Demo Abstract: Tunable Vibration Energy Harvester

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ABSTRACT

Machinery condition monitoring is an established application for wireless sensor networks and energy harvesting technologies. However, vibration energy harvesters are generally applicable only to fixed-frequency vibration sources, as commercial vibration energy harvesters are highly-tuned to specific frequencies. Attempts have been made to deliver a tunable vibration energy harvester, but up to now none have been applicable to real applications. This demonstrator is a tunable vibration-powered condition monitoring system which is applicable to internal combustion engines that run at variable speeds. It has been deployed and tested on a ferry's diesel engine.

Categories and Subject Descriptors

B.2.m [**Hardware**]: Miscellaneous

General Terms

Design, Measurement

Keywords

energy harvesting, wireless sensing, condition monitoring

1. INTRODUCTION

Vibration energy harvesting is now an established technology. By continuously monitoring the characteristics of machines (e.g. vibration, temperature trends), problems may be identified so that maintenance can be carried out before a breakdown occurs. Vibration energy harvesters may be used to power these monitoring systems, allowing them to both monitor and be powered by the vibration of the machine, and to operate without wires or batteries. They are highly-tuned devices, designed to work with the dominant vibration frequencies that are present on mains-powered machinery (50 or 60 Hz), or a multiple thereof. For this reason, they are suitable for deployment in a limited range of applications, as they are not suitable for internal combustion engines, such as car engines, whose dominant vibration frequency is proportional to their changing RPM, or to variable-speed induction motors. Recent studies have looked at strategies for increasing the range of operating frequencies of vibration energy harvesters [2].

ENSSys'13, November 13 2013, Rome, Italy
ACM 978-1-4503-2432-8/13/11.
http://dx.doi.org/10.1145/2534208.2534226

Figure 1: The test platform: a ro-ro vehicle ferry.

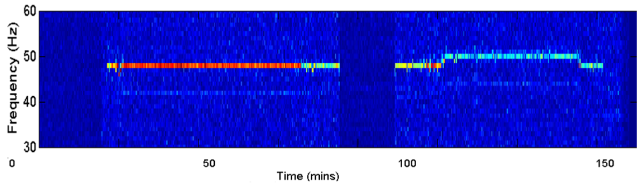

Figure 2: Vibration of engine (red = $1g_{pk}$).

Until this project, a number of tunable vibration energy harvesters had been demonstrated in the lab, but had been designed for hypothetical situations which were not representative of real applications. This project looked at the real vibration characteristics of a range of applications, and targeted a demonstrator system at the vibration of ferry engines. The demonstrator is self-powered, tuning to the varying speed of the engine and powering a sensor node which monitors the temperature and vibration characteristics of the engine, processes the data, and transmits it wirelessly.

2. DETAILS OF THE APPLICATION

The ferry (Fig. 1) has two eight-cylinder four-stroke marine diesel engines. The engines are typically run at approximately 715 or 750 RPM when at sea, and 350 RPM when idling. We designed the system to operate with the higher-

