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Status and development of hybrid energy systems from hybrid ground source heat pump in China and other countries

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ABSTRACT

Hybrid energy systems (HES) facilitate the efficient utilization of renewable resources and sustainable energy, and they are expected to be more prevalent in the future. With ground source heat pump (GSHP) as the main body and core technology, the hybrid ground source heat pump (HGSHP) system is used frequently in recent years and its integration and synthesis skills face higher requirements. The worldwide hybrid system has usually been composed of types of energy source devices, such as solar collector, boiler (coal, gas, oil), electric heater, waste energy device, cooling tower, cooler, and thermal storage system with natural cold and hot. Actually, they lead to the complicated unsteady processes and various hybrid energy systems. In China, the applications of these systems are growing year by year, but the new technology breakthrough is being in difficulty and even in an awkward situation. This paper review the progress of GSHP combined with HES all over the world, and surveyed the development of HGSHP in China. Meanwhile, the basic proposals for development in the future are presented to make up the gap in the field of HES and HGSHP. A coming work aims to research the basic problems during the demonstration application, such as investigation of system design parameters, component configuration and control strategies of a HGSHP system. These problems will strengthen theoretical and practical understanding of HES and facilitate more extensive application of HGSHP in China.

Contents

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1. Introduction

Hybrid ground source heat pump (HGSHP) systems incorporate both ground source heat pump (GSHP) systems and auxiliary thermal rejecters (or supplemental thermal sources), such as cooling towers, fluid coolers, pavement heating systems, shallow ponds, waste heat, solar collectors and boilers [1]. GSHP systems have become increasingly common in residential, commercial, and institutional buildings. In cases where there is significant imbalance between the annual heat rejection to the ground and the annual heat extraction from the ground, the loop fluid temperature tends to rise (or fall) from year to year. This effect can be moderated by increasing the size of ground loop heat exchanger. However, the capital cost requirements may be excessive and an alternative is to add an additional thermal sink or source. Nowadays the HGSHP systems are becoming an attractive choice for air conditioning in buildings due to their advantages of high energy efficiency and environmental friendliness compared with the conventional alternatives.

Hybrid energy systems (HES) are strategic and necessary measures for the efficient utilization of renewable resources and sustainable energy. HES can substitute the fossil fuels by using stored heat (cold) energy or renewable energy. The hybrid system can use the fluctuating energy more efficiently by matching the energy supply with demand. By contributing to energy efficiency, it significantly reduces environmental impacts from energy activities, increases the potential uptake of some renewable energy technologies, amplifies the potential of sustainable energy development and subsequently leads to better energy security. As we know, the most important aspect of HES is combining with the progress of HGSHP in the field of using geothermal energy.

Direct-use of geothermal energy is one of the oldest, most versatile and a common form of utilization of geothermal energy [2]. In 2010, the total installed capacity for geothermal direct utilization was 50.6 GW in the world, indicating a 78.9% increase over that of 2005, and a compound annual growth rate of 12.33% [3]. The worldwide geothermal energy use was 438.1 PJ/y, indicating a 60.2% increase over that of 2005 and a compound annual growth rate of 9.89%. The worldwide capacity factor was 0.27 (this number reflects the equivalent percentage of full load operating hours per year), down from 0.31 in 2005 and 0.40 in 2000. GSHP had the largest installed capacity and energy use, accounting for 69.7% and 49.0% of the worldwide capacity and energy use, respectively. The installed capacity was 35.2 GW and the energy use was 214.8 PJ/y. Energy savings amounted to 46.2 million tons of equivalent oil annually, preventing 46.6 million tons of carbon and 148.2 million tons of CO_2 being released to the atmosphere which includes savings in GSHP system. Assuming that these growth rates have persisted in the last 2 years, global geothermal heat capacity reached an estimated 66 GW in 2012, delivering as much as 548 PJ/y of geothermal energy use [4].GSHP represents the largest and historically fastest-growing segment of geothermal direct use. In 2012, it reached an estimated 50 GW of capacity; this amounts to about three-quarters of estimated total geothermal heat capacity, and more than half of heat output (> 300 PJ/y).

Most of the installations occur in North American, Europe and China, increasing from 26 countries in 2000 to 33 countries in 2005, 43 countries in 2010 and at least 78 countries in 2012. China remains the presumptive leader in direct geothermal energy use (75.3 PJ/y in 2010), followed by the United States (67.7 PJ/y in 2012), Sweden (49.7 PJ/y in 2010), Turkey (36.7 PJ/y in 2010), Iceland (25.9 PJ/y in 2012), and Japan (25.6 PJ/y in 2010). Iceland, Sweden, Norway, New Zealand, and Denmark lead for average annual geothermal energy use per person. About 90% of Iceland's total heating demand is derived from geothermal resources. In the EU, GSHP capacity rose by about 10% between 2010 and 2011, to a total of 14 GW, led by Sweden (4.3 GW), Germany (3 GW), France (1.8 GW), and Finland (1.4 GW). Canada had more than 100,000 systems in operation by early 2013, and the United States is adding about 50,000 heat pumps per year. In 2012, Ball State University in Indiana installed the largest U.S. ground-source closed-loop district geothermal system to heat and cool 47 buildings [5]. In China, geothermal district heating capacity has continued to increase at about 10% annually. The total installed capacity was 8.9 GW and the energy use was 75.3 PJ/y in 2010.

The number of policies and targets in place worldwide to support the development and deployment of renewable energy technologies increased yet again in 2012 and early 2013, and the number of countries supporting renewable energy continued to rise. As of early 2013, renewable energy support policies were identified in 127 countries, an increase of 18 from the 109 countries reported in 2012. More than two-thirds of these countries were developing or emerging economies. Besides, countries continued to enact new policies and targets for the promotion of renewable technologies in the heating and cooling sectors during 2012. Roughly 20 countries have specific renewable heating/cooling targets in place, including those for solar water heating. In addition, at least 19 countries/states have heat obligations/mandates to promote the use of renewable heat technologies [4]. Fig. 1 presents estimated renewable energy share of global final energy consumption in 2012.

China is one of the most populous countries and has been the largest energy consumer in 2013. Rising energy demand and import has made China a significant factor in the world energy market. Taking into account the characteristics of energy supply, China is facing two severe challenges of energy shortage and environment protection. Therefore, in order to maintain fast and stable economy, China has to find several policy measures for energy development and consumption [6].

In 2011, China non-fossil energy accounted for 8% of the total primary energy consumption, which means an annual reduction of more than 600 million tons of CO_2 emission. Through unswerving