CONSTRUCTION OF THE RENEWABLE ENERGY HYBRID DEMONSTRATION SITE USING SEASONAL STORAGE IN JINCHEON, KOREA

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Abstract – Jincheon Eco-Friendly Energy Town started as the objective of the construction of the energy independent Eco-Friendly Energy Town. The new and renewable energy facilities such as the large solar collector, water and ground source heat pump, fuel cell system, and photovoltaic system will be installed by 2016 near the sewage treatment plant and 6 public buildings in Chungbuk innovation city. From the preliminary simulation and load research, the basic plan by the system capacity matching decision was established. The demonstration operation study for optimization will be progressed for two years after construction completion. In this paper, the outline of this project, thermal load estimations, capacity design for equipment, and operating methods are introduced.

1. INTRODUCTION

Korean government is promoting the eco-friendly energy town policy which is converting unwanted public facility into eco-friendly energy production facility by the eco-friendly energy facility construction in opposed area such as sewage treatment center and landfill. According to the policy, MOTIE(Ministry of Trade, Industry and Energy) and ME(Ministry of Environment) promoted pilot projects such as large scaled photovoltaic business on landfill and biomass business using rural animal-waste, respectively. By this manner, MSIP(Ministry of Science, ICT and Future Planning) announced the Jincheon Eco-Friendly Energy Town Project plan in 2014. In the project that targets sewage treatment plant and public buildings in Chungbuk innovation city, various new and renewable energy systems will be integrated and the optimizing technology will be developed. KIER(Korea Institute of Energy Research) was selected as the execution organization of the Jincheon project scheduled from 2015 to 2018(2015-16: technology development, 2017-18: demonstration operation and supplementation). KIER is government-funded national research institute for energy efficiency improvement, new and renewable energy usage, climate change response, and energy materials and devices research.

The objective of Jincheon project is the construction of the energy independent Eco-Friendly Energy Town with various renewable energy systems and seasonal thermal energy storage(STES) based on block heating system which can supply year-round stable thermal energy, as shown in Fig. 1. Electricity energy that can cover electricity load will be produced, but it will be connected to grid line. Thermal energy independent ratio was planned as 100%. In addition, the development of the stable operation method of the integrated system by monitoring/analysis/modification, the presentation of the maintenance manual for long-term operation, and the development of the eco-friendly energy hybrid standardization manual and business model are included in the demonstration research. South Korea depends on import more than 95% of required energy, and new and renewable energy only cover 4% of national energy demands. Therefore, finding various practical energy supply methods using new and renewable energy hybrid technique is very important.

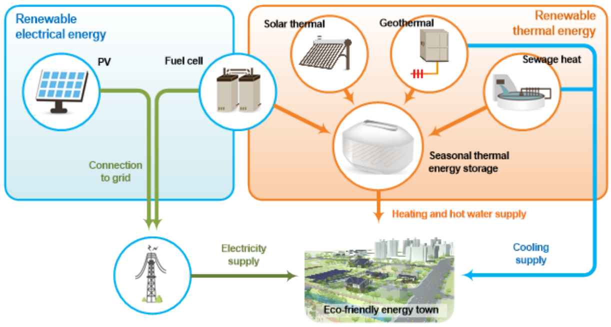

Fig. 1. Basic concept of hybrid new and renewable energy system in Jincheon Eco-Friendly Energy Town (Heo et al., 2015)

The new and renewable energy facilities such as the large solar collector, water and ground source heat pump, fuel cell system, and photovoltaic system will be installed in Jincheon Eco-Friendly Energy Town(Lee et al., 2014). In addition, seasonal thermal energy storage for the year-round stable thermal energy supply and a buffer tank for efficient thermal energy supply, and pipe line, control and monitoring system will be installed until OCT. 2016. Heating and hot water will be supplied to some completed public buildings, and demonstration research by on-site operation will be performed until May 2019.

2. ESTIMATION OF HEATING AND COOLING LOADS

Thermal energy produced from block heating system with various new and renewable energy systems and seasonal thermal energy storage will be supplied to 5 public buildings including a high school, and the energy

Table 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	378.6

Table 2. Maximum load

Load	Heating	Cooling
Maximum day load	8,750 kWh (2,488 RTh)	3,250 kWh (925 RTh)
Maximum load	1,110 kW (316 RT)	350 kW (100 RT)

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, and estimated heating load was lower than the preliminary expectation due to the enforced energy guideline of Chungbuk innovation city. On the other hand, cooling load was similar to the preliminary expectation.

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. Thermal load for hot water was estimated as 186.9 MWh with recommendation of SOLITES. The pipeline heat loss from STES to the high school (about 1 km) was estimated as 196.4 MWh. Therefore, the total thermal energy of 761.5 MWh should be supplied to recover the heat loss.

