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◐ 논문발표목차

풍차구조를 이용한 전자기 에너지 하베스터에 관한 연구

An Electromagnetic Energy Harvester based on Windmill-structure

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Key words : Energy harvesting, Electromagnetic, Windmill-structure, Wireless sensors network (WSN)

1. INTRODUCTION

In recent years, wireless sensors network (WSN) has been regarded as one of the most significant technologies for human beings in 21st century [1]. Numbers of the sensor nodes can sense and transmit the signals among the enormous information network, thereby realizing various functions such as urgency report and fault monitoring. In order to power each sensor in the large WSN, batteries are applied in the current commercial WSN products. Unfortunately, the limited power of batteries in WSN applications will result in a large amount of maintenance cost and mounting constrains [2]. Moreover, it may not be possible to replace a battery in the case of a built-in sensor [3]. Therefore, we propose a windmill-structured electromagnetic energy harvester which can transfer ambient wind energy into unlimited electricity to power the sensors in WSN applications.

2. DESIGN AND FABRICATION

Wind energy is a green, renewable and sufficient energy resource in environment. Both nature wind and airflow due to object motion can be utilized for power generation. Base on this concept, we present an electromagnetic windmill-structured energy harvester. As shown in Fig. 1, a windmill-structure wing is mounted on a frame by an axis. Four magnets are fixed on the end of the windmill-structure wing. At the bottom of the frame, a coil with is installed below the windmill-structure. During working, due to the excitation caused by wind (air flow), the windmill-structure will rotate and as a result, four end-magnets pass near the coils by turns. Therefore, the electricity can be generated by this design, which convert the wind energy into electricity.

In order to test the performance of this design, a prototype of windmill-structured energy harvester is fabricated utilizing a Projet™ HD 3500 Plus Professional 3D printer (3D Systems, Corp, Rock Hill, USA), which can be seen in Fig. 2.

3. EXPERIMENT AND RESULTS

In the performance testing experiment, we design two experiments for device characterization. One is the static device enduring dynamic wind, another is the moving device in static wind environment.

A. Static device in dynamic wind environment

As Fig. 2 shows, the energy harvester is placed in a fixed position. At the same position line, an anemograph is mounted to measure the wind velocity applied to the energy harvester. In order to simulate the nature wind, the wind is generated by an adjustable speed electric fan in front of the device. According to the Beaufort Wind Scale that developed in 1805 by Sir Francis Beaufort, U.K. Royal Navy, the nature wind in daily life is usually below 18 m/s. Therefore, we selected this wind velocity as the maximum input in our experiment.

With various wind velocities, as shown in Fig. 3 (a) and (b), this windmill-structured energy harvester can generate a peak output current of 256 mA and a peak output power of 307 mW.

B. Moving device in static wind environment

It can be seen from Fig.4, this performance characterization is carried out on a driving car. A multimeter is utilized to measure the output voltage. With various driving speed, a maximum output V_{rms} (Root mean square voltage) of 117 mV is achieved at a car's driving speed of 40 km/h.

4. CONCLUSION

In this paper, we have presented the design, fabrication and characterization of an electromagnetic windmill-structured energy harvester which can effectively generate power under wind excitation. A maximum power of 307 mW and a peak current of 256 mA is achieved, which fulfills the requirement of low-power autonomous sensors.

ACKNOWLEDGEMENT

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3. C. Alippi, et al, "An adaptive system for optimal solar energy harvesting in wireless sensor network nodes", IEEE Trans. on Circuits and Syst. **55**, 1742-1750, 2008.

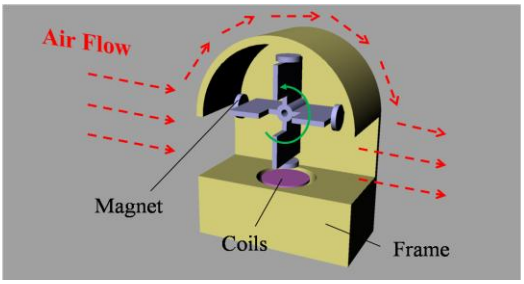

Fig. 1 The schematic of the energy harvester.

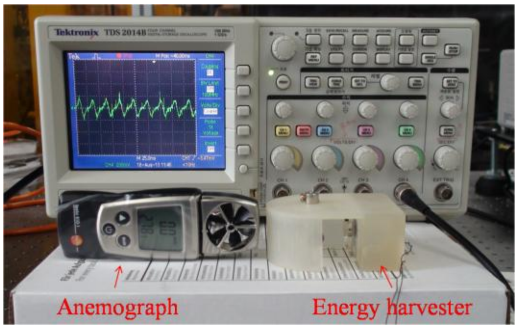

Fig. 2 Performance testing experiment setup of the windmill-structured energy harvester.

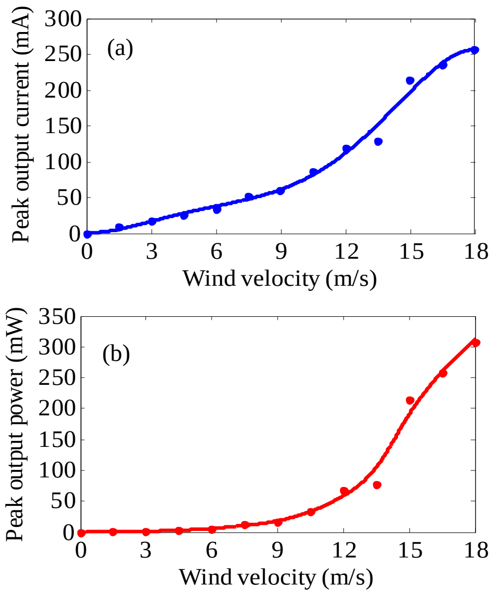

Fig. 3 Performance testing results of the energy harvester: (a) peak output current versus wind velocity (b) peak output power versus wind velocity.

