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Study of Piezoelectric Energy Harvester

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***Abstract-* This work presents a miniature piezoelectric model that analyses the generated electrical energy occurring from the variations in the acceleration. It consists of a seismic energy harvester or a bimorph whichisfixedtoavibratingsourceatoneendandaproof masstoanotherend.Thebimorphisatgroundpotential and two electrodes are placed at the outer surface of the cantilever beam. A fixed electric load calculates the frequency of vibration and the acceleration thus caused by the virtue of DC output voltage is found to be linear. Various Piezoelectric materials are used to analyze the vibration and acceleration on the model. This energy harvesters find applications in volcanic seismic equipment's as this modeled system can provide a small amount of energy to detect the seismicwaves.**

Keywords- Bimorph, vibration frequency, Seismic, piezoelectric, proof mass.

I. INTRODUCTION

Withtheadvancementsintheefficient systems,the energy requirements have been drastically decreased [1]. One of such kind is the energy harvester which converts the mechanical vibrations into useful electrical signals which then is used to power up electrical or electronic devices. Energy harvestersplay a vital role in wireless sensor networks (WSN's) [2]. Especially communication standard IEEE 802.15.4, a very popular communication standard, Zigbee, LowPan are commonly used in WSN's [3] [4]. Neurosky uses a similar concept where-in brainwaves aremonitoredenablingbrainandcomputerinterfacing [5]. There are various harvesting modalities such as solar, vibrational, biochemical, and motion based, which takes energy from outside environment and convertsintoharvestedformtoincreasethelifetimeof the system [6, 7, 8, 9]. Also, vast applications include inthefieldofsolarpanels[10],thatusesthermoelectric generators [11], or by conversion of radio energy into useful energy form [12]. Such models are also used in recycling energy [13]. Systems that involve dangerous monitoring fields [14], handheld devices usually work for long periods [15]. Also in microprocessor and various microcontrollers technology there is a requirement reduced low power which have led to develop applications that use these devices as power supplies[16].

Piezoelectric materials such as PZT have been usedfromlongtimeformechanicaltoelectricalenergy harvesting [17] [18] [19] [20]. These materials have limited mechanical strain abilities such as that used in large excitation mechanisms. The harvesting cycle basically has a possible large loop, which is bounded only by the material limitations [21]. Recent studies haveshownthattheelectrostrictivepolymersgenerates largestrainbymakinguseoflesselectricfieldintensity [22].

II. DESIGNMETHODOLOGY

A. Designmodel

The design model of the energy harvester is given in Fig1.

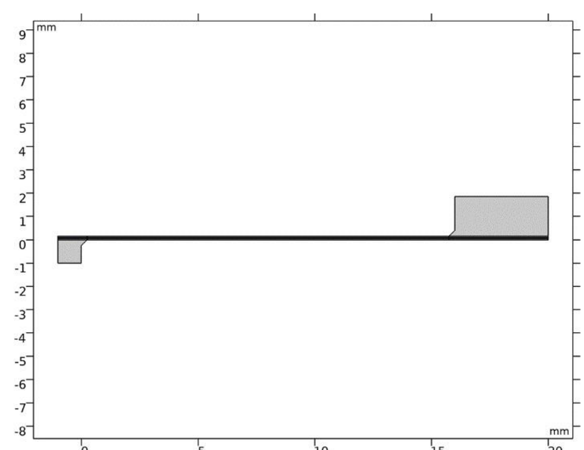

Fig1: 2D model geometry, showing the energy harvester

ThepowerharvesterhasapiezoelectricBimorphfixed atoneendandtheotherendissuspendedoveraproof mass. The Bimorph is at ground potential and two electrodesembeddedontothesurfaceofthecantilever beam.Thismodelingmakessurethatthesamevoltage is induced to the both electrodes however the stress above and below the neutral layer is of opposite sign. Apieceofvibratingsourceisadjoinedwiththeclamp. This enables the device to be analyzed in avibrating reference frame. The energy harvester is modeled by the use of sinusoidal body load.

B. Electromechanical modeling

Piezoelectric generators used for harvesting vibrating energy work on mechanical resonators, or a simple beam which sends the required energy to thematerial. The proposed model in this paper is similar to the one used inFig2.