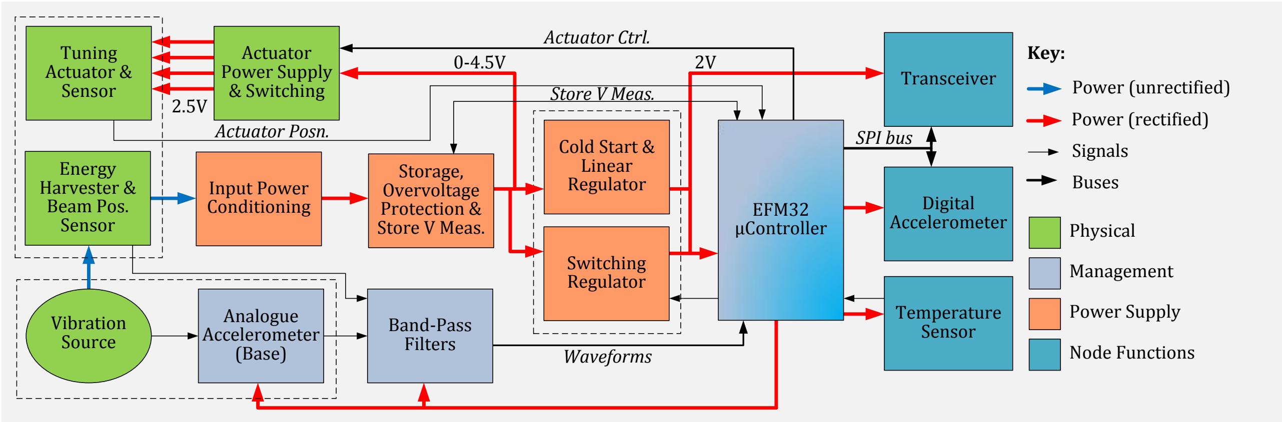

Figure 3: Topology of complete sensor node, incorporating tunable vibration energy harvester.

frequency vibrations, as the vibration amplitudes while idling are negligible in comparison and the additional amount of energy harvested would not compensate for the energy expended in tuning. An example of the operating profile of the engine is shown in Fig. 2. It may be observed that the engine speed is set and remains at the set frequency with some small perturbations. This differs from some other applications, such as car engines, which exhibit rapid and continuous frequency variations.

3. SYSTEM DESIGN

The system was designed to be compatible with the vibration characteristics obtained in the on-ferry testing, plus a margin for drift and nonlinearity. The overall system topology is shown in Fig. 3. The vibration energy harvester is shown in Fig. 4. It is an electromagnetic vibration energy harvester, with additional tuning magnets to adjust its resonant frequency. The distance, d, between the tuning magnets is adjusted autonomously using a stepper motor. Detail about the generator design may be found separately [1].

The overall system is managed by an EFM32 ARM Cortex M3 microcontroller. The generator tuning controller incorporates three sensors: an analogue accelerometer, a beam position sensor, and a linear position sensor to detect the position of the tuning actuator. The outputs from the accelerometer and the beam position sensor are put through identical band-pass filters to exclude frequencies outside the tunable range. The microcontroller runs an efficient zero-crossing detection algorithm to identify the frequency and amplitude of vibrations. The system then identifies whether tuning is necessary and, if so, uses a characteristic equation to translate the frequency to a desired actuator position. The tuning actuator then adjusts the position of the tuning magnet appropriately. The linear position sensor allows the position of the actuator to be determined on cold-start.

The sensor node activities are enabled by a digital accelerometer and analogue temperature sensor. The system periodically takes a series of samples from the accelerometer, computes an FFT, and transmits it using the 868 MHz TI CC2500 radio transceiver. The system is fully autonomous, adapting its activity based on the amount of energy stored. It incorporates a number of power supplies: a linear regulator to reduce the quiescent current draw during sleep, a switching regulator to reduce the active current draw, and a separate switching converter for the stepper motor.

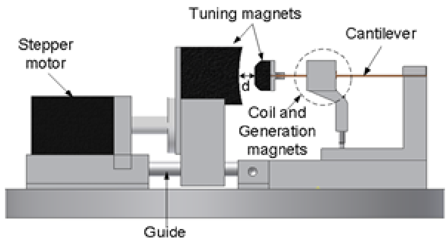

Figure 4: Elevation view of tunable harvester.

4. FUNCTIONALITY OF DEMONSTRATOR

The presented demonstrator is capable of autonomous operation, but is also able to operate in a 'demo mode' which simulates changes in the source vibration frequency and sensor inputs. This causes the tuning actuator to move to 'tune' to various frequencies, and the system to transmit data periodically over its radio link. This functionality is being demonstrated, plus videos of the operation of the system on the ferry in autonomous self-powered mode.

5. ACKNOWLEDGMENTS

The authors would like to thank Red Funnel for allowing access to their ferries for testing. This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) under grant number EP/G067740/1 "Next Generation Energy-Harvesting Electronics: Holistic Approach."

6. REFERENCES

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