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Energy Harvester: Alternative Source for Powering Electronic Devices

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Abstract: Increase in the application of sensor nodes in wireless sensor network, WSN directly demands that energy density of batteries and its capacity be increased. As a result, the financial implication of batteries (as it regards to cost of the battery and its maintenance) increases geometrically. Energy harvester, an optional solution to the energy constraints of batteries, provides ambient energy which is readily and cheaply available. This paper articulates sources of energy harvesting, principles of harvesting energy and different techniques involved in providing alternate sources of energy for sensors and remote low/ultra-low power devices.

Keywords: Energy Harvester, Energy Storage, Wireless Sensor Networks.

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I. INTRODUCTION

The small size of modern electronic devices has partly been contributed by the physical size of the battery. The capacity of the battery also influences the life span of electronic devices. The short lifespan of batteries has been of serious concern as it affects the normal operation of electronic devices especially in WSNs where sensor nodes are expected to undergo 24hours operation. This short fall can be taken care of with the advent of ambient energy harvester. Energy harvester has been defined as a device used in capturing and converting available ambient energy in the environment into usable electrical energy.

According to [1], the concept of energy harvesting (EH) or power harvesting is thus a mechanism of deriving energy from the sources present in the environment. The energy which can be sourced from wind, sun, mechanical vibration, thermal gradient, sound energy, Radio Frequency (RF)/electromagnetic waves as the case may be are raw energy sources to be harnessed. The harnessed energy in electrical form is converted before it is conditioned for stability either for direct use or stored for later use. This provides an alternative source of power for applications in electronic devices such as in wireless sensor nodes deployed in several locations especially in remote areas. According to [5], understanding the operation of energy harvesters demand better knowledge of:

a) The characteristics of the energy source.
b) The way in which energy is transferred from the source to the energy harvester.
c) The electromechanical conversion in the energy harvesting transducer and
d) How the energy is transferred from the energy harvester to the electrical load.

2.0 Sources of Energy and Energy Harvesting

Various sources of energy and their harvesting techniques are shown in table 1 [3, 4]. It is evident that batteries can store energy in the form of chemical energy through electrochemical processes. The amount of energy stored largely depends on the energy density and capacity of the battery.

Table 1: Energy Sources

s/n	Energy source	Examples	Energy Harvester
1.	Natural Energy	wind, water flow, ocean waves, and solar energy	Wind/ mechanical/ photo

			voltaic
2.	Mechanical Energy	Vibrations from machines, human vibrations, mechanical stress, strain from high-pressure motors, manufacturing machines, and waste rotations	Piezo-electric
3.	Thermal Energy	Waste heat energy variations from furnaces, heaters, and friction sources;	Thermo-electric
4.	Light Energy	Indoor source: room light from electric bulb. Outdoor source: from sunlight.	Photo-voltaic
5.	Electro-magnetic Energy	Antennas, inductors, coils, and transformers	RF or Electro-magnetic

Due to continuous charging and discharging operation of batteries, frequent high failure and discharge rates demands constant check up and replacement. This in effect increases the maintenance and operating cost. Also, the release of toxic substances due to battery depletion which is harmful to humans should be treated with care. There are however other usable storage devices apart from such as Micro-fuel cells, capacitors and super capacitors, etc. [2, 3].

3.0 Purpose of Energy Harvester

Below are various reasons why investment in energy harvesters is paramount:

1. The lifespan of batteries used in wireless sensors and embedded devices is limited.
2. With EH frequent rate of replacing battery is minimized.
3. In effect to (2), high cost of maintaining batteries is drastically reduced.
4. Because Energy Harvesters are located close to the source of energy, transmission losses along cables are reduced.
5. Energy Harvesting makes on-site charging of batteries, capacitors and super capacitors possible.
6. Due to (5) life span of sensor nodes are elongated. By this simpler act, sensors work round the clock. Hence, they are said to be battery-independent.
7. EH do not pose any environmental pollution threat or health hazards.
8. It provides continuous energy that can be used directly in devices by providing a backup.