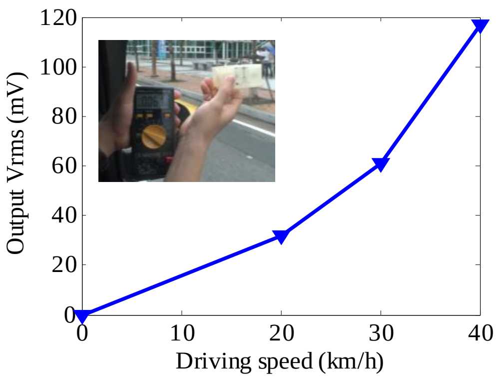

Fig. 4 The output V_{rms} versus car's driving speed.

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An Electromagnetic Energy Harvester based on Windmill-structure

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Presentation Layout

Introduction

❖ Key technology in 21st Century

Wireless Sensor Networks (WSN): To connect the whole world by various large information networks.

Drawbacks: Using battery to power the sensors in WSN; frequent replacement; Installation constrains; high operating cost.

❖ Solution

Energy harvester:

1. Collect the ambient waste energy, possess unlimited power source

2. Instead of battery;

3.No need to replace.

Introduction

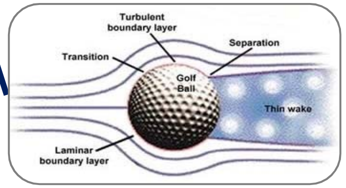
❖ Why wind energy resource

Air flow

Wind Energy

- Sufficient
- Green
- Renewable
- Low cost
- Widely exist
- Mature tech

Nature



Motion

❖ Possible applications

Wind Energy

- Nature: Wind dynamic, object static
- Motion: Wind static, object dynamic

Mass flow meter

Structure monitor

Automotive battery charging

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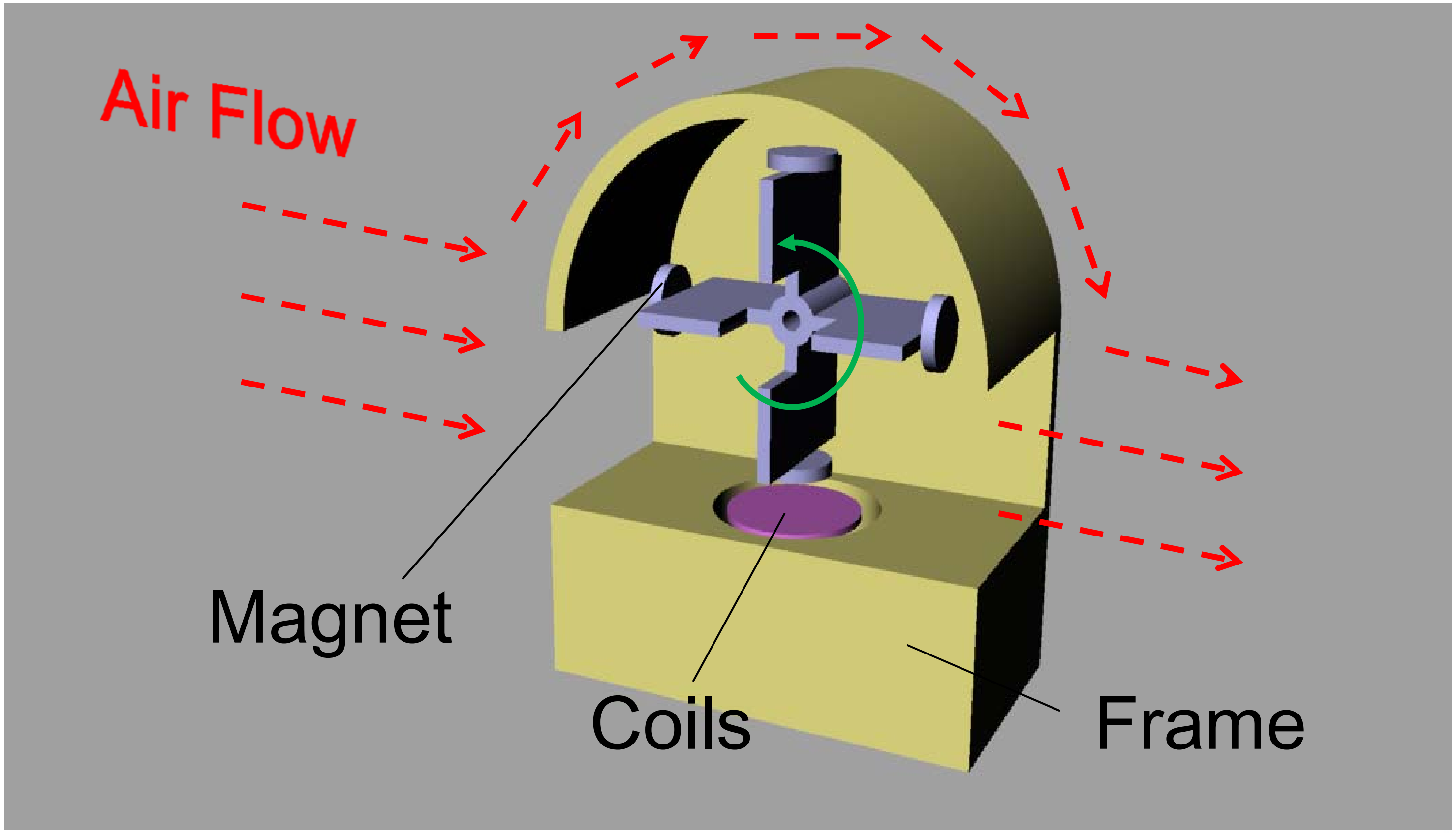
Design concept

