EFFECT OF NETWORKED CHP SYSTEM WITH GRID ON CO2 REDUCTION IN COLD REGIONS

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Overview

The installation of CHPs (combined heat and power) in cold regions is important to reduce CO2 emissions, and reverse power flow of surplus electricity plays key role in the effective operation of CHPs. The authors have proposed the networked CHP system; micro CHPs are installed to the consumer side and controlled by a control center. The advantage of this system is the effective utilization of existing power grid and gas pipes, and then, the system can be easily installed to regions where heat pipes are not penetrated like Japan. In this study, we clarify the CO2 emissions reduction effect of networking CHPs in the cold region of Japan by applying the electricity and heat supply system model. We also analyse the influence of consumer composition on the networking effect of CHPs.

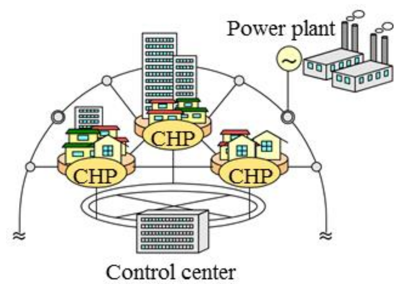

Fig.1 Conceptual figure of networked CHP system

Methods

The model analysis of this study targeted the electricity and heat supply system under a single distribution substation, and the six types of consumers, condominium, detached house, hotel, office, store, and hospital were included in the system. The energy demands of consumers were satisfied by CHPs, gas boilers, hot water tanks, electric air coolers, and gas absorption coolers, placed at consumer side, and grid electricity. In the non-networked CHP system, the energy instruments were discretely operated, and the electricity from CHPs could not be shared among the consumers. On the other hand, in the networked CHP system, the surplus electricity from CHPs could be reversely flowed to the grid and shared among the consumers while the reversely flowed electricity could not be crossed over the distribution substation.

The model applied to this study determines the facility composition and operation patterns of the electricity and heat supply system to minimize the annual energy supply cost: the sum of facilities initial cost, fuel cost, and supply cost of grid electricity. Every types of consumer have one day hourly demand pattern of heating, cooling, and other electricity use for winter, interphase, and summer. The fuel cell CHPs were assumed to be installed to detached houses, the gas engine CHPs were assumed to be installed to commercial buildings, and no CHP could be installed to condominium. The electricity and heat efficiency of CHPs were decreased as their load factors were decreased.

The three areas with different consumer compositions, urban residential, commercial, and local city areas in the cold region of Japan, were analysed by the model. Fig.2 shows the share in the total floor area of each types of consumer in these areas. The model analysis was performed for six cases supposing that the non-networked and networked CHP systems were installed to these three areas. In each case, the relationship between the CO2 emissions reduction and energy supply cost was investigated by solving the model repeatedly under the different levels of CO2 emissions constraint. The initial cost of fuel cell and gas engine type CHPs were assumed to be 700 and 300 thousand JPY/ kW, respectively.

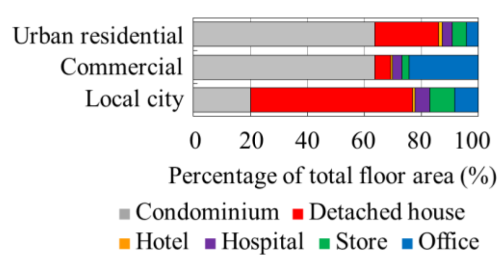

Fig.2 Share of Consumers in Floor Areas in Target Regions

Results

Fig.3 shows the heat demand and supply balance of detached houses in urban residential area; (a) and (b) are results for non-networked and networked CHP systems. The CO2 emissions constraints were set so that the annual energy supply cost increases by 5.4% compared with the system without CHPs. In the case of non-networked CHP system, only a small part of heat demand is covered by CHPs even in the winter. On the other hand, in the case of networked CHP system, quite a few part of heat demand is covered by CHPs. The CHPs need to be operated with high load because of expensive initial cost and efficiency reduction by partial load operation. However, such a high load operation becomes impossible if the large amounts of CHPs are installed because the heat demand is much higher than the electricity demand and the surplus heat cannot be wasted. Then, only few amounts of CHPs can be installed in the non-networked CHP system. On the other hand, in the networked CHP system, CHPs can be operated at the full load in longer time even if the more capacities are installed because the surplus electricity from detached houses can be supplied to other types of consumers. Fig.4 shows the total electricity demand and supply balance of all consumers in the system. The gas engine CHPs installed to commercial buildings are flexibly operated mainly in the peak demand hours while the fuel cell CHPs installed to detached houses are operated at the constant load. From this result, the proper combination of residential and commercial consumers appears to be important to maximize the CO2 emissions reduction effect of CHP networking.

