SOLAR THERMAL BASED NEW AND RENEWABLE ENERGY HYBRID SYSTEM FOR THE DISTRICT HEATING AND COOLING IN SOUTH KOREA

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Abstract

Considering the renewable energy ratio of only 4% in South Korea, the centralized renewable hybrid district heating and cooling demonstration complex would be new alternatives to expand new and renewable energy. In this paper, the current status of recently completed the first centralized renewable hybrid district heating and cooling demonstration complex is introduced. In addition, the methods for load estimation, installed capacities of installed new and renewable energy equipment, and control strategies with operation modes are simply explained.

Key-words: renewable hybrid, district heating, solar thermal system, seasonal thermal energy storage

1. Introduction

South Korea is one of the countries where the amount of energy usage is continuously increasing, but it imports about 95% of its energy sources from abroad because there are few natural energy resources available. Since more than 83% of the consumed primary energy is fossil energy, and with the dependency on nuclear power generation so high in the area of power generation, the ratio of renewable energy is only about 4% whereas the ratio of nuclear energy is about 12% as shown in Fig. 1.

Most of the new and renewable energy accounts for waste incineration and bio energy, and solar thermal energy and geothermal power are only about 1.2%. The reason why the spread of solar thermal energy is

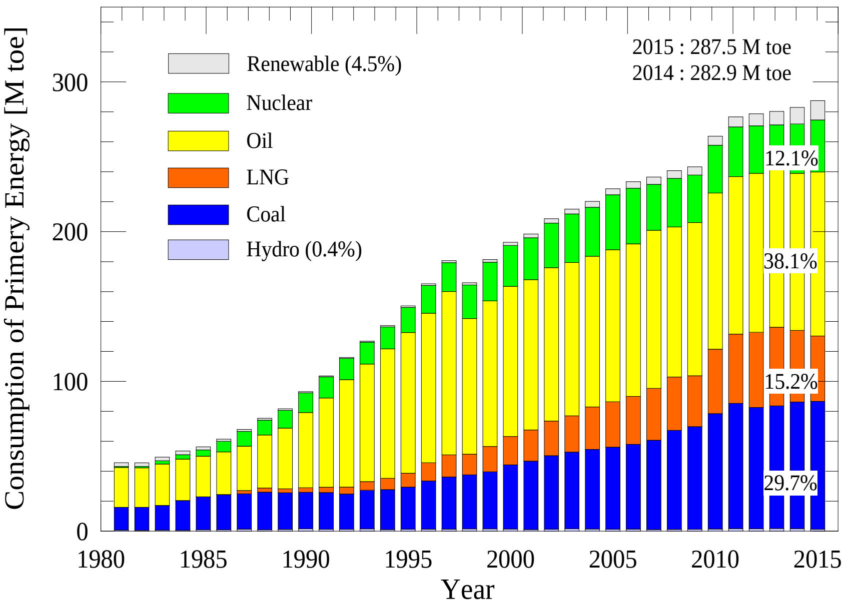

Fig. 1: Consumption of primary energy and the ratio with energy resource types in South Korea

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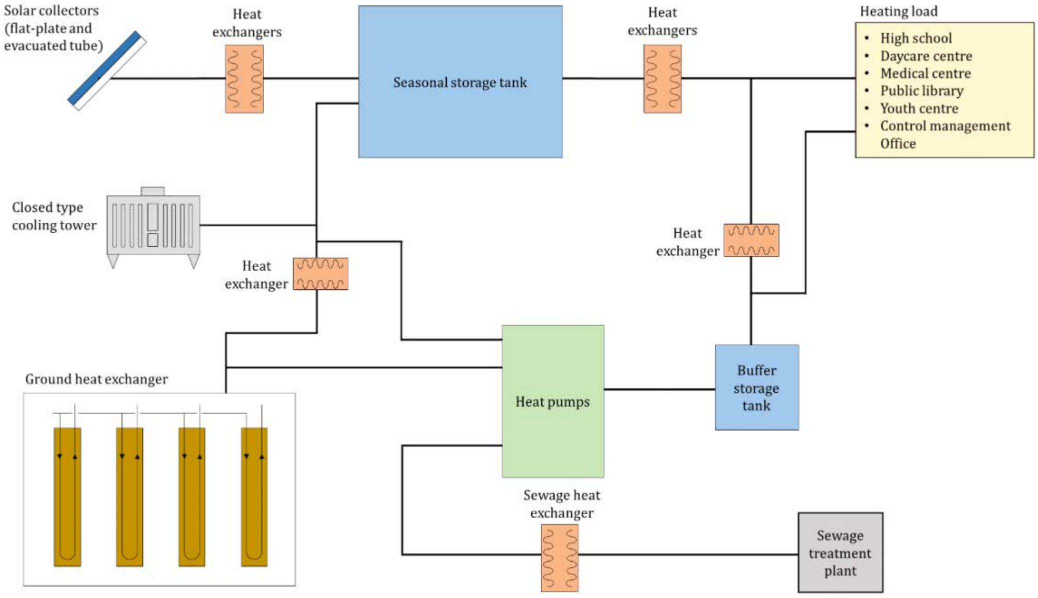