❖ ***Windmill structure:***

Collect energy from the airflow



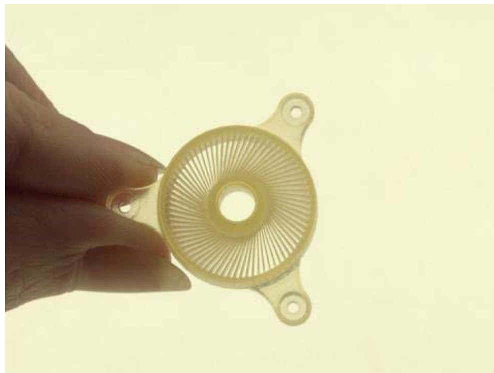
Fabrication

❖ 3D Printing technology:

ProjetTM HD 3500 Plus
Professional 3D printer

Artistic Models

Valve with Internal



Laser Thin Walled

Multi-headed Dragon

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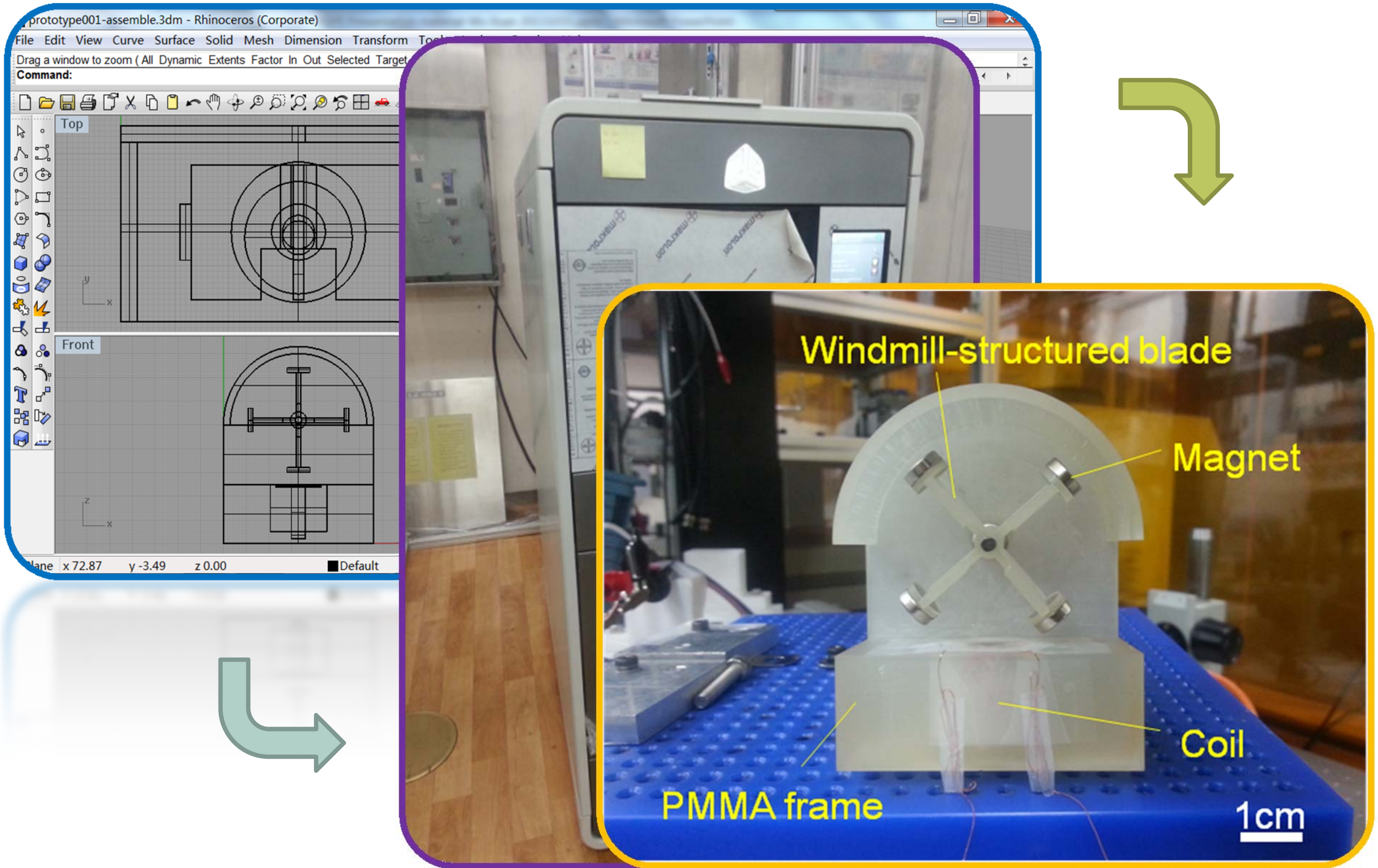
Fabrication

