Household Energy Conservation Using Piezoelectric Tiles and Solar Tracker

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Abstract. For a growing nation like India, energy criterion determines the development of the country. The demand for energy in our country is exponentially growing. Conservation of energy could be the best solution to increased energy demand. In this paper, we use piezoelectric tiles and solar tracking systems in the household requirements for energy conservation. The piezoelectric tiles convert surface stress into electrical energy and solar tracker tracks the sun whole day and convert heat energy to electrical energy. We save that energy in the battery for household purposes for future uses. Here we use IR sensors and LDR sensors in various places in the house such as the kitchen, the entrance of the bathroom, house entrance, etc. When these sensors sense, the light turns ON when we enter or in the bathroom, kitchen, house, hall, etc. The LDR sensor is most commonly used as light-sensitive devices to indicate the absence or presence of light or to measure the light intensity. Depending upon the light intensity the lights will turn ON or OFF condition. If it is daytime, the LDR sensor senses the higher light intensity, so the lights will not be turned on even if the IR sensor senses. This simple model based on sensors is designed to cut energy consumption. The proposed system as energy harvesting and energy conservation is subdivided into two stages. In this paper, the survey on Indian electricity consumption and weight analysis of piezoelectric tiles is conducted.

Keywords: Piezoelectric Tiles, Solar Tracker, IR sensors, LDR sensors.

1. Introduction

The energy is the number one key metric in a nation's growth. In the global society, a huge amount of energy is harvested, distributed, transformed, and used daily. Modern technology requires an enormous amount of electrical energy for its different functions. Electricity generation is the world's biggest pollution source. On the one side, growing concern over the space between mass demand and electricity supply for masses have highlighted the exploration of alternative source of energy and their viable use. Fossil fuels account for 85 percent of energy production. Fossil fuel resources are limited, and their use leads to global warming due to greenhouse gas emissions.
World gross electricity generation rises from 20.2 trillion kWh to 39.0 trillion kWh in 2010 to 2040 by 93 percent. The electricity supplies a growing share of the total energy need of the world, and the fastest-growing form of energy supply in the world [8]. Each year, electricity demand will rise following prosperity improvement, population growth, and growth in the economy. The increased need for electricity has brought force on all-natural resources to bear on their availability and costs.

Solar energy is one of the renewable energy sources with the most promise and rapid growth. This fundamental technology is intended to change expensive fossil fuel consumption by switching free, sunlight into renewable, clean electricity. Lots of advanced studies in this area are performed using improved quantification and analytical technology to reduce costs per watt, improve yield, increase adoption, and also try to improve the market through innovational applications. The piezoelectric effect is a special property which lets materials to convert mechanical energy into electricity in the opposite direction, and electrical energy into mechanical energy. Human walking, rain, wave, tide, and wind can be a stimulus for piezoelectric materials. This effect may or may be imparted to an existing non-piezoelectrical material [9]. But it is not possible to make all materials piezoelectric, only some crystal ceramics can turn piezoelectric.

Piezoelectric tiles and solar tracking system are used in this paper for the renewable energy, which is implemented to collect the energy from the sun and pressure produced while walking on the tiles, save it in a battery, and convert this energy to an AC. It makes energy use as a supplementary power source or as an independent source of power in standard-sized homes. The system is intended to respond in the shortest possible amount of time to its environment.

2. Literature Review

The author V. Poulek et al., [1] provided a comprehensive solar tracker system design with a 360-degree tracking angle. The concept presented here is a single-axis tracking system. They become inoperative when the solar irradiation is not great enough to make sufficient variation in luminosity. These sensors should be noted to have a maximum range of narrow tracking fields of 180. This has had its performance limited. The author Sandeep Kale et al.,[2] developed energy harvester through the use of human footsteps among different energy sources. When applied to the sensors in the form of an ambient vibration or direct pressure, the generation of electrical energy depends on different factors such as the sensor's electromechanical coupling coefficient, transducers, number of piezoelectric, piezoelectric the amount of load applied, and also the arrangement scheme.

Author Xiaofeng Li et al.,[5] present the potential use of a traded piezoelectric energy harvester. The design result showed that for the proposed optimized tile pavement model, 1.1 MW h / yr is determined as the total annual energy harvesting potential. The author Tsung-Tsi Wu et al.,[3] an energy harvesting floor is developed with the piezoelectric material which converts the energy from the extra motion of walking into electricity. Electricity produced is then used to operate the module of the wireless transmitter to identify the user's present position.

3. Survey Of Electricity Consumption In India

As of 2000, electricity consumption [6] has tripled in Indian homes. The percentage of electricity-access households has increased from 55 percent in 2001 to over 80 percent in 2017. Indian households consumed an average of around 90 units (kWh) of electricity per month is sufficient to run small kitchen appliances, four ceiling fans, four-tube lights, a TV, a refrigerator with typical Indian use times, and efficiency levels. It also represents three-fourth of the average monthly household consumption in China, one-tenth of that in the US, and one-third of the average worldwide.