(a)

(b)

Fig. 2: New and renewable energy hybrid system configuration (a) and current on-site pictures (b) of demonstration complex

slow is that the consumer confidence on the solar thermal system applied in the household is not high enough. Most companies related with solar thermal energy are small and follow-up service is not managed satisfactorily. In addition, relatively inexpensive cost of other heat energy sources is the one of the reason why consumers are reluctant to use solar thermal system. Therefore, in order to expand the use of solar energy, it is necessary to supply a large-scale solar thermal system that can be equipped with maintenance system in addition to a small domestic solar heater. The primary goal of this project is to construct a centralized renewable hybrid district heating and cooling demonstration complex based on a large-scale solar thermal system, targeting sewage treatment plants area and six public buildings (schools, libraries, etc.) located in Jincheon, Chungbuk Innovation City. The ultimate goal is to secure the necessary control technologies for the optimal hybrid operation while demonstrating the facilities, and establish a basis for expanding and distributing similar systems in the future.

2. Estimation of heating and cooling loads

In this project, it is aimed to build an energy independence demonstration complex that can provide annually stable heat and electric energy through the various new and renewable energy hybrid facilities. Seasonal thermal energy storage (STES) was applied for the stable thermal energy supply. The electric energy is produced by photovoltaic and fuel cell systems as much as the electricity demand in the demonstration complex for net energy independence, but it is connected to grid line to sell the produced electricity energy instead of self-consumption due to the economical factor. Initially, it was planned to supply only the heat energy necessary for heating and hot water supply. However, since the heat pump is used as an auxiliary system, it was decided to supply cold heat required for cooling to public buildings (except for a high school). In case of a high school, additional cooling system is installed, because the cooling load of high school is too much to be covered by the originally planned heat pump facilities.

In order to determine the capacity of the required renewable energy facility, the heating and cooling load of each public building was estimated first. The energy load is estimated based on the detailed building design and operating statistics on similar buildings (Lee et al., 2014). EnergyPlus was used for the heating load analysis. The thermal load of high school was estimated based on operating statistics of sites near high school, although exact load estimation was very difficult because operating circumstances are different in each school. Table 1 shows total annual heating and cooling load calculated based on the ambient temperature conditions of 24^{o}C and 26^{o}C in winter and summer, respectively. Total thermal energy load for heating and hot water supply were estimated as 761.5 MWh.

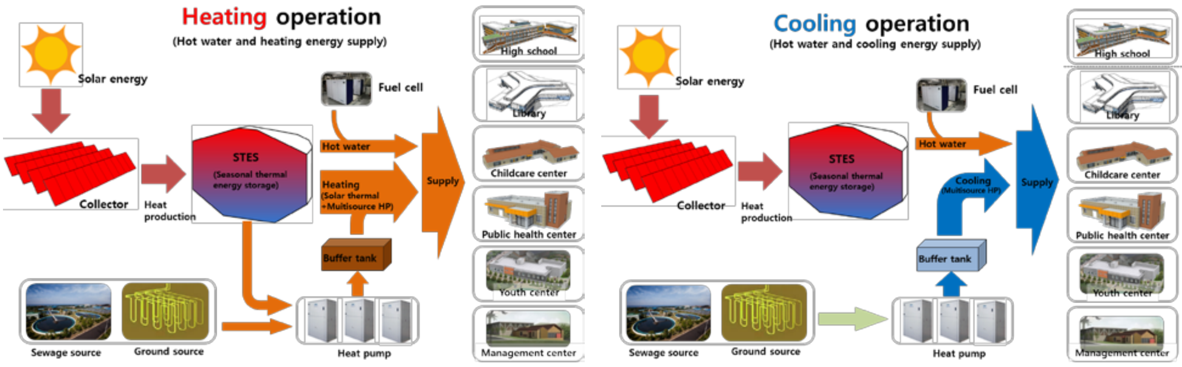
3. Capacity of installed new and renewable energy equipment and status

The capacities of new and renewable energy systems were determined based on the estimated thermal energy load and the TRNSYS-based simulation program. Due to field spatial limits, maximum installation area of solar thermal collector and size of STES were about 1,600 m^2 and 4,000 m^3, respectively. To cover the deficient thermal energy, water source heat pump (WSHP) of 350 kW and ground source heat pump (GSHP) of 175 kW were designed. In case of heating operation, totally 350 kW WSHP is operated to raise the residual heat in STES, and GSHP of 175 kW will be used as the auxiliary system. When the residual heat in STES is insufficient, sewage heat in the water purification center is used as the heat source. In case of cooling operation, alternating operation of WSHP would be possible with additional WSHP of 175 kW among 350 kW, because the cooling load of 4 public buildings can be covered by a GSHP of 175 kW and a WSHP of 175 kW. In addition, it is estimated that about 750 kW of photovoltaic power generation equipment is needed to produce about 850 MWh/year of electricity, which is expected to be consumed in public buildings in the demonstration complex.

