

**Development of fault diagnosis logic for fuel cell systems  
based on data analytics**

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## **1. ABSTRACT**

Osaka Gas commercialized the polymer electrolyte fuel cell system in 2009. In 2012, the company commercialized a solid oxide fuel cell system and by October 2013, cumulative sales of these systems had topped 20,000 units. However, the complex structure of fuel cell systems can make it difficult to identify the troubled component in the event of a system failure, and if such systems are to be more widely disseminated, the development of a method of fault diagnosis that allows easy identification of troubled component without requiring a high level of specialist knowledge is desirable.

Unlike other gas equipment, diagnosing faults in fuel cell systems involves acquiring operation data, including temperature, pressure, flow rate, etc, at various points within the fuel cell system, and analyzing those data in order to identify the troubled component. For this reason, Osaka Gas holds a large volume of operating trend data acquired in the course of responding to faults in systems already in use.

For the fault of polymer electrolyte fuel cell systems, we aim at development of the tool which can carry out automatic diagnosis of the parts which should be replaced by extracting the characteristic trends of the measurement data. This report describes Osaka Gas's efforts about the tool development.

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## 2. INTRODUCTION

### 2.1 Market development of residential fuel cell co-generation system (ENE-FARM) by Osaka Gas

Osaka Gas commercialized the polymer electrolyte fuel cell (PEFC) system in 2009. In 2012, the company commercialized a solid oxide fuel cell (SOFC) system. The specifications of residential fuel cell co-generation system (ENE-FARM) which Osaka Gas sells now are shown in Table.1 and appearances of ENE-FARM are shown in Fig.1 and Fig.2. PEFC co-generation systems are achieving electrical conversion efficiency 39.0%(LHV), and SOFC co-generation system is achieving 46.5%(LHV). The sales result of ENE-FARM by Osaka Gas is shown in Fig.3. Cumulative sales of these systems had topped 20,000 units by October 2013 and reached 26,000 units by June 2014.

Table.1 Specification of ENE-FARM power generation unit

Fuel cell system	PEFC(Polymer Electrolyte Fuel Cell)		SOFC(Solid Oxide Fuel Cell)
Manufacturer	Panasonic Corporation	Toshiba Fuel Cell Power Systems Corporation	Aisin Seiki Co.,Ltd.
Max.output	0.75kW	0.7kW	0.7kW
Min.output	0.2kW	0.25kW	0.05kW
Electrical Conversion Efficiency	39.0% (LHV)	39.0% (LHV)	46.5% (LHV)
Heat Recovery Efficiency	56.0% (LHV)	56.0% (LHV)	43.5% (LHV)
Dimensions	W 400mm D 400mm H 1850mm	W 780mm D 300mm H 1000mm	W 600mm D 335mm H 935mm
Dry weight	90kg	94kg	96kg
Fuel type	LNG based natural gas (category 13A)		



Fig.1 Appearance of ENE-FARM  
(Toshiba Fuel Cell Power  
Systems Corporation )



Fig.2 Appearance of ENE-FARM  
(Aisin Seiki Co.,Ltd.)

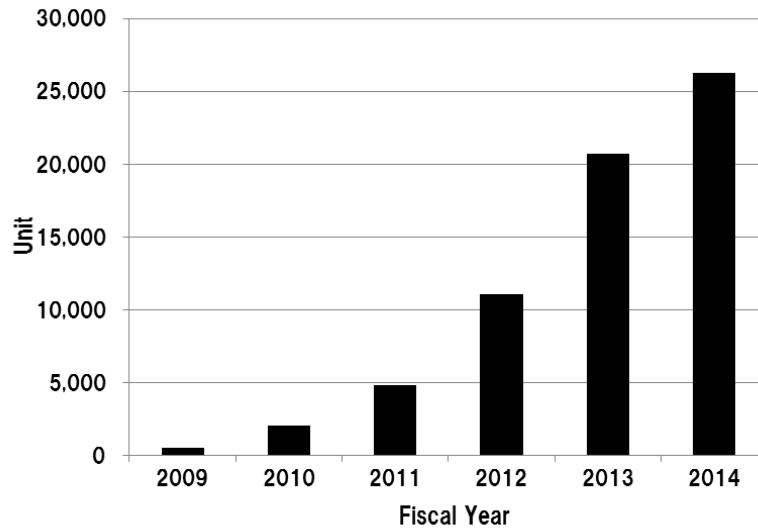


Fig.3 Sales result of ENE-FARM

## 2.2 Characteristics and problem of ENE-FARM maintenance

The fuel cell system is the system which converts the chemical energy into electricity through a chemical reaction of hydrogen reformed from natural gas and oxygen from the air. The typical system layout of PEFC system is shown in Fig.4. The system layout of PEFC system is complex and the number of components is large in comparison with the conventional gas equipment such as boiler.

