CAREER EPISODE 2

DESIGN AND APPLICATION OF HYBRID ENERGY HARVESTING SYSTEM IN SMART CITIES

INTRODUCTION

CE 2.1

I am a graduate in Electrical Engineering from ███████████████████████ ███████. During my studies, I have worked on various projects that have helped me develop my technical skills and knowledge. One such project involved "Design and application of hybrid energy harvesting system in smart cities". I worked on this project during my seventh semester. This was a semester project for the course Electrical Power Distribution and Utilization (EL471). I started the project in the month of ██████████ and I completed the project successfully in ███████.

BACKGROUND

CE 2.2.1

The use of conventional energy sources not only had an impact on the economy, but it also affected the environment. In order to overcome this issue, I presented a hybrid energy harvesting system, including piezoelectric and EM energy harvester. This hybrid energy harvester was capable of harvesting energy from the surrounding environment that would otherwise go to waste without any useful utilization. This system I presented used the vibrations from surroundings and converted them to electrical energy for driving small electronic devices that required 5 volts of voltage. This system was easy to install and eco-friendly, which can be installed on pedestrian walkways, roads or any other place with vibrations. The most important application of this system was in smart cities where small IoT based devices required a power source. With the use of this system, environmental pollution can be reduced and energy can be utilized from the environment.

CE 2.2.2

I started working on this project by gathering information on the topic through research papers, other related projects and some of the books. I read the books available in the library of my university as well as the related books from other sources. I prepared my notes and summarized the necessary information for easy access to information. I defined the objectives of my project and developed a plan for it. I created a timeline with the tasks

and required activities, and the estimated time required for completion of my project. This helped me in completion of my project within the expected timeframe.

CE 2.2.3

For better understanding of my professor on my project, I drafted a project proposal with brief description of the project, its objectives and goals, the methods and techniques which I will be following to complete the project and lastly the expected outcomes. To discuss the idea and progress of the project, I did several meetings with my professor on the weekly basis. Having these discussions with my professor increased my confidence and knowledge of the topic. I submitted report of the project that included every little detail about the project. Further, I also prepared presentation for the project. My presentation was interesting and engaging for the students as I used visuals and kept it simple. I received appreciation from my professor and class fellows for not only achieving good results but also for my presentation abilities.
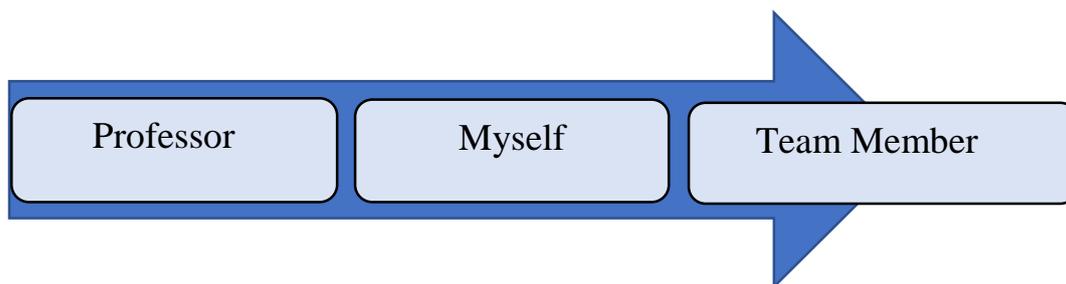
PROJECT REPORTING HIERARCHY

Professor	Myself	Team Member

Figure 1 Hierarchy of the project

PERSONAL ENGINEERING ACTIVITY

CE 2.3.1

Non-conventional sources of energy have become the center of attention with the decrease in the size of electronic devices. For the conversion of this energy to useful energy that is electrical power, transducers based electronic circuity like solar cells, microphones, generators for light conversion, sound and conversion of mechanical to electrical signals are required. However, this conversion of energy comes at a price, meaning that some part of the energy is lost during this process of conversion, as explained by law of thermodynamics. Energy harvesting is beneficial for the cases where there are no general power sources like at remote locations, under the water, under the ground etc. keeping all of above in mind, I proposed a solution of designing and application of energy harvesting

for capturing stray energy from the surroundings to use for applications which require low power. For validation of this project, I compared my results with the base paper.

