Development of Fuel Cells Adapted to Meet New Needs

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ABSTRACT

Since the Great East Japan Earthquake, there has been broad investigation into the improvement of the quality of power-source security through introduction of 100 kW fuel cells, which are a highly efficient form of distributable power, and into the use of fuel cells for sewage digester gas power generation, which is a form of renewable energy.

Utilizing technology for switching to independent power during power outages and technology for converting to LP gas, Fuji Electric has developed fuel cells with improved power security and installed them in the Kawasaki Factory. Fuji Electric is also developing fuel cells adapted to meet new needs, such as fuel cells that can operate on both sewage digester gas and utility gas for small-scale sewage treatment plants and fuel cells that meets the CE marking requirements for the EU.

1. Introduction

Since the Great East Japan Earthquake in March 2011, there has been increasing expectation with regards to improved power supply security and distributed power sources. In addition, biomass power generation has come to be widely studied since the start of the "Feed-in Tariff Scheme for renewable energy" in July 2012.

Fuji Electric began selling its 100 kW fuel cells in 1998, and since then, the fuel cells have accumulated a track record of usage at a wide range of sites. The fuel cells have often been used for utility gas, but they have also been used for sewage digester gas (i.e., bio-gas) at two sites, which utilize a total of 6 fuel cells. From 2010, we started offering our latest model, the "FP-100i," to the market. In addition, we have also developed and made delivery to Germany a model that uses the cathode exhaust gas (low-oxygen concentration air) of the fuel cells as a new application.

This paper discusses the development of fuel cells adapted to meet new markets including power-source security use, small-scale sewage treatment plant use as well as EU standard specified with the CE mark.

2. Fuel Cells for Power-Source Security

Figure 1 provides an overview of Fuji Electric's fuel cells that correspond to power-source security needs. Diesel generators, which can be put into operation in a short period of time, have been most often used as emergency power generators at times of system fault or blackout due to natural disasters. Although they are economical to implement, they have the drawback of being noisy, emitting exhaust gas, and providing low-efficiency equipment utilization. Fuji Electric's 100 kW fuel cells allow for normal operation of equipment since they are cogeneration systems that are always clean, highly efficient and environmentally friendly. They utilize a technology for switching to grid-independent mode during time of blackouts, and they provide the power required to operate the most specific loads. Thus, it is possible to increase the reserve of emergency power supply sources by using diesel power generators etc., as emergency power sources for emergency loads, while also utilizing fuel cells to supply power to other specific loads. In addition, in the event that utility gas supply stoppages occur, the fuel cells can be used to switchover to LP gas reserves for continued operation of services.

(1) Switching from grid-connected operation to grid-independent operation

Figure 2 shows an example of switching to grid-independent operation. If a blackout occurs in the grid-connected operation mode, parallel off*[1] is automatically made from the grid, and shift to standby operation mode. At such a time, the fuel cells can be used stand-alone to supply power, and because the generated power is consumed inside in the fuel cells, grid-independent operation mode can start in about 30 seconds from the time of blackout detection. Furthermore, during grid-independent operation mode, rotating machines, in which inrush current occurs, can be activated through overcurrent and overload protection functions as well as limiter functions. A constant state of process connection can be maintained as is even when a load increases or decreases during grid-independent operation. This contributes to creating a

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*1: Parallel off: Disconnecting power generation equipment and so on from a power grid