Principles of Energy Harvesting

Figure 1 below explains the principles of Energy Harvesting

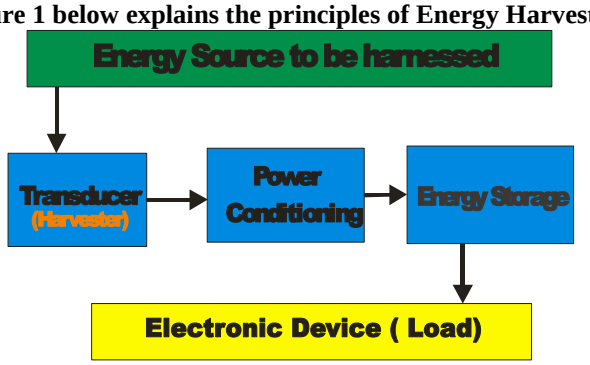

Fig 1.0: Basic Energy Harvester

The Figure clearly shows the components of energy harvester to include: transducer (Harvester), the power conditioning circuit and the storage device.

i) **Transducer:** The Energy Harvester uses the transducer to harness energy from the available energy source. Though this depends on the type of harvester and the converting technique used. Since the output of the transducer which is electrical energy (voltage or current) is intermittent, there is need to stabilize the electrical output. This process is known as conditioning the power from the transducer.

ii) **Power Conditioning Circuit:** A power conditioning (conversion) circuit consists mainly of a passive rectifier and a DC-DC converter whose function is to stabilize the output of the transducer, the passive diode bridge does the energy conversion, while the filter capacitor smoothens (filters) the output current or voltage. The DC-DC converter attached to the conversion circuit improves the efficiency of the rectified voltage output with tolerance of 3V to 5V. In other to minimize energy losses during the process of energy conversion, adequate care must be taken in designing the rectifier. Figure 2 shows the Passive Rectifier circuit with DC-DC converter.

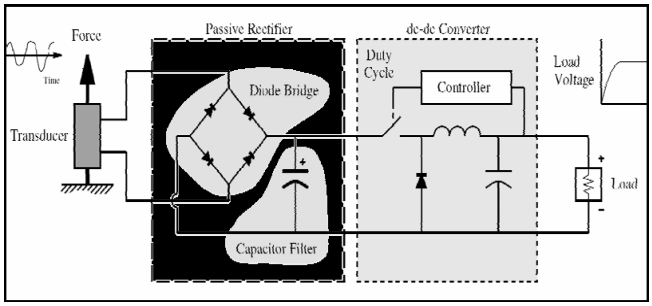

Fig 2.0: Passive Rectifier with DC-DC Converter [1].

iii) **Energy Storage:** This is necessary so that energy can be stored for future use. Devices that can be used for this process include rechargeable batteries, capacitors, and super capacitors.

5.0 Various Types of Energy Harvesters

Various types of energy harvesters include:

- Photovoltaic energy harvester
- Piezoelectric energy harvester
- Thermoelectric energy harvester
- Wind energy harvester
- Electromagnetic/RF harvester

5.1 Photovoltaic Energy Harvester

Photovoltaic devices harness energy from solar radiations (from outdoor or indoor sources) converting them into direct electric current using photovoltaic cells (PVC). Other photovoltaic devices include photo sensors or Photo diode. This type of energy harvester is commonly used in WSNs.

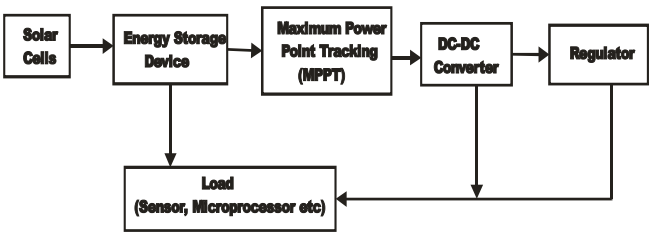

Fig 3.0: Block diagram of solar energy harvesting system for wireless sensor [7].

5.2 Piezoelectric Energy Harvester

A piezoelectric energy harvester converts mechanical vibrations to electrical energy. Piezoelectric energy can be sourced from low-frequency seismic vibrations, acoustic noise, vibration from machinery, human motion. Most piezoelectric electricity sources produce power in milli-watts. This type of energy harvester is suitable for micro-scale devices such as self-winding wrist watches. Common Piezoelectric materials are Quartz, Polycrystalline ceramic, Lead Zirconate Titanate (PZT) [2].

5.3 Thermoelectric Energy Harvester

This uses ambient sun energy to convert temperature differences across the material into equivalent electric voltage/current. Thermoelectric generator (TEG) which is the harvester makes use of the principle of See-back in which voltage is produced by temperature difference at the junction of two dissimilar conductors or semiconductors [6]. It is made up of arrays of thermocouples that are connected to a common source of heat.

