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This document appeared in

Detlef Stolten, Thomas Grube (Eds.):
18th World Hydrogen Energy Conference 2010 - WHEC 2010
Parallel Sessions Book 6: Stationary Applications / Transportation Applications
Proceedings of the WHEC, May 16.-21. 2010, Essen
Schriften des Forschungszentrums Jülich / Energy & Environment, Vol. 78-6
Institute of Energy Research - Fuel Cells (IEF-3)
Forschungszentrum Jülich GmbH, Zentralbibliothek, Verlag, 2010
ISBN: 978-3-89336-656-9

Development of Stationary PEFC Co-generation System in Panasonic

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1 Introduction

Panasonic has set "Coexistence with the global environment" as one of its business visions for the 21st century to promote environmental sustainability management. We have defined fuel cells as the most important key business in the Panasonic Group and are promoting the commercialization of household fuel cell cogeneration systems.

Since the introduction of 1 kW-class fuel cell cogeneration systems to the market in 2005, we have installed and operated approximately 500 systems as of the end of March 2009, as part of the large-scale field test project. In May 2009, the systems were released to the general market. We expect to sell 1,000 systems or more in the first fiscal year and will adopt various strategies to encourage full-fledged distribution.

In this report, we describe the development status of Panasonic's household fuel cell cogeneration systems and the product specifications.

2 Concept behind the Development of Fuel Cell Systems

Asthe basic concept for full-fledged distribution of household fuel cell cogeneration systems, we believe that it is necessary to establish safety and quality first, to improve the efficiency and cost reduction for enhancing the advantages of the systems to be purchased by customers, while improving their durability and reliability.

The fuel cell system is a complex aggregate of materials and devices, so system technologies and "integration of technologies" is the key. Not only major device technologies such as fuel processors, stacks, inverters, etc., but technologies and expertise that have been built up by Panasonic during our development of home appliances have been used for overall system optimization.

Panasonic has been developing fuel cell systems by integrating the technologies available at its laboratories and business domain companies and integrating its own technologies.

3 Development Status of Fuel Cell Stacks

The key issues in the development of stacks are to achieve a power-generating lifetime of 40,000 hours and a durability of 4,000 start/stop operations. To achieve such a high durability over a short period of time, we have advanced our development by focusing on identifying degradation factors. With regard to the membrane-electrode assembly (MEA), the most important component in the stack, our study of degradation factors has revealed that the voltage drops due to the following three factors.

1. Damage of the electrolyte membrane due to deterioration (degradation of the gas separation function)

2. Degradation of electrochemical activity due to loss of capability of the platinum catalyst
3. Clogging of generated water due to the degradation of gas diffusion layers

In view of these degradation factors, the development was pushed forward from the viewpoints of material development, stack design, and forecast evaluation technologies. As a result, we could see the way ahead for improving system durability. Some of the durability test results are shown in Figure 1.

During the 24,000-hour durability test, the voltage dropped only by approximately 3.5% from the initial value. This was within our expected level of degradation. A durability of more than 4,000 start/stop operations was also achieved.

