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A REVIEW ON SOURCES OF ENERGY HARVESTING FOR EMBEDDED SYSTEMS

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Abstract : As we know that, batteries have been the source of energy for most mobile, and remote system applications. Now, with pervasive computing specification in the fields of wireless sensor networks, embedded systems and low-power, electronics such as Micro Electro Mechanical System (MEMS) devices, a backup source of energies are required. Also with limited range of finite power sources of energy and the demand for delivering energy for an existence of a system, it is a demand for ascetic powered devices. The method of extricating energy from environment is described that energy harvesting. Energy harvesting, which extracted from the water wheel and windmill, is generally mediated as a little maintenance explication for a variety of applications. There are different forms of energy that could be scavenged, like mechanical, thermal, acoustic, solar, wave, and wind. This paper deals as a review for analyzing the sources of energy harvesting based on different technical papers assessable in the internet or Google.

Keywords: Energy Harvesting, Mechanical Vibration, Thermoelectric Generators, Photovoltaic Cells, Piezoelectric Materials

INTRODUCTION

With the large improvements in the field of wireless sensor networks, for a long lifetime, a few desire applications require the sensor nodes to have. Using traditional batteries is not constantly beneficial since they desire human arbitration to replace them. Hence, acquiring the electrical power needed to operate these devices is a major concern. An alternative type of energy source to traditional batteries must be considered. Electrical energy required to run these mechanism can be retrieve by tapping the thermal, light, or mechanical energies available in the atmosphere. This process helps in providing unlimited energy for the lifespan of the electronic device. Therefore, the process of deriving energy from the tendency environment and converting it into consumable electrical energy is known as energy harvesting or power cruise. The forms of typical climate energies are sunlight, RF energy, thermal energy and mechanical energy.

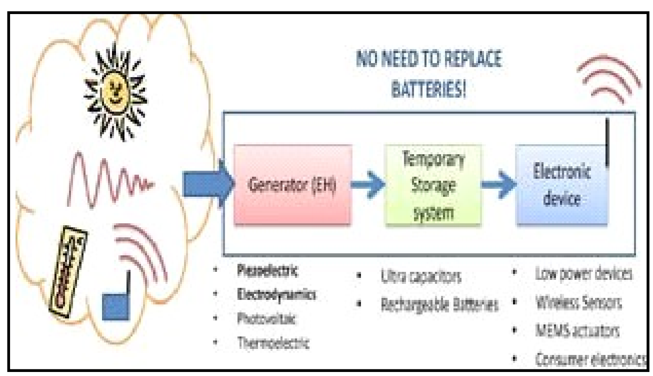

Fig. 1: Energy Harvesting

The energy harvesting sources could be use for increasing the endurance and efficiency of the devices by either replacing or augmenting the life of battery usage. In remote location the devices powered by energy harvesters could be use to give essential information on operational and structural circumstances by placing them. There is an increasingly volume of research carried out on energy harvesting.

This paper is a review of various technical papers on energy harvesting. We determine the distinctive sources of energy available for harvesting.

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Why Energy Harvesting?

We can use energy harvesting to provide electricity from items whose sizes are as small as cell phones or as large as satellites. The primary reasons for which it is used are:

A. Convenience

There is no need for changing or recharging batteries for devices such as laptops or cell phones or other electronic devices.

B. Backup Energy Sources

Such devices can be used as backups for primary power sources. Reliability is increased as a backup energy harvesting source prevents power interruptions. It holds its use in operations such as in hospitals that need energy in emergencies such as blackouts.

C. Mobility

Wireless sensor networks can have mobile nodes that are powered using energy harvesting. It is a useful feature for firefighters, the military, and law enforcement.

D. Business Practices

Energy harvesting helps consumers in cutting down the costs in terms of the packaging, development, disposal, longevity, and reuse of certain products. We can have a reduced cost for Product installation and maintenance. For example, costs would be saved by eliminating chemical batteries and rechargers, along with the extensive wiring required in the use of cell phones. Consequently, it improves their design, development, and packaging.

