NEXT GENERATION MODEL OF THE WORLD'S FIRST RESIDENTIAL PEMFC COGENERATION SYSTEM GOES ON SALE

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Introduction

Tokyo Gas has been aggressively developing its new PEMFC (Proton Exchange Membrane Fuel Cell) systems since it had successfully launched the world's first PEMFC CHP (Combined Heat and Power) systems for residential use in 2005 [1][2]. The new system is both revolutionary and sophisticated so as to be sold from May 2009 as one of ordinary commodities, whereas the previous was introduced to its limited customers at 400 thousand Yen (4 thousand Dollars) for 4-year use. As of the end of March 2008, five hundred and twenty of the previous models were installed, whose experiences were utilized to design the new model.

Hundreds of the new models were manufactured limitedly in 2008 and they have been already in real operation in the same scheme as the previous were. In May 2009, the new model went on sale successfully and is scheduled to be sold by more than a thousand per year.

Objectives of the paper

The objectives of this paper are the following two.

First, the challenges which we faced in the installations of the previous models and how to solve them out in the development of the new model are reported.

Secondly, the field performance of the new models and its comparison with that of the previous ones are analyzed. As CHP's performance is dependant on each customer's electricity/heat balance and demand pattern, it is very important to gather lots of data from hundreds of customers with various energy demands.

Development

a. Specifications

Panasonic Co., Ltd. has been cooperating with Tokyo Gas to develop the system. The following table (Table 1) shows the specifications of the new system, listed with those of the previous one.

Rated power output is 1kW at which the electrical efficiency is more than 37%LHV and the heat recovery efficiency is more than 52%LHV, 2 points higher than the previous one. As for the electrical efficiency, the practical value turned out to be even higher as described later, since catalogue specifications tend to be somewhat conservative.

b. Challenges of the new models

The challenges in the development of the new model are categorized into 6, which are cost, durability, reliability, installation, maintenance and user-interface.

Table 1: Specifications of the previous and new systems

		Previous model	New model
Fuel type		LNG based natural gas (category 13A)	
Fuel Cell Unit	Rated power	1kW	
	Dimensions (mm)	W800 D375 H1000	W780 D400 H860
	Electrical efficiency (LHV/HHV)	37%/33%	37%/33%
	Power output range	300-1000W	
	Heat recovery efficiency (LHV/HHV)	50%/45%	52%/47%
	Heat recovery temperature	60C	
	Fuel consumption rate (HHV)	3.0kW	3.0kW
HWS* unit	Dimensions (mm)	W850 D510 H1900	W750 D480 H1883
	Backup burner input (HHV)	69.5kW	64.7kW
	Heat recovery tank capacity	200L	

