BYE BYE PRIMARY BATTERIES, HELLO ENERGY HARVESTERS

Harvesting vibration energy from the environment and storing it in a capacitor or a rechargeable battery provides a solution for powering devices such as sensors in an Internet-of-Things network. Kinergizer develops state-of-the-art motion energy harvesting solutions that ensure uninterrupted operation of these low-power devices, making primary batteries unnecessary. Predictive maintenance is one of the promising applications.

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Introduction

Over the last couple of years, large steps have been taken in implementing sustainable and green alternatives for energy production. Think of renewable energy solutions such as wind turbines, solar farms, hydropower plants and tidal energy. These technologies are all examples of energy harvesting: extracting a part of the ambient energy and converting it into electrical energy. For instance, in a hydropower plant, part of the kinetic energy of the water is converted into useful electrical energy, while a photovoltaic panel converts a part of the radiant energy of the incident light.

The previous examples are all on the megawatt scale. On the milliwatt scale, however, innovations for green energy can be made as well. These are based on another type of ambient energy that has a lot of undiscovered potential: vibration energy harvesting. Although vibration energy harvesting does not have the same impact in terms of generated electrical power as the examples mentioned above, it can play an instrumental role in the development of key Internet-of-Things (IoT) applications, which will impact everyone on a daily basis.

For example, by implementing vibration energy harvesters, the lifetime of wireless sensor networks in vibration-heavy environments can be greatly extended by eliminating the need of early replacement of their batteries. This saves costs and makes wireless sensor networks a more sustainable solution. But how can a vibration energy harvester enable such a benefit?

AUTHOR'S NOTE

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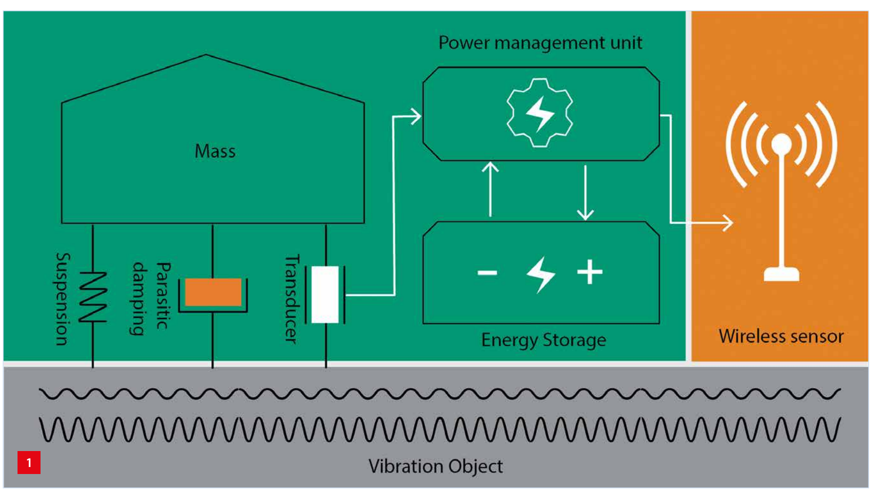


Schematic representation of a vibration energy harvester unit.

Basic working principle

With vibration energy harvesters, a part of the energy present in ambient vibrations is scavenged and transduced into electrical energy. Figure 1 shows the basic working principle of a vibration energy harvester (for confidentiality reasons, no more details can be shared). A vibrating object to which the harvester has been mounted transfers energy to the energy harvester. A mass suspended in the harvester then starts to build up kinetic energy. Part of the energy of the mass is inevitably dissipated into some parasitic damping, which is always present. Another part of the kinetic energy is intentionally extracted from the mass by a transducer. This component transduces the mechanical kinetic energy into electrical energy. The power management unit then makes sure that the energy storage, which can be a supercapacitor or a rechargeable battery, can be charged and that a sensor unit can draw power from it.

Predictive maintenance

An interesting use case for energy harvesting devices is predictive maintenance. No machine will last forever. At a certain point, parts have reached their end of life and failure

Application example of Kinergizer's energy-harvesting solution.
(a) The Hiper-D energy harvester (ø35 mm, 75 mm height, 90 g mass, 1-5 mW power).
(b) Mounted to a train bogie axle box.

of the machine will occur. Of course, nowadays the lifetime of components can be accurately predicted, but a premature failure of components does still happen. The consequences of such failure can be severe and, in some cases, can even endanger lives.

Mitigation of machine failure is therefore of great importance. Several known methods exist, the oldest of which being reactive maintenance: when a part fails, it is replaced. Of course, this does not prevent machine failure and is therefore not very effective. A better version is preventive maintenance. Parts are checked periodically and replaced based on a schedule. Using this maintenance scheme, parts could be replaced too early, increasing waste and costs. Next to that, periodical checks rapidly become expensive due to the involved man hours and potential machine downtime.

This has led to the principle of predictive maintenance: using wireless sensor nodes to track changes in e.g. temperature and vibrations, the health of a machine can be monitored. An accurate prediction of the required service interval can then be made, saving costs and minimising downtime. Advanced sensors do not only determine that a failure is imminent, but can also pinpoint the component that is close to failure.