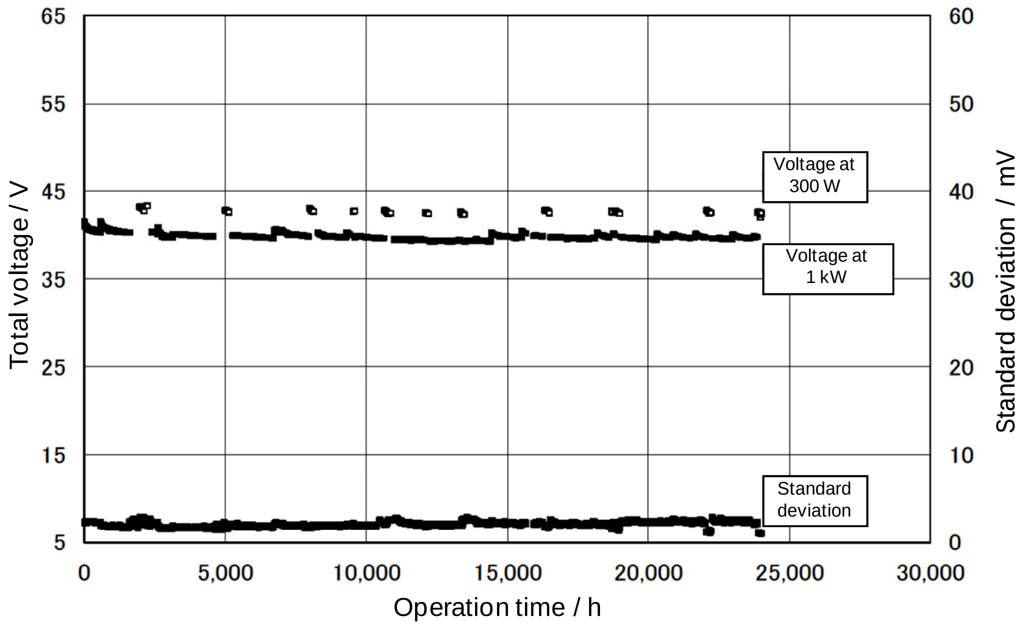

Figure 1: Full-stack durability test conditions.

4 Development Status of Fuel Processors

For fuel processors, what is required is better reforming efficiency to improve the power generation efficiency, better stability of hydrogen supply to the stacks, and a durability of 10 years or more. Improved reforming efficiency is of particular importance, since a household fuel cell is energy-generating equipment. The reforming efficiency is the ratio of the calorific value of the hydrogen used for power generation to the calorific value of the supplied raw materials.

In our conventional fuel processors, the reforming, denaturation, and preferential oxidization processes were independently controlled to stabilize performance. On the other hand, to achieve high efficiency by using heat effectively, thermal fluid simulations, in which reactions are taken into consideration, were used to study configurations that can optimize the reactions and fluid flow. As a result, we have developed integrated small multi-walled coaxial cylindrical fuel processors, on which evaporation, reforming, denaturation, and preferential oxidization devices are circularly located around the burner.

The heat from burner combustion is used in 'downhill' from the high-temperature device (for reforming) to the low-temperature device (for evaporation). Also, the heat of the generated gas is transferred from the high-temperature device to the low-temperature devices to ensure its most effective use.

Figure 2 shows the efficiency of reforming with reference to the operating conditions of the integrated fuel processor. The efficiency of reforming was 77% (Lower Heating Value, LHV) during the rated operation and 69% (LHV) during low-load operation (while generating 1 kW of power). The efficiency was significantly better under medium and low-load operating conditions than in conventional fuel processors.

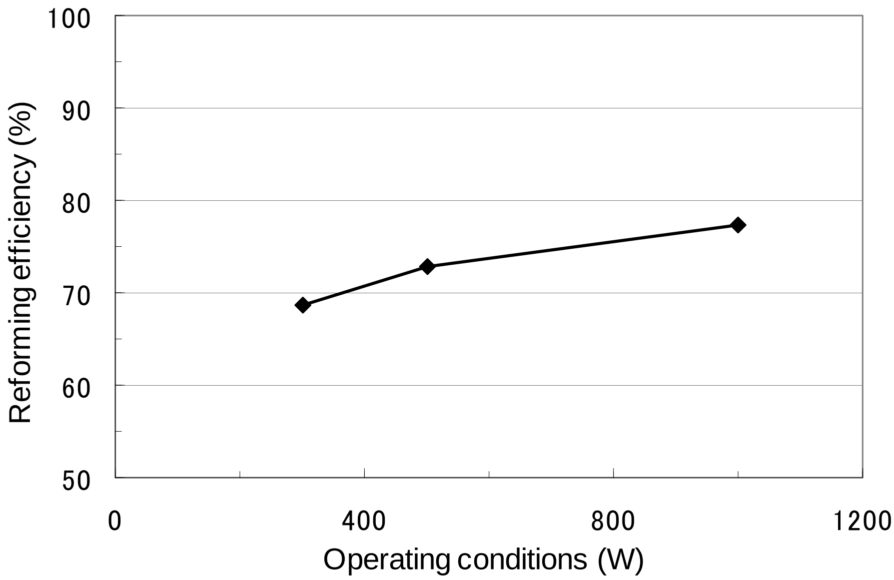

Figure 2: Reforming efficiency.

5 Development Status of Household Fuel Cell Cogeneration Systems

5.1 Product overview

The appearance of the newly developed fuel cell cogeneration system is shown in Figure 3, the product specifications in Table 1, and the outline of performance in Table 2.

With regard to performance, efficiency in the actual usage range of 500 W to 1 kW has been improved to achieve a high degree of energy saving. In addition, a durability of 10 years or more, necessary for a household equipment item, has been ensured. We adopted the following strategies to improve the equipment's energy-saving performance and durability.

Figure 3: Appearance of the fuel cell cogeneration system.

Table 1: Specifications of the fuel cell cogeneration system.