Between 2004 and 2015, low-initial household electrification states like Bihar, Assam, Jharkhand Chhattisgarh showed high growth in their residential electricity consumption (about 11
percent -16 percent). Higher-household electrification states such as Punjab, Delhi, Tamil Nadu, Haryana grew at lesser, but still substantial, rates (6 percent -8 percent), with the large absolute numbers.

Homes in India, electricity consumption – from ceiling fans, lights, refrigerators, televisions, among others – have raised 50 times between today and 1971 (see Figure 1), although India's household energy consumption per capita is not more than a third of the world average. The household electric power is now outstripping development in industry, agriculture, and commerce. Residences in India, which use advanced energy services for clean cooking, cooling, access to media, and lighting, are forecast to account for 85 percent of the country's floor space by 2050. The residential sector uses around 25 percent of total present power consumption in the country (with the growth of nine percent in 2015-2016) at the time when one-fourth of the residences don't have electric power connection and they facing continual power reductions.

An average monthly electrified household consumption can be estimated using CEA data with the census data and rural electrification data in various states and we validate this against State regulatory tariff orders and discover impressive results (see Figure 2).

The consumption of electricity within states also exhibits significant household inequity. According to surveys carried out by the National Sample Survey Office (NSSO), around twenty percent of electrically powered households consume not more than 30 electric power units a month, while around eighty percent consume less than 100 units a month. In the countryside, less than 100
units consume 90 percent of electrified households. This distribution varies according to states. Around 15 to 20 percent of all the households consume not more than 30 units per month in most states. Karnataka, West Bengal, Bihar, and Jharkhand are the states which consume the least electricity.

4. Hardware Description

4.1 Piezoelectric Tiles

If humans walk around, certain load apply on the surface, such pressure may be used to produce electricity. Piezo-electric crystal is possible with the idea of converting energy from pressurized weight into electric power. If we use piezoelectric crystals as a material that converts energy, the power-producing floors can be a major application. The piezoelectric materials have a crystal structure and are capable of converting mechanical power (stresses and strains) into electric energy.

Ceramic tiles are promising use of piezoelectric vibratory capture effect, subjected by humans. When such tiles are implemented in places where a massive number of people's movements are expected, such as in airports, malls, bus stands, railway, and person's steps on them, then the small surface charge is developed on the crystals by the piezoelectric effect. Although a single person's generated energy will be too small, it would also increase if the number of the steps on these tiles were to increase the energy generated by it.

Electricity generation through the use of ceramic piezoelectric tiles have three stages [10]:

Stage 1. The piezoelectric ceramic tile is the system for generating electric energy which converts vibratory energy into electric energy.

Stage 2. The rectifier device as a part of electrical power conversion into DC voltage.

Stage 3. The Functioning amplifier module including a voltage controller and the voltage amplifier. The generated output voltage can either be used as a power source or saved in batteries.

4.1.1 Working Principle

The following is the working principle of the piezoelectric tiles. When the pressure is applied to the tile's surface, it moves downwards. Piezo material comes into contact with the projections on the tile surface.

![Figure 3. Block Diagram](image)

Inside the piezo material, the force applied produces stresses which will generate electricity. There is clearance to give free deflection between the surface of the springs and the tile. The spring is provided that the piezo material is stable and protected from being destructed by the excess load.
Inside the frame, the base plate is firmly fitted to provide support during compression to the piezo material. When applied to the sensors in the form of ambient vibration or direct strain, the generation of electrical energy depends on different factors like the number of piezoelectrics, the electromechanical coupling coefficient of piezoelectric sensors, transducers, the amount of load applied, and also the arrangement system.

4.2 Solar Tracker

Solar trackers are systems that automatically orient solar accumulator towards the sun, such as concentrated solar thermal (CSP), or concentrated photovoltaic (CPV), flat photovoltaic panels. Such a system rise power production by optimizing the incidence angle between the incoming sunrays and the solar collectors. Those with one degree of freedom, such as single-axis vertical trackers (VSAT), or single-axis tilted trackers (TSAT), horizontal single-axis trackers (HSAT), are called single-axis trackers. Dual-axis trackers have freedom for two degrees which makes them highly efficient. It is verified that solar energy production in mid-latitude regions can also be increased by 41 percent while using dual-axis tracking systems.

The sun trail at Rabat (Morocco), for example, varies from 120 to 240 in the east-west from winter to summer in Figure 4.

4.2.1 Design Specification

The designed and developed solar energy system incorporates a solar panel, an inverter, and a battery. The solar panel is implemented with a tracking mechanism, which directs the panel to the sunlight area of high intensity. It also has a method for focusing sunlight on the photoreceptors of the solar panel. All of these achieve the maximum amount of solar energy collected from the sun within a specified timeframe. Thus the solar panel’s performance in solar energy absorption is increased by 15 percent. Additionally, the solar panel is connected to a battery, so it can be fully charged in eight hours. The system is equipped with an inverter converting the 12 VDC from a battery to a 60 Hz, 120 VAC. The inverter provides enough power for electrical gadgets such as a standard TV or a laptop of at least 300 Watts. The weighing system is semi-portable, and less than 100 lbs.

