International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

Road Tyre Friction Used to Generation of Electrification

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Abstract: ***The current scenario of energy demands in India have waded new research areas for hunting the alternative energy resources to compensate the polluting non renewable resources. It brings larger importance to the idea of harvesting the frictional energy between the Roads and the vehicular tyres. This is exerted as a stress on the road surface accompanied by Heat dissipation. This wasted form for energy can be made productive by using Piezoelectric Generator and Thermoelectric Generator. Piezoelectric Generator generates electricity in response to stress acting on its mechanical axis while Thermoelectric Generator generates power when an ambient temperature difference is provided. These are embedded below the road surface with suitable insulations and proper structure to improve its performance. This system would have very low capital cost when compared to the total cost of power generation, transmission and distribution in conventional power generation methods with the life time of this system in concern . The pollution free electricity thus generated from the road by using these generators can be stored in a battery and later used for the domestic electrification. This method will be best suited for the electrification of all time loads like Traffic signals, street lights, lighting especially in highways.***

Keywords: ***Piezoelectric Generator, Thermoelectric Generator, Power, Heat.***

I. INTRODUCTION

The process of power generation using any of the alternative energy resources can be established if and only if the power output and cost efficiency of the efficient than the conventional methods. So now the trend has moved towards finding methods to make use of the unused or the wasted energy rather than finding new resources for generation. One such wasted form of energy is the frictional energy in roads which exists between the road and the vehicular tyres.

This resource can be resorted in two forms: the stress exerted on the road and the heat dissipated from the roads which are cooled by the natural circulation of air. So we propose a new approach of using a hybrid model of Piezoelectric Generator and Thermoelectric Generator. The Piezoelectric Generator works on the principle of piezoelectric effect and generates electricity in response to stress applied. The Thermoelectric Generator works on the principle of thermo electric effect and generates electricity with respect to the temperature difference applied over it. These two modules charge two battery circuits i.e. when one is charged by the simultaneous operation of the two modules while the other will be discharging to the necessary loads.

Revised Manuscript Received on December 30, 2019.
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These modules when separately operated have very low output efficiency but while using them together they give better outputs on the basis of cost efficiency with respect to the life time of these modules. The pollution free electricity thus is generated from the road and made available for the domestic electrification.

II. BLOCK DIAGRAM

The main component of the system is Peripheral Interface Controller (PIC IC 16F887A) which is used to get the user inputs and controls the various components of the model correspondingly and thus acts as the heart of the model coordinating all peripherals.

A Menu keypad is designed to give the inputs to the PIC controller for selection of suitable relay operations i.e. automatic or manual mode; charging or discharging mode.

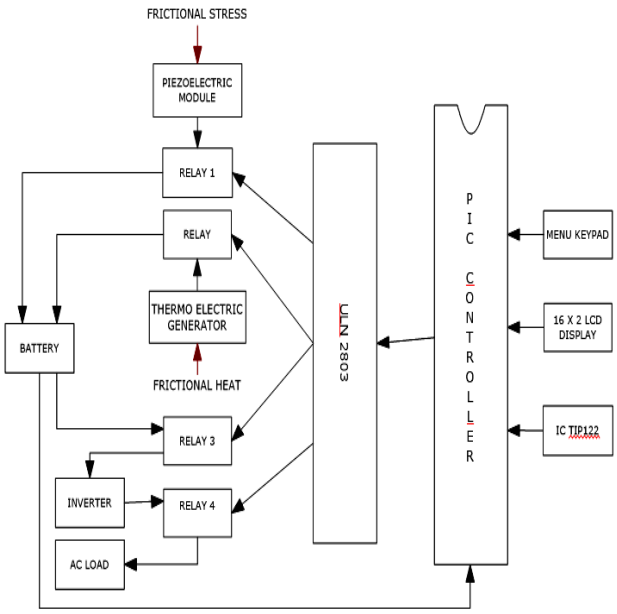

Fig. 1 Block Diagram of proposed system

The PIC controller drives the relays by means of a relay driver circuit ULN 2803. This ULN is a NPN Darlington pair operating on negative switching principle. In order to operate the system in different mode we have four relays: Relay 1, Relay 2, Relay 3 and Relay 4. The Relay 1 connects the piezoelectric module to the battery. The Relay 2 connects the peltier module to the battery. Thus Relay 1 and Relay 2 are used for the charging of Battery.