CE 2.3.2

I started with defining the objectives of this project which comprised of deigning a hybrid harvesting system, validating the proposed scheme via simulations, implementing the design and validating the results by comparison with the base paper. I designed the block diagram of this project which included piezoelectric energy harvester, EM energy harvester, AC to DC converter, energy storage, DC to DC boost converter and a load of 5V. The construction of piezoelectric included Pb, Zr and Ti to form a crystal-like structure. When pressure is applied on this crystal its position changes by the ions from positive and negative charges to dipole moment. As a result, the balance between the charge is lost and potential energy is created across the crystal.
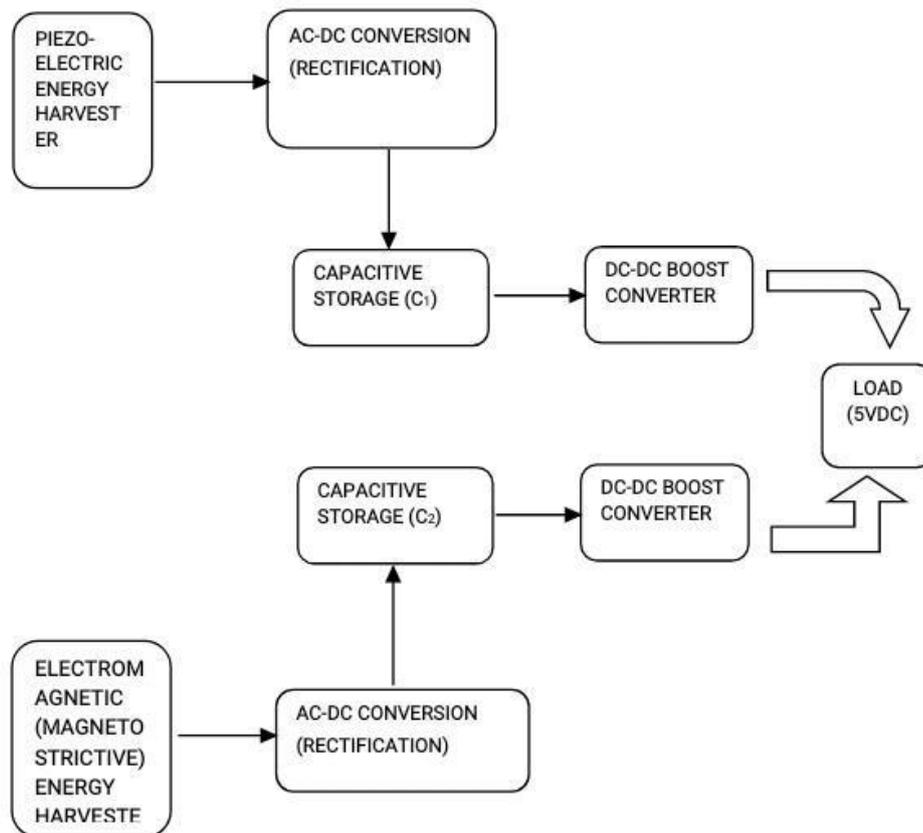

Figure 2 Block diagram

CE 2.3.3

The energy harvester I used was for determining the vastness of the expansion and the limit of the material expansion that's been shrunk. For AC to DC conversion I used a rectifier. Piezoelectric and electromagnetic energy harvesters both convert vibrational energy into electrical energy. However, this conversion process only produces AC current which is suitable for milliamp AC powered devices. For driving DC load, a rectifier circuit was required for conversion of sinusoidally changing AC current to an equivalent current in form of DC. Piezoelectronic-magnetostricitve energy harvesting machine was used to grab the energy which was stray. Vibrations were captured by these transducers after specific resonant frequencies. These captured vibrations generated the voltage from every transducer which was then transmitted to circuitry for managing the power. This circuit can be used at output for rectification and regulation of voltage.

