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Harvesting Energy through Road

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Abstract – *Harvesting energy through road is an approach for generating power by using Green Technologies. These green technologies include: thermo-electric generator with piping system, piezo-electric method & photovoltaic noise barrier system. The main objective is to reduce the carbon emissions & protect the environment. This report documents the theoretical study of the above mentioned three systems for a certain length of road. The study extends from basic principle to the payback period calculation of each green technologies.*

Key Words: **Green energy, thermoelectric generator, piezoelectric material, P.V sound barriers, harvesting energy.**

1. INTRODUCTION

"Investing in green technology is an investment done for our future"

Investing in green technologies is beneficial because of the fact that conventional sources of fuel is limited to generations. Green technology helps to achieve sustainability in energy management. Thermo-electric generator with piping system works on the heat absorbed by the pavements. The piezo-electric system works on the principle of generating electricity by converting vibrations created by vehicles to electricity, while PVNB system rests its base on harnessing power from sunlight for generating electricity.

2. PROBLEM DEFINITION

Large amount of electricity is consumed by street lights, hoarding and other loads at high cost generated through conventional means. This conventional means also create pollution while producing electricity.

Total Street light transmission cost/day = Rs. 89, 39,204.25

Total cost of electricity/day= 19, 89, 39,336 Rs.

Thermoelectric generator with piping system

Green energy harvesting aims to supply electricity to street light systems from one or different energy sources present in the environment without grid connection. These energy sources is thermal energy (thermoelectricity). The thermoelectric energy harvesting technology converted into electrical energy. This system works on seebeck effect, the electricity generated is directly proportional to the temperature difference of hot side and cold side. The daily working time of this system is around 6 to 7 hour per day. The stored energy could then be used for supporting nearby facilities for electricity and for heating of water during winter time.

DESIGN FOR 5 KM OF HIGHWAY

Hot water storage tank

It involves storing water in it which further supplied heat to the semiconductor which is used to convert it into to electricity. The material of this tank selected is copper along with anti-oxidant layer in order to prevent corrosion

-Thermal conductivity = 385 watt/mk

This water tank build is insulated in order to prevent the liberation of heat from the water tank which also help to maintain constant temperature at hot side. The material used for insulation of hot side of TEG is ceramic

-High insulation capacity [It can insulate heat up to 1800^0 c].

Pump

The water is to be pumped through pipeline which is circulated in the close loop from pipes to the water tank.

-Flow rate = 500 to 2000 litre/hour

Copper pipe

It basically consist of the pipes that are arranged in zigzag pattern.

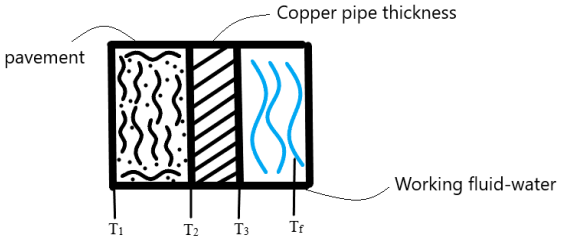
For flow rate of 20 litre/min

Inside diameter of pipe is given by $D = \sqrt{Q_w} / 3600v \times 4 / \pi$

Velocity = 0.2 m/s

Pipe inside diameter = 46.07 mm

Heat transfer through pavement



Here, T_1 = Temperature of base layer of pavement = 60^0 c

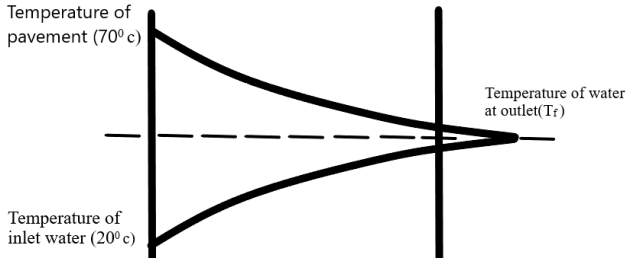
T_2 = Temperature at outer layer of copper pipe

