Design of an Efficient System to Harvest Energy from Structural Load

M.S.Godwin Premi, G.Merlin Sheeba, Z.Mary Livinsa, G.Mary Valantina
School of Electrical and Electronics Engineering, Sathyabama Institute of Science and Technology, Chennai, India

godwin.etc@sathyabama.ac.in

Abstract. Human has needed and used energy at an increased rate for their various uses. As a result, huge amount of energy is exhausted and lost. Our objective is to harvest energy from the vehicle with or without load using mechanical gear system and to increase the efficiency level of the energy. The gear system will make the generator rotate, thus producing energy. This work is a real-time work as a lot of vehicles moving daily will cross over the setup, generating efficient amount of electrical energy. It is an eco-friendly system as it doesn’t harms anything. It is a conventional power generation system when compared to existing systems. The work deals with the design of the model in real-time of the energy harvester using gear arrangements and increase in efficiency level of energy. The most challenging part in this assignment is the material that is to be used as top plate assembly, such that it can absorb heavy loads like buses, trucks with water tanks etc. Below the plate there are springs in which deformation will take place. The gear assembly is connected to the bottom of the spring through its teeth. When the spring gets deformed due to load, the gear assembly will be rotated which in turn will rotate the generator as it is coupled to the gear assembly. So energy will be produced. To increase its efficiency, gear assembly consisting of different sizes of gears, is used to increase the rotation of the generator which will produce more electrical energy. Generally, the output will be AC (alternating current), so AC to DC (direct current) converter is used. Amplifiers can also be used to make the energy more efficient and store it in battery for further application.

1. Introduction
Energy is the ability to do work. It surrounds us in all aspects. In the present world it is observed that the non-renewable sources of energy are becoming the conventional sources of energy. It is a matter of concern that we are losing the resources that are available in our environment. Various non-conventional technologies for the generation of power and to move it more sustainable has been already discovered.

Naturally resources like wind, tides, solar, biomass etc are already being used to generate energy which is known as non-conventional resources. They are pollution free and produce a clean form of energy. The various types of non-conventional sources are solar energy, wind energy, tidal energy, geothermal energy, biomass energy. Though the resources of this energy are abundant but in the present scenario there is a need to save or secure the energy for our future generation to use.

Power is considered to be an asset for the developed countries. One of the main reasons for the dominance of the developed countries is the availability of its power. Human has needed and exploited the energy at an increasing rate from the time of its birth. The main reasons of energy crisis are the
rapid growth of population and the standard of living of human beings also increased. It is observed that India with 20% of world population consumes only 1% of energy generated in world whereas America with 7% of world population consumes 32% of the power generated which shows the dominance of developed countries. The main source of power generation is the fossil fuel which will be exhausted in the next few decades. In turn, it is important to establish a method to generate some minute energy also in spite of the fossil fuels that are being burned up by the vehicles [1,4]. It can be an alternative and effective method to generate electricity [5]. There are various ways in which we can generate the electricity. Vehicles passing through University gates, offices, can contribute to the energy generation itself.

This work deals with such a technique that can generate power which is eco-friendly in nature. It basically grasps the energy that is being wasted when vehicles or human crossing a place. Though the energy production is not so high hence amplifier is used to make it effectively applicable. This project mainly involves the gear mechanism driven by chain to obtain energy from the load. The objectives of this work are to generate power from the load, to make it cost effective, sustainable for communities, to make it pollution free, easily accessible and non-conventional source of power generation system and to obtain the maximum output from the system reducing the noise level as far as possible [8].

2. Literature Survey

Mathane Nitashree V, Salunkhe Arati L et al [2] proposed the concept of capturing the energy rather than conversion. The load that falls on the rubber plate below which the piezosensor is placed which captures the force and produces electric energy. Here power is directly produced but piezo sensor can’t take heavy load and also it is very sensitive.

M. Sailaja, M. Raja Roy et al [3] proposed the concept of energy generation speed breakers. In this paper the idea is to tap the potential energy that a vehicle acquires when it rolls over the speed breakers in road. In this the rack and pinion, lever, roller mechanism can be used. Rack and Pinion mechanism yields a better result. But the slip of the tyres when the vehicle rolls over the speed breakers reduces the efficiency of energy production.

Noor Fatima, Jiyaul Mustafa et al proposed the generation of energy using crankshaft arrangement. In this paper the author uses the crank mechanism to generate electricity. The stroke motion of the vehicle is converted to the kinetic rotational crank. It converts the kinetic energy using moving plates placed, which captures the small movements. In this method also, the flywheels are used.

Chunhua Sua, Hangbing Wang, Jie Liu et al [7] realized the generation of energy using Piezo Harvesting Unit. It is one of the advanced technologies used in the China pavements for the generation of power. It uses PHV as energy transducer. Below the typical asphalt this PHV is placed having similar thickness to that of asphalt. Atleast 100mJ of energy can be harvested but it is very costly. With load the energy varies linearly.

Ramesh Raja R, Sherin Mathew [6] proposed the concept of power generation from the staircases which are installed in homes, colleges, railway stations, etc, can be used for domestic purposes. Here the mechanism used is flywheel and it is driven by Belt-drive mechanism. But drive mechanism is nothing but the pulley system which can’t withstand heavy loads.

3. Component Details

3.1. Top Plate Assembly

The top plate that is used in the work is basically of cast iron material. Though the cost is high for cast iron material still it gives the assurance for holding heavy loads. In most cases of such experiments, generally mild steel is being used, but mild steel gets tapped because it’s low strength. The cast iron material is used in this work by considering the good casting properties, good vibration damping and good wear resistance. Cast iron material is available in reasonable cost with good strength. They
consist of carbon (2.5-4%), silicon (1-3%), and the remaining is of iron. Specification: Length: 2 ft., Breadth: 1 ft.