Fig.5 shows the increase in the annual energy supply cost against the decrease in the CO2 emissions for the three areas with the non-networked and networked CHP system; the cost and CO2 changes are presented as the rate against the system without CHPs. If the more CO2 emissions can be reduced by the less annual energy supply cost, the curves in Fig.5 shift to lower right side. The curves for networked CHP systems are located at the right hand of these for non-networked systems in all three areas. The result indicates that the networking of CHPs through electricity grid can help the more effective CO2 emissions reduction. However, the degree of effectiveness is different among the areas; the degree of curve shift to right hand by CHP networking is the largest in the local city area and the smallest in the commercial area. The smaller networking effect in the commercial area is caused by the smaller share of detached houses; the high-efficient fuel cell CHPs can only be installed to the detached houses. On the other hand, the local city includes larger share of detached houses, and the larger capacity of fuel cell CHPs can be installed.

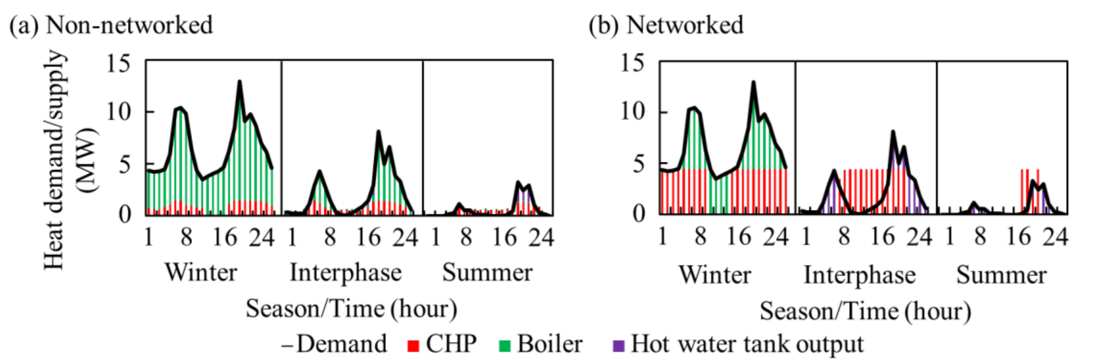

Fig.3 Heat energy balance of detached houses in urban residential area (a) Non-networked (b) Networked

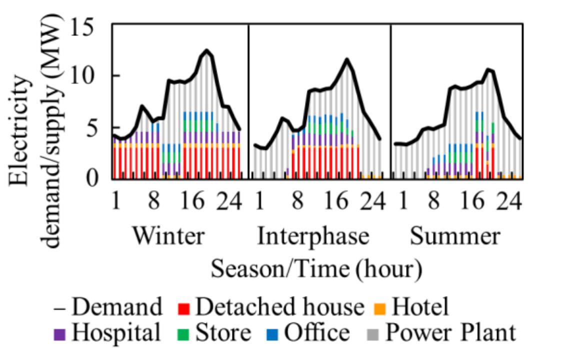

Fig.4 Total electricity energy balance of whole systems (Urban residential area, networked)

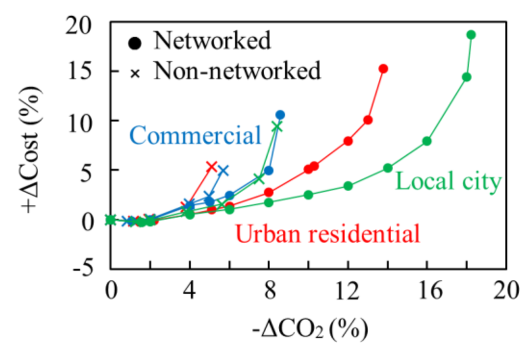

Fig.5 The rate of cost increase against the rate of the CO2 emission of networked and non-networked systems in each region

Conclusions

The installation of networked CHP can improve the effect of CO2 emission reduction because the larger capacities of CHPs can be operated at full load by permitting the reverse power flow of electricity. The CO2 emissions reduction effect of CHP networking is affected by the balance of the total floor area of detached house and the other consumers, and then, effectiveness of the networked CHP system is different among the installed areas.