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A Hybrid Model of Solar and Piezo For Distributed Energy Generation at Delhi Railway Station

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ABSTRACT

This paper demonstrates the models of Piezo and solar (1KW) cost effective energy systems. Advantages of both systems are compared and a cost analysis of the system is carried on with the existing system. Combination of the two systems become controllable as solar energy alone is an uncontrollable source of energy whereas Piezo energy is totally dependent on stress or pressure. Use of the energy from pv/Piezo is also helpful in reducing our dependency on fossil fuels. Cost analysis of this hybrid model shows that units and system cost decreases as compared to the existing models. Therefore the system is more reliable and environmental friendly.

Keywords: Annual Energy output (AEO), Annualized Cost system (ACS), Cost of Electricity (COE), Cumulative Utilization Factor (CUF)

I. INTRODUCTION

The energy collected from renewable resources like biomass, solar energy etc is called Renewable energy, these are naturally replenished on a human timescale, such as wind, rain, sunlight, waves, tides and geothermal heat[1]. In contrast to other energy resources concentrated in limited areas or location, renewable energy resources cover a wide geographical area and their deployment results in climate change mitigation, significant energy security and economic benefits [2]. A recent review in literature [3], concludes that harmful emissions from greenhouse gas (GHG) emitters are responsible for various environmental changes and disturbances like unexpected climate changes, global warming etc. Therefore a larger liability mitigation value would provide powerful incentives for deployment of renewable energy technologies.

Now a day's renewable energy sources are considered best solutions for wind, solar and hydroelectric power plants as these resources are not limited [4-5]. Also, in case of minimal availability of weather related energy resources (like wind and solar energy) the use of indoor energy harvesting sources are believed to be an important component in the energy reliability and diversity [6]. For this purpose different types of harvestable ambient energy sources including flowing water, electromagnetic waves, waste heating and particularly vibration can be used inside a building [7-8]. Therefore piezoelectric energy generation which is a vibration-based energy harvesting scheme has gained maximum attention because of the ease at which they can be integrated into a system and its capability to capture the ambient energy from surroundings and then directly convert the applied energy in the form of strain into usable electrical energy.

In the piezoelectric (PZ) effect, electricity can be generated when piezoelectric materials are mechanically deformed. When a certain solid material for example biological matter or crystal is pulled or pressed electric

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charge is generated across it, this effect is called piezoelectric effect where the conversion of mechanical stress into electrical charge takes place [9].

Solar PV technology is widely used all over the world. This method uses photovoltaic (PV) effect to generate electrical energy through the conversion of solar light into direct current (DC) electricity [10]. This technology employs solar modules comprising a number of solar cells consisting of photovoltaic material. The two broad classifications of Solar PV applications are: standalone (off-grid) system and grid connected system [11].

Komali Yenneti [12], et.al, explains the temporal evolution of policy and institutions responsible for solar energy development, after critically reviews the political economy of grid-connected solar energy in India, It indicates that the implementation of a range of programs, policies, and institutions plays a vital role in India's solar energy portfolio on sector from less than 10 MW installed capacity in the 2000 to 3000 MW in 2014.

Sreenath Sukumaran [13], et.al, states that the atmospheric concentration of carbon dioxide (CO2) has been increasing and it remained above 400 ppm throughout the year 2016 for the first time. In the emission of Greenhouse gas the aviation industry is the main contributor. In this regard, aviation industry as a whole and airports in particular are trying to limit their carbon foot print. A suitable solution is to replace the conventional electricity energy consumption of airport with clean energy sources. Solar PV route is nonpolluting source of electricity for large generation need larger area. Since vast areas are mandatory in airport as buffer zones, this land can be effectively used for utility scale solar PV plant. A 2 MWp onsite solar PV power plant is proposed for Raj Bhoj International Airport (RBIA), India

Tahira Bano[14], et.al, deals with Leveled Electricity Cost (LEC) calculation of five Solar Photovoltaic power (SPV) plants having different capacities 1MW, 5MW, 10MW, 25MW and 151MW. The calculation has been performed from the power generated data of the year 2014. The effect of different parameters like inflation rate, interest rate, deprecation time (plant life) and cumulative utilization factor (CUF), on LEC have been analyzed. A comparative study of the plants is done by varying these parameters. Maintenance and operation cost was supposed to be 1% of the capital cost.

