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Research Article

Research on Green Building Rooftop Plant Power Generation System Based on Bionics Principles

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Abstract: This research is based on the detailed design and study of a plant power generation system for green building roofs based on the combination of bionics and design science. The selection of power generation plants is carried out through experiments and research, and based on which the connection between the plant power generation unit and the internal circuit of the building is studied to generate a complete building roof plant power generation system.

Keywords: Bionics; Green building; Hydroelectricity generation

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1 The value of combining bionics with green building development

1.1 Research background of bionic design

Bionic design is the act of combining bionics and design in the process of product design and development, through the study and analysis of the shape, colour, sound, function, structure and other features of natural organisms, based on which those features that are favourable to product design are selected and used in a design, combined with the research results of bionics for innovative design[1]. Bionic design is the product of an innovative combination of bionics and product design, through bionic research, people can understand the characteristics of natural organisms more clearly, and by using these biological characteristics to make design solutions more easily adaptable to the environment.

1.2 The value of bionic design for the development of green building facilities

Green building facility is a new type of urban infrastructure with ecological and environmental protection as its main characteristics. In recent years, with the rapid development of the economy, the construction of urban infrastructure has become more and more perfect, meeting the basic needs of people's lives while bringing a lot of convenience to people. However, the development and construction of part of the infrastructure have brought significant impact on the natural environment, such as the construction of street lights at night, which breaks the living habits of some nocturnal creatures and causes disorder of the logical ecological chain at night; the large-scale development of buildings and roads destroys the original forest ecosystem and leads to the decline of species. Thus, it is essential for people to consider the ecological impact of facilities while developing infrastructure.

Bionic design reduces the impact of infrastructure on the environment by introducing bionics into the development and design of facilities by incorporating the characteristics of organisms in the background, thereby minimising the effects of support on the environment and increasing the adaptability of the situation to infrastructure, thus achieving the goal of environmentally friendly construction.

2 Examples and comparisons of plant power generation systems

2.1 The case of plant-based power generation systems

Researchers in Japan have found that the cells can generate a continuous current by mixing chlorophyll extracted from spinach leaves with lecithin, coating them on transparent crystalline sheets of tin oxide, using them as batteries and placing them in the sun, and testing them for positive and negative currents. It was found that the photovoltaic plant cells produced about 10%-20% electricity per unit area than the solar panels, and therefore, this power generation facility has excellent potential for development.

The University of Cambridge, UK, improved the Japanese plant photovoltaic cell by setting the electrodes of the power generation facility in fern pots to collect the electricity produced by ferns through photosynthesis. According to relevant experimental data, a bowl of greenery with a diameter of 1 m can generate about 1 kWh of electricity in sunny weather[2].

Compared with ferns, Stanford University researchers chose algae plants, which are more adaptable to the environment than ferns, as electricity-generating plants. The research team at Stanford University developed a nanoscale electrode and inserted this electrode into the plant cells, the nanoscale electrode causes microscopic wounds to the plant cells that do not damage the plant cells, the plant cells can still carry out any normal photosynthesis and respiration inside, the cell walls of the plant cells recover and can wrap around the electrode, and the electrode exports the electrons produced by photosynthesis, thus Realization of electricity generation[3].

2.2 Current problems with plant power generation systems in buildings

From the three plant power generation systems mentioned above, it can be seen that there are several problems with the current stage of plant power generation systems.

The life span of plant photovoltaic cells that use chlorophyll extracted from plants is too short, and the extracted chlorophyll is easily damaged, and the duration of photosynthesis is limited.

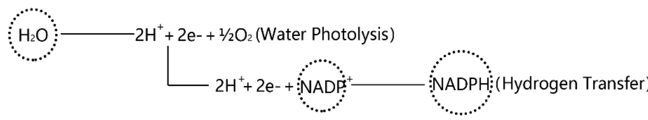
The photovoltaic cells using potted ferns to generate electricity have a long life. Still, the generating monomer is too large to be easily placed, and particular placement areas need to be set up separately for them.

Although the power generation efficiency is high, and the damage to the plant cells is negligible, the power generation efficiency and a lifetime of the photovoltaic cells are very high. However, the development cost of the nanoscale electrode is very high, and if each plant cell is placed with such a nanoscale electrode, the labour cost and production cost are incredibly high, so the plant photovoltaic cell cannot be mass-produced and applied.

3 Research on the bionic principle-based building roof plant power generation system

3.1 Principles of plant power generation

Photoelectric technology is a technology that uses the electron flow produced by plants in photosynthesis to generate electricity, which uses living plants as a power generation unit to convert biomass energy into electrical energy. The fundamentals of the reaction are as follows.



From the above formula, it is clear that electron transfer from H2O to NADP is a reverse oxidation-reduction reaction. When a photon hits a pigment molecule, it excites high-energy electrons, and plants are thus using the light energy to generate electron flow. As shown in Figure 1, the plant power generation system is to set up the plant power generation unit in the form of a single array in the power generation facility. The power generation facility exports the electron flow through positive and negative electrodes. It transmits the current to the various appliances in the building through the transformer equipment, thus realizing the utilization of plant electricity [4].

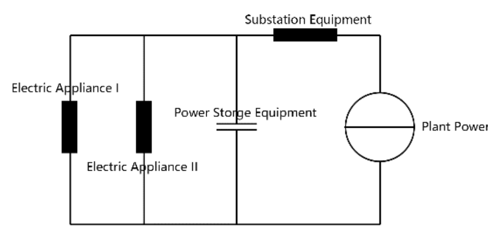


Figure 1. Equivalent circuit diagram of plant power generation system

3.2 Screening of plants for power generation

Ferns and algae plants were found to be suitable for plant power generation. Still, algae plants have higher requirements for growing environment, need to be cultivated in water, and require higher technical level. Ferns are less demanding on the growing environment and have a relatively high ability to adapt to various types of situations.

