International Journal of Pure and Applied Mathematics
Volume 118 No. 24 2018
ISSN: 1314-3395 (on-line version)
url: http://www.acadpubl.eu/hub/
Special Issue
http://www.acadpubl.eu/hub/

RAILWAY CONDITION MONITORING USING WIRELESS ZIGBEE NODES

Mrs. S. S. Gayathiri[1], Atharva Vitekar[2], Karthik Padmanabhan[3], Bharat Arya[4]
[1]Assistant Professor,[2,3,4]Student,
Department of ECE,
SRM Institute of science and technology,
Chennai, India.

May 23, 2018

Abstract

Indian railways have emerged as the predominant mode of transport for mid to long distance travel. The current system poses a lot of safety threats due to irregular checks and the manual nature of the system. This paper proposes a system of monitoring whereby IR, humidity, temperature and directional sensors are used to ensure track safety. An added novelty is the implementation of well-known energy harvesting methods such as piezo plates and Peltier disks as well as a newer technology called magento levitation energy harvesting. The low cost, manufacturing ease, and suitable implementation make this setup ideal for the Indian Railway system and other similar systems in the vicinity.

***Key Words*:**Piezoelectric effect, Peltier effect, Magneto Levitation energy harvesting, Wireless Sensor Networks

1 Introduction

This paper describes the range of sensing technologies has expanded rapidly, whereas sensor devices have become cheaper. This has led to a rapid expansion in condition monitoring of systems, structures, vehicles, and machinery using sensors. Key factors are the recent advances in networking technologies such as wireless communication and mobile ad hoc networking coupled with the technology to integrate devices.

It can be used for monitoring the railway infrastructure such as bridges, rail tracks, track beds, and track equipment along with vehicle health monitoring such as chassis, bogies, wheels, and wagons. Condition monitoring reduces human inspection requirement through automated monitoring, reduces maintenance through detecting faults before they escalate, and improves safety and reliability. This is vital for the development, upgrading, and expansion of railway networks. Human negligence and human error have become the primary cause for train accidents in India. The expanded development in the railroad area has brought about an expansion in the train activity thickness over the world. This has brought about the expansion in the quantity of mischances including trains. A train accident also occurs due to natural crises. Currently major train accident occurs in Madhya Pradesh at Harda. Second train accident occurs in Mumbai local train overshoots platform at Churchgate. First train accident occurred due to natural crises & human negligence. Second train accident occurred due to human error. To overcome all these limitation we develop new system such as Railway Track Monitoring and Accident Avoidance Using Smart Sensor Network (SSN).

2 LITERATURE REVIEW

The base paper uses a Magnetic Levitation Energy Harvester using their own design, which produces a peak-peak Voltage of 2.3V [1] when the train travels at the rate of 105 km/hr. In this paper, a new Design for a Magnetic Energy Harvester is used along with the use of other alternate Energy Harvesting devices which will use the other forms of inputs to convert into energy, i.e., Peizoelectric Energy Harvesting [2] and Peltier Plate (Thermo Electric Harvestor)

Harvesting [3].

Zigbee nodes [4] are used for the communication of the sensor data to the mainframe (computer in this case) which will further send the information to the concerned personnel.The various railway track signaling systems [5] and event detection and its signal characterization [6] was studied, helping in better understanding of the Indian railway system, on which the prototype has to be implemented.

3 SETUP AND NOVELITY

The system is based upon a basic peripheral interface based upon a Programmable Interface controller. Here, the sensors act as peripherals which collect information and the energy harvesting units collect and store energy in the battery. The novelty here is that energy is harvested through 3 independent mechanisms and one of these is the magneto levitation unit which is relatively new and unused. The circuit is powered by the energy harvested via the 3 methods making it self-sustaining. The system design is given in Figure 1.

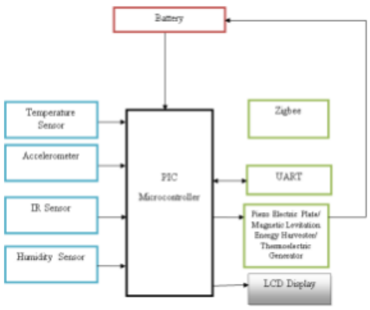

Figure 1 System Design

A. PIC Microcontroller

The architectural decisions are directed at the maximization of speed-to-cost ratio. The PIC instruction set is suited to implementation of fast lookup tables in the program space. It is also cheap which is suitable to our objectives. We used the PIC16F877A as it was easily available in the market and had an appropriate number of peripherals.

