Integrated Energy Simulation for Building and MEP Systems Including Thermal Cascading Systems

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Summary

This research focuses on the evaluation of thermal energy efficiency in a building including thermal cascading systems such as cogeneration, solar-thermal heat combined with final energy consumption for space heating and cooling, a dehumidifier, and a water heater. In order to achieve the national target of GHG emission reduction in Japan, much grater use of renewable energy, unused thermal energy is strongly required in the building sectors. The thermal energy efficiency of the whole system varies depending on not only calorific balances but also on the temperature of heat conveying media and its flow-rate to each consumption unit. Based on the concept of the simulation tools, the major development work involves the modeling of cogeneration units. As the first development phase, a sample system consisting of one unit of each form of equipment has been completed adopting the forward method. This paper describes the development of the method and shows some results for a case study.

Keywords: Integrated energy simulation, Cogeneration, Forward method, Thermal energy balance, Partial load performance

1. Introduction

Cogeneration systems (CGS) are, along with solar power generation, designated “efficiency improving” technologies under the Japanese Energy Conservation Standards for Buildings. They work by generating electricity onsite to power for machinery, lighting, and so on. They produce heat which is used on-site for air conditioning and water heating, thus raising the efficiency of primary energy use. Unlike most high-efficiency equipment, the performance of cogeneration systems is affected by the balance of electricity demand and heating/cooling demand, as well as by the timing of such demand. Assessing the effects quantitatively necessitates coupled calculation with all heat and electricity demand, including buildings, air conditioning, electrical equipment, and sanitation facilities.

One simulation program that enables such calculation to be made is the Building Energy Simulation Tool (BEST) now under development in Japan, with the initiative of Ministry of Land, Infrastructure, Transport and Tourism, which handles housing and facilities in an integrated manner in order to assess the energy performance of buildings as a whole. [2] The BEST includes CGS as one of the key modules.

In view of the above background, the purpose of this study is to show advantageous effect that BEST simulation for an actual heat source system which couples cogeneration systems with solar thermal systems in a building.

2. Target of the heat source system

2.1 Compendium

Figure 1 shows the overviews of the heat source system including a lot of equipment and parts. Because the BEST program can be connected one by one module, it is possible to model the system flexiblly. One of the fetured points is automatic control module, PID controllers[6] which plays a role to stabilize the heating system. It can also be studied when varying the temperature and flow rate is controlled. In this paper, a case study is conduted utilizing this feature.