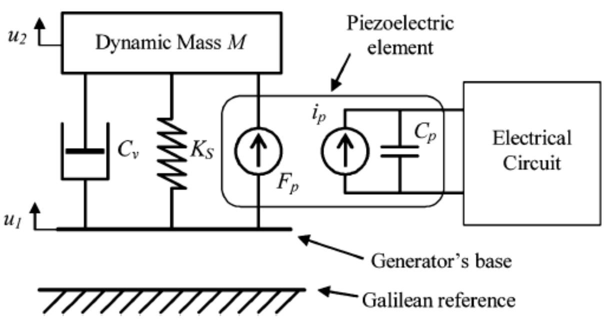

Fig2: Energy harvester generator model [2]

In many cases, the model parameters can be deduced from the properties of used material and also from the mechanical setup [23]. Most of the model show good agreement with the finite element models, as Comsol solves these equations. [24].

C. Piezoelectric materials

Natural occurring materials like Quartz, bones, tendons, enamel, dentin and others display piezoelectricproperties[25].Theprocessofproducing electricity when some materials are subjected to pressure is called as Piezoelectricity. Different materials have unique properties. So, they are classified based on the source. They can be either natural or they can synthetic. The relationship of various materials is shown inFig3.

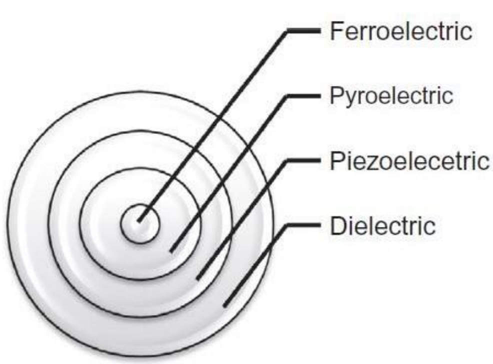

Fig3: Relationship between different piezoelectric materials [25]

In this current work, four different materials are used to study the piezoelectric behavior such as Lead Zirconate Titanate, Quartz, Barium Titanate and Rochelle salt.

III. SIMULATIONRESULTS

The simulation is carried out on Comsol Multiphysics 5.1 which are shown in Fig4- Fig21

Fig 6 shows the input mechanical power and the harvested power (in mW) and also the inducedvoltage acrosstheharvester(inthiscaseBimorph)asafunction of frequency at the time the harvester is excited by sinusoidalacceleration,theelectricalloadis12kΩ.The computedresonantfrequencyofthecantilever is73Hz whereastheresponseshowsthepeakof76Hz.(Fig6)

Fig8 shows the DC voltage and mechanical/ electrical powervs.themagnitudeofthemechanicalacceleration with fixed frequency of 75.5Hz where the load impedance is12kΩ.

It can be seen from the same plot that the voltage gradually increases with load (linear) whereas the power harvested increases quadatically. As expected from equation 4 in [1].

