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DESIGN OF ENERGY CAPTURING MEDIUM USING PIEZOELECTRIC EFFECT

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ABSTRACT

Piezoelectric materials (PZT) offer a promising approach as an efficient method to reduce our dependence on conventional source of electricity. Besides the power generation through piezoelectric materials being a non-conventional approach, helps to reduce the environmental pollution. The basic requirement for this research arises in the source of pressure generation for electricity production. The works on this research was founded that dubbed "Crowd Farming" can be a useful technique to extract power from piezoelectric materials. In our work, piezoelectric flooring system will be installed in a crowded area, as the source of pressure is to be derived from the footsteps of the crowd applied on the floor. Here the crowd contributes to the power Source. The stress acting on every object either locomotive vehicle or moving human beings on earth exerts a pressure which cause a micro level deflection in the floor.

Keywords: pressure generation, crowded area, power generation.

INTRODUCTION

Energy harvesting is otherwise known as power harvesting or energy scavenging is the process by which the energy is derived from various external sources such as application of loads, power sources, captured and stored for micro and macro levels. The former inculcates non-conventional and renewable forms of energy resources. Moreover the present world is finding new techniques to tackle the problem of scarcity of electric energy.

With the conventional source of generation of electricity being polluting or non-reusable (coal, fossil fuels), the search for a clean, renewable energy has caused a keen interest in the evolution of piezoelectricity. One such non-conventional source is the piezoelectric effect where the electric energy is generated using piezoelectric crystal. Hence the focus got navigated towards non-conventional source of electricity generation. Energy harvesting devices converting ambient energy into electrical energy have attracted much interest in both the military and industrial sectors. Some systems convert motion, such as that of Tidal waves, reciprocating & Rotating motion into electricity to be used by monitoring sensors in the higher power output devices (or arrays of such devices) deployed at remote locations to serve as reliable power stations. The former may be used to enhance to recharging cell phones, mobile computers, radio communication equipment, etc. Thus these energy harvesters help in various fields of engineering for different purposes. In this work we utilized it in the field of electricity generation and storage using crowd farming technique.

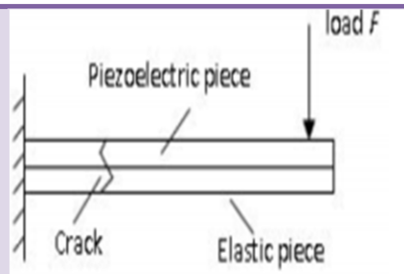
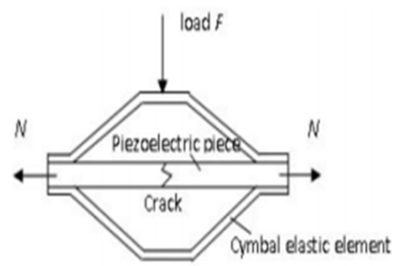
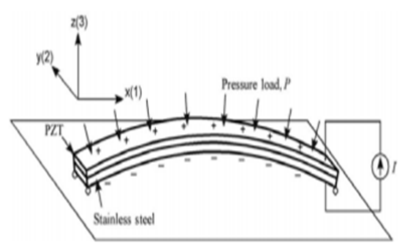
S.NO	TYPE OF ARRANGEMENT	FIGURE	ADVANTAGES / DISADVANTAGES
1	Cantilever type		Simple structure / used only for low vibration harvesting
2	Cymbal type		Produce large output / used for micro harvesting
3	Stack type *		Can be used for large loads Large scale harvesting
4	Shell type		More efficient than cantilever type / used only under torsional loads

Table.1 Showing the various positions of dimensions were piezoelectric crystals are used

This paper consists of usage of the piezoelectric crystals for the power generation by means of applied physical humans and non human loads due to gravitational force.

The piezo model for power generation is shown in figure 1with the crystals placed at the bottom of the footsteps as it is been in the practical application, were the load or force is applied perpendicularly for which the magnetic interaction takes place as a result respective power is produced

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Figure.1 Shows the arrangement of piezo modal

This setup is installed for the repeated cycle of power generation on a power generation which is to be stored in the battery for power storage.

