Validation Accompanying the Introduction of a New Form of Energy (Fuel Cell System)

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ABSTRACT

In FY2014 fuel cell facilities were installed in radio relay stations owned by the Yokohama Waterworks Bureau. While there are multiple examples of fuel cells being installed in Japan, this marked the first time fuel cells were introduced by the Yokohama Waterworks Bureau. For this reason, demonstration tests were carried out verifying the stability of power supply and confirming fuel consumption amounts. This paper will provide a report on the details and results of said demonstration tests.

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INTRODUCTION

The Yokohama Waterworks Bureau installs uninterruptible power supply systems to instrument power supplies to ensure an uninterrupted power supply in the event of a disaster or other emergency. However, such a setup only allows for a short four hour power supply, leading to the distinct possibility that the power supply may be cut off before the emergency city workers arrive at the affected facility when a disaster occurs. To use the Great East Japan Earthquake as an example, it took three days to restore power after the power was cut off. Fuel cells began attracting attention as a means of supplying power for a 72 hour period, ensuring a long-term emergency power supply in circumstances where the main power grid is offline. This led to a fuel cell system being installed at the Nokendai High-zone Distribution Tank. This paper will report on the details leading up to the introduction of this fuel cell system, and evaluation results of demonstration tests on the system.

ISSUES WITH LONG-TERM POWER BLACKOUTS

The Yokohama Waterworks Bureau installs uninterruptible power supply systems as a backup power supply for instruments used for monitoring and controls for use in a power blackout caused by a disaster or other such emergency. These uninterruptible power supply systems are capable of supplying power for four hours. This causes concerns regarding in the difficulty of quickly restoring water supply as this short power supply prevents pressure and flow measuring of pumping stations and instrument control in extended blackout periods.

SUMMARY ON FUEL CELLS

Details on fuel cell use

The fuel cell installed by the Yokohama Waterworks Bureau is one of over 400 fuel cells found in Japan. Additionally, a communications company adopted the use of the same fuel cells in March 2013 as an emergency power supply at base stations as a countermeasure against long-term power outages resulting from a widespread disaster or other such emergency.

Power generation system

A methanol/water solution stored in the fuel cell itself is used to generate around 40 hours of continuous power supply. When the remaining fuel is insufficient, back up fuel stored in a plastic container can be used to provide an additional continuous power supply lasting at least 72 hours. Power is generated through a system whereby electricity is generated through a reverse water electrolytic process ($2H_2+O_2 \rightarrow 2H_2O$) where the methanol/water solution acts as the fuel, and hydrogen and oxygen as raw materials. (Fig. 1 Power generation flow reference for fuel cells)

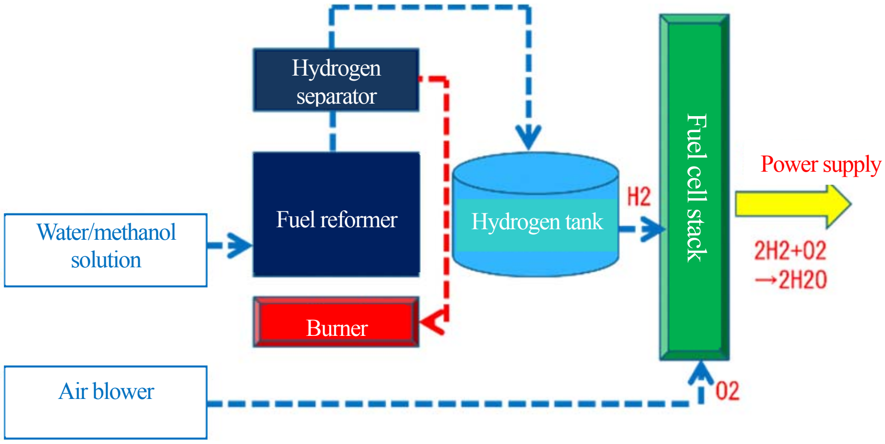

Figure. 1 Power generation flow of fuel cells

Procedure for switching power supplies in the event of a blackout

This section describes the procedure used to switch to the backup power supply when there is a blackout. Under normal circumstances a commercial power supply is used to supply power to radio equipment via a startup power supply. (See Fig. 2 Power supply procedure under normal circumstances.)