1.2 Key Components of an Energy Harvesting System

The requirements of an energy harvesting system are an energy source such as vibration, heat, light or air flow and three other key electronic components, including:

1. An energy conversion device that can convert the energy into electrical form such as a piezoelectric element.
2. An energy harvesting module that is a device which captures, stores and handles the power for the device.

1.3 How can Energy Harvesters be used in WSNS?

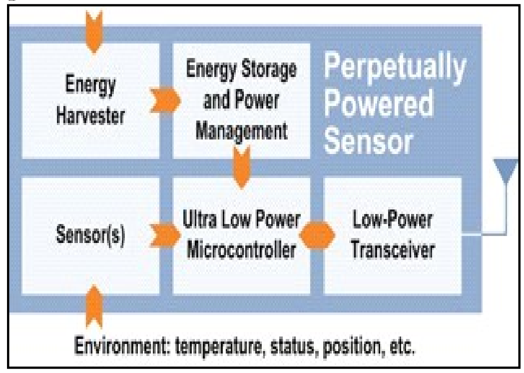

Fig. 2: Anatomy of a Wireless Sensor Network

Fig.2. is a typical system diagram of a WSN, which consists of five major components: the energy harvester, the energy storage element and power management circuitry, sensor, ultra-low power microcontroller, and low-power transceiver. The energy storage element is used to accumulate the energy for usage when the energy harvester is not harvesting energy, for example a solar panel system during the night. The energy storage element needs to be rechargeable. The power management section is of great importance due to three reasons i.e. it connects the harvester to the system, charges the storage element, and provides power to the system. Microcontroller is used to record and process the sensor data. Finally, transceiver transmits the data to the central host.

HARVESTING OF ENERGY SOURCES

The distribution of energy harvesting can be standardized on the basis of the type of energy sources they use to slink of the power. E.g. piezoelectric harvesting apparatus slink mechanical energy & convert it into useful electrical energy. The different sources for energy collection are photovoltaic cells, wind turbines, mechanical vibration and thermoelectric generators devices analogous as electromagnetic devices, piezoelectric device. Table 1 shows different type of the harvesting procedure with their power generation capacity.

Table 1: Energy Harvesting Sources

Harvesting Method	Power Density
Solar Cells	15mW/cm^3
Piezoelectric	330µW/cm^3
Vibration	116µW/cm^3
Thermoelectric	40µW/cm^3

The list introduce electrical properties like as maximum voltage, power density and current; physical properties like as the size, shape and weight; environmental properties analogous as water resistance & operating temperature range; as well as maintenance and operational properties. For improving the lifetime and performance of the system, we need to sufficient care could be taken while using the energy harvesters in the embedded systems.

3.0 MECHANICAL VIBRATION

When an apparatus/device is subjected to an external force or vibration, an inertial mass could be use to create a movement. This movement could be transformed to electrical energy adopting three systems: electromagnetic piezoelectric and electrostatic. This types of energies utilized here is the mechanical energy.

3.1 Piezoelectric Materials

These materials convert mechanical energy from pressure, vibrations or force into electricity. They are capable of generating electrical charge when a mechanical load is applied on them. This property of piezoelectric materials is considered by the researchers to develop various piezoelectric harvesters in order to power different applications.

Due to their inherent ability to detect vibrations, piezoelectric materials have become a viable energy-scavenging source. Currently a wide variety of piezoelectric materials are available and the appropriate choice for sensing, actuating, or harvesting energy depends on their characteristics. Some are naturally occurring materials such as quartz.

Using piezoelectric materials to harvest energy requires a mode of storing the energy generated. This means they can either implement a circuit used to store the energy harvested or a circuit developed to utilize the energy harvested in producing excess energy. The energy harvested can be stored in rechargeable batteries instead of using capacitors to store the energy. The attribute of common capacitors to discharge quickly makes them unsuitable as energy storage devices in computational electronics.