Item	Specifications
Fuel type	City gas
Electrical output range	300 to 1,000 W
Operational control system	Automatic power generation (with demand learning function), hot-water reserving-based power generation, timer-controlled power generation, or manual power generation

Table 2: Performance of the fuel cell cogeneration system.

Item	Performance
Power generation efficiency	38% (LHV) at 100% output 39% (LHV) at 75% output
Heat recovery efficiency	55% (LHV) at 100% output 50% (LHV) at 75% output
Hot-water temperature	Equal to or greater than 60 ˚C

5.2 Strategies used to improve energy-saving performance

Fuel cell cogeneration systems generate hydrogen from city gas in the fuel processor and, in the fuel cell stack, react the hydrogen with oxygen taken from the air to generate electricity and heat. The generated electricity is then converted to usable alternating-current power via an inverter, and the generated heat heats up water held in a hot-water reservoir. The hot water is supplied as is or for heating purposes. Therefore, to achieve a high overall efficiency, it is necessary to improve the efficiency of the fuel processor, stack, and inverter. In our developed fuel cell system, we targeted achieving efficiency improvements in the actual usage range of 500 W to 1 kW. We worked on developing the above-mentioned high-efficiency integrated fuel processor and low-loss inverters.

The inverter consists of a boost converter that boosts low DC voltages and a utility interactive inverter that converts DC output to 200 V AC and interacts with the commercial power supply. The conventional hard switching system has a large overlap loss of "current x voltage" when switching at low voltage (large current) and its efficiency is significantly lower in the low to medium output ranges. In the newly developed inverter, the voltage change timing is controlled by software switching over the entire operating range to eliminate the "current x voltage" overlap loss, and the thermal losses from power transistors have been significantly reduced. As a result, the efficiency in the 300- to 750-W output range has been significantly improved. As shown in Figure 4, the new fuel cell cogeneration system achieves its highest power generation efficiency of 39% (LHV) at 750 W output, and 38% or higher (LHV) over the entire output range (500 W to 1 kW), at which the system is most often operated, due to the adoption of a more efficient fuel processor and a low-loss inverter.

Learning control software, based on a neuro-algorithm, is incorporated to save even more energy by optimizing the operation conditions. The predictive control to which the energy management technologies are applied has achieved the optimum system operation in accordance with the actual usage conditions in each household.

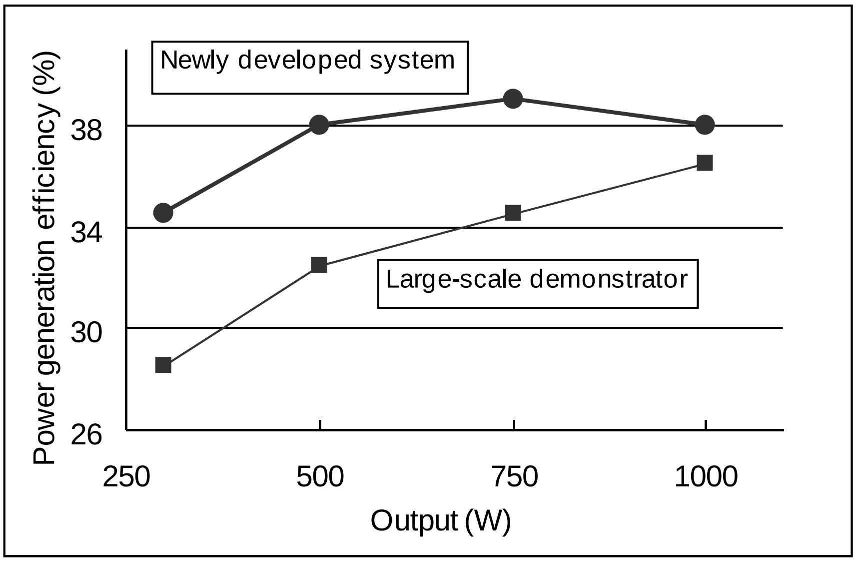

Figure 4: Power generation efficiency of the fuel cell cogeneration system.

6 Future Directions

Following the large-scale field test project, which lasted for four years starting in 2005, the systems were released onto the general market in May 2009. Panasonic is adopting various strategies for the full-fledged distribution of the system. The chief problem is naturally cost.

The cost must be reduced for full-fledged distribution of the system. We plan to focus our development efforts towards achieving a market price of 600,000 yen. We will need to develop unique technologies, such as system simplification, etc., to unify the basic specifications and component standardization in the industry; and also reduce the cost by means of economies of scale. We plan to positively promote the blending of technical capabilities by collaboration with two or more national projects.