CE 2.3.4

DC-DC boost converter was used to boost the converted DC energy to 5 volts. The DC voltage which was filtered was used to drive the DC load which does not require any specific level of voltage. However, in my case I had the requirement of driving 12 volts milliampere devices which was achieved using DC to DC boost converter which stepped up this voltage from min value to required value. Both the energy harvester responded differently to the AC output voltage that is why I required DC to DC boost converter in my project for energy harvesting. AC energy that was generated from the piezo- electronic and magneto-strictive energy harvester was converted to DC separately with the help of a rectifier. Then I stored this DC energy with the help of capacitors which were then boosted for producing required 5 volts of output for load driving.
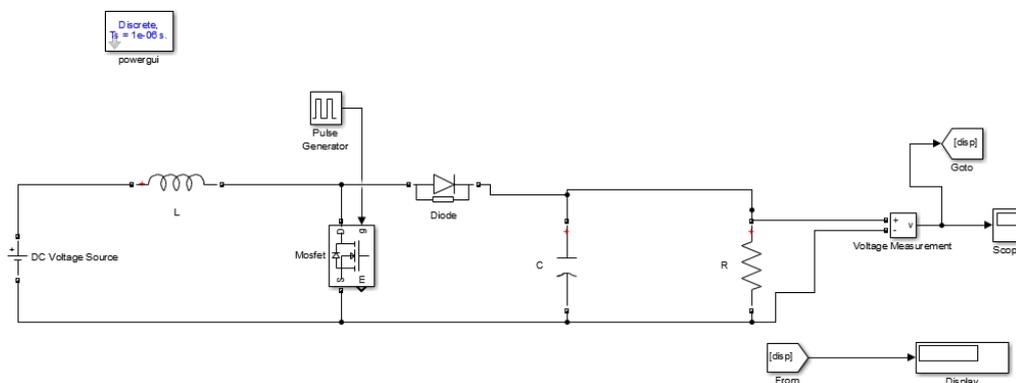
Figure 3 Boost converter circuit

CE 2.3.5

I used MATLAB Simulink for implementation and simulation of my design. After analyzing the simulations and parameters used to create the electric models of both harvesters, I gained valuable insights into the electrical behavior of the hybrid energy harvester. In this regard, I carried out the study and recorded the observations of different parameter values. The analyzed parameters encompassed the peak AC output voltage of both harvesters, the average DC rectified voltage, the averaged boosted voltage output, and the average input power required for boosting the converter in the circuit. With knowledge of these values of average power, I calculated the approximated efficiency of the overall system. The output voltages contained ripple content which necessitated additional filtration to achieve a smoother output.

CE 2.3.6

I showed the simulation results by the name of input vibrations. It is the sinusoidal signal which set the harvesters to mechanical vibrations. Its amplitude was shown around 7 units in results of simulation. The electromagnetic transducer generated a sinusoidal output equal to the input vibrations with a peak value of nearly 3V. The piezo-electronic harvester reported a peak voltage of nearly 3.2V as a result of the excitation which was given to this transducer. I achieved this output voltage by optimizing the electrical parameters and with the use of bimorph-type piezo-electronic device. I rectified the AC voltage to DC voltage of almost 0.98V by using a full wave bridge rectifier. The DC voltage I obtained was after filtering the pulsating AC voltage with the use of a1000 microfarad capacitor which was placed parallel to the full eave bridge rectifier circuitry before the stage of boost conversion.
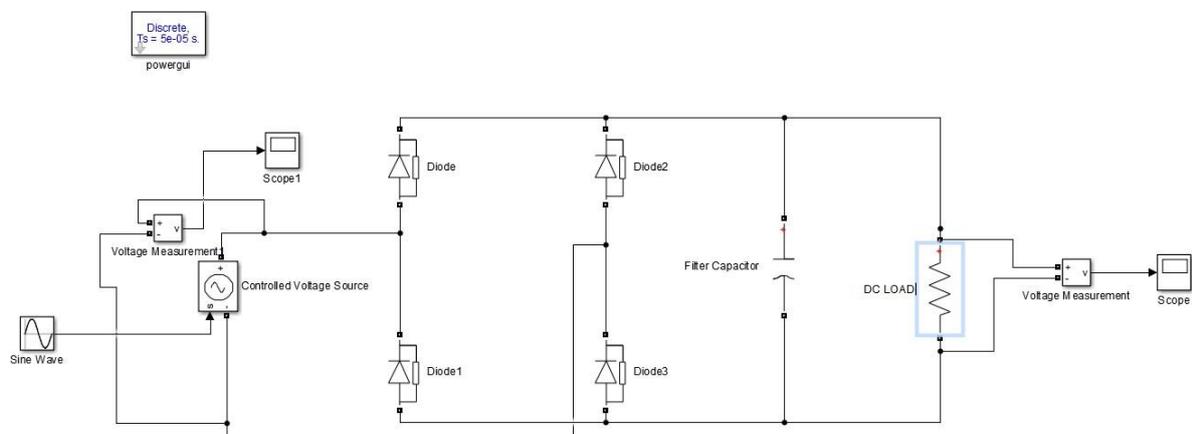

Figure 4 Circuit of Full bridge Rectifier implemented in Simulink

CE 2.3.7

This rectified 1.3V was then boosted to 6V which can be used by a DC module to drive its load. Most of the energy lost in this design was at this point of boost conversion. Similarly, DC voltage from the rectifier of electromagnetic harvester was boosted up to level of 5V. For further improvement of this voltage electronic devices like MOSFETs can be applied. I displayed the input waveform of both the devices. It contained few ripples which fluctuated between min and max value. I calculated the average of these values to be 61 milliwatt for piezo-electronic device and 31 milliwatt for electromagnetic device. I observed the overall power after the rectification process to be twice as that of the electromagnetic device. It was because of the more optimized model for piezo-electronic then the electromagnetic device.