5.4Wind Energy Harvester

This energy device uses Micro wind turbines for harvesting wind energy in the form of kinetic energy to electrical energy in powering low powered electronic devices. When air flows across the blades of the turbine, a net pressure difference is developed between the wind speeds above and below the blades. This results in a lift force which rotates the blade in effect producing an energy source.

5.5 RF/ Electromagnetic Energy Harvester

This converts RF energy in form of electromagnetic waves from cellular base stations, satellites, TV and radio broadcasting station into DC energy using matching and rectifier circuit. The effectiveness of the Radio frequency harvester (RFH) circuit is mainly determined by the RF-to-DC conversion efficiency and the DC output voltage. The conversion efficiency of this transducer determined by the effectiveness of the antenna in harnessing RF power, the precision of the matching circuit in converting energy in the chosen frequency range, and the choice of the number of stages and diodes in the multiplier circuit. Figure 3.1 shows the block diagram of an RF energy harvesting system.

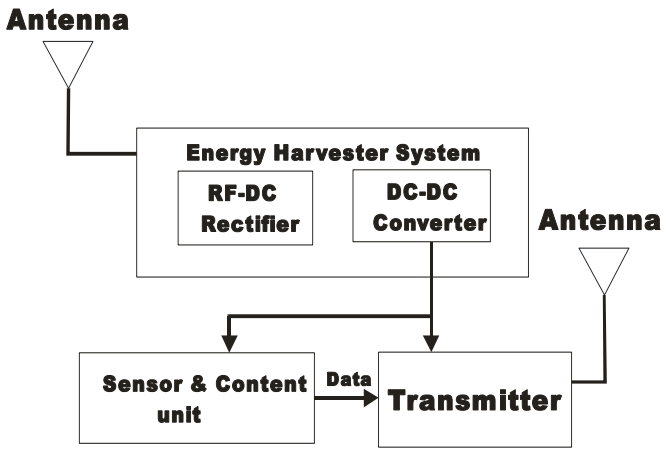

Fig 4.0: RF Energy Harvester

6.0 Application of Energy Harvesting

There are various applications areas of energy harvesting, particularly in wireless sensors which include:

- **Structural Health monitoring**

This facilitates adequate monitoring of structures such as buildings, bridges, aircraft fuselages etc

- **Environmental Monitoring**

Energy harvesters are used in sensor networks for monitoring the environment against natural disasters such as earthquake, flooding, volcano eruption, landslide etc. It can also be useful in tracking of persons, animals and objects.

- **Powering traffic light and signs**

It provides a direct or redundant power needed for display of traffic light/signs and street light every minute of the day especially in remote applications with the use of photovoltaic cells.

- **Health conditioning:** It can be used in biomedical devices for monitoring patients' heart-beat, drug delivery and progress of patients in health recovery. Also, it can be used in implantable, wearable devices and in remote monitoring of patients.
- **Industrial conditioning:** Used in monitoring the operation of machines in industries.
- **Wireless tire pressure sensor:** Here the vibration energy harnessed from mechanical rotation of wheels provides the power for powering devices such as sensors.
- **Pipe line Actuators:** Used in opening and closing of pipeline valves, temperature pressure monitoring and in detection of defects or leakages.
- **Solar powered cellular base station**

Road/rail side traffic signs and monitoring
using solar panels and wind turbines.

- **Powering of Electronic Devices** such as portable calculators, watches, and Bluetooth headsets.
- Asset tracking or radiofrequency identification (RFID)
- Remote corrosion monitoring systems

7.0 Challenges of Energy Harvester

Apart from solar cell, the ultra low power harnessed from other EH has been the major challenge limiting commercialization of EH. Others may include energy losses encountered during energy conversion processes, mismatch in voltage available from a harvester and the regulated system voltage, Vulnerability of RF harvester to eavesdropping attack and many others.

I. CONCLUSION

Harvesting energy from available environmental sources has continued to gain more interest as the need for low powered electronic devices increases. Although the quantity of energy converted by some of these harvesters is significantly low, recent technological advances continues to improve and provide low and ultra-low powered devices where applicable harvesters are needed. With this, energy harvesting has come to stay as an alternative to battery powered devices especially for remote areas.

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