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Features:Environmental Protection Technologies

The Technology Center's Cogeneration Efforts

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1. Introduction

With the quick growth of world economy over the past fifty years, energy consumption has been accelerating in growth. Accordingly, the public is increasing spotlighting issues such as global warming stemming from a rise in carbon dioxide emissions, acid rain, and other global-scale environmental contamination, resources exhaustion, and other problems. Under these circumstances, cogeneration systems, fuel cells, photovoltaic power system, wind power generation and other systems are being introduced as energy-saving, new-energy equipment. This paper outlines the actual condition of cogeneration systems and a case study of the Technology Center at Sanyo Denki, and presents the findings of a field test conducted toward the commercialization of such systems.

Cogeneration generally means a continuous production of two energies (electric or motive and effective thermal energies) from a single energy source. Cogeneration is a term made by combining "co"(which means "joint") and "generation"(power generation). An enhanced version of cogeneration is called a cogeneration system (CGS). Traditional power generation equipment expels 60-70% of the heat generated, with the exception of power use of 30-37% of the energy loaded. One feature of the cogeneration system is that waste heat can be collected and used to increase energy efficiency up to about 80% (about 30% for power generation efficiency and about 50% for heat usage efficiency). This can be used for private power generation to obtain more inexpensive and efficient power than commercial power accompanied with transmission losses. At the same time, resulting exhaust heat can be used to save power and fuels for room cooling and heating. Expectations therefore run high that the CGS will spread widely as energy-efficient environmental equipment capable of coping with global-scale environmental issues caused by the rise in carbon dioxide emissions mentioned previously.

2. CGS today

2.1 Reducing NOx emissions from the engine

CGS are provided with a diesel engine (DE), gas engine (GE), or gas turbine (GT) because of their respective characteristics listed in Table 1, in view of the fuel supply system, heat use style, installation conditions, pollution controls and other considerations.

Now that air pollution controls are being stepped up in ordinances of local self-governing bodies in comparison to the national Methods of Air-pollution Control, NOx reducing technologies are being put to practical use as shown in the bottom field (Typical Case) of Table 1.

2.2 Heat exchangers and other thermal equipment

The CGS collects the heat created from cooling water and from exhaust gases discharged from traditional engine power generators via a heat exchanger, and is used in water heaters, hot-air room-heating radiators, and thermal equipment for cooling with an absorptive freezer. Cooling water whose excess heat was removed by a cooling tower or other equipment is returned to the engine, where it is cools engine and collects waste heat.

Table 1 Comparison of engines for cogeneration systems

	Diesel engine	Gas engine		Gas turbine
		Ternary catalyst	Lean burn	
Output range	～ 10,000kW	～ 1,500kW	～ 5,000kW	～ 10,000kW
Power generation efficiency	30 ～ 35%	30 ～ 35%	35 ～ 40%	20 ～ 30%
Heat collection ratio	35 ～ 38%	40 ～ 50%	35 ～ 45%	35 ～ 55%
Overall efficiency	70 ～ 75%	75 ～ 80%	75 ～ 80%	65 ～ 75%
Heat-electricity ratio	Approx. 1.0	Approx. 1.5	Approx. 1.0	Approx. 2.0 ～ 3.0
Jacket water temperature	80 ～ 90 °C	80 ～ 90 °C	80 ～ 90 °C	
Exhaust gas temperature	300 ～ 400 °C	550 ～ 600 °C	450 ～ 550 °C	500 ～ 550 °C
Load variation characteristics	Small frequency fluctuations	Large frequency fluctuations		Minimum frequency fluctuations
Partial load characteristics	Small decline in power generation efficiency	Small decline in power generation efficiency		Large decline in power generation efficiency
Unit price of fuel	Cheap	Expensive		Possible for both liquids and gases
Unit price of equipment	Cheap	More expensive than DE		More expensive than GE
Target NOx value	No action to 900ppm Ammonia denitration 300ppm (expensive)	～ 150ppm	150 ～ 200ppm	100 ～ 150ppm (Many deliveries for water/steam injection)
(Regulation as per the Atmospheric Contamination Prevention Law)	950ppm	600ppm		294ppm
(Metropolitan Ordinance)	150 ～ 1,000ppm	150 ～ 200ppm		100 ～ 250ppm

2.3 Control

The CGS can be automatically started and stopped by a scheduled timer. For an efficient run, the CGS can be automatically started and stopped according to the load condition while monitoring the amount of commercial power. One can thus control the number of generators automatic load division, minimum incoming power at a constant level, and power factor.

2.4 Utility Connected System

In 1986, the Ministry of International Trade and Industry announced its Guideline for Utility Connected System Technical Requirements, which allowed CGS-generated power to be connected with a commercial power system. Utility Connected System allows power quality to be governed by the commercial power system, thus making it stabilize. Load fluctuations, on the other hand, are supplied from the system, which allows operators to set the load factor of the generator to a high setting. However, it is necessary to install a protective device that prevents accidents when the commercial power system fails.