The Relay 3 is used to operate inverter, to convert the DC output in battery into AC voltage to operate AC load. The PWM Inverter SG3525A is used in 120° conduction mode in here. So if a DC loads needs to be operated, it can be connected to Relay 3. The Relay 4 connects the AC voltage from the inverter to the load.

Thereby Relay 3 and Relay 4 are used for discharging of Battery through a load. The Battery voltage is continuously monitored by the PIC controller. When the battery voltage crosses the upper threshold limit the load (Street light, traffic signals, emergency lamps etc) is automatically supplied by this battery voltage cutting it off from the AC supply Mains and thereby saving power that can be used elsewhere. In addition to this, piezoelectric voltage and peltier voltage are also measured to have continuous track on the charging rate of the battery and to know the generation at the current time period. These values are displayed by means of LCD display which has 16*2 bit resolution.

The various modes of selection are automatic mode, peltier mode, piezoelectric mode, inverter mode and load mode. The automatic mode serves only for charging of the battery while the manual mode can be used for charging and discharging purpose. In order to restart entire system we use a IC TIP122 which acts as master clear unit which can be used in case of any interruption in supply to controller or in order restart after maintenance works .

III. HARDWARE IMPLEMENTATION

PIC Controller

PIC is expanded as" peripheral interface controller" also called as "programming interface Controller. The electronic circuits that can be programmed to carry out a vast range of tasks. It is made by microchip technology.

A PIC microcontroller is a 16 bit processor with built in memory and RAM with 40 pin microchip. It requires 5v dc input and hardware has separate code and date space.

It has only 35 word instructions. All single cycle instructions except for program branches which are two cycles with operating speed of 200MHz for clock input and 200nS for instruction cycle. Its advantages are low cost, high quality, availability and serial programming.

LCD Display

LCD (Liquid Crystal Display) screen is an electronic display module. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These LCDs are economical and easily programmable and hence they are preferred over seven segments and other multi segment LED.A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this module each character is displayed in 5x7 pixel matrix. The LCD has two registers namely, Command and Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

ULN2803

The ULN2803 is a high-voltage, high-current Darlington transistor array. The device consists of eight npn Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads. The collector-current rating of each Darlington pair is 500 mA. The Darlington pairs may be connected in parallel for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED and gas discharge), line drivers, and logic buffers. The ULN2803A has a 2.7-kΩ series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices.

Relay Section

A relay is an electrically activated switch that consists of a coil internally which will creates a magnetic field that attracts a movable lever and then changes switch contacts when a current is flowing through it. The typical usage of relay is to allow a low DC voltage circuit to switch on or off a high voltage (DC or AC) circuit without direct electrical connection between them. This means two circuits used in switching are magnetically and mechanically linked but not electrically connected.

The relay used in the kit is JQC-3FC(T73).It is a Single Pole Double Throw (SPDT) relay that has 5 terminal pins which consists of a pair of coil pins, a common pin, a normally open (NO) pin and a normally closed (NC) pin. When the relay is not activated, the common pin is in contact with the NC pin and when it is activated, the common pin will break away from contact with the NC pin and subsequently makes contact with the NO pin. When the relay is deactivated, the common pin will conversely break away from contact with the NO pin and return back in contact with the NC pin.

Four relays are used in the circuit for switching the piezoelectric module, peltier module, inverter and load. Suitable connection is made to operate the modules under automatic and manual modes.

IV. EXISTING MODELS

The power generation from the roads have been demonstrated in various models. Some of them are

Piezoelectric crystals are embedded in sheets which are lined on the pavement to generate electricity when people walk over it. This has been implemented in schools and sideways in parts of California.

Another prominent design of embedding piezoelectric crystals on the road is by complete resurfacing of the existing the roads. But it is applicable only for asphalt or concrete roads. This model is implemented by Innowatech Energy Harvesting System and the average estimation of energy generation given by Innowatech research scholars is 200kW/hr for 1km road and 120kW/hr in case of rails.

The thermoelectric generator is used to generate electricity from the ignition system of vehicles provided with proper cooling facilities.

Foot step power generators are embedded on the shoes. The weight of human body acts as the stress input and the electricity generated is stored in a battery which can be later used for small torch lights and flash lamps. For a weight of 50kgs, an output up to 4v has been generated.

The disadvantages of the conventional power generation methods can be noted as:

A motor and a generator setup which usually needs consistent maintenance, proper winding insulation and speed control techniques.

Large capital cost to embed piezoelectric crystals in case of resurfacing of roads.

Maintaining a cold sink in vehicular ignition system (usually done by natural air circulation).

