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TECHNICAL DEVELOPMENT OF HIGH EFFICIENCY AND ADDED VALUE FOR 35kW MICRO CHP SYSTEMS

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ABSTRACT

The number of CHP systems has increased year by year as a highly energy-saving and cost-effective method of supplying electricity and heat efficiently. The Yanmar CP series is such a micro CHP system. Since the release of 9.8kW/CP10 in October 1998, Yanmar has expanded the product lineup to meet the energy-saving needs of a variety of customers, covering a capacity range from 5kW to 35kW. The result of this is that in Japan there are now more than 5,100 units installed at a range of customer sites including welfare facilities, hospitals, restaurants, spas and hotels. In particular with strong sales promotion in the area Osaka Gas Co., Ltd. area there are more than 2,500 unit installations.

With the aim of increasing the range of applications further, Yanmar Energy Systems Co., Ltd., with Osaka Gas Co., Ltd., developed the 35kW/CP35, which was released onto the market in November 2008.

The developed the 35kW/CP35 has a newly developed engine that was designed to achieve the high efficiency. As a result, the 35kW/CP35 has achieved an electrical efficiency of 34%, which is the highest level of its class as gas engine CHP system. For the 35kW/CP35, up to 16 units (available capacity of 35~560kW depending on customers' demand) can be connected to the dedicated system controller to operate the number of units for a given load. Multiple unit installations are expected to be introduced into the market of large-scale facilities. Using multiple units, the partial load efficiency improves by controlling the number of units depending on the range of energy demand in comparison with one large-scale cogeneration system. Therefore high efficient operation can be achieved.

We have been trying to propose various value-added applications using CP systems as follows;

A system that can survive grid power failure has a dedicated battery within the package. It can be continuously operated by the battery for supplying control power during grid power failure. Also, it can supply a pre-selected load with electrical power in combination with a dedicated unit (switching board) for blackout start operation. This system enables various electric facilities to be available continuously during grid power failure. This type of unit has applications: air conditioning systems and lighting at hospitals and welfare facilities that require secure power supply or elevators in offices and apartment housing complexes, etc.

A system that utilizes operates using a LPG air mixture for emergencies has a secure power supply when the city gas utilities are cut off by a disaster. LPG gas canisters can be stocked with relative ease. By locating LPG gas canisters near to the system, the 35kW/CP35 can be operated and can supply the power to critical loads by supplying a mixture of LPG and air.

A system equipped with a biogas engine that operates using biogas derived from organic substances, such as leftover foods, animal wastes and sewage sludge. The 25kW/CP25 has been available with a biogas-engine and now, to increase the added value, a low cost gas mixture system of biogas and natural gas for 35kW/CP35 is being considered.

The 35kW/CP35 is a model that realizes high efficiency, high performance and cost-saving. We hope to respond to various customer needs with additional value as well as contributing to further promotion of CHP plant introduction.

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1. Introduction

Year on year, the number of gas cogeneration systems operating in the field has been increasing. These energy saving systems allow the efficient usage of electricity and heat, the reduction of CO2 emissions and provide economic benefits for users. The Yanmar CP series, with its inverter grid connection feature, is one of these such systems.

Since the launch of the 9.8kW / CP10 gas micro-cogeneration unit in October 1998, in order to meet the energy needs of a wide range of customers, the CP product range has been widened to now cover the range 5kW to 35kW (Table 1). The result of this is that in Japan there are now more than 5,100 units installed at a range of customer sites including welfare facilities, hospitals, restaurants, spas and hotels. In particular with strong sales promotion in the area Osaka Gas Co., Ltd. area there are more than 2,500 unit installations.

With the aim of increasing the range of applications further, Yanmar Energy Systems Co., Ltd., with Osaka Gas Co., Ltd., developed the 35kW/CP35, which was released onto the market in November 2008. To further increase the added value for customers systems were subsequently designed to improve energy security, such as systems that can operate during incoming mains power supply outages, and systems that supply power for elevators. In addition, an 'uninterruptible power source system' connected to a UPS (uninterruptible power supply)' and an 'emergency propane air system' were newly developed. In this report these systems and also future developments are described.

