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Design and Construction of Vehicle Wheel Energy Harvesting System for Street Lighting

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---***ABSTRACT***---
. Designing energy harvesting system that are pollution free has become a significant goal within the research community. One of the numerous systems that have been proposed is the VWEHS system that produces electrical power by utilizing the movements of commuting vehicles through tunnels, boulevards, and streets. When vehicles pass over a VWEHS system, the system translates vertically. Consequently, a kinetic energy is produced and transferred into electrical power. In this paper, a prototype version of a Vehicle wheel Energy harvesting system, which aims to harvest energy from moving vehicles by using their kinetic energy, is designed, constructed, and tested. A computer software, Matlab was used to design the system device circuit. An experimental analysis is performed on the rack-and-pinion system. Results have shown that electrical power up to about 55 W generated when a mass of 80 kg is applied to the VWEHS system considered. Extrapolation of results confirms around 0.56 kW powers can be produced when various vehicles with different masses pass through the ramps.
KEYWORDS*: Speed ramps, energy harvesting system, electricity, kinetic energy, voltage, current, power.*

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I. INTRODUCTION

1.1 Background of the Study

The vehicle wheel energy harvesting system (VWEHS) for street lighting provides many important benefits. It can be used in addition to the national production of electricity which are generated through the hydro, thermal and solar. Street lighting also improves safety for drivers, riders and other road users. Driving outside of day light hours is more dangerous because of lack of streetlights in towns and cities. Only a quarter of all travels by car drivers is between 7pm and 8am, yet this period account for 40% of fatal and serious injuries to the road users. For this reason, ways of reducing the risk to all road users during the hours of darkness is key to society (Azam *et al.*, 2016).

During dark and unlit conditions our eye switches to scotopic vision (reduced illumination) which has a range of 30 - 45µcd/m^2. It takes four seconds for our eyes to change from photopic vision (used in normal day light) to scotopic vision. This is also an example of a Troxler effect (a description of temporarily blindness) while using the road in the dark.

Designing energy recovery system that are pollution free and less consumption of scarce resources has become a significant goal in research community. One of the numerous systems that have been proposed is the lighting VWEHS using the speed ramp convertor that produces electrical power by using the free movement of vehicles and other road users. When vehicles and other road users pass over the VWEHS system, the system translate vertically, consequently a kinetic energy is produced and transferred into electrical power. Results have shown that electrical power up to 45W is generated when a mass of an 80kg is applied on VWEHS system. Extrapolation of results confirms around .056kW of electrical power can be produced when various vehicles and road users with different masses pass on the VWEHS system.

In a recent time, the electrical energy has become one of the basic requirements of human beings. The ratio of electricity requirement is increasing by day. But we know that the resources for the power generation are limited, and this has caused energy crisis. The increased in power results in conventional resources for power generation and increase the pollution emissions to the environment. It is time to think about non-conventional energy resources which are eco-friendly to the environment. In other to minimize the emission of greenhouse gases, renewable energy technologies are widely used for electricity generation, solar and wind technologies are used as well (Ankita and Meenu, 2013).

The vehicular growth in Ghana is increasing day by day (Flynt Edmond, 2018). Due to the increasing rate of accidents in town and cities, there have been a corresponding increase in the number of ramps on our roads. The weight of vehicles and passers-by along the ramps can be utilized for electricity generation purposes.

This project studies the method of generating electricity using speed ramp on road to obtain maximum power. In this mechanism a spring and a gear attached to other electrical and electronic components are used. This mechanism converts the kinetic energy of moving vehicle into electrical energy with the help of speed ramp on the road. This can generate many kilowatts of power by using downward and upwards motion of the spring. The downward motion is caused by the weight of the car and the upward motion is due to restoring force utilizing the restore power in the spring.

1.2 Problem Statement

Nowadays renewable energy and energy recovery are considered the most efficient strategies to reduce the financial and economical drawbacks of the excessive utilization of fossil fuel and Gas. Nonetheless. Most of the investigations have been paying attention on the solar energy, wind energy and other wave energy. On the other hand, the operational mode of many of the utilized systems is not sufficiently optimized. This strongly indicates that; high amount of energy is still wasted and may not be recovered (Azam *et al*., 2016).

The pursuance of the VWEHS system constitutes an excellent solution for energy recovery in areas that are poor in connection with the national energy resources. Such areas suffer road accidents, rubbery and other social vices. Hence creating an easy means to provide lighting system for the areas which are difficult to be connected to the national grid or solar system through the utilization of the movement of vehicles and other road users (motorcycles and passers-by). In this context, the present work concerns the need to design and construct a prototype of Road Signal lighting system using a construction speed ramp convertor which can be recovered from several existing systems such as combustion system and other resources.

1.3 Objectives of the Study

The general objective of the study is to design and construct a vehicle wheel energy harvesting system (VWEHS) to generate electricity for street lighting system using the movement of cars and other road users with the help of speed ramp convertor.

The specific objectives of the study include the following:

- To design the Vehicle Wheel Energy Harvesting System for street lighting (VWEHS) using speed ramp convertor module.
- To construct a prototype of the Vehicle Wheel Energy Harvesting System.

1.4 Significance of Study

The project is intended to increase the power generation in the country which could lead to electricity expansion in the country. The road accidents that are normally occurred because of darkness in towns can also be reduced. Besides, the robbery incidents and other social vices that occur along the roads at night may also be reduced.

The project when fully implemented, will enable the government to use part of the expenses spend on providing streetlights through national grid to provide other social amenities for the people in the country.

1.5 Scope and Limitation of the Study

The project is directed to the field of designing the VWEHS, built from electrical, mechanical and electronic components to generate a specific amount of power for street lighting using the speed ramp convertor. The following are the limitations:

- When there is no constant or appropriates movement of vehicles the mechanism will not work to expectations.
- The Vehicle Wheel Energy Harvesting System (VWEHS) has to be checked from time to time to maintain efficiency.

II. LITERATURE REVIEW

2.1 Overview of Vehicle Wheel Energy Harvesting System

Vehicle growth in Ghana is increasing day by day. The weight of vehicles and passers-by can be utilized for electricity generation purposes. This project studies the method of generating electricity using speed ramp on road to obtain maximum power. The flow of moving vehicle is important. In this mechanism a spring and a gear attached to other electrical and electronic components are used. This mechanism converts the kinetic energy of moving vehicle into electrical energy with the help of speed ramp on the road. This is generating many kilowatts of power by using downward and upwards motion of the spring. The downward motion is caused by the weight of the car and the upward motion is due to restoring force utilizing the restore power in the spring (Ashok *et al*., 2012).