V. PROPOSED MODEL

We propose a hybrid model for harvesting both the frictional stress and heat from the roads to provide a sustainable means of power generation. This module consists of a combination of piezoelectric generator and a thermoelectric generator.

Whenever a vehicle passes over the roads its entire weight acts over its tyres which exerts an ambient stress on the as it passes. This stress can be directly converted into electrical energy by the principle of piezoelectric effect i.e. mechanical energy is converted into electrical energy proportionally. Similarly the friction between the vehicle tyres and the road surface is dissipated in the form of heat which is cooled by means of the natural circulation of air. This heat energy is converted to electrical energy using the principle of thermoelectric effect where in the difference in temperature is converted into electrical energy. For accurate measurements a suitable cooling sink can be provided.

This modules separately used have several drawback. In case of thermoelectric generator there is a possibility of condensation whenever there is an ambient temperature difference across the module under no load conditions. Similarly piezoelectric generator has a very low efficiency when operated solely. By using the hybrid model of piezoelectric and thermoelectric generator the overall efficiency of the system has been increased by a large ratio with respect to the input given. The cost efficiency is also improved when compared to the cost of generation, transmission and distribution to the consumer. The advantage of this model is that there is better design with reduced number of piezoelectric crystals rather than implementing it throughout the road and the use of thermoelectric generator increases its total output and thereby provides a better source of energy with longer usage.

VI. MODULES USED

Piezoelectric Generator

Piezoelectricity is the electric charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress. The word piezoelectricity means electricity resulting from pressure. It is derived, which means to squeeze or press, and electric or electron.

The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials. The piezoelectric effect is a reversible process in those materials exhibiting the direct piezoelectric effect.

Crystals will generate measurable piezoelectricity when their static structure is deformed by about 0.1% of the original dimension. Conversely, those same crystals will change about 0.1% of their static dimension when an external electric field is applied to the material. The inverse piezoelectric effect is used in production of ultrasonic sound waves.

Piezoelectricity is found in useful applications such as the production and detection of sound, generation of high voltages, electronic frequency generation, microbalances, to drive an ultrasonic nozzle, and Ultrafine focusing of optical assemblies.

Thermo electric Generator

Thermoelectric generators (also called See beck generators) are devices that convert heat (temperature differences) directly into electrical energy, using a phenomenon called the See beck effect (a form of thermoelectric effect)

Reference (cold) junction compensation methods:

Thermocouples provide an output which is related to the temperatures of the two junctions. For them to function as absolute temperature measuring devices, rather than differential, the reference junctions must be maintained at a known temperature .The most common method is to measure the temperature at the reference junction with a direct-reading temperature sensor. This process is called cold-junction compensation (CJC) which is forcing the junction from the thermocouple metal to copper metal to a known temperature, such as 0 ºC, by submersing the junction in an ice-bath, and then connecting the copper wire from each junction to a voltage measurement device.

Their typical efficiencies are around 5–8%. Older devices used bimetallic junctions and were bulky.

More recent devices use highly doped semiconductors made from bismuth telluride (Bi_2Te_3), lead telluride (PbTe), calcium manganese oxide (CMO) or combinations thereof, depending on temperature. These are solid-state devices and unlike dynamos have no moving parts, with the occasional exception of a fan or pump.

They are mainly used for cathodic protection, radio communication, and other telemetry and on gas pipelines.

VII. REAL TIME IMPLEMENTATION

In the real time implementation, a hybrid model is used which utilizes the wasted energy i.e. frictional stress and heat from the vehicles. The hybrid model uses two modules

- Piezoelectric module
- Peltier module

Piezoelectric Generator Module

The module uses the frictional stress from the vehicles. The piezoelectric discs are embedded on the road and the stress is applied directly over the discs. By embedding the piezoelectric disc over the road surface it's not sure that the entire stress of the vehicles passing on the roads is uniformly distributed over the embedded disc. To overcome this, a new model is proposed.

Construction

This model consists of two gears mounted beneath a roller fixed at the road surface. The two gears are connected at the centre and from the lower gear a shaft is connected to metal rod. The metal rod has spherical or rectangular projection at other end. This metal rod passes into a rectangular metal box like structure with the piezoelectric disc connected interior of the box. These crystals are connected along breadth of the box.

Working

As the vehicle passes over the rollers on the road surface, the rollers rotate which intern rotates the gears. The gearing mechanism rotates the metal road connected to it. As the rod rotates the projection strikes the piezoelectric disc. By this the frictional stress of the vehicle is applied to disc indirectly. As the vehicles passes over the rollers continuously, a continuous stress is applied to piezoelectric disc which results in a continuous generation of power.