PROPOSED MODEL

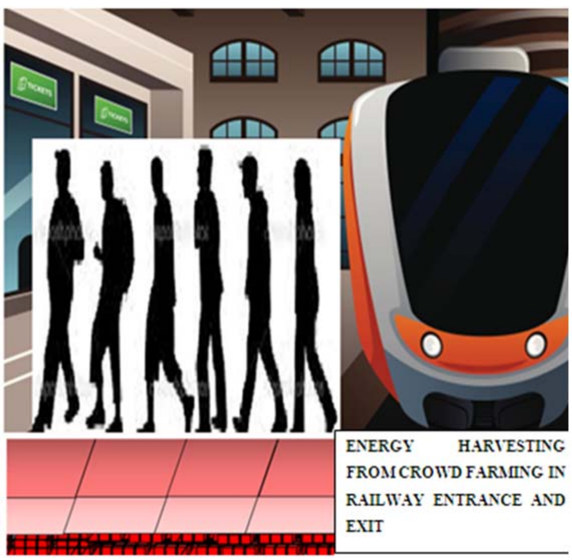

Figure .2 Energy harvesting in entrance and exit of railway stations

As per the above figures1,2 were the practical model and its usage in the real time situation is used for the purpose it has been created.

The flooring setup is made up of mild steel and the setup is welded using arc welding process. The area of top layer of our floor model is 0.240 m^2. The floor setup can be compressed up to 10mm vertically. The factor of safety of the setup under shock is to be 10 to 12. The layer is to be made up of three solid membranes.

- Top layer must be comprised of tiles and to be hard and elastic for transmission of vibrations.
- Middle layer must be comprised of sponge like particle that permit only vibrations in one direction.
- Base must be covered that must protect the Piezoelectric crystals from damages due to heavy loading.

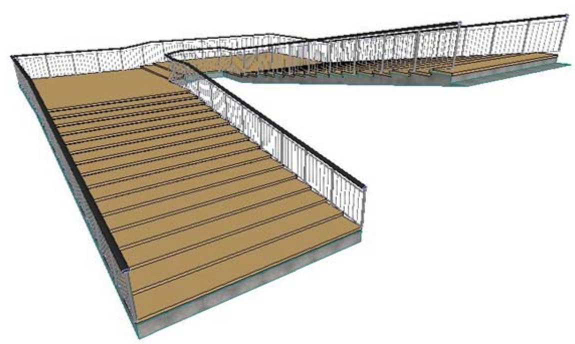

Figure.2 Shows the medium were the piezo crystals are used

Figure.3 Showing the piezo electric generator IC89C52 Microcontroller displaying output of our work

PIEZOELECTRIC CRYSTAL

These crystals are major constituents of modulus of elasticity; they are comparable to that of many metals and goes up to 10^6 N/m² Even though piezoelectric sensors are electromechanical systems that react to compression; the sensing elements show almost zero deflection.

Figure.4 Showing piezo electric crystal

LEAD ACID BATTERY

The batteries have exceptional durability that makes them to keep the charge over long period during needful, Due to zero-maintenance, low cost, long life time with minimum maintenance at ampere hour efficiency and watt hour efficiency, Hence due to these perspective of the battery they can stimulate the rate of power in demand.

INVERTOR SETUP

The former is a device that coverts direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate electrical equipments for the appropriate working.

Solid-state inverters have no moving parts and are used in a wide range of applications, In case of varying power voltages for the current applications that transport bulk power.

It is divided in to two main types of inverter. In one case output modified sine wave inverter is similar to a square wave output except that the output goes to zero volts for a time before switching positive or negative.

Figure.5 Inverter set up

CALCULATION OF ENERGY GENERATION IN CRYSTAL

In actual experiment one crystal yielded 0.9 V at weight of 50 kg
In theoretical calculation,
Voltage generated can calculated using,
$E = g \times t \times P$ Where,
g_{31}=Voltage sensitivity of PZT ($10 \times 10^{-}$Vm)

t = Thickness of one crystal (0.5 mm)
P = Pressure exerted on the PZT crystal
Pressure = Force exerted by human walk / Area of one crystal
Force by human walk is
490.5 N (i.e. 50 × 9.81),