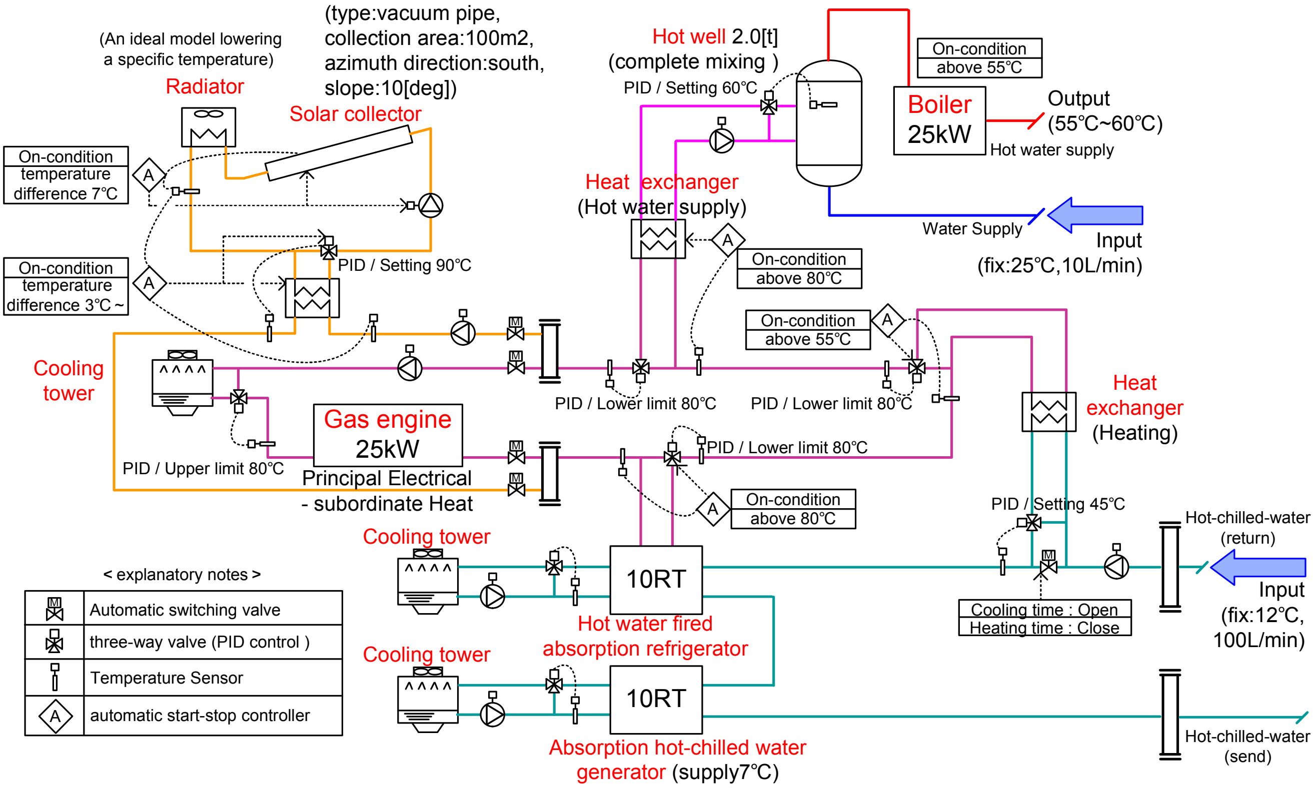

Fig. 1 Heat source system and calculation condition

2.2 An example of results

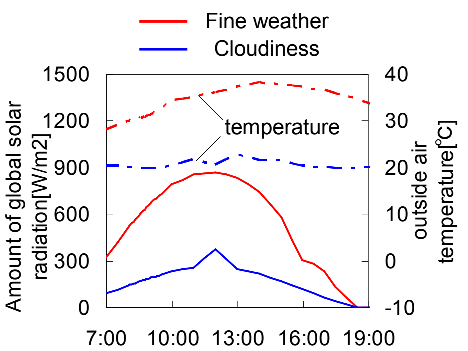

Fig. 2 Weather data of two days

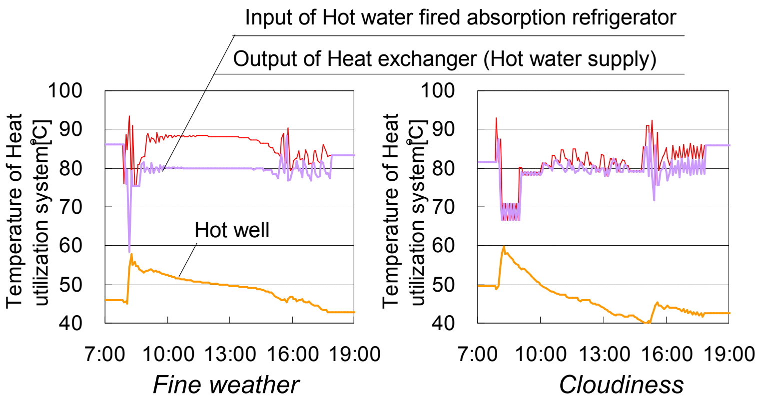

Fig. 3 Comparison of the temperature of two days

It is described the common calculation conditions of the case study. Meteorological data for air temperature and solar radiation is the standard weather data. The calculation period is in August. Figure 2 shows the sample weather data of a sunny day and a cloudy day in summer. The temperature of the sunny day exceeds 30 degrees. Figure 3 compares the results of the sunny day and the cloudy day, temperature changes are shown in chronological order. Time schedule of solar collector and gas engine are shown in Table 1, case 1-3. In the graph, the temperature has changed greatly in the evening; this is a feature of the simulation program to stabilize the cogeneration system. The graph shows three temperatures, hot well temp., input of hot water driven absorption refrigerator temp., and output of heat exchanger (hot water supply) temp. Fine day you can see the steady solar, about 8 degrees, cloudy days you cannot. But, not available during periods of heat can be compensated by cogeneration heat.