The amount of power generated depends on the number of vehicles passing through the road and the speed at which they travel.

Thermoelectric Generator Module

The peltier module utilizes the frictional heat that is being wasted by the vehicles. The peltier principle is not used in the real time system. This module is implemented by using a Thermoelectric Generator (TEG).

TEG is made of semiconductor materials sandwiched between ceramic plates.TEG is embedded beneath the road surface and phase changing materials are used along with it.

Phase change material is material which absorbs heat and dissipates the entire heat after reaching a maximum temperature. While absorbing heat this material is in molten state, after reaching a tolerance level the material solidifies and dissipates the absorbed heat.

The power can be generated without using phase changing materials but the temperature difference between the two junctions is low. Higher output can be obtained by using the phase changing materials.

The output of the peltier module is based on the number of vehicles and the climatic conditions.

The output from the two modules is stored in a battery. Two batteries are used, One is charged initially and after reaching the upper threshold battery is connected to the load through inverter i.e. it supplies the street and traffic lighting.

While the second battery is switched to charging mode. As the battery 1 reaches lower threshold it is switched back to charging mode. Thus the two batteries are charged and discharged alternatively thus providing a continuous availability of power for lighting purpose.

VIII. RESULT ANALYSIS

The results obtained from two modules are tabulated below,

1. Thermo-electrics Generator Module:

Table. 1 Results of power generation using Thermo-electrics Generator

COLD JUNCTION TEMPERATURE (Celsius)	HOT JUNCTION TEMPERATURE (Celsius)	VOLTAGE GENERATED (volt)
0	41	0.3
0	100	0.9
0	135	1.0
0	148	1.1
0	150	1.3
0	166	2.3
0	230	2.9
32	135	0.5
32	148	0.8
32	150	1.1
32	166	1.5
32	230	1.7

From the table we see that, larger temperature difference between the hot and cold junctions, the higher will be the voltage generated. Keeping the cold junction temperature at constant and increasing hot junction temperature, an increase output voltage is obtained. Thus the only constraint is the ambient temperature difference between the hot and cold junctions, depending on which voltage is being generated.

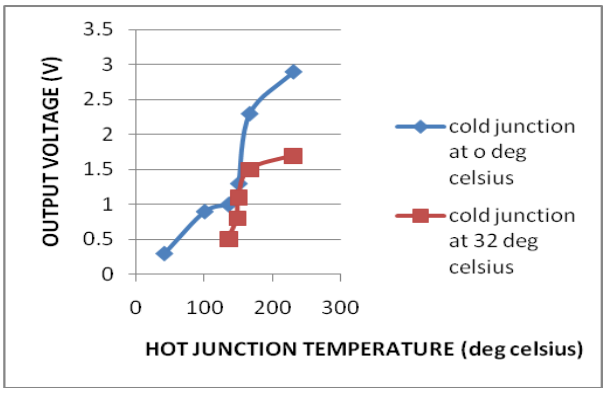

Fig. 2 Hot Junction Temperature Vs Output Voltage at constant cold Junction Temperature

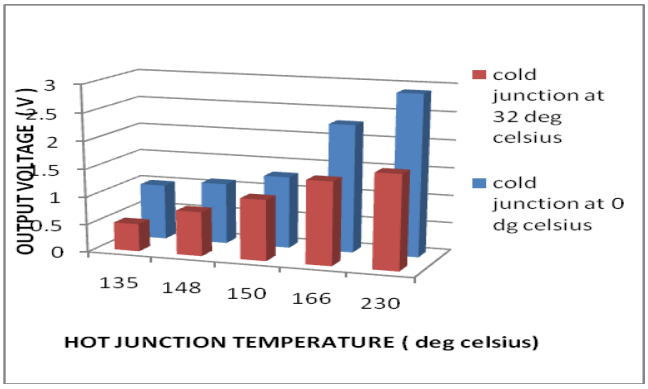

Fig. 3 Bar chart for Hot Junction Temperature Vs Output Voltage at constant cold Junction Temperature

2. Piezoelectric Generator module:

Table. 2 Results power generation using Piezoelectric Generator

NO OF CRYSTALS ON WHICH STRESS IS APPLIED	Vrms (volt)	Vmin (volt)	Vmax (volt)
1	4.35	-6.80	7.20
2	5.35	-8.60	9.00
3	6.15	-9.40	9.80
4	6.3	-10.20	11.00

It is seen from table that when a uniform stress is applied over a number of piezoelectric disc, the voltage generated is increased. When more stress is applied on the piezoelectric disc, the voltage generated is high. Thus the voltage generated in the piezoelectric module depends on the stress being applied and the number of disc over which stress is applied.

