New Energy Generation System for Fuji Electric Human Resources Development Center

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1. Introduction

Ever since the 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3) held in December 1997 in Kyoto, Japan, there has been greater concern and interest in reducing burdens on the environment. The training institute at Fuji Electric Human Resources Development Center has introduced an energy management system for integrated management of an amorphous solar cell system, a phosphoric acid fuel cell system and a micro gas turbine. This paper presents a general description of Fuji Electric's energy management system.

2. Overview

Table 1 lists a summary of the training institute's facilities and specifications.

The training institute, containing both training facilities and accommodation facilities, requires both electrical power and heat. With the goal of reducing CO_2, NOx and other burdens on the environment and of enhancing energy utilization efficiency, this institute has installed a 10 kW photovoltaic system, a 100 kW environmentally friendly fuel cell system, and a 26 kW micro gas turbine. Figure 1 shows an overview of the entire system. For the purpose of enhancing energy utilization efficiency, we estimated the demand for electric power and heat based on the number of reservations for training and accommodations. An energy management system has been constructed using high efficiency fuel cells, having high electric power generating efficiency, to handle the electric power demand and a micro gas turbine, having high waste heat collection efficiency, to handle the heat demand.

The introduction of photovoltaic power generation, fuel cells and other new energy generation equipment is expected to result in reduction of the following burdens on the environment.

- ○ CO_2 reduction: Approximately 28 t-C/year (17 % reduction)
  169 t-C/year before introduction is reduced to 141 t-C/year after introduction
- ○ NOx reduction: Approximately 84 kg/year (33 % reduction)
  253 kg/year before introduction is reduced to 169 kg/year after introduction

Table 1 Training institute's facilities and specifications

Large training room	1 room
Mid-size training room	3 rooms
Small training room	12 rooms
Open training room	2 rooms
Accommodation floor	Floors 4 to 6 (equipped with bath and toilet)
Total floor space	6 floors and approx. 6,000 m^2

3. Power Generation System Specifications

3.1 Photovoltaic system

With the goal of commercial feasibility, present day photovoltaic systems use amorphous-silicon solar cells, and the development of these amorphous-silicon solar cells is being advanced. This system is configured from amorphous-silicon solar cells, a 10 kW power conditioner, and measuring equipment (including weather monitoring equipment), and has grid-connected operation. The solar cells are mounted on a stand angled at 30° on the roof of the training institute. Table 2 lists the specifications of the solar cells and the power conditioner.

3.1.1 Photovoltaic module

Figure 2 shows the external view of the type of amorphous-silicon solar cell module that is installed on the institute's roof. The basic module structure utilizes the same glass module structure commonly used in crystal-silicon solar cells. Figure 3 shows the onsite solar cell installation.

3.1.2 Power conditioner

The power conditioner installed in this system has a 10 kW inverter unit, and extra capacity can be added in increments of 10 kW. In addition to the inverter unit, the power condition also has a display unit equipped with control functions and an I/O unit. The power condition is a rack-mounted type.

