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Studies on Optimization and Integration of Photovoltaics in traditional Lingnan buildings: a case study in Guangzhou

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Abstract

The traditional Lingnan buildings are widely spread out in southern part of China and has been adaptive to the hot-humid climate. These kinds of buildings can be traced back over five hundred years from now. Their climate-adaptive characteristics are mainly based on passive technology, including sunshine shading, natural ventilation, and tile roof and so on. The paper appeals to future exploration of the potential of energy saving by combining one or several of these passive traditional building technologies with new technologies in solar energy applications. The concept of Building Integrated Photovoltaic (BIPV) is employed to optimize the solar energy application on the rooftop of Lingnan buildings. A case study in Guangzhou is utilized to showcase the optimization procedure and benefits of BIPV. As a conclusion, the design guidelines and technical-economic benefits are proposed for further applications in other similar architypes.

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Keywords: Building Integrated Photovoltaic (BIPV); traditional Lingnan building; solar radiation; parametric study

1. Introduction

1.1. Research Actuality

Energy is considered as a prime agent in the generation of wealth and a significant factor in the economic development, but wanton depletion of resources may lead to an energy crisis. Solar energy application, as a new

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technology, has great potential for development which could effectively easy up energy crisis. Research activities on solar energy applications have also been made all over the world.

Akash Kumar Shukla, K. Sudhakar and Prashant Baredar [1] have reviewed the advancement in BIPV product technologies in recent year, include BIPV products and its market potential, international standards and specification of BIPV products, advancement in BIPV materials and life cycle assessment of the BIPV product.

Agrawal and Tiwari [2] have carried out experimental observations for BIPV/T system fitted on the roof top of a building. They have developed a one-dimensional transient model in order to select an appropriate BIPV/T system suitable for India.

In China, research is on solar energy applications in modern architectural forms, Ren [3] has used a computer simulation to make the process of transform from simple qualitative method to quantitative analysis for study of BIPV design of hot-humid region in this paper, and presented the core task of BIPV design to get a form which meets architecture and photovoltaic requirements simultaneously. In hot-humid area, the architecture requirements are primarily shading and cooling.

Hua and Zhou [4] have researched the application of BIPV in ultra-high-rise building in the pearl river new town. The solar photovoltaic modules are determined by the sunshine conditions on Guangzhou and architectural form.

Both in China and other countries, BIPV research and application have focused on modern architectural forms more than traditional building. There are some barriers of BIPV application on traditional building. Firstly, The differences of construction methods between tradition and modernity make BIPV application on traditional building more difficult than modern buildings. Secondly, the shelter from decorative components of traditional building makes it more complicated to calculate the power generation of the BIPV systems. Thirdly, the form and position of PV panels also make a great impact on the image of traditional building. Facing the sky, the rooftop of traditional building can receive abundant solar radiation. So, it is beneficial to make rooftop Integrated PV panels. But The shelter from decorative components of roof also reduces solar radiation, and then influences the BIPV system's efficiency. Thus, analyses of the shielding effect of decorative component on the rooftop is important.

1.2. The climatic characteristics in Guangzhou

Guangzhou is located in the central part of Guangdong Province. To the north is Nanling Mountain. To the south, South China Sea. As a part of Lingnan area, it belongs to the subtropical monsoon climate, which is mostly warm throughout the year. The period of summer in Guangzhou is relatively long and the winter in Guangzhou is relatively warm. Besides, there are abundant rainfalls and sunshine. According to the meteorological department documents, the date shows that the total annual radiation can reach to the 4400 ~ 5000MJ/(m^2*a) [5], in another word, the solar radiation is rich in resources, which is conducive to the application of BIPV. There are numerous mountains in Lingnan area, in order to conform to the terrain, the traditional building orientation is not unified in general. It is necessary to different orientations of the building roof for solar radiation analysis.

1.3. The features of traditional rooftop

Ordinarily, the rooftop of traditional building is sloping, and the whole rooftop is composed of some roofs with different slope, according to some certain rules. For example, as for Qing Dynasty-style roof, every part of the roof is supported by two purlins, Due to the difference of height of purlins between the roof, the different levels of certain slopes of each part of roof are formed. Each slope of part of roof is determined by the lift height and flat length. The projection length on its horizontal plane is called flat length and the length of the projection on the vertical surface is called lift height. Except for roofs which are extended out of wall in the horizontal direction, the lift height of other roofs are more than 1/2 of their flat length, each parts of the roof increase the height along the depth direction, in another word, the closer to the ridge, the slope of roof are steeper. However, in general, the maximum lift height cannot be more than 9/10 of flat length [6], which means the slope of roof is less than 43.3 °. The minimum annual noonday sun elevation angle in Guangzhou is 43.6 °, showed in Fig.1, larger than the traditional architecture of the biggest step frame roof slope, even if the north to the slope roof, which means the winter solstice can also be irradiated to solar radiation.