$P = 490.5 / (\pi \times 2.5 \times 2.5 \times 10^{-2} \times 10^{-2})$

$P = 0.249\ MN / m^2$

Thus the Voltage being generated in theoretical calculation is

$E = 10 \times 10^{-3} \times 0.5 \times 10^{-3} \times 0.249 \times 10^{6}$

$E = 1.245\ V.$

CALCULATION OF ENERGY GENERATED IN STEPS

Energy that can be generated in our model per step is as follows,
490.5 × 0.01 =4.9 J/Step
Thus we take half the efficiency since some of them may pass by pressing single foot in rush etc.
4.9/2 = 2.455 J/ Step is generated in one foot step
To calculate the energy generated in kWh following calculations are made,
$2.455\ J/Step \times (0.240\ m^2 / 0.01\ m) \times 1kWh / 3.6x10^{6}\ J$
= 0.0000164 kWh
In case consider 1, 00,000 person is using the floor the energy generated will be, 1.64 kWh/day but the energy storage has some losses in voltage drops thus we also experimented with it.

CALCULATION OF ENERGY STORED

The experiment was conducted for 1 hr duration by applying continuous uniform load was applied on the floor setups according to the desired power output. Thereby the following results are verified and they are tabulated.

SNO	LOAD In Kg	CHARGING TIMING In Hours	VOLTAGE STORED In Volts	TIME REQUIRED TO CHARGE 12 V BATTERY In Hours
1	60	60	0.56	21
2	85	60	0.8	15

Table.2 Calculation of charging time using various load conditions

CALCULATION OF DISCHARGE TIME

Peukert's law expresses the capacity of a battery in terms of the rate at which it is discharged from former. As its rate increases, the battery capacity may tend to decrease.

$$t = H\left(\frac{C}{IH}\right)^k$$

In our work we discharged the 12V battery, 7.2 Ah using 40W bulb and the experimental time consumed for the discharge of the battery took4.5 hours. The theoretical discharge time is calculated using Peukert's law. The following are specification of the lead acid battery used in our work.
t = time consumed by 30W bulb
H =0.36 A
C = 7.2 Ah
I= (40 W/ 12 V) =3.33A
K= 1.44 for lead acid battery
From the Peukert's law

$$t = 0.36\left(\frac{7.2}{3.33*0.36}\right)^{1.44}$$

$$t = 4.75\ Hr$$

Therefore the value of t is 4.75 hours from above formulae calculations and in practical experimented it is 4.5 Hr.

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Electrical equipment used	Charge consumed by Electrical equipments in watts	Time taken by 12 V lead acid battery to discharge in hours
Incandescent bulb	100	1.27
	75	1.92
	60	2.65
	40	4.75
Halogen bulb	72	2.04
	53	3.17
	43	4.28
	28	7.94
CFL (Compact Fluorescent)	23	10.54
	20	12.89
	15	19.51
	10	34.98
LED (Light Emitting Diode)	20	12.89
	14	21.55
	12	26.90
	8	48.23

Table.3 Calculation of discharge time for various electrical equipment

SOFTWARE DESIGN

The part were modelled in Autocad and Were imported to pro-e for 3D modelling To get a clear picture of the model for Better analysis.

Auto CAD MODEL:

