An Integrated System for Application Technology of Renewable Energy Buildings

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Abstract

In recent years, China faces two problems: natural resources shortage and environmental pollution. Consequently, China has attached more and more attention to environmental protection. The pollution-free renewable energy is increasingly favoured. Construction is an industry with high energy consumption and heavy pollution. The application of renewable energy in the construction industry can greatly alleviate energy shortage and effectively eliminate the problem of environmental pollution, which is of vital significance to promote the sustainable development of China’s economy. In view of this, this paper elaborates the significance of renewable energy buildings and application technology, makes an in-depth study on the integrated system for the application technology of renewable energy buildings, and explores the benefits this integrated system from the social, economic and ecological perspectives.

Keywords: Renewable Energy, Construction Engineering, Application Technology, Integrated System.

1. RESEARCH BACKGROUND

1.1 Research overview

Social development is inseparable from energy. Since the industrial revolution, the world’s energy demands begin to show a sharp upsurge trend, leading to increasing consumption of oil, natural gas and other natural resources. When enormous natural energy is utilized, people’s living environment is subject to seriously heavy pollution (Zhang and Zhang, 2010). Especially, as a substantial amount of greenhouse gases greatly exacerbates global warming and also poses a major threat to the socio-economic development and human living environment. In recent years, increasing emphasis has been laid on environmental protection in China, and renewable energy has gradually received people’s attention. Construction, a industry with high energy consumption and high pollution, exerts a vital significance to the sustainable development of social economy. In the process of architectural usage, the application of renewable energy in the construction industry can validly cut down energy consumption and eliminate the environmental pollution problems in this industry, which accordingly, has become an imminent future development trend. Renewable energy buildings (REB) emerge as the times require (Tan et al., 2010). Thus, REB are of great significance to drive China’s sustainable economic development and improve China’s energy consumption structure and greenhouse gas emissions pressure.

1.2 Research objective

Renewable energy has the advantages of pollution-free and renewability. Its application in the construction industry can reduce high-carbon energy emissions, substantially ease the expansion pressure of greenhouse gases, and effectively protect the ecological environment (Jin and Sui, 2016). This paper aims to discuss the significance of renewable energy in the construction industry from the perspective of sustainable development of society, to clarify the application advantages of renewable energy in the construction industry, and to explore the application mechanism and feasibility of renewable energy, such as solar energy, in the architectural integrated system, to identify the principle of REB application technology, to respectively discuss the architectural application technology of the four kinds of renewable energy, to deeply study the superiority and applicability of the integrated system for REB application technology and to make a detailed analysis on the
application benefits of this integrated system from the social, economic and ecological perspectives (Zhong et al., 2016). The in-depth study on this system clarifies the promotion value and the practical significance of REB.

2. AN ANALYSIS ON REB APPLICATION TECHNOLOGY

2.1 Application technology of groundsource heat pump

Heat pump, an energy-saving device, can achieve circulation towards high-grade heat sources by way of high-grade energy, thus reaching the effect of energy saving. Heat pump is both a heating system and a refrigeration system in which heating and refrigerating are carried out by a condenser and an evaporator (Guo et al., 2015). There are various types of heat pumps with different heat source types, purposes, technique types, drive modes and working principles. At present, in China, surface water heat pump, groundwater heat pump and soil coupling heat pump all are collectively referred to as the ground source heat pump (GSHP). The GSHP mainly adopts the earth as a heat source Because the temperature in the stratum is relatively constant, the heat source of earth can greatly improve the efficiency of the GSHP. The GSHP mainly plays the role of energy storage in the REB. In the winter, the GSHP can utilize the heat in the earth through heat bumps so as to reduce the temperature in the earth and to achieve the accumulation of cold air. When the summer approaches, the heat pump transfers heat from buildings to the earth, thereby reducing the temperature of buildings and acting as a heat bank (Yu et al., 2015). The GSHP system has three applications in the REB, namely heating cycle, refrigeration cycle and hot water circulation. Arguably, the GSHP technology makes full use of the characteristics of constant geotemperature in the superficial layer, achieves summer refrigerating and winter heating, greatly improves the efficiency of energy use, lowers the loss of electric energy, effectively reduces the emissions of gaseous pollutants, and demonstrates a vastly broad application value.