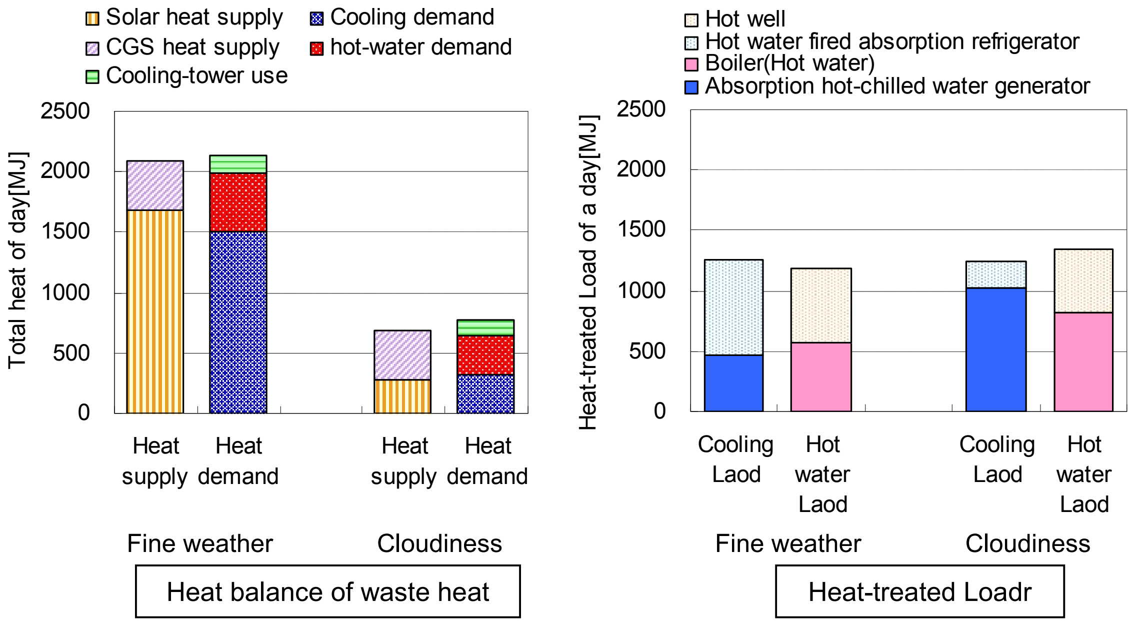

Fig. 4 Comparison of the total heat of two days

Figure 4 left shows the total heat of a day, it shows the use of the CGS waste heat by category. The waste heat coming from CGS and its use is well balanced, but solar heat collector amount is difference of 1450[MJ]. The heat went out the difference in space cooling. The reason is because they decided where the first heat. Figure 4 right shows the heat-treated load of a day, it shows the cooling load and hot water load. In fine weather, the 60 percent of cooling load can take advantage of solar heat. In cloudiness, the only 20 percent of it can take advantage of solar heat. In addition, compared to cloudiness, the heat of boiler is less.

3. Case study

3.1 Case study 1 : Differences in time schedule of heat source

Table 1 Time schedule of 3 cases

	case1-1	case1-2	case1-3
Solar collector	8:00 ~ 18:00	-	8:00 ~ 15:00
Gas engine & Cooling tower	-	8:00 ~ 18:00	15:00 ~ 18:00

