

A REVIEW ON PIEZOELECTRIC AND SOLAR ENERGY HARVESTERS

Ayesha Shirazi¹, Jisha Qureshi²

¹Student, Department of Electronics Engineering, Shri Ramdeobaba College of Engineering and Management Nagpur, Maharashtra, India

²Student, Department of Electronics Engineering, Shri Ramdeobaba College of Engineering and Management Nagpur, Maharashtra, India

-----***-----

Abstract - With the upcoming aging society where energy is consumed on a regular basis and sources of energies are degrading day by day, energy harvesting has become a vital source of research. Energy harvesting is generating a clean source of energy from energy which is being wasted that is utilizing energy resources such solar, water, wind, muscular etc. to form usable form of energy. Hence Energy Harvesting is a way of using the extra energy or in other words not wasting even a single extract of energy. It is important as the current non-renewable energy sources are at verge of extent. In this paper we represent two different energyharvesting methods solar and piezoelectric along with their fundamentals, working and models.

Key Words: Energy Harvesting, Extract, Non- renewable, Extent, Solar, Piezoelectric

1. INTRODUCTION

We use natural resources like oil, carbon, coal, fuel etc. to produce electricity, transportation, heating and manufacturing. 85% of the energy utilized in the industrial processes is this form of energy. But the drawback of this energy is that it is non-renewable and produces a lot of pollution. As these sources are depleting, their cost is increasing, the best examples are petrol, LPG gas, and electricity which we use on a regular basis. So the replacement of these energy sources has been started with renewable energy resources. Hence non-renewable energies are conserved and pollution free clean energy is produced. Renewable energy resources such as water, wind, solar, muscular etc. are converted into usable energy form like electrical energy. The method of converting renewable energy into electrical energy is known as Energy harvesting. Hence Energy harvesting have become the topic of research.

The best use of an Energy harvester is for battery backup. In industrial and consumer applications like satellites, calculators, street lights, toys, portable power supplies, etc small solar cells are used in which the solar energy is harvested into electrical energy with photovoltaic cell.

The most widely used energy harvesters rely on piezoelectric materials, solar energy and RF. In this paper we will discuss piezoelectric and solar energy harvesters, their fundamentals, working and modelling.

2. PIEZOELECTRIC ENERGY HARVESTER

Fundamentals: Piezoelectric materials are child class or inherited class of ferroelectrics. The property of ferroelectric material is, that it exhibits local charge separation known as electric dipole due to its random molecular structure orientation. When this material is heated above the Curie temperature and a strong electric field is applied, the electric dipoles according to the field reorient themselves, this process is known as polling. These dipoles do not change their orientation even after cooling, hence the material is said to be polled and now it exhibits piezoelectric effect.

Working: The most widely used Energy harvester is the piezoelectric Energy harvester. The word 'piezo' means 'to apply stress or strain'. Hence piezoelectric materials require stress or strain to generate electric charges. When a strain is applied to the piezoelectric material, the atoms present in it tend to move, this movement of atoms due to applied strain results in the generation of internal electric charge or electric potential energy which can be used as a good source of energy. In this way the mechanical energy is converted into electrical energy. The piezoelectric energy harvester is based on the same principle. These energy harvesters, scaled in few centimeters generate energy in milliwatts using immediate vibrations below 1KHz frequency. Hence are regarded as perfect solutions for micro power generator as they generate enough energy to drive low power devices which have power dissipation in few milliwatts.

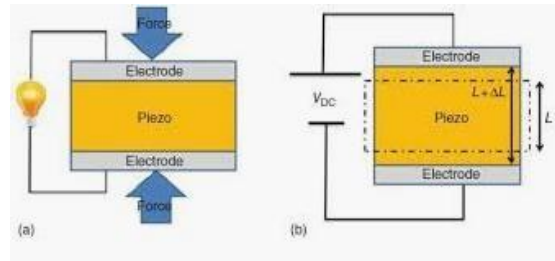


Figure 1. Piezoelectric effect.