Fig.1 Overview of entire system

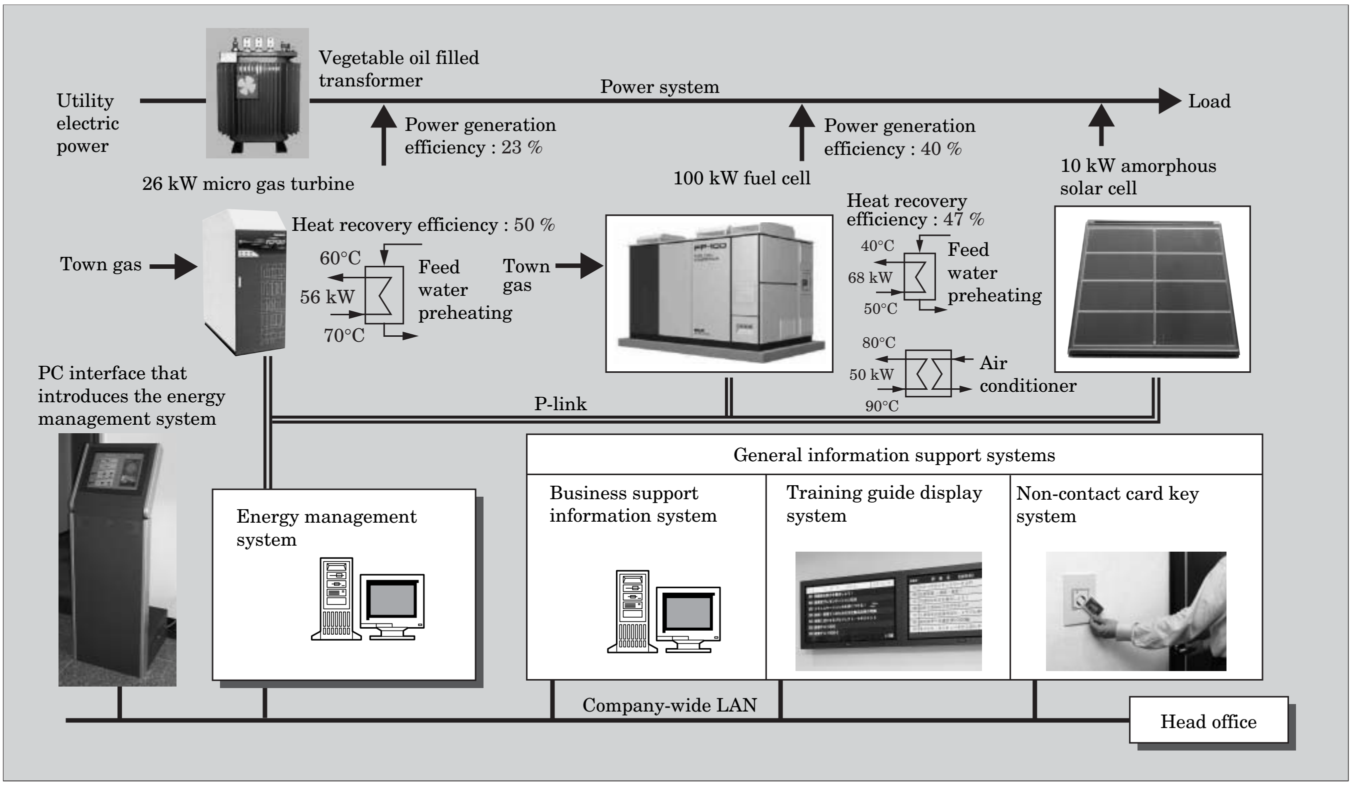


Table 2 Solar cell & power conditioner specifications

Solar cell	Type	Glass encapsulated amorphous-silicon solar cell
	Max. power of module	48 W
	No. of modules	210 (3 series × 70 parallel)
	Total installed capacity	10.08 kW
	Angle of installation	30° facing South
Power conditioner	Type	PVI plus10
	Rated input voltage	300 V DC
	Operating voltage range	190 to 450 V DC
	System condition	3-phase 3-line 210 V 50 Hz
	AC output power	10 kW
	Effective energy efficiency	94 % or greater
	Power factor	95 %
	Current distortion factor	Total: 5 % or less Each of the following degrees: 3 % or less

3.1.3 Measurement

One objective of the installed photovoltaic system is to verify operation of the amorphous-silicon solar cells currently being researched and developed. Therefore, in addition to measurements of output power and meteorological data, the solar cells were subdivided into small units (sub-arrays) and measurement points were determined so that a performance evaluation of the amorphous-silicon solar cells could be carried out. The measured items are listed in Table 3. This measurement system transmits the measured data via an intranet.

Fig.2 External view of solar cell module

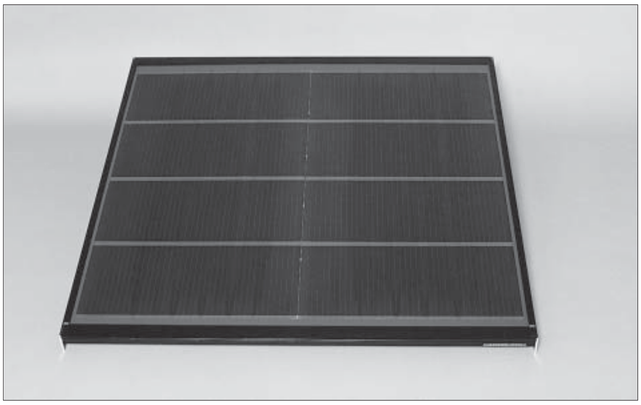


Fig.3 Onsite installation of solar cells

Table 3   Measurement items

Measurement group	Measurement item	Signal classification	No. of measurement points
Solar cell	Solar irradiation (horizontal)	0 to 1 kW/m^2	2
	Cell temperature	−20 to +100°C	9
	Cell output current	0 to 3 A	24
	Cell output voltage	0 to 400 V	2
Inverter	Line voltage (3 phase)	0 to 300 V	3
	Line current (3 phase)	0 to 50 A	3
	Electric power output	0 to 15 kW	1
	Electric power energy	0.1 kWh/Puls	1
Weather	Ambient temperature	Pt100 Ω	1
	Humidity	0 to 100 %RH	1
	Rainfall	0.5 mm/Puls	1
Status monitoring	Inverter failure	On/Off	1
	Inverter operation, shutdown	On/Off	1
	UPS abnormality	On/Off	1