Kinetic energy can be utilized to produce power by using a special arrangement called POWER HUMP. It is an Electro-Mechanical unit. It is a mechatronic type of arrangement. The amount of electricity consumed in one night by all the streetlights around Chennai city (India) is equal to consumption of electricity in a remote village for one month and 14 days. The design of speed breakers was developed long ago but only utilized by few nations, as there were limitations of speed breaker power generators. These power generators can be classified according to their mechanism and the type of power generated through it (Ashok *et al*., 2012).

Kinetic energy of a particular object is the energy that is produced due to its motion and mass. The following equation is used to determine the kinetic energy of standard object like paper, cars or planets.

$E_K = 1/2\ mv^2$

Where E_{k} = Kinetic energy of object

m = mass of object

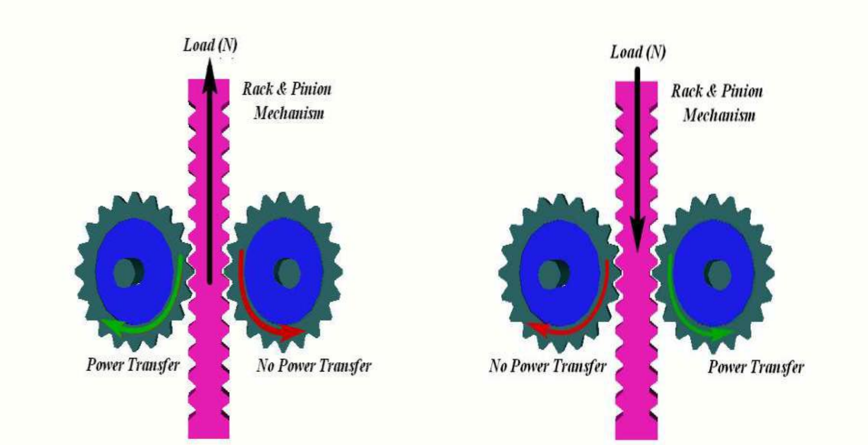
v = speed of object.

2.2 Translator

Each translator is a double slotted planar plate. The translator is wound as three-phase connection winding. The generated power in the translators is delivered to output terminals of generator using flexible wires.

2.3 Stators Topology

It is a planar back iron with mounted magnets on it. The arrangement of magnets is N-S-N. There is a spacer with high permeability between each two adjacent magnets Fig 2.1. The operation principle of the SBG (speed breaker generators) can be described as follows. As the vehicle wheels pass the SBG, the translators will be pushed down. Since the magnets have provided a high-density magnetic field in the airgaps, motion of translators will cause induction of voltage in the translator's windings. The produced power will be transferred via the flexible wires to output terminal of generators. It should be noted that, the flexible wires can be interpreted as brush and slip rings in electrical rotating machines. (Anita *et al*., 2013).



Right sided sprig power transfer Left sided spring power transfer.

Fig 2.1 Construction of VWEHS System

The above display working principle of rack and pinion mechanism and internal mechanism of VWEHS. Gears of different teeth and diameter are mounted on both pinion's shaft to maximize the number of revolutions. A gear mounted on the common shaft is placed between both pinion's shafts. The flywheel is mounted on the common shaft. It keeps the rotation of the shaft in uniform angular motion. It stores the jerky rotations of pinion's shaft. Mechanical rotation is used to rotate the shaft of the generator through a belt. The shaft of maximum RPM (common shaft) is coupled with DC generator. A dc generator produces direct current. According to Faraday's law of induction which state's that (when a coil moves inside the magnetic field, it generates electric current). It rotates the rotor of the generator and in this way, the electricity is generated (Ashok *et al*., 2012).

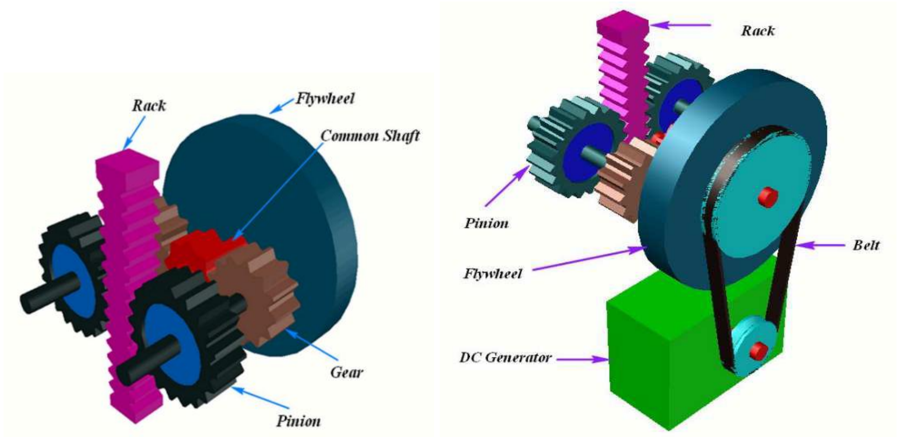


Fig. 2.2 Rack and pinion mechanism (internal mechanism of VWEHS)

Fig. 2.2 represents the model of VWEHS mechanism. It identifies the model by offing road and speed ramp. Four springs are used to provide the upward motion. Utilizing energy (under the application of restoring force when the load is removed) rack moves upward and regain its original position. Two Support platforms for spring are welded to the frame to support the springs. Three supporting bars support whole mechanism. Guide slots lead speed breaker in the straight line and save it from trouble. Rubber beadings are used around the edges of VWEHS to prevent water and dust from entering into it (Ashok *et al*., 2012)

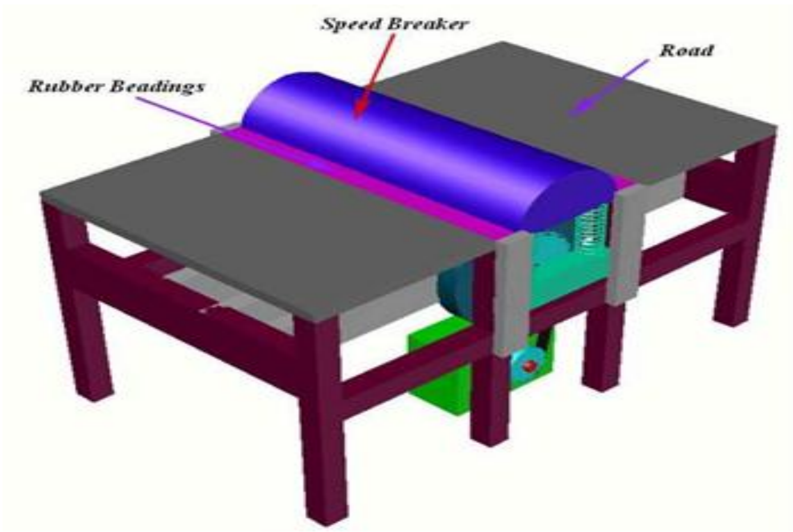


Fig 2.3 Prototype model of Vehicle Wheel Energy Harvesting System (VWEHS)

