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Efficacy of integrated photovoltaics-air source heat pump systems for application in Central-south China

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ABSTRACT

Photovoltaics (PV) and air source heat pump (ASHP) are very important techniques for energy conservation and carbon reduction. It is essential to master the completed design idea and thermodynamic analysis method for the integration of PV and ASHP. Then, a design idea depending on the biggest power load of building appliances for the PV system was proposed in this paper. The thermodynamic analysis method for the PV integrated ASHP system considering the building process of PV modules was also provided here. To show the idea and method, the feasibility and exergy performance of an integrated PV-ASHP system (ASHP system driven by AC power inverted from PV) for domestic residential applications in Central-south China was investigated. Exergy efficiency and exergy consumption cost of the household PV-ASHP system were modelled based on the max PV conversion efficiency. The analyses show adequate efficacy of the PV-ASHP system with good thermodynamic and economic performance for their application in Central-south China. The PV-ASHP integrated system would have the best performance if the installed capacity of the individual PV system was decided by the required rating power of the ASHP system for HVAC (Heating, Ventilation and Air Conditioning). It could also be supported by the thermodynamic analysis results. The design idea and analysis method in this paper not only illustrate the potential and the validity of the integrated system in Central-south China but also would enable sustainable development and applying of solar energy and other renewable energy.

Contents

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1. Introduction

Air source heat pump (ASHP) is one important building appliance which was first proposed by Thomson. The ambient air was used as a heat source or sink so that it could be applied widely and easily, especially in those regions where both heating and cooling were required. However, the air source heat pumps are still relying on the electricity mostly which will burden the national grid extremely. Thus, research was conducted in many countries to develop new technologies on the performance improvement of the air source heat pump [1–7]. To decrease the consumption of high quality energy including the electricity energy and fossil energy, alternative energy sources were also taken into account to be combined with air source heat pump including the solar energy, geothermal energy, etc [8–10].

Photovoltaic (PV) technologies can be an important solution for energy conservation and to combat greenhouse gas emissions and ambient air pollution. In recent years, there have been many building integrated photovoltaics (BIPV) modules being introduced by the various official or commercial support programs in various countries and the application potential of these have been widely disseminated [11–18].

Therefore, some investigators tried to find a way to connect the PV with the heat pump system [19–20]. Earlier studies focused mainly on complex systems that the heat generated by the PV modules during its operation was used as the evaporating heat source of the heat pump for heating water or indoor air [21–26]. There was one study focused on the heat pump for indoor heating with assisted solar power [27]. The research was about compression/condensation process of the heat pump system used in Europe, but not about the efficacy of an overall integrated system powered by PV for HVAC used in Central-south China.

In addition, it is the right season in summer in Central-south China that the ASHP system for HVAC (Heating, Ventilation and Air Conditioning) will be required mostly. Proportionately, the PV modules will also have the best power output performance in summer. The connection of the PV and ASHP system will be great helpful for the energy conservation in the region such as Central-south China.

While, few literatures discussed this kind of integrated ASHP system for HVAC, not even to provide a kind of reasonable design idea to design the PV system or an accessible thermodynamic analysis method to decide the efficacy of such an integrated system in an appointed region such as Central-south China.

However, it is very important to develop and apply a design idea and thermodynamic analysis method for the continuous development and applying of PV integrated ASHP system. To show such the thermodynamic analysis and design method clearly, the efficacy of a demonstrated PV integrated ASHP system for HVAC in Central-south China was investigated. In our work, it is not a simple combination of PV technology and air source heat pump (ASHP). The upper chain stage of the PV modules such as the building process is also taken into consideration. The ASHP was driven by the AC power inverted from PV modules (PV-ASHP). A prototype system has been granted two invention patents in China [28,29]. To our knowledge such system has not been studied or evaluated before, especially for application in Central-south China.

2. Description of the Central-south region of China

The Central South (Yangtze River Valley) region of China has been a rapidly growing economic hub of China in recent years. Due

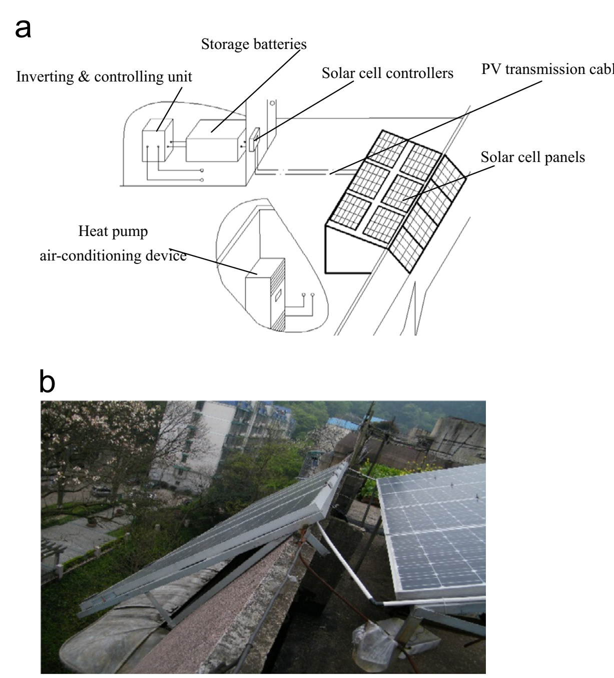

Fig. 1. (a) The components of the PV-ASHP integrated system. (b) The components of the PV-ASHP integrated system.

Table 1
Four zones of solar radiation in China.

Zone	Solar availability	Annual sunlight (h)	Regions
I	Very abundant	3200–3300	Most of Tibet, south of Xinjiang, west of Inner Mongolia, west of Gansu, west of Qinghai
II	Abundant	3000–3200	Most of Xinjiang, east of Gansu, east of Qinghai, Ningxia, Shanxi, Shaanxi, Hebei, Beijing, Tianjin, northeast of Shandong, east of Inner Mongolia,
III	Available	1400–3000	Heilongjiang, Jilin, Liaoning, Anhui, Jiangxi, south of Shaanxi, Shandong, Henan, Zhejiang, Jiangsu, Hubei, Hunan, Fujian, Guangdong, Guangxi, Shanghai, Hainan, south of Guizhou
IV	Poor	<1400	Sichuan, Guizhou, Chongqing