In the event of a blackout, a lithium-ion battery inside the startup power supply will start powering the fuel cell and the radio equipment. The fuel cell will then start supplying power using the power supplied from the lithium-ion battery inside the startup power supply. The fuel cell takes about three minutes to establish a power supply, and it begins supplying power to the radio equipment once the generator voltage has been established. (See Fig. 3 Procedure for switching power supplies in the event of a blackout.) This results in power being supplied from both the fuel cell and the startup power supply for a certain period of time. The power supply will switch to the higher voltage power supplied from the fuel cell as the voltage of the lithium-ion battery inside the startup power supply gradually continues to drop. This control method allows for an uninterrupted supply of power where radio equipment do not experience a down time.

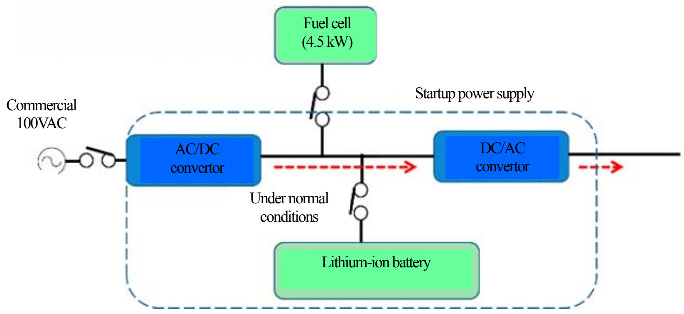

Figure. 2 Power supply procedure under normal circumstances

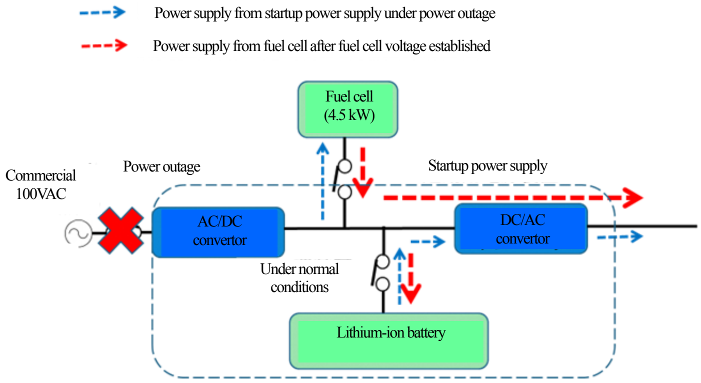

Figure. 3 Procedure for switching power supplies in the event of a blackout

Advantages of fuel cells

Environment

The power generation method used in fuel cells is friendlier to the environment — eliminating carbon dioxide emissions — and allows for a compact design that offers low noise generation.

Safety

The fuel used in fuel cells is a safe methanol/water solution (59% concentration) that is not recognized as a dangerous substance.

Long-term power supply capabilities

Fuel cells are capable of providing a long-term power supply, supplying 40 hours of power at a 4.5kW load. This duration can also be extended further through the supplement of fuel sources.

Fuel cell installation points

Fuel cells are installed at the Nokendai High-zone Distribution Tank, a site established as a radio relay station with the Kosuzume Purification Plant for monitoring information for the Kanazawa distribution reservoir and the Asahina dividing basin on the Kosuzume Purification Plant system, and for controlling and operating facilities over the radio system. (See Fig. 4 Outline diagram of the installation point.)

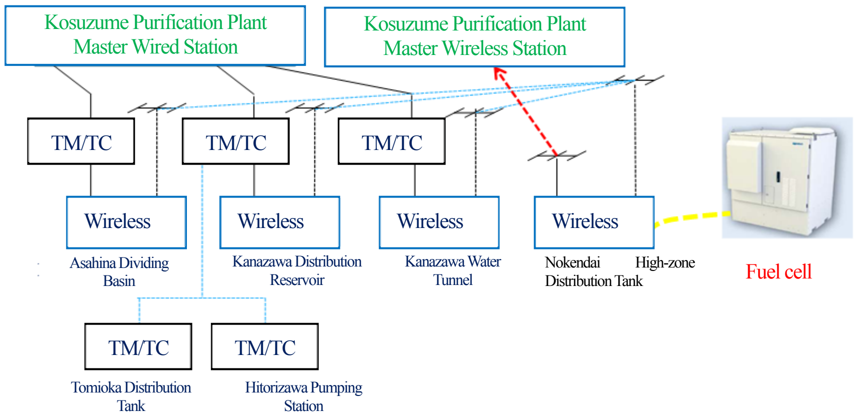

Figure. 4 Outline diagram of the installation point

EVALUATION TESTING DETAILS

Purpose of evaluation testing

Evaluation testing was performed twice to verify that the fuel cell system in place would be capable of operating over an extended period of time in the event of a disaster.