The capacities and type of energy town energy facilities were determined based on the heating and hot water load because original plan was to supply thermal energy based on the solar thermal energy. However, water and ground source heat pumps were selected as the auxiliary system, which is possible to produce cooling water as well. Therefore, the cooling energy supply (about 128.0 MWh) to public buildings (except for a high school) is added to the original plan. In case of a high school, additional cooling system will be installed, because the cooling load of high school is too much to be covered by the originally planned heat pump facilities in the integrated management center.

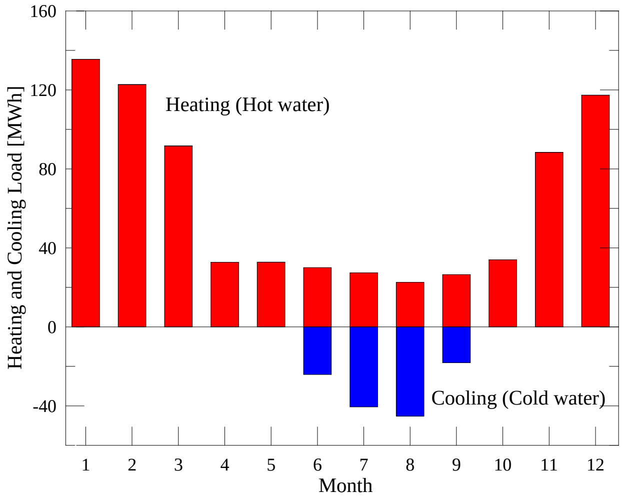

Fig. 2. Monthly heating and cooling energy load

Fig. 2 shows monthly heating and cooling energy load, and hot water load and pipeline heat loss are included in heating load. In addition, energy peak day and load for the eco-friendly energy town was estimated based on thermal load analysis of public buildings and summarized in Table 2. This energy peak load and day was considered to design the heat pump and buffer tank capacities.

3. CAPACITY OF EQUIPMENT

The capacities of energy facilities planned to be installed in the site were determined based on the estimated thermal energy load and the TRNSYS-based simulation program developed by SOLITES. 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, the water source heat pump as the auxiliary system was scaled-up.

To cover cooling load of public buildings except for a high school, basically about 350 kW heat pump system is required. Ground source heat pump (GSHP) of 175 kW and water source heat pump (WSHP) of 175 kW was originally designed. However, WSHP of 175 kW was not enough to use residual heat in STES for the heating according to simulation results. Therefore, additional WSHP of 175 kW was added. 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. Fig. 2 shows the simulation results on the energy system balance and the yearly temperature distribution in STES.

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

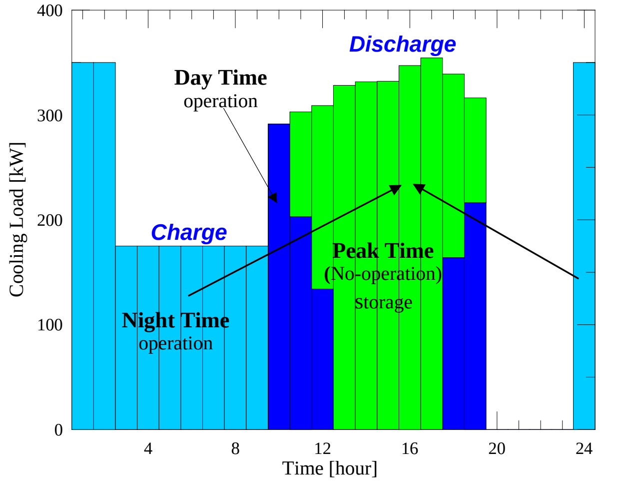

Fig. 3. Effect of thermal energy storage using buffer tank

buildings can be covered by a GSHP of 175 kW and a WSHP of 175 kW.

With related to buffer tank, some of the thermal energy produced in off-peak load time period can be stored in buffer tank, and be utilized in day time period. The use of buffer tank contributes to levelling the national electric power load and reduction of operating costs because electricity price in off-peak load time period is cheaper than that in peak time period. Buffer tank of 200 m^2 was installed, and the capacity was determined to cover more than 60% of peak cooling load and 40% of peak heating load. Fig. 3 shows the effect of thermal energy storage using buffer tank in cooling mode. In addition, Figs. 4 and 5 show the simulation results on the energy system balance and the yearly temperature distribution in STES.

4. OPERATING METHODS

Fig. 6 shows total system configuration. Collector pump operates over the reference insolation, and inverter type storage pump will be controlled to maintain the water temperature in pipe connected to the upper side of STES as more than 60°C. In addition, overheat protection operating modes are designed. When the STES is overheated, it will be relieved by a cooling tower and borehole heat exchangers

When heating supply is needed, the hot water in upper side of STES is utilized first. When the water temperature is too low to supply, WSHP is operated using the residual heat of STES as the low temperature source. The hot water from WSHP is stored in buffer tank, and supplied to public buildings. The heat exchangers for heating and hot water supply are installed individually. The return temperature is controlled by the inverter pump, and 3-way valve is also installed for the emergency cases.