2.5 Deregulation

In December 1995, the Electric Utility Law underwent a major revision. It incorporated such additional provisions as the foundation of wholesale supply enterprises and designated electric enterprises (the liberalization of power supply in a building). As a result, one is now free to feed power to a wider range.

3. CGS at Sanyo Denki's Technology Center

The CGS at Sanyo Denki's Technology Center was introduced to check the effects of the company's investments in plant and equipment through field tests for commercialization which system is shown in Fig.1.

The amount of power received was changed from high voltage B to high voltage A, while the contract power was changed from 750kW to 490kW, thus reducing the basic contract charge. Other objectives were to suppress peaks in the amount of power received and save energy in response to the heat demand of coolers and heaters.

The equipment was also specified taking the following requirements into consideration:

1. Heat usage simulation in terms of the required heat quantity of the cooling/heating load
2. Comparison of engine system, power generation efficiency, and NOx emissions
3. Heat recovery system, utility connected system, and other systems.
4. Fuel infrastructure
5. Equipment cost and recovery time.

An examination of these considerations led to the selection of a high-generation-efficiency gas engine with reduced environmental hostility. As shown in Fig. 2, the total heat efficiency was as high as 82% maximum.

The following is an overview of the equipment specifications.

- Engine power generator
  Lean-burn gas engine power generator (manufactured by Austria's Jenbacher, a company with many years of experience with high power generation efficiencies)

- Power generating output
  263kW in utility connected system, 184kW in a standalone run

- Output voltage
  3-phase, 210V (60Hz)

- Classification of interconnection
  Commercial power, low-voltage utility connected system

- Heat use
  Hot water for wintertime room heating, heat source in a cold/hot water generator of the summertime absorption type, and an all-season LPG vaporization heat source (431kW output (370Mcal/h))

- Fuel equipment
  Two 2.9t LPG bulk tanks (LPG type because there is no city gas infrastructure)

This equipment supplies approximately 30% of the power quantity of this center, 20% of the room cooling energy, and 70% of the room heating energy. The system is so designed that, when the commercial power blacks out, it is disconnected instantaneously and private power generation is used to keep feeding particular loads.

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4. Field test/operation status

4.1 Amount of CGS-generated power

As of the end of July 1999, the total amount of generated power as measured in a CGS field test that lasted about two years was 1,150,000kWh. Its monthly average was approximately 48,000kWh. Since the amount of commercial power received is approximately 142,000kWh on a monthly average, approximately one quarter of the total power consumption is supplied by CGS power generation. The total operation time is 4,600 hours, or 192 hours on a monthly average.

4.2 Operation system of the CGS

The CGS is run on the principle that electricity is followed by heat. It generates power according to the amount of power received and cuts peaks during the daytime. Exhaust heat is used as much as possible in room cooling/heating and hot water dispensing. Excess heat is radiated. One monitors actual power consumption, and when one finds the load increasing and that the commercial power is 420kW or more and within the time schedule (8:00a.m. to 9:00p.m.) of the central monitoring equipment, the CGS starts automatically. When the load declines and the commercial power received is 120kW or less, or when it is out of the time schedule, the CGS stops automatically. Therefore, when power consumption is high such as in summer or winter, the system runs for many hours. In the intermediate seasons when power consumption is low, such as spring and fall, the system runs for fewer hours.

4.3 Monitoring of CGS operation

The CGS is monitored by the central monitoring equipment, which displays and records the operation time schedule, track record, and errors that occurred.

4.4 CGS maintenance

For about six months after installation, the CGS required about 10 hours of maintenance and repairs each month. The time was then reduced to several hours per month. The system has thus been in good operational condition.

5. Field test/effects of investments

After the 263kW CGS was installed, a field test was conducted for about 2 years to monitor the parameters outlined below.

1. LPG consumption (and charges) of the CGS
2. Power generated
3. Operation time
4. Amount (and charges) of commercial power received
5. Heat supply to room cooling and heating.

The monitoring of the above parameters led to confirmation of the following effects:

1. The CGS reduced power charges by about 5 million yen per year.
2. The CGS reduced the size of the power reception contract (high voltage B) from 750kW to 490kW (high voltage A). The basic charge then declined by about 9 million yen per year.
3. The use of waste heat reduced the LPG charges by about 2 million yen per year.

Thus, even if a subtraction of about 9 million yen per year of the LPG charge and maintenance cost is made, the advantage amounts to 7 million yen per year. The single recovery time with an equipment cost of 62 million yen reaches 8.8 years if things continue as they do now.

6. Carbon dioxide reduction

The reduction of carbon dioxide, which is most environmentally hostile amounts to the reduction (20,000m^3 /year: 2 million yen per year) of yearly LPG consumption through the use of waste heat. This amounts to about 30 tons per year in terms of carbon dioxide emissions.

