

# Energy harvesting: A Practical Reality for Wireless Sensing

## Fast Forward

- Energy harvesting enables remote sensing at low cost.
- Energy harvesting is the ideal solution for indefinite long-term powering of wireless sensor nodes or networks (WSN) without maintenance.
- Energy-harvesting-powered WSN is possible due to the convergence of new technologies.

By Roy Freeland

There are some very exciting high growth projections for wireless sensing for the Automation industry. More sensors mean more process efficiency, lower operating costs, lower maintenance costs, higher reliability, and greater safety. Wireless sensing provides the opportunity to install masses of sensors with virtually no cost of installation by reducing the need for cables carrying the signals from



the field to the control room. Wiring costs can easily be 80%, or more in a hazardous area, of the total cost of installing a new sensor. Who wouldn't like to get the same job for one-fifth of the cost or five times as many sensors for the budget? And it is not just the cost of the installation; there are many cases where plant has to be shutdown to facilitate installation adding another massive sum to the cost of new sensors.

Most of us routinely use wireless (cell phones, Wi-Fi) for communication, and the potential for machine-to-machine wireless communication is considered to be even larger. Wireless transmission of sensor data is now well established as a reliable method of monitoring industrial plants. It is even being perceived by some users as more reliable and maintenance free than hard wiring.

This whole new approach to Automation has been made possible by the convergence of new technologies:

- Low power electronics including microprocessors with sleep modes
- RF transmission systems that use digitally encoded signals (e.g. digital television and Wi-Fi) with an order of magnitude less power required than older analogue systems
- New energy harvesting techniques

So why is there so much interest in energy harvesting? Simply, you cannot get the full benefit of wireless unless the power source is also wireless. This means either a battery or some form of energy harvester. Until recently, the usual power source available to power a wireless sensor node or network (WSN) has been batteries. With their limited and non-deterministic life span, hazardous content, shipping and disposal requirements, batteries alone are not likely to provide a power source that will last the life cycle of the WSN

application without maintenance intervention. The ideal solution is an energy harvester that is “fit and “forget” and will have a lifespan in excess of the WSN that it is powering.

**What is energy harvesting?** Energy harvesting is the extraction of usable energy (usually converted into electrical energy) from otherwise wasted energy available in the environment. On the macro scale (MegaWatts - MW) this includes hydro-electricity, wave power, solar panels, and wind turbines. However for wireless sensing, we are talking about harvesting immediately available energy such as vibration, heat, light, and RF energy to produce milliWatts - mW.

### Power requirements for WSNs

Whether the power source is an energy harvester or a battery, it is important to minimize power consumption. Much can be done to minimize average power requirement; for example reducing reporting frequency. If a wireless system is being used for machinery condition monitoring, then it is unnecessary to specify the transmission of full vibration spectra every minute, when it is replacing a man on bicycle with a hand-held device who goes around once a month (provided it is not raining and he has nothing more urgent to do). Also parameters can be monitored and analyzed in the WSN, and it can be programmed to transmit alarm signals only when there is a problem.

To illustrate the issues, this article takes the example of a WSN that requires an average power of 3mW to compare various options. This is not untypical of either a frequent reporting requirement (such as several times per minute) or a high data requirement (such as complete vibration spectra).

The following table shows the theoretical life of standard sized cells from a leading Lithium battery manufacturer. In practice, the theoretical capacity is reduced by such factors as the need for intermittent high currents for RF transmission, self-discharge, and low temperatures. Some newer designs perform closer to theoretical capacity and may include energy storage to help with the peak power requirements of WSNs.

| Battery size | Nominal capacity | Life at 3mW (3.6V)  |
|--------------|------------------|---------------------|
| AA           | 2.4 Ah           | Less than 3 months  |
| C            | 8.5 Ah           | Less than 10 months |
| D            | 19 Ah            | Less than 2 years   |

### Energy harvester power

So what are the options for energy harvesters to deliver 3mW? The following are systems available today, and they represent each of the main types of energy source that can be used in practice in many types of plant and other machine applications to provide the required power. Each of these uses a source of energy readily available in many but not all applications. However, with this choice, it should be possible to select a suitable device for the vast majority of applications.

