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Harvesting energy from rainfall

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Abstract: The goal of this project is to utilize energy stored in rain water to provide power to the buildings, which are situated in the regions, affected by power cuts during summer. This can be achieved by making use of a structured disposal pipeline system, use of individual small scale generator turbine, and use of piezoelectric generators to harness the kinetic energy of falling water. This project deals with the required piping design needed for maximum power output. This project also highlights the advantages and the shortcomings of the proposed design and also its feasibility.

Keywords: Renewable, Piezoelectric, Inelastic, PVDF

1. Introduction

Fast production demands fast utilization of resources. One such major resource is electricity. Electricity is the lifeline for all the industrial work. Rising standard of living and development of technology has made use of appliances imperative in our day to day life. Thus there is also a vast rise in power consumption in residential areas. In order to suffice the growing power demands, we are now largely dependent on the extraction of power from non-conventional, renewable sources of energy.

This paper focuses largely on the areas receiving moderate to heavy rainfall. Solar and wind energy are the major forms of renewable energy our mankind look forward to.

Apart from these, high rainfall regions can also utilize the rain to generate power on residential basis. This work could be considered as a good alternative to power systems in raining outdoor environments where solar energy is difficult to exploit [2]. Following figure shows the brief block diagram of this project.

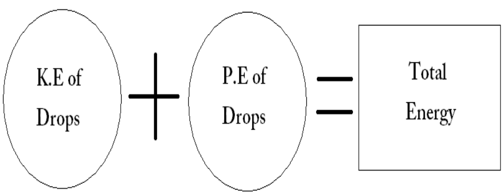

Figure 1.

This system converts the energy of falling rain drops in two ways.

A. Utilizing the potential head available at building tops

Multi-storey buildings having large terrace areas act can act as water reservoirs. The water accumulated can be made to pass through a turbine situated at ground level. This will result in generation of electricity.

B. Utilizing the kinetic energy of falling raindrops

These consist of using piezoelectric materials to convert the mechanical energy of falling drops into electricity.

Piezoelectric materials exhibit the unique property known as the piezoelectric effect. When these materials are subjected to a compressive or tensile stress, an electric field is generated across the material, creating a voltage difference resulting in current flow. This effect is due to the asymmetric nature of their unit cell when a stress is applied. As seen in Figure, the unit cell contains a small positively charges particle in the centre. When a stress is applied this particle becomes shifted in one direction which creates a charge distribution, and subsequent electric field. These materials come in several different forms. The most common is crystals, but they are also found as plastics and ceramics.

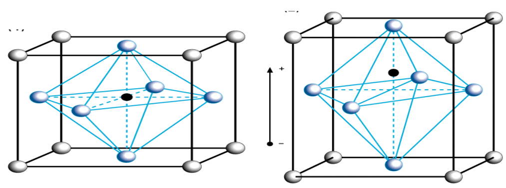

Figure 2. *Lattice structure of piezoelectric crystals*

The power generated from above methods are then stored in storage batteries. This power can be used during summer when there are large power cuts.

2. Components and Design

2.1. Turbines

For utilization of the potential head of the accumulated water, the water is channeled through pipes and made to pass through turbine situated at the ground level. The discharge out from the guiding pipe will be in the range of several liters/ min.

This is a low discharge condition and hence Pelton wheel will result in higher efficiencies. For multi-storey buildings 'H' m tall. The potential energy of volume V m^3 of water accumulated will be equal to

$$\text{Potential energy} = d*V*g\ H$$

Where, d= density of rain water

g= acceleration due to gravity (9.81 m/s^2)

For regions receiving heavy rainfall during monsoon of about 100mm per day, the potential energy available per day for the buildings with terrace area of $100m^2$ is

$$\text{P.E available/day} = d*(0.1*100)*9.81*H$$

The accumulated water is made to pass through a nozzle on the turbine blades. The power generated per day with an overall efficiency of 'n_o' is

$$\text{Power generated/day} = n_o*d*(0.1*100)*9.81*H$$

Considering density of water=1000kg/m3, Head H=50m with n_o =0.7. The total power output from the turbine will be P=3.4 MJ/ day. Thus power generated in the entire rainy season will be about 340MJ for a building of 50m height and roof area of $100m^2$.

2.2. Piezoelectric Generators

This method aims at utilizing the kinetic energy of the falling drop, to generate electricity. Scientists from CEA/Leti-Minatec, an R&D institute in Grenoble, France, specializing in microelectronics, have recently developed a system that recovers the vibration energy from a piezoelectric structure impacted by a falling raindrop [4].

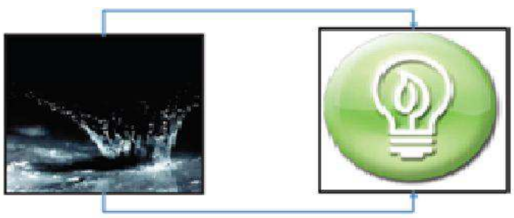

Figure 3.