* Hot Water Storage

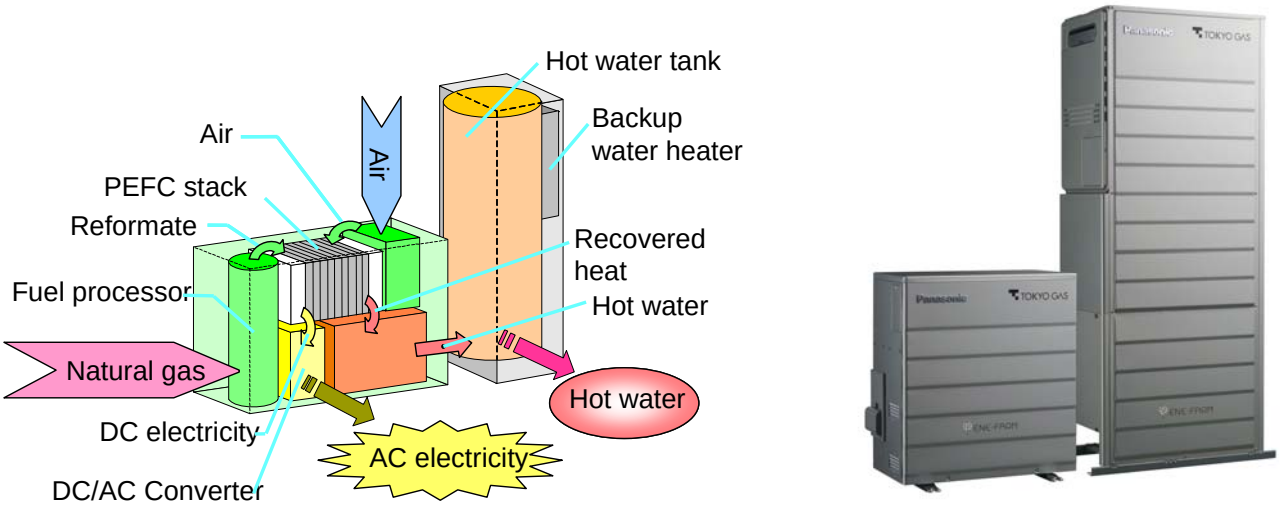
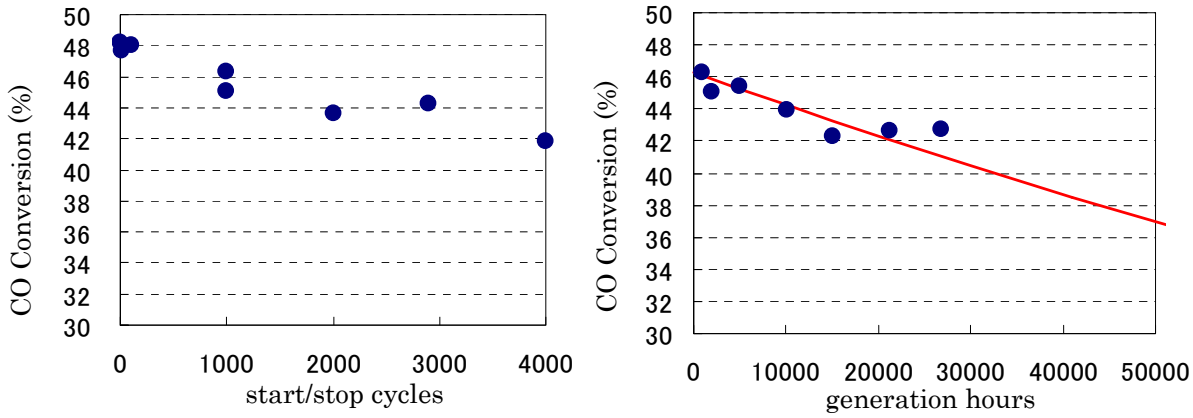


Figure 1: Schematic of system (Left) and Exterior of new model (Right)

As for cost, all the components of the system, including the FC stack and the fuel processor, were re-designed or re-selected from scratch to reduce manufacturing cost. The costs of the pumps, valves, fans and other balance of plant (BOP) were reduced thanks to a NEDO (New Energy and Industrial Technology Development Organization) project, in which all the PEMFC system makers in Japan try to unify their spec requirements for each component so that a best component can be adopted by all the makers, resulting in its cost reduction by mass-production effect.

In 2009, the price of the new models is set to be around 3 million Yen (30 thousand Dollars). Customers will purchase it much cheaper using a subsidy supported by METI (Ministry of Economy, Trade and Industry)

Regarding durability, the new models can generate electricity for 40000 hours or 4000 start/stop cycles which is supposed to be equivalent to 10-year use, where the previous can for 3 years. The durability of each component was verified by the data of accelerated/stress tests, continuous tests, start/stop tests or actual records.



Graphs 1: Examples of catalyst degradation stress tests to evaluate the fuel processor

Reliability is essential to sell a product, which is why a very challenging target was set for the system. A failure rate is defined as how often one system needs maintenance per annum excluding the regular maintenance such as exchanging the air filters, ion exchangers, desulfurizer, etc. The rate of the previous model was more than one hundred which means the service staff needs to fix one system once a year and occasionally a couple of times or more. The new model is estimated to achieve the targeted 5% by intensive endeavors and the redesign.

Installation issues. The difficulty in installing the previous model was that it takes 4 people to carry, 5 days to place and operate and wider space to put than it should ideally do. The new one weighs much less so that it can be carried by 2 people. Practically, 1-2 day(s) is necessary to finish the construction thanks to its simplified installation procedures. The installation space is reduced by changing the direction in which it is maintained.

With respect to maintenance, the interval of the regular maintenance is prolonged from 1 year to 2 years. In addition, maintenance itself is much easier thanks to the auto drainage function which is newly developed and the simplified layout of the piping and BOP.

