Complementary Generation Based on Solar Power and Rain Power in Sponge City

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Abstract. Aiming at improving the environment and the problem that how to effectively use rainwater collected in the construction of a sponge city, a scheme was proposed to generate electricity by rainwater potential energy on the roof and solar power during dry weathers. When it's raining, the amount of rainwater controlled by the intelligent level control system and discharge device enters the system through a designed collector. After passing the packet filter and pressure pipeline, the rainwater potential energy is converted into electrical energy through a hydroelectric generator and finally stored in a water reservoir. The electrical energy is stored in a battery. When there’s no rain, solar energy is stored by a solar panel and a high-efficiency light tracking system to provide water working system or a small resident electrical system with electrical energy in the sponge city. Compared with thermal power generation, they do not cause environmental pollution. As a consequence, the two mechanisms complement each other in time and space to achieve the goals of environmental protection, energy conservation and emission reduction.

Keywords: rain power generation; solar power generation; sponge city; energy saving and emission reduction; environmental protection.

1. Introduction
Sponge city resembles a sponge that has good flexibility in dealing with environmental changes and natural disasters. It absorbs water, stores water, seeps water, and purifies water when it rains. When the water is needed, it “releases” stored water and uses it. Rainwater is a kind of clean, renewable energy source which has Rain has greater kinetic energy when falling. South China is rich in rainfall. Meanwhile, the construction of “eco-sponge cities” is developing rapidly. Based on this situation, the use of rainwater can obtain a large amount of electrical energy [1]. Great social and economic benefits can also be created by rainwater harvesting and power generation. Through rainwater harvesting, water resources in the natural environment are fully utilized for irrigation, car washing or other domestic water use. It has become an effective way to carry out rainwater harvesting and power generation in cities. At the same time, there is high light intensity in southern China. Solar panels are used to make full use of sunlight as the result of that solar energy is direct, universal, and clean. Rain-free weather and rainy weather have rain power and solar power respectively, which achieves the goals of environmental protection. The two systems complement each other, which make full use of resources, save energy and environmental protection effectively.
2. System Overview

Figure 1 shows how the system works. When it's raining, the rainwater power generation part is similar to the principle of the small hydropower generation system. The flow is discharged through the intelligent liquid level control and discharge device, and the valve is opened when the water level in the collector reaches the set water level. Next, the rainwater passes through the packet filter and enters the pressure pipeline. Furthermore, the constant pressure pushes the turbine generator to generate electricity. After that, excess power is stored in a battery by transformers, inverters, and accumulators which can meet residents' needs and reduce grid load. The rainwater that has been filtered many times will be used for car washing in the underground garage of high-rise public buildings, watering green belts or replenishing the fire-fighting pool, which will increase the utilization rate of rainwater and save water resources.

However, when there's no rain, solar power systems partially replenish and stabilize the system. Photoelectric direct conversion device solar cells are adopted, and solar tracking is performed through a photo-resistor, which effectively improves the utilization efficiency of light energy. The photoelectric effect is used to directly convert solar radiation energy into electrical energy, which could achieve complementary adjustment function with rainwater power generation and supply the water use system of the sponge city. Having a long-life span, solar batteries can be used once for long-term use. Compared with thermal power generation, they do not cause environmental pollution.

![Combined Rain and Solar Power Generation System](image)

Figure 1. Combined Rain and Solar Power Generation System

3. Rain Power Generation System with Intelligent Control

Rainwater stored on the roof is stored in the collector through rainwater pipes and other rainwater collecting devices installed on the roof. Integrated circuits designed in stages are used to achieve joint control of liquid level and water protection. When rainwater is used to generate electricity, the effluent condition is controlled by the liquid level controller. In addition, the collected water reaches the specified amount for centralized power generation instead of collecting rainwater while generating power. At this time, the water supply pipeline is a full-line pressure flow [2]. Therefore, the generator with the
appropriate power should be selected first, and then the pipe diameter of the water transmission pipeline should be determined according to the flow parameters of the generator.

