Design and Implementation of the Wideband Tunable PZT Energy Harvester in Power Generation Plant in Malaysia.

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Abstract

This paper discusses on the design of the wideband tunable energy harvesting vibration based system and tested at the Connaught Bridge power station, Malaysia. The systems are divided into 2 main components which are the energy harvester module (piezoelectric) and the power management and conditioning module. In the first component, the energy harvester-generator converted the kinetic energy into electrical energy. A prototype PZT bimorph generator was produced and then installed on an electric motor used to drive the air fan. For the open circuit, the PZT generators produced at maxiumum of 10.4V AC at different resonant frequencies ranged from 47 to 50 Hz. Readings were taken at different places on the motor body; it was found that the optimal power was produced near the bearing of the motor. Simulation results are revealed that the output voltage from power management energy harvesting circuit is 5.0 with output power of 1.96mW. The efficiency was found 74%. The total power losses were 0.678mW. Lastly this design circuits presents a stand-alone system, single supply voltage and compatibility for micro-scale circuit integration.

Key words: vibration-based, energy harvesting, piezoelectric, power management, bimorph generator

Introduction

There has been a significant increase in the research on vibration-based energy harvesting for low power applications in recent years. This is due to smaller electronics applications such as wireless and mobile electronics and the demand for better lifespan of batteries. The applications such as for wireless medical implants and embedded sensors in buildings and similar structures are just a few of many examples. The trends are now to develop micro power generators [1] or even nano power generator that can harvest energy [2]. The mechanical models, general concepts of wideband energy harvester design are based on the vibration control theory [3]. Similar works for the piezoelectric transductions are also given in reference [4] to [6]. One of the useful applications of this device is for condition monitoring using wireless devices. This device can be positioned on a gas turbine in power plant where at a critical vibration pattern it will generate power to activate a wireless sensor to caution for maintenance. Thus, the aim of this proposal is to design of a wideband vibration based energy harvester for condition monitoring sensor in power plant application.

Bimorph design

The generator was designed to work at 40 -60 Hz resonance frequencies. It was decided to make a generator with a combination of four cantilevers, each of which was dedicated to a single particular frequency (different proof mass) to widen the working bandwidth.

The generator consists of a four cantilevers, each cantilevers with a length 25mm, width = 12.7 mm, thickness =0.51 mm, different proof masses and suitable holder was chosen. The proof mass consists of a screw, washers and nuts .Different sizes of washers and nut were used .in order that the generator worked at wide band resonance frequencies by adding or removing washers in order to match the motor resonance frequency . A magnet was used to attach the holder to the vibrating surface.

Different shapes of cantilevers tried were rectangular, trapezoidal and triangular. Although the triangular shapes produced more power than the others due to the features of a constant stress distribution across its length, while the stress distribution for the rectangular beam varies; the triangular shapes suffered ruptures at the tip ends. Taking reliability, durability, and robustness into account, the rectangular shape was finally chosen.

Power management circuit design

Fig.1 shows the power management energy harvesting circuit vibration based system. The harvester device produce an AC voltage and therefore need to be rectified to DC voltage before it is possible to charge the capacitor. The circuit contains AC-DC rectifier circuit, energy storage device, comparator circuit and DC-DC regulator circuit. There are advantages by using this software because in library's contains all the device that are use in this design. The storage capacitor used was 2.2mF. The output from storage device then connected to the comparator circuit. LTC1540 comparator device from Linear Technology is used for the comparator circuit. Meanwhile the LT1934 DC-DC step-down device from Linear Technology was used as to regulate the output voltage from the storage capacitor before connected to the application circuit such as sensor, microcontroller and RF module.

DOI: http://dx.doi.org/10.2314/IWPMA_47

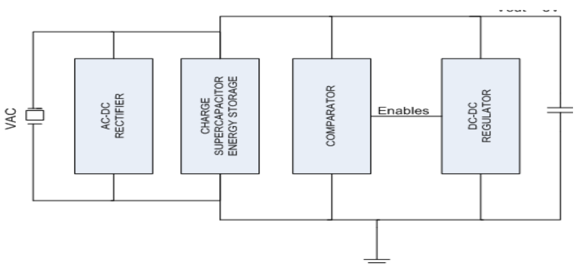

Fig.1: Block diagram proposed power management energy harvesting circuit

Field Testing

The data was collected at the Connaught Bridge power station. The vibration spectrums were obtained for the air-cooled condenser motors at the power station. Tab. 1 shows the specification of the power management circuit of the energy harvester used for the sesnors at the motor fan. The produced power is influenced by many factors such as cantilever dimensions, shape, resonance frequency value and acceleration of the vibrating source. Increasing the frequency band width by implementing more than one cantilever was also investigated.

Meanwhile for the power management energy harvesting circuit and applications systems have a few recommendations to improve and as a further works. The RF module needs to investigate by using wireless sensor network to send data from sensor in a long distance. The RF module has a limitation for data transmission which was maximum 100 meters only. By applying this method the study on wireless data transmission need to consider in term of power, data package, amplifier data and router need to study in depth.

The design can power up 3 sensors, in order to power up more than 3 sensors, the management circuits need to produce more high power. Finally, the overall system of energy harvesting vibration is expected to have lifespan of between 5 to 10 years.

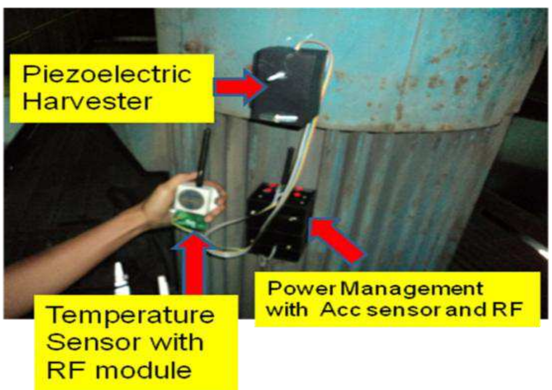

Fig. 2 : Testing at the power plant

Tab.1: Specification of the power management circuit.

Harvester Frequency Range	40 – 60 Hz
Input voltage	5V – 100V AC
Voltage protection clamp	10V DC
Power input	2.618mW (@ 47Hz)
Power output	1.94mW (@ 47Hz)
Efficiency	74%
Power losses	0.678mW
Output Voltage DC-DC	5V (to electronic application circuit)
Operation system	Standalone system (powered by harvester) Single supply voltage Small scale size

Conclusions

The main objective of this work is to design a wideband vibration based energy harvester for wireless condition monitoring sensor in power plant application. The configuration has been tested within a range of frequencies of 0 to 100 Hz. It was found that the power output will increase with the increase of the number of the cantilevers that are used in this design. The experiments showed that power peaks in each configuration is depending on the peak frequency of the cantilevers. The output power of the piezoelectric generator was connected to the AC-DC rectifier of the power management circuit. The power management circuit produce 74% efficiency with the 0.678mW power loses of the input power from piezoelectric generator. The power management operated with the single supply voltage from piezoelectric generator and have an enough power to power up accelerometer sensor and temperature sensor with the RF module. This energy harvesting vibration based system has proved that it can work as self powered system by sending a data capture from sensors and received at the RF receiver module by showing the data at the graphical user interface at the laptop.

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DOI: http://dx.doi.org/10.2314/IWPMA_47