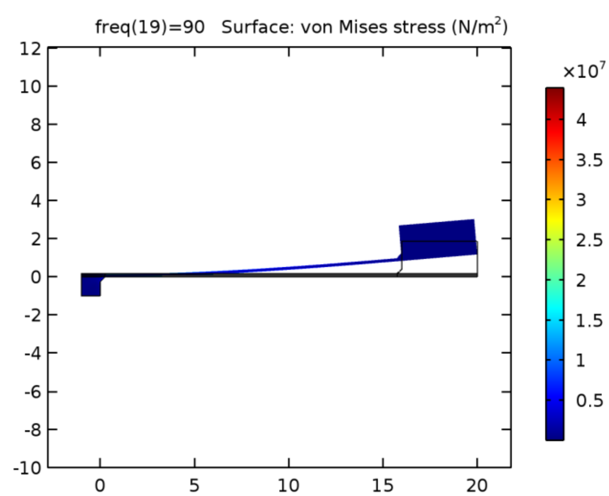

Fig4: Von Mises Stress (N/m^2): Lead Zirconate Titanate

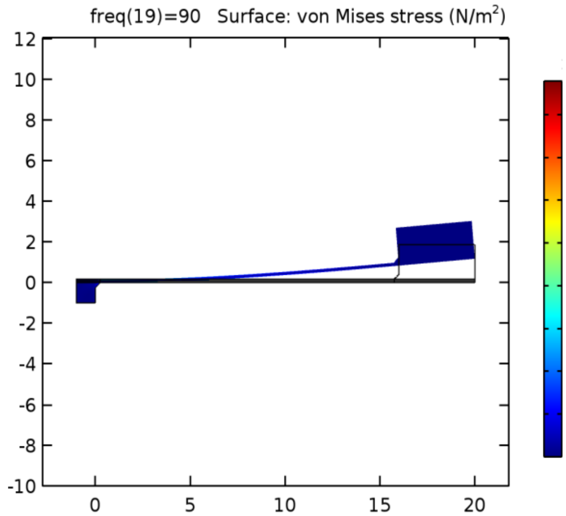

Fig5: Electrical Potential (V): Lead Zirconate Titanate

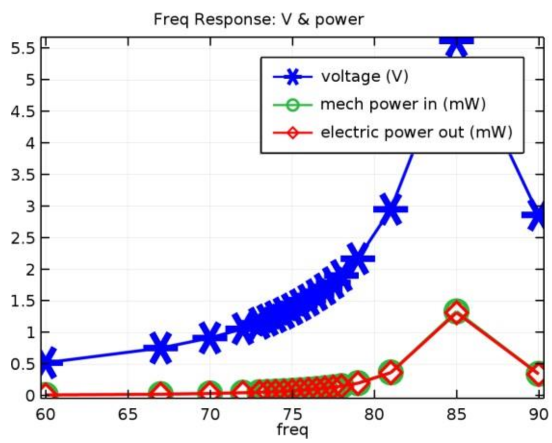

Fig6:FreqDependence:VandPower:LeadZirconateTitanate

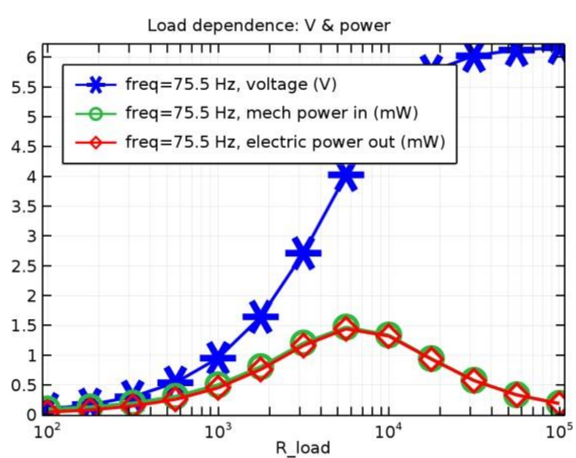

Fig7:LoadDependence:VandPower:LeadZirconateTitanate

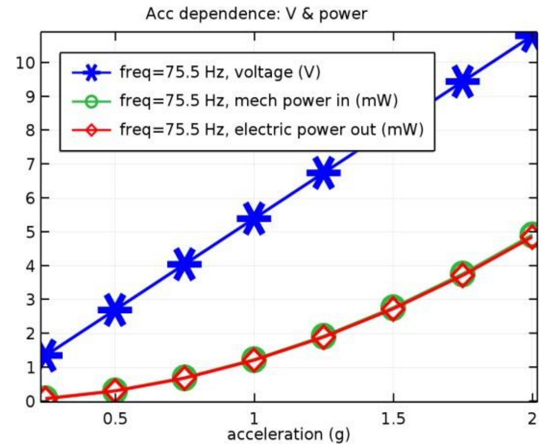

Fig8: Acceleration depend: V &Power: Lead Zirconate Titanate

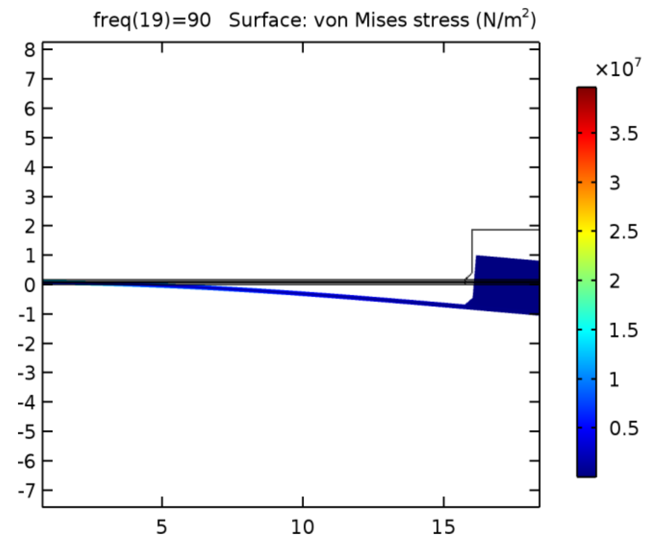

Fig9: Von Mises Stress (N/m^2): Barium Titanate

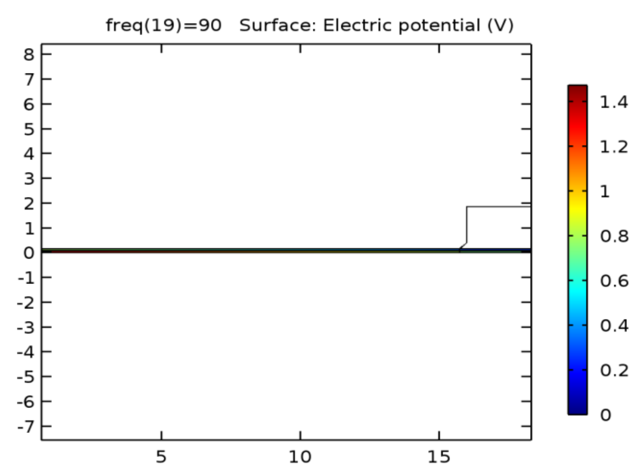

