STUDY ON OPERATION AND EFFICIENCY OF DISTRIBUTED ENERGY SYSTEM IN KITAKYUSHU SCIENCE AND RESEARCH PARK

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Abstract: With the increasing demand of energy, the distributed energy system (DES), which with high efficiency of energy utilization and low environmental load, has been recognized by the society. The Kitakyushu Science and Research Park (KSRP) has been installed a distributed energy system which use the gas engine and full cell as the power generations in 2001. Now, the device of DES has run 15 years, it has been closed to the design life.This paper was collected and analyzed the operation and inspection data of fuel cell during 10 years. This paper analyzes the maintenance records of fuel cell use, failure modes and effects analysis method (FMEA). The result of this paper has been given to provide some plan and suggestion for the future development and maintenance.

Keywords: fuel cell, distributed energy system, maintenance

I. INTRODUCTION

Recently, distributed energy system becomes more and more conspicuous. It has the characteristics of high energy utilization efficiency and less environmental pollution; it is a kind of environment friendly energy utilization system. Distributed Energy System (DES) is becoming increasingly popular in supplying for energy needs. DES is widely used in hospital, hotels, and university campus and so on. And the most common kind of the distributed energy system is gas engine and fuel cell. This report will mainly discuss the part of fuel cell. A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction of positively charged hydrogen ions with oxygen or another oxidizing agent.

Kitakyushu Science Research Park began using gas engine and fuel cell as power generation distributed energy system in 2001, and now it has been 15 years, the system is close to the life of design. This report will survey and sort out the power generation data of the fuel cell in Kitakyushu Science Research Park from 2001 to 2011, and summarize the situation of power generation of fuel cell as time goes by, aimed at researching the relation between the production of fuel cell and its inspection and malfunction.

The power generation data of fuel cell was collected and analyzed in this paper. The section 2 introduces the operation status and introduces the power generation data of fuel cell during 10 years. The section 3 does the analysis and discussion of results, and to assess the effect of failure for fuel cell. The section 4 is the conclusions.

II. SURVEY CONTENTL

The data which used in this paper is the power generation production data, the computation of gas used, fuel cell exhaust heat utilization and its instantaneous flow rate, and the temperature data of energy center of each hour in each day in the year 2001 to 2011. The data began to record in June 2001, there had only 7 months' data. And there had only 1 month data in 2011 because the fuel cell has been stopped in January 2011. So the data of 2011 will not be used in this paper.

In order to show the status of fuel cell operationclearly, the operation status was divided into four statuses. Table 1 shows all the status of the operation of fuel cell, they are schedule work days,inspection and repair, malfunction and others such as supporting student tour.

In this paper, the data of power generation efficiency of fuel cell is also necessary; it can be described as follow:

Table 1 The content of operation status

	Items
Operation Status	Schedule Work
	Inspection and Repair
	Malfunction
	Others

$$\eta\mathrm{E} = \frac{G \times 0.86}{N \times 0.11} \times \frac{273 + 20}{273 + Tec} \times 100\%$$

Where ηE is the power generation efficiency of fuel cell, G is the power generation production, N is the cumulative value of gas used, and Tec is the temperature of energy center. All of them are the data of each hour in each day of one year.

And the data of heat exhaust efficiency can be described as follow:

$$\eta H = \frac{V \times (Tf - Tr) \times 0.01}{N \times 0.11 + C \times 0.025} \times 100\%$$

Where ηH is the heat exhaust efficiency of fuel cell, V is the exhaust heat water instantaneous flow rate, Tf - Tris the exhaust heat utilization of fuel cell, N is the cumulative value of gas used, and C is the cost of electricity. All of them are the data of each hour in each day of one year.

The operation status of fuel cell depend on the equipment whether could run on normal condition, it means that it depends on the failures and reliability of equipment. In other words, the reliability and maintenance could be analyzed based on the power generation data. The power generation production and efficiency can be used to assess the status of the operation of fuel cell.

III. SURVEY RESULT

1. Analysis of fuel cell operation

Fig.1 is a line graph about the days when fuel cell was operating in each year. Remove two special years which are the beginning and ending, and calculate the average of the rest of these years. The number is 346. It indicates that only two years the operation days are less than the average days. The two years have the most stoppage days. And each time the fuel cell stopped for long days, the next year would operate better.

