivalent to 4184J.

(3.2.1)Measurement of Energy Expenditure (Human Power Input)

Different methods of energy measurement are available: Direct Calorimetry based on the heat production, Indirect Calorimetry based on the volume of oxygen consumed, Open circuit Spirometry based on the measurement of ventilatory volumes, Open-flow system etc. for the purpose of this report, the indirect calorimetry method is adopted. This method includes:

- Measurement of oxygen consumption
- One litre of O2 consumed = 21KJ used (varies slightly with metabolic fuel consumption carbos/fats)
- Oxygen consumption is measured by difference method:

(3.2.1.1)Maximal Oxygen Consumption – The VO2 max

According to Stephen (2009), VO2 max is the maximum volume of oxygen that the body can consume duringintense, whole-body exercise, while breathing air at sea level. This volume is expressed as a rate, either liters per minute (L/min) or millilitres per kg bodyweight per minute (ml/kg/min). Because oxygen consumption is linearly related to energy expenditure, when we measure oxygen consumption, we are indirectly measuring an individual's maximal capacity to do work aerobically. The "typical" young untrained male will have an absolute VO2 max of 3.5liters/min, while the typical same-age female will be about 2 liters/min. This is a 43% difference! Where does it come from? Well first, much of the difference is due to the fact that males are bigger, on average, than females. We humans are all (sort of) geometrically similar, so heart size scales in proportion to lean body size. If we divide VO2 by bodyweight, the difference is diminished (45ml/min/kg vs. 38ml/min/kg) to 15 to 20%, but not eliminated. Young untrained women average about 25% body fat compared to 15% in young men. So, if we factor out body composition differences by dividing VO2 by lean body mass (Bodyweight minus estimated fat weight) the difference in maximal O2 consumption decreases to perhaps 7-10%. By measuring oxygen consumption (VO2) during the exercise on a bicycle ergometer, the energy expended as well as the mechanical efficiency can be determined. VO2 can be converted to energy units to give power input, so long as the exercise does not require oxygen at a rate greater than the highest rate at which a person can consume oxygen (i.e. VO2 max). As a rule of thumb, 1-litre of oxygen consumed is equivalent to 5kcal of energy “turned over” in aerobic metabolism. Therefore if we assume the person’s VO2 consumption as 2.5L/min, we know that this person is turning over energy at the rate of 10.5kcal/min. this is equal to:

10.5Kcal/1hr [4.19J/1 Calorie][1hr/3600 sec] = 12 Watts

(3.3) Design Analysis

(3.3.1) General Design Consideration

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 have 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.

(3.3.2) Frame Design

One of the key factors to design the frame is to choose the material to construct the frame. Initially we take the frame of a cargo rickshaw which is made up of iron that can withstand weight up to 200Kg. Remove its tires, handlebar, fork and its luggage rack. We weld a three iron bars beneath the frame to give it a stand. Then we cut down all excess pieces of metal on the frame to make it lighter. Then to install the gears the shaft is nicely cut into two pieces. A set up is welded to install the rear derailleur to change the gears. Also a few iron bars are welded in the middle of the frame to insert seat on which the person pedaling will sit. The whole setup comes in such a way that the person pedaling can apply maximum power efficiently having least impact on his body. The gear system makes pedaling efficient and helps to increase RPM and also decrease the fatigue of the person who is pedaling.

(3.4) System Force Torque and Power Input

This system is designed assuming the average mass of 65kg and pedaling time as 60mins. From reviewed literatures, the pedal input force, torque and power can be computed as below:

Input Force

F=mv/t

Input Torque

T=F*R

Input Power

$$\frac{2\pi NT}{60}$$

(3.5) Power Output of the Pedals

Work = Force*Distance

Distance = 2πr

(3.6) Alternator Selection

The choice of alternator to use for the project was one of the major problems encountered as regards to the design of this project as much emphasis was given to "low speed" considering the pedaling speed of an average human and in order not to exceed maximum gear ratio.

Here we have used a maruti 800 car alternator which gives 13.5 volts at 1500rpm. The output of the alternator is DC as it is a car alternator and comes with inbuilt rectifier.

(3.7) Battery Selection

The battery was selected on the basis of time it needs to be operated on full load. Here we aim to switch ON one fan, one light and charge at least two mobile phones for about 6-7 hours. Generally the relationship between the energy stored in the battery and the time is given by the formulas given below:

Power = Voltage*Current [Watts]

Energy = Current*Time [Watt-hr]

Fulfilling the 12 VDC battery requirements, a battery with 100 Ah was opted for. Our load that is 1Fan, 1Light and 2 mobile phones requires about 127 Watts. With 12 VDC battery and 127 Watts load, we have about 10.5 Amp current, which gives us about 9.5 hours of usage at full load.