1. **Vibration:** Perpetuum's vibration harvester will produce 3mW from about 40-50mg of vibration depending on the exact frequency. Its bandwidth is important to ensure adequate coverage of a wide range of machines.
2. **Heat:** Micropelt's thermal harvester will produce 3mW from a suitable heat source at about 55C assuming ambient temperature of 25C. The rate of heat transfer is important; installing a probe in a way which impedes convection or heat flux increases the required temperature differential.
3. **Photovoltaic:** G24 Innovations Photovoltaic Dye sensitized thin film photovoltaic require an area of 233mm x 135mm to produce 3mW (typical industrial indoor environment) with a light level of 500 lux.
4. **RF power transmission:** Powercast's RF transmission system will produce 3mW of usable power at a range of 1.2m (4ft) from a 3W transmitter. Multiple transmitters or receivers can produce 3mW at longer range. This system is technically wireless power transmission rather than energy harvesting.

### Power source standards

The ISA100.18 Working Group is preparing standards and information documents on power sources for WSNs. Key objectives are to define specifications for the interchangeability of various power sources, including batteries, energy harvesters, and other possible types, such as 4-20mA loops, and to define performance specifications so users can compare different harvesters and choose the optimum power source for each application. The working group is cooperating with a range of organizations, including VDI and NAMUR on battery standards for WSNs and other organizations using 802.15.4, such as Wireless HART and Zigbee as well as other low power wireless protocols.

### Practical applications

End users who have trialed battery powered WSNs have generally become very enthusiastic about the benefits. However, we are now seeing views being expressed that the power supply issue must be resolved, and changing batteries is not acceptable in most industrial situations. This is not only because of the cost of the work to order, stock, organize, and physically replace batteries but also, particularly in hazardous area and inaccessible areas, there is an understandable reluctance to send maintenance staff into potentially dangerous areas. The major systems builders are, therefore, almost without exception working on offering energy harvesting powered options for their WSNs.

A good example is the GE Bently Nevada wireless condition monitoring system installed as a pilot at Shell's Nyhamna Gas Plant for predictive maintenance. This was a site built in Norway to process natural gas from the Ormen Lange field in the North Sea and pump it across to England. Although it was a greenfield site, it was found the cost of hard wiring was excessive to monitor most of the plant. Therefore a wireless system powered by vibration energy harvesters was used on a number of machines to provide full vibration data from accelerometers to the central data processing system.

Newer installations with the latest vibration energy harvester powered system have been installed in power stations. It is notable that previous experience with the power available from vibration harvesters lead to a decision to use one harvester to power a node with four sensors rather than the previous ratio of 1 to1 for harvesters and sensors. It is a fascinating insight into the business case that it is economical to use vibration energy harvester to produce milliWatts of power in a plant that is producing Megawatts.

Micropelt's thermal harvester is being used to monitor the temperature of power bus bars to identify critical situations. Any rapid rise in temperature will cause an alarm to be transmitted wirelessly to a control room.

National Instruments recently started to offer vibration and photovoltaic solutions to powering their wireless devices.



Temperature monitoring WSN powered by Micropelt's thermal harvester.



BE Bently Nevada vibration energy-harvester-powered wireless sensor node installed for machinery condition monitoring at Shell's Nyhamna Gas plant.

## The future

The benefits of using wireless for automation monitoring and eventually control are so strong that practical solutions for suitable power sources will continue to develop. Energy harvesting has many different forms that have been fully demonstrated to be ideal solutions for indefinite long term powering of WSNs without maintenance. Although the power requirements of some electronics will continue to fall, we are probably getting close to the limit of low power RF transmissions as well as the chemical energy density possible in primary battery cells. The energy available from various energy harvesting techniques in most applications already significantly exceeds the power requirements of existing WSNs. The recent rush to design in energy harvesting options for battery powered WSNs will not only lead to much wider use of energy harvesters but also ensure much wider use of low-cost wireless sensing with all the benefits of increased monitoring for plant safety and efficiency.

### ABOUT THE AUTHOR

**Roy Freeland** ([Roy.freeland@perpetuum.com](mailto:Roy.freeland@perpetuum.com)) is president of Perpetuum Ltd and co-chair of the ISA100.18 Power Sources Working Group. He has wide international experience in running engineering and electronics companies in the U.K., U.S., Sweden, France, and Canada. He was chief executive of United Industries Plc, a British Publicly Quoted Group, and managing director of Meggitt Electronics, as well as holding senior group management positions with Spirent and Spectris.

**How to calculate the power needed?** Typical wireless sensor nodes have a duty cycle with varying power requirements ranging from “sleep” or “quiescent” modes, where little is happening and power consumption may be of the order of 0.1mW or less, to brief bursts of higher consumption when microprocessors are handling and interpreting data with peaks of power of 100mW or more when the RF transmission occurs. The energy harvester does not normally supply the peak level of power continuously but charges up a capacitor, super capacitor, or rechargeable battery to provide the peak-power requirements. The important calculation is, therefore, the average power required over the complete duty cycle, including inactive periods.