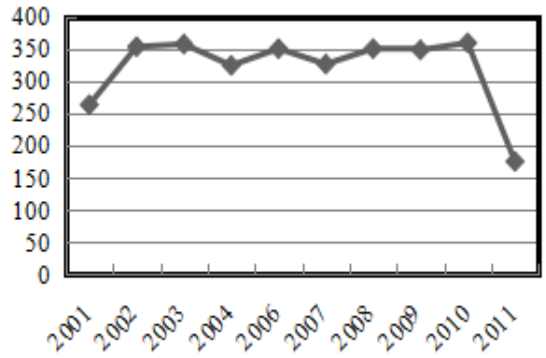

Fig.1 Operation days in each year

2. Analysis of power generation production

Fig.2 is the contrast of total power generation production of fuel cell of each year from 2001 to 2010. The data of 2011 will not be used because it has only one month's data. And the data of 2001 has only 7 months' data because the fuel cell began operation in June 2001. According to the Fig 1, it is noticeable that the year which has the most power generation production is 2006, in total of 1666296 kwh, and the year 2010 is least except 2001 during the 10 years, in total of 1155170 kwh. The power generation production of 2005 is lower than 2004 and 2006, according to the inspection data, there was a stoppage by failure. And after the inspection and repair for this failure, the next two years' power generation production have increased more than the two years which before the inspection and repair. But the total power generation production also became lower and lower with the time went by. It was caused by the abrasion and aging of the fuel cell equipment.

Fig.3 is the count of hours of different power generation production in one year during 10 years. The data of 2011 will not be used because it has only one month's data. And the data of 2001 has only 7 months' data because the fuel cell began operation in June 2001. The power generation production was equally divided into 4 parts according to their power generation: 0~60 kwh, 60~120 kwh, 120~180 kwh, 180~240 kwh. Fig 2 indicated that the power generation production of 180~240 kwh became less and less as time went by, and at the same time, the power generation production of 120~180 kwh and 60~120 kwh began increased. It means that the aging of the fuel cell will affect its power generation production, with the high power generation was decreasing, the low.

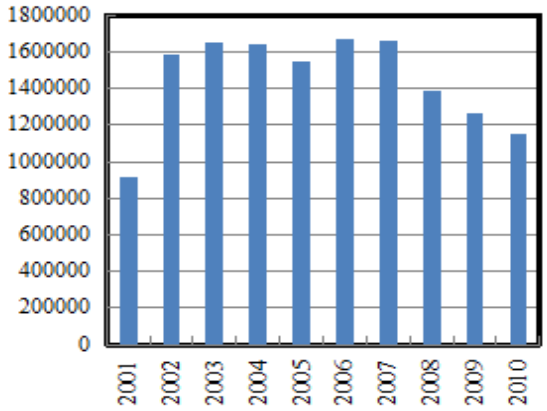

Fig.2Total power generation production of fuel cell during 10 years

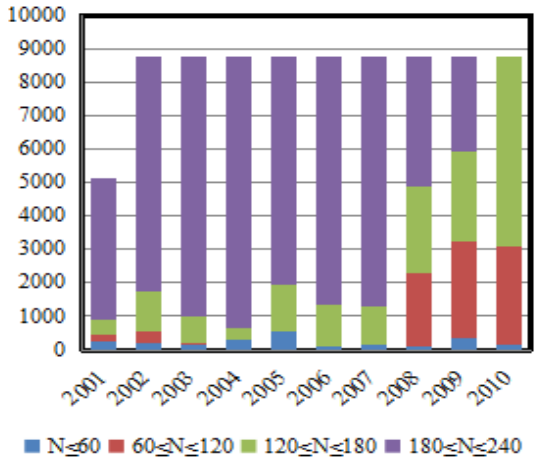

Fig.3 The count of hours of different power generation production during 10 years

IV. ANALYSIS OF FUEL CELL EFFICIENCY

In order to show the difference of operation status of fuel cell on the initial stage, intermediate stage and final stage, the year 2002, 2006, 2010 will be chose to compare.