3.2. **Open Coil Helical Spring**

A spring is an elastic body which gets deformed when there is a compression load over it. In other words, it can also be called as shock absorber. They are usually made up of hard steel. It has to be chosen carefully such that it is neither more flexible (continue to vibrate even after bump) nor rigid (will hardly absorb road shocks). They contain 0.6 to 0.75 % of carbon and 0.6 to 1 % manganese. They are helical in nature so that it returns to its natural position, when unloaded. The pitch of the spring is very high. They can prevent the pulling forces between two or more objects. A round of spring does not lie in the same plane as the axis of helix. Though there are certain advantages but a major drawback of this is the high amount of spring noise that is produced which reduces the efficiency to an extent. Specifications: Diameter of wire (d) = 2mm; Mean diameter of spring (D) =30mm; Number of turns (n) =14; Free length =315mm.

3.2.1. **Rack and Pinion Gear**

A rack and pinion is a linear type of actuator. It is a gear mechanism which works in a pair that convert linear motion into rotational motion and vice versa. This type of gear can be found in steering wheel, railway rack, stairlifts etc. The former is a linear gear while the later, is circular gear. The spring movement is attached with the rack gear which is having the toothed part which connects the teeth of pinion gear, the rotating one. The rack and pinion mechanism has been chosen over the roller and lever mechanism because of its compactness, robust, cheap, reliability of holding heavy loads, simple arrangement etc. The disadvantages of this gear are leakage, less durability and vibration. Specifications of rack and pinion gear: Material: mild steel; Number of teeth =38; Length of rack =35cm; Diameter of pinion =3-3.5cm; Number of teeth in pinon =64.

3.2.2. **Spur Gears**

Spur Gears are radially projecting teeth from a cylinder or disk. They have several different purposes but, in this work, they are being used to increase the speed of rotation. The increase in the number of spur gears of varying size arranged in descending order is directly proportional to the rotation speed of the generator. The contact surfaces of the gears are tangential to the direction of rotation of axis. The reason for selecting spur gears is because of high power, high efficiency, reliable service and compact layout. Specifications: Number of teeth =96 and Thickness of the gear =10mm.
3.3. Generator and Battery
It converts the rotational motion to electrical energy. A dynamo machine consists of a stationary structure, called the stator, which provides a constant magnetic field, and a set of rotating windings called the armature which turn within that field. The shaft of the generator is basically coupled with the rotating spur gears. From the generator, the battery is connected directly which is rechargeable. In this work, two batteries of 3.5 volts is connected in series. Totally the battery can have up to 6.5 volts.

3.4. Chain Drive
The entire mechanism is chain driven as it can absorb heavy load. It is used to drive the rotation between the rack and pinion gear and spur gear. The chain length is of 50-55 cm. It should be chosen precisely so that it doesn’t get too loose or too tight and should have flexible rotation.

4. Methodology
The vehicle with or without load passing over the system or structure should produce energy. The load passing over the structure will exert a force on the system and the structure will rotate the generator to produce electrical energy which is further amplified for various applications.

When a vehicle passes over the plate top assembly, the springs below the assembly gets deformed. The top plate assembly that is to be used is of cast iron material so that it can withstand heavy load unlike steel plates. The deformation of the spring depends on its diameter, length and height of plate stand and the length of the shaft. The deformation in the spring results a linear motion in the rack gear of the assembly. The linear motion of the rack is converted into rotational motion with the help of pinion gear. To increase the number of rotations, this rack and pinion gear assembly is coupled to the spur gear which in turn is coupled to the generator. On the rotation of generator energy is produced. Here mechanical energy is converted to the electrical energy. The energy generated is stored in battery. From the battery, the power is amplified and then used for further applications.
Table 1. Harvested Power for different weights

| Weight applied on the top plate (in kg) | Displacement (in cm) | Power Obtained (in watts) |
|----------------------------------------|----------------------|---------------------------|
| 85                                     | 10                   | 1.389                     |
| 90                                     | 12.4                 | 1.824                     |
| 95                                     | 14.9                 | 2.314                     |
| 100                                    | 17.3                 | 2.828                     |
| 105                                    | 20.3                 | 3.485                     |
| 110                                    | 22.6                 | 4.065                     |
| 115                                    | 25.6                 | 4.813                     |
| 120                                    | 28.1                 | 5.513                     |
| 125                                    | 31.3                 | 6.396                     |

5. Performance Metrics
In order to understand the performance of the energy harvesting system, the calculations are being carried out for harvested energy from a motor cycle.
Average mass of the motorcycle=120kg.
Average mass of the rider=65kg.
Total weight=(120+65)kg =185kg
When a motor cycle wheel is crossing the plate, there is a displacement(d) of 10cm which is measured manually.
Force= weight applied on the plate(w)*acceleration due to gravity
   =w in kg*9.81m/s² = 9.81 w Newtons
Work done= Force*Displacement = w*g*d
Output Power = Work done/second
              = 0.1635 wd watts

Fig. 6. Weight versus displacement and power
The fig.6. shows the relationship between the amount of weight applied to the system and the displacement and also the power harvested from the weight applied on the top plate. It is understood that the displacement is increasing with increased weight and thus more power is generated.

6. Conclusion
This system, though, produces a minimal amount of energy but can be conserved for future use. To use this energy effectively it is advisable to use a DC step up power booster to convert the low voltages to high voltage to a quite extent. This mode of power generation is eco-friendly as it causes no harm to the environment. The main disadvantage in this system is it produces spring noise which can’t be entirely removed. But it can be reduced to the acceptable level. By this system implementation we can reduce our dependency on conventional sources to a minimum extent.

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