Fig10: Electrical Potential (V): Barium Titanate

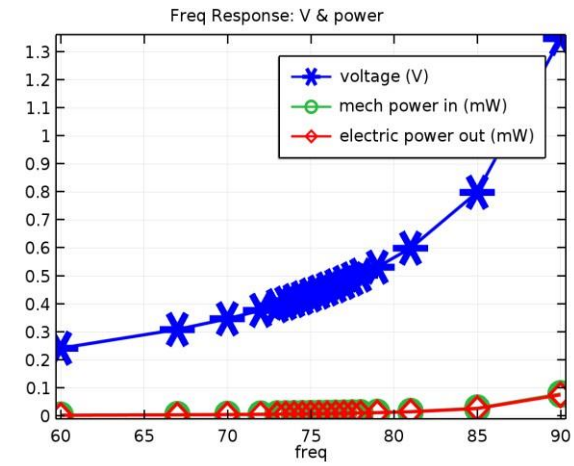

Fig11: Frequency response: V and Power: Barium Titanate

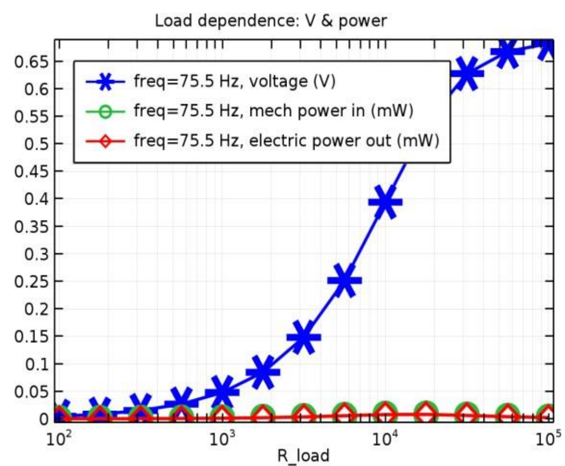

Fig12: Load Dependence: V and Power: Barium Titanate

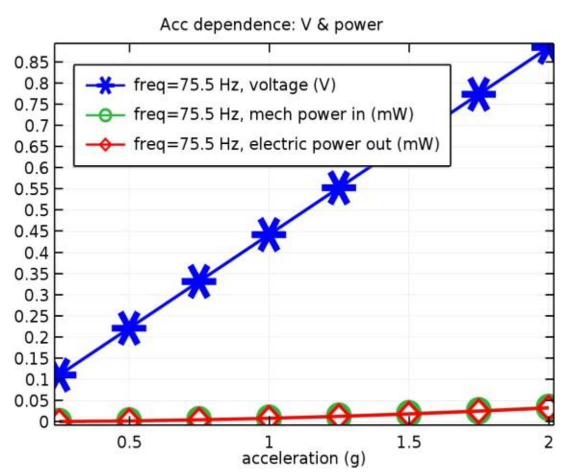

Fig13: Acceleration Dependence: V and Power: Barium Titanate

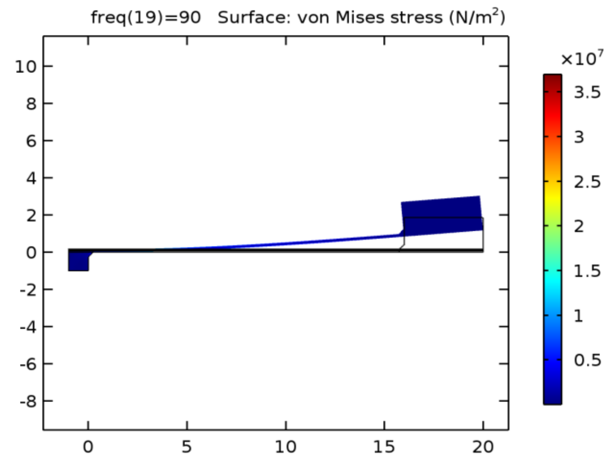

Fig14: Von Mises Stress (N/m^2): Quartz

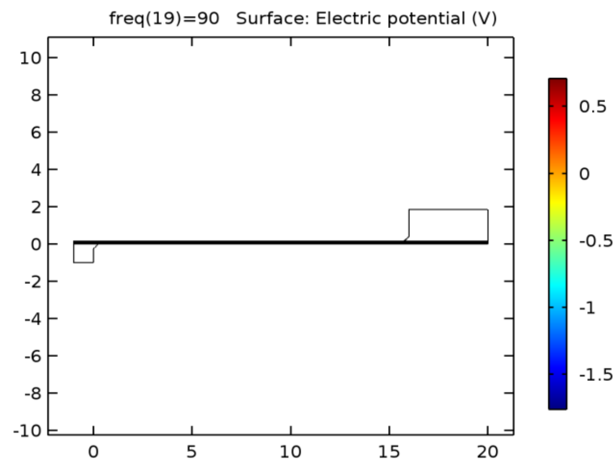

Fig15: Electrical Potential (V): Quartz

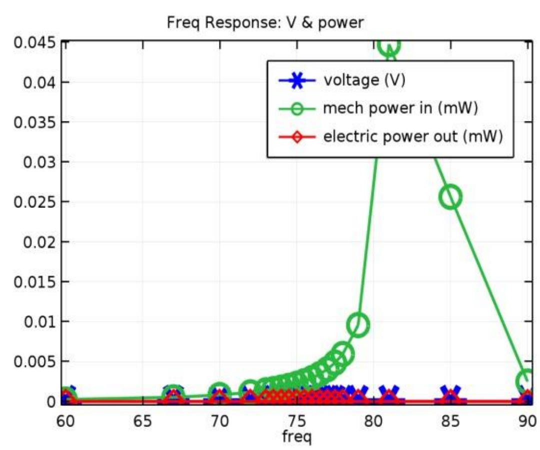

Fig16: Frequency response: V and Power: Quartz

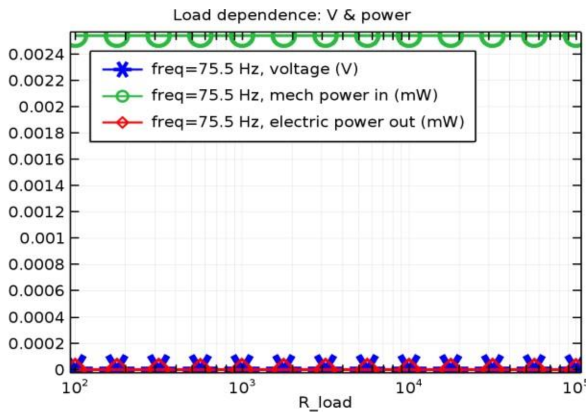