(3.8) Gear Ratio

The gear ratio is also known as its speed ratio, is the ratio of the angular velocity of the input gear to the angular velocity of the output gear. The gear ratio can be calculated directly from the number of teeth on the gears in the system. This system is made up of 2 stage gear systems. The teeth on gears are designed so that the gars can roll on the chain link smoothly without slipping. The number of teeth on gear is proportional to the radius of its pitch circle, which means that the ratios of the gears' angular velocities, radii and number of teeth are equal. Mathematically,

$W_A/W_B = R_B/R_A = N_B/N_A = D_B/D_A$

Where,

$W_{A,B}$ =angular speed of sprocket A and B respectively

$R_{A,B}$= Radius of sprocket A and B respectively

$N_{A,B}$ = Number of teeth on sprocket A and B respectively

$D_{A,B}$ = Diameter of sprocket A and B respectively

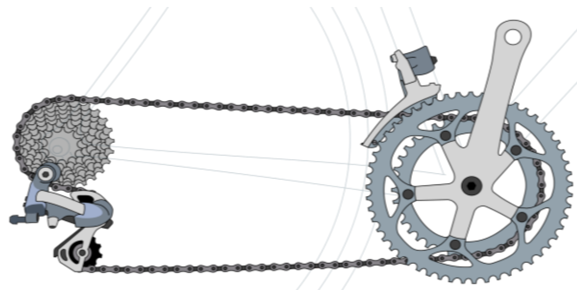

Figure 3.2 Gear system

3.9 Belt Selection

There are lots of factors to be considered when selecting the type of belt to be used;

- The speed of the driving or driven pulley
- The power to be transmitted
- The center distance between pulleys
- Speed ratio
- Service condition

3.10 Electrical Circuit Connection

The basic circuit involved only the alternator and battery connected in series with the indicator bulb.

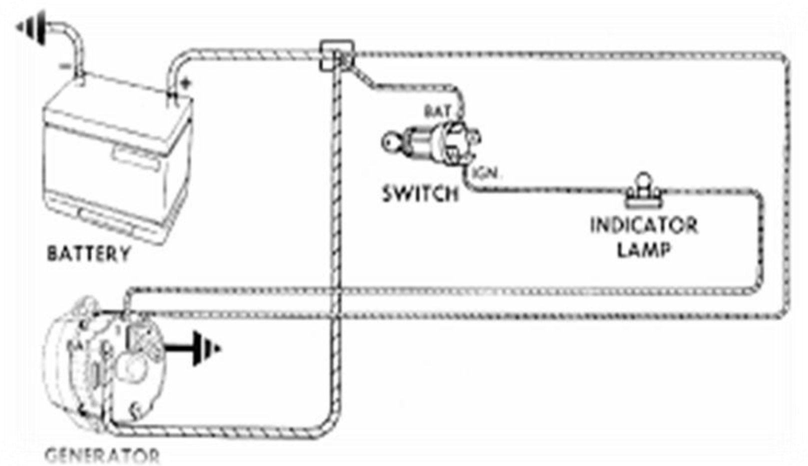

Figure 3.3 Circuit Diagram

(3.11) Indicator Bulb and Diode Trio

- This brings us back full circle to the starting point – the alternator warning lamp. In an actual alternator, there is a path to ground from the field current supply input to the regulator.
- When the key is turned on, current flows through the warning lamp, through the resisters, transistors, and field coil, and then to ground, causing the lamp to illuminate.
- Once the alternator is at full output, voltage from the diode trio becomes equal to the battery voltage. At this time, with 12 volts on both sides, the lamp is out.
- If the alternator should fail, voltage from the diode trio would drop, and once again the lamp would light from the battery voltage. If the alternator output is only a little low, the lamp will be dimly lit. If the alternator fails completely, and the output voltage goes to zero, the lamp will be lit at full brilliance
- The diode trio consists, as the name suggests, of three diodes, one per phase, which provides field current to the alternator regulator. This output will be discussed in more detail later in the "field current supply" section.

(3.12) Equipment Used

The following equipments were used:

- Tachometer – to measure the speed (rpm) of the generator

- Multi-meter – to measure the voltage and current produced from the generator

IV. RESULT

This section presents the result of the input and output data. The results were obtained base on both the evaluation of the models presented in section three and the fabricated design. The input and output data are tabulated for clarity, also, graphs were used when necessary to show the dependence of some parameters on the others.

(4.1) Parameters

The input parameters represent the known values from which the general design was based upon. It includes the operational speed of the human, generator to produce the required voltage which was obtained from the specification of the DC motor purchased.

- ❖ The power that is used during the cycle to turn the generator mostly depends on the pedaling speed of the individual.

Table 4.1 Input Parameters for the Analysis

/N	PARAMETER	YMBOL	VALUE	UNIT
	Human Input Rotational Speed	A	60	RPM
	Diameter of the Flywheel	C	26	Inch
	Mass		65	Kg
	Number of teeth on the large sprocket	A	44	-
	Alternator Power rating		480	Watt
	Alternator Speed rating	D	1500	RPM
	Operational Time		60	Min

	Diameter of the large sprocket	A	9	Inch
	Diameter of the small sprocket-1	B1	1	Inch
0	Diameter of the small sprocket-2	B2	2	Inch
1	Diameter of the small sprocket-3	B3	3	Inch
2	Diameter of the small sprocket-4	B4	4	Inch
3	Diameter of the small sprocket-5	B5	5	Inch
4	Diameter of the small sprocket-6	B6	6	Inch
5	Maximal oxygen consumption	O_{2MAX}	2.5	1/min

- The power that is used during the cycle to turn the generator mostly depends on the pedaling speed of the individual

(4.2) Result

When an average human being of mass 65kg pedals this cycle at 60rpm he is able to attain a total of 1800rpm at the alternator. The alternator generates 14.5 volts and 7Amp DC.

Since power is equal to the product of voltage and current according to this our whole model develops a total power of 101.5 Watts.

This amount of power can-

- Light up to five 7W LED Bulbs
- Charge two 8W Mobile Chargers
- Run one 50W Fan

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