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Energy Harvesting from Electromagnetic Materials

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Abstract—

Energy harvesting has gained significant attention as a promising solution for powering low-power electronic devices without relying on batteries. This work focuses on the design of electromagnetic microgenerators and power processing circuits for low-voltage energy harvesting applications.

The study presents novel converter topologies, efficient auxiliary circuits, and optimized control techniques to improve harvested energy output. Various converter designs are analyzed in terms of operation, modeling, and power losses, along with suitable interfacing methods between microgenerators and converters.

Low-power auxiliary circuits such as start-up circuits, controllers, and gate drivers are also developed to achieve self-sustained operation. In addition, control strategies for voltage regulation and maximum energy extraction are implemented to enhance overall system efficiency. The proposed system demonstrates the feasibility of electromagnetic energy harvesting for self-powered electronic applications.

Keywords— Electromagnetic Energy Harvesting, Electromagnetic Microgenerator, Vibration Energy Harvesting, Cantilever Beam Generator,

I. INTRODUCTION

Electromagnetic induction, discovered by Michael Faraday in 1831, is the process of generating electric current through the relative motion between a conductor and a magnetic field. Electromagnetic vibration energy harvesters commonly use permanent magnets, coils, and cantilever beams to convert ambient vibrations into electrical energy. In most designs, magnets are attached to the cantilever beam to serve as the inertial mass, improving energy conversion efficiency.

II. LITERATURE REVIEW

Several researchers have investigated electromagnetic vibration-based energy harvesters for low-power applications. Williams et al. developed a micro electromagnetic generator of size 5 mm × 5 mm × 1 mm and predicted outputs of 1 µW at 70 Hz and 0.1 mW at 330 Hz. J. R. Amirtharajah designed a macro-scale generator powered by human walking vibrations, capable of generating 400 µW at 2 Hz.

Glynne-Jones investigated cantilever-based generators with different magnet configurations. Their improved four-magnet design produced output voltages up to 1 V and generated an instantaneous power of 4 mW when mounted on a car engine. Similarly, El-Hami developed a cantilever electromagnetic generator using NdFeB magnets and copper coils, achieving power generation above 1 mW at 320 Hz.

Researchers from Chinese University of Hong Kong, including Li et al. and Ching et al., proposed compact generators with spiral springs and fixed coils. Their devices produced voltages up to 4.4 V and power outputs reaching 830 µW at resonant frequencies between 64 Hz and 110 Hz. S. P. Beeby designed a compact electromagnetic generator optimized for low ambient vibrations. The device generated 46 µW at 52 Hz with a voltage of 428 mVrms and achieved an energy conversion efficiency of approximately 30%.

Further advancements include the miniaturized rotary generator proposed by Lun-De Liao, which produced 7.23 mW and 4.5 V at 10,000 rpm using NdFeB magnetic rings and planar copper coils. Zuraini Dahari performed finite element analysis (FEA) on different electromagnetic generator configurations using ANSYS software to evaluate magnetic behavior and performance.

Additionally, Byung-Chul Lee developed a low-frequency electromagnetic energy harvester using an FR-4 planar spring, NdFeB magnets, and a copper coil. The device achieved a maximum output power of 65.33 µW at 8 Hz with a high normalized power density, demonstrating suitability for low-frequency vibration applications.

III. EXPERIMENTAL TEST SETUP

In order to measure the output characteristics of the Electromagnetic energy harvester, a vibration testing system is employed. A schematic drawing of the experimental setup for EMH system is shown in Figure 6.1. It consists of a vibration exciter, power amplifier, dSpace software or an oscilloscope, LVDT and DC power supply, electromagnetic device. The vibration signal is generated from the signal generator, amplified via the power amplifier and finally utilized to control the vibration amplitude and frequency of the shaker. Electromagnetic energy harvester device is mounted on the shaker by using end plate. Accordingly, the electromagnetic device will undergo excitations and generate output voltage signal which is recorded by the oscilloscope or DSpace software. Displacement signals will be measured by LVDT and then displayed on the monitor of computer. The photo of the experimental system for testing the Electromagnetic Energy Harvester is shown in Figure.

