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An Approach to Tap Electrical Energy from Ground Vibrations

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Abstract. Electrical Energy Generation has become an important aspect in Power Systems because of incremental demands from citizenry in Electrical Distribution System. Electrical power generation using piezo sensors can efficiently convert unwanted vibrations into direct electricity as a renewable energy source. Blasting operations in mines and quarries always result in ground vibrations, which are of major environmental concern. Studies were carried out in three different limestone mines and two different sandstone formations of coal mines, situated in Southern India, to assess and analyze the seismic energy resulting from the blast induced ground vibrations. In addition, Piezo generator circuits were developed and used in addition to the seismographs at different distances, from short to long range, in all mining locations, to tap the ground vibrations. In total, Electrical energy was tapped from 66 blast induced ground vibrations in limestone formation and 41 blast induced ground vibrations in sandstone formation, using piezo sensor based piezo generators developed. The range of voltage tapped from ground vibrations is up to 4531.42mV in limestone formation and 4277.51mV in sandstone formation.

INTRODUCTION

When the charge detonates in a blasthole under confinement, the chemical energy of the explosive is converted into heat and work to the surroundings with a massive pressure [1]–[3]. Explosion of a spherical charge in an infinite rock medium result in three major zones: (1) Explosion cavity, where explosion energy is liberated and the process is hydrodynamic; (2) Transition zone, where plastic flow, crushing and cracking occur; and (3) Seismic zone, where strain waves travel as seismic waves [4]–[6].

Piezo-gen technique

Piezoelectricity is a phenomenon of electricity assembled in some solid materials (such as crystalline particles, certain ceramic substances, and biological composition for example DNA, bone and various proteins) due to applied physical stress. The electricity resulting from applied pressure is known as piezoelectricity. The word “piezo” derived from the Greek “piezein”, means to press or squeeze, and “electric” or “electron”, derived from “amber”, which is an earliest source of electric charge. Piezoelectricity was discovered in 1880 by French physicists Jacques and Pierre Curie [7]–[9]. Piezoelectricity is the capability of materials for example certain ceramics and crystals, to produce electrical power with physical tension [10], [11]. But, piezoelectricity is not resulted by a variation in charge density on the surface but by dipole density in the bulk.

Application of piezo generator in blast field in the place of seismograph enables to generate electrical energy which is proportional to the seismic energy induced from a blast at given point. Electrical energy generated, if sufficient, can be used for running low powered VLSI systems as ambient power source. It is identified that obtained electrical energy will be in direct proportion to input ground vibration intensity. Therefore, the amount of voltage which is acquired by piezo generator may be calibrated in such a way to obtain intensity of blast vibration with the developed piezo generator model (about 1,000 USD), like conventional vibration monitor which is of higher cost (about 15,000 USD). An attempt has been made in the present research program to assess the seismic energy dissipated at different distances from a blast site and to tap the electrical energy from blast induced ground vibrations.

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DEVELOPMENT OF PIEZO GENERATOR

Basic piezo generator circuit

Experiments were carried out rigorously during development and improvement process of piezo generator circuits to achieve the devised output. Initially, circuits were developed on an electronic bread board and required modifications in the circuit layout were made, regularly, to get optimum output voltage. After getting satisfactory results, the final circuits were developed by incorporating all the required modifications on Printed Circuit Boards (PCBs). After the development process, testing of piezo generator circuits was carried out to get gratified with the obtaining output. Initially, a basic circuit model was developed with simple piezo ceramic sensor, available as a piezo buzzer or piezo disc. Generated electrical potential was having improper frequency with more unwanted ripples (harmonics). Hence, the generated AC voltage was converted back to DC voltage using four germanium based diodes, forming a simple bridge rectifier circuit. Germanium based diodes were used which may further reduce losses in the output (in the form of voltage drop) compared to silicon based diodes. Thereafter, the obtained electrical voltage was stored in a DC Capacitor of 2200ìf, 25V for utilization purpose. Besides, a Power LED having 5V capacity with a switch was connected across the capacitor to discharge higher voltages, if any, in case the capacitor gets fully charged, as a preventive measure of capacitor from damage. A switch control was employed in the circuit, so as to enable the LED to ON/OFF. The magnitude of obtained voltage due to blast induced ground vibrations was assessed using multimeter by connecting the instrument terminals across the capacitor (Figure 1).

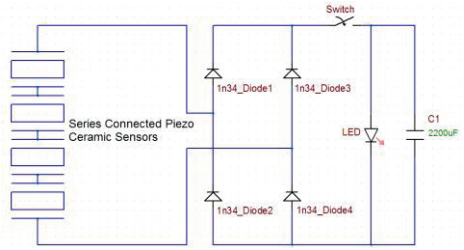

FIGURE 1. Schematic of basic piezo generator circuit developed

Later, to find exact magnitude of the generated voltage tapped from blast induced ground vibrations, the circuit was modified by integrating a microcontroller to piezo sensor along with microSD card (to store generated voltage magnitude values), which is discussed in the following section.

Modified piezo generator circuit

Blast induced ground vibrations were tapped using piezo sensor, analogous to basic circuit model. In the improved version of basic circuit model, piezo sensor was connected to LM-358 (Op-Amp) differential amplifier to convert the input analog data (voltage magnitude value) into digital data (for storage purpose). The LM-358 is having a resolution of 1024 size (digital), means 5V of analog voltage generated due to piezo sensor can be replicated in digital form of up to a maximum value of 1024. Since, the input generated voltage (tapped from ground vibrations) is restricted to 5V using voltage regulator so as to prevent the microcontroller (having a maximum capacity of 5V) from damage. Therefore, output of the Op-Amp represents 1 (Digital) = 4.89mV (Analog). Similarly, all digital values (values stored in microSD card) need to be multiplied by the factor (4.89×10^{-3}) to obtain the actual magnitude of voltage generated from blast vibrations. An LED was also connected in the circuit and LED was set up to glow whenever the blast vibration gets tapped and voltage is generated.