T_3 = Temperature at inner layer of copper pipe

T_f = Temperature of water at outlet pipe

Through heat transfer equation,

Heat flow rate [Q] = 108.14 Watt



$T_2 = 69.93^0$ C

$T_3 = 69.92^0$c

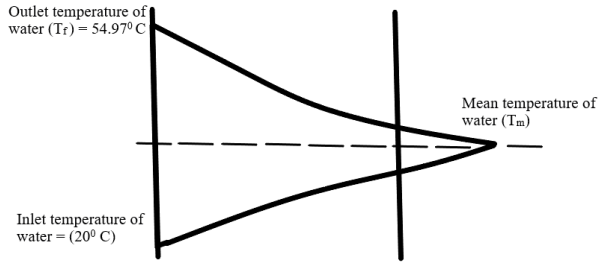
$T_f = 54.97^0$ C

Length of pipe (L) = 70 m .....(NTU = U × A/ C)

Where, NTU= no. of transfer units

C = heat capacity of water
U = overall heat transfer coefficient of water

A= surface area of pipe



Heat flow rate throughout the system is same. – (neglecting heat losses)

$m \times Cp \times (T_f - T_m) = m \times Cp \times (T_m - T_n)$

$T_m = 37.48^0$ C

Semiconductor

The semiconductor material used is Bismuth telluride in thermoelectric generator Bismuth telluride is a narrow-gap layered semiconductor with a trigonal unit cell.

The system is designed in order to produce 85.71 watts per minute

So, No. of module is given by (n),

8/ (n) = 3/85.72

n = 228.58 units

n = 230 units

Cooling tank

It is the component attached to the cooling side of the semiconductor cell.

-It does not corrode much with water underneath the road (0.2 micron per year)

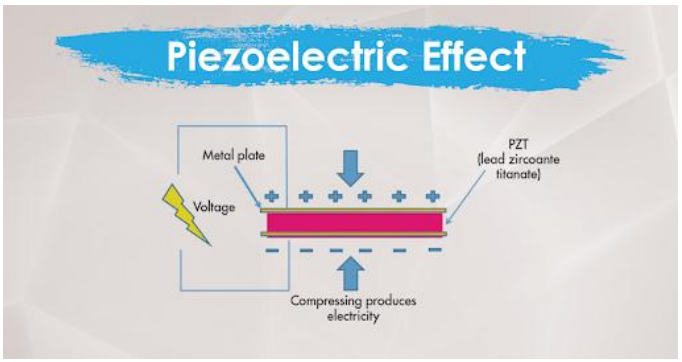
Battery

The battery selected for storing the electricity is lead acid battery. (30kW)

-High power rate
-Maintenance free design

Piezoelectric material for power generation

PIEZO ELECTRIC PRINCIPLE:



Principle is based on basic crystal lattice. Certain crystalline structures have a charge balance with negative and positive polarization, which neutralize along the imaginary polar axis. When this charge balance is perturbed with external stress onto the crystal mesh, the energy is transferred by electric charge carriers creating a current in the crystal. In order to attain the piezoelectric effect, the polycrystalline is heated to the Curie point along with strong electric field. The heat allows the molecules to move more freely and the electric field forces the dipoles to rearrange in accordance with the external field. As a result, the material possesses piezoelectric effect: a voltage of the same polarity as of the poling voltage appears between electrodes when the material is compressed; and opposite polarity appears when stretched.

SELECTION OF PIEZO MATERIALS:

Basically piezo material selection depends on various parameters:

1. Stress as input
2. The strain coefficient gives the relationship between the applied stress and the electric induction
3. The voltage constant gives the voltage Equation
4. The coupling factor which determines efficiency of combining piezoelectric material properties with it mechanical and electrical properties
5. Young modulus that defines the robustness and toughness
6. Dielectric permittivity.

Thus, all this parameters are crucial in designing in piezoelectric system that makes material selection factor critical.

We have selected Lead zicronate titanate(PZT-5h) as it has the highest power density, also cost effective, and has high product of strain coefficient and voltage constant.

1. Piezo Sensing Unit:

This composes of 4 main parts i.e.., piezo tile, electrode sheets, stainless steel gaskets, and electronic silica gel.

2. Rectifier Circuit:

Usually, in real-world application of vibration power harvesting, a rectifier circuit is necessary to convert AC to DC in order to charge a battery or to feed directly an electronic device. A very simple and common non-controlled rectifier circuit is the full-wave rectifier with Diode Bridge.

3. Charge Storing Element (Batteries):

To store the charge output from the system, rechargeable batteries are required. Also capacitors can be used but for temporary run. Rechargeable batteries can avail the charge whenever required for different applications. Here the battery selected is Lead Acid.

4. Inverter:

A inverter is required to use the stored charge of batteries into street lights, traffic signal systems and other highway road accessories as this devices consumes ac load. Here the capacity of inverter is 80kwh as per power generation rate.