Modelling: The design and simulation of a piezoelectric energy harvester generating output between 1 to 5 volts along with its power conditioning was represented by Dhanajay Kumar, Pradyuman Chaturvedi and Nupur Jejurkar, in 2014 IEEE students Conference on Electrical, Electronics and Computer Science. Their basic arrangement consist of an energy harvester circuitary, six double sided piezoelectric diaphragms and a shaker model. The energy harvester presented by them consists of a piezoelectric transducer, static converter and electrical load storage. The transducer produces alternating current charges from the vibrations given to it as inputs. A static converter is used before supplying the output to the storage.

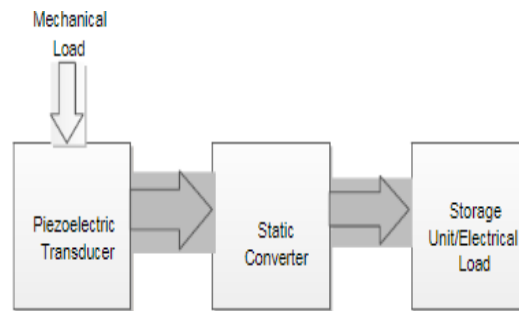


Figure 2. Schematic Diagram of a vibrating Piezoelectric Energy Harvester.

Piezoelectric diaphragms with electrodes on both the sides are used in the transducer model as shown in figure 1. The resonant frequency of these diaphragms is given by Helmholtz's equation[2].

$$f_0 = \frac{C}{2\pi} \sqrt{\frac{4a^2}{d^2h(t + ka)}}$$

Where f_0 = resonant frequency in Hz, C = velocity of energy wave, a = radius of diaphragm, k = material constant and t = thickness of support.

The hardware consisted of six diaphragms connected in parallel to each other and mounted on a wooden board. Those diaphragms act as piezoelectric transducers arranged in 2*3 matrix format with a shaker. An AC voltage is obtained at the output due to strain applied on the tile which is situated above the diaphragms. The magnitude of ac output obtained depends on the various factors such as packing density of piezoelectric transducer, frequency of excitation, and type of strain applied on the surface[2]. The ac output is then fed to the energy harvester LTC3588 designed for low power generation using MATLAB. The ac output is hence stored in energy harvester which can be further utilized as a power source.

3. SOLAR ENERGY HARVESTER.

Fundamentals: Silicon is a Semiconductor with conductive properties, it is doped to obtain both negative and positive charges or in other words to create an electric field. When sunlight fall on such a silicon cell it tends the electrons present in it to move and hence electric charges are produced, this effect is known as photovoltaic effect. The flowing electrons are captured and stored for further use. All three types of silicon are used for different purposes. Amorphous silicon, gives flexibility to solar cells. Polycrystalline cells are less efficient than monocrystalline cells, but they are also less expensive[3]. Monocrystalline cells are highly effective, hence used where high efficiency is required.

Working: Photovoltaic cells convert solar radiations into electrical energy. This is achieved in three simple steps:

1. The silicon solar cells absorb lights due to which electrons present in it tend to move.
2. These flowing electrons produce current.
3. This current is captured and stored.

Modelling: Solar energy harvesters are commonly used for supplying backup electricity in houses, hospitals, offices etc. High amount of energy can be created by wiring many solar cells together. Small scaled solar cells are used as batteries for small mobile devices such as cell phones, calculators, sensors etc. Two solar energy harvester circuits have been presented by IEEE members D. Dondi, A. Bertacchini, L. Larcher, P. Pavan, D. Brunelli and L. Benini in 2008. Their harvester was designed for low power applications, it is suggested that the solar energy harvester can be configured with ultra low power devices when there is low sunlight, while when there are high radiations it can be configured with high switching frequency circuit. The architecture of the solar harvester consists of three stages input, tracking and output.

In input stage the solar energy is stored in energy reservoir. In tracking stage a maximum power point tracker (MPPT) is used to sense the intensity of light and control the photovoltaic energy entering the unit for efficient use. The output converts this energy into stable voltage supply.