B. LCD Display

It is a flat-panel display or other electronic visual display that uses the light-modulating properties of liquid crystals. This is a 7 segment LCD display and we use it in the project to display our own board results.

C. Temperature Sensor

The temperature sensor is a basic device which uses the temperature coefficient and the negative temperature coefficient in order to appropriately identify changes in temperature.

D. Zigbee Module

ZigBee is a wireless networking standard that is aimed at remote control and sensor applications which is suitable for operation in harsh radio environments and in isolated locations. ZigBee technology builds on IEEE standard 802.15.4 which defines the physical and MAC layers.

E. Piezoelectric Plates

A piezoelectric plate is a device that uses the piezoelectric effect to measure pressure, acceleration, strain or force by converting them to an electrical charge. Piezoelectricity is the electricity generated by piezo element by effect called the piezoelectric effect. It is the ability of certain materials to generate an AC (alternating current) voltage when subjected to mechanical stress or vibration, or to vibrate when subjected to an AC voltage, or both.

The calculations for the piezo plates are as follows:-

12 piezo plates were used, a minimum of 1V is required per step and a maximum of 10.5V could be potentially created per step. Here a step acts as a mass (person in this example), applying pressure on the device and creating a subsequent force which through the inverse piezoelectric effect creates electricity. Using a 50kg dummy, it was calculated that 9600 steps would be required for a 1V raise over roughly 80 minutes.

The array of 15 peizoplates were designed in a stack of 2, as shown in the figure 2.

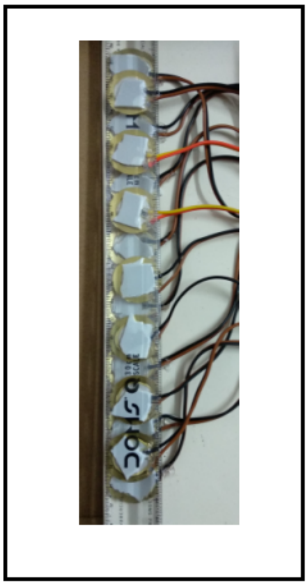

Figure 2 Peizo Electric Plates Setup

F. Thermo Electric Generator(Peltier Plate)

A Peltier cooler can also be used as a thermoelectric generator. When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the two sides. Peltier is interfaced with the circuit such that when it is placed in hot environments, the difference in temperatures on both sides of the plates will induce the emf that is fed back into the circuit.

According to our calculations, with the temperature difference of 338.15 K between the 2 sides causes a potential difference of around 1V. This can be achieved in real time, by using a evaporation based cooling system for one side and the sunlight on the other. We replicated the environment using a Soldering Iron.

The Peltier Plate model TEC1-12706 is used. The performance specification for it are given in Table I.

TABLE I PERFORMANCE SPECIFICATIONS OF TEC1-12706

	Min	Max
Temperature on hot side (Degree Celsius)	25	50
Qmax (Watts)	50	57
Delta Tmax (Degree Celsius)	66	75
Imax (Amperes)	6.4	6.4
Vmax (Volts)	14.4	16.4
Module Resistance (Ohms)	1.98	2.30

G. Magnetic Levitation Energy Harvester

A Magnetic Levitation energy harvester generates energy by the vibrations of the levitating magnet, which develops an emf which results in generation of electricity.

The magneto unit harvests energy through the movement of the tracks. As the track vibrates, the movement is carried over to the levitation unit. Since the position of the magnets are such that like poles face each other, a natural levitating position is established. This position is then altered as energy is transferred to the unit and only the levitating magnet has the freedom to absorb the energy and move as a result. When this movement occurs, the coil wrapped around the shaft of the device gets magnetically excited due to its innate properties as a metal and this causes induction of electro magnetic force. In turn, a current is formed in the coil which can then be used to establish circuitry with the battery and that is how energy is harvested.

Common materials used for magnetic levitation are those containing Neodymium, Iron and Boron in various concentrations. This provides the ideal conditions for appropriate magnetization considering the mass of each of the magnets used in the setup. Unfortunately, logistical issues did not allow this paper to delve into those types of ideal magnets therefore local, commercially available ferromagnets were used.

The chassis of the Magnetic Levitation Energy Harvester was designed using a 3D printer. The initial design was rejected in favor of a more streamlined design that was adopted, as shown in the Figure 3. The rejected chassis is shown in the figure 4.

Figure 3 Magnetic Levitation Energy Harvester (final design)

Figure 4 Initial design of Magnetic Levitation Energy Harvester

H. Universal Asynchronous Transmitter/Reciever

UART stands for Universal Asynchronous Receiver/Transmitter. Its not a communication protocol like SPI and I2C, but a physical circuit in a microcontroller, or a stand-alone IC. A UARTs main purpose is to transmit and receive serial data. One of the best things about UART is that it only uses two wires to transmit data between devices.