Fig17: Load Dependence: V and Power: Quartz

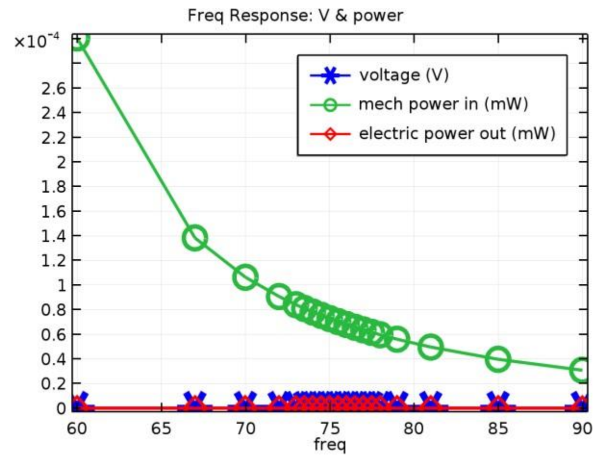

Fig19: Frequency response: V and Power: Rochelle salt

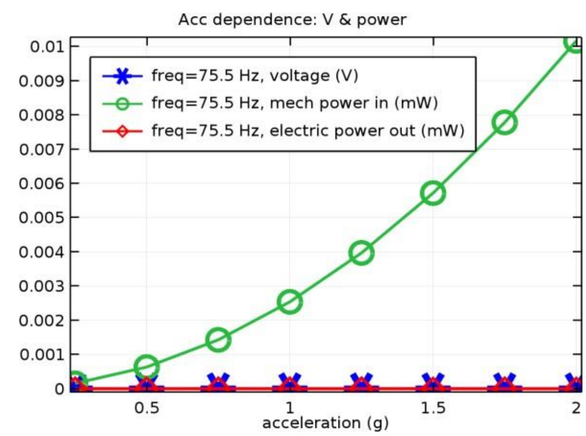

Fig17: Acceleration Dependence: V and Power: Quartz

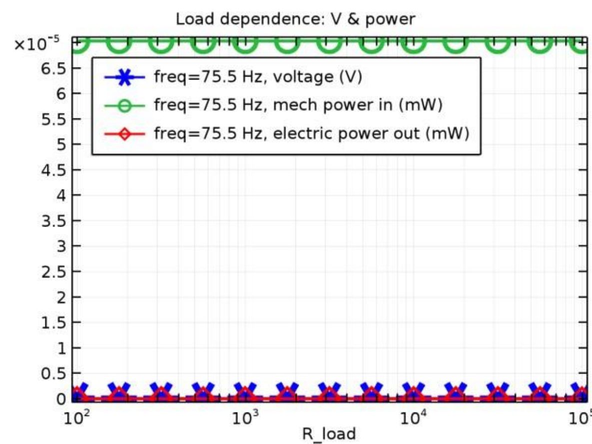

Fig20: Load Dependence: V and Power: Rochelle salt

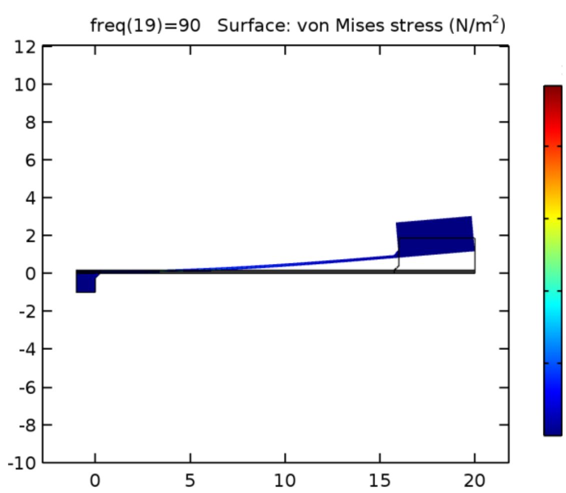

Fig18: Von Mises Stress (N/m^2): Rochelle salt

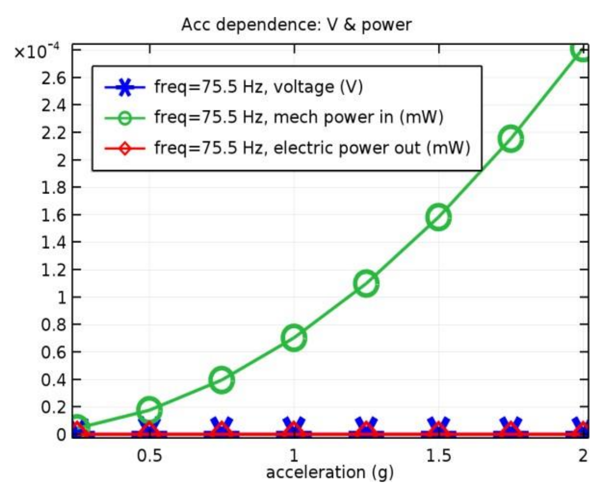

Fig21: Acceleration Dependence: V and Power: Rochelle salt

IV. CONCLUSION

After the invention of piezoelectric effects in the 19th century, there has been a much progress in utilizing them in energy generation. One of them as an energy harvester. This work covers the study of modelled energy harvester with four different piezoelectric materials. The frequency response, Load dependency and acceleration dependency in all four cases are studied. The results here obtained are in good qualitative agreement with those presented in the paper in Ref.1. These miniature energy harvesters which converts the input vibrations into useful electricalenergycanbeusedinsmallportabledevices to power them up and also be helpful in the design of various integrated interfaces in thefuture.

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