# A passively self-tuned torsional vibration energy harvester

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**Abstract**. Rotational speed fluctuations adversely affect rotordynamic applications e.g. powertrains, pumps, and CNC milling machines. Monitoring the behaviour of those systems is critical for maintenance purposes and robust operation. Recent technological advances involve self-powered wireless sensing systems for condition monitoring. An elegant way to power sensing is by using ambient (vibration) energy, which is ample in the above mechanical systems. Vibration energy harvesters are used to harness oscillatory energy to power sensing nodes (comprising sensor(s), power management unit, and wireless communication system) mounted in critical locations. The key in achieving efficient vibration energy harvesting is to design the harvester so that it operates in resonance with the donor system. In this work, a novel electromagnetic vibration energy harvester is presented which utilises pendulum dynamics to achieve resonance conditions within a vast range of operating speeds of the shaft.

## Introduction

The sustained growth in modern sensing applications is driven by increasing demands for structure health monitoring, the industry internet of things and assisting technologies. The reduced size and cost of modern sensing units enable them to be mounted in locations that have been previously deemed inaccessible. However, the accelerating trend in the use of sensors often comes with increase in the weight and complexity of the associated wiring loom (e.g. modern mid-size vehicles may have as many as 40 electronic control units [1] and up to 50 kg of cabling [2]). Wireless sensing nodes lead to significant weight savings by eliminating wiring looms with consequent excellent potential for energy savings. Powering these sensors poses a challenge with main disadvantages being the regular servicing and replacement of slip rings and batteries, leading to costly downtimes. Vibration energy harvesters aim to solve this issue by generating power to feed sensors using the otherwise wasted oscillatory energy of rotating shafts (e.g. torsional speed fluctuations). Kim [3] utilised a piezoelectric vibration energy harvester to power a wireless torque sensor. The key issue though is to achieving broadband vibration energy harvesting.

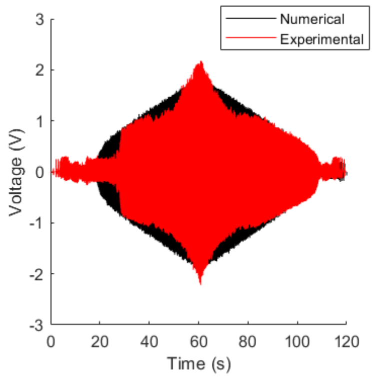


Figure 1: Predicted and measured generated voltage during shaft speed forward and backward manoeuvres.

## Results and discussion

In the present work, an electromagnetic vibration energy harvester is proposed for rotational systems. The harvester's operation is based on pendulum dynamics in order to ensure that resonance conditions are maintained during a large range of rotating shaft speed variation for maximum power generation. The harvester is capable of generating consistently sufficient amounts of energy to power a wireless sensor node (energy amounts higher than $1mW$ are achieved at shaft speeds above 1000 *rpm* with $5mW$ generated at 2000 *rpm* and above). A numerical model of the energy harvester has been developed and used to optimise key design parameters, such as inertia, damping and harvester's dimensions. A physical prototype of the energy harvester has been built and tested in the laboratory attached on a rotating shaft. Figure 1 depicts the numerical model predictions against experimentally measured generated voltage during accelerating shaft speed (up to 2000 rpm) and decelerating manoeuvres.

## References

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