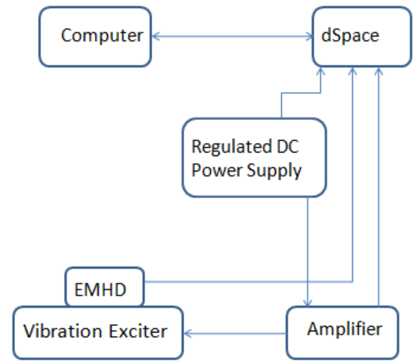

Figure- A Schematic Diagram of Set up

IV. EXPERIMENTAL PROCEDURE

Energy Harvester device is mounted on Shaker Machine using End Plate. Excitations are then given to EMEH device using Shaker machine input voltage 0.5V, 0.75V, 1V and 1.25 V constant and varying frequencies from 1 Hz to 25 Hz. Various load resistors were applied across the coil terminals, and the resulting load voltage, and electrical power measured for a fixed base excitation. The experimental results are then processed using MATLAB programs and graphs of Frequency Vs Voltage, Frequency Vs relative displacement were obtained. For finding the damping factor, readings were taken by giving excitations to EMEH in resonance frequency range 10 to 12 Hz and input voltage 0.5V, 0.75V, 1V and 1.25 V. For getting Logarithmic graph, each time the amplitude was suddenly dropped to zero, readings and graph were recorded.

V. RESULTS AND DISCUSSION

The experimental readings obtained by keeping input voltage 0.5V, 0.75V, 1V and 1.25 V and varying the frequencies from 1Hz to 25 Hz are plotted using MATLAB program.

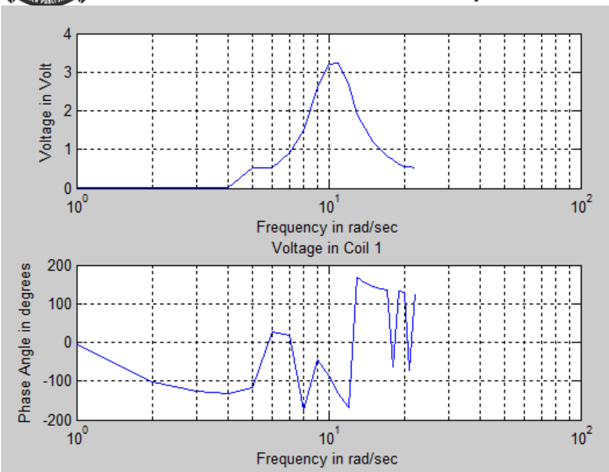

Figure Graph of frequency V/s voltage and frequency V/s phase angle at 0.5 input voltage.

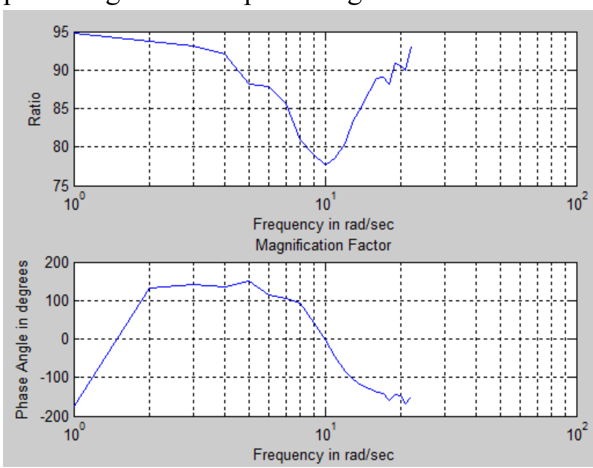

Figure Graph of frequency V/s ratio and frequency V/s phase angle at 0.5 input voltage.

VI. CONCLUSION

A Novel EMEH using the flexural spring system was manufactured and experiments were carried out in low frequency range 1 to 25 Hz. This EMEH yields Total Power Output of 65mW when it is connected to a load resistance of 3 KΩ which represents the optimum load resistance of the harvester and is the maximum power reported till date by any EMEH. From our results, we conclude that the proposed EMEH is suitable to harvest power at a low frequency level.

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