Table 4   Phosphoric acid fuel cell specifications

Rated output	100 kW (power transmitting side)
System condition	3-phase 3-line 210 V 50 Hz
Power generation efficiency	40 % (for rated output, LHV)
Heat recovery efficiency	47 % (for rated output, LHV)
Total energy efficiency	87 % (for rated output, LHV)
Exhaust gas properties	NOx : 5 ppm or less (O_2 = 7 % conversion) SOx, dust concentration : below detectable limit
Fuel consumption	22 Nm^3/h (town gas 13A)
Operating system, mode	Fully automated, linked to the utility system
Main dimensions	2.2 m (W) × 3.8 m (L) × 2.5 m (H)
Mass	10 t

3.2 Phosphoric acid fuel cell system

3.2.1 Specifications and features of 100 kW phosphoric acid fuel cells

Table 4 lists the fuel cell specifications. The power generation efficiency is 40 %, and this value is highly efficient compared to other types of 100 kW generating equipment. Use of recovered waste heat boosts the total energy efficiency to 87 %. The ratio of electric output to waste heat output is approximately 1:1 and this is well suited for cogeneration that mainly uses electricity. Waste heat becomes largest when the power generation load is at its rated value. One advantage of fuel cells is that their power generation efficiency does not decrease for partial loads of even 50 %. This is a huge advantage compared to other cogeneration devices that experience significantly lower efficiency for partial loads.

Fig.4   Fuel cell power unit installed onsite

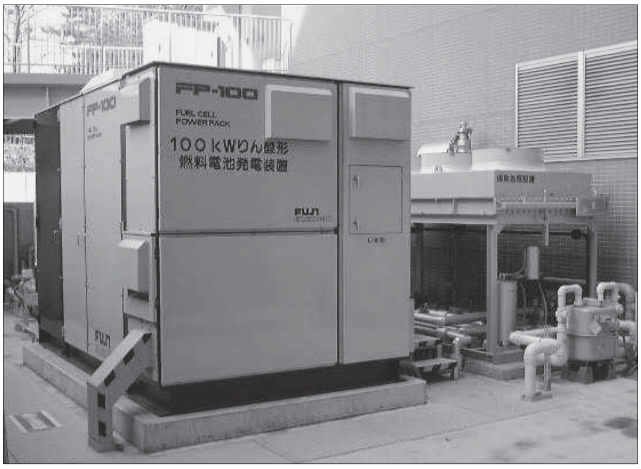


Table 5   Micro gas turbine specifications

Rated output	26 kW (power transmitting side)
System condition	3-phase 3-line 210 V 50 Hz
Power generation efficiency	23 % (for rated output, LHV)
Heat recovery efficiency	50 % (for rated output, LHV)
Total energy efficiency	73 % (for rated output, LHV)
Exhaust gas properties	NOx : 15 ppm or less
Fuel consumption	9.7 Nm^3/h (town gas 13A)
Operating system, mode	Fully automated, linked to the utility system
Main dimensions	0.79 m (W) × 1.9 m (L) × 2.1 m (H)
Mass	1.2 t

3.2.2 Fuel cell power system

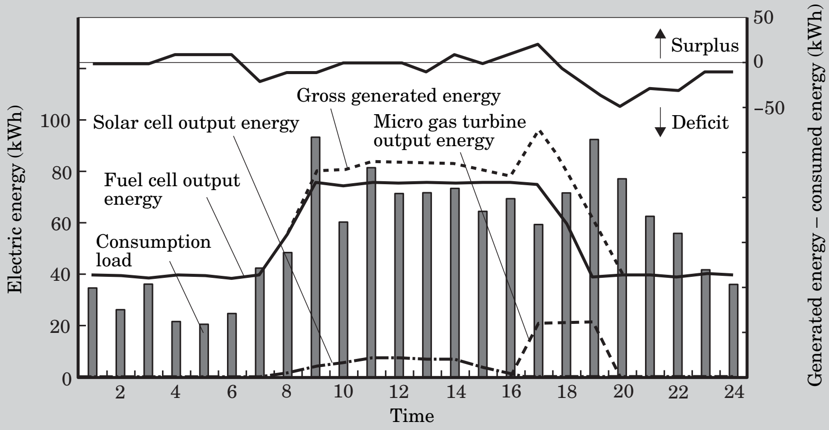
This system is comprised of a fuel cell power unit, waste heat treatment equipment, water treatment equipment, nitrogen equipment, and a water-fired chiller; it is linked to the utility system and operates continuously. Figure 4 shows a photograph of the fuel cell power unit.