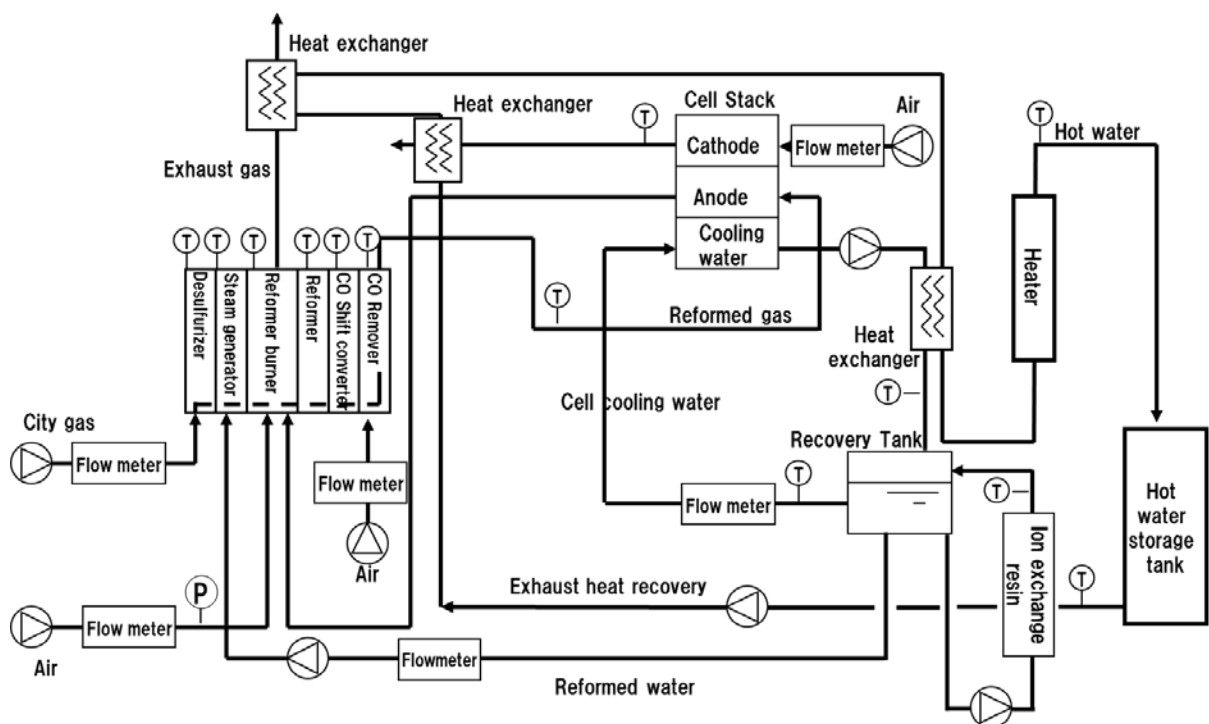


Fig.4 System layout of PEFC

The typical maintenance scene of conventional gas equipment is shown in Fig.5 and that of ENE-FARM is shown in Fig.6. The fault diagnosis of the conventional gas equipment such as boiler is measuring the voltage and resistance using a tester at the utmost. On the other hand, the fault diagnosis of ENE-FARM is identifying the troubled component from the operation data which is read from ENE-FARM using PC. The operation data is including temperature, pressure, flow rate, etc., at various points within the fuel cell system, and the image of data is shown in Fig.7. The number of measurement values is large, and the system is complex, so it is difficult to identify the troubled component without special knowledge about fuel cell system.