❖ **Prototype fabrication – 3D printing:**



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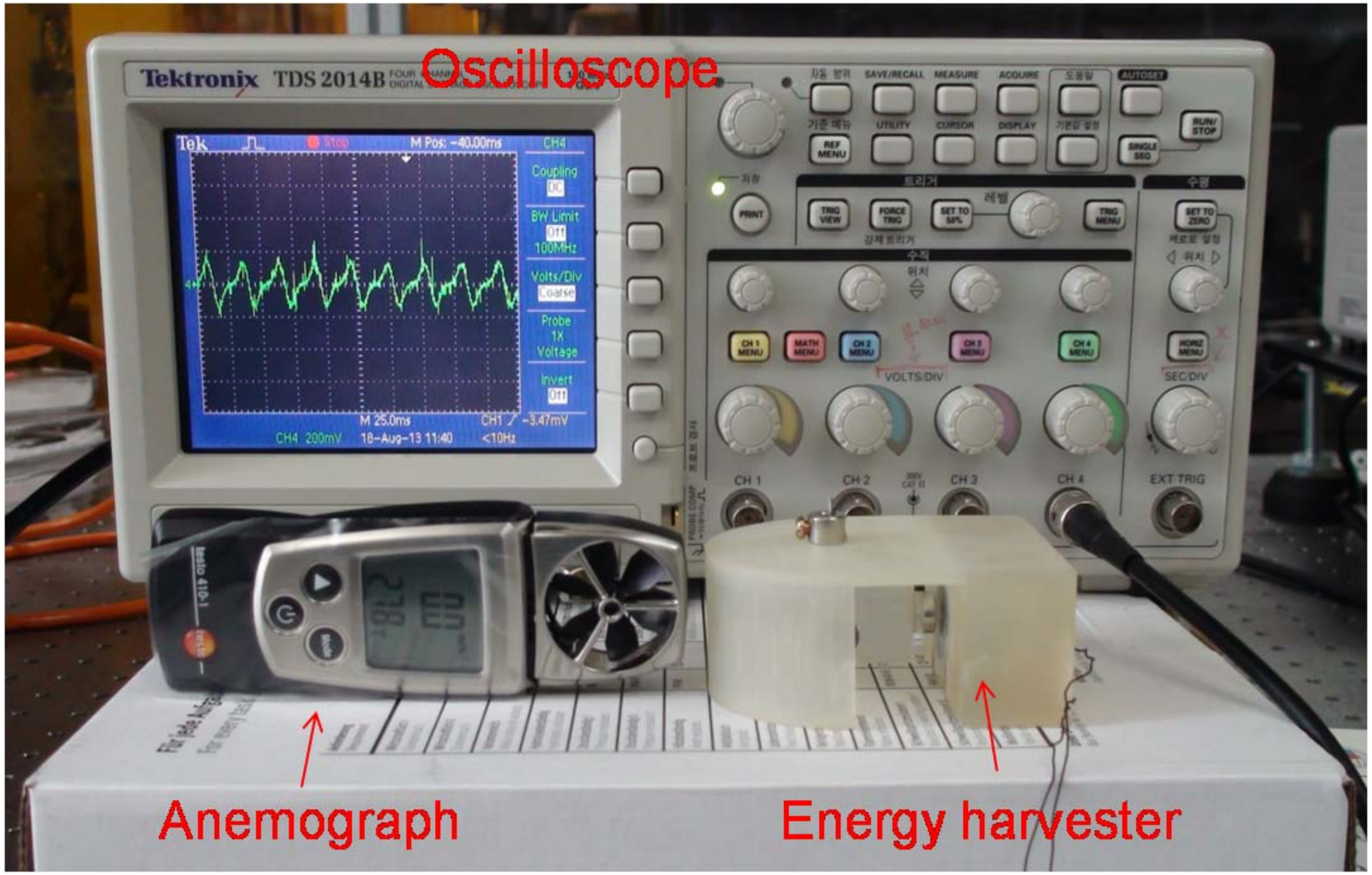
Experiment setup

❖ ***Experiment 1: Dynamic wind, static object***

Various wind velocity: an anemograph is used to measure the velocity of air flow.



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Beaufort Wind Scale

❖ *Beaufort Wind Scale*

Developed in 1805 by Sir Francis Beaufort, U.K. Royal Navy

http://www.appropedia.org/Wind_power

Beaufort No.	Description	Wind speed	Land conditions
0	Calm	<0.3m/s	Calm. Smoke rises vertically.
1	Light air	0.3-1.5m/s	Smoke drift indicates wind direction and wind vanes cease moving.
2	Light breeze	1.6-3.4m/s	Wind felt on exposed skin. Leaves rustle and wind vanes begin to move.
3	Gentle breeze	3.4-5.4m/s	Leaves and small twigs constantly moving, light flags extended.

Beaufort Wind Scale

Beaufort No.	Description	Wind speed	Land conditions
4	Moderate breeze	5.5-7.9m/s	Dust and loose paper raised. Small branches begin to move.
5	Fresh breeze	8.0-10.7m/s	Branches of a moderate size move. Small trees in leaf begin to sway.
6	Strong breeze	10.8-13.8m/s	Large branches in motion. Whistling heard in overhead wires. Umbrella use difficult. Empty plastic garbage cans tip over.
7	High wind, Moderate gale, near gale	13.9-17.1m/s	Whole trees in motion. Effort needed to walk against the wind.

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Beaufort Wind Scale

Beaufort No.	Description	Wind speed	Land conditions
8	Gale, Fresh gale	17.2-20.7m/s	Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded.
Testing range 9	Strong gale	20.8–24.4m/s	Branches break off trees, some small trees blow over. Construction ,temporary signs and barricades blow over.
10	Storm, whole gale	24.5–28.4m/s	Trees are broken off or uprooted, saplings bent and deformed. Poorly attached shingles in poor condition peel off roofs.