Electricity and heat are too essential for people to realize that they are valuable. If a cogeneration supplies power and heat without offering information, people, especially domestic consumers, will not notice its real value. That is why the user-interface is strengthened. In Japan, most of recent hot water heaters have their control devices on the wall of the living room and the bathroom, which are rather simple and display the temperature of hot water only. But the control device of the new model is aimed to give enough information to the user and thus able to display how much electricity and hot water are/were generated, how long the system

has operated, when it will start power generation of the day and how much the user did contribute to the CO2 emission reduction. Furthermore, the user can select power generation modes, by which he or she determines more actively when and how much the system operates.

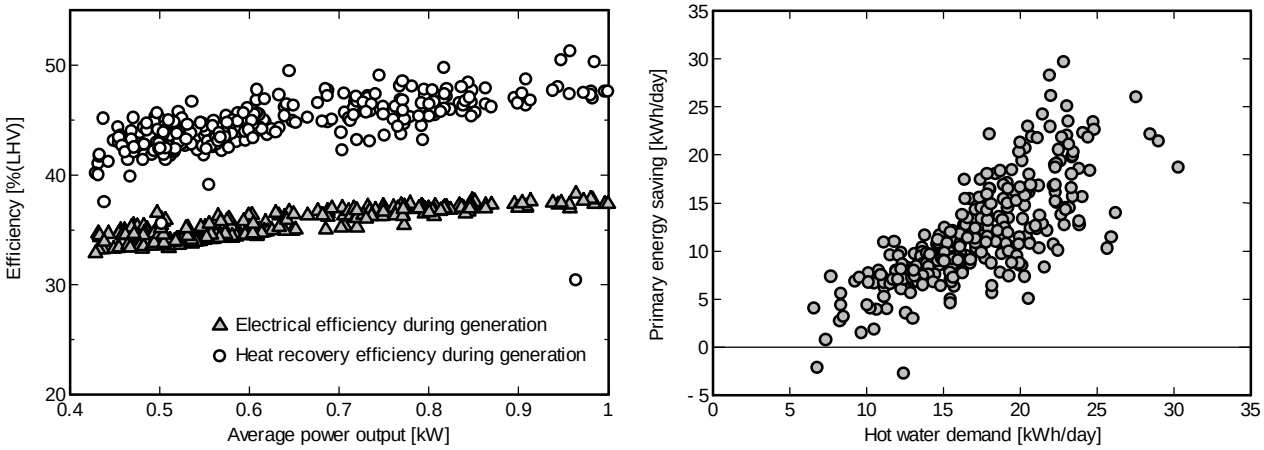
Figure 2: The control device displaying a history chart of past electricity generation

Results

a. Operation data of field tests

The graphs below show the operation results of our field tests which began just before the limited introduction did. A dot indicates a result of one day operation of a site and the graphs include 3-month data in total.

The electrical and heat-recovery efficiencies are verified to be as high as the specifications, even in the actual fields. Furthermore, the data show that the systems managed to reduce primary energy consumption every day except the only two days when the systems were out of operation almost all day. Here, the saving is defined as the difference of the primary energy consumptions between the CHP system and the conventional energy supply system where the electricity is supplied from the grid with electrical efficiency 0.369 and the hot water from a gas-fired hot water heater with thermal efficiency 0.78.



Graphs 2: New model's operation results of our field tests conducted in end-users' houses

