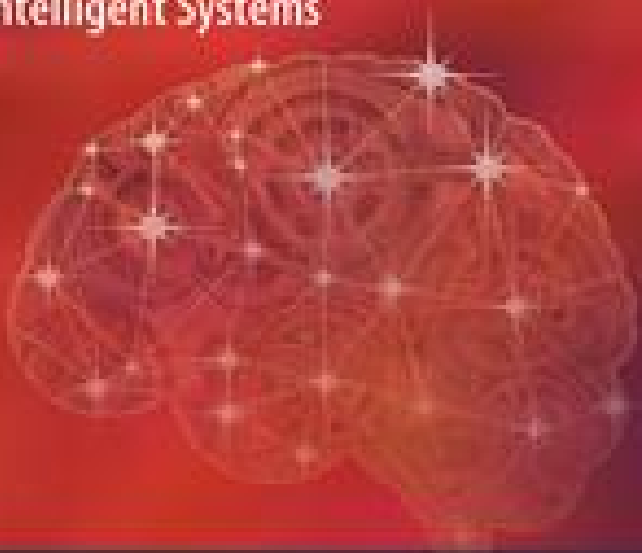
Learning and Analytics in Intelligent Systems



Learning and Analytics in Intelligent Systems

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Extraction of Electricity from Blast Induced Ground Vibration Waves – Case Study

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Abstract. Generation of Electrical Energy has become a basic aspect in Power System because of increase in demand from the electrical community. Power can be generated in a different number of ways. Numerous developments were made in power generation technology for the generation of electricity, but those are all dependent on conventional sources. Generation of Electrical Energy using Piezo Sensors will efficiently convert unwanted vibrations into direct electricity. It is also evident that obtained electrical energy will be in the par with the input vibration intensity from the research studies.

Keywords: Seismic energy · Electricity generation · Piezo electricity · Seismograph

1 Introduction

The detonation of explosive charge in a typical blasthole under confinement releases a pressure in the form of chemical energy. The obtained chemical energy will further be converted into heat along with some force at the surroundings with a massive pressure [1]. Detonation of a explosive charge in a rock mass creates three major regions: (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 [2–4].

The process of detonation in a typical mine/quarry blast is dependent on the end effects involved. Initially, a part of the ruptured rock is closely associated to the strain wave, makes the ground vibrations to flow near the blasted hole. Later, the rock movement will begin due to fracture of rock mass. The energy transfer in to a rock mass will takes place in steps. Primary, development of fractures, also called as elastic and plastic deformation of the rock mass, will happen. Further, heat transfer in the rock mass will occur. Finally, movement of rock mass will be observed due to gases venting through open fractures and stemming [5].

In the earlier research, various monitoring instrumentation tools were used (viz. Vibration monitors, high-speed camera of 1000 fps capacity, and fragmentation monitoring systems), to analyze the dynamics of the blast and thereby the vibration parameters.

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2 Piezo-Gen Technique

Piezoelectricity is a generation of electricity in some solid substances due to application of mechanical stress/pressure. The word "piezo" originated from the Greek literature "piezein" indicates to squeeze or press, and "electric" or "electron", originated from "amber", which is an ancient source of electricity. French physicists, Curie and Curie, had discovered the concept of piezoelectricity in the year 1880 [6–8].

Piezoelectricity is also the competence of solid materials, viz. crystalline, ceramic substances, to produce an electric potential (EMF) due to the mechanical stress or heat on them [7, 9]. Nevertheless, piezoelectricity is not due to change in the surface charge density, however, by dipole density of the material. From the earlier literature, application of 2kN force over a 1 cm^3 volume of quartz material can generate an electrical voltage of about 12500 V [10]. Physical expansion and contraction of a piezoelectric material changes the dipole moment (p = q.d), creating a voltage (Fig. 1).
where,

p = q.d = dipole moment, C-m
q = magnitude of electrical charge, C
d = distance between two poles, m.

