Survey of a fusion technology for wireless PEC with energy harvesting in nuclear industry

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1. Introduction

The wireless sensor network has a power-supply problem by constitution. Large amount of sensors are used in wireless networks and each sensor needs energy source for its operation. The life of a battery used in a sensor is finite. When a battery went out, we must exchange it with new one. But the number of sensors used in the wireless network is too numerous, so it is somewhat terrible job to exchange the exhausted batteries with new ones.

Various researches have been executed to solve this problem. The mainstreams of them are energy efficiency and energy harvesting. The protocols such as flat-based routing, hierarchical-based routing, location-based routing and MAC protocol have been developed and applied to sensor networks for energy efficiency. But energy harvesting methods can be a ultimate solution.

Energy harvesting is the process for capturing and storing of energies. A variety of different sources exist for harvesting energy, such as solar power, thermal energy, wind energy, salinity gradients and kinetic energy.

We described an energy harvesting technology and a wireless pulsed eddy currents(PEC) inspection based on it.

2. Energy harvesting

Advanced technical developments have increased the efficiency of devices in capturing trace amounts of energy from the environment and transforming them into electrical energy. In addition, advancements in microprocessor technology have increased power efficiency, effectively reducing power consumption requirements. In combination, these developments have sparked interest in the engineering community to develop more and more applications that utilize energy harvesting for power.

Energy harvesting from a natural source where a remote application is deployed, and where such natural energy source is essentially inexhaustible, is an increasingly attractive alternative to inconvenient wall plugs and costly batteries. This essentially free energy source, when designed and installed properly, is available maintenance-free and is now available throughout the lifetime of the application. Such systems can be more reliable than wall plugs or batteries.

In addition, energy harvesting can be used as an alternative energy source to supplement a primary power source and to enhance the reliability of the overall system and prevent power interruptions.

An energy harvesting system that can be used in the nuclear field requires an energy source such as vibration, heat, micro wave and radioactivity. It requires three other key electronic components, including:

a. An Energy conversion device such as piezoelectric element and nuclear micro battery that can translate the energy into electrical form

b. An energy harvesting module that captures, stores and manages power for the device

c. An End application such as a ZigBee-enable wireless sensor network or control and monitoring devices

3. Plused eddy currents

Conventional eddy current inspection techniques use sinusoidal alternating electrical current of a particular frequency to excite the probe. The pulsed eddy current technique uses a step function voltage to excite the probe. The advantage of using a step function voltage is that it contains a continuum of frequencies. As a result, the electromagnetic response to several different frequencies can be measured with just a single step.

Since the depth of penetration is dependent on the frequency of excitation, information from a range of depths can be obtained all at once. If measurements are made in the time domain, indications produced by flaws or other features near the inspection coil will be seen first and more distant features will be seen later in time.

To improve the strength and ease interpretation of the signal, a reference signal is usually collected, to which all other signals are compared. Flaws, conductivity, and dimensional changes produce a change in the signal and a difference between the reference signal and the measurement signal that is displayed. The distance of the flaw and other features relative to the probe will cause the signal to shift in time. Therefore, time gating techniques can be used to gain information about the depth of a feature of interest[1].

PEC can be effectively used in a piping wall thinning defect inspection part of nuclear power plants. It has not the problem of propagation speed decrease that is derived from a material corrosion. It is far better than ultra sonic inspection to get precise thickness information of a pipe. When we apply ultra sonic technology to a piping wall thinning field, we can identify the thickness of the used pipe is growing as time passes.

4. Wireless PEC with energy harvesting

We describe energy a wireless pulsed eddy currents (PEC) inspection based on energy harvesting.

There are couples of thousand pipes these must be inspected to find out wall thinning defects. It means that thousands of wall thinning defect inspection sensors are needed in terms of the wireless sensor network. In this case, the energy consumption and recharging (or battery exchange) problems will be produced. It is impossible to exchange batteries whenever they went out. Because over-haul period and access to a radioactive area are strictly limited in nuclear power plants. So a wireless PEC inspection will be a good approach. But it is not easy to implement wireless PEC module. There are some problems such as a calibration, power consumption and a jamming. In this paper we will refer to the power consumption.

A piping wall thinning defect inspection has a special character that it doesn't have to be executed frequently. It has a long-term inspection cycle, for example every week or every month, but consumes lots of power for every inspection. It is a key point to implement a wireless PEC inspection for the piping wall thinning defect. The wireless PEC sensor and ad-hoc module may have lots of time to charge the battery. The acquisition data from the PEC sensor have the information for the distance, resistivity and thickness of an insulated pipe. We can extract the thickness information among them. It is possible to find the precise thickness of the insulated pipe using only several data points of the thickness information. This factor gives us great power efficiency in wireless data communication.

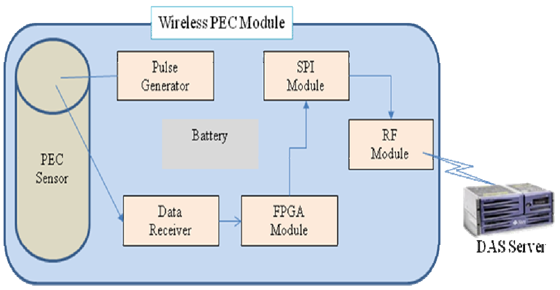

Figure 1. Wireless PEC module

We research two energy harvesting skills, one is using radioactivity the other is using vibration.

There has been a significant increase in the research on vibration-based energy harvesting in recent years. Most research is focused on a particular technology, and it is often difficult to compare widely differing designs and approaches to vibration-based energy harvesting. Estimates of maximum theoretical power density based on a range of commonly occurring vibrations are presented. Estimating range from 0.5 to 100mW/cm^3 for vibrations in the range of 1–10 m/s^2 at 50–350 Hz[2].

An atomic cell is a nuclear-oriented battery. KAERI has executed a research on beta ray based atomic cell. In a Ni-63-PN junction device experiment, we obtained flowing result.

P = Isc x Voc = 0.005 x 7.47E-8 = 0.375nW

It is too little to operate the wireless PEC module. Researches for an intensive and efficient atomic cell may be continued for a couple of years.

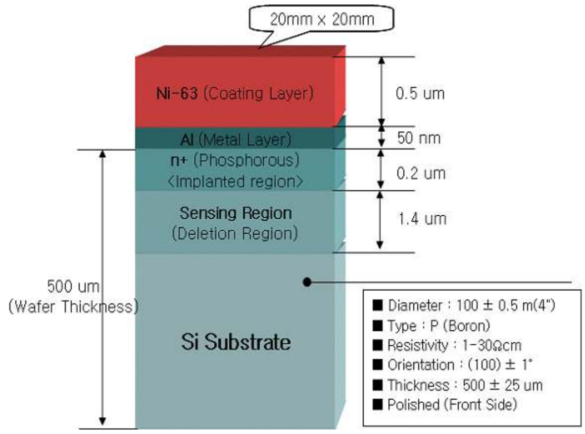

Figure 2. Structure of beta ray based atomic cell

5. Conclusion

We describe a wireless NDT inspection method – a wireless PEC module with energy harvesting. Even though energy harvesting technology is not sufficient, the lack of skill will be fulfilled within a few years. The wireless PEC inspection is a good solution for a piping wall thinning defect inspection.

Acknowledgement

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