CHEW: A Compact Harvesting - Energy Windbelt

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Abstract:

Power consumed by equipment left idle, constitutes a significant portion of total wasted power. In this work, we first build a compact, cost effective and simple power generator that scavenges energy from wind generating equipment such as pedestal fans, air-conditioners, exhaust fans etc. We use this system to detect idle loads and provide a trigger signal for users to take appropriate action. Our system uses a two-step conversion principle, where we use the “Aeroelastic flutter” principle to convert wind energy to vibration. Vibration is then converted to electrical energy using “Electromagnetic induction”. This article provides a step-by-step procedure for construction and working of the compact wind energy harvester. Our article has harvested power measurement results for energy reuse from several domestic appliances.

Key words: Energy scavenging, Wind Belt, Electric Double Layer Capacitors, Accumulate and use, Aeroelastic Flutter, Electromagnetic Induction.

Introduction and Motivation

Harvesting energy from ambient sources to power low power electronics to run several applications has sparked interest and motivated many researchers for more than a decade now. Several hardware and software applications have been developed to efficiently extract the maximum power possible from various sources for perpetual operation of Wireless Sensor Networks (WSN) [1] [2]. For outdoor applications, the abundant solar energy has contributed largely for sustained operation of WSNs. Though weak, other ambient sources have also been used to drive ultra low power electronics. For example, Gaurav et al. [3] have used an accumulate-and-use topology to harvest RF energy from ambient radiations. Several energy harvesting sources have been studied and reported in literature for outdoor applications.

In recent times, scavenging energy from indoor environment has attracted many researchers [4] [5] [6]. The weak and unpredictable availability of energy from indoor sources pose many challenges in harvesting energy and using it for useful purposes. Sources such as ambient light, thermal energy, vibration etc. have been considered for harvesting purposes. In this paper, we consider harvesting energy from wind coming from airconditioners and fans to run our ultra low power electronics.

Cutting down energy wastage in idling equipment by switching off is the next best thing after energy efficiency. Our motivation is to improve power utilization by detecting absence of people in a room and thus provide an alert for a control action. While switching off a running automobile engine during an extended red light at a traffic junction is one example, occupancy detection in a room or building can lead to turning off idling loads such as pedestal fans, airconditioners, televisions and other plugged electrical appliances. We address the problem where users often switch on power consuming loads but fail to turn them off.

Our self-powered wind belt system ``CHEW'', is a technology that works on the principle of aeroelastic flutter. Deformations of elastomechanic bodies in airflow, is the focus of this principle and was first observed in the year 1940 during the failure of the tacoma bridge [7]. This phenomenon also paved the way for researchers [8], [9] to construct windbelts. This simple and compact energy harvester is an add-on to existing equipment. The equipment extracts energy, by their usage, to power a PIR sensor and a communication system. The PIR sensor signals for an appropriate control action to be taken, when there is no human presence in the room.

Construction

Figure. 1 shows our mini windbelt used to harvest the ambient wind and convert it to electrical energy. The platform consists of a sturdy PVC base which houses dual energy trapping units or coils, an elastic belt made of mylar sheet wound around bobbins and screws to adjust the tension in the belt. Two pairs of magnets are placed on either side of the belt; positioned opposite the coils. When subject to airflow, the resulting vibrations in the belt cause electricity generation in the coils due to change in magnetic flux. This electricity is used to drive ultra low power electronics as shown in Fig. 2. The dimensions of our compact model are 7in X 2.1in X 2.75in. It can be easily fixed to airconditioners and fans. The belt is 6 inches in length and can carry magnets of different sizes; based on the application requirement. For example, in indoor applications such as a pedestal fan, we have used 5mm diameter magnets with a 7mm belt width. For lower wind speeds such as an airconditioner, we used a belt of 5mm width and 5mm diameter magnets. For the outdoor

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applications where wind speeds are not consistent, we used 4mm diameter magnets and a belt of 5mm width. These sizes were found to be optimal to harvest energy from flutter.

Application Scenario

The intended application of the system is in offices and homes; where occupants switch on loads such as Fans and airconditioners. The idea here is to automatically detect the absence of people and trigger a wireless communication to a central controller. The sensor used in this application was Pyroelectric effect based passive infrared (PIR) sensor. We used this sensor since its power requirements for continuous operation is roughly 0.3mW.