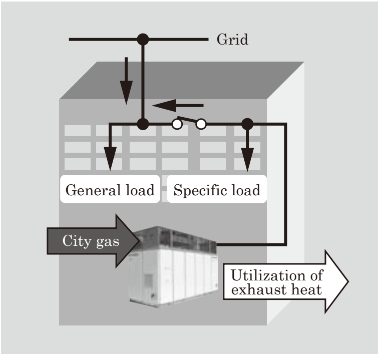
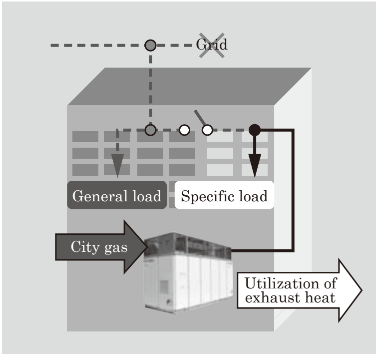
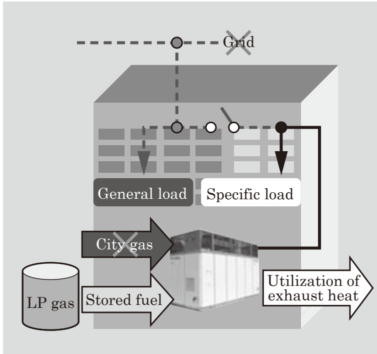
Situation	Normal operation	Blackout	Blackout+Stoppage of fuel gas supply
Overview	Highly efficient and energy-saving clean power source Efficiency of 42% at generation terminal	Shifting to the standby mode and supplying power to electric loads	Shifting to the standby mode and supplying power to electric loads
Power	100 kW	100 kVA	70 kVA
Fuel	City gas	City gas	Stored LP gas (A 50 kg cylinder of LP gas allows for 3 hours of operation)
Operation	Grid-connected operation	Grid-independent operation	Grid-independent operation
Power supply range			

Fig.1 Overview of fuel cell functions that correspond to power-source security needs

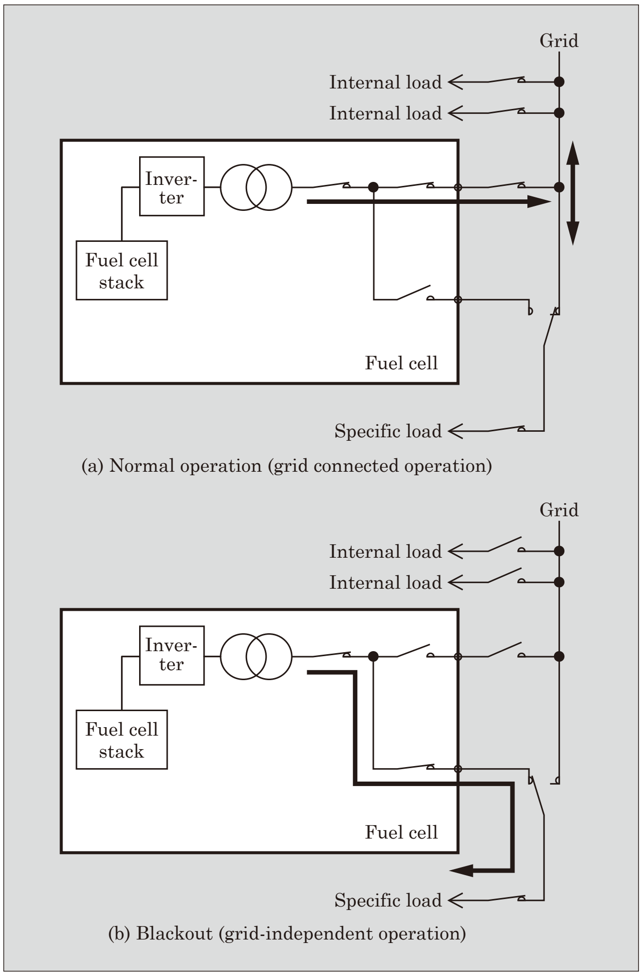


Fig.2 Example of switching during blackout

system that has stable control of the fuel cells by stepwise switching of independent loads and the electric heater in the fuel cells.

(2) Switching from city gas to stored LP gas

Switching from city gas to stored LP gas is carried out by closing the shut-off valve of the city gas and opening the shut-off valve of the stored LP gas when detection is made of a pressure drop signal in the original city gas.

Since the calorific value of LP gas per unit of volume is about 2 times the calorific value of city gas reforming conditions for producing hydrogen are different. In addition, several difficult elements exist in the switching of various types of fuel during operation, such as the need for gas replacement in the process equipment, which is built into the generating system, as well as the occurrence of start-up delays in the LP gas flow meter. Therefore, we utilized simulation results to incorporate a valve operation for maintaining a suitable amount of gas flow, while also making switching to various fuel types possible through specially designed control operation via the standby mode. It should be also noted that since operations that utilize stored LP gas are limited to an output of 70 kVA, approximately 3 hours of power supply is possible per 50 kg cylinder.