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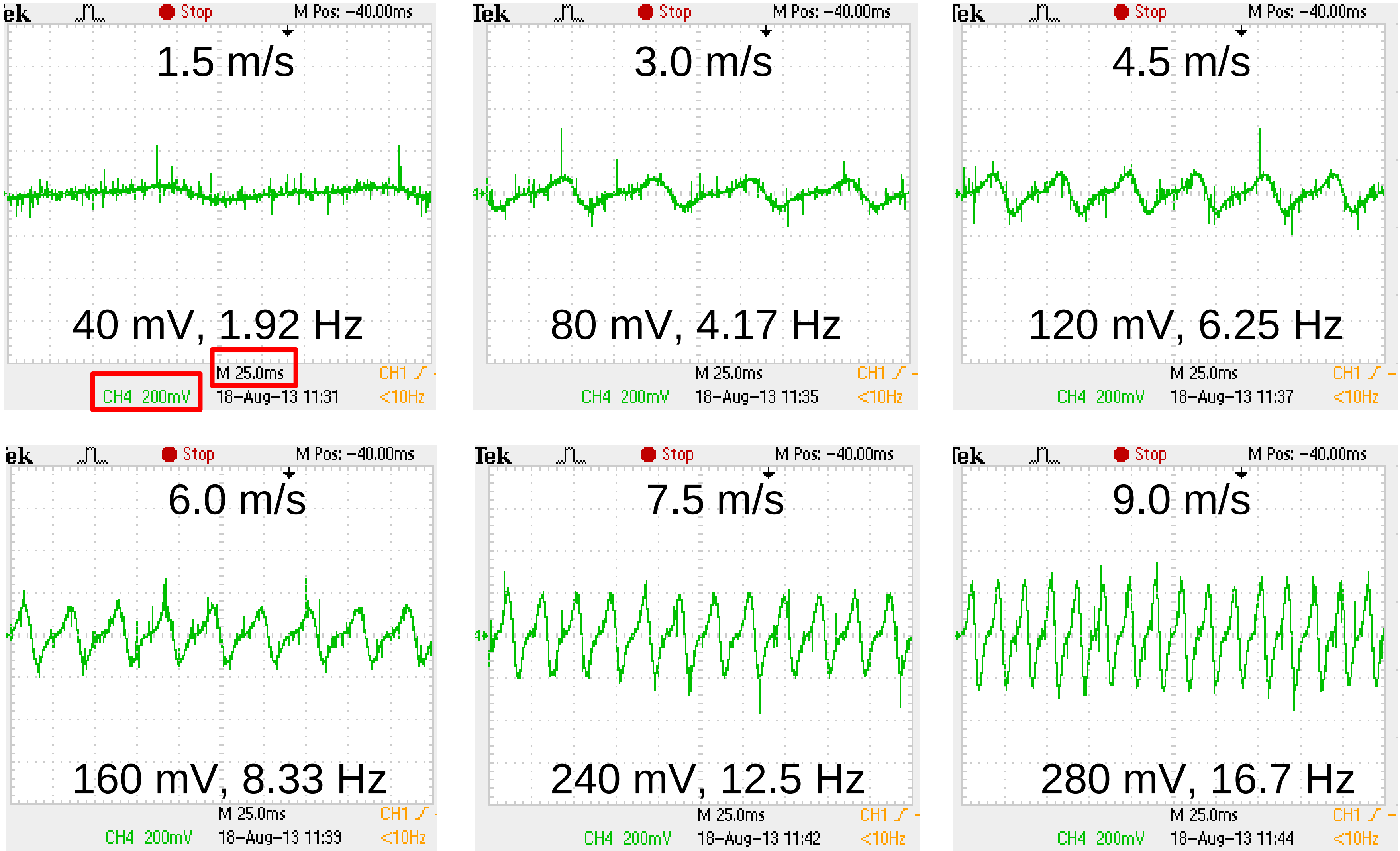
Beaufort Wind Scale

Beaufort No.	Description	Wind speed	Land conditions
11	Violent storm	28.5–32.6m/s	Widespread damage to vegetation. Many roofing surfaces are damaged; asphalt tiles that have curled up and/or fractured due to age may break away completely.
12	Hurricane	≥ 32.7 m/s	Very widespread damage to vegetation. Some windows may break; mobile homes and poorly constructed sheds and barns are damaged. Debris may be hurled about.