2. System Outline

2.1 Development Items

In order to achieve high efficiency, the gas engine for the 35kW CP unit was newly developed. The engine that was developed is a single chamber lean burn engine operating with a Miller cycle. This engine design was optimized by fuel combustion analysis with changes made to the combustion chamber design, compression ratio and valve timing, all these factors are known to influence engine efficiency.

Also, the thermal efficiency of this engine was increased by optimizing the mixer configuration to allow the use an even leaner mixture, and by reducing pressure losses in the engine aspiration system. The result is that, in the under 100kW class, with this engine achieved the world's highest generating efficiency of 34%.

In addition, up to 16 35kW/CP35 units can be controlled using one dedicated system controller, making it possible to handle customer power requirements ranging from 35kW to 560kW. With this capability, it is expected that with this unit it will be possible to enter the larger installation market.

In the case of multiple unit installations it is possible to control the number of units running according to changes in the demand for power. In part a load situation, multiple unit operation is more efficient compared to the operation of a single large cogeneration unit, so high efficiency is possible (Figure 1). Multiple unit operation also allows for the equalization of unit run times by operating the

units in rotation, this extends the maintenance interval and also allows for maintenance of several units at the same time (Figure 2), thus reducing maintenance costs.

2.2 System Flow

In order to increase the range of applications beyond the standard grid connection model, a black out start capable (BOS) unit with an on-board battery, allowing the unit to operate during an incoming mains supply power outage, was specified. The external appearance of this unit is shown in Figure 3 and the specification is shown in Table 2

This unit is a system consisting of a gas engine, generator and inverter to supply electrical power as well as hot water. The system flow of the 35kW/CP35 (BOS) unit is shown in Figure 4. The electrical power generated by the electrical generator is supplied to the power grid through the inverter section. The heat reclaimed from the engine body and exhaust is used as hot water for water heating or heating etc. by connecting devices that can use waste heat. For the BOS model unit there is a battery included inside the package, so when the supply of power from the grid is disrupted the battery provides the unit with its own secure control power supply and also allows the unit to start up in island mode. In addition, by using in combination with a dedicated stand alone operation unit (switch-over board), when there is a supply power outage it is possible to supply power to predetermined loads.

3. Approach for greater power supply security

3.1 Power supply unit for elevators during power supply outage

In Japan, multi-dwelling housing accounts for 50% or more of residences in metropolitan areas. The Yanmar system has been confirmed not only to be suitable use in multi-dwellings for energy conservation, but has also been confirmed to be effective as a power supply for elevators during times of power outage. As a result, in buildings where there is no obligation according to building regulations to install an emergency use elevator and backup power generator, the safety and security offered by this system is attracting attention as a means of adding value to the installation of this kind of system in multi-dwelling housing. For example:

1) Elevators can operate also during a power outage.
2) The power supply in common areas can be secured during a power outage so security can be maintained.
3) Power can be supplied to water pumps during a power outage making it possible to use tap water and toilets etc in each dwelling.

3.2 Uninterruptible power supply system connected to UPS

This time, by using the 35kW/CP35 (BOS specification) as the primary side power supply of a UPS, a system was developed that can supply uninterrupted power to important loads for long periods even when there is an issue with the incoming power supply. This system is shown in Figure 5. In a usual system after there is a power outage, when the 35kW/CP35 switches from grid connect mode to

stand alone mode there is a momentary loss of power supply. With this system, even when the operation mode changes, the power supply to critical loads is maintained by power from the UPS. After Island mode operation has started, since the 35kW/CP35 unit supplies power to the UPS it is possible to handle power outages of long durations. With this system, critical loads such as hospitals and care facilities, that must be constantly supplied with power even during power outages can be constantly supplied.

3.3 Emergency use propane-air system

The emergency use propane-air specification unit is able to supply electrical power even if electrical power supply and the town gas supply are both interrupted, as could happen in some kind of disaster situation. Propane cylinders are comparatively easy to handle and store, and with this system it is possible to supply power to critical loads using the 35kW/CP35 unit operating in island mode supplied by a propane air mixture from a propane air mixture generation unit located near the unit.