Fig. 2 shows the new and renewable energy system configuration and current on-site pictures, respectively. All public buildings except for a youth center have been completed, and renewable energy facilities and seasonal thermal energy storage have been installed. The solar thermal systems were installed on the parking lot and the grounds where the geothermal heat exchanger was installed, and the photovoltaic systems were distributed on the installable space. The heat pump, the fuel cell, and the buffer storage tank were installed in the machine room including the monitoring center.

Tab. 1: Heating and cooling load for public buildings

Building	Heating load [MWh]	Cooling load [MWh]
High school	219.7	(250.7)
Library	76.1	81.0
Youth center	32.8	19.1
Child care center	31.7	21.6
Public health center	17.9	6.2
SUM	378.2	127.9



(a) (b)

Fig. 3: Operating options with heating (a) and cooling operations (b)

4. Operating methods

Operating options for new and renewable energy hybrid district heating system are divided into four operational methods as explained in section 4.1-4.4, and Fig. 3 shows the operation options with heating and cooling mode.

4.1. Operation based on solar thermal system

The heat energy produced in the flat plate and evacuated tube collectors is stored as hot water in the seasonal thermal energy storage through the heat exchanger. The stored hot water is supplied to public buildings for heating and hot water supply, and two separate heat exchangers were installed with purposes for separating the heat storage fluid in the STES and circulating fluid in the supply/return circulation pipe. At this time, the return temperature is controlled lower than 40^{o}C for the thermal stratification in STES by using both a variable speed pump and a 3-way valve. The return temperature will be preferentially controlled by the inverter pump, but 3-way valve might be additionally used according to the operation status by the inverter control. In the heating and hot water supply operation, the supply water is continuously circulated during business hours. When the heating and hot water load occur in public buildings, the temperature difference between supply and return water was observed. By this temperature difference detection, the heat energy in STES is supplied to the load. When the heat supply water temperature is less than 50^{o}C, operation mode is changed from the mode based on solar thermal system to the mode based on heat pump system because it can be considered that the thermal energy in STES is not available to supply to the load.

4.2. Operation for solar thermal overheating protection

In case that the STES is overheated by the over produced heat energy from solar collectors, overheating protection operation mode is provided to reduce the high temperature in STES. Except for summer season for cooling operation, the over produced heat is first released to underground through borehole heat exchangers, and the leftover heat is released to atmosphere by an additional cooling tower.

4.3. Heating operation based on heat pump system

Ground and sewage source heat pumps were installed as the auxiliary heating system. Besides, water source heat pump that uses residual heat less than 40^{o}C in STES as the heat source is also utilized. The hot water produced from heat pump is stored in the buffer storage tank and then supplied to the load. The reason why the buffer tank is used is to utilize the off-peak load time power. The operational cost can be reduced when hot water produced by heat pump operation during the night time is supplied to the load in day time. Of course, in case of heavy heating and hot water load, the heat pump should be operated during the day time.

It was checked that the capacities of heat pump and buffer storage tank can afford to respond to the maximum load of public buildings. The exchanger is installed for the separation between the heat storage fluid in the buffer storage tank and the circulating fluid in the supply / return circulation pipe. The heat pump operation in day time was set based on the temperature of hot water supplied to the load side.

4.4. Cooling operation based on heat pump system

In summer, cold heat is supplied to public buildings (except for a high school). Ground source and sewage source heat pumps are used as the cooling equipment, and the cold heat is supplied to the load side through buffer storage tank. Buffer storage tank is applied for the utilization of the night time power as in the case in heating operation. In high school, additional direct-fired absorption chiller is used for the cooling. During the cooling operation, it is possible to supply hot water to the load side by using the stored heat in STES.

5. Conclusion

In November 2016, the first centralized renewable hybrid district heating and cooling demonstration complex based on a large-scale solar thermal system has been constructed in South Korea. The method for load estimation and capacities of installed new and renewable energy equipment were introduced, and the concept of major operation modes and control strategies were simply explained. While demonstrating the facilities, control technologies for the optimal hybrid operation will be improved and this experience will be a valuable basis for expanding and distributing similar systems in the South Korea.

6. Acknowledgement

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7. References

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