5. Microcontroller:

A LCD is interfaced to tile using PLC Microcontroller to display the power generation across the piezo tile. This in turn gives us efficiency of systems, rectifier's circuit losses, and other circuit loses if associated as per application.

Power generation analysis for 1 km of strech

Here, considering a distance of 1Km and a double lane highway of width 7m. (Width of highway is taken as per Indian national highway standards)

Average speed of vehicles on NH = 100kmph

As per the dimensions of piezo tile and dimensions of sensing unit and spacing defined,

No. of sensing units accommodating in stretch of 1Km = 3500

Between consecutive units appropriate spacing is provided for sake of efficiency of system and life of pavements.

Now power generated /piezo /vehicle /hr = 0.137 watts (obtained from real-time software matlab-simulink)

So power generation at peak time and off peak times at various traffic flow rate is calculated below:

Time	Traffic flow	Generation (kwh)	Average (kwh)
Peak Time	400	191.8	165.
	300	183.024	
	200	122.02	
Off peak time	25	15.25	26.42
	50	30.51	
	70	33.5	

Now, average of peak and off peak time = 96kwh

Rectifier losses:

A bridge rectifier has efficiency of 81.2%

Therefore for losses, efficiency = ac input / dc output

0.812 = 96/ dc output

Dc output = 77.95kwh

Losses = ac input – dc output

= 96-77.95

= 18.05kwh

Now considering the 1-1.2% losses of inverter,

The final power generation = 75kwh

When the vehicles at speed of 80, 100, 120 Kmph speed travels through this pavement having piezo unit, it creates vibration and stresses are applied to piezo tiles. Mechanical stresses applied on piezo material by vehicles through metal packaging, forces the electric charge within the crystal of piezo out of balance. Excess negative and positive charge appear on opposite side of crystal face of piezo material.

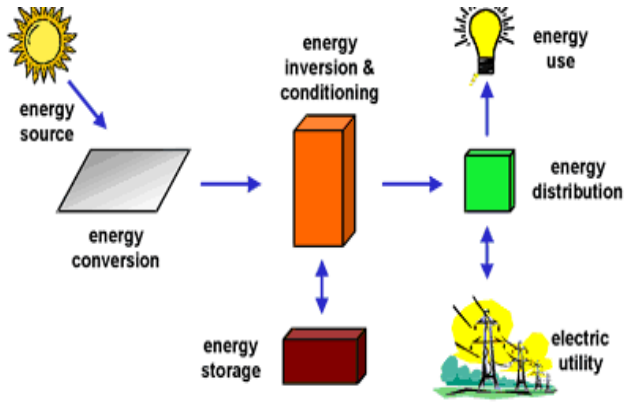
This charge is collected through electro plates which is used to generate voltage. As here, the output is alternating current in nature, it requires an AC-DC rectifier. Thus this output is connected to bridge type full wave rectifier. This rectifier circuit is associated with capacitors to eliminate the ripples

considerably. This DC voltage is then stored to rechargeable lead acid batteries for further use in street lights and traffic signals. As pavement accessories requires ac load thus an inverter is used to use this stored charge in battery. And LCD is interfaced to piezo sensing units using microcontroller to display the power generation.

PV Sound Barrier system

For The construction of PV sound barrier the first and foremost thing needed is the sound barrier which are placed alongside the roads or railroads or any place. The second thing needed is the solar panel itself. After the solar panel Converter, a storage and control unit is needed.

When the sun light strikes on the solar panel the electron start to move and electricity is generated. This electricity produced is in the form of alternate current thus this alternate current is passed through an inverter which converts the alternate current to direct current. The electricity converted east then passed to be stored in the batteries. Restore electricity is supply to the control unit which direction the flow of the electricity to the load or back to the battery.



DESIGN FOR 5 KM OF HIGHWAY

SOLAR PANEL:-
The term solar panel is used colloquially for a photo-voltaic (PV) module. A PV module is an assembly of photo-voltaic cells mounted in a framework for installation. Photo-voltaic cells use sunlight as a source of energy and generate direct current electricity. A collection of PV modules is called a PV Panel

Solar panels are of two types:-

- Polycrystalline
- Mono-crystalline

Polycrystalline:-
Polycrystalline or Multi-crystalline solar panels are solar panels that consist of several crystals of silicon in a single PV cell. Several fragments of silicon are melted together to form the wafers of polycrystalline solar panels.