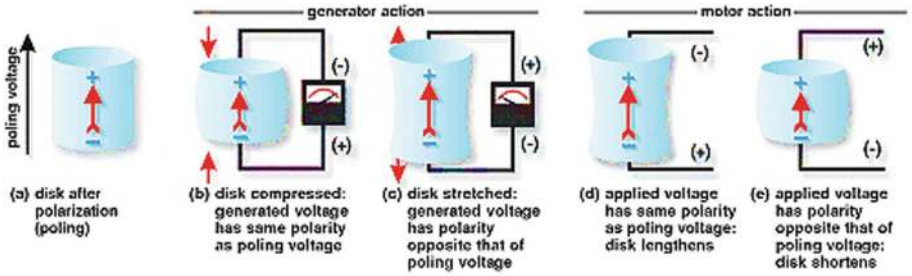

Fig. 1. Working mechanism of simple piezo transducer [11]

3 Assessment of Seismic Energy

3.1 Ground Vibrations Monitoring

During the research studies, the intensity of blast induced ground vibrations was monitored using three units of Minimate Plus, Instantel, Canada. These ground vibration monitors are of 8-Channels. In the four channel instruments, the first three channels record three mutually orthogonal ground vibration components, namely Transverse, Vertical and Longitudinal. The fourth channel records the noise level-using microphone. Minimates with geophones and microphones connected were placed at different distances covering both short and long distances, from the blast site. The vibration events were later transferred to a computer using advanced blastware software. Generally, the dynamics of blast induced ground vibrations were monitored at

specified distances from blast site with a geophone/ground vibration monitor in three mutually orthogonal – longitudinal, transverse and vertical directions. Among all these waveforms, whichever is the peak, that particular absolute value was taken as peak particle velocity (PPV). Seismic energy was estimated for all the signals in three directions using DADiSP signal processing software. DADiSP is a signal processing tool/software, using which shock energy dissipated in the form of waves is calculated. Longitudinal, Transverse and Vertical component of blast vibration event were imported from blastware software to digital signal processing software DADiSP in ASCII format. Fast Fourier Transformation (FFT) was performed subsequently to find the frequency component of the time domain of blast wave signal as blast wave recorded by Minimate Plus and processed by Blastware falls in the category of random progressive signal. The estimation of absolute area describes the intrinsic energy of the blast wave signal distributed in various frequency bands. The energy of the signal x(t) is given by $\int_{-\infty}^{\infty} |\boldsymbol{x}(\boldsymbol{t})|^2 \, dt$ [12].

4 Field Investigations and Results

Blasts were carried out in various mines for the extraction and assessment of seismic energy. Ground Vibration monitors were placed near blast field at various distances to find the impact of blast on nearby structures. Geophones were attached to the ground with the help of Plaster of Paris for proper contact. The developed piezo generator circuits were placed in the similar locations where conventional seismographs are positioned [13]. Altogether, 55 blasts were studied and electrical energy was tapped. In total, 10 blasts were carried out in Choutapalli limestone mine, 11 blasts were carried out in Yepalamadhavaram limestone mine and 34 blasts were carried out in Singareni Collieries Company Ltd.

The following are some photographs depicting obtained electricity from undesirable seismic waves, extracted through the developed piezo-gen circuit in various mine locations (Figs. 2, 3 and 4) [13]. The various seismic data collected at various distances in different blasts are compared with the obtained electrical energy data as shown in the below Tables 1 and 2.

Fig. 2. Extraction of electricity using Piezo-Gen circuit from undesirable blast vibrations at limestone mine

Fig. 3. Observation of obtained voltage from the blast vibrations by multimeter for the assessment of seismic energy

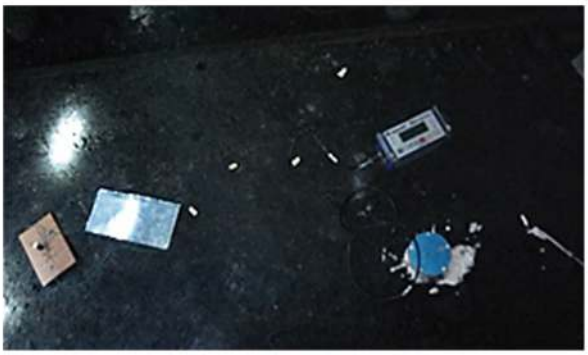

Fig. 4. Piezo-Gen circuit placed beside the geophone underground coal mine

Table 1. Summary of extracted electricity from blasts conducted in limestone mines

Sl. no.	Distance (m)	MCD (kg)	PPV (mm/s)	Seismic energy (MJ)	Electricity extracted (MJ)
1	100.00	30.17	30.60	248254	245232
2	125.00	30.17	22.40	1299398	1202928
3	130.00	30.17	9.40	80993	76343
4	108.00	36.67	6.10	347919	300540
5	120.00	36.67	4.95	49502	42653

Table 2. Summary of extracted electricity from blasts conducted in underground coal mine