(3) Case of an installation at a factory

Power-source security fuel cells have been installed at Fuji Electric's Kawasaki Factory and have been in operation since February 2012 (see Fig. 3). During normal operations, they are used as a city gas cogeneration resource, but they can also be used to supply power to critical factory equipment during a blackout. Exhaust heat is being used to preheat water that is supplied to the air-conditioning, heating and boiler systems.

Fig.3 Fuel cells installed at Fuji Electric's Kawasaki Factory

3. Fuel Cells for Small-Scale Sewage Treatment Plants

Sewage treatment plants exist for the conservation of the water quality of public water resources. They collect the domestic wastewater that is discharged from each household, and then, purify the wastewater so that it can be returned to rivers and oceans. Dirt or grime that is removed during water purification is referred to as sewage sludge. In order to reduce and stabilize the amount of sewage sludge, anaerobic digestion treatment is performed to decompose organic materials in an oxygen absent state, and as a result, sewage digester gas is generated, which acts a principal ingredient for methane gas.

Currently, anaerobic digestion treatment of sewage sludge is being performed at approximately 260 sewage treatment plants throughout Japan. The total amount of sewage digestion gas produced annually is about 260 million cubic meters. Most of this amount is used as auxiliary heating fuel for heating sludge digestion tanks and for performing sludge combustion; however, digester gas power generation systems are still in the small minority. However, in the aftermath of the Great East Japan Earthquake, expectations have been increasing with regards to sewage digester gas power generation as a way to secure power supply sources during a time of disaster, and this has been especially true since the start of the "Feed-in Tariff Scheme for Renewable Energy" in 2012.

Sewage digester gas is composed of 60% methane and 40% CO_2, and approximately 1,200 m^3 of sewage digester gas is required per day in order to ensure the rated operation of a 100 kW fuel cell. About half of the sewage treatment plants that produce sewage digester gas are small-scale facilities that do not meet the per day production requirements mentioned above. Therefore, in order to install 100 kW fuel cells at these sewage treatment plants, we have developed a power generation system that works in combination with utility gas and can be used at plants that do not produce enough sewage digester gas.

The power generation system produces energy based on sewage digester gas, and falls back on city gas only when there is an insufficient amount of sewage digester gas to produce the required amount of power needed. Figure 4 provides an overview of the gas mixing operation.

In February 2012, this power generation system was installed at a sewage treatment plant in the city of Osaka as a power generator for the "Breakthrough by Dynamic Approach in Sewage High Technology Project" (B-DASH Project) of the Ministry of Land, Infrastructure, Transport and Tourism. Demonstration testing has been ongoing since April 2012. Demonstration projects related to energy management systems that utilize the ultrahigh solids-