CE 2.3.8

I calculated the average output power of both the harvesters by summing the min and max value and then dividing it by 2. The value I calculated came out to be almost 55 milliwatt. This value represented the combined contribution of both the harvesters. I calculated the overall efficiency of this hybrid system by dividing the sum of all input powers to the total average output power I calculated. This gave the idea of efficiency in form of fraction. I obtained the efficiency by multiplying this value by hundred which came out to be 60%. Further improvements can be made in this project by controlling the losses in every step for enhancing the overall efficiency of this proposed system.

CE 2.3.9

This project involved implementation of circuits for real-time simulation which was fascinating and challenging for me as it involved designing and construction of electronic circuits that accurately imitated the behavior of a real-world system. I learnt the use of MATLAB Simulink software which allowed me to test and validate the performance of my system under a wide range of conditions before its deployment. Implementing circuits for real-time simulation requires a deep understanding of circuit design principles, as well as a strong knowledge of the underlying physics and mathematics of the system being modeled which I learnt as a result of this project. This project also allowed me to use my

creativity and technical skills to build a system that accurately represented the behavior of the real-world system.
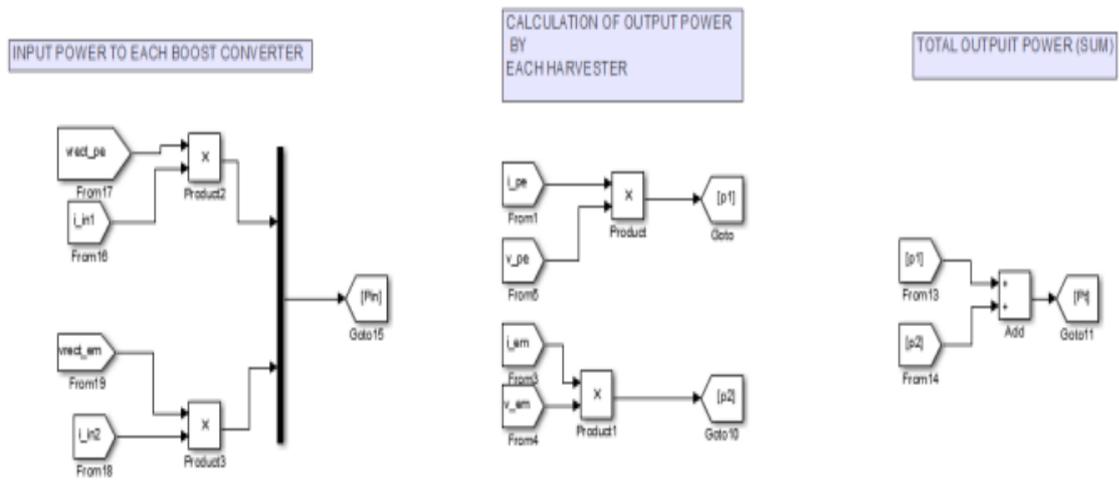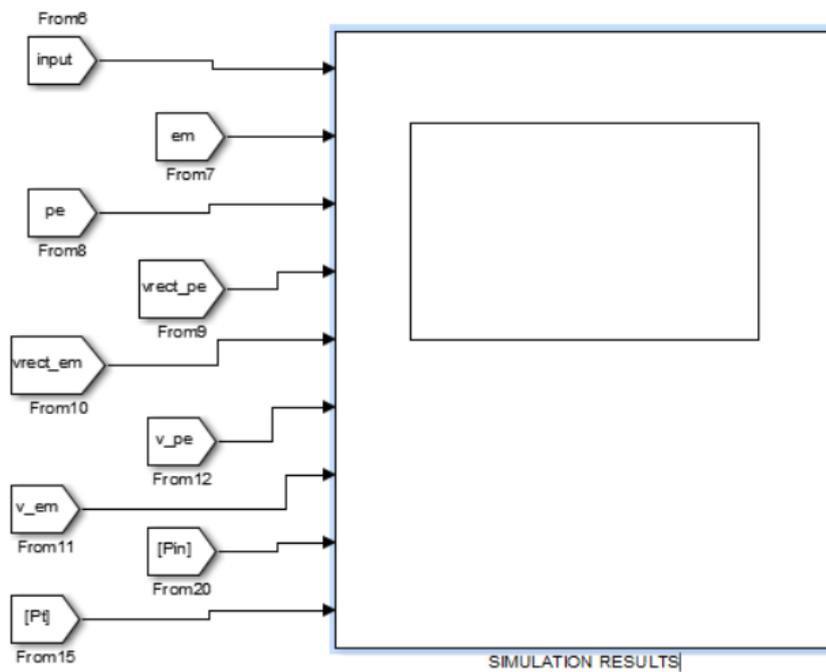