Abhnil A. Prasad[15], et.al, provides a systematic quantitative analysis of the complementary characteristics of solar and wind resources on the Australian continent. As such, wind power density and surface incident shortwave flux are derived from the hourly Modern Era Retrospective Analysis for Research and Applications (MERRA) product for the entire continent for the period from 1979 to 2014. It was found that the temporal synergy between solar and wind resource is maximum along the western and southern coast of Australia. Tasmania, south-eastern (parallel to eastern Great Dividing Range), and northern regions (Cairns and Kimberley Plateau)

Akash Kumar Shukla [16], et.al, demonstrated a design to provide uninterrupted power supply for a hostel building using rooftop stand-alone solar PV system. It briefly explains each component of the rooftop standalone solar PV system and its performance analysis using simulation software. Detailed analysis for cost including maintenance and installation of the system during its life span is also done.

Rahnuma Rifat Chowdhury [17], et.al,They investigated the feasibility of applying piezoelectricity for conversion of roadway mechanical vibrations into electricity. They also investigated that solar concentrators can be practically employed to considerably enhance the output power of the solar panel.

Pankaj Aswal [18], et.al, was interested in determining if the technology has the potential to generate electricity with performance, reliability, and cost projections that are comparable to existing or emerging renewable energy

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sources. The objective of the project was to provide a vibration and displacement in the light and heavy motor vehicles. And the same vibration is passed to piezoelectric material which is present under the road. Piezoelectric-based energy-harvesting technology as applied to the generation of electricity from roadways.

Lukai Guo et.al [19], was interested to determine harness renewable energy in the transportation sector, research on the application of thermoelectric and piezoelectric effects in energy harvesting pavements has proceed significantly over the last few years.

II. SIMULATION SETUPS

The architecture of solar energy (PV) module is as shown in Fig. 1. The V-I characteristics of the simple PV module, PV module at different radiations and temperatures are as shown in Fig.2, Fig.3 and Fig.4 respectively.