The first test was performed on July 28, 2015 and tested the fuel cell system running in continuous operation for an hour to verify that it was functioning normally.

The second test was performed from December 3, 2015 to December 4 and tested the fuel cell system running in continuous operation for 15 hours to test the soundness of the equipment when in continuous operation and to check the fuel consumption level.

Evaluation testing details

One hour operation test

The one hour operation test simulated a power blackout by shutting down the commercial 100VAC power source to perform two measurements of the voltage value of the fuel cell equipment and four measurements of its current value to verify that the fuel cell system was functioning normally. (See Fig. 5 Visual image of the test performed.)

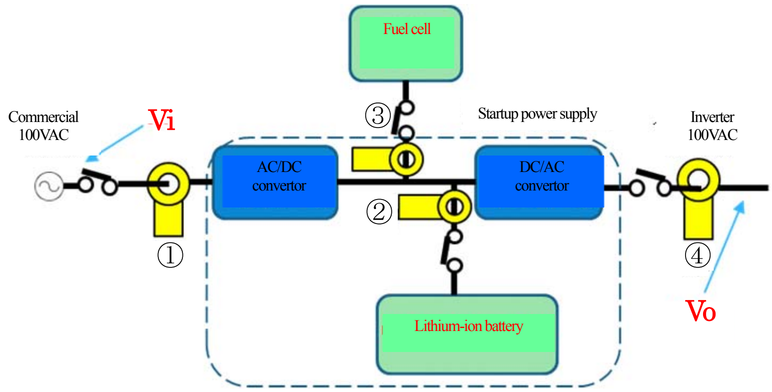

Figure. 5 Visual image of the test performed

15 hour operation test

The 15 hour operation test simulated a power blackout in the same manner as the one hour test to largely measure fuel consumption by the fuel cell equipment.

EVALUATION TESTING RESULTS

When power is out/restored

Voltage testing results are shown in Fig. 6. As we see in the diagram, the waveform of the voltage output by the fuel cell system after the commercial power supply is shut down/restored exhibits no signs of disarray, showing that the fuel cell outputs power at a stable voltage.