High temperature water (90°C) is used as the heat source for a water-fired chiller (10RT) and can be used for the air conditioning in an institutional kitchen or elsewhere. Lower temperature water (50°C) is fed through a heat exchanger and is used for feed water preheating.

The operational load is estimated based on the number of reservations for training and accommodations, and a pattern upon which to base the operational control can be selected by the energy management system.

Moreover, this system is able to supply electricity during an outage of the utility power. Specifically, when a power outage occurs, the load feeder that is not supplying power is cut off. Meanwhile, the fuel cell system halts the inverter output by means of a power outage detector, and after a certain amount of time has elapsed, performs a soft start by gradually increasing voltage so that restart is implemented with suppressed

Fig.5 Example of electric power generation and consumption



rush current. The system then performs load feeding as a stand-alone operation. Furthermore, during stand-alone fuel cell operation, so that there is no abrupt spike in the load, the system takes into consideration the specific load selected and the application of the load.

3.3 Micro gas turbine

Specifications of the micro gas turbine are listed in Table 5. This cogeneration system is configured from a Capstone turbine main unit, a 26 kW micro gas turbine with an attached waste heat recovery unit, a town gas pressure blower, air-fin coolers, etc. This system is linked to the utility system and uses waste heat for feed water preheating. The ratio of electric output to waste heat recovery output is approximately 1:2 and this is well suited for cogeneration that mainly uses waste heat. The energy management system operates the micro gas turbine in the evening when the demand for heat is greatest.

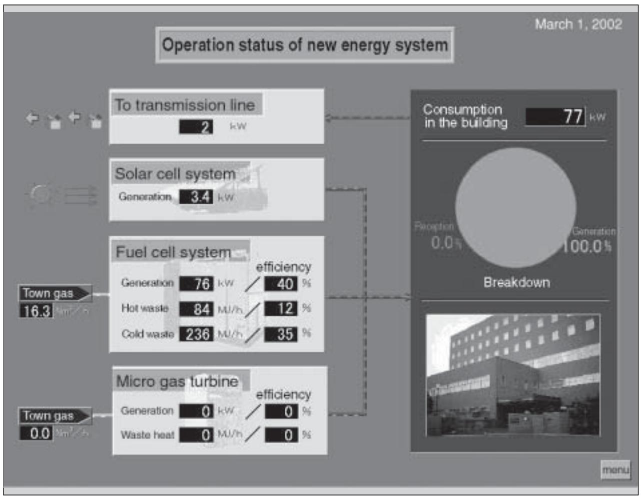
4. Energy Management System

The energy management system controls operation of the power generating equipment in order to maximize the energy utilization efficiency of the electric power and heat consumed by the training institute. The energy management system is equipped with the following three functions.

(1) Operating pattern selection function

The energy usage quantity (estimated demand) is calculated based on training that has been registered in the work support system and the number of reservations for accommodations. An optimal operating pattern for the fuel cells and micro gas turbine is determined and control is performed accordingly. Because there is no database of energy demand data for the institute, estimated demand is calculated commensurate with the probable usage for the reserved

Fig.6 Example monitor screen showing status of new energy generation system



training and accommodation floors based on the energy usage of a typical office building or hotel. The energy utilization efficiency is enhanced by operating the fuel cell system, which has high power generating efficiency, in response to the power demand and a micro gas turbine, which has high waste heat recovery efficiency, in response to heat demand. Since continuous operation of the fuel cells is desired, the fuel cells are operated at minimum output power during nighttime hours and on holidays when demand for power is low. The present operating pattern outputs 75 % of the rated power during daytime hours and 40 % of the rated power during nighttime hours. Figure 5 shows an example of the generation and consumption of electric power. It can be seen that the generated power roughly satisfies the demand for power consumption.

We will continue to accumulate and analyze data of the training institute's energy usage and will conduct verification testing of operation patterns so that the demand estimate is optimized and is commensurate with the energy usage of this institute.

(2) Logging function

The energy generation status of fuel cells, solar cells and the micro gas turbine and the energy consumption status of the building are logged and daily, monthly and annual reports can be generated.

(3) Monitor display

The energy generation and consumption statuses can be monitored from the lobby of the training institute. In consideration of the lobby design, this function is implemented with a station-type LCD monitor. Figure 6 shows an example display of the status of the new energy generation system.

5. Conclusion

Fuji Electric will construct a database of energy consumption status and other data, and plans to verify the behavior of environmentally friendly operation that enhances the energy utilization efficiency. Moreover, based on the knowledge and experience acquired through the construction and operation of this system, Fuji intends to intensify its ongoing efforts to provide optimal energy solutions.