Sl. No.	Distance (m)	MCD (kg)	PPV (mm/s)	Seismic energy (MJ)	Electricity extracted (MJ)
1	54.75	2.59	2.67	156122	123185
2	58.28	2.59	1.02	59990	44402
3	67.80	2.59	4.19	7133334	5250688
4	61.85	3.33	7.49	486001	439429
5	63.64	3.33	5.08	61229	33356
6	68.74	3.33	5.08	4500852	3037611
7	61.81	2.96	3.55	405538	320185
8	66.67	2.96	1.52	98359408	81513971
9	73.62	2.96	2.15	3215421	2113462
10	98.28	2.96	1.52	4766935	3618080
11	110.26	2.96	0.64	92201932	71141568
12	88.71	2.59	0.63	84232644	71975752
13	101.08	2.96	0.63	75042381	71675872
14	40.00	3.33	7.37	543915	303769
15	60.00	3.33	6.10	40070581	31248263
16	62.09	3.33	5.08	920512	757222
17	35.00	2.96	5.59	33162509	22980792
18	55.00	2.96	5.72	28491223	21762289
19	61.85	2.96	4.83	1388977	1122289
20	70.00	2.96	4.45	8638939	7328110
21	35.11	3.33	22.22	37634381	17394886
22	45.08	3.33	17.40	7741455	7402328
23	55.07	3.33	7.24	55507124	22103881
24	40.00	2.59	8.38	17768342	11519133
25	50.00	2.59	1.78	33645	18533
26	60.00	2.59	4.70	5883851	4534639
27	60.00	2.96	5.59	30312788	21312155
28	80.00	2.96	6.73	150689	125553
29	100.00	2.96	2.54	5659210	3921140

Typical sample event report and FFT reports generated (Figs. 5 and 6). Seismic energy has obtained from the events recorded using signal-processing tool, DADiSP. Sample of signal processing window is shown in Figs. 7 and 8.

