Development of a Solid Oxide Fuel Cell - Micro Gas Turbine (SOFC-MGT) Hybrid System


Yoshinori Kobayashi[*1] (born in 1958)


Kazuo Tomida[*2] (born in 1968)


Tsutomu Tokumoto[*3] (born in 1959)


Kazuhisa Okamoto[*3] (born in 1967)


Kazunari. Sasaki[*4] (born in 1965)

1. Overview

Global consumption of primary energy continues to increase. Therefore, increasing the efficiency of energy use and reducing the environmental load are paramount for the development of a sustainable society. Fuel cells can directly convert the chemical energy stored in fuel to electricity, and operate at high efficiencies. Among the different types of fuel cell, solid oxide fuel cells (SOFCs) can be the most efficient, due to the high operation temperature, and by utilizing the exhaust heat in a combined power generation system. Since 1983 we have been exploring the potential of SOFCs as an integral component in such combined power generation systems, in which a gas turbine (GT) is integrated to make use of the SOFC exhaust gases. We have achieved the first practical demonstration of a hybrid power generation system combining SOFCs with a micro gas turbine (MGT). This is an important step in the development of SOFC-GT combined power generation systems. Our 250 kW class SOFC-MGT hybrid system has been in operation at Kyushu University since May 2015.

2. Technical Description

Figures 1 to 3 show a schematic of the segmented-in-series tubular type SOFC; the major components of the SOFC-MGT hybrid system; and a flow diagram of the operation principles, respectively. The SOFC (i.e. the anode, electrolyte, and cathode) is formed on the outer surface of a ceramic tube. Ceramic tubes are used because of their high mechanical strength, and an electron-conductive ceramic is used to connect these cells in series. Therefore, the electrical output from a single cell stack is collected efficiently at low current and high voltage. Individual *cell stacks* are formed into bundles with a support component, fuel/air inlet and exhaust outlet ports, to form a *cartridge* with an output of several tens of kW. Multiple cartridges are then arranged together to form a *module* with the required capacity. This modular system takes into account ease of system installation as well as maintenance. The unreacted fuel and air in the SOFC exhaust are kept separate and taken downstream for combustion in the gas turbine. Utilization of the SOFC exhaust gases in this way helps to achieve highly efficient combined cycle system operation.

A 250 kW class SOFC-MGT hybrid system (designated Type 10) was installed at Tokyo Gas Co., Ltd.'s Senju Techno Station in 2013, and recently logged a record 4100 hours continuous operation. A more advanced system (designated Type 15) was installed on the Ito Campus of Kyushu University and has been in operation since May 2015. Characteristic improvements in the Type 15 model are a reduction of the diameter and increase in the length of the cell stacks, and an increased packing density of individual cell stacks in the cartridge. These features were implemented in order to reduce the footprint of the system by more than 40%. Since regulations requiring continuous monitoring of pressurized fuel cell systems were relaxed for the 250kW class system in December 2015, the burden of the end user has been reduced. The Type 15 system, installed at the Next-Generation Fuel Cell Research Center (NEXT-FC) in Kyushu University, was provided for the *"Verification of a Smart Fuel Cell Society"* program within the *"Green Asia International Strategic Comprehensive Special Zone"*. This system achieved a total of >5000 hours operation in January 2016, and has continued to supply a several percent of the total power consumption of the entire Ito Campus daily.

3. Summary

For a long time, the development of SOFC-MGT hybrid systems by the major heavy electric machinery manufacturers was unsuccessful. Therefore, the development of the first practical system in the world is highly significant. Previously in Japan, fuel cell systems operating at > 100 kPa were obliged to be continuously monitored for a long time period. Such regulation led to a greater level of technical rigor and did not highlight any disadvantages for such systems. We are aiming to spread this system more widely in anticipation of the 2020 Tokyo Olympic and Paralympic Games. In addition, development of large-scale SOFC-GT combined power generation systems and integrated coal gasification SOFC systems are planned in order to take advantage of this technology and realize extremely high efficiency in the next-generation of thermal power plants.

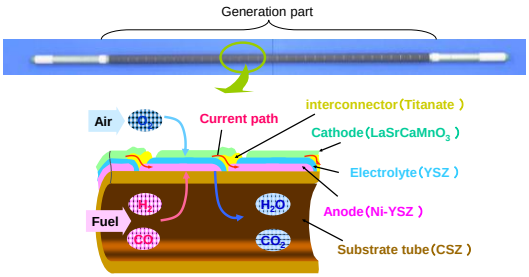

Figure 1: Schematic of a single cell stack of a segmented-in-series tubular SOFC.

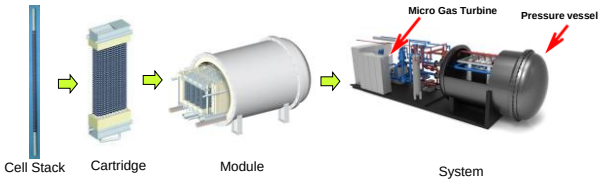

Figure 2: Schematic of the tubular SOFC cell stack, cartridge, module, and system.

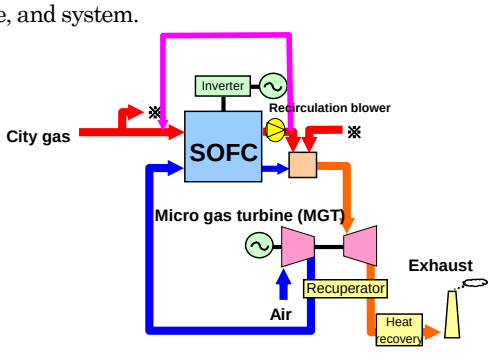

Figure 3: Flow diagram of an SOFC-MGT hybrid system.

*1 Mitsubishi Hitachi Power Systems, Ltd.　(Currently The University of Tokyo)
*2 Mitsubishi Hitachi Power Systems, Ltd.
*3 Tokyo Gas Co., Ltd
*4 Kyushu University