2.2 Application technology of solar waterheating

Solar water heating technology is a device that collects solar radiation to heat the water through collectors. Solar collectors can collect heat from solar radiation and heat the water inside them. When water is heated to a specified temperature by the solar radiation, the temperature sensor, controller, water pump and other devices in the collector automatically transport the heated water to the insulation tank, and cold water automatically is added to the collector. When the level of the heated water in the insulation tank reaches the upper limit, the temperature controller conducts the fixed temperature cycling of hot water by means of heat preservation setting, and a sound cycling between the insulation tank and the heat collector is formed (Xia et al., 2015). A solar water heater is composed of five major parts, namely, insulation tank, bracket, collector, control system and connecting tubes. Based on the structure and principle of the collector, solar water heaters can be divided into vacuum tube water heater and flat-plate water heater. Collector is the main core component of the solar hot water technology. Figure 1 illustrates the schematic diagram of the solar water heating system.

![Schematic Diagram of Solar Water Heating System](image)

2.3 Application technology of air-conditioning heating and refrigerating

This technology takes into account the functions of heating and refrigerating at the same time. Because solar energy is applied for heating and refrigerating, this technology has the advantages of pollution-free and low energy consumption (Sun et al., 2014). At present, numerous countries in the world have begun to carry out an in-depth study on solar air-conditioning technology. Consequently, solar energy is of vital significance to energy conservation and natural environment protection. Solar refrigeration technology provides heating medium water
to the refrigerator through the collector, and the temperature of heating medium water directly affects the refrigerating effect of the air conditioning system. The higher the temperature is, the greater the refrigerating effect is. According to the relevant statistics, when the temperature of the heating medium water reaches 60°C, the performance coefficient of the refrigerator would lie between 0 and 40. When the temperature rises to 120°C, the performance coefficient of the refrigerator would increase to 110 or more. A great quantity of practice shows that, after the integration of heat-pipe evacuated tube collector and lithium bromide refrigerator, the refrigerating effect is the best and the energy saving effect is strongest. Solar heating technology supplies heating by transferring the heating medium water in the collector to the heating equipment at the end (Liu, 2016). The solar heating and refrigerating air conditioning system is mainly composed of collector, hot water tank, cold water tank, water pump, control system, lithium bromide refrigerator, refrigerating tower, control system and connecting tubes. The refrigerator in the solar air-conditioner takes lithium bromide or water as the heating or refrigerating medium, which avails environmental protection, enormously improves the efficiency of solar energy utilization and brings a vastly broad prospect for development.

2.4 Application technology of solar photovoltaic utilization

Solar photovoltaic utilization technology, also known as photovoltaic power generation technology, converts luminous energy into electric energy through the semiconductor (Liang, 2017). As the core component of the solar photovoltaic utilization technology, solar cells are connected in series and packaged into a solar battery pack, and then power control and other devices are installed to form a complete set of photovoltaic power generation devices. The current solar power generation methods mainly include photo-biological power generation, photochemical power generation, photovoltaic power generation and photoinduction power generation, among which, photovoltaic power generation is most widely applied and also the most promising power generation technology. Photovoltaic power generation is featured with pollution-free, noise-free, zero need for regular maintenance and other application advantages. The application of photovoltaic module in the buildings can not only make full use of material resources, but also greatly lower the costs of power supply. Photovoltaic power generation system mainly constitutes six parts, including anti-charging diode, charging controller, measuring equipment, photovoltaic battery panel, accumulator and inverter.

