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Design of a High sensitivity fluid energy harvester

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Abstract

A device was design and fabricated to harness kinetic energy of rain droplets and low velocity wind flows to produce electrical energy from a single device. The technique used by the device was based on the principles of electromagnetic induction and cantilever. Readily available materials were characterized and used for the fabrication of cantilever. Under the laboratory conditions, water droplets having diameter 4mm and wind with speed around 0.5m/s were used as the two distinct sources. Without making any changes in the geometry or the materials used, the device was able to convert kinetic energy from both the sources to provide voltage in the range of 0.7-1VAC.

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1. Introduction

Energy sources which are readily available in the immediate surroundings in various forms can be termed as the ambient energy sources. These can be either natural or manmade sources of energy which are available with varying magnitudes. These sources can be in the form of electromagnetic emissions from 50Hz electrical lines and RF communications, indoor and outdoor low velocity (0.1-1m/s) wind flows, seismic vibrations due to passing of vehicles, rain droplets, etc. In all of these sources one thing which is common is that the energies from all such

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sources are available as a by-product of work done by a dynamic system in electrical or mechanical form. Ambient energy harnessing for low power electronic sensors/sensor nodes and instrumentation has attracted many researchers over the past two decades. The potential use of the ambient energy has been always concentrated around making the low power sensor/sensor nodes autonomous for monitoring certain physical parameters at a remote location. Sensor systems may be robust but over a period of time the power supply becomes economically unaffordable. To tackle with this problem, energy harvesting through renewable energy sources is the first step. The device used to harness should be easy and cost efficacious to fabricate through the existing industrial manufacturing processes. Various types of energy harvesters have been proposed by many researchers, out of which piezoelectricity and electromagnetism have gathered most of the attention.

Out of the many reported devices for harnessing ambient energy sources, charging of cell phones and handy cameras were done [1, 2] by converting vibrational energy into electrical energy. Their work was based on harnessing impact energy arising due to shocks generated when the devices were handled. Their energy harnessing device was designed, fabricated and studied using piezoelectric (PZT) material. When their device was used, a small steel ball bounced on the PZT providing electrical energy. They could achieve a maximum efficiency of 35% for converting mechanical into electrical energy for the ball jumping upto a height of 5mm. Ambient energy sources available in nature were also explored by many researchers. A single rain droplet could produce approximately 2μJ to 1mJ of energy [3, 4] during normal to downpour (droplet diameter 3-5mm) of rainfall respectively. Their fabricated device could convert only the kinetic energy of water droplet into electrical energy by using piezoelectric material namely Polyvinylidenefluoride (PVDF). The team was able to recover approximately 1nJ of electrical energy and 1μW of instantaneous power using raindrops. Very few researchers have mimicked the nature for designing their energy harvesting devices. These natural geometries if replicated into energy harvesting devices, can easily convert energy from unsteady fluid flows into electrical power as compare to traditional designs. Out of many researchers who mimicked the natural designs, [5, 6] developed PZT energy harvesting devices based on the geometry of a tree trunk and grass. Their design yielded 1-5μW of power under unsteady wind speed of 1.8-4.3m/s.

On another front there were steady developments in ambient energy harvesters using electromagnetism. Energy was harvested from the air duct flows for powering wireless sensors [7]. The device had a wing integrated on a cantilever with four Neodymium Iron Boron (NdFeB) magnets with a stator coil. The device worked with an airflow speed of 1.5m/s giving an output power of 20μW. Weak and strong air flows from the environment were harvested by using a wind belt based vibratory linear energy scavenger [8] and a Helmholtz resonator based generator. It could produce output voltage of 81mV peak to peak at 0.53 KHz from an air pressure of 50KPa and 4mV peak to peak at 1.4 KHz from an air pressure of 0.2KPa respectively. Wind induced vibration of a stay cable [9] were utilized to generate power which can be used to drive a wireless sensor node. Their fabricated device could generate 233.49mW peak to peak and 27.14mW RMS power output at an input acceleration of 74.8mg. Humdinger wind belt electromagnetic energy harvester [10-15], their patented devices could convert the fluid flows into belt oscillations on which magnets are arranged. Stator coils pickup these flux variations and produce electrical energy.

In all the previously reported devices, limitations like complex designs, very low output voltage, non-functionality to harness other ambient energy sources, etc. has motivated us to provide a unique solution. We conceptualized an idea of harnessing ambient kinetic energies of rain droplets and low velocity (less than 1m/s) wind flows through a single device using only one energy conversion principle (electromagnetic transducer) and a mechanical cantilever. To the best of our knowledge there does not exist, such device which can convert energy from two completely uncorrelated renewable ambient energy sources such as kinetic energy of rain water droplets and ambient winds. The challenge was to develop a device which could harness from both the sources without the need of any alterations in its geometry or the materials used when it is exposed to any of the two ambient energy sources. To harness energy from a low density energy source, a system needs to be sensitive towards changes caused by the low energy transfer between the source and the system. The inspiration to solve this problem came through the real time observation of tree/plant leaf which oscillate when the raindrop hits the leaf or when the wind blows by it. Based on this a device was designed and fabricated using a cantilever made from overhead transparency projector (OHP) sheets on which a copper coil was mounted while a NdFeB magnet was kept below the coil part of the cantilever.

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