2.3 Types of VWEHS System

One type of speed breaker design for power generation, may not be suitable for all the road conditions, therefore, different types of designs are introduced,

2.3.1 Connection through Chain Drive Mechanism.

When the vehicle comes on the speed breaker, because of its weight, the top portion of the speed breaker moves downwards and the shaft consisting of the U portion rotates in a direction. Due to this rotation of the shaft, the sprocket will rotate and the rotational energy from one shaft is transferred to the other shaft with the help of chain drive mechanism, Fig. 1. This rotates the gear on the bottom shaft, which in turn will help to rotate the gear placed on the motor. This rotation of the gear starts the generator and generates electricity which can be stored in the battery and can be converted to A.C. current using inverter and can be used for lighting of the lamp's signals sign boards on the road (Ashok *et al*., 2012).

2.3.2 Roller mechanism

In roller mechanism, a roller rotates when vehicles pass over it. This mechanism allows the dynamo which is connected to a rotor shaft to rotate and generate power (Mohamad *et al*., 2015).

2.3.3 Crank-shaft mechanism

This mechanism changes the vertical translational motion of the speed breaker to a rotational motion through speed-breaker and crank-shaft connection. Therefore, the dynamo which is connected to a spur gear through a shaft is receiving the rotation, consequently, power is generated (Mohamad *et al*., 2015).

2.3.4 Magnetic mechanism

A magnetic mechanism is mainly built from translators and stators. When the vehicle passes over the bump, the translators move downward and generate power in the stators.
(Mohamad *et al*., 2015).

2.4 Advantages of using VWEHS as power generator.

- Require simple construction methods.
- Free from all types of pollutions.
- It is economical and easy to install.
- Maintenance cost is low.
- This concept is quite promising due to its good efficiency as well as energy recovery criteria.
- No fuel transportation problem.
- No consumption of fossil fuel which is non-renewable.
- No manual work necessary during generation.
- Energy available all year round.
- We can use it at all places according to desired design.

2.5 Equations Involving VWEHS System

Consider 100 cars of mass 400kg pass over a speed ramp in an hour. The height of rack is 14cm, the diameter of the final pulley is 18mm and having revolution speed (N) is equal to 37 RPM. Down word motion of speed ramp is due to the weight of moving the vehicle and upward motion of speed ramp takes place due to the utilization of energy from springs. Each car pushes speed breaker two times.

Force = F = mg

(1) $F = 400 \times 9.8 = 3920N$

(2) $r = 9mm$ $T = r \times F$ (Nm)

(3) $T = 9x\ 10\text{-}3 \times 3920$

(4) $T = 35.28$ (Nm)

(5) $P = T\omega$

(6) $P = 35.28 \times 2\pi N/60$

(7) $P = 35.28 \times (2 \times 3.14 \times 37)/60$

(8) $P = 136.62$ W

Total generated in forward and reversed stroke.

$P = 2 \times 136.62$ W

$P = 273.24$ W

Revolution in one minute = 200/60 = 3.33rev/min

Power generated per minute = 273.24 × 3.33 = 909.89 W (minute)

Power generated in one Hour = 909.89 x 60 = 54.59 KW (hour).

Where

F = force, m = mass, g = gravitational force, r = revolution, T = torque, P = power and ω = angular velocity

2.6 Electronic Components Overview

Some electronic components were employed to aid the design and construction of the Road Signal Lighting System, because of their unique properties of conversion and physical quantities such as temperature, pressure, and resistivity to be measured into an electronic signal which can be read, displayed, boosted and use it to control some other quantity or direction. Diodes would be used to control the direction of current and convert AC to DC power. The diode can also be used as a rectifier and a signal limiter, it serves as switches and voltage regulator. An Electric alternator is used to generate electrical energy for the usage of the VWEHS System. Bipolar Transistors are used to prevent overheating and damage due to high current, serves as a protection device in case of Back-EMF from an inductive load (Mohamad *et al*., 2015).\

2.7 Other types of VWEHS System.

- Generation of power with the use of Speed Breakers.
- Recycling Kinetic energy from speed bump.

2.8 Empirical Review

2.8.1 Electric Power Generation by Speed Breaker Generators

Electric power is a scarce commodity in Nigeria as in most developing countries like India. Intermittent power outages are witnessed in various cities and villages. Electricity is the form of energy which is most widely used in nature. Electric power obtained from the conversion of other sources of energy, like coal, natural gas, oil, nuclear power and other natural sources are called primary sources. Electricity generation was first developed in 1800's using Faraday's dynamo generator. After almost 2 centuries later, the same basic principles are still being used to generate electricity, but on a much larger scale. The primary energy resources are the conventional types and are in limited quantity because they are not renewable, and on the other hand they create pollution to the atmosphere. A revolutionary method of power generation through speed breaker power generators is proposed as an innovative and useful concept. On speed breakers, tremendous amount of energy is being wasted by vehicles, and several models were introduced to utilize this energy through speed breakers. This paper attempts to show different methods of renewable energy generation through speed breaker (Swathaman *et al*., 2011).

2.8.2 Speed Bump for Power Generation

Designing energy recovery systems that are pollution free has become a significant goal within the research community. One of numerous systems that have been proposed is Speed Bump Power Generator SBPG system that produces electrical power by utilizing the movements of commuting vehicles on highways, boulevards, and streets. When vehicles pass over a SBPG system, the system translates vertically. Consequently, a kinetic energy is produced and transferred into electrical power. In this paper, different types of SBPG systems are presented. An experimental analysis is performed on the rack-and-pinion system. Results have shown that electrical power up to 45 W generated when a mass of 80 Kg is applied to SBPG system considered. Extrapolation of results confirms around 0.56 KW powers can be produced when various vehicles with different masses pass through the bumps (Mohamad *et al*., 2015).