3. AN INTEGRATED SYSTEM FOR REB APPLICATION TECHNOLOGY

3.1 The GSHP system

In the integrated system for the REB, the GSHP system mainly fully utilizes geothermal energy in the superficial layer, which is a type of renewable low-temperature energy widely distributed in the surface of the earth. The parameter design and equipment selection should take an adequate consideration of climatic characteristics and application requirements of the building exterior, so as to accordingly set the maximum temperature and the minimum temperature for winter and summer (Liu et al, 2011). The total air-conditioned area of the building is fully combined to calculate the building’s heating and refrigerating period and to set the average heating and refrigerating indexes as well as the total refrigerating and heating load. The selection of the number and model of the units should be based on the maximum load requirements. It is recommended to select two to three heat pump units, with one for the winter and two for the summer. One unit should be guaranteed to be a heating recycling unit (Ma and Ma, 2011). When the GSHP system is applied for heating, the temperature for the supply and return water should be calculated on basis of 45/40°C. Based on the formula $G = \frac{M \times 0.86}{45°C–40°C} \times 1.05$, the water flow at the maximum heating load, G, can be derived, and its unit is t/h. M represents the total heating amount. When GSHP system is adopted for refrigerating, the temperature of the supply and return water should be calculated according to 7/12°C. On basis of the formula $G = \frac{N \times 0.86}{12°C–7°C} \times 1.05$, the water flow at the maximum refrigerating load can be derived. G stands for the water flow at the maximum heating load and its unit is t/h. N represents the total refrigerating amount. In addition, it is necessary to calculate the length of the ground-source soil coupler and the length of the soil coupler that can meet the maximum load in winter and in summer. The calculation formula for the length of the soil coupler in winter heating is $L = \frac{M - K + Z}{C}$, where $M$ represents the total heating amount; $K$ stands for power; $Z$ is heat recovery amount; $C$ represents the power per meter. The formula for the length of the soil coupler in summer refrigerating is $L = \frac{N + D}{C}$, where $N$ represents the total refrigerating amount; $D$ stands for thermal compensation amount; $C$ represents the power per meter. After calculating the coupling length, the circulating water flow in the maximum heating load in winter and the circulating water flow of the refrigerating tower under the maximum refrigerating load in summer are computed.
and the formula are \( G = \frac{(M - K) \times 0.86}{10^\circ C - 6^\circ C} \times 1.5 \) and \( G = \frac{(N + K) \times 0.86}{30^\circ C - 25^\circ C} \times 1.05 \) respectively. When the GSHP system is integrated, it should be noted that winter heating has higher requirements for water temperature. The method of big flow and small temperature difference is applied to reduce the condensate temperature of the units to the greatest extent possible in order to improve the heating amount and the unit effectiveness. In summer, water temperature should be low so as to improve the refrigerating capacity and the unit efficiency (Ye et al, 2012). Besides, the water flow rate of the carrier should be improved in order to enhance the heat exchange efficiency of the heat transfer. Furthermore, the carrier water should be treated accordingly to ensure that the carrier water temperature can meet the requirements of heating or refrigerating equipment and that the heat and refrigerating capacity cannot satisfy the load requirements of the buildings. When the GSHP system is applied for heating, the temperature difference of the supply and return water should not exceed 6°C. During the refrigerating, the temperature of the supply and return water in the evaporator should not be over 5°C.

3.2 Solar air conditioner and water heating system

When the solar air conditioning system is integrated, the matching area of solar air conditioning should be determined based on the performance coefficient of the refrigerator and the floor area required for installation (Sun, 2014). Moreover, the refrigerating capacity of the air conditioning units is calculated in accord with the HVAC drawings of the building, and the design load of the refrigeration is further derived. The computation is based on the daily refrigerating time of the building to calculate the daily refrigerating demand of the solar air conditioning system. The calculation steps of the heating load is basically the same as those of the refrigerating load. In the integration of the solar air conditioning system, the heat pipe evacuated tube collectors can be divided into four sub-arrays, and each sub-array should have four sets of collectors. When integrating the solar hot water system, the design parameters of the solar hot water system should be determined first, then the equipment selection should be carried out by integrating 36 sets of flat type solar collectors into the roof of the buildings, so as to ensure that the function of the solar collector is brought into play to the greatest degree.

