A Modern Approach to Energy Generation and Conservation using Rain Water

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***Abstract*— By 2025, 1.8 billion people will experience absolute water scarcity and 2/3 of the people will be living under stressed water condition. The need of the hour is to consume water in a proper and smart way as it is one of the most precious resources given to us. One of the ways of doing that is utilizing rain water efficiently rather than just wasting it by letting it go into the drains. As urban areas doesn't have much of a land from where water can seep through the ground and contribute to the ground water most of the water gets wasted. This will be preinstalled on skyscrapers in large cities where the water scarcity is predominant.**

In cities, when it rains, the water falls either on roofs of the buildings or on the road and in both the cases is directed towards the drains. The roofs of the skyscrapers will be constructed in such a way that it can hold some gallons of water. The roof top will be covered with flaps attached on all four sides of the building made of solar panels, which are closed (towards the roof) on the normal days with no rain and act as a shield for the roof. The Building Management System (BMS) will comprise of an environmental monitoring system, which will continuously monitor temperature, humidity and air pressure and will also sense rain. When rain will be detected, the actuators will be activated such that flaps will be opened outwards, tilted towards the rooftop to allow water to be stored in the rooftop tanks. These flaps will direct the water falling around the building to the roof, in order to minimize wastage. The flaps will be designed in such a manner that the flaps of adjacent buildings will fit in together, to allow maximum coverage of area.

This water collected on the roof will be directed through specialized pipes installed from top to bottom along the building on all edges. These pipes will have small turbines all along the length of the pipe. The water will be made to pass through these pipes, so that when the turbines rotate, some electricity is generated. These pipes installed along the edges, will also serve the purpose of reducing the indoor temperature of the building, acting as a natural coolant. The water leaving through the outlet of the pipe can further be used for many purposes like cleaning and gardening.

The idea and technology proposed here solves issues of water scarcity and generate electricity on a very small scale the greatest advantage of the technology being that it is renewable. Thus, it proposes techniques to get the best out of what we have.

Keywords—water conservation; hydro energy; solar energy; electricity generation

I. INTRODUCTION

All life on earth is sustained by energy from the sun. Plants and animals can store energy and some of this energy remains with them when they die. It is the remains of these ancient animals and plants that make up fossil fuels. Over the last 200 years an ever-increasing proportion of our energy has come from non-renewable sources. At the current rate of extraction and usage, non-renewable fossil fuels are predicted to be usable for another 300 years. Burning fossil fuels generates green house gases and relying on them for energy generation is unsustainable. Hence there is a pressing need to find a renewable and sustainable form of energy. Renewable or infinite energy resources are sources of power that quickly replenish themselves and can be used again and again.

There is an urgent need to switch to the renewable forms of energy. Most renewable energy comes either directly or indirectly from the sun. Sunlight, or solar energy, can be used directly for heating and lighting homes and other buildings, for generating electricity, and for hot water heating, solar cooling, and a variety of commercial and industrial uses. The sun's heat also drives the winds, whose energy, is captured with wind turbines. Then, the winds and the sun's heat cause water to evaporate. When this water vapor turns into rain or snow and flows downhill into rivers or streams, its energy can be captured using hydroelectric power. Along with the rain and snow, sunlight causes plants to grow. The organic matter that makes up those plants is known as biomass. Biomass can be used to produce electricity, transportation fuels, or chemicals. The use of biomass for any of these purposes is called bioenergy.

Many of the smart ways of using renewable energy in place of non-renewable energy do exist which are very efficient in their implementation and are adopted by some countries. We ought to have more such smart ideas to tackle the problem.

Today, nearly 1 billion people in the developing world don't have access to water. Scarcity of water is a growing concern in the current scenario. As more people put ever increasing demands on limited supplies, the cost and effort to build or even maintain access to water will increase. Additionally, water's importance to political and social stability will only grow with the crisis.

One such solution is related to water conservation with energy generation. The proposed solution works efficiently in the areas which receive a large amount of rainfall and sunlight, such as the equatorial belt, the western part of the Western Ghats and North East India. The water collected on the roof tops of tall buildings through rain is allowed to flow through specialized pipes in a controlled manner, in order to produce electricity. The water is then stored in a tank under the building and then used for different purposes.

II. BASIC FRAMEWORK

The basic framework of the system contains electrical and mechanical subsystems.

A. Electrical Subsystem

The electrical subsystem is responsible for automating the entire system. It is used to control the various electromechanical components and maintain the coordination and integrity between different subsystems and various components. This is done with various electrical and electronic components like a motor, a controller, solar panels, batteries, maximum Power Point Tracker (MPPT), motor controller, rain sensor, electromechanical valve and temperature sensor.