The New York Times reported in 1906 on an early implementation of speed bumps in the U.S.A town of Chatham, New Jersey, which planned to raise its crosswalks five inches above the road level: "This scheme of stopping automobile speeding has been discussed by different municipalities, but Chatham was the first to implement it". According to information from Ministry of Transport, Nigeria has over 56,000km of roads and statistics provided by the Ministry of Road Transport & Highways in India show that the lengths of national highway by 2012 was 76,818 km. In year 2002, 58.8 million and in 2004, 72.7 million vehicles were plying on Indian roads. The annual rate of growth of motor vehicle population in India has been almost 10 percent during the last decade. There is tremendous vehicular growth in India year by year. Nigeria has over 50 million vehicles plying on its roads with a growth rate of 15 % in 2012. On the Roads these vehicles waste tremendous amount of energy due to speed breakers, the increasing traffic and number of speed breakers on roads gave rise to the manufacturing of an innovative device which can channel the energy being wasted by vehicles on speed breakers to some useful work. Different models to harness this energy were introduced according to the road conditions. After each generation the efficiency of model increased, and the limitations diminished. Different kinds of models have variant designs, some use gears, belts, dynamos etc with different applications at different places. Each model was encouraged due to limitations of previous ones. This paper illustrates various models and provides the review of different technologies used in the generation of energy with the help of speed breakers.

Now the question arises as to why only the speed breaker is used and not the rough or plane roads where the kinetic energy of the vehicle is more than that obtained on the speed breaker. The answer to this question is obvious; consider for example: any heavy vehicle moving with a speed of 100 mph on the road and passing over this roller which is fitted at the level of the road then this roller will gain the speed of nearly 90 mph (due to losses). Now suppose a bicycle is moving with a speed of 20 mph and is going to pass this roller (which is moving at a speed of 90 mph), then due to this difference in the speed there will be a collision. That is the main reason for using this concept on the speed breaker. The rough or plane road will not provide the torque necessary for energy generation.

The energy estimation when the vehicle moves over the speed breaker is that the speed breaker reduces its speed. As these breakers have a little height it gains an increase in its potential energy. A vehicle weighing 1,000Kg passes over the system it pushes the damper to a depth of 10 cm it can produce approximately 0.98-kilowatt power (ideally). So, from one such speed breaker on a busy highway, where about 100 vehicles pass every minute, about one kilowatt of electricity can be produced every single minute. This type of energy is a non-conventional resource or renewable energy. While moving, the vehicle possesses some kinetic energy, and it is being wasted. This kinetic energy can be utilized to produce power by using a special arrangement called POWER HUMP. It is an Electro-Mechanical unit. It is a mechatronic type of arrangement. The amount of electricity consumed in one night by all the streetlights around Chennai city (India) is equal to consumption of electricity in a remote village for one month and 14 days. The design of speed breakers was developed long ago but only utilized by few nations, as there were limitations of speed breaker power generators. These power generators can be classified according to their mechanism and the type of power generated through it (Mohamad *et al*., 2015).

III. METHODOLOGY

3.1 Introduction

Vehicle Wheel Energy Harvesting System is a communication tool for road users in a way that, where there is darkness, the system (VWEHS) is introduced to save nations, communities' and to meet societal needs. The most common energy resources available in Ghana are the thermal, hydro and solar energy for powering of streetlights. The design of the VWEHS is to look at the use of a weight of vehicles passing by to generate a specific amount of energy to power the streetlight for better communication on the road in areas which are not connected to the national grid or solar system.

3.2 Tools, Equipment and Component

The following were tools, equipment and components were used for the project:

i. Cable Striper,
ii. Long Nose plier,
iii. Plier
iv. Cable Cutter.
v. Fluke Digital Multi-meter
vi. Set of Screw Drivers
vii. Soldering Iron
viii. Soldering lead
ix. Vero board (Printed Circuit Board)

3.3 System Design

3.3.1 Block Diagram for Design

The block diagram was designed using Matlab software. The block diagram is interconnected using arrow lines from a complete unit as shown in the figure 3.1 below.

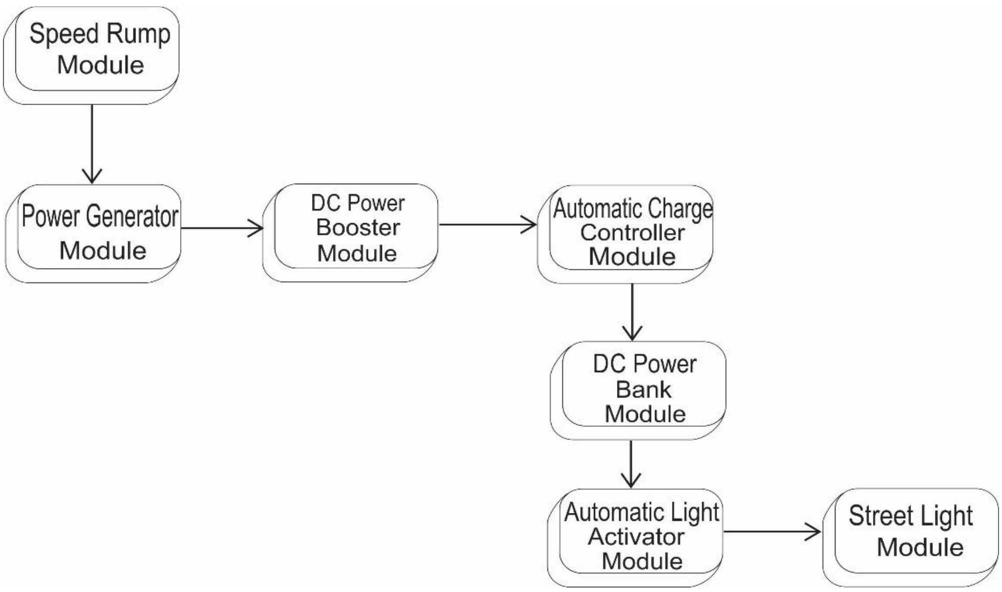


Figure 3.1 Block Diagram For System Device

The system is designed to generate high DC to power a streetlight whenever a vehicle passes on a speed ramp. The system consists of a power generator module, DC power booster module, automatic charge control module, DC power bank module, automatic light activator control module and street light modules.

When a vehicle passes on the speed ramp, the power generator module which is coupled with the speed ramp generates a 5Vdc. The generated voltage is deemed inadequate to charge the 12V power bank. Thus, a DC power booster module is introduced.

The voltage regulator then regulates the boosted 12 volts. The design objective of the automatic charging controller module is to charge the power bank unit to its full capacity and cut off automatically to avoid over charging.

The purpose of the DC power bank module is to store electrical energy which will be utilised by the load (Street Light) when there is no movement of vehicles. Hence, should the generator stop generating, there will be the availability of DC source.

The output is then connected to the automatic lighting activator module. Light dependent resistor is used to determine whether there is day light or darkness. The sensed value is sent to power the street light module.