According to relevant literature, five ferns, namely dog fern, large-leaved runner, well-border fern, needle hair fern and broad-scaled fern, are better in cold resistance. The open-air overwintering experiments on these five ferns revealed that three species of ferns, namely the good rail fern, the broad-leaved fern and the big-leaved fern, were almost free from frost damage in the outdoor environment, and the good rail fern had the strongest cold hardiness.

In terms of drought resistance, these five plants were introduced from Nanjing and Hangzhou, where the temperature is relatively high so that these plants can survive in a hot and humid climate without any protection[5].

In summary, since the power generation facility is set on the roof, the selection of plants for power generation mainly considers the adaptability of plants to cold and hot and humid environments in the open air, so this scheme decided to choose fresh fence edge grass as the main plant for plant power generation.

3.3 Design of power generation units

As shown in Figure 2, the power generation unit of this plant power generation system is designed in detail for its appearance based on bionics. The physical structure of the power generation unit is designed to mimic the biological structure of plant cells, which mainly consists of a plant living chamber, positive and negative electrodes, protective glass and air pores.

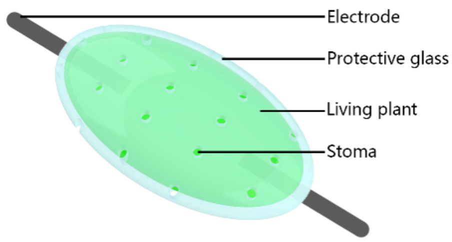


Figure 2. Plant power generation monomer

Among them, the plant living chamber mainly consists of the living plant and the environment that satisfies the growth of the existing plant, which is the core part of the power generation unit, where the living plant converts light energy into electrical energy through photosynthesis; positive and negative electrodes are set at both ends of the plant living chamber, and the wires are connected to the living plant to transmit the current generated by the power generation of the plant; the protective glass, which imitates the structure of the plant cell wall, is set at the outer wall of the plant living chamber to protect the living plant; the stomata, which imitates the working principle of the stomata of the plant cell, are set at the protective glass for the gas exchange of the photosynthesis and respiration of the living plant.

3.4 Application of power generation systems in buildings

As shown in Figure 3, to maximize the collection of sunlight, the power generation system is installed in a parallel array at the roof position of the building, and the substation and storage facilities are connected in series with the power generation system in the interior of the building to form the power supply of the whole building. All the electricity consuming facilities inside the building are connected in parallel with the facility.

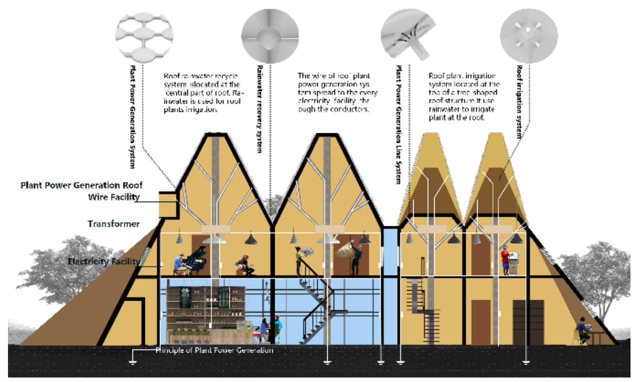


Figure 3. Structural diagram of green building plant power generation system

During the day, the rooftop plant power generation system converts solar energy into electricity for the building's internal appliances, while the electricity storage facility stores most of the excess heat generated during the day for use at night to power interior lighting and other devices.

3.5 Maintenance of the power generation system

The maintenance of the power generation system is mainly concerned with irrigation and protection of the power generating plants, as shown in Figure 4. In terms of security, the plant generating unit is located inside the roof of the building with a layer of protective glass on the outside to protect the plant making unit from directly contacting with the external environment. An exhaust vent is provided at the low end of the eaves for gas exchange between the power generating plants and the outside world. In terms of irrigation of the power generation plants, the system uses the roof structure to recover rainwater and applies the collected rainwater for irrigation of the power generation plants and water use inside the building.

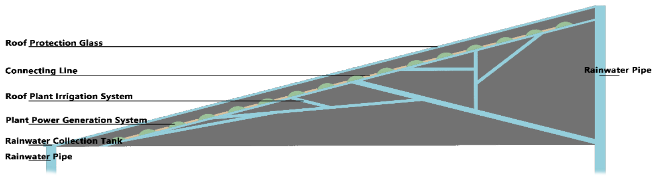


Figure 4. Section of rooftop plant power generation and irrigation system

4 Vision for the future of plant power generation systems in buildings

4.1 Applications

Plant power technology is used in a wide range of applications and has natural advantages in the improvement of the urban environment and ecological restoration. In green buildings, the implementation of plant power generation system can cover a large number of plants on the premises to form a small environmental community, thus reducing the impact of building development on the green environment and integrating the buildings and the ecological environmental are very important. Plant power generation system could also be installed in parks, street-side urban greening and other areas where plants are concentrated, and the power generated by plants could be used for urban street lights. Moreover, in terms of ecological restoration, photoelectricity systems could be applied to the planting areas in desert areas. Since most of desert plants are single species and in large quantities, it is easy to build special photoelectricity zones to form desert photoelectricity plants that can be used to supply electricity to residents and facilities in the surrounding areas.

4.2 Development opportunities

This new type of plant power generation system will be widely used in the development of green buildings in the future. Compared with photovoltaic power generation panels, plant power generation equipment has a more reliable power generation capacity, and its damage and influence on the ecological environment is minimal. With the increasing maturity of plant power generation technology, this technology will be widely applied in the urban construction and building development in the future.

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