Fig.5 Maintenance of conventional gas equipment



Fig.6 Maintenance of ENE-FARM

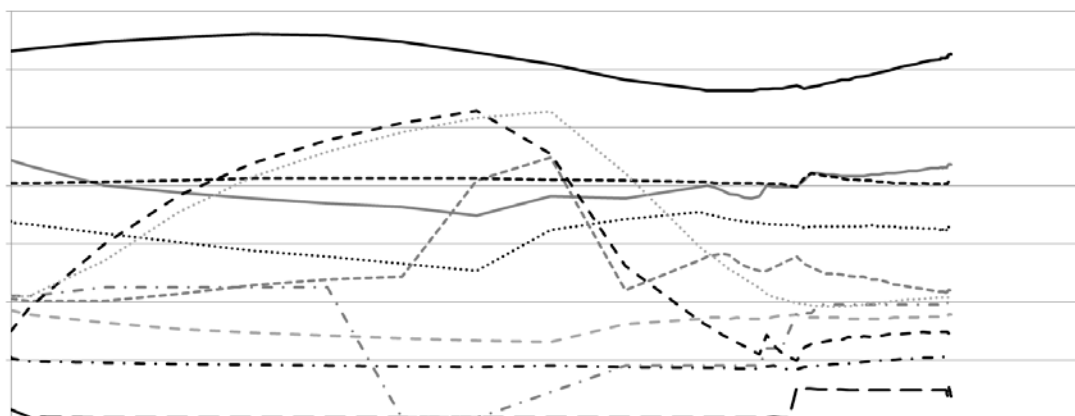


Fig.7 Image of ENE-FARM operation data

Irrelevant fault diagnosis causes the increase of the maintenance cost because untroubled components are replaced by mistake. Therefore Osaka Gas has trained many maintenance persons to be able to identify the troubled component by themselves. Furthermore, Osaka Gas set up the "Maintenance Support Center" which carry out diagnosis of the data received from the maintenance person who goes for the repair. Maintenance Support Center contains skilled maintenance persons. But it may be not enough if fuel cell systems are to be more widely disseminated. So in future, the development of a method of fault diagnosis that allows easy identification of troubled component without requiring a high level of specialist knowledge is desirable.

This report describes Osaka Gas's efforts to construct the logic of fault diagnosis.

### 3. FUTURE PLAN

The future plan of ENE-FARM maintenance is shown in fig.8. The person who goes for the repair of the ENE-FARM send the operation data acquired from ENE-FARM to the data center. The data center has the fault diagnosis logic based on data analysis and carry out automatic diagnosis of the parts which should be replaced. The data center returns the result of diagnosis to the person who is going to repair the ENE-FARM. Furthermore, repeating the similar procedure, diagnosis accuracy is improved by increase of operation data.

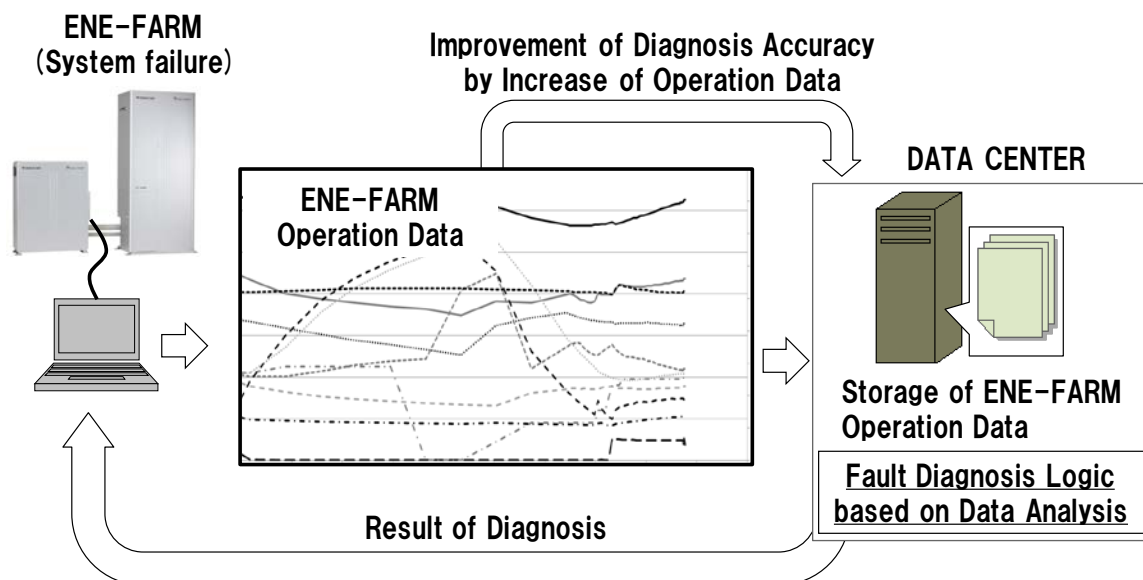


Fig.8 Future Plan of ENE-FARM Maintenance

## 4. DEVELOPMENT OF FAULT DIAGNOSIS LOGIC

Osaka Gas holds a large quantity of operation data acquired from ENE-FARM at the time of repair. We are trying to develop the fault diagnosis logic for fuel cell systems based on these operation data.