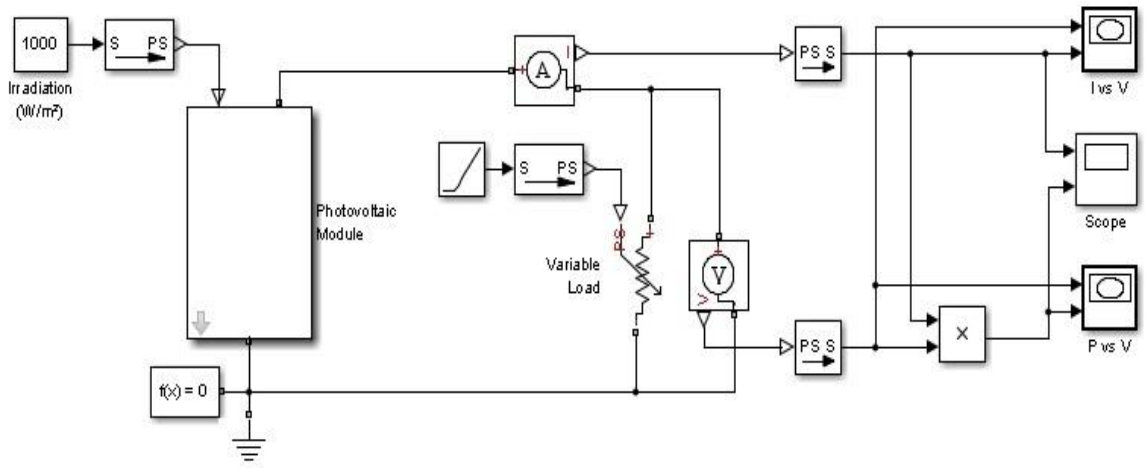

Fig. 1 Matlab Simulink model of PV module

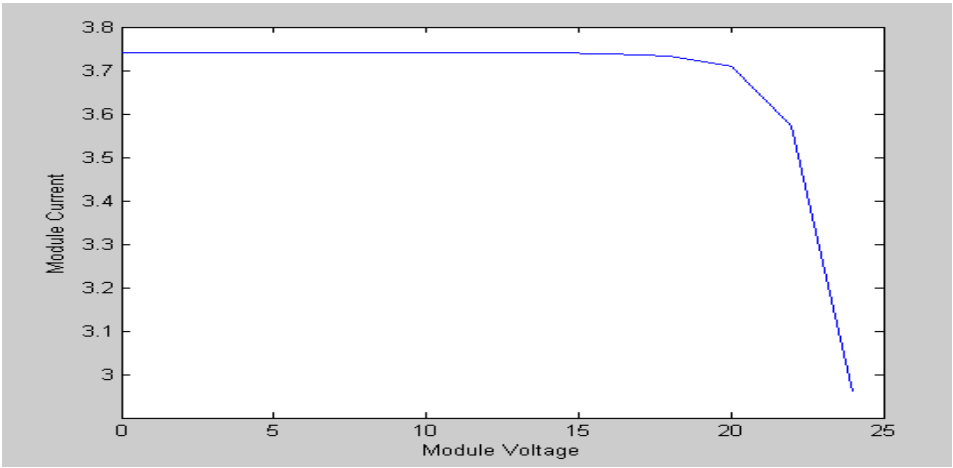

Fig. 2 V-I curve of solar cell

I = IL-I0 (e^q (V+IRS)/nkT),

Where, IL = Photo Current

I0 = diode saturation current

RS = series current

Q = charge of electron

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K = constant

T = temperature