In this development, by modifying the air intake hole of the propane air generator to give high calorie content, it was confirmed that the 35kW/CP35 unit operated with the same level of performance as with town gas. A comparison of the unit performance operating with propane air mixture and town gas is shown in figure 6, according to this graph the loading and unloading performance is judged to be equivalent to that of town gas, and it was also confirmed that the rotational speed and DC voltage were both within prescribed ranges. For this system the maximum possible run time can be adjusted by varying the number of propane cylinders connected to the system, in this way it is possible to design each system to suit needs of each customer.

3.4 Installation example at Osaka Gas Co., Ltd. Hikone Gas building

Here we will introduce an example 35kW/CP35 electrical power supply security system installed at Osaka Gas Co., Ltd. Hikone Gas Building that started operation in January 2011. In addition to the savings in energy, cost and CO2 emissions of current similar CP systems this system also has the following features.

1) In the case of an emergency, this system, with the 7-cylinder stock of propane (each containing 50kg of LPG), is able to supply critical loads with power for 24 hours.
2) With the UPS combination this system can supply critical loads with power without interruption even if there is an issue with the incoming power supply.

Figure 7 shows the system flow of the Hikone Building system, and Figure 8 shows the external appearance of the building and installation. For the Hikone Building, by implementing this combination 35kW/CP35, UPS and propane air system, the ability to supply critical loads with power, even if there are issues with the incoming electrical and gas supplies, means that this building is expected to be able to serve as a disaster prevention center in an emergency situation.

4. Developments from now

As a means of increasing energy security and reducing greenhouse gas emissions, the use of distributed power supplies and the increased use of renewable energy are areas of technologies that are attracting a lot of attention. Using wind-power or solar power to generate electricity is unstable due to the dependence on weather conditions, and so it is necessary to pursue technologies that can store electricity or stabilize power grids, as well as reducing costs. Also, issues have accumulated with the generation of electricity by biogas such as how to secure enough raw materials to continuously generate fuel.

For these reasons, technology like gas micro-cogeneration, that provide an efficient form of secure energy, can improve the effectiveness of other technologies in the power supply system as a whole and become an important solution for technological issues that exist with the development of smart grids. Yanmar already sells 25kW biogas powered micro-cogeneration systems that can operate using biogas generated from food waste, animal manure, sewage waste or naturally venting gas, these systems have accumulated over 30,000 hours of runtime.

From now Yanmar will continue to develop micro-cogeneration systems to handle various fuel compositions including models that can operate using mixtures of biogas and natural gas. In addition, as well as expanding the product lineup in terms of power output, systems that can support grid power optimization control will also be developed.

5. Final remarks

This time, by connecting a UPS unit to make an uninterruptible power source, and by enabling operation with a propane air supply for an emergency system, systems that increase the security of the power supply offered by CP35 cogeneration units have been designed. The addition of these systems to the currently available gas air-conditioning systems and emergency use elevator power supply system, means that the product lineup offered by Yanmar can give a wide range of support in the area of power security.

In the development of the propane air system Yanmar would like to thank both Gasnet Co., Ltd. and Ito Koki Co., Ltd. for their support and assistance.

From now, Yanmar will continue contributing to the spread of gas powered micro-cogeneration by expanding the number of applications, increasing added value and widening the range of customer needs met by these systems.

Table 1 : The Yanmar CP series Line up

Fuel : N=Natural gas , P=Propane, B=Bio gas

	4 / 5 kW			10 kW		
	Grid	Grid-BOS	Off-Grid	Grid	Grid-BOS	Off-Grid
Japan	NP			NP	NP	NP
Europe	N			N		
North America				NP	NP	NP

	25 kW			35 kW		
	Grid	Grid-BOS	Off-Grid	Grid	Grid-BOS	Off-Grid
Japan	NPB	NPB	NPB	NP	NP	NP
Europe	NB					
North America						

Notes Grid-BOS : Black Out Start on Grid