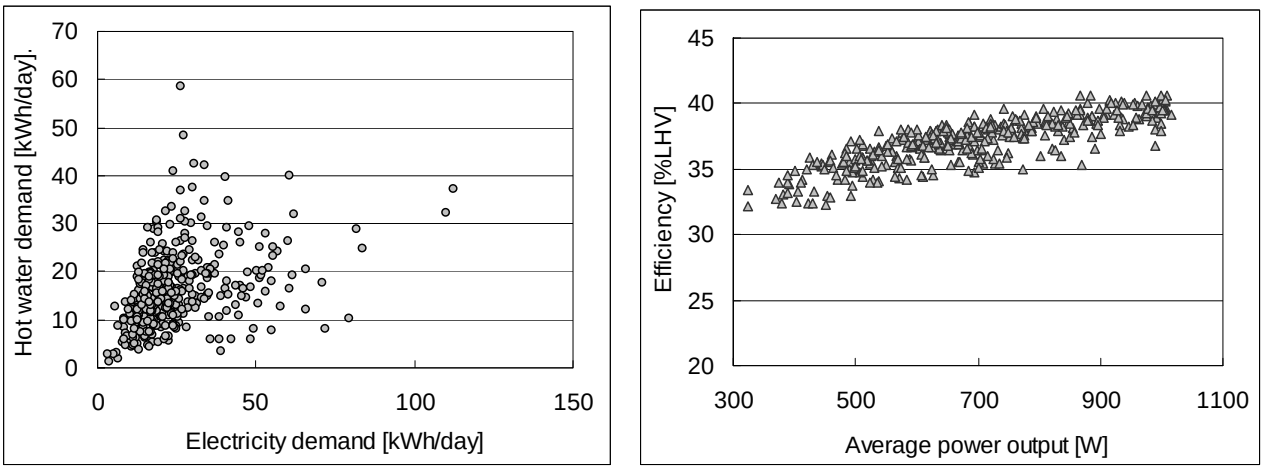
b. Results of the limited introduction

Since Tokyo Gas introduced the new model limitedly to its customers in April 2008, the operation data of them in the actual field have been gathered through a wireless cell phone network. The limited introduction was carried out in “the Large Scale Demonstration Project” conducted by NEF (New Energy Foundation) and supported by METI.

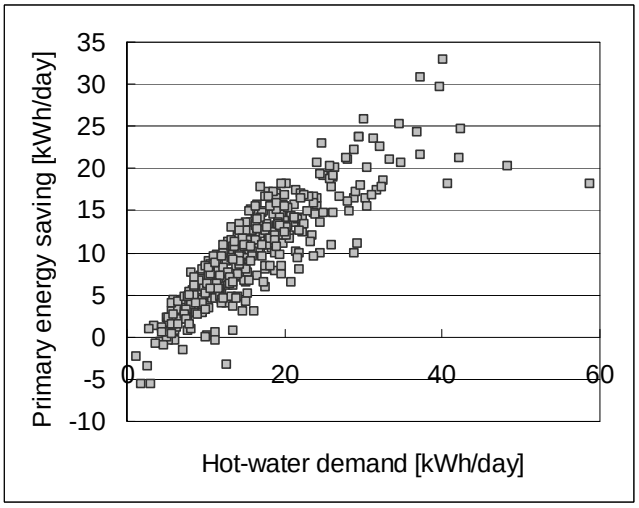
As of March 2009, there are 276 new systems installed in the field. From them, 166 systems are selected and analyzed which stated their operation before the end of November. The graphs below show the operation data of the 166 sites from October to December of 2009, and a plot indicates a monthly operation result of a site.

The demand distribution is confirmed in the left graph. As broadly well known, the performance of a CHP is dependant on how large the heat and electric demands are respectively. It is clarified that various customers with a wide range of energy demands are selected.

The right graph shows that the electrical efficiency is very high. In some cases, the efficiency is even higher than 40% based on low heat value. As a result, from the view point of the primary energy saving as well, the performance is verified sufficiently high.(Graph 4)



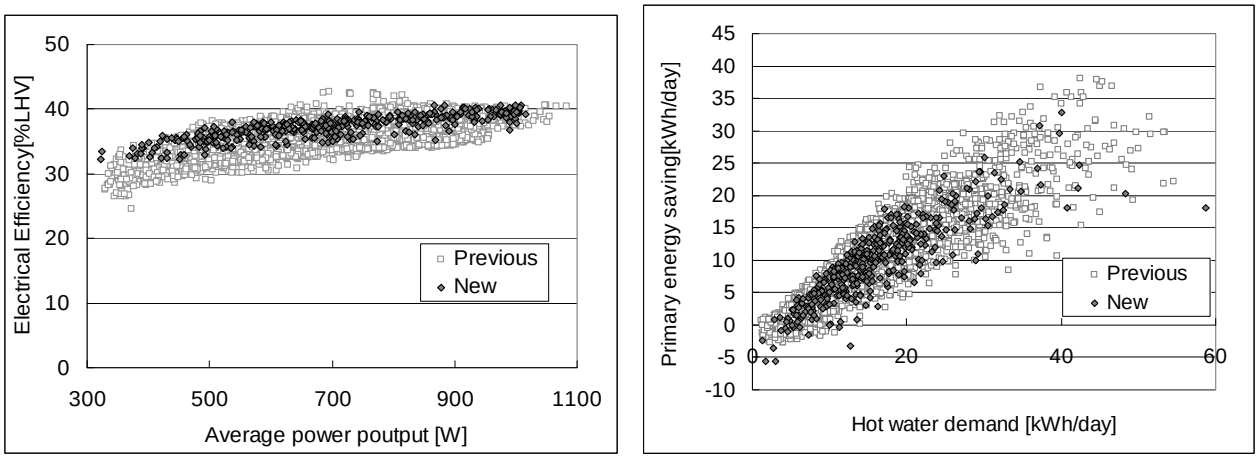
Graphs 3: Energy demand distribution and the electrical efficiency in the field