7. Conclusion

This paper has so far outlined the actual condition of cogeneration systems today and a case study of Sanyo Denki's Technology Center. As for the company's case study, the history of events leading to the introduction of the system is presented in

Technical Report No. 4 Nov. 1997. For the present report, the authors surveyed again the actual operation status of the system, 2 years after installation.

The authors will continue to collect data for this system and attempt to use them for effective operation.

Due to the changes in the environment surrounding energy issues, the role of CGS is becoming increasingly important. To promote the introduction of the CGS even further, it is expected that efforts will be made to develop utility connected system guidelines and conduct various deregulation attempts.

Similar to other companies, Sanyo Denki will base itself on experiences with CGS and consider new power generation systems by means of increasing efficiency and reliability and reducing footprint and noise, thus promoting the commercialization of the system. This, together with attempts to contribute to environmental projects, will presumably help protect the global environment.

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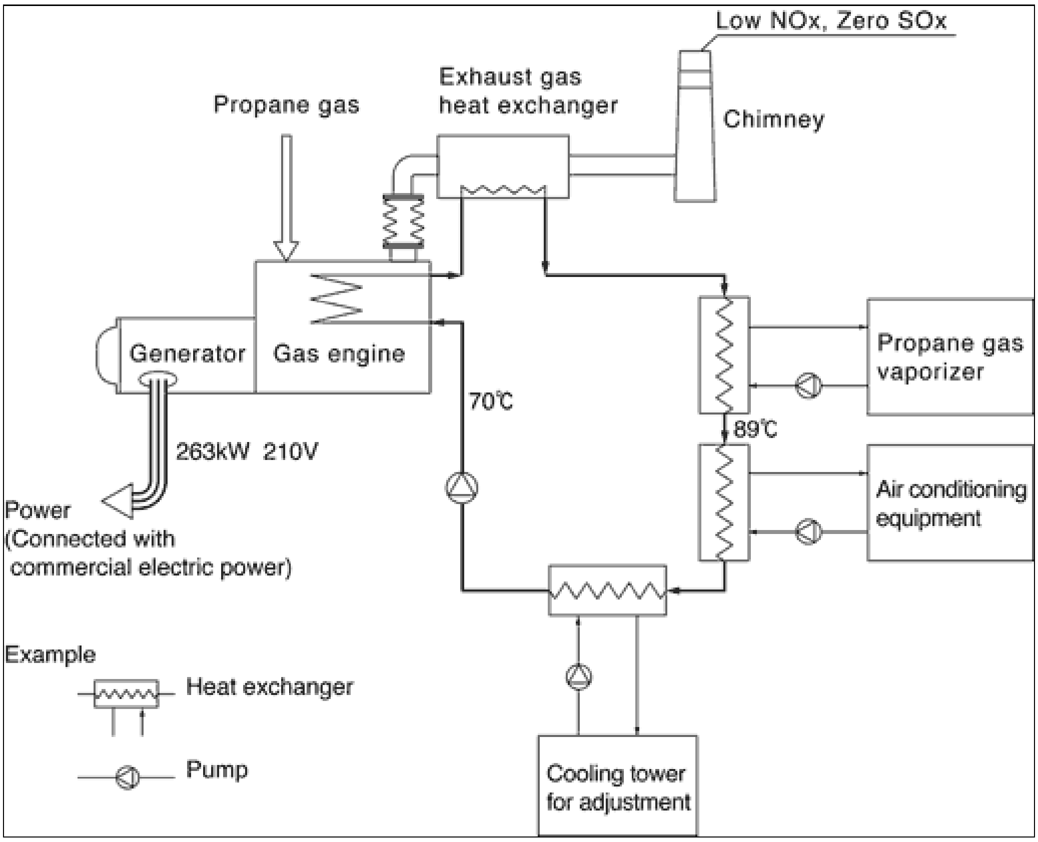

fig.1 System based on waste heat from cogeneration

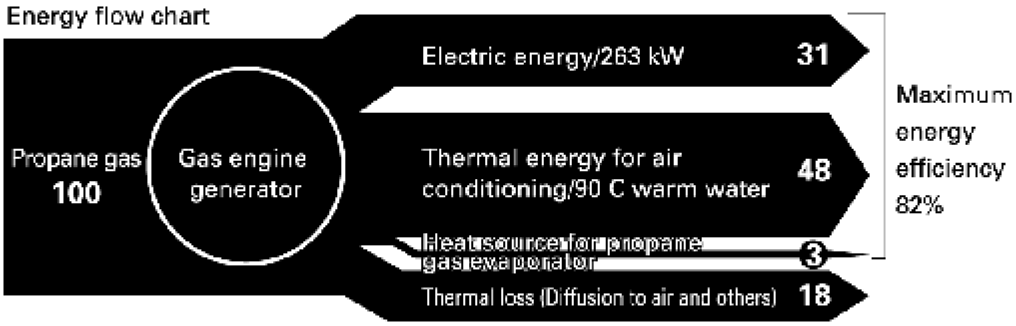

fig.2 Energy flowchart