Experiment results

❖ ***Output Waveform:***



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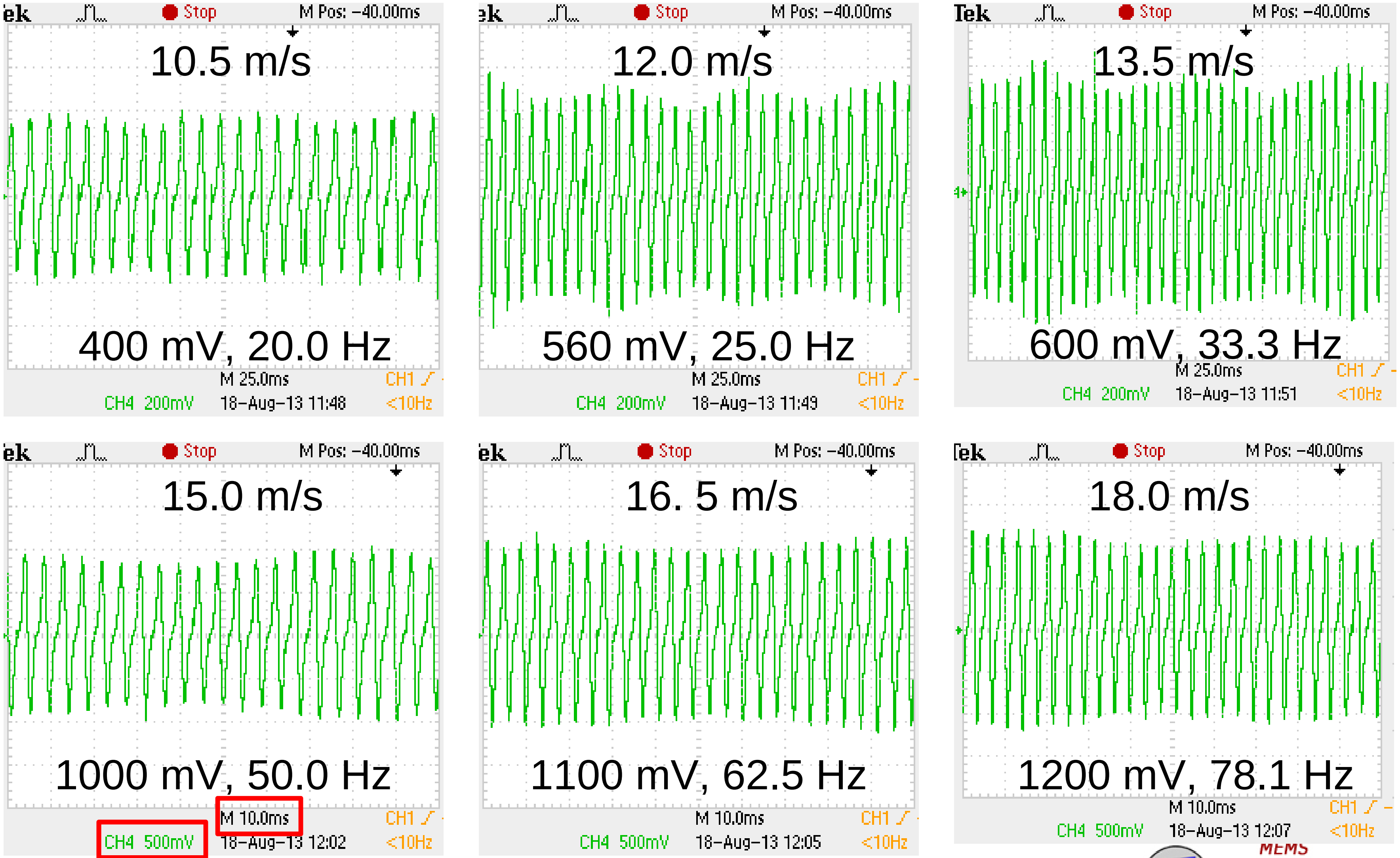
Experiment results

❖ Output Waveform:



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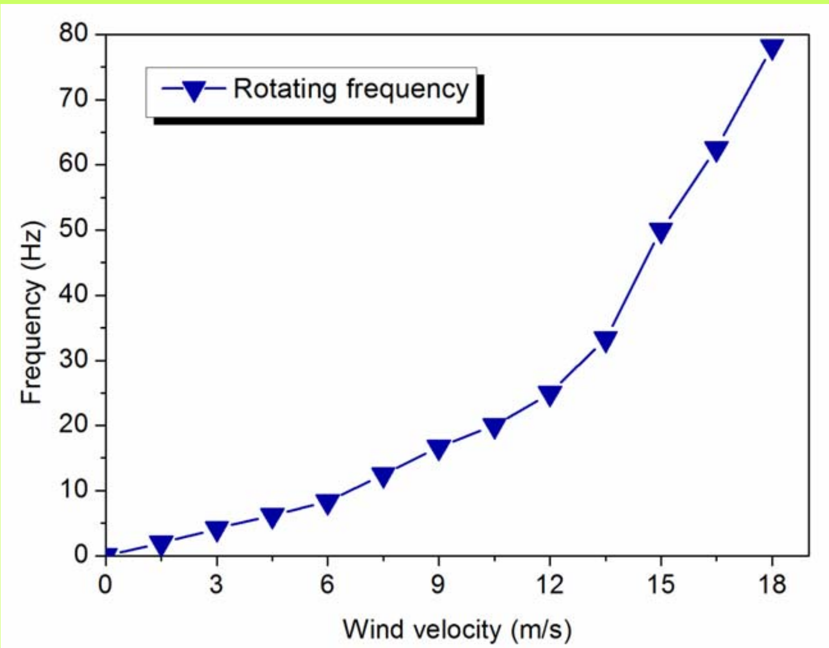
Experiment results

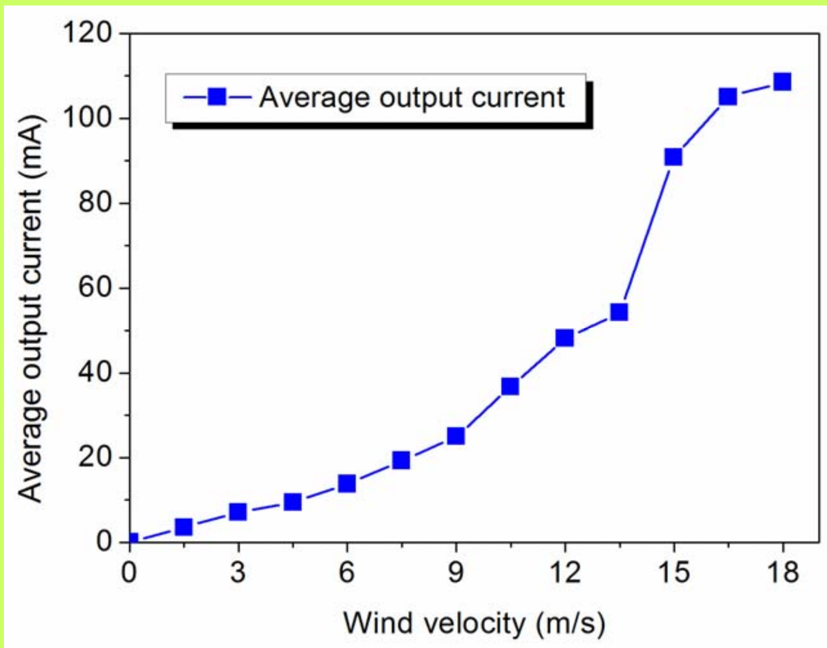
❖ *Rotating frequency & Average current:*

