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Data measurement and analysis of a solar heating system with seasonal storage

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Abstract

The technologies for seasonal thermal energy storage are of great significance in balancing the energy utilization and in enabling the renewable sources, especially solar energy, to be more widely used. The solar heating system with seasonal storage discussed in this paper is located in LuoYang City (Approx. E112', N34.5'), in HeNan Province of China. The working data of the whole system, including temperatures of different parts, water flow, thermal energy, and solar irradiation, etc. are measured continuously and recorded using the technology of internet remote data transmission. The efficiency of the solar heating system is considered to be good when operating in general weather conditions, for example, 45% on sunny days. The average heat loss factor of the heat storage tank is only 0.50W/(K·m^3),the ratio between surface and volume is about1.08 1/m.

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*Keywords:*Solar thermal energy;Seasonal storage;Data measurement.

1. Introduction

Over the past few decades, rapid worldwide population growth and increasing standard of living has put a heavy burden on conventional energy resources and caused a lot of energy problems: shortage, dependency, high prices and price fluctuation, pollution, climate change, etc. that have caused a reconsideration of new acceptable and sustainable development patterns[1]. Numerous countries have commenced development programs of power systems utilising non-conventional energy sources when making plans for the application of conventional energy since the 1973–1974 energy crisis [2]. Solar energy, as a pollution-free, inexhaustible and increasingly affordable energy resource, has received unprecedented consideration and approval, and extensive dependability studies and numerous practical applications have eventuated throughout the world. Among the various solar energy applications, solar energy storage

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has been an active research area, especially seasonal storage which can not only significantly increase the utilization of solar energy, but also widen the application of solar collectors and water heating systems[3].

Nomenclature

G Solar irradiance, W/m^2;
H Total daily solar irradiation during 7:00 and 17:00, MJ/m^2;
Q Total daily solar irradiation received by collectors during 7:00 and 17:00, MW·h;
Q_1 Output thermal energy of collectors measured by a heat meter, MW·h;
Q_2 Input thermal energy of the heat storage tank measured by a heat meter, MW·h;
Q_3 Output thermal energy of the heat storage tank measured by a heat meter, MW·h;
Q_4 Input thermal energy of the water-source heat pump measured by a heat meter, MW·h;
Q_{pipe} Heat loss of the pipelines between collectors and tanks, MW·h;
t_a Ambient temperature, °C;
$Tb1\_1\sim Tb1\_17$ Water temperature in tank 1#(marking in figure 5), °C;
$Tb2\_1\sim Tb2\_17$ Water temperature in tank 2#(marking in figure 5), °C;
t_i Initial water temperature in a tank during the average heat loss factor test , °C;
t_f Final water temperature in a tank during the average heat loss factor test, °C;
$\Delta\tau$ Time interval for the average heat loss factor test, s;
$U_{s,l}$ Average heat loss factor of the heat storage tank, W/(K·m^3);
t_b Average initial water temperature of two heat storage tanks during the thermal efficiency test, °C;
t_e Average final water temperature of two heat storage tanks during the thermal efficiency test, °C;
η Thermal efficiency of the solar heating system with seasonal storage, $\eta=cm(t_e-t_b)/Q$;
t_s Average water temperature in the heat storage tank, °C;
r_1 the internal diameter of the tank;
r_2 the external diameter of the tank;
S the heat dissipation area of the top and bottom of the tank;
l the height of the tank;
λ the thermal conductivity of polyurethane, equal to 0.035W/(m·K).

Over the past few decades, rapid worldwide population growth and increasing standard of living has put a heavy burden on conventional energy resources and caused a lot of energy problems: shortage, dependency, high prices and price fluctuation, pollution, climate change, etc. that have caused a reconsideration of new acceptable and sustainable development patterns[1]. Numerous countries have commenced development programs of power systems utilising non-conventional energy sources when making plans for the application of conventional energy since the 1973–1974 energy crisis [2]. Solar energy, as a pollution-free, inexhaustible and increasingly affordable energy resource, has received unprecedented consideration and approval, and extensive dependability studies and numerous practical applications have eventuated throughout the world. Among the various solar energy applications, solar energy storage has been an active research area, especially seasonal storage which can not only significantly increase the utilization of solar energy, but also widen the application of solar collectors and water heating systems [3].

The use of seasonal storage has more notable advantages than short-term storage. Fisch et al.(1998)summarised dozens of large-scale solar heating systems in Europe with different storage applications of short-term (diurnal) and long-term (seasonal) storage and the results showed that the pattern of seasonal storage could satisfy 50-70% of the annual heat demand, whereas the diurnal pattern could only meet 10-20%, and that the investment costs per square meter of solar collector for large-scale solar plants are only twice as high for systems with seasonal storage than for those with short-term storage[4]. Nevertheless, Hooper (give reference) stated that a solar heating system for a Canadian home using seasonal storage would require 25% of the collector surface needed for the same system type equipped with short-term storage[5].

Most systems choose to use sensible heat storage or natural phase-change materials as their heat storage mediums such as water, soil, cavern, and rock and so on in view of economic factors[6]. Hence, the seasonal system in this paper also uses water as its heat transfer medium and storage medium. In this manuscript we give some analyses and discussions based on the test data gathered from various monitors of the whole system.