The raindrop falling from the sky is accelerated along its motion. This tends to increase its velocity. At the same time the Drag force offered by the air increases as its velocity increase. At a certain point the drop experiences equilibrium and the drop continues to fall with a constant speed called as terminal velocity. It is this kinetic energy of the drop which gets converted into electricity due to piezoelectric materials.

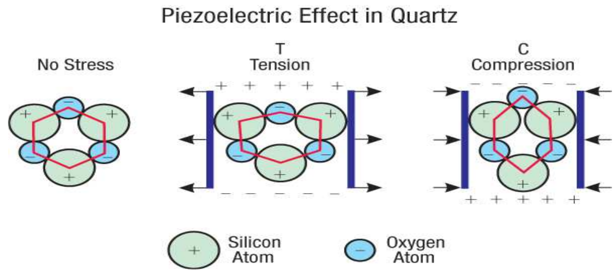

***Figure 4.** Piezoelectric effect in quartz*

When a raindrop impacts a surface, it produces a perfectly inelastic shock. [4] For application in our rain drop scenario we have to consider a membrane material sensitive to surface impacts. Refer to diagram below for a simplified representation of our system. To capture the raindrops' mechanical energy, we can use a PVDF (polyvinylidene fluoride) polymer, a piezoelectric material that converts mechanical energy into electrical energy. When a raindrop impacts the 25-micrometer-thick PVDF, the polymer starts to vibrate. Electrodes embedded in the PVDF are used to recover the electrical charges generated by the vibrations [4].

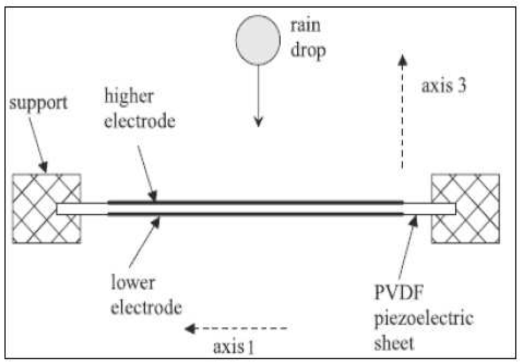

***Figure 5**. schemtic diagram of vibration-electrical convertor assembly*

Various tests conducted by the various researches showed that, the instantaneous power converted per rain drop for a converter area of few sq.cms ranges from few micro watts and goes up to 12mW [2].

The recoverable energy depends directly on the size of the piezoelectric membrane, the size of raindrops, and their frequency. The available energy per drop varies between 2 μJ from 1 MJ depending on its size [2]. Following table shows the variation in power generated for various drop sizes.

***Table 1.** Variation in power generated for various drop sizes [2]*

Types of drop	Cable dimension	Recoverable voltage	Recoverable electrical energy	Recoverable instantaneous power
Rain: D: 1mm V:2.8m/s	L:10cm W:3mm H:25um	1.6V	1.7nJ	1.8uW
Medium D:2mm V:0.75m/s	L:10cm W:3mm H:25um	3V	5nJ	2.5uW
Downpour D:5mm V:5.7m/s	L:10cm W:1.3cm H:25um	98V	25uJ	12.5mW

Based on data available, energy generated for a span of 4 months in a region having rainfall of 100mm per day will be approximately 21.6 kJ per sq.m of converter area. Thus for a converter area of 100 sq.m, the energy generated will be nearly 2.16MJ for the entire season.

2.3. Design of Rooftops

The important factor to be considered in implementation of this project is the design of rooftops. Rain water making contact with the roof tops will be used to generate electricity in above mentioned two ways.

Power generated by the turbine is due to the flow of water accumulated on the rooftops of buildings. For maximum power generation, majority of the rain water from the roof top must be channeled down the pipe. For this, the roof surface must be provided with 5-10 degrees of inclination with the horizontal. Also, multiple outlets must be provided for large terraces so that there is maximum outflow of water and minimum water logging.

Also for maximum power output from piezoelectric generators, rain drops need to strike the surface every single time. Water accumulation results in piezoelectric sensors getting submerged thus rendering them useless. Hence proper inclination of 5-10 degrees must be provided.

3. Benefits and Drawbacks

3.1. Benefits

1. This system can be considered an alternative to power systems in rainy outdoor environments where solar energy is difficult to gather.

2. This is a clean source of energy with zero pollutant emissions.

3. This energy generation method is independent of time of the day. It is fully functional during day as well as night.

4. Use of new renewable sources of electricity is the need of the day and advancement in piezo sensor industry will improve the output capacity.

3.2. Drawbacks

1. Electricity produced by these means, at present would cost more than electricity generated from fossil fuels at their current costs.

2. The Piezoelectric sensors and turbine that is needed to be installed are costly components.

3. Power generated is very low for direct use. For effective utilization in needed times, the energy generated must be stored in batteries which also increase the system cost.

4. Such system is only operational during rainy season. Thus the payback period of this plan is quite large.

4. Conclusion

The current power output of this project is very less with respect to the power consumption. The investment cost is high and returns are low, thus currently it can't be implemented. Piezoelectric technology can also be used to empower mobile objects like cars and busses. Constant research in the field piezoelectric materials assures the potential of this project.

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