Figure.2 shows the block diagram electronics designed to harvest power from the mini windbelt. Since each coil produces an AC output, the power is fed through rectifier blocks to convert it to DC and is stored in an ultra-capacitor (storage buffer) which serves as power source for the electronics.

The entire system works on the principle of **accumulate and use**. The power management block waits for sufficient charge to be built on the storage buffer. Once the charge on the storage buffer crosses certain threshold, the power management block boosts the charge and makes it available for the embedded block to function. A PIR based presence sensor is interfaced to the embedded block. The amount of energy required for various blocks to function is as indicated in Tab. 1.

Tab. 1: Use-case Energy Required

Electronic Block	Energy (mJ)
PIR Sensor	0.54
Boost Converter + Embedded Block	2.47

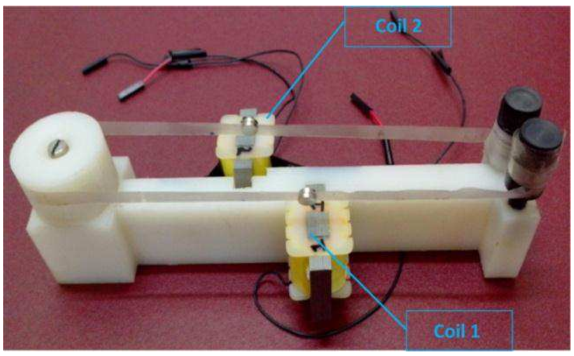

Fig. 1: The Mini Windbelt

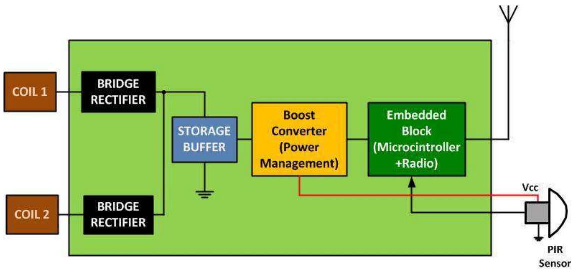

Fig. 2: Wind harvester Electronics

Results

The measured output for coil 2 from the wind harvester is tabulated in Tab 2. We made use of a pedestal fan as the source of wind. A hot wire anemometer was used to measure the wind speed around the area. It was observed that a minimum wind speed of 3.2 m/s was sufficient to continuously charge the capacitor after rectification. For a wind speed of 4 m/s, the airconditioner output was measured as 4 volts peak-to-peak from a single coil.

Tab. 2: Raw Output from harvester

Wind Speed (m/s)	Raw AC output (V peak-to-peak)
4.0	4
3.2	1
2.3	0.4

Table 3 shows the maximum frequency of signal, maximum current obtained from each coil and the inductance of each coil.

Tab. 3: Frequency of Sinusoidal waveform

Coil	Frequency (Hz)	Inductance (mH)	Maximum Current: I_{max} (mA)
Coil 1	114	139.08	1.22
Coil 2	104	136.46	1.08

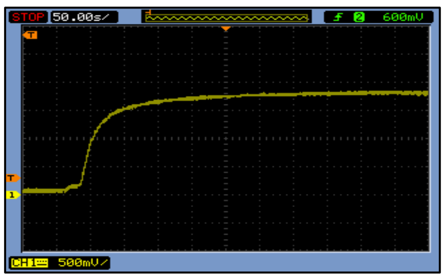

Fig. 3: Charging of a 30mF EDLC capacitor

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Figure 3. shows a snapshot of the 30mF EDLC capacitor charging to its peak. It can be observed that the peak voltage is around 1.75V. Energy E stored in the capacitor can be calculated as

$$E = \frac{1}{2} C V^2 = 45.93mJ$$

Conclusions

In this work we have reported the construction of a mini wind belt based on the aeroelastic principle. This novel design uses two 2 sets of magnets and coils arranged independently over a double belt. Table 4 shows the acquired wind speed at different distances from different sources of wind. We built a device to convert wind energy to electrical energy and successfully made low power electronics function with it.

Tab. 4: Opportunity for harvesting

Source	Wind Speed (m/s)	Distance (m)
Ceiling Fan	3.2	1
Air-Conditioner's Louvers	6.4	0.1

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