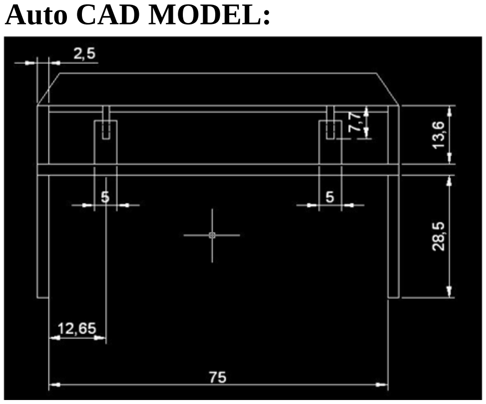

Figure.6 Front view

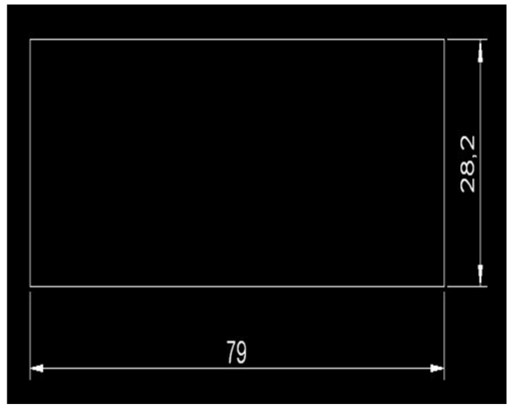

Figure.7 Top view

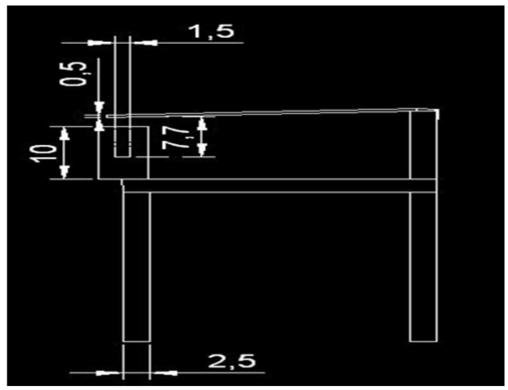

Figure.8 Side view

The various part models are drawn as per the real time dimensions of the staircases, In reaching accuracy towards the results analytically.

PRO-E MODEL

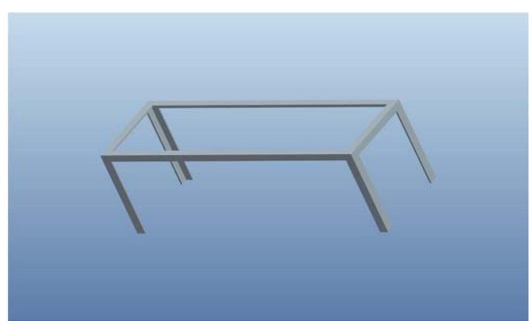

Figure.9 Showing the Frame

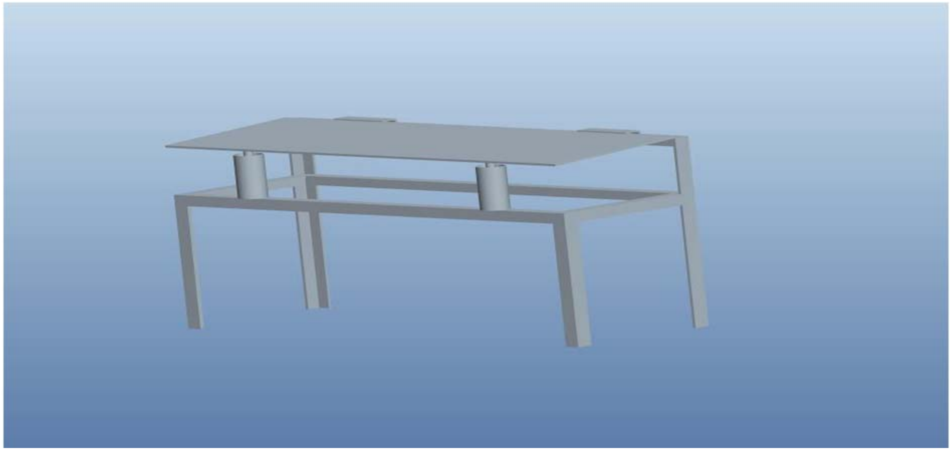

Figure.9 Pro-E model of stand frame and entire model setup

The various diagrams are drawn for various constraints in order to structurally analyze the structure to implement it for practical application.