All the above processes of tapping ground vibrations, indication of vibration tapping and voltage generation, storing the value of voltage magnitude into microSD card, were controlled by a microcontroller (ATMega328P-PU). Power was supplied to the circuit through 9V battery for running Microcontroller, Op-Amp and Memory Module. Oscillator circuit to generate clock pulses for finding the next vibration was connected to the microcontroller. Final circuit to find the exact magnitude of electrical voltage generated (tapped from blast induced ground vibrations) was developed by assembling all the components and integrating ATMega328P-PU microcontroller to the piezo sensor along with microSD card (to store output magnitude values).

FIELD INVESTIGATIONS AND RESULTS

Piezo generator circuits developed were placed beside the conventional seismographs for maintaining accuracy in the obtained data. In total, 65 blasts were analyzed for the assessment of seismic energy based on electrical energy generation technique, out of which 10 blasts were carried out in Choutapalli limestone mine, 11 blasts were carried out in Yepalamadhavaram limestone mine, 10 blasts were carried out in Yanakandla limestone mine belong to M/s My Home Industries Limited and 34 blasts were carried out in coal mines of The Singareni Collieries Company Limited, only coal mine in Southern India. Comparison of seismic energy with electrical energy was done to find the amount of strain energy extracted from piezo generator circuit model. Table 1 gives the sample summary of seismic energy and electrical energy. From the field data obtained with basic piezo generator circuit, MATLAB based comparison was made for finding relationship between seismic energy and electrical energy.

TABLE 1 Sample summary of seismic energy and electrical energy

Distance (m)	Scaled Distance (m/ kg)	Seismic Energy (ìJ)	Electrical Energy (ìJ)
100	12.31	2738832.38	3659414.94
110	13.54	1511665.32	3439512.65
120	14.77	1470468.86	3395392.29
150	18.46	6916156.65	3180444.76
160	19.69	5245447.10	6673691.18
170	20.93	8461652.43	9661865.74
184	26.02	1562458.55	3269370.34
178	18.97	9277651.80	10758291.55
188	20.04	4747405.68	6231893.85
200	21.32	366544.54	1158347.87
292	31.13	376992.65	830904.87
150	16.27	10544797.69	12532839.03
209	22.67	2280225.67	2166323.13
234	25.38	1055142.78	937364.56
295	32.00	134876.62	449110.19
696	32.81	513484.49	563178.40
719	33.89	136859.22	479100.78
750	35.36	171645.30	484351.16
800	37.71	557770.65	309872.58
603	28.12	1980472.55	2324044.37
636	29.65	160142.93	800497.02

Figure 2 shows a MATLAB based comparison of seismic energy and electrical energy. Regression analysis was carried out to assess the seismic energy from electrical energy with basic piezo-gen circuit. Figure 3 shows the correlation of seismic energy with electrical energy based on the obtained field results with basic piezo-gen circuit.

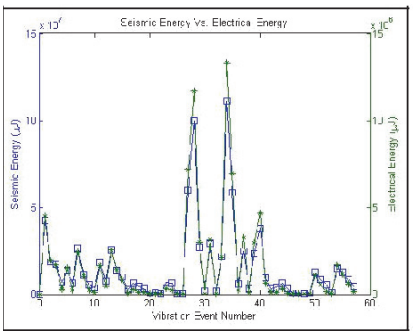

FIGURE 2. Seismic energy versus electrical energy

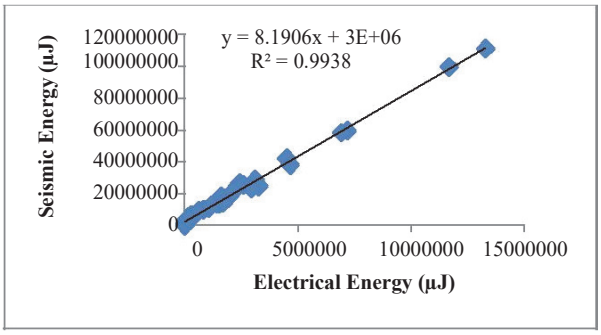

FIGURE 3. Correlation between energies

CONCLUSIONS

Investigations were carried out in two different rock formations, limestone and sandstone, to to tap electricity from blast induced ground vibrations through developed piezo generator. The study has led to draw the following conclusions:

- The seismic waves induced due to blast can be efficiently tapped and converted with the help of Piezo-Gen circuit to obtain useful Electrical Energy.
- The range of voltage tapped from ground vibrations is from 9.77mV to 4531.42mV in limestone, and 415.06mV to 4277.51mV in sandstone rock formations.
- The values of electrical energy tapped from ground vibrations in four different rock formations are up to 1,32,91,238µJ in limestone and 3,84,97,572µJ in sandstone formations. It may be concluded that softer the rock formation, greater will be the electrical energy potential, from ground vibrations.
- Electrical energy generated from the seismic waves was used to run a LED connected across Capacitor and small PCB based circuit (low powered VLSI based circuit or ambient power based load) for finding the intensity of vibrations as the cheapest alternative to the existing conventional seismograph. Hence, the Piezo-Gen circuit has become as a renewable source for generation of electrical energy from blast vibrations and further will be more useful in assessing the seismic energy in blast field.

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