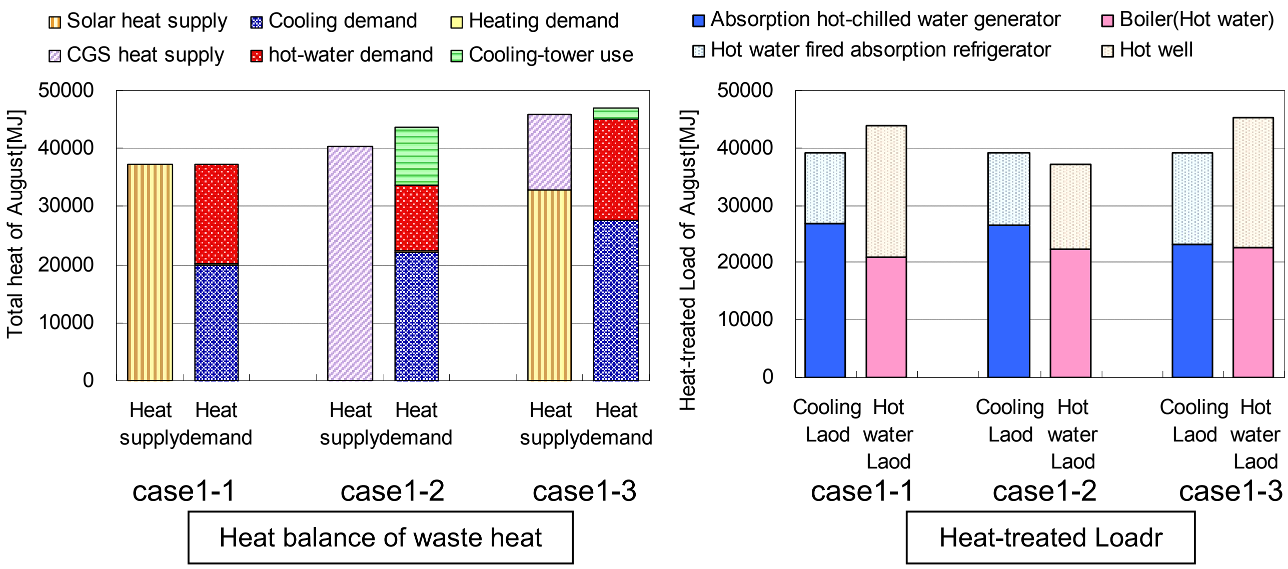

Fig. 5 Comparison of the total heat of August

Table 1 shows a comparison of case studies with different operating hours that solar only case1-1, CGS only case1-2, case1-3 is driving the two systems. Figure 5 left shows the heat balance of total waste heat of August in each equipment of each case. The total waste heat of case1-3 is the most common in 3 cases. The reason is because the waste heat of cloudiness is complemented by CGS.

3.2 Case study 2 : Differences in temperature of heat utilization system (Solar collector)

Table 2 the controlled temperature of 3 cases

	case2-1	case2-2	case2-3
temperature of heat utilization system	80[deg]	70[deg]	60[deg]

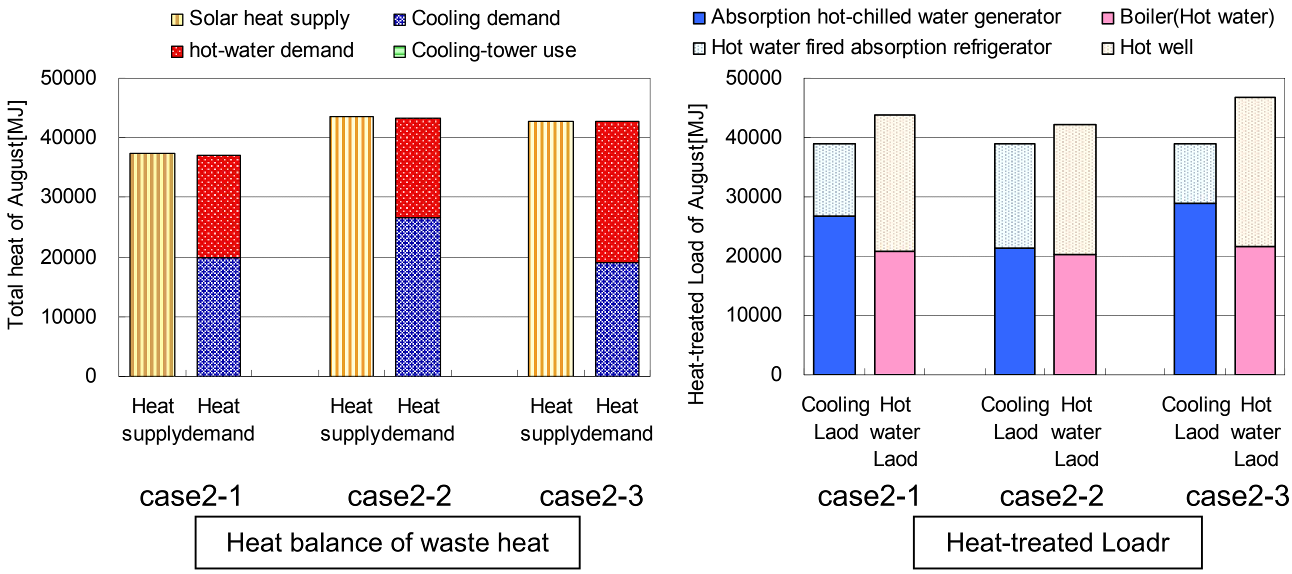

Fig. 6 Comparison of the total heat due to differences in temperature of Heat utilization system

While cogeneration system has lower temperature of waste heat to protect the gas engine, for solar system, the lower the water temperature through solar energy collector is preferred for effective heat recovery. In order to estimate the effect, this study set three cases of different control temperature set 80[deg], 70[deg], 60[deg]. Figure 6 shows the monthly accumulated weight. It shows that lowering the temperature increase the amount of heat recovery. And it was found that cooling demand increase. The most of cooling load from hot water fired absorption refrigerator is 60[deg].

4. Conclusion

This paper explains that the BEST program can calculate the CGS system coupled with solar collectors. Using solar heat collection system, it revealed that lower controlling temperature enables more heat to be obtained.

In the future research, optimal operation time and operation to vary boundary condition is expected to be considered.

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