Graph 4: Primary energy saving by the new models

c. Comparison of the performance between the new and the previous

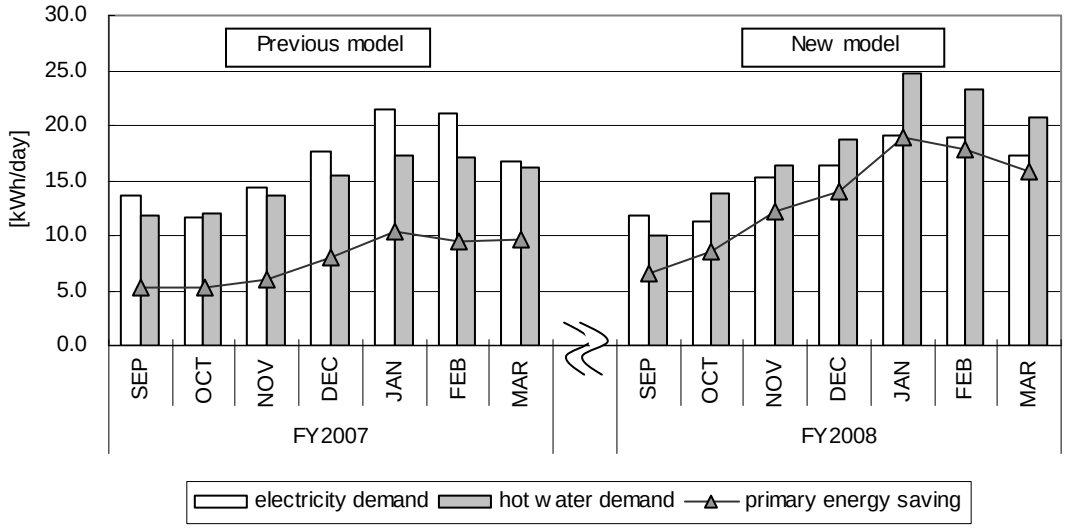
The performance of the new model is compared with that of the previous one. In Graphs 5, the data of the 166 sites in the limited introduction are plotted with the operation data of the previous models obtained from January to December of 2007. The new model is higher than the previous one in the electrical efficiency especially in partial load conditions. As for the primary energy saving, the best performance is accomplished by the previous model because of the wide distribution band, the new model turned out to perform better than the previous on average.



Graphs 5: Electrical efficiencies and primary energy savings of previous/new systems

In order to closely look at the comparison, a single site was selected for analysis where the previous model had been used last year and was replaced to the new model, to be used this year.

As seen in Graph 3, the new one is almost 40% better than the old one at reducing the primary energy consumption. That is partially because the customer changed his/her way of using energy so that the system can have the better performance. In short, this customer has come to use less electrical energy and more thermal energy, which makes the performance even higher.



Graph 6: Comparison of performance between the previous and new models

Summary

- ✓ Tokyo Gas succeeded in developing the next generation model of its residential PEMFC cogeneration system, which went on sale in May 2009.
- ✓ The new model is designed to be much cheaper, to have 40000hs /4000cycles durability corresponding 10 years' use, to have higher reliability, to be easier to install and maintain and to have a user-friendly interface.
- ✓ It is verified that the new model has a better performance than the previous one which was already very good at reducing the primary energy consumption.

Acknowledgement

Our deepest appreciation goes to NEF, NEDO and METI, as the limited introduction in which the operation data were gathered has been carried out in "the Large Scale Demonstration Project" conducted NEF, the cost of the BOP was reduced thanks to the NEDO project, and the customers of the new models are subsidized by METI.

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