4.3 LDR Sensor
A photo-resistor is also called a Light Dependent Resistor (LDR). As well known as a Photo Driver. LDR sensors are used for light detection. The passive component is a resistor, whose resistance value decreases with decreased light intensity.

![Figure 5. LDR Sensor](image)

### 4.4 Infrared Sensor

The IR sensor is an electronic device measuring and detecting its environment radiation. IR sensor emits radiation from the infrared and/or detects it to feel its surroundings. The basic idea of IR Sensor used as an obstacle detector is to transmit an IR signal, this IR signal bounces off the surface of an obstacle and receives the signal at the IR receiver.

![Figure 6. IR Sensor](image)

### 5. Proposed System

The system proposed is split into two stages: one is energy harvesting and the other is energy conservation.

**STAGE I : Energy Harvesting**

Piezoelectric tiles and solar trackers are used to design the energy harvesting system. Piezoelectric tile operates under the piezoelectric effect principle. The tiles are installed at places where all of us in the house use most frequently. It will undergo certain pressure when the person steps on the tiles, and this pressure will be converted into electric energy. This pressure is dependent on the weight of the person stepping on the tiles as explained in Section VI. The voltage generated through a piezoelectric tile is then supplied for recharging and supplying the dc charges to a storage battery. Although one person's generated energy would be too small, it would also increase if the number of moves on these tiles increases than the electricity charges it produces.
Steps for converting the pressure into electrical energy:

Step 1. The piezoelectric ceramic tile as a pressure converter to electric energy.

Step 2. Pressure on ceramic tile is produced by foot pressure, where the tiles contain piezoelectric materials.

Step 3. AC-DC tension rectifier circuit

Step 4. DC-DC voltage booster with a schematic Joule Thief circuit, or Buck-Boost.

Figure 7. Working model of piezoelectric tiles [2]

One of the vibration sources which is used as a stimulator for generating power using piezoelectric materials embedded in tile is the pressure caused by the foot entering the ceramic tile. Ac voltage is produced by the piezoelectric material. The AC-DC voltage rectifier circuit is used to convert voltage from the AC to DC. The Voltage regulator circuit and Joule Thief Method are used to increasing DC voltage. The electric energy generated will be stored inside the battery.

Figure 8. AC to DC Converter Bridge Rectifier Type [5]
In the system, the solar tracker will track the sun in two directions to capture the maximum rays of the sun. Solar panels that track the sun generate about 30 percent more energy per day than a fixed panel. The fixed solar panel will generate less energy because it will generate energy morning or afternoon or evening only. But the solar tracker will track the sun continuously and change its position according to the sun's direction. So we're going with tracker solar. They will store this generated energy in the battery. The electricity generated by piezoelectric tiles and solar tracker is stored in the battery and will be used for household needs.

**STAGE 2: Energy Conservation**

We have automated the Light ON and OFF for energy conservation of the LDR sensor and the IR sensor to do so. Those sensors will be placed in the kitchen, bathroom, hall, and all rooms’ entrances. The LDR sensor will detect only the light's absences. The IR sensor detects the person entering the room and detects the person's presence in the room too. So when the person enters the room or the person in the room during the daytime, the IR sensor becomes enabled but the LDR sensor is not enabled, it will only be enabled when the light intensity is low. So, only when both sensors are enabled the light will be turned ON. When the person exits the room or the room is empty the light is turned OFF automatically. By automatically turning the lights on and off we can avoid the energy wastage.

**6. Weight Analyses Of Piezoelectric Tiles**

People whose mass varies between 40 kg to 75 kg are allowed to walk on piezoelectric tile and the voltage generating capacity of piezo tiles is evaluated. Figure 10 plots the relationship between the person's weight and the power generated. The maximum voltage generation is seen in the graph while applying the maximum weight/force on it. Therefore, when a weight of 75 kg is applied on tile, it generates a peak power of 4.5W across the tile.
Conclusion

Electricity matters so much. Phones, computers, the internet, televisions, heating systems, light bulbs, almost all the modern services are powered electrically. No wonder electricity need is continuing to increase. Despite the significance of electricity and its higher requirement, lots of countries still lack access to electricity. The reason for this is the electricity amount paid. We explained in this paper that the solar tracker and piezoelectric ceramic tiles are the hopeful options for overcoming the increased requirement for electricity and the lack of electricity access. Piezoelectric ceramic tiles are not only a source of renewable energy but also a safe, unique, reliable, geographic, and economic source. Energy conservation is effected through the use of sensor technology. With the solar tracker and piezoelectric application, the advantageous use is made of the rising population which is considered a bane. With this technique, it is possible to harvest a non-polluting form of energy. The future of electric power generation is piezoelectric materials.

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Figure 10. Graph of piezo tile Weight V/s power