3.3 Photovoltaic power generation system

In the integration of the photovoltaic power generation system, a number of solar cell panels are installed in the facade windows of the buildings to block the sun and beautify the buildings. Besides, solar battery panels are utilized to generate electricity. A solar photovoltaic power generation system consists of five parts, namely, metering device, inverter, photovoltaic module, power distribution system and distribution box. Figure 2 demonstrates the working principle diagram of this system.

![Schematic Diagram of Photovoltaic Power Generation System](image)

Figure 2. Schematic Diagram of Photovoltaic Power Generation System

Photovoltaic modules in the photovoltaic power generation system can convert solar energy into direct current and converge it to the inverter through a distribution box, so that direct current is converted into a sinusoidal current that meets the grid requirements. When the solar cell module is installed, the battery pack should be flatly laid on the stainless steel bracket and connected to the inverter. The watt-hour meter should be installed in the power distribution room and the LCD display interface should be inserted to the inverter interface, in order to master the photovoltaic power generation situation of the entire building through the LCD display interface.

3.4 Integrated control system

In order to fully implement the REB application technology, a remote control system should be established to realize the integrated control of each application technology. The remote control system mainly includes GPRS communication module, control cabinet, the Internet, client side and terminal server, displays the in situ
temperature, the water level and other data of the building, and facilitates to grasp the working state changes of each device (She et al. 2013). In addition, the integrated control system can also remotely control each application system and equipment. Figure 3 illustrates the operating principle of the remote control system.

**Figure 3.** Working Principle Diagram of Remote Control System

When the integrated system is connected, given that solar energy is affected by environmental factors, the performance coefficient of the heat pump system is enhanced to remedy the shortage of heat sources. In case of abundant solar energy, a remote control system can be employed to make the solar collector share part of the burdens in the building. In the winter or rainy weather, the GSHP is adopted to provide heat for the buildings.

4. **BENEFIT ANALYSIS ON THE INTEGRATED SYSTEM FOR REB APPLICATION TECHNOLOGY**

4.1 **Social benefits**

The development of the integrated system for REB application technology can effectively meet the requirements of social energy saving. Especially concerning the current energy shortage, when solar energy is sufficient, the building itself can utilize solar energy to achieve their own refrigerating, heating and water heating requirements. In case of inadequate solar energy, the building can meet the daily energy needs by means of the GSHP system, which largely alleviates the tense situation of natural energy and greatly reducing the operating costs of the building. Under the protection of relevant policies in China, this integrated system is bound to have a broad development prospect.

4.2 **Economic benefits**

A great quantity of practice indicates that, in the application technology of the REB, the operating costs of the GSHP system are far lower than those of the traditional refrigeration heating system, with up to 50% or more of energy saving. The solar air-conditioning system has relatively low costs, and the total amount of pollutant discharge is significantly reduced. Each year, the solar water heating system can save about 16,000 Yuan, and the annual quantity of electricity saving is 40,000 kilowatts per hour. The average service life of the solar photovoltaic power generation system is more than 25 years, and the installation price is only 30 million. The total generating capacity is up to 420,000 degrees, and the amount of power generation is far more than that of the independent power station. Thus, the integrated system for REB application technology is provided with strong economic benefits.

4.3 **Ecological benefits**

This system has enormous ecological benefits. According to the practice, only the subdistrict office of Longhu street has applied this integrated system. The amount of annual electricity savings is up to 32,000 kilowatts; the annual coal substitution is about 52 tons; carbon dioxide emissions is reduced by about 130 tons.
5. CONCLUSION

In summary, the application of the integrated system for REB application technology can reduce the operating costs of the buildings, effectively improve the natural energy shortage, cut down environmental pollution and achieve the objective of energy-saving emission reduction, which also conforms to the development trend of the times and satisfies the target of energy-saving emission reduction. Without doubt, renewable energy refers to not just solar energy, also wind energy, bioenergy, etc., so it has different configuration methods of the refrigerating and heating sources. Only with the continuous exploration on the combined application of other renewable energy and buildings as well as the implementation of complementary advantages of different technologies, can the integrated system for REB application technology play its role to the largest extent.

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