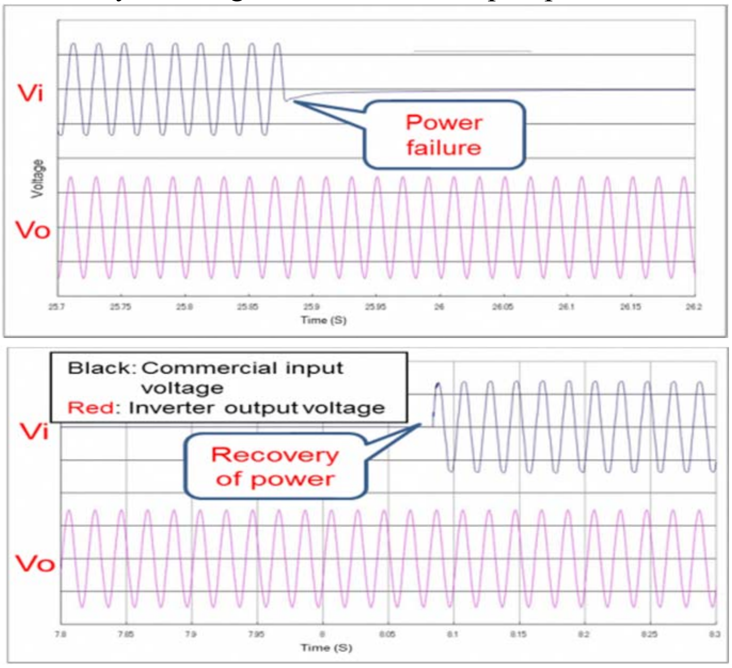

Figure. 6 Waveform diagram

Switching power supply when in a blackout

The results of tests performed on the output current when in a blackout are shown in Fig. 7. We can see that, when a blackout occurs, (1) the incoming current from the commercial power supply becomes zero, and (2) power is supplied from the lithium-ion battery inside the startup power supply to the load side. The fuel cell commences operation about three minutes after (3). As shown by (4), we can see that the power supply source has switched from the lithium-ion battery to the fuel cell. This is because the power supply source switches to the higher voltage fuel cell around 15 minutes after a drop in voltage from the lithium-ion battery. With this we can confirm that this allows for an uninterrupted supply of power where radio equipment do not experience a down time. (See Fig. 7 Power supply switch chart.)

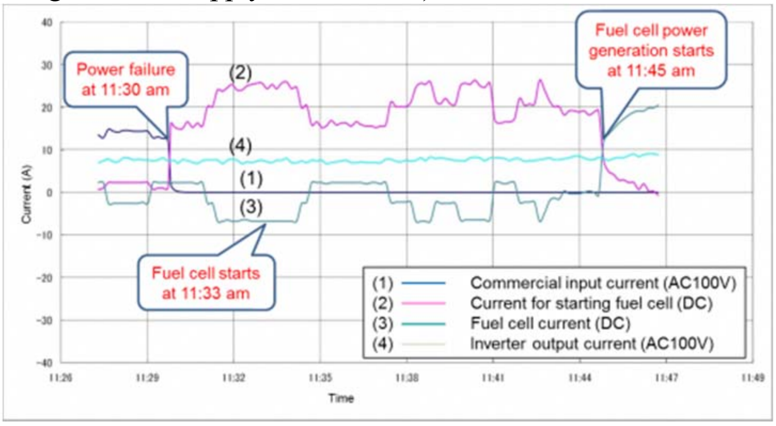

Figure. 7 Power supply switch chart

Fuel consumption amount

We were able to verify that the fuel amount dropped 12.5% as a result of 10 hours and 20 minutes of continuous operation. These results show that power could be supplied for approximately 82 hours and 40 minutes with a 225L tank stored in the main tank unit. (See Fig. 8 Fuel consumption graph.)

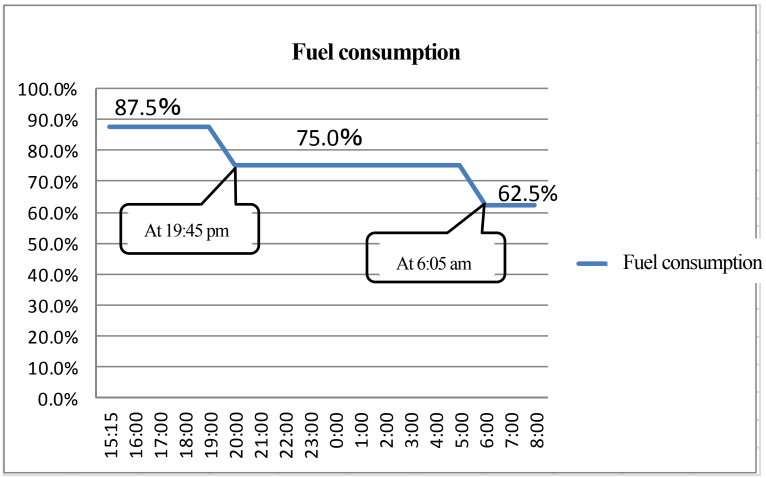

Figure. 8 Fuel consumption graph

CONCLUSION

The voltage test indicates that the system is functioning normally, showing no signs of disarray in the voltage output by the fuel cell system after the power outage/restoration, and that the fuel cell outputs power at a stable voltage.

The current test shows that power is supplied normally from the lithium-ion battery in the startup power supply for the 15 minute period it takes on average to start up the fuel cell system after a power outage. This test also indicates that the system is functioning normally by the lithium-ion battery inside the startup power supply starting to charge and output from the fuel cell being cut off once the power is restored.

In terms of fuel consumption, we were able to verify that the fuel tank alone is sufficient enough to generate power for over 72 hours, and testing showed the system clearing all reference values.

Based on these fuel cell evaluation results, we consider that a planned rollout of further fuel cell installations can be carried out.