Figure 5 Power calculation blocks
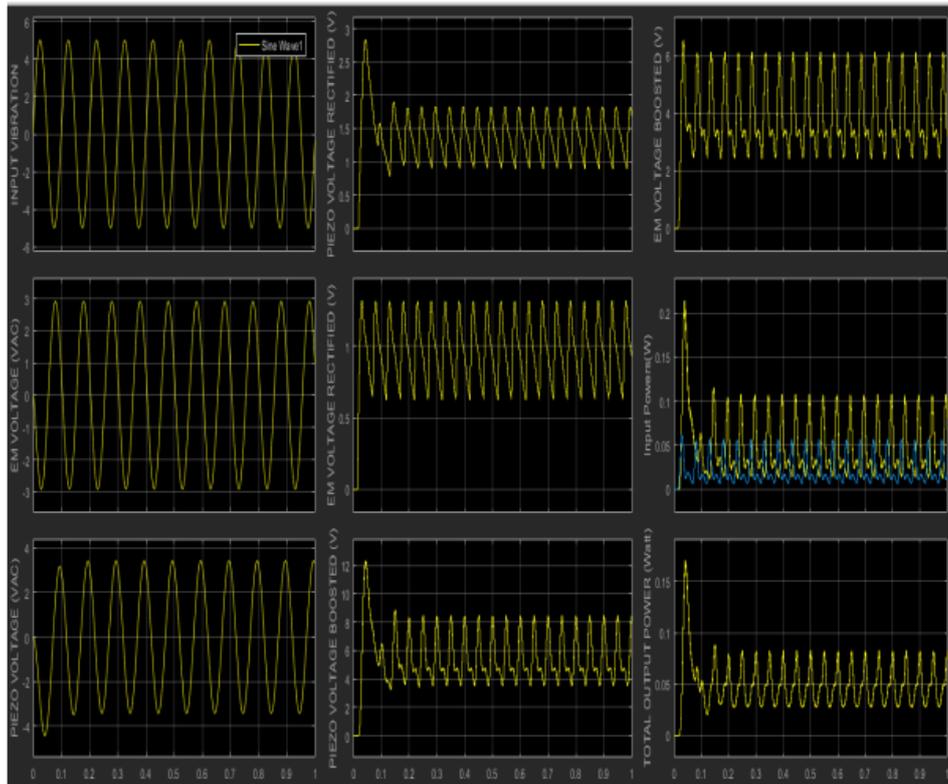

Figure 6 Scope

Figure 7 Simulation results

Energy Harvester	V_{peak} (VAC)	Rectified Voltage (VDC)	Boosted voltage (avg.) (VDC)	Power input(avg) (mW)
Piezoelectric	3.246	1.37	6	61.1
Electromagnetic	2.916	0.98	4.28	31.34

Table 1 Outputs Observed

P_{in} = Gross input power= 61.1+31.4 =92.44mW

P_o=Total power output of both harvesters=55.2 mW

So,

Efficiency=59.71%

SUMMARY

CE 2.4.1

Considering the energy requirement with the increase in demand of electric power, there was a need to design a system which harvested the energy from the surroundings and convert them into electrical signals. For this purpose, I proposed a deign and application of using two energy harvesters; piezo-electronic and electromagnetic harvester for converting vibrational form of energy to DC voltage. The results I obtained from this design proved this proposed system to be approximately 60% efficient, which can be improved further for obtaining better results. I also faced few issues in implementation of my problem using MATLAB but with the help of my supervisor, I was able to overcome all of them. I was able to learn about various energy sources, system integration, practical skills of engineering and problem-solving skills. While working on this project, I made a conscious effort to follow to all the engineering constraints and guidelines, which further helped me in refining and improving my skills.