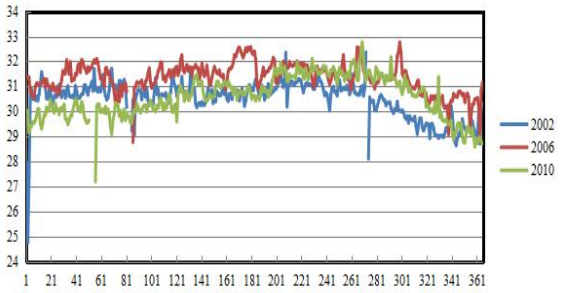

Fig.4 The average power generation efficiency of three years

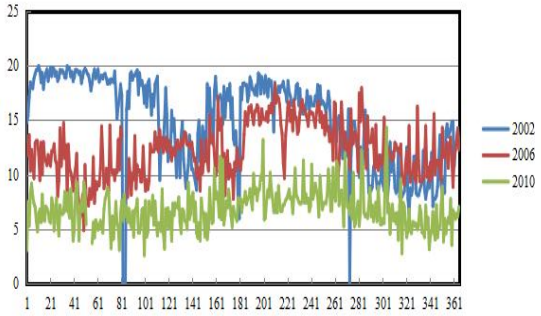

Fig.5 The average exhausts heat efficiency of three years

These three years have the same interval of time, and they are all belonging to the three stages of the fuel cell operation. Fig.4 is the comparison of these three years' average efficiency. At the time dealing with the average power generation efficiency, the impact of 0 power generation efficiency has been removed. It shows that the average power generation efficiency of 2006 is generally higher than 2002 and 2010. Because the fuel cell was operating all days in one year, the fluctuation of the average power generation efficiency of one year is not too obviousto see. It is noticeable that at the beginning of 2002, the average power generation efficiency is lowest, it is because the fuel cell was still in thedebugging stage at that time, its power generation production was not enough stable. And the power generation efficiency of the year 2010 is almost lower than2006, it is because the equipment of the fuel cell was aging and wear.

According to the power generation efficiency of fuel cell, it clearly shows that in the operation status of fuel cell and through compared with the power generationproduction and its inspection records data, it shows the relationship between the efficiency and maintenance of fuel cell. With the maintenance and inspection of fuel cell, the power generation efficiency changed obviously.

V. THE ANALYSIS OF EXHAUST HEAT EFFICIENCY

In this paper, the exhaust heat efficiency also has been processed. The exhaust heat data of 2002, 2006, and 2010 are used in this paper. Fig.5 is the comparison of these three years' average exhaust heat efficiency. The impact of 0 exhaust heat efficiency has been removed. According to the Fig.5, it shows that the exhaust heat efficiency has an obvious decreasing trend in the three years. The efficiency of 2002 is about 15.0%, 2006 is 12.3% and 2010 is 6.78%. It means that the exhaust heat capacity becomes gradually weakened as the time goes by. It is noticeable that in the second half of 2002, the exhaust heat efficiency was lower than 2006. It is caused that the fuel cell was still in thedebugging stage at that time, its operation, power production and exhaust heat was not stable enough.

Compared to the exhaust heat efficiency of 2002, the efficiency of 2006 and 2010 are more stable. In another word, the fuel cell has kept in an inefficient operating condition stalely in the second half of its life.

CONCLUSION

In this study, we have surveyed and sorted out the record data of the fuel cell in Kitakyushu Science Research Park. According to survey, sort out, and count the data of fuel cell of the 10 years, the following conclusions can be gotten:

1. Kitakyushu Science and Research Park started using the fuel cell in 2001, it has been 10 years until it was stopped.

2. During 10 years, the year which has the most power generation production is 2006, in total of 1666296 kwh, and the year 2010 is least in total of 1155170 kwh. There was an failure in 2005, after the inspection and repair for this failure, the next two years' power generation production have increased more than the two years which before the inspection and repair. But the total power generation production also became lower and lower with the time went by. It may be caused by the abrasion and aging of the fuel cell equipment.

3. The aging of the fuel cell will affect its power generation production, with the high power generation was decreasing; the low power generation was increasing.

4. The average power generation efficiency of 2006 is generally higher than 2002 and 2010. Because the fuel cell was operating all days in one year, the fluctuation of the average power generation efficiency of one.

5. The average exhaust heat efficiency of 2006 is generally higher than 2002 and 2010.

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