Energy harvesting IOT sensors: The key to green technology for sustainable transition

openaccessgovernment.org/article/energy-harvesting-iot-sensors-the-key-to-green-technology-for-sustainable-transition/194351

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The Sensor Systems unit at RISE (Research Institutes of Sweden AB) develops advanced technologies that enable energy harvesting from the surrounding environment. Cristina Rusu, Henrik Staaf share some good news from the field!

Using the technologies developed at RISE's Sensor Systems unit, low-grade 'residual' energies, such as motion, heat, and light, are converted into high-value electrical energy. By capturing this 'low-grade' energy that would otherwise go unused from existing energy sources, companies can dramatically extend the battery lifetime of their sensor systems, and in many cases, eliminate the need for battery replacement entirely, as well as drastically reduce the length/ number of power cables.

Sensor systems are becoming increasingly important for monitoring and optimizing machinery and processes in industry. However, powering these systems with batteries or cables is costly and often inefficient, especially in large-scale environments. Energy harvesting makes it possible to use ambient energy to power sensors, which both reduces costs and minimizes environmental impact. The challenge lies in moving from

“macro” energy production and usage, such as wind power, to driving smaller and low-power consumption IoT devices. Today, this is typically supplied by batteries in IoT applications and industrial equipment.

Energy harvesting is all about utilizing the energy already present in the environment. For example, tapping into vibrations or rotations from industrial or construction machinery, or thermal gradients from hot pipes or engines to power sensor systems.

For companies deploying large numbers of sensors in factories or other sites, battery replacement can pose a major challenge if it occurs within the window of production downtime. Installing cables is often impractical and expensive. Energy harvesting offers a solution where sensors can become self-powered for their entire operational lifetime.

A modern work machine is a complex system of interacting components, all of which must be energy efficient. Achieving this requires continuous measurement using sensors, providing the data needed to determine when maintenance or tool replacement is necessary, before equipment becomes worn out.

Energy harvesting already being tested in practice

Sensor Systems unit @RISE is collaborating with HSP Gripen, HIAB, and VOITH in the project “Embedded Control System for Hydraulic and Industrial Equipment” funded by Vinnova and Smarter Electronic Systems program. The project’s focus is to develop and test various energy harvesting technologies for future integration of self-powered sensor systems into their equipment. These solutions and technologies are tested under realistic, real-world conditions at companies in Hudiksvall, Sweden.

Within the project, relevant and effective locations for energy harvesting have been mapped and identified as suitable for implementation. The energy sources originate from hydraulic tools and rotating drivetrains for which various conceptual solutions are being developed enabling harvesting from different energy sources.

Thermoelectric generators (TEGs) utilize temperature differences to generate electricity, making them well-suited for machines that heat up during operation. Piezoelectric materials generate electricity from mechanical stress, which is useful in environments with constant motion or vibration. Electromagnetic harvesters extract energy from magnetic fields in systems such as power lines and rotating equipment.

“Electrification and digitalization go hand in hand, and harvesting energy for sensors is the key to system-level optimization of entire machinery systems. Sweden and RISE are home to some of the world’s leading researchers in this area, and it is incredibly exciting to be at the forefront”, says Paul Bogatir, cluster manager and research coordinator at HHK, Hudiksvall Hydraulics Cluster.

We are the first in the world to achieve exceptional results from field tests on hydraulic machines and rotating drivetrains. This is a groundbreaking project that demonstrates the technology can be deployed in demanding, real-world environments. Test results show

that it is possible to harvest energy from rotational motion, which powers a load sensor while maintaining continuous data communication via Bluetooth at 10 kHz transmission frequency during operation. A supercapacitor is an energy storage device that charges to its maximum capacity during operation. The harvested and stored energy in the supercapacitor is used to enable cold starts of the system. During startup, sufficient energy is provided for a short period to power the system initially, until continuous energy harvesting reaches a level that supports ongoing operation and continued charging of the supercapacitor.

Test results also show it is possible to harvest energy through thermal energy harvesting on a crane in a hydraulic system. At a temperature gradient of approximately 20 °C, enough energy is generated during operation to simultaneously transmit pressure data from the hydraulic system at a frequency of 1 kHz. Energy harvesting occurs continuously from system startup and increases progressively until the working temperature of the hydraulic oil is reached. Energy storage is managed in a battery, which enables cold starts of the system even after extended downtime due to its low self-discharge. When a net energy surplus is achieved, the battery continues to charge to its maximum level during operation and also after operation as the hydraulic oil gradually cools.

In both cases, a net positive energy yield is achieved, which means that the energy source, whether a supercapacitor or battery, does not need to be replaced during the sensor system's lifetime.

The results demonstrate how companies can save both time and money by being able to monitor how their machines and products are used. This provides insights into when service or repairs are required. It is not just about cost savings, but also about creating sustainable systems that require less maintenance.

Future of R&D in energy harvesting

This project provides valuable insights for both industry and research on the requirements for R&D in energy harvesting for industrial applications. It also strengthens research and innovation competencies, fostering investment, knowledge, and advanced digitalization with sustainable technologies for proactive work towards environmental goals.

Energy harvesting technology also aligns with the green transition and circular economy, where companies strive to reduce their ecological footprint. By monitoring products and machinery in real time, companies can extend the lifespan of their assets and reduce the need for new production.

With these advances, the Sensor Systems Group at RISE demonstrates that energy harvesting is not just a vision of the future, but a real, actionable solution for companies looking to reduce their environmental impact and optimize their energy use, starting today.

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