N = number of PV module

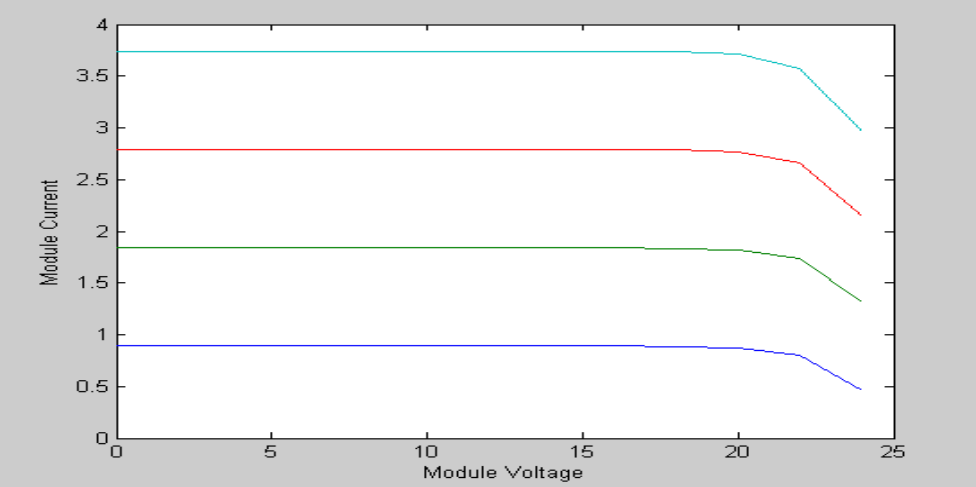

Fig. 3 V-I curve of solar cell for different radiation of the sun

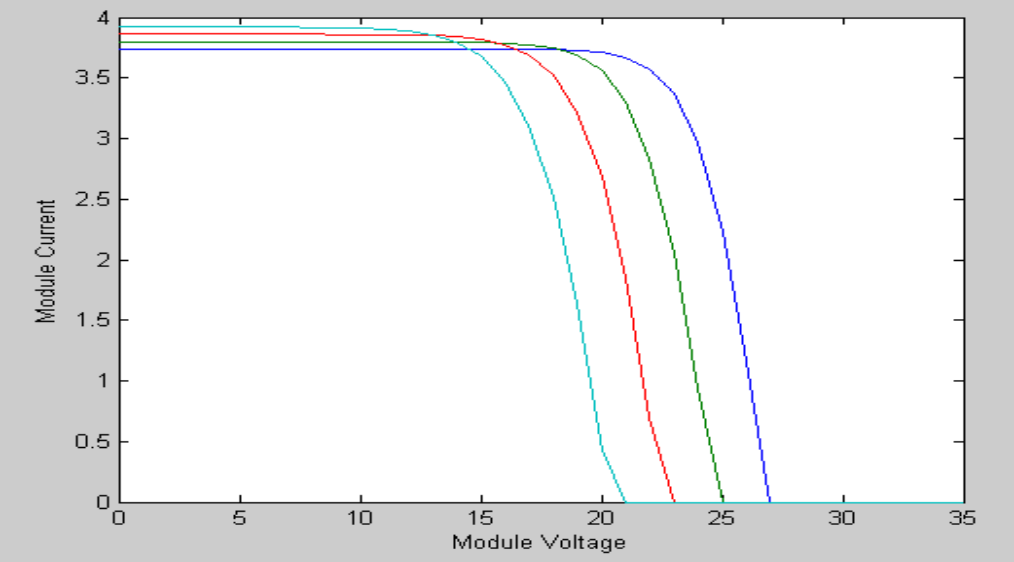

Fig. 4 V-I curve of solar cell different temperature

Fig. 5 shows the architecture of piezoelectric model.

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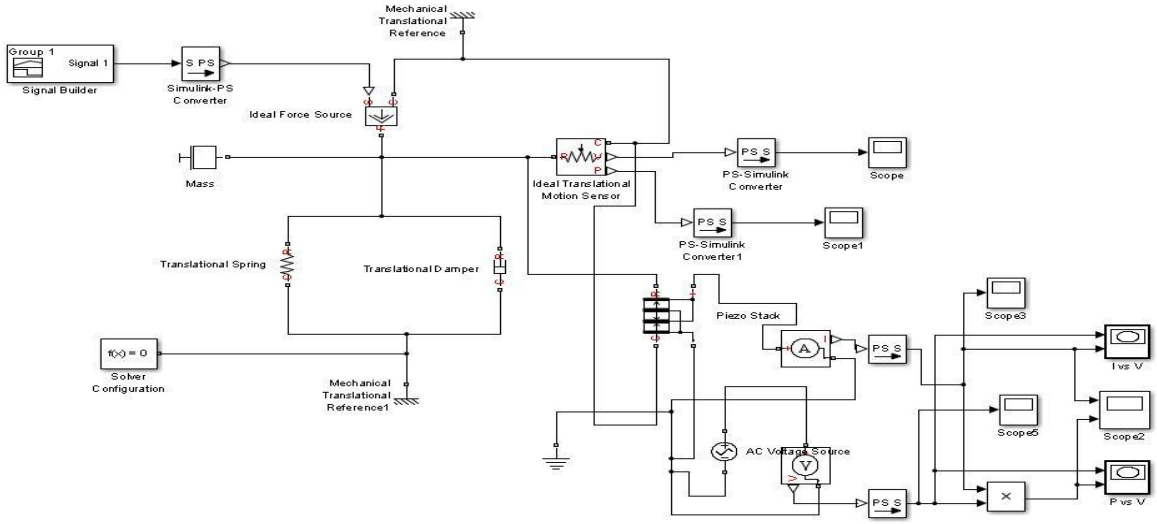