This can be illustrated from the graphs below:

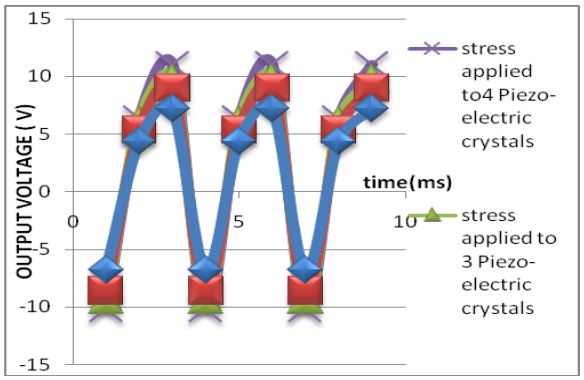

Fig. 4 Output voltage Vs Time graph for Piezoelectric Generator

DSO WAVEFORMS

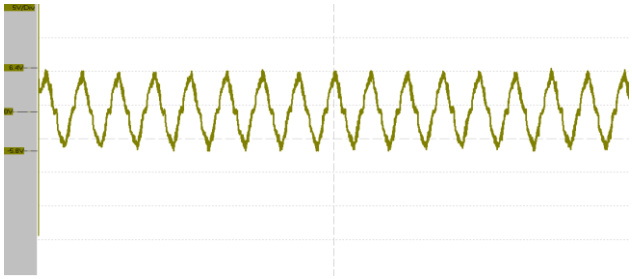

Fig. 5 AC Supply Waveform

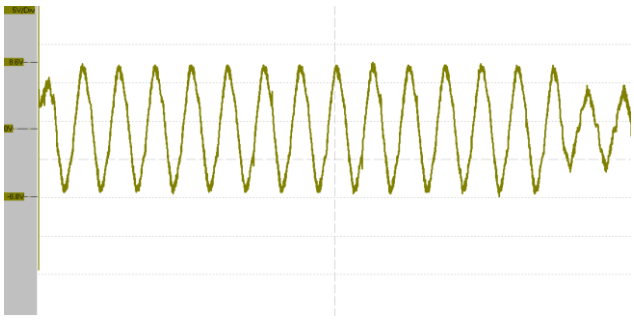

Fig. 6 Stress applied to Piezoelectric Generator

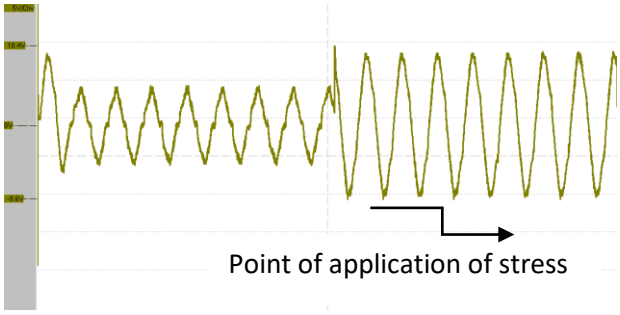

Fig. 7 Point of application of Stress to Piezoelectric Generator

IX. CONCLUSION

Thus the output power generated from both the modules is purely variable and cannot be estimated accurately. This is because the piezoelectric output depends completely on the number of vehicles passing by and the weight of these vehicles. Similarly output of the thermo electric generator also depends on the climatic conditions.

The Expected output from the Thermo electric Generator is about an approximate of 18 kW/hr. The Piezoelectric Generator consisting of piezoelectric plates that can generate a minimum of (5-10) V for every strike. This module will be excited less than two times for small vehicles considering the stationary inertia of the gear mechanism while it can be exited more than twice for heavy vehicles as the torque produced due to their weight and speed. Also the busy roadways like bridges and highways have a continuous pass by of vehicles which provides the advantage of rotating inertia acting as the prebiasing force for the model. Thus for about 5000 vehicles passing by a road we can expect about 15000 strikes and more on the piezoelectric plates which could give a output of (75 – 150) kW/hr. Thus an overall output of (85 – 160) kW/hr can be obtained from single module. The only concern in this module is providing proper insulation to the model to prevent the direct mechanical damage caused by the striking of wipers. If this is properly done to get a long life time then this is one among the best alternative resource that can provide greater cost efficiency.

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