3.3.2 Circuit Diagram for Design

Matlab software was used to design the system device circuit. The components were imported from library menu of the software. These components were laid out and their pins were joined appropriately with lines as shown in the figure 3.8 below.

The Circuit Diagram

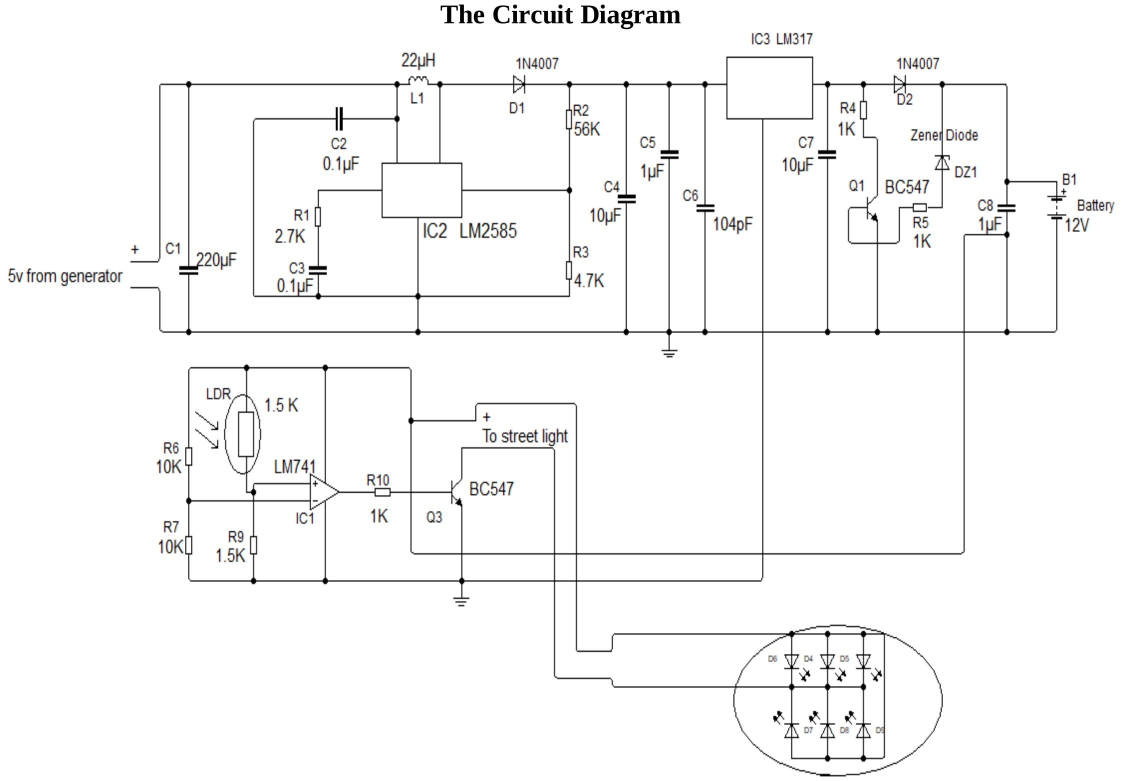


Figure 3.2 System Device Circuit

From the above circuit, the 5V generator is connected to an IC made up of components such as: Resisters, Capacitors, Inductors and Diodes, which is the dc power booster. The resistors prevent the flow of current. The low rating capacitors are used for filtering while the higher rating is used for amplification.

The inductor produces a magnetic field and the diodes for voltage regulation. It is then connected to another IC which is made up of components such as:

Resisters, Capacitors, a Transistor and a Zener diode, which is the automatic charger control module.

The transistor is use as a switch to regulate the flow of power to the dc battery bank, the 12-volt Zener diode is used to regulate and cut off the voltage to the battery bank when it charges up to the 12v and when it drains it allows it recharge again.

The purpose of the power bank unit is to store electrical energy which will be utilised by the load (Street Light) when there is no movement of vehicles. Hence, should the generator stop generating, then there will be the availability of DC source. The output is then connected to the automatic lighting control unit. The lighting control unit uses operational amplifiers that operate as a comparator. A light dependent resistor is used for sensor to determine whether there is day light or darkness. The sensed value sensed by the sensor is sent to the comparator to compare the signal with the reference signal.

The resultant from the comparator determines whether there should be an output or not. When there is darkness, an output signal is sent to a transistor as an amplifier to increase the magnitude of the output signal which will turn ON or OFF the streetlight.

3.4 Electronic Components

The table below shows some electronic components used in the circuit diagram above.

Table 3.1 Component Specification

ITEM NUMBER	COMPONENT NAME	QUANTITY	SPECIFICATION
1	RECTIFIER DIODE	2	D1, D2 (IN4007)
2	ZENER DIODE	1	DZ1 (12 v)
3	ELECTROLYTIC CAPACITOR	7	C1(220UF), C2, C3(0.1UF) C4, C6, C7(10UF), C5, C8(1UF)
4	GENERATOR	1	5V DC Alternator
5	IC	3	IC1(LM741), IC2 (LM2585), IC(LM317)
6	BATTERY	1	B1(12V)
7	INDUCTOR	1	L1 |(22UH)
8	RESISTORS	8	R1(2.7K), R2(56K), R3(4.7K) R4, R5, R9(1K), R6, R7(10K), R8(1.5K)
9	BIPOLAR TRANSISTORS (NPN)|	2	Q1, Q2(BC547)
10	LED	6	L1, L2, L3, L4, L5, L6(WHITE) 3V
11	LDR	1	1.5K
12	Compression spring	2	
13	Rack and pinion gears	2	

3.5 Function of the Components used

3.5.1 Zener Diode (DZI 12V)

The Zener diode used in the circuit is to provide a constant 12v output voltage to charge the load (DC battery bank) and for voltage references and as shunt regulators to regulate the voltage across the circuits. When connected in parallel with a variable voltage source so that it is reverse biased, a Zener diode conducts when the voltage reaches the diode's reverse breakdown voltage, which is the Zener voltage. 2.1- Rectifier diode.

3.5.2 The Rectifier Diode

The Rectifier diodes are used for power supply, where AC is converted to DC. The DC voltage is obtained by passing through the rectifier's output through a filter to remove the ripple AC components. The rectifier when connected across an alternating voltage source V_s. since the diode only conducts when the anode is positive with respect to the cathode, current will flow only during the positive half cycle of the input voltage.