The sensors will be active at each time and when it senses rain the signals will sent to the controller to take further actions. The controller then sends the signals to the actuators to open the flaps, with the solar panel, for the rain water to accumulate. Further, the water is forced to pass through customized pipes through electromechanical valves in a controlled manner. The water will then gush through the pipes turning the turbines transducing the energy from mechanical to electrical and hence getting stored in a battery through the MPPT. The same power can thus be used to power up low voltage devices.

B. Mechanical Subsystem

The mechanical subsystem contains components like turbines and electromechanical valves which are coordinated with the electrical subsystem for the operation of the complete setup.
The internal system works in such a way that when flowing water moves to a generator, its force hits the turbine, it moves the rotor of magnets. It travels past the wire seeder which causes electricity to flow as shown Fig. 1.

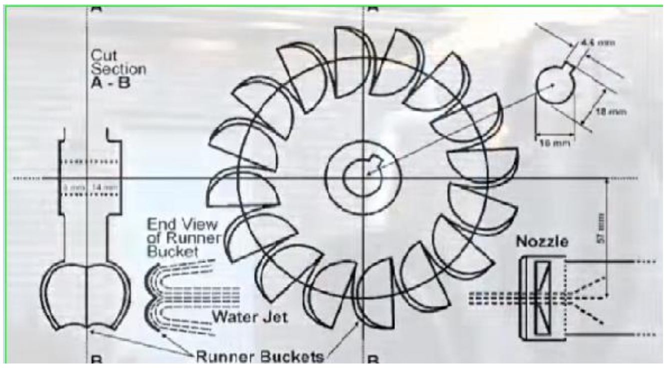

Fig. 1. Working of the Micro-Turbine

III. ESTIMATION OF POWER GENERATED

A significant amount of rainwater accumulation can be done over the rooftops. In urban areas in India, a resident is allowed to develop one's own structure up to a maximum height of 15 m and in apartments/commercial buildings the limit is much higher with sky scrapper going beyond 10 stories (40 m).

A. Amount Of water collected annually

Let us take into consideration a city 'X'. Let us consider that 'P'% of the area can be occupied by buildings and houses that may have rainwater harvesting. Let's assume that only 'Q'% of buildings are following norm to have rainwater harvesting implemented.

- Area available for rainwater harvesting =A * P * Q.
- Drainage Area for harvesting (average of 0.9 on a steep pitched roof and 0.4 on a flat roof with gravel) [DA]= 0.65
- Filter efficiency [FE] = 0.9
- Annual Rainfall [AR] = 617 mm (Average rainfall of all states in India).
- Amount of water collected in a year in L [W] = A * DA * FE * AR

B. Power Generation.

- Amount of water collected in a year = W L
- Mass of water collected (m) = W kg
- Value of g = 9.8 m/s^2
- Height of fall (h)
- Potential Energy of Water PE = m*g*h

C. Example of Delhi

- Area available for rainwater harvesting [A] (assuming 10% of the total area is available for rain water harvesting) = 1,484,000,000 * 10% * 10% = 14,840,000 sq m

- Drainage Area for harvesting (average of 0.9 on a steep pitched roof and 0.4 on a flat roof with gravel) [DA]= 0.65
- Filter efficiency [FE] = 0.9
- Annual Rainfall [AR] = 617 mm
- Amount of water collected in a year in L = A * DA * FE * AR = 14,840,000 * 0.65 * 0.9 * 617 = 5,356,423,800 L
- Amount of water collected in a year = 5,356,423,800 L
- Mass of water collected (m) = 5,356,423,800 kg
- Value of g = 9.8 m/s2
- Height of fall (h) = 10 m
- Potential Energy of Water PE = m*g*h = 5,356,423,800 * 9.8 * 10 = 524,930,000,000 Joules = 145,813.8 kWh (Units of Energy)

If we consider that an average household in Delhi consumes about 60 units per month then this energy can power approximately 200 homes for a year. It is to be noted that we have considered only 10% of potential buildings complying with rainwater harvesting and this number can potentially go up to 2000 homes per year in Delhi.

IV. Electrical Distribution

The electrical distribution will be done in such a way that the proposed solution will act as an alternative source of energy to the existing solar energy system.

A. Wiring

The solar energy setup and the proposed setup will be connected using an electromechanical relay using a single pole, double throw mechanism. On usual days, the relay will connect the solar power setup to the main supply and on rainy days, it will connect the main switch to the proposed setup.

The wiring in the building will be done in such a way that the entire lighting system in the common areas will be connected on one line and the power generated using rainwater can exclusively be used for this purpose, so as to reduce power consumption from existing sources.

B. Motors

The role of the motors is to open the solar panels whenever the rain is detected. The motors used will be brushed geared dc motors which will be activated whenever the controller receives a high signal from the rain sensor connected to it. The motors are being driven by motor drivers which work on the principal of ‘H Bridge’ as shown in the figure 3. The H Bridge enables the motors to move in anticlockwise as well as clockwise direction.