4 METHODOLOGY

Virtual Simulation of the circuit using software tools such as MPLAB IDE to check the working of the system and the input and output of various components. Then the components that are required are assembled and tested in real time. The designed system is then implemented and the output is verified. Using the results from the prototype and literature review to calculate the performance in real time scenarios. This is achieved through tabulation and calculations using real world data and the trends produced in the prototype.

Evaluating on the setup and whether it is practical to adopt such a system for Indian or otherwise railways is to be done. Many factors, such as cost, energy generated and components used are studied to make this observation. The flowchart of methodology is given in Figure 5.

As seen in the flow chart, when the train moves over the track, the sensors detect the data and check whether the threshold is broken. If not, there is a change in LCD display. But if there is some issue, it will communicate it to the Zigbee module. This Zigbee Module will communicate with the Zigbee coordinator and relay information to the processing center.

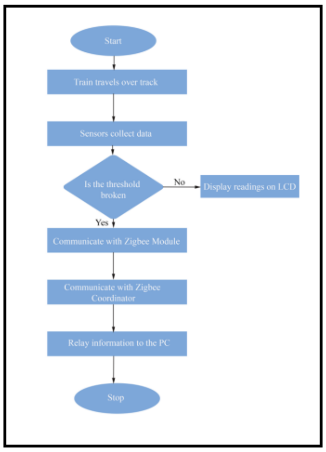

Figure 5 Methodology Flowchart

5 RESULT

The end result is a system which incorporates all the aforementioned components. This has been demonstrated in the picture provided below in Table II. As shown in the figure, the final setup was an incorporation of various methods of energy harvesting and this in turn created a self-powered system. The amount of energy harvested through individual units is shown in the table below (values are subject to conditions present during testing): -

TABLE II RESULT

Method of energy generation	**Applied Stimulus**	**Amount of energy generated in Millivolts (mV)**
Piezo electric plates	50-60 Kg	28-40
Magento Levitation energy harvester	40-80 Vibrations per minute	15-20
Thermoelectric/Peltier plate	603.15-623.15 K	40-100

Testing was done through means of establishing preset conditions and observing the energy generated as a result. Note here that the scope of this paper only tests the functionality of the setup and should therefore not be treated as a final design.

For the piezoplates, the setup shows that several plates were placed under a long beam. Functionality of the unit as a whole was therefore tested by applying pressure to the beam and observing the energy generated across the terminals of the rectifier circuit.

For the peltier plates, heat was applied through means of a soldering iron. This was done in an effort to replicate the heat produced by the sun during peak hours and therefore the output was recorded.

The magneto levitation harvester relies on vibrational kinetic energy transfer. Therefore, manual vibration was provided to observe the limits of the system and these were then noted down.

6 CONCLUSION

The design suggested in the paper was proven to be functional and successful in accomplishing the original goals set forth in the abstract. A setup has been created which can effectively address the lack of safety or energy harvesting in the Indian Railway system. The setup is both cheap, compact and scalable however there are certain pertinent issues with the system which need to be addressed:-

A. The setup relies on parts which are not easy to obtain

The setup provided in this paper relies on certain parts which can only be obtained via means of importing parts. This goes against the principles of sustainable development and also can prove to be a liability if adopted to an industrial scale where equipment is bound to be much pricier.

B. The setup is not industry ready

While several aspects of the design address real life problems, the overall setup is still not an industrial grade design. In order to do this, more extensive work and further engineering would be necessary.

C. The setup does not generate sufficient energy

While the setup maybe adept at generating enough energy to provide power for the sensing unit, it does not harvest enough energy for it be considered commercially viable on a larger scale. The setup needs to satisfy a greater demand of energy and therefore this project falls short in this aspect.

7 FUTURE WORK

Upon viewing the weaknesses of this project provided in the conclusion, certain changes can be implemented in future designs to properly deal with this issues.

A. Create an industrial grade design

The first task would be to create a design which can readily be implemented into real life scenarios. This would require more extensive research and using more robust, quality materials which could ensure effectiveness while operating in real tracks

B. Use alternate deigns for the piezoplate setup

The usage of a plastic beam on top of the piezo setup was a poor decision design wise for several reasons which all revolve around the fact that this provided too much damping. As a result, the piezoplates, which otherwise could have provided a big boost in energy generation, Therefore, a different material for the beam or perhaps an alternative setup.

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