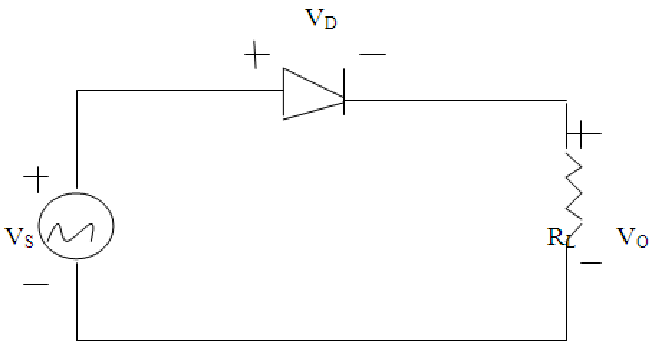


Fig 3.3 The simple half wave rectifier circuit.

The supply voltage is given by $V_S = V_M \sin\omega t$

Where ω (=2πf= 2π/T) is the angular frequency in rad/s, we are interested in obtaining DC voltage across the "load resistance" R_L.

During the positive half cycle of the source, the ideal diode is forward biased and operates as closed switch. The source voltage is directly connected across the load. During the negative half cycle, the diode is reverse biased and acts as an open switch. The source voltage is disconnected from the load. As no current flows through the load, the load voltage V_O is Zero. Both the load voltage and current are of one polarity and hence said to be rectified. The wave form of the source voltage V_S and output voltage V_O are shown above Fig 3.4 The waveforms of the Source voltage (V_S) and Output voltage (V_O)

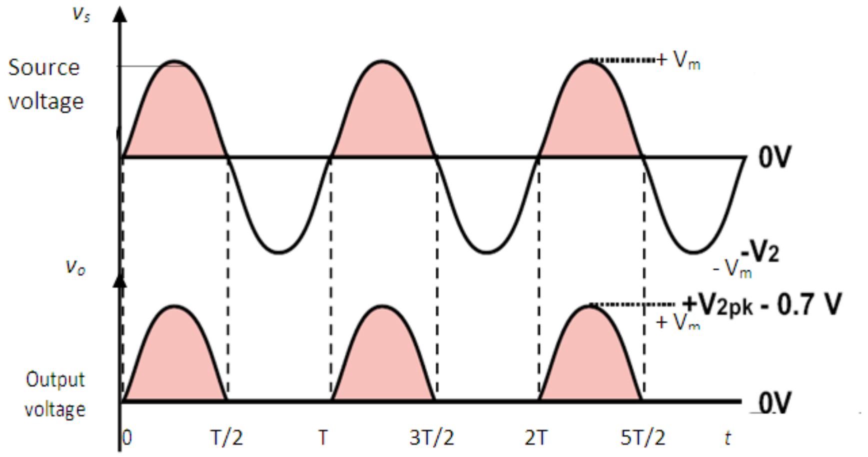


Fig.3.4 The source and output voltages

We notice that the output voltage varies between the peak voltage V_m and V_o Zero in each cycle. This variation is called ripple and corresponding voltage is called the peak-to-peak ripple voltage $V_{p\text{-}p.}$

Average load and current

If a DC voltmeter is connected to measure the output voltage of the rectifier (i.e., across the load resistance). The reading obtained would be the average load voltage V_{ave} , also called the DC output voltage. The meter averages out pulse and displays this average.

$V_{ave} = \int_0^T v_0 dt = \int_0^{T/2} V_m \sin(\omega t)\, dt + \int_{T/2}^{T} 0.dt$

$= 2V_m/\omega T\,[\cos 0 - \cos \omega T/2] = 2V_m/2\pi\,[\cos 0 - \cos \pi]$

Or. $V_{ave} = V_m/\pi$.

The output waveform and average voltage shown below.

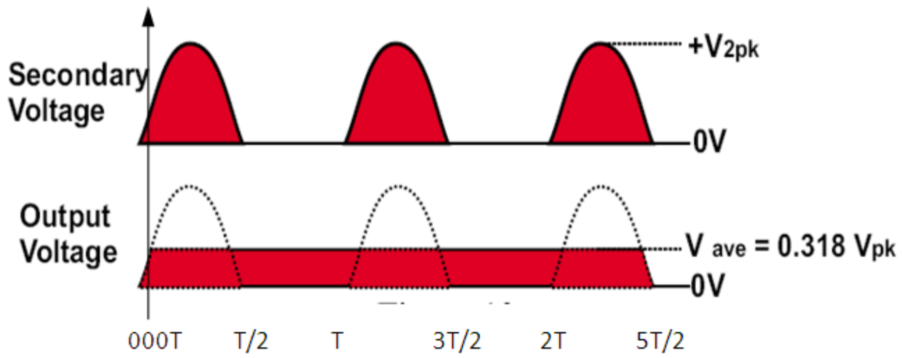


Fig. 3.5 Output voltage and average voltage for half-wave rectifier.

The output V_o may be viewed as a DC voltage plus a ripple voltage. As we can see, the output has a large amount of ripple.

Just as we can convert a peak voltage to average voltage, we can also convert a peak current to an average current. The value of the average load current is the value that would be measured by a DC ammeter.

$I_L = V_{ave}/R_L$

Where I_L is the average current passing through the load resistance.

The maximum amount of reverse bias that a diode will be exposed to is called the peak inverse voltage or PIV. For the half wave rectifier, the value of PIV is PIV = V_m

The reasoning for the above equation is that when the diode is reverse biased, there is no voltage across the load. Therefore, all of the secondary voltage (V_m) appears across the diode. The PIV is important because it determines the minimum allowable value of reverse voltage for any diode used in the circuit.

3.5.3 Diode rectifier for power supply

The purpose of a power supply is to take electrical energy in one form and convert it into another. There are many types of power supply. Most are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronic circuits and other devices such as the VWEHS **System** and Telecommunication equipment. In Ghana, supply from 240V AC mains is converted into smooth DC using AC-DC power supply.

Fig 3.5 Main components of a regulated supply to convert 240V AC voltage to 5V DC.

3.5.4 Zener Diode:

The Zener diode contains a heavily doped p-n junction allowing electrons to tunnel from the valence band of the p-type material to the conduction band of the n-type material. Zener diode permits current to flow in the forward direction like a normal diode but also in the reverse direction if the voltage is larger than the breakdown voltage known as Zener Knee voltage. Zener diode is specially designed to have greatly reduced breakdown voltage. Zener diode breakdown voltage of 3.2V will exhibit a voltage drop of 3.2V if reverse bias voltage applied across it is more than its Zener voltage. Zener diode would be used to regulate the voltage across the RSLS system by connecting it in parallel with a variable voltage source so that it is reverse biased.