Average current (RMS current) calculation → $I_{max} = 109mA$

Rotating frequency versus the input wind velocity



Average output current versus wind velocity in open circuit

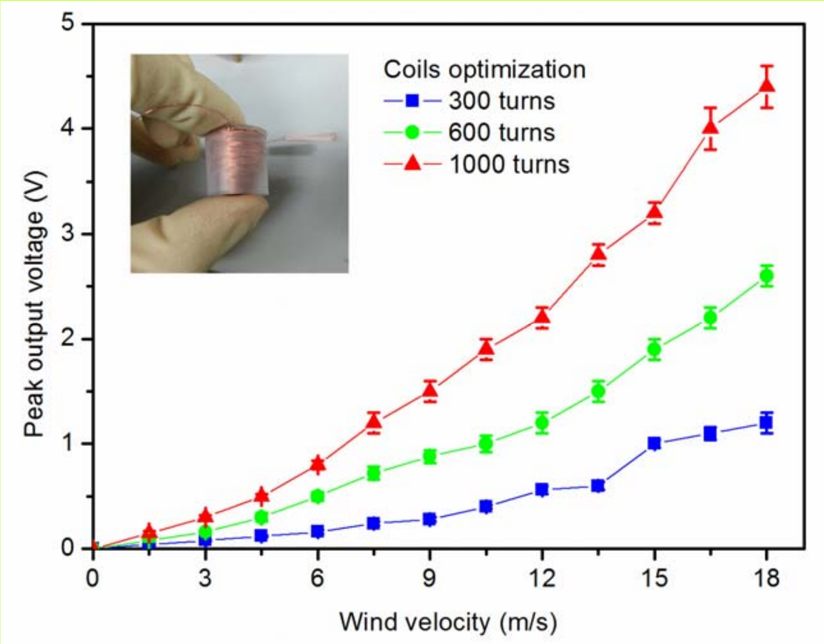


Experiment results

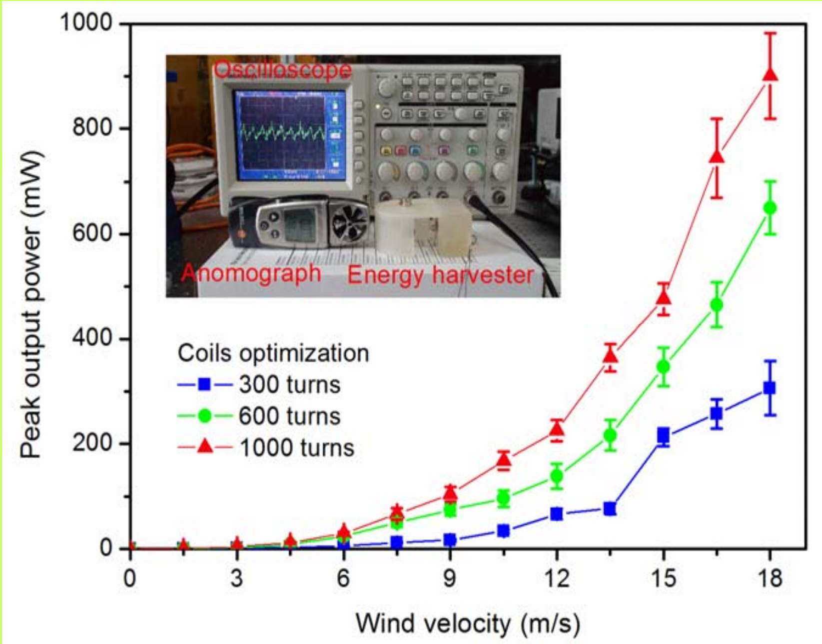
❖ ***Coils optimization:***

Numbers of coil turns → **300, 600, 1000**

Peak output voltage versus the wind velocity in open circuit



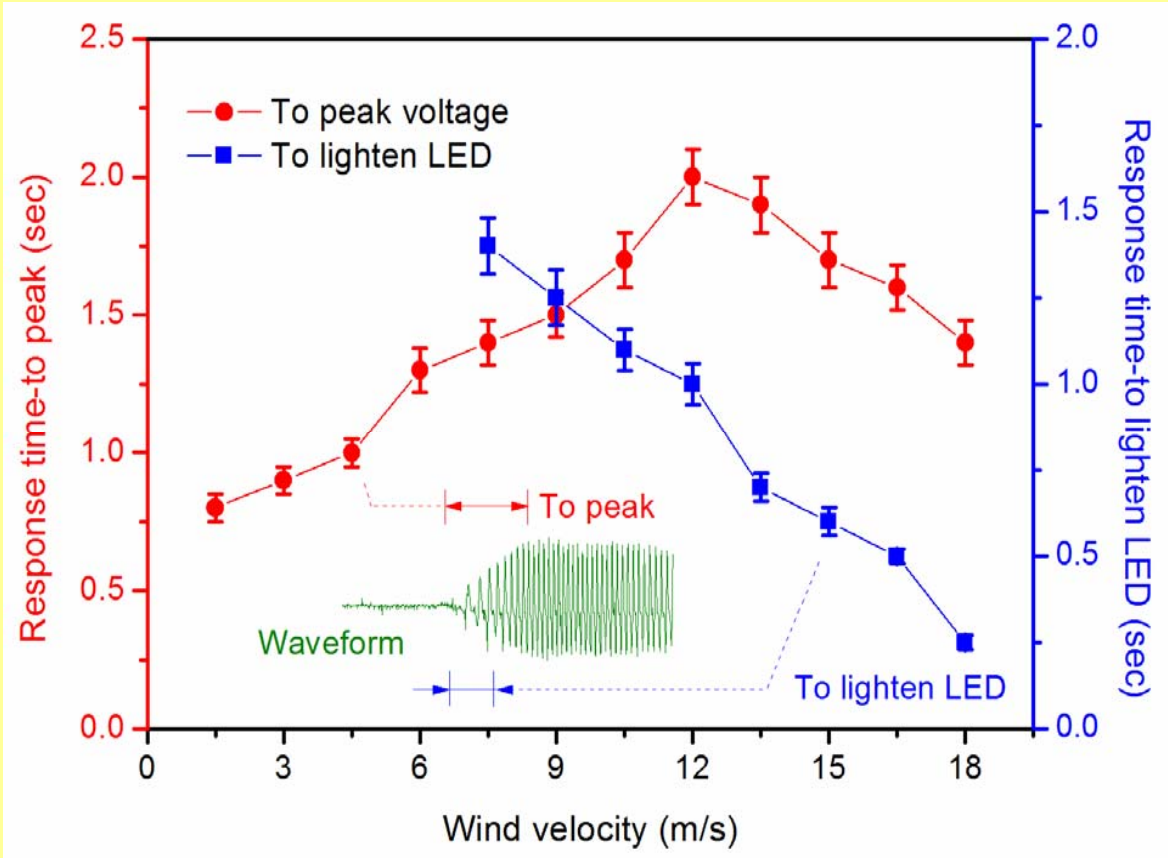
Peak output power versus wind velocity in open circuit