A piezo-generator made of a bridge rectifier and a capacitor to store the energy. This resulted in achieving a maximum efficiency of 35% that is three times that of the energy harvested from a solar cell.

Energy- harvesting device is being developed where a thick film of piezoelectric layer is deposited on to a thin steel beam. When the beam is resonated, the piezoelectric material is deformed and electrical energy is generated. By changing the material used, the magnitude of power generated can be improved.

The piezoelectric generator is used commercially in a wireless light switch. The power generated with the toggling of the switch is used in a transmit-only wireless network node. This node communicates with a receive-only wireless node powered by the mains attached to the light. A study is currently underway to examine generating power by inserting piezoelectric devices within orthopedic implants.

The current piezoelectric energy harvesting research falls into two key areas. One is developing optimal energy harvesting structures and the other is designing electrical circuits that are efficient enough to store the generated charge

As we know that harvesting of energy greatly improved efficiency over existing designs under sinusoidal vibration. This circuit uses a step-down converter and harvested more than four times the power of the same circuit when the converter was not used. More than 70 mW of power was harvested from the new system, which is sufficient to power a wireless sensor network node, even in continuous receive mode.

The properties of piezoelectric materials vary with age, stress and temperature. The possible advantages of using piezoelectric materials are the direct generation of desired voltage since they do not need a separate voltage source and additional components. These generators are compatible with the MEMs. These generators are the simplest and can be used in force and impact-coupled harvesting applications. Some disadvantages are that piezoelectric materials are brittle in nature and sometimes allow the leakage of charge.

3.2 Electrostatic (Capacitive) Energy Harvesting

This type of harvesting is based on the changing capacitance of vibration-dependent varactors. Vibrations separate the plates of an initially charged varactor (variable capacitor), and mechanical energy is converted into electrical energy. Electrostatic generators are mechanical devices that produce electricity by using manual power. The basic operating principle of harvested energy is provided with work done against the electrostatic force between the plates of the capacitor used.

The classification of the electrostatic generators into three types which are: in-plane overlap, in-plane gap closing and out-of-plane gap closing. The various electrostatic generators under the three different types are discussed in several papers.

The significant advantage of using the electrostatic converters is their ability to integrate with microelectronics and they do not need any smart material. One of the disadvantages of using electrostatic converters is that they need an additional voltage source to initially charge the capacitor.

3.3 Electromagnetic Energy Harvesting

Electromagnetic Energy Harvesting can be achieved by the principle of electromagnetic induction. Electromagnetic induction is defined as the process of generating voltage in a conductor by changing the magnetic field around the conductor. One of the most effective ways of producing electromagnetic induction for energy harvesting is with the help of permanent magnets, a coil and a resonating cantilever beam. A vibration-based electromechanical power generator is consisted of a cantilever beam and a pair of magnets.

The techniques employed to generate power from electromagnetic resources. The electromagnetic generators designed have the advantage of being enclosed and can be protected from the outside environment.

Electromagnetic induction provides the advantage of improved reliability and reduced mechanical damping as there would not be any mechanical contact between any parts; also, no separate voltage source is require.

It is concentrated on harvesting energy from magneto strictive materials. These magneto strictive materials are used to build actuators and sensors as they have the capability of converting magnetic energy into kinetic energy. These materials are highly flexible, are suited to high frequency vibration and overcome the limitations of the other vibrational sources. Harvest energy by using magneto astrictive materials and provide power to wireless sensors in Structural Health Monitoring. It is difficult to integrate these materials with MEMs.

The Electrostatic and Piezoelectric harvesters are capable of producing voltage ranging from 2 to 10V, whereas the electromagnetic harvesters have a limitation of producing maximum voltage of 0.1V.The advantage of using mechanical vibrations to harvest energy is that they are the most prevalent energy source available in many environments.

