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Study for Optimal Energy Management System in Houses Collectively Receiving Electricity at Low Voltage

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Abstract

Currently collective electricity receiving and its trade among houses are promoted as a method of energy saving. Previous researches investigated the possibility of collective receiving of high voltage electric power. In this research, we evaluate collective electricity receiving at low voltage and its trade among houses with photovoltaics and fuel cells. In this system, power receiving facility for high voltage is not necessary, although the price of electricity is higher. We develop a Mixed Integer Non-Linear Problem (MINLP) model of the system, introducing the wheeling rate as a benefit of the aggregator. Then we adopted the concept of Nucleolus in game theory to maximize the minimum benefit of all houses. By doing this, we design a system that distributes profits fairly among house.

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Keywords: collective electricity receiving, low voltage, electricity trade among houses, Nucleolus, MINLP;

1. Introduction

Now global warming phenomenon by a greenhouse gas and exhaustion of a fossil fuel are becoming a social problem, so building of low carbon society is very important. When we consider reducing the emission of GHG, it is very important to see which way of power generation (such as thermal power generation or renewable power

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resources) is used. On the other hand, the energy saving of demand side is also important. While energy saving is promoted by various ways, we focus on energy saving by residential sector.

These days, private power generators such as photovoltaics(PV) and fuel cells(FC) are introduced in houses. PV is the system that generates electric power by solar power. It is renewable energy, so is unlimited and clean resource. FC produces electricity and thermal energy through the chemical reaction of hydrogen and oxygen, and is very efficient when both of electricity and thermal power are used[1]. Households can control these energy resources optimally by the introduction of HEMS (Home Energy Management System) and it can apply for demand response, so it is considered to develop from now on [2].

As another way of energy saving by residents, houses collectively receiving electricity at high voltage are promoted in Japan. Collective receiving is the system that aggregated households buy the high-voltage electric power collectively and share it. In general, high-voltage electric power is less expensive than low-voltage power, so the system has economic advantage [3]. However, voltage transformation is necessary for houses which use at low voltage, and it needs the initial cost for voltage transformer.

In this research, we introduce collective receiving system of low-voltage electricity. An aggregator buys the low voltage electricity collectively and supplies it to every household, and this system has a feature that voltage transformation cost is not necessary while they can't buy inexpensive electric power of the high voltage. We also introduce the electric power trading system to send surplus electricity to the house which wants it, and it allows the flexible work of energy equipment [4].

However, there is a problem that the aggregator can't make a profit. In the high voltage collective receiving system, aggregators can buy inexpensive high-voltage electricity and sell electricity to each household, so they can make a profit by the difference. On the other hand, aggregators in low voltage collective receiving system buy only low-voltage electricity, so they need to make a profit by other ways. Then, we introduce the wheeling rate, which is paid to the aggregator by the households who accommodate electricity with other households. It will be the sources of aggregator's profit.

We simulate the flow of energy in the houses which have electricity trading system, design optimal electricity rate, and evaluate the economy and energy saving.

2. Simulation model

The optimal operation of the photovoltaics and a fuel cells and the optimal charge system were decided by solving optimization problem.

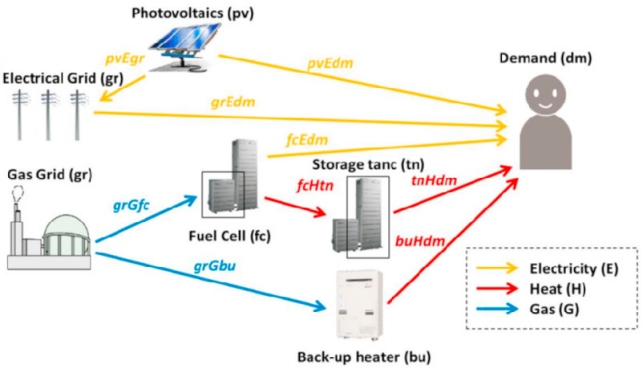

Figure 1. The flow of energy in the house PV and FC installed

The data used in the model is the electric power consumption, the heat consumption and the photovoltaic generation amount of 5 households. All households have both of fuel cell and photovoltaic. The flow of energy is shown in Figure 1. A fuel cell consumes hydrogen made from gas and generates the electric power and heat. The electricity is consumed at the own house or sent to other houses, and heat is stored in a hot water storage tank. The demand of heat is supplied from storage tank or back-up heater which consumes gas and produces heat. FC is