Mono-crystalline:-
A mono-crystalline solar panel is a solar panel comprising mono-crystalline solar cells. These cells are made from a cylindrical silicon ingot grown from a single crystal of silicon of high purity in the same way as a semiconductor.

	Mono-crystalline solar panels	Polycrystalline solar panels
Cost	More expensive	Less expensive
Efficiency	More efficient	Less efficient
Aesthetics	Solar cells are a black hue	Solar cells have a bluish hue
Longevity	25+ years	25+ years

For the application of our interest, mono-crystalline solar panel are the best to be used.

Specifications of the solar panel used:-

- Wattage (Wp):- 180W
- Operating voltage:- 12V
- Voltage at max power:-19.95V
- Current at max power:-9.03amps
- Open circuit voltage:-23.26V
- Short circuit current:-9.31amps
- Number of cells= 36
- Height=4.8 feet
- Width=2.2 feet

POWER GENERATION IN 1 DAY = 3*440*0.2 = 264W=0.264KW
Where, 3= power generated in 1 minute
440= average total time sunlight is available (in minutes
0.2= efficiency of mono-crystalline solar panel
SOLAR PANELS REQUIRED TO POWER ALL STREETLIGHTS IN 5KM = Power consumption in 1 day/power generation in 1 day =92
POWER GENERATED BY 183 SOLAR PANELS IN 1 DAY
=92*264
=24288W
=24.288KW

Inverter:-
A power inverter, or inverter, is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry.
Factors considered while selecting an inverter:-

- Wave Form Output (Pure or Modified Sine)
- Size of the RV Inverter.
- The Amount of Battery Power.
- Operating Time.

Battery:-
Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather).
The battery selection factors are as follows:-

- Round trip efficiency
- Depth of discharge
- Capacity & power
- Battery life & warranty

Battery calculations:-

- Amp hour=24288/12=4026 Amp hour
- No. Of batteries in battery pack = 2024/200=11
- The batteries are connected in parallel to have constant voltage.

Controlling unit:-
It delivers power from the PV array to system loads and the battery bank. When the battery bank is nearly full, the controller will taper off the charging current to maintain the required voltage to fully charge the battery and keep it topped off.
Factors for selection of solar charge controller:-

- Voltage selection
- Current capacity

There are two types of charge controllers:-
Pulse-width modulation (PWM) :-
PWM types are relatively simple, using a switch between the PV array and the battery. The switch is able to open and close rapidly, thus being able to pulse or "throttle back" the electricity coming from a solar panel in order to taper off the charge current as the batteries become full.

Maximum power point tracking (MPPT):-
They can adjust (or track) the input voltage and current of the PV array to find the optimum operating voltage that will generate the most power at a given moment.
For the application in consideration PWM controlling unit is preferred.

SOUND BARRIER:-
The sound barrier is the backbone of the PVNB system. It is the component which houses the solar panel. Several different materials may be used for sound barriers. These materials can include masonry, earthwork, steel, concrete, wood, plastics, insulating wool, or composites.

(NOTE):- Noise barriers in a PVNB system are either pre-installed or are included in the system. Thus they are not considered in the process of payback period as it depends on the circumstances.

CONCLUSIONS

Every system has its own pros and cons and its implementation is based on the circumstances present and parameter required. Also its construction and efficiency depends on the surroundings of the application area.

The conclusion points for the above research paper are:-

The paper discusses about the theoretical calculation of three energy generating system based on green technology concept for certain distance:-

-Thermo-electric generator with piping system:- 5km
-Piezo-electric system:- 1km
-Photovoltaic sound barrier system (PVNB):- 5km

Piezo-electric system for power generation is comparatively very costly but it also provides consider amount of electricity on the other side of the table too.

Photovoltaic Sound Barrier System and Thermo-electric generator with piping system are cost effective as well as the system can be used to fulfill average load requirement.

The Piezo-electric system has components of high cost compared to the other two systems due to its complex construction parameters.

Duration of sunlight reaching the system puts time constraints on the energy production time for thermo-electric system and PVNB system but the piezo-electric system can produce energy 24*7 depending on the traffic pattern.

The PVNB system is to be installed above ground level exposing it to environment this exposure lets dust and other elements to reduce the efficiency of the system.

Payback period for the system's are :-
Thermo- Piezo- Photovoltaic
Electric < electric < sound barrier
System system system
(6years 33 days) (9 years 154 days) (13 years 259 days)

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