In this chapter, a case of logic development is introduced. In this case, we pick the system failure caused by fault of water pump. This example is picked by the following reasons.

- It is difficult to identify the troubled component (water pump) because fault of various components can cause the same phenomenon.

- The mechanism of the phenomenon is technically obvious. (The phenomena which the fault of the component caused are known.)

We tried to develop the logic from 100 operation data acquired in the course of responding to faults in systems already in use.

The process of developing diagnosis logics is shown in Fig.9. The details of each step are described below.

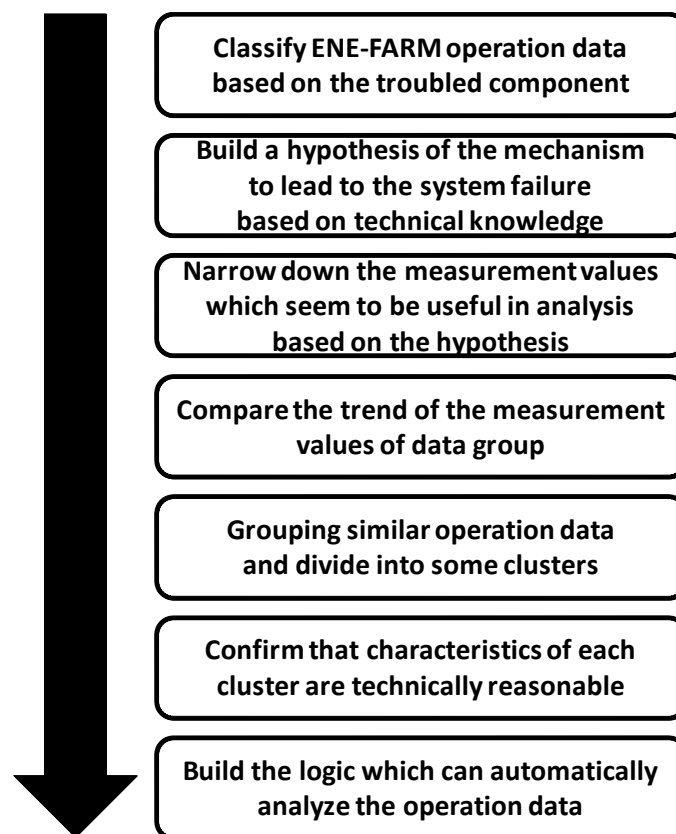


Fig.9 Process of developing fault diagnosis logics

### 【 STEP①】 Classify ENE-FARM operation data based on the troubled component

In this case, 100 operation data which suggest the trouble of water pump were extracted.



**【 STEP②】 Build a hypothesis of the mechanism to lead to the system failure based on technical knowledge**

For the data group of STEP①, we built a hypothesis about phenomena which occur before system failure based on specialist knowledge about fuel cell.

**【 STEP③】 Narrow down the measurement values which seem to be useful in analysis based on the hypothesis**

We narrowed down the measurement values which seem to be useful in analysis based on the hypothesis from the various measurement values including temperature, pressure, flow rate, etc, at various points within the fuel cell system.

In this case, we confirmed that the hypothesis was correct by drawing graphs of all operation data, and narrowed down the measurement values which seem to be useful in analysis. 5 measurement values were selected.

**【 STEP④】 Compare the trend of the measurement values of data group**

We compared the trend of the measurement values narrowed down in STEP③ by drawing graphs of all operation data.

**【 STEP⑤】 Grouping similar operation data and divide into some clusters**

We grouped operation data which have similar trend of several certain measurement values in certain period.

In this case, we divided 100 operation data into 5 clusters.

**【 STEP⑥】 Confirm that characteristics of each cluster are technically reasonable**

In each cluster, we confirmed that trends of measurement values are technically reasonable as the data of the fault.

**【 STEP⑦】 Build the logic which can automatically analyze the operation data**

We built the logic which can automatically judge whether the operation data is similar to that of each cluster or not.

In this case, 3 clusters are concluded to be technically reasonable, we build the logics for these clusters.

We tried to diagnose the operation data except above 100 data using the fault diagnosis logic developed in this study, and confirmed that the fault diagnosis can judge the operation data which suggest the fault of water pump.

## **5. CONCLUSIONS**

We are trying to develop the fault diagnosis logic for fuel cell systems based on data analysis with a view to developing the tool which can carry out automatic diagnosis of the parts which should be replaced. We found it possible to develop the fault diagnosis logic by extracting the characteristics of the operation data gathered from many units that the same components were troubled. It may be possible to identify the troubled component without special knowledge by developing the fault diagnosis tool in the future.

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