In case of a high school, one pipeline for hot water supply and heating is connected to substation because cooling energy is not supplied to the high school. In cases of the 4 public buildings except for a high school, the two pipelines for hot water supply, heating and cooling were

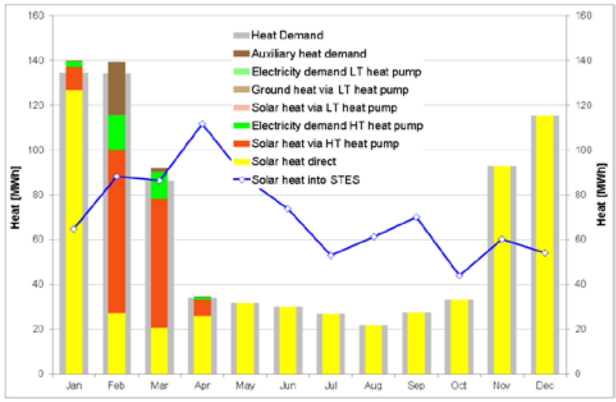

Fig. 4. Energy system balance from simulation results

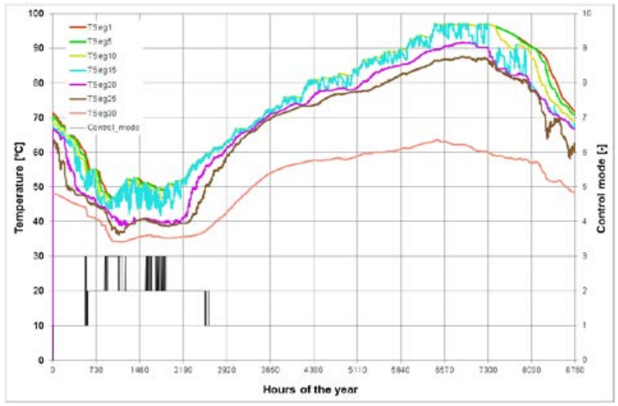

Fig. 5. Yearly temperature distribution in STES

installed for the simultaneous use of cooling and hot water. Buffer tank will be controlled according to the temperature conditions and the next day load, and the most effective control methods will be derived from demonstration operation.

5. CONCLUSIONS

The solar thermal based block heating system with seasonal thermal energy storage will be installed by OCT.

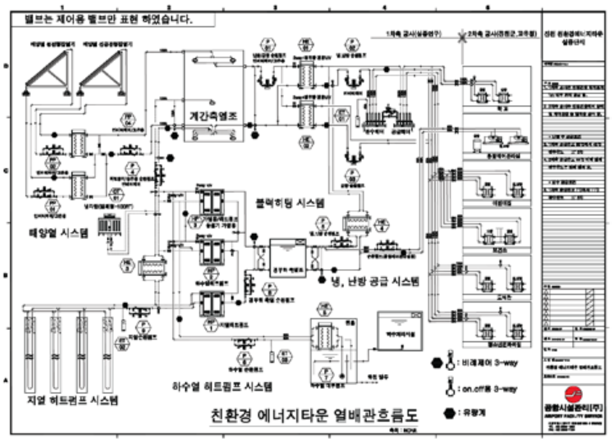

Fig. 6. Total system configuration

2016. Year-round stable thermal and cooling energy supply is the objective (except for the cooling in a high school), and various renewable energy systems and seasonal thermal energy storage (STES) integration technique will be obtained from the demonstration operation. Based on TRNSYS-based simulation analysis, solar thermal collector of 1,600 m^2, ground source heat pump of 176 kW, water source heat pump of 350 kW, seasonal thermal energy storage of 4,000 m^3 were determined to cover yearly thermal load of 761 MWh and yearly cooling load of 128 MWh. From the demonstration research (2016-2017) by on-site operation, efficient operating methods will be derived and year-round stable heating and cooling energy will be produced and supplied to public buildings. Based on the analysis of the monitoring results, the effect of the small scaled block heating system by new and renewable energy in South Korea will be proved and presented. The Jincheon Eco-Friendly Energy Town Project started from the Korean government policy converting unwanted public facility into eco-friendly energy production facility by the eco-friendly energy facility construction in opposed area. Through the related technology development and demonstration research, the synergy effect by new and renewable energy hybrid is expected. In addition, it will contribute to the wide spread of zero energy community in Korea.

ACKNOWLEGEMENT

This research was sponsored by MSIP(Ministry of Science, ICT and Future Planning) Eco-Friendly Energy Town Program of (Grand No. NRF-2015M3D2A1032742) and specially thanks to SOLITES team for simulation work.

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