Fig.5 Simulink model of Piezoelectric

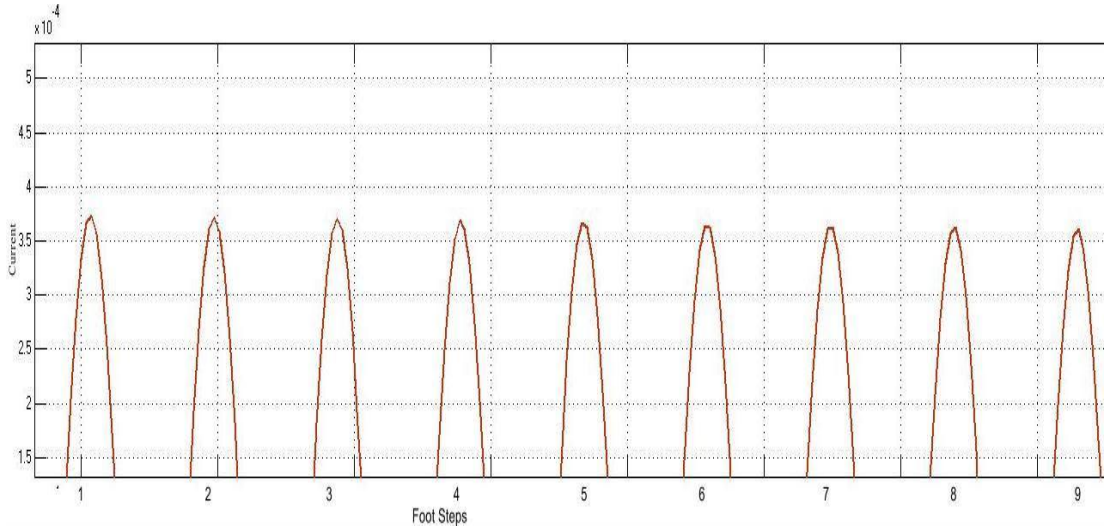

Fig. 6 Current generation on footsteps

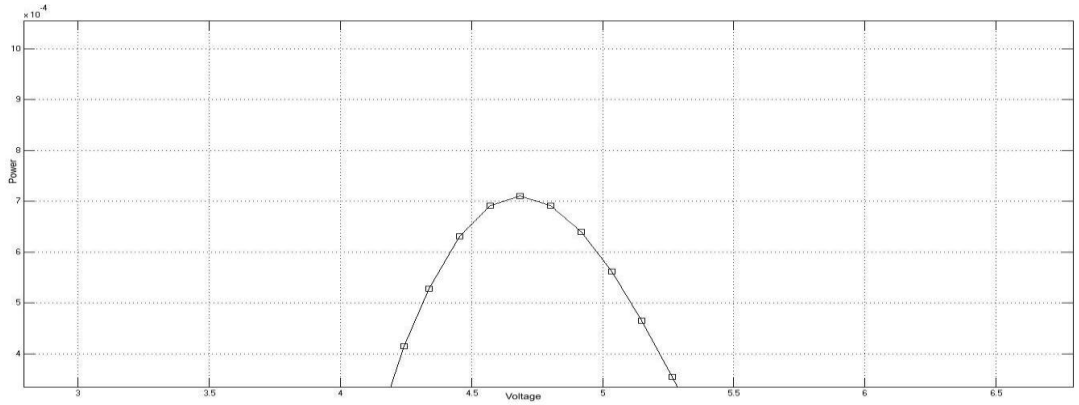

Fig. 7 P-V graph

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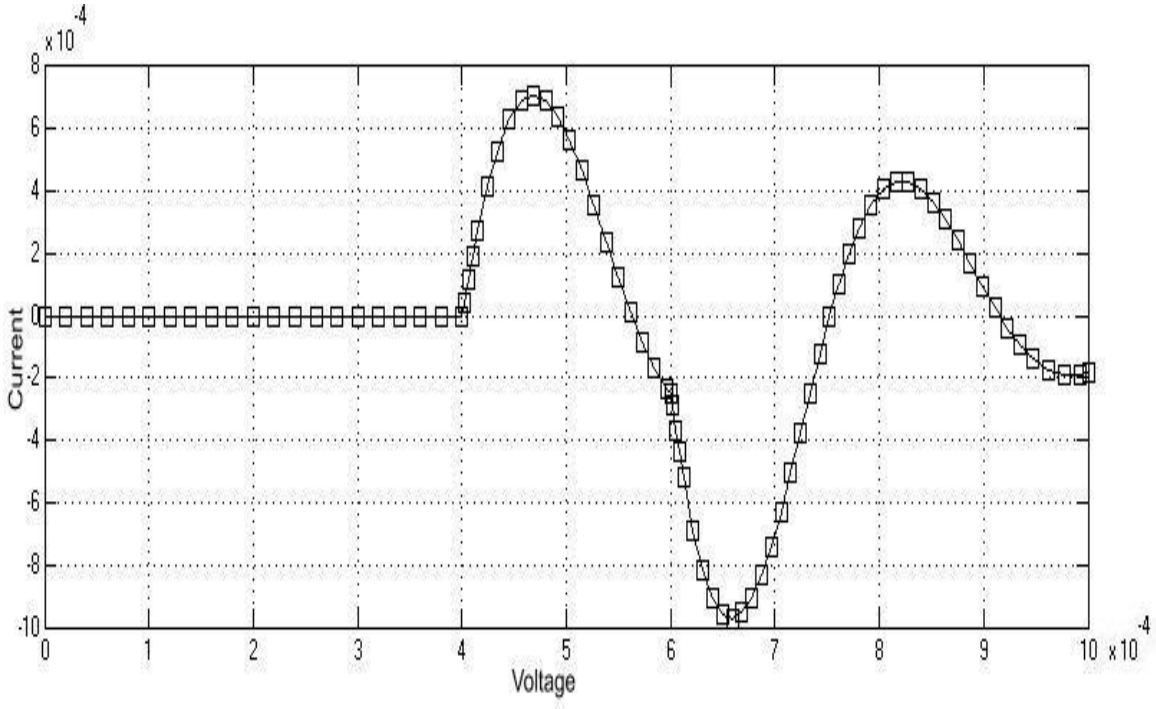

Fig.8 V-I graph

III. RESULTS AND DISCUSSIONS

3.1.Cost analysis of solar plant of 1KW

Table1.Units generated annually by solar plant of 1kw

TYPE	**Annual Generated Units**
Solar plant (1KW)	1664.4

In this table we have discussed the annual unit produced by solar plant of 1kw.

Where 1KW= (Size of System in KW*CUF*No of days*No of hours)/100.

CUF for India Is = 19%

Table2.specifications of solar model

System Size (kW)	1 KW
Annual Production (kWh)	1664.4 Units
Capital Cost	50000 INR
Lifespan	25 years
Annual Maintenance Cost (1% of Capital Cost)	500 INR
Interest Rate (%)	12.75 %

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Table3.annualized cost of solar model

MODEL	Cost in Rupees
Annualized Capital Cost	6385
Maintenance Cost	500
Total Annual Cost	6885

Annualized capital cost = (Asset Price*Discount Rate)/1-(1+Discount Rate)$^{-\text{Number of Periods}}$

3.1.1 per unit cost of solar system

AEO – annual energy output

ACS – Total Annualized Cost

COE - Cost of Electricity (Rs/KWh)

COE = Total Annualized Cost (ACS) / annual energy output (AEO)

= 6885/ 1664

= 4.13 Rs/ unit

3.2 Cost analysis of piezoelectric model

Table4. Parameters of piezoelectric tile

Parameter	**Value**
Size of Tile	1.6m * 0.45m
Lifespan of Tile	5 years
Cost of Tile	$7.6
Energy Generation	7W at 12V DC (average human foot step)
Recyclable	100%

Table5.Delhi railway station-data

Parameter	**Value**
Daily Pedestrian	5 Lakh (per day)
Walk of 1 Pedestrian (from Parking to Platform)	1KM
Distance covered by 5Lakh Pedestrians	5 Lakh Kilometers

Table6.Parameters of delhi railway station

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1foot step	2.5 feet
1Km	3280.84 feet
5 Lakh Km	1640420000 feet = 656,168,000 footsteps / day

In this table we have given the specification of Delhi railway station.