Experiment results

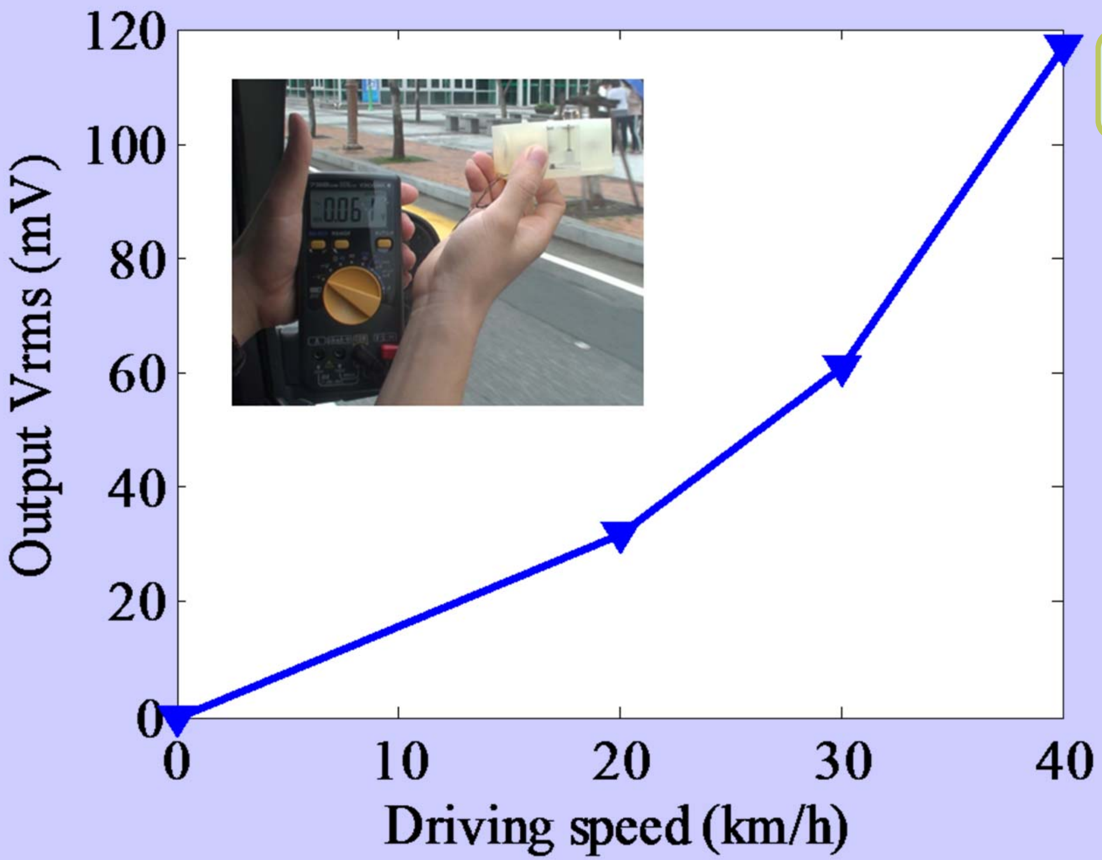
❖ *Response time:*

A small LED is lightened by this energy harvester when a wind velocity is over 7.5 m/s.



Experiment 2

❖ ***Experiment 2: Static wind, dynamic object***



V_{rms} VS speed

The output V_{rms} can be measured by a multimeter during car's driving versus various driving speeds. (Maximum V_{rms} = 117 mV, coil number=300).

Summary

❖ *A windmill-structured energy harvester:*

1. **Windmill structure** — With the windmill structure, this energy harvester can scavenge energy from the airflow in our environment.
2. **3D printing technology** — 3D printing technology is utilized to manufacture the prototype of the windmill-structured energy harvester.
3. **Electromagnetic method** — Electromagnetic method is applied to this design, which can generate a higher current than piezoelectric designs.
4. **Wide application** — A maximum voltage of 4.4 V & maximum output power of 900.5 mW is achieved, meets requirements of WSN.

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Thank You !

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