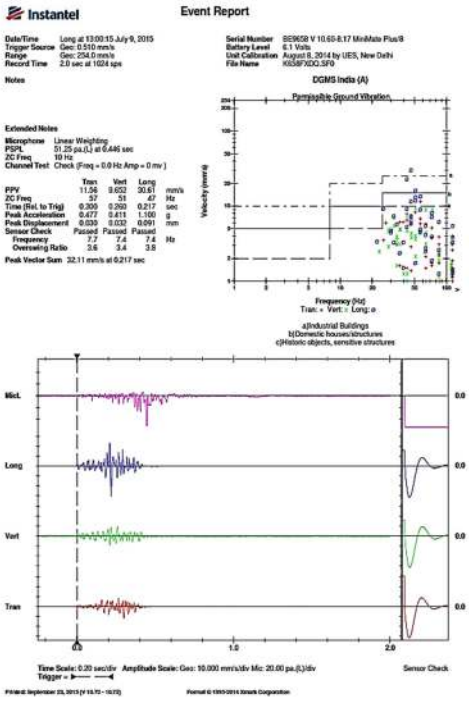

Fig. 5. Typical event report

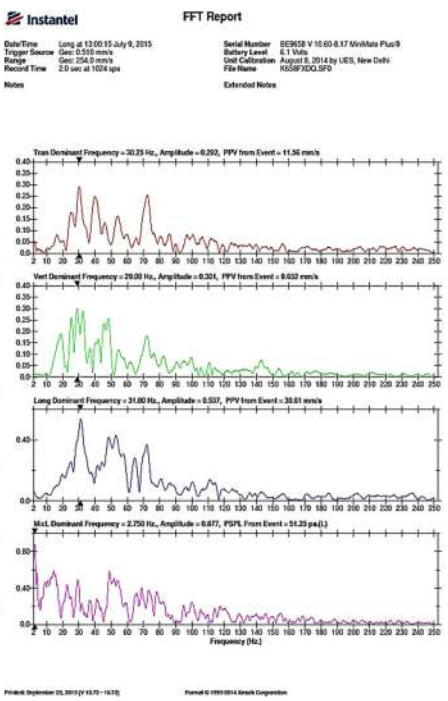

Fig. 6. Typical FFT Report from Blastware

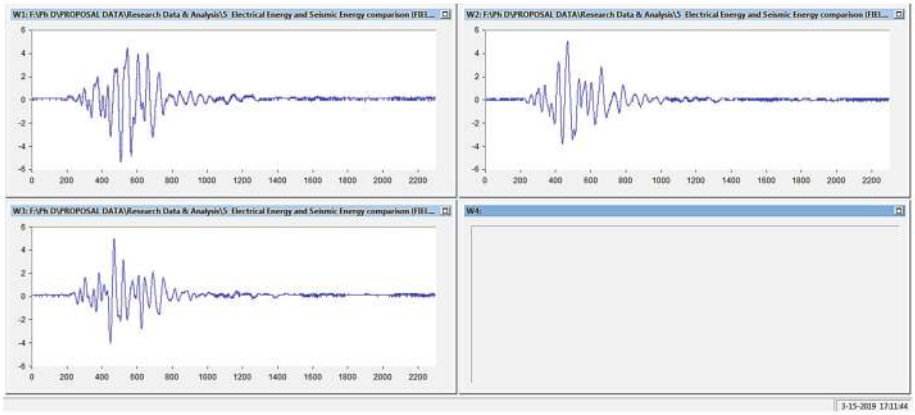

Fig. 7. Sample of signal processing window

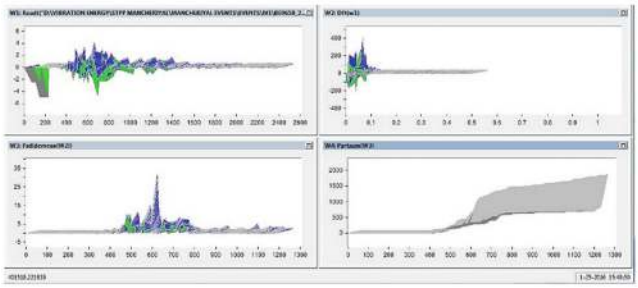

Fig. 8. Estimation of seismic energy

Also, comparison of seismic energy with the generated electrical energy has made to observe the amount of undesirable vibrations which were converted to electricity (Figs. 9 and 10). From the analysis made (Figs. 9 and 10), it is observed that amount of seismic energy extracted in the form of Electricity is 80–90% of the total seismic energy in limestone mines and that is about 75–80% in the case of underground mine locations.

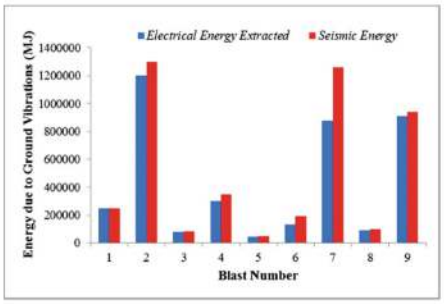

Fig. 9. Electricity extracted in limestone mine

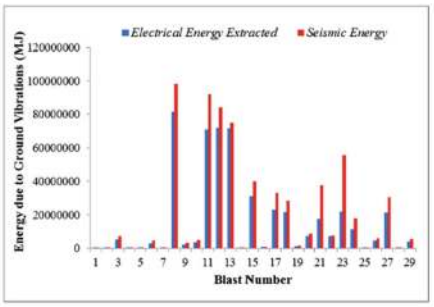

Fig. 10. Electricity extracted in coal mine

5 Conclusions

In the research study, detailed field investigations were carried out to estimate the seismic energy dissipated by ground vibrations caused due to blasting operations, using signal processing approach and to tap electricity from blast induced ground vibrations by piezo generator. Following are the main conclusions drawn from the research study:

- It was observed from previous literature, the amount of explosive energy distributed would be more in seismic form. From the results, it is observed that the amount of seismic energy is being increased with the increase in Maximum charge per delay; hence, the optimal usage for MCD will improve the performance of blast by reducing seismic losses further optimizing explosive utilization.

- From the research studies, it is clear that blast induced ground vibrations may be effectively tapped and converted into useful electrical energy with the developed patented Piezo-Gen circuit (Indian Patent Application No.: 201941002334A, published on Jan. 25, 2019).
- The use of DADiSP for the assessment of seismic energy is an excellent advantage to the industry for doing effective signal processing mechanisms in a simple manner.
- It is also observed that amount of seismic energy obtained in case of limestone mines is much higher than underground coalmines. Therefore, explosive energy losses in limestone mines are more than in case of underground coal mine.
- In addition, it is observed in the case of underground mine that even with the parting more than 70 m between the blast location and monitoring station, the vibrations will travel effectively giving tendency to get more energy loss. In such cases, the application of Piezo-Gen circuit will gives a chance to extract some amount of undesirable blast wave energy.
- Hence, the Piezo-Gen circuit has become as a renewable source for generation of electricity from blast vibrations and further will be more useful in assessing the seismic energy in blast field.

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