Figure 2. The Intelligent Liquid Level Control and Discharge Device

Firstly, the power is controlled by electric relay. As shown in Figure 2, A is the collector upper limit water level control point. When the water level rises to the A point water level, the water contacts the probe, and then the controller automatically opens the valve. Rainwater that exceeds the specific point A water level passes through the waste flow device and flows through the packet filter into the reservoir to maintain the set water volume. The set amount of rainwater flows through the packet filter to reduce the damage to the power generation system caused by impurities. After entering the pressure pipeline, the constant pressure pushes the hydroelectric generator to generate electricity and stores the electric energy in the battery. Besides, the water that finished power generation is discharged downstream through the draft tube. The higher the water head is, the greater the flow is. Consequently, the output power of the turbine is greater. What’s more, B is the collector lower limit water level control point. When the water level drops below the B water level, the water and the probe disengage, and then the controller automatically closes the valve, used as water shortage protection, in order to prevent instability of the power generation system.

As has been said, the collector drains water in a timely manner, the waste flow device reduces the difficulty of rainwater utilization which improves the efficiency of the purification system and reduces the operating costs. Further, they prevent the unstable effects caused by different rainfalls and damage to the buildings from excessive water weight.

At the same time, an automatic control device is set to control the battery charge to prevent overcharging damage to the battery. After power generation, tail water is discharged into a water storage facility such as a pool located in a low place for further recycling. The water storage facilities of this system are located in the lower part of the pool. Furthermore, with reference to the statistical data of the local weather bureau and daily water use data, the water supply capacity of the flood season and dry season can be properly designed to save investment, which can achieve maximum social and economic benefits.

4. Intelligent Tracking Solar Power System

As shown in Figure 3, in the solar panel’s working area, a bearing bar is erected vertically, and universal joints are connected to both ends of the bar to obtain 360 degrees of rotational freedom. Also, there is a vertical thin rod in the center of the solar tracking system. Under the sun's rays, the thin rod will be projected on the photodiode of the disc, so that different photodiodes are exposed to different light intensities which causes different input current values. The two adjacent photodiodes can compare the magnitude of the voltage at the output by the voltage comparator. When the height and orientation of the sun changes, the motor is controlled by a single-chip microcomputer to change the rotation speed so that the rod rotates in a telescopic manner. In consequence, the solar panel is directed toward the sun light, which makes solar energy be used more efficiently [3]. When a rainy day or night is encountered, a photodiode is used in combination with a single-chip microcomputer control system to keep the battery
panel in a horizontal state. Thus, the solar power generation system is in a standby state for rain power generation.

![Intelligent Tracking Solar Power System](image)

**Figure 3.** Intelligent Tracking Solar Power System

Increasing the solar controller to control the working status of the entire system plays the role of charge protection and over-discharge protection for the battery. In the areas with large temperature differences, qualified controllers should also have temperature compensation. Other additional functions, such as light-controlled switches and time-controlled switches, should be optional for the controller.

**5. The Dual Energy-saving Complementary System**

In the "eco-sponge city" construction system, part of the collected rainwater is directly used for firefighting, irrigation and urban afforestation in the surrounding area, while the other part is subjected to purification and water quality after being purified. The generated energy can be used as a power drain for draining or treating the quality of rainwater nearby and can also supplement the regional power supply. When the rainfall is large and the power generation is plentiful, the excess power can be saved by the pumped storage. Combined with solar energy to achieve dual energy-saving complementary regulation of power supply, the balance of the use of rain energy and continuity can be improved obviously [4]. What needs to be pointed out is not that the main goal is to supply electricity to the outside, but instead to use electric energy to “self-produced and self-consumed” as the goal. That is, to “maintain solar energy and rain energy” through energy dissipation, which uses the converted electric energy for rainwater quality treatment, stagnant water supply and drainage, etc. in order to provide new ideas for the construction of sponge cities.

**References**

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