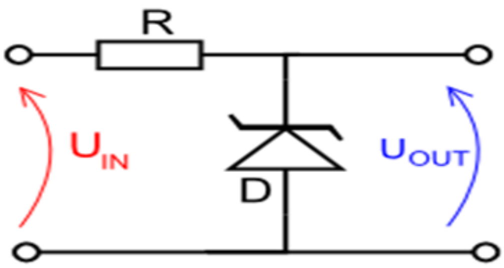


Fig 3.6 Zener diode circuit

3.5.5 Lead Acid Battery

This will store and discharge the current, Automotive and traction applications. The Lead battery would serve as a Standby/Back-up/Emergency power for the VWEHS System.
This has little attention to cost and maintenance. The lead Acid battery image

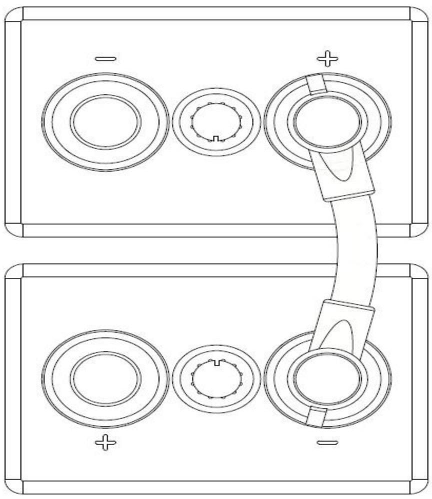


Fig3.7 Diagram of lead acid

3,5.6 Electrolytic Capacitor)) (C1(220UF), C2, C3(0.1UF) C4, C6, C7(10UF), C5, C8(1UF)

The electrolytic capacitors used in the circuit are to store charges and filtering with **a** linear relationship between the voltage and the time integral of the current**.** The electrolytic capacitor is a type of capacitor that uses an electrolyte to achieve a larger capacitance than other capacitor types. An electrolyte is a liquid or gel containing a high concentration of ions. Almost all electrolytic capacitors are polarized, which means that the voltage on the positive terminal must always be greater than the voltage on the negative terminal.

3.5.7 Generator (5V DC Alternator)

The Generators used in this project is to generate 5V inertial voltage to power the circuit by rotating a coil of wire in a magnetic field from the weight of the passing by vehicles on the speed ramp, causing a current to flow in the wire. In electricity generation, a generator is a device that converts motive power into electrical power for use in an external circuit. (Michael Faraday, British scientist 1831).

3.5.8 Integrated Circuit (IC) (IC1, LM741), IC2 (LM2585), IC, LM317)

The integrated circuit (IC), used in the circuit is a semiconductor wafer which contains some tiny resistors, capacitors, and transistors and functions as an amplifier, oscillator, timer, counter, computer memory, or microprocessor.

3.5.9 Battery (B1,12V))

The battery used in the circuit is to store electrical energy, which will be utilised by the load (Street Light) when there is no movement of vehicles. Hence, should the generator stop generating, then there will be availability of DC source.

3.5.10 Inductor (L1, 22UH)

The inductor used in the circuit is a passive two-terminal electrical component which resists changes in electric current passing through it. Energy is stored in a magnetic field in the coil as long as current flows.

3.5.11 Resistors (R1, 27K), R2(56K), R3(4.7K) R4, R5, R9(1K), R6, R7(10K), R8,1.5K)

The resistors used in the circuit are to implement electrical resistance as a circuit element. the Re
sistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits and also to adjust signal levels, bias active elements, and terminate transmission lines.

3.5.12 Bipolar Transistor (Q1, Q2, BC547)

The bipolar transistor (BJT) used in the circuit is an n-p-n type, which turns on when current flows through the base of the transistor. In this type of transistor, the current flows from the collector to the emitter. The transistor is used as a switch to turn on and charge the battery bank unit to its full capacity and cut off automatically to avoid over charging.

3.5.13 Light Emitted Diode (LED) (L1, L2, L3, L4, L5, L6(WHITE)

The light-emitting diodes (LED) used in the circuit is a semiconductor device that emits light when an electric current is passed through it. Light is produced when the particles that carry the current (known as electrons and holes) combine within the semiconductor material.

3.5.14 Light Resistor diode (LDR)

The Light Dependent Resistor (LDR) or a photo resistor used in the circuit is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are made up of semiconductor materials having high resistance. A light dependent resistor works on the principle of photo conductivity. Photo conductivity is an optical phenomenon in which the materials conductivity is increased when light is absorbed by the material (Chris Woodford, 2018).

IV. RESULTS AND DISCUSSIONS

4.1 Results

The circuit had been constructed and proved to be a working model.
A prototype of the VWEHS was constructed and masses of 41 kg, 65 kg and 80 kg were applied on the speed-breaker systems and the experimental voltages and currents generated as well as rotational speeds were measured. The table below shows the different masses to the voltage, current and power generated.

Table 4.1 The Test Results

Masses (kg)	Voltages (V)	Current (A)	Power (W)
45Kg	5.0V	1.6A	8 W
65Kg	12V	2.0A	24 W
80Kg	21.5V	2.6A	55.9W

Three different masses, 41 kg, 65 kg and 80 kg were applied on the speed-breaker systems and the produced amounts of voltage, current and angular speed are measured. It was observed that as the mass increases the produced voltage increases linearly. For instance, a mass of 41 kg, produces 5.0V. This voltage reaches 12V for a mass of 65 kg and 21.5 V for a mass of 80 kg. Similarly, the current and power also increased. It demonstrates clearly that the voltage, output power and current varies directly with the mass.
The formula for power can be interpreted using the equation below.
$P = I V$

Where (P = power, I = current, V = voltage).