PHOTOVOLTAIC CELLS

A photovoltaic cell is a device that converts light energy into electrical energy. The form of energy exploited is typically light energy obtained usually from sunlight.

For locations where the availability of light is guaranteed and usage of batteries and other means of power supply are not feasible or expensive, usage of photovoltaic cells is a convenient solution. A few examples of such locations are marine locations and roadway signs.

While designing sources which scavenge solar energy, factors such as availability of day light, periods of dense cloud and snow cover, effects of operation at higher latitudes, characteristics of the photovoltaic cell used, the intensity of the incident light, power supply requirements are to be considered.

An array of 100 solar cells is used to produce power to supply MEMs electrostatic actuators. The project could successfully produce voltage of about 150V. Studies on delivering power to a remote system with an optical fiber are discussed. Here, a photocell is used to convert the light energy into electrical power.

The most popular photovoltaic cells are the silicon-based cells. These are more sensitive to light, are easily available and offer a reasonable price to performance ratio.

Current research carried out using photovoltaic cells as energy scavengers includes the Smart Dust Program at the University of California, where the wireless sensor networks employ photovoltaic cells. The dust motes communicate optically instead of via RF communication.

A network of solar energy harvesting sensor nodes called heliomotes is being considered, where each heliomote consists of a solar energy harvesting circuit. This circuit is capable of powering a sensor node, store excess energy in a rechargeable battery and also has the capability of tracking the environmental energy available. A digital interface provides the tracked energy information to the sensor node.

Nowadays, the embedded systems rely on multiple power sources to augment their energy for a longer time. Such multiple power source (MPS) embedded systems harvest energy for the ambient sources such as solar power or by using rechargeable batteries. Therefore, the energy harvested from the ambient source is utilized to power the system and the rechargeable battery. This involves a less efficient way of using the scavenged energy. Hence, larger solar panels must be utilized.

The added advantage of using energy scavenging devices is that they are usually small. For example, there are network nodes which do not use any self-contained energy source; they only scavenge energy from the surroundings. Such nodes can be very small since they do not have to carry their energy with them. However, the supply of energy may be interrupted at a period of time since the power obtained from the surroundings cannot be guaranteed all the time. For example, for the sources which scavenge solar energy, the effect of location and weather of that location play a very important role. Also, the average power available is typically low for energy scavengers.

THERMOELECTRIC GENERATORS

Thermoelectric generators follow the principle of thermoelectricity to produce the required electrical energy. The phenomena of creating electric potential with a temperature difference and vice-versa can be termed as thermoelectricity. Here, the thermal energy is scavenged to obtain electrical energy to power the electronic devices. Thermoelectric devices are primarily used in space and terrestrial applications.

It is a method to generate electrical energy using thermoelectric generators. The temperature difference obtained naturally between the air and soil is used. A seebeck heat pump, which is helps to convert the ambient temperature difference into electrical power source. This temperature gradient is generated by waste heat and solar radiation. These results show that thermoelectric generators produce relatively more power than piezoelectric devices.

Solid-state thermoelectric generators are considered to have long life, low maintenance and high reliability. However, their usage is limited because of their low energy conversion efficiency and high costs. Efforts are being made to introduce new thermoelectric materials to overcome the disadvantage of low energy conversion rates. The thermoelectric devices are desired to operate at high temperatures gradients. We studied that waste heat at low temperature can be utilized with thermo-electric technology to obtain electrical energy.

CONCLUSION

Harvesting energy from the environment is being considered as a viable option to replace the current power supplies for energy constrained embedded systems. The desire to use self-powered devices drives to achieve enormous growth in the field of energy harvesting. With the few limitations such as low amount of power generated using the power harvesters, the researchers are working towards generating new methods. These methods would help in placing the energy harvesters as one of the best sources to power portable devices in the field of wireless technology.

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