INSTALLED CAPACITY OPTIMIZATION IN COMBINATION OF DISTRIBUTED ENERGY RESOURCE DEVICES FOR RESIDENTIAL BUILDINGS

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論文題名　：　INSTALLED CAPACITY OPTIMIZATION IN COMBINATION OF DISTRIBUTED ENERGY RESOURCE DEVICES FOR RESIDENTIAL BUILDINGS
（住宅の分散型エネルギー機器組み合わせにおける設備容量の最適化）

区　　分　：　甲

論 文 内 容 の 要 旨

Rapid depletion of fossil fuels will surely lead to shortage of end-use energy supply if no actions are taken. Energy consumption level of commercial and residential sector is growing larger and larger and increasing at a much faster rate than that of the other sectors. Thus, taking effective actions focusing on the commercial and residential sector brooks no delay.

Two main points of view for the effective actions are to increase efficiency in both conversion and transport of energy and to use alternative sources of energy. To increase central electric power plants utilizing renewable energy such as geothermal energy, wind energy, etc. instead of additional conventional electric power plants is considered, however, construction of these plants usually takes many years and they can not utilize exhaust heat in the energy conversion process. On the other hand, distributed energy resource (DER) devices such as photovoltaics, solar hot water panels, a fuel cell, etc., can be easily installed in on-site buildings and energy cascading utilization is expected in the DER devices.

Accordingly, this research aims for proposing a method to integrate the DER devices and determining the optimal combination with installed capacities, and for clarifying the reduction effects of energy consumption and expenses in residential buildings through case studies by a numerical simulation.

This dissertation consists of six chapters. The chapter outlines are described as follows:

In Chapter 1, general background of today’s situation of dramatically rising energy consumption is revealed. The previous researches on combination and optimization of the DER devices are presented, the objectives of this research is given, and the structure of this dissertation is illustrated.

In Chapter 2, in order to show how the ‘Kang’, which is a Chinese traditional heating system using surplus exhaust heat (smoke) from cooking, use energy in an efficient way and improve indoor thermal environment, thermal processes of building with the Kang are described, the mathematical models are built, and results of the field tests and simulations are analyzed. Through the works of this chapter, the success and persistence of the Kang inspires me with this kind of idea as using one kind of energy in two ways to make efficient use of energy in modern energy systems.

In Chapter 3, dynamic models of photovoltaics, solar hot water panels and a fuel cell as three kinds of DER device are built on the basis of their working principles. Especially, the dynamic model of photovoltaics with effects of ambient temperature and that of solar hot water panels with effects of collector’s heating loss are originally developed. The electric power and/or hot water generation capacity and efficiency of these devices are analyzed, and the device respectively demonstrates a relatively high efficiency in generating energy for residential use. This chapter provides the mathematical models for integration of the devices in the next chapter.

In Chapter 4, the DER device's models, which are built in the previous chapter, are integrated as an overall system with the operation strategies for the generation of electric power and hot water. The simulation program of the overall system with the DER devices installed to a typical residential building located in Fukuoka City are newly developed, and the standard weather data, the municipal water temperature data, the electric power and hot water loads calculated by another existing simulation program are collected as the input data of the system simulation developed. Finally, four patterns of combination of the selected DER devices are respectively analyzed. The reduction effects of energy consumption are compared, and the reasonable results show that the integration method of the DER devices is validated. As a result of the case study, the total energy reduction is 77GJ/year when the 5.8kW PV panels are used and it increases to 88GJ/year by the combination with a typical SOFC.

In Chapter 5, a genetic algorithm is applied to optimize the installed capacities of the DER devices. As a result, the optimum combination of the DER devices for energy reduction is 30 modules of photovoltaic panel, a fuel cell with a capacity of 740W with the hot water tank volume of 200L. In this case, about 57% of energy consumption can be reduced and 7,714kWh of surplus yearly amount of electric power can be obtained. The optimum combination for cost economization change to 28 modules of photovoltaic panel and a solar hot water panel with 8 tubes and the tank volume of 150L in the initial ten years. In the subsequent ten years, a fuel cell with a capacity of 630W with the hot water tank volume of 170L is additionally installed to the system because the unit price would be decreased. In this case, about 16% of the life cycle cost for 20 years can be saved.

In Chapter 6, summary of this dissertation is given, and scope for further work is described. The methodology proposed in this dissertation is validated to reduce considerable quantity of residential energy consumption and expenses. The results of this research can help residents reform their existing DER devices, assist developers to equip the newly completed buildings with optimal DER devices, and also support designers in designing the hardware of newer types of DER devices.