TECHNICAL PART OF MODEL

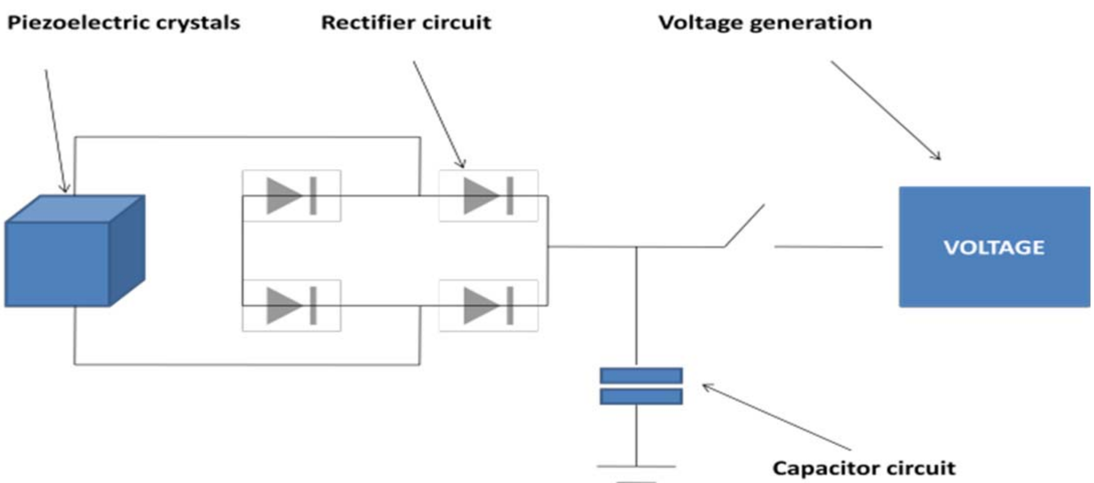

Figure.10 Electrical circuit of our mode

FEA ANALYSIS

The Finite Element Analysis work is carried out in the ANSYS for various structures during different loading that is to be faced by the crystals at minute variations ,which is shown from the below diagrams ,These loads were applied from the survey of the real time application in the payments ,Public areas & Railway stations.

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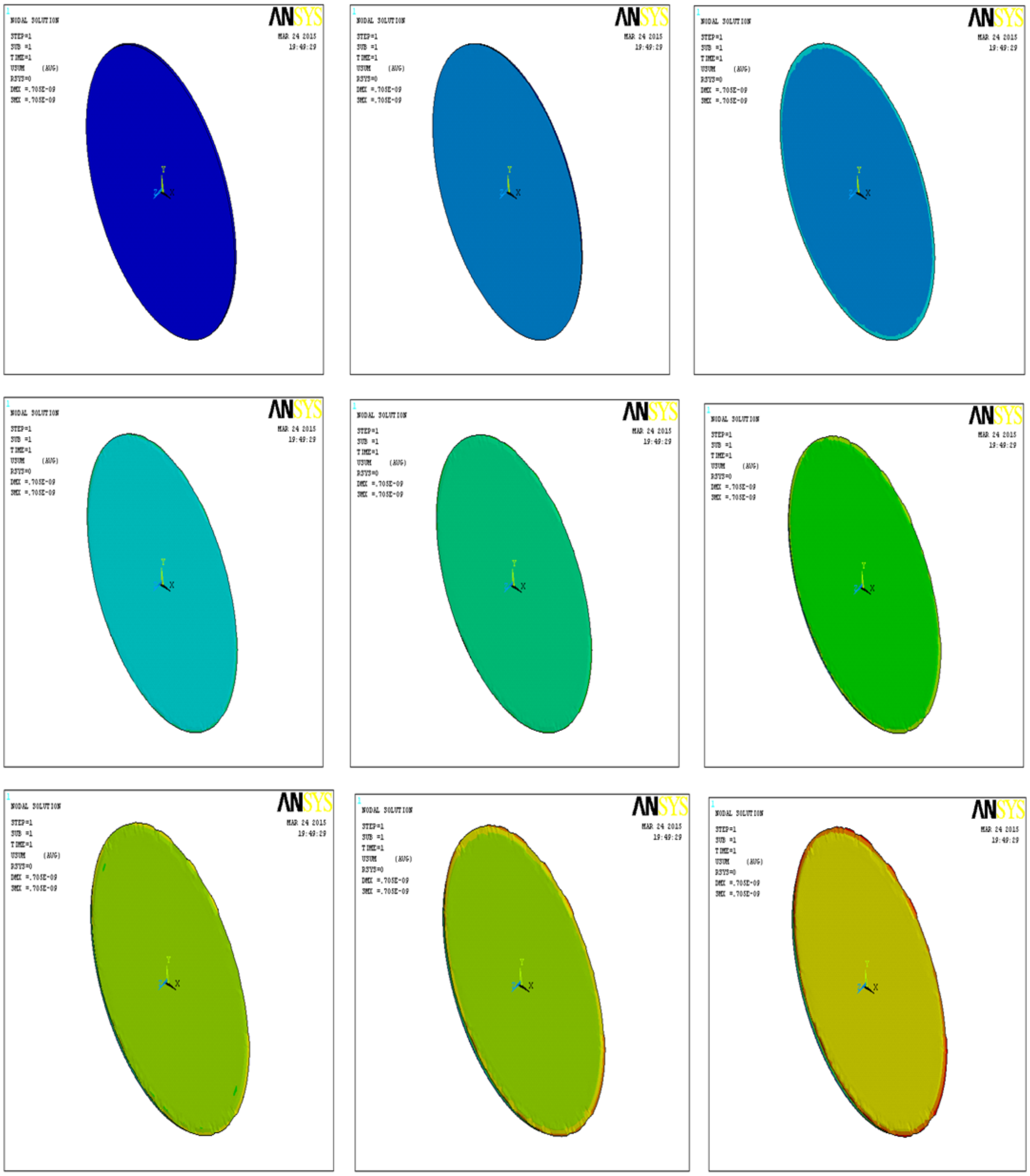