Table7.Annual energy calculation

Parameter	Value
1 foot step is kept for	.6 seconds
1 foot step production	7 W (for .6 seconds)
Energy = Power(Watt) * Time (Seconds) = 7 * .6 = 4.2 Joules	
Energy	4.2 Joules per foot step
1foot step	4.2 Joules
656,168,000 footsteps / day	2.76 Giga Joules / day
Annual Energy Generation	2.76 * 365 = 1005.90 GJ
1 GJ	277.78 KWh
1005.90 GJ	279418.9 KWh = 279419 units

In this table we have calculate the annual energy of Piezo electric.

Table8.Model specifications

Area Coverage	1Km * 5 Meters = 5000 m^2
Size of Tile	1.6m * 0.45m
Area Covered By 1 Tile	.72 m^2
Tiles Required	6950 Tiles

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Cost Of 1 Tile	$7.6
Cost Of 6950 Tiles	$ 52,820 = Rs. 34,86,120

In this table we have discussed the specification of Piezo electric model

Table 9.Details of model

Tiles Required	**Capital Cost (In Rs)**	**Annual Maintenance Cost (1% of Capital Cost)**	**Lifetime (Years)**	**Interest Rate (%)**	**Annual Production (units)**
6950	34,86,120	34,861	5	12.75	2,79,419

Table10.Annualized cost of piezo model

MODEL	Cost in Rupees
Annualized Capital Cost	9,87,734
Maintenance Cost	34,861
Total Annual Cost	10,22,595

In this table we have discussed of annualized cost of Piezo model

The annual cost of controlling resource over its whole life. For capital budgeting decisions, Comparable annual cost is generally used by firms. Equivalent or comparable annual cost is calculated as:

$(\text{Asset Price}*\text{Discount Rate})/1-(1+\text{Discount Rate})^{-\text{Number of Periods}}$

Where

Asset Price= Capital cost of the component

Discount Rate= the rate at which bank provides the loan

Number of periods= lifetime of component

Annualized cost of the Component= Equivalent Annual Cost + Maintenance Cost

3.2.1 Economic impact

COE = Total Annualized Cost (ACS) / annual energy output (AEO)

= 10, 22, 595 / 2, 79,419

= 3.66 Rs/ unit

AEO – Annual Energy Output (Sum of energy produced by system over a day * 365 days)

ACS – Total Annualized Cost

COE - Cost of Electricity (Rs. /KWh)

The investigation exposed that the furnishing of the Piezoelectric tiles would assign to environmental awareness by green energy generation and improving sustainability, and the amounts of electricity harvested over their 5

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year lifespan could recover the costs of initial purchase, transport, installation, maintenance and disposal of the tiles.

Table11. Per unit cost of Piezo electric model

Parameters	PIEZO MODEL	EXISTING MODEL(GRID)
COST PER UNIT (in Rs.)	3.66	7 (approx.)
Units Consumed	1000	1000
Bill	3.66 * 1000= 3660	7 * 1000 = 7000

In this table we have discussed the per unit cost of Piezo electric model

3.3 Comparison of hybrid model with existing model

The table shown that the comparison between the hybrid model of solar and Piezo electric model with existing model.

Table12. Comparison of hybrid model of solar and Piezo electric model with existing model.

Parameters	**PIEZO+SOLAR MODEL**PIEZO+SOLAR	**EXISTING MODEL**
COST PER UNIT (in Rs.)	(3.66+4.13)/2 =7.79/2=3.895	8.40
Units Consumed	476280	476280
Bill	3.895 * 476280 = 1855110.6	8.40 * 476280 = 4000752

IV. CONCLUSION

This paper shows comparison of a hybrid model with the existing models and is analyzed that this hybrid model is much more reliable and cost effective. Also various analysis of the system reveals that this system consumes lesser number of units annually, which makes it convenient to be used at various places commercially. This model uses renewable energy resources for electric generation, which is required now a day.

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