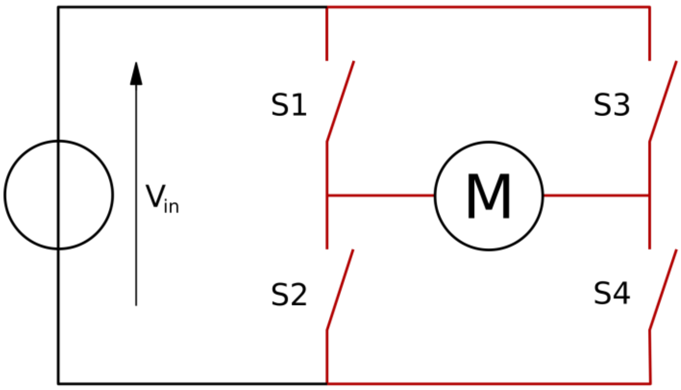

Fig. 2. H-Bridge

C. Storage

The electricity generated will be stored in a rechargeable battery will be connected to the solar panels and the turbines through the MPPT. Maximum power point tracking (MPPT) is a technique that charge controllers use for wind turbines and photovoltaic (PV) solar systems to maximize power output. It checks the maximum point and charges the battery accordingly using the Battery Management System (BMS). The BMS enables all the cells of the battery to get charged evenly manages the discharge.

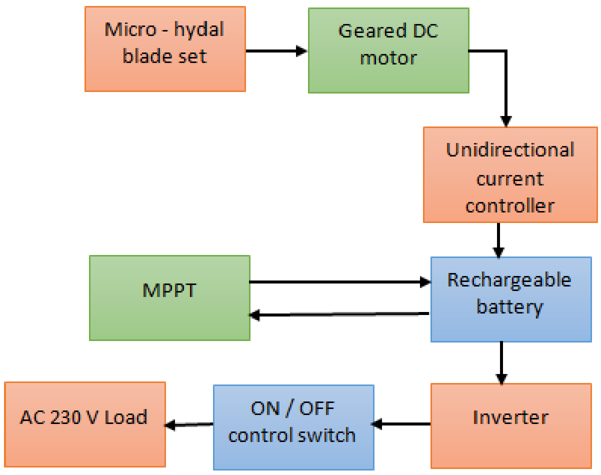

Fig. 3. Block Diagram of the Electrical Subsystem

V. Mechanical Structure

The mechanical structure will consist of custom made pipes, which will have a train of turbines inside it as shown in Fig.4. When water is released through the electromechanical valve placed on the rooftop, all the turbines will rotate sequentially, so as to produce electricity.

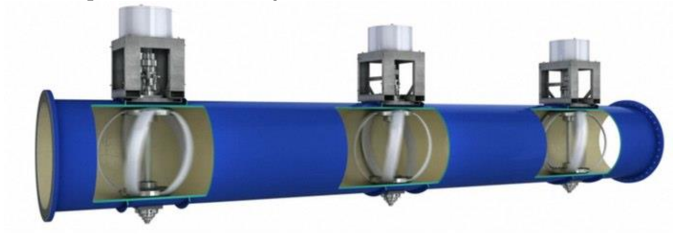

Fig. 4. Cross-Section of the Customised Pipes with Turbines

VI. Cost, Efficiency and Feasibility

The cost of installation of this system is significant, but it will be recovered over a period of time.

Example of Delhi

Average cost of one unit = Rs.6.00
1 unit= 1 kWh
Average amount of electricity generated in an year by the proposed system (assuming the system to be 90% efficient) = 145,813.8 kWh
Cost of electricity = Rs.8,74,882.80
Approximate cost of installation = Rs.30,00,000.00
So, the cost of installation will be recovered in approximately 4 years, which makes the system feasible for skyscrapers.

VII. Description of Current Prototype

The current prototype is designed in such a way, so as to demonstrate the proof of concept for the stated design. When rain is detected by the rain sensor, the solar panels placed on the roof open up to allow water to collect in a reservoir right below it. When water collected crosses a certain level, the electromechanical valves open up to allow water to flow through the pipes.

The pipes have micro-turbines placed all along their length, which operate sequentially to produce electricity. This has been shown by connecting LED lights to them, which glow when water flow through the pipe. The water which leaves through the outlet of the pipe is collected in a tank under the building so that it can be used for different applications.

VIII. Conclusion

The stated concept can be used an extension to the existing concept of rainwater harvesting, allowing people to utilize rainwater in a more efficient fashion. This will also reduce the usage cost of electricity significantly in areas receiving large amount of rainfall. Thus, this is a way of ensuring sustainable development and making optimum use of this partially tapped resource.

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