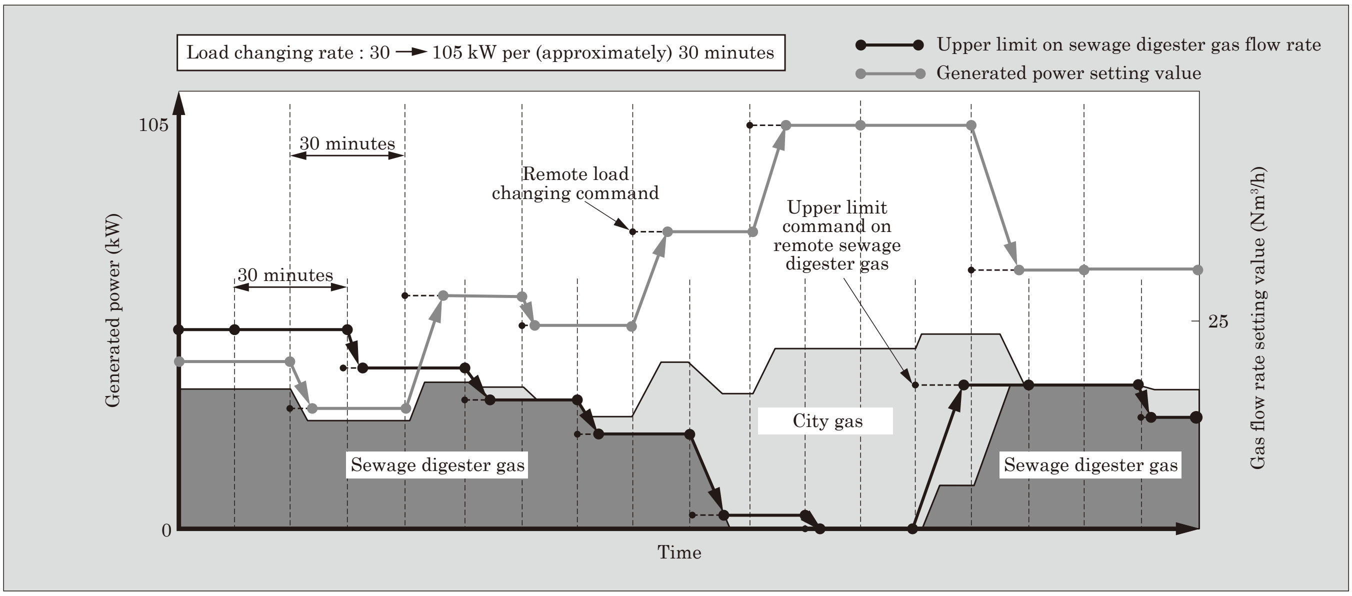


Fig.4 Overview of gas mixing operation

liquid separation technology of the B-DASH project aim at creating sewage treatment plants that can generate a self-sufficient amount of energy. This is accomplished by implementing a system that combines the use of three break-through technologies including “ultrahigh solids-liquid separation,” “high efficiency high-temperature digestion” and a “smart power generation system.” Among the types of systems for smart power generation, fuel cells are used as power sources in hybrid-type power generators that combine the use of sewage digester gas and city gas.

4. CE Mark Compliant Fuel Cells

4.1 State of cogeneration in the global market

Figure 5 shows the penetration rate of cogeneration in the global market. The EU and the United States are both outpacing Japan with respect to their cogeneration penetration rate. Natural gas is being increasingly used in the EU as a means of securing energy and alleviating climate change problems. In particular, natural gas cogeneration is being set forth as a substantial and popular assistance measure since it is one of the few technologies that is immediately effective toward energy conservation and savings. As a popular assistance measure, it provides initial cost assistance (cogeneration, heat infrastructure subsidies, grants and tax incentives) and running cost assistance (electricity purchasing and tax incentives for fuel costs).

4.2 German market and low-concentration oxygen air supply

Fuji Electric is expanding its business in the German market in partnership with the German company N2telligence GmbH. The German market is characterized by the following two points:

(1) Generous support measures by the German government

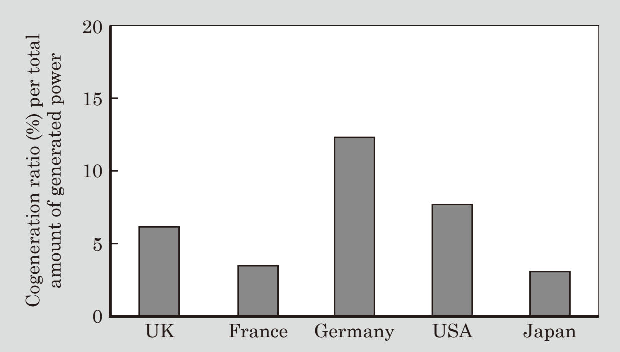
Germany plans to abolish its nuclear power plants. However, conventional coal-fired thermal power station have to be renewed, and thus they are difficult to complement those. Therefore, expectations are high with respect to renewable energies and natural gas cogeneration as a means of backing up power output fluctuations. The German government revised the Combined Heat and Power (CHP) Law in 2009, and has set forth a target to achieve a 25% increase in its cogeneration utilization ratio by 2020. Hydrogen-based infrastructures are also becoming more popular, and there is high anticipation regarding the use of hydrogen fuel cells.

(2) Popularization of fire prevention system based on low-concentration oxygen atmosphere

Fire prevention systems that utilize a low-concentration oxygen atmosphere inside buildings such as data centers and warehouses in order to prevent the outbreak of fires are becoming popular in Germany. Generally, since supply of such an atmosphere to the inside of a room is done by separating nitrogen from the air by a nitrogen generator, capital investment is required; in addition to this cost, other issues also become a factor including compressors, etc., which operate by consuming a large amount of energy.