Figure.11 Showing the Structural analysis of the piezo crystals

2. The structural analysis of the crystal where the uniform load is applied thus with (young's modulus) 62×10^{9} and Poisson's ratio 0.28 and the element applied are the Brick8node185 and the pressure value applied on crystal is 784 N. Thus the crystal is within the safety limits.

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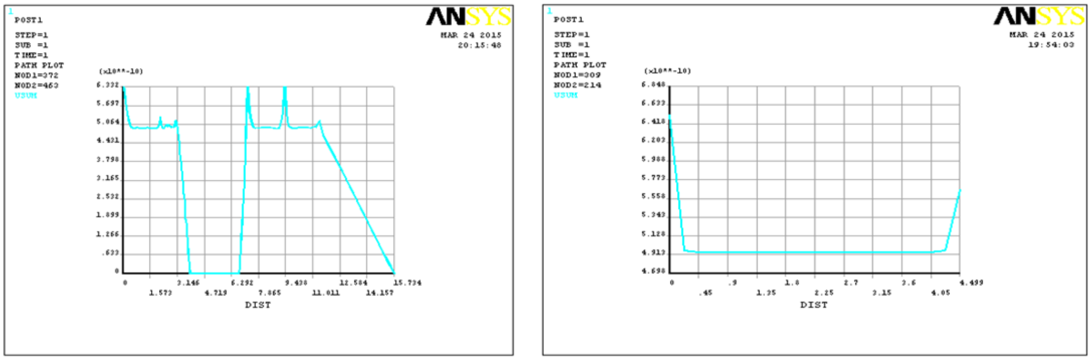

Figure.12 Showing the Displacement node results from ANSYS

1. The displacements of nodes at different stress regions are plotted and the safe limit of piezoelectric crystal with the load 80 kg is analyzed and the crystal is safe, the deformations are within the safety limits. The nodes at the maximum stress level and minimum stress level are analyzed.

CONCLUSION

Thus the flooring is made for withstanding up to 1000N force and can be able to charge a 12 V lead acid battery in 12 hours duration at constant load of 60 kg is being applied over it. This model of piezoelectric generation is completed with good efficiency and further the development of this methodology to railway stations will give greater output. The output is in terms of volts and in 15 minutes a constant load of 85 kg stored 0.2 V in the battery. The storage capacity and time taken to store varies from different batteries according to use. This model can be used in step as well as in the flooring as it able to generate electricity in both cases of design models. Piezoelectric crystals which are able to resist wear and tear produce greater voltage which can be stayed for a fraction of second. These vibrations are in the form of wave, which is of discontinuous pattern. When the voltage developed increases, the efficiency is also increased, as voltage is directly proportional to current (ohms law). The voltage developed here is in the range of 1000 volts. The voltage produced is directly proportional to pressure created and the kind of piezo material used. Internal impedance is in the order of mega ohms. The failure of crystals is solved by adding some other compounds that increases life time as a result synthetic crystals could have greater life span. Thus this model increases efficiency of the crystal life.

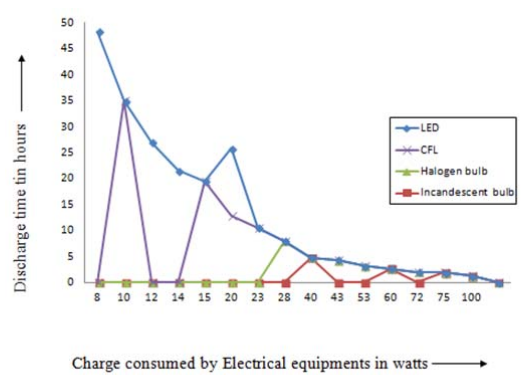

Figure.13 Showing the stacking results

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