4.1 Graphs of mass to voltage, current, and power

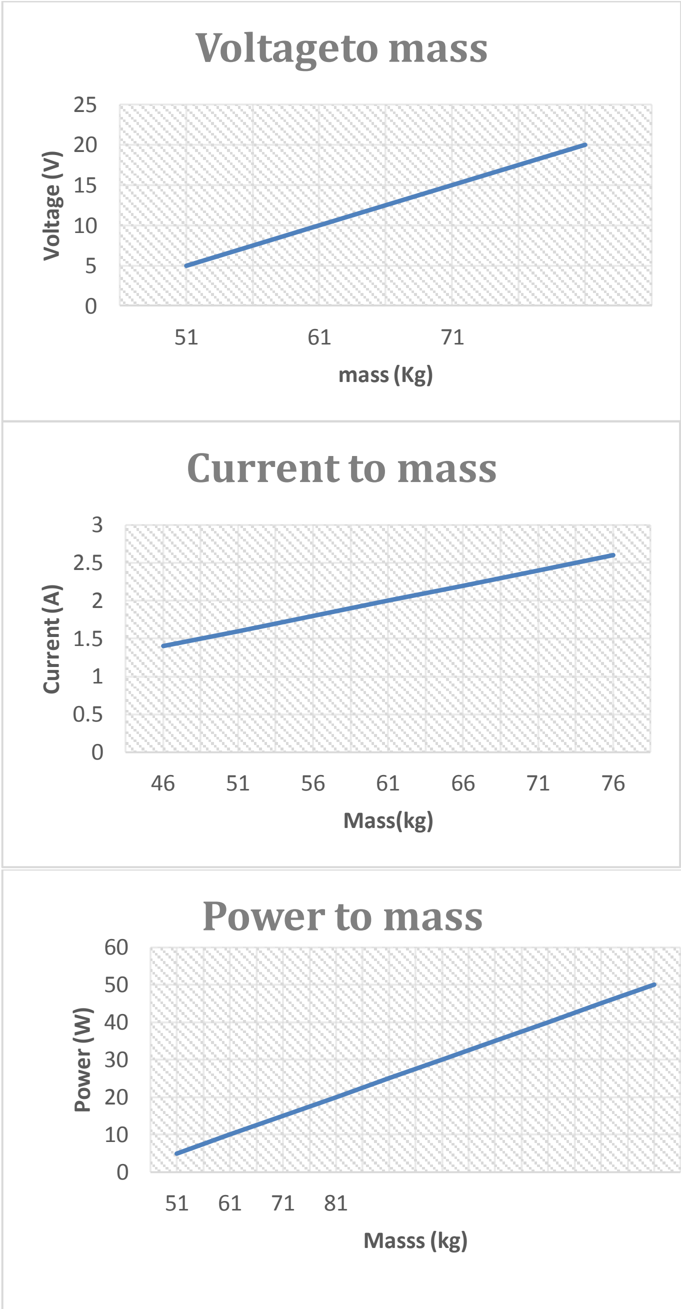


Fig 4.1 Variation of voltage, current and power in function of mass

4.2 Discussion of Result

As expected, the trend of measured current trembles the measured voltage. Nonetheless, the calculated powers produce 0.178 W/kg, 0.369 W/kg and 0.699 W/kg respectively, therefore, it can be said that the power generation per unit mass increases as the mass applied to the VWEHS system increases. Consequently, the average power generation per unit mass of 0.415 W/kg shows a potential regarding the performance of vehicle wheel energy harvesting systems.

4.3 Findings

The Vehicle Wheel Energy Harvesting System is a system that can use the kinetic energy of vehicles and convert them into electrical energy for street lighting.

Nonetheless, it was revealed that powers of roughly 24.0 to 55.9 W can be generated from the speed-breaker system when masses of 65 kg and 80 kg are applied. Hence, a consequence average of 0.415 W/kg forms a promising sign for the performance of such systems in real applications. Extrapolations to a real physical system indicate that a minimum average power of 0.56 kW can be generated for every passing vehicle. In other words, installing a speed bump power generator on road will provide a power that may be utilized to lighten city streets, boulevards, and supply low-voltage powers to cameras or speed-sensors.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the findings and the tested results, the researchers can conclude that A prototype (VWEHS) had been designed, constructed, and tested. The system has a device built in the speed ramps on the road which uses kinetic energy of moving vehicles and converts them into electrical energy. Hence the objectives of the project have been achieved.

5.2 Recommendations

Implementation of the vehicle wheel energy harvesting system should be encouraged on roads with more ramps and heavy traffic roads around the country to harvest electrical Power from moving vehicle. In its own little way, it will be able to reduce the electricity demand on the national grid.

The various parts of the device such as speed ramp cover profile have not been optimized in the research, we do recommend a further study on the various component's parameters so as to harness maximum power out of the harvester.

The researchers also recommend a further study to perform stress analysis on the critical components such as, connecting rod, speed bump cover, base plate, and rack and pinion gear assembly.

There must be another study on the in-depth analysis of the vehicles and tire dynamics, which are not performed in this project.

Last but not the least, the more comprehensive and rigorous in-field testing is required to analyze the real impact of the vehicle onto the vehicle wheel energy harvesting system.

REFERENCES

[1]. Ali A. E., Aqeel A., Shoukat A. and Yousef-Zai F. Q. (2016) 'Selection and/or peer-review under responsibility' of Energy and Environmental Engineering Research Group (EEERG), Mehran University of Engineering and Technology, Jamshoro, Pakistan.

[2]. Alok U. S., Deepak S., Madhawendra K., Vijay P. and Prof. Surendra A. D., (2013) 'Generation of Electricity Through Speed Breaker Mechanism', Satyam Education & Social Welfare Society Group of Institution Bhopal, International Journal of Innovations in Engineering and Technology vol.2.

[3]. Ankita K. and MeenuBala, C. (2013) 'Power Generation from Speed Breaker', International Journal of Advance Research in Science and Engineering, Vol. No.2, ISSN-23198354(E).

[4]. Mohamed Rahman (2012) 'A Novel Speed Breaker for Electrical Energy Generation Suitable for Elimination of Remote Parts of Power Systems where is Near to Roads" Journal of Basic and Applied Scientific Nigeria Ministry of Transport website.

[5]. Ashok K. S., Omkar T., Umesh A. and Vikas S., (2012) 'Development of Speed Breaker Device for Generation of Compressed Air on Highways in Remote Areas', International Journal of Recent Research and Review, Vol. 1, ISSN 2277 – 8322.

[6]. Aswathaman V. and Priyadharshini D., (2011) 'Every speed breaker is now a source of power', International Conference on Biology, Environment and Chemistry IPCBEE vol.1, Singapore.

[7]. Rajat G., Suyash S. and Saurabh G., (2013) 'A Revolutionary Technique of Power Generation Through Speed Breaker Power Generators'. International Journal of Engineering Research & Technology (IJERT), Vol. 2.

[8]. Shubhra Priyadarshani, (2007) "Generating electricity from speed breakers", Guwahati Assam.

GLOSSARY

VWEHS ………………………………………. Vehicle Wheel Energy Harvesting System
RPM ………………………………………….. Revolution Per Minute
SBG ………………………………………… Speed Breaker Generators
DC ……………………………………………Direct Current
AC…………………………………………….. Alternating current
IC……………………………………………… Integrated Circuit
PIV …………………………………………… Peek Inverse Voltage
BJT ……………………………………………. Bipolar Junction Transistor
LDR ……………………………………………. Light Dependant Resistor

Stephen Kwaku Okrah, et. al. "Design and Construction of Vehicle Wheel Energy Harvesting System for Street Lighting." *The International Journal of Engineering and Science (IJES)*, 10(05), (2021): pp. 22-35.