The sensors used are mainly powered by primary batteries and just like machines, primary batteries do not last forever. Depending on the capacity of the battery, the number of variables to process and the measurement interval, the power consumption of the sensor node can quickly become too large. The batteries are then likely to be depleted before the service life of the component that the sensor is meant to monitor. As a result, the battery must be replaced to continue the monitoring and this is often a costly process. It is important to note that, although batteries might not be expensive, replacing them actually is. The batteries are often placed together with the sensor in a sealed package, making it infeasible to replace the battery only; the entire unit must be replaced. The sensor nodes are also often located at places that are hard to reach, which leads to more downtime of the equipment and more required labour for replacement. Therefore, although batteries are not expensive, the additional factors escalate the operational costs quite rapidly. Taking all this into consideration, predictive maintenance fails to serve its purpose in this way.

Fortunately, this is a problem that can be solved. As vibrations and reduced service life of components often go hand in hand, vibration energy harvesting forms a perfect solution to this issue, by utilising an energy harvester and a rechargeable battery to power the sensor. A good example where this principle can be applied is the railway sector.

Railway sector

Railway transport is deemed to be one of the greenest ways of transport and is on its way to achieving net-zero carbon emission. To make travelling by train appealing to the traveller, train arrival times must be accurate and precise, so the system needs to be reliable with minimum downtime. The high reliability of the train bogies (chassis) plays an important part in achieving that goal.

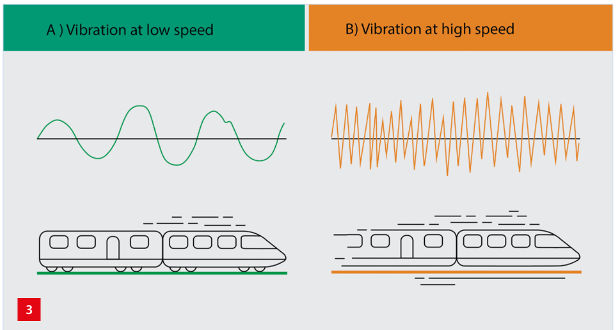
Currently, wireless sensor nodes powered by primary batteries are already being used to monitor the health of the bogie. However, the lifetime of those batteries is a limiting factor to the sensor. Either the power consumption of the sensor must be budgeted, limiting its capabilities, or the sensor's lifetime is only limited to a few years, increasing the operating costs by an imminent need for early sensor replacement.

Kinergizer aims to provide an energy harvester solution that increases the power budget of the mounted sensor while ensuring that the sensor can operate reliably for at least ten years or more. Figure 2 shows an energy harvester mounted to a train bogie axle box.

Train bogies are subject to a harsh vibration environment with large vibration amplitudes. Depending on the speed and other conditions of the train, large variations in amplitude and frequency content can be expected. To guarantee a reliable output power, the energy harvester must not be too dependent on a specific input vibration: it needs to be robust to varying input conditions.

Kinergizer's energy harvester solutions are therefore engineered in such a way that they supply a sufficient amount of power to the sensor for all foreseeable vibration conditions. Figure 3 illustrates this concept: whether the signal's frequency or amplitude is low or high, or whether the signal is wideband, ideally the energy harvester can scavenge a sufficient amount of energy in all cases.

To power a wireless sensor node, energy harvesters need to deliver a fair amount of power, sometimes up to several tens of milliwatts. Size greatly favours the output power, yet is often limited due to geometrical constraints of the application. So, to ensure a high power density, meaning high power from a small volume, components must be tightly packed. The precision of components must therefore be high and must be precisely assembled to prevent moving parts from rubbing against each other. At the same time, those closely-packed moving parts must be resistant to acceleration levels that could exceed several tens of g's and must be able to resist shocks that can exceed 100 g. To ensure that the energy harvesters can deliver power in such an environment, the products are thoroughly lab-tested



Kinergizer's energy harvesters are designed to extract power from a wide variety of input vibrations.

to experimentally validate the shock resistance. Additionally, to meet railway standards, 25 years of service life is simulated in an accelerated life test, in combination with an operational temperature range of –40 °C to +85 °C. In this way, the energy harvester is certified to reliably power the wireless sensor nodes on the train.

The future of wireless sensing is green

Utilising a wireless sensor network brings several merits. The performance of machines and their components or static structures such as bridges can be continuously monitored. This enables the operator to predict service intervals accurately and helps to prevent structural failure of components. The catch is that when a sensor node is installed, it should be an install-and-forget solution. Furthermore, due to the growing market in wireless sensor networks, it is not desirable to make this market a battery-devouring enterprise.

The continuous effort of lowering the power consumption of chips has enabled energy harvesting to become a feasible alternative to primary batteries as a power supply, creating the possibility of having green and sustainable wireless sensor networks. Therefore, we at Kinergizer believe that the future of wireless sensing in vibrating environments is to those who harvest energy.