Unlike gas engines that generate power through combustion of fuel and air, fuel cells generate electricity by an electrochemical reaction of oxygen in the air and fuel which are separated by an electrolyte. With regards to the air that is supplied by the fuel cell, since only the oxygen in the air is selectively consumed, the air that is discharged has a low-concentration oxygen that does not contain harmful flue gas. This low-oxygen concentration air is supplied to the inside of a room, and as a result, a low-concentration oxygen atmosphere is created. Therefore, initial costs and running costs required for nitrogen generators can be reduced. The German company N2telligence GmbH has developed a fire prevention system that utilizes low-concentration oxygen air produced by fuel cells, and they are selling their system under the concept of “Quattro Generation,” a system that provides 4 additional values in relation to electricity, hot water, cold water and low-concentration oxygen air.

In order to contribute to the development of



Source: Drawing based on “The International CHP/DHC Collaborative” http://www.iea.org/chp/

Fig.5 Penetration rate of cogeneration (2005)

Fig.6 Fuel cell installed at Wismar

Fig.7 Fuel cell installed at Hamburg

Quattro Generation, Fuji Electric started implementing demonstration operations in 2010 at the Wismar testing site of N2telligence GmbH. In 2011, we developed a model for the EU that is the CE mark compliant, and in July 2012, we made delivery of Unit 1 to Mercedes-Benz building (Hamburg). Figure 6 shows the installation at the Wismar testing site, and Fig. 7 shows the installation at Hamburg.

4.3 CE mark compliance

The CE mark is required for selling products to the EU. The CE mark was established under the framework of a unified law by the EU in order to ensure the free flow of products within the EU. Alternatively, products that do not have the CE mark will be denied customs clearance and will not be able to be exported. In order to receive the CE mark on a product, a compliance assessment is performed on the product in accordance with applicable EC directives. A declaration of conformity is required to be carried out based solely on the responsibility of the product manufacturer. EN regulations are used to determine if compliance is made to the applicable EC directives.

Fuels cells are different than general electrical products and they also have the aspects of a small chemical plant. At the same time, the applicable EC directives and conformity regulations cover a lot of ground with respect to electrical products and machinery. Since there was no precedent, we received the cooperation of a public institution to conduct a study on the applicable EC directives and EN regulations. The result of the study was that our product was applicable to several EC directives including the machinery directive, electromagnetic compatibility directive, pressure equipment directive and safety directive for devices that are used in an atmosphere that has potential for explosion.

Fuel cells for use in Japan are designed based on the “Electricity Business Act,” technical standards for thermal power generation equipment, technical standards for electrical equipment, and Japanese Industrial Standards (JIS). In order to export the fuel cells to the EU, we revised the design based on Japanese regulations, while making enhancements to conform to and accommodate additional international regulations. Risk assessment through hazard analysis is critically important with regards to the CE mark compliance. Inflammable gas leaks were particularly considered as significant events with the greatest possible impact, and thus we changed a part of the design to better meet international regulations. In addition, we also implemented risk assessment with regards to user maintenance work and enhanced measures to prevent shocks and injury from occurring. Based on these measures, we issued a self declaration of the CE mark compliance after receiving confirmation from the public institution in March 2011.

When we delivered the first product for the EU, the fuel cell was accommodated with several additional devices as a result of revising the Japanese market based design for fuel cells. We are currently working on a design that is especially dedicated for the EU and are planning on commencing sales in fiscal 2013.

5. Postscript

Even in the Great East Japan Earthquake, 100 kW fuel cells continued operation. One hundred kilowatt fuel cells are expected to gain increasing popularity in the future as a highly efficient distributed power source, since they are capable of grid-independent operation during times of disaster as well as provide a fuel switching option when working in combination with city gas and LP gas.

Fuji Electric is dedicated in its efforts to apply its cultivated technologies and fuel cell functionalities to continually enhance the range of application of its products and improve user benefits, while also contributing to prevention of global warming and environmental conservation.

Fuji Electric
Innovating Energy Technology

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