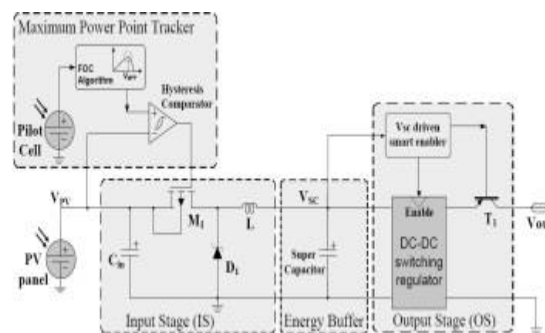


Fig 3. Schematic for Solar Harvester.

A. Input Stage: The energy collected in photovoltaic panel (PV) is stored in the supercapacitor which is of 50F which tolerates maximum voltage of 2.5 volts. The input stage is designed as a step down DC converter since the output of PV is ~3V. Buck converter are typically driven by a Pulse-Width-Modulated (PWM) signal generated by a controller to obtain stable voltage[6]. In this model, the control signal is dependent on the condition of PV panel and energy reservoirs. MOSFET's switching frequency is a derivative of capacitor charge state and light intensity. Thus circuit efficiency and reliability is directly proportional to its switching frequency.

B. Maximum Power Point Tracker (MPPT): In order to achieve maximum power the current and voltage of PV panel should match the conditions of MPPT. This can be done through technology. As efficiency is directly proportional to switching frequency two models have been discussed to satisfy this purpose by employing two comparators of different frequencies and power consumption. An ultra low power (ULP) LTC1440 comparator and High Speed (HS) LT1720 with maximum frequencies ~60kHz and ~1MHz respectively and power consumption ~10 and 100 microwatts respectively.

C. Output Stage: The off shelf DC-DC step up voltage regulator is combined with custom enabling circuit as shown in fig. 3 to supply stable output voltage. The power supply for harvester circuitry is given from both output stage and PV panel.

Results: The results are obtained by targeting energy harvester to WSN devices under normal environmental conditions. The sensor used is 802.15.2/ZigBee compatible embedded system having power consumption less than ~50mW. The harvesters efficiency have been calculated by keeping in mind all three powers the power stored in super capacitor, the power collected in PV panels and power dissipated from sensor nodes. The experiments are done by IEEE members that shows, though the power dissipation of the model consisting of HS comparator is more, its efficiency is higher than the ULP comparator model as it is more sensitive to light intensity. Efficiency of HS comparator is 90% whereas the efficiency of ULP comparator is 80%. Contrary to this, it is also proved that ULP comparator model is more efficient and reliable when the intensity of light is less from the experiments. Hence HS are efficient when there is high light intensity.

4. CONCLUSION

Both the types of energy harvesters the piezoelectric and solar have been reviewed. Their fundamentals, working, architecture and models have been represented. The paper shows that both the energy harvesters are suitable as battery backups for electrical applications. Two categories of solar harvester have been represented having two different comparators for high as well as low frequency and their efficiency is discussed.

REFERENCES

- [1] Dhananjay Kumar, Pradyumn Chaturvedi and Nupur Jejurikar Dhananjay Kumar, Pradyumn Chaturvedi and Nupur Jejurikar, "Piezoelectric Energy Harvester Design and Power Conditioning." 2014 IEEE Students' Conference on Electrical, Electronics and Computer Science
- [2] Pisharody Harikrishnan G, an Optimal Design for Piezoelectric Energy Harvesting System, IEEE PES Innovative Smart Grid Technologies-India, 2011.
- [3] <https://news.energysage.com/what-are-solar-panels-made-of-list-of-solar-pv-materials/>
- [4] X.J. Zhang, Kazunori Hoshino, in Molecular Sensors and Nanodevices, 2014
- [5] Chris Woodford. "EXPLAINTHATSTUFF" August 21, 2018.
- [6] D. Dondi, A. Bertacchini, L. Larcher, P. Pavan, D. Brunelli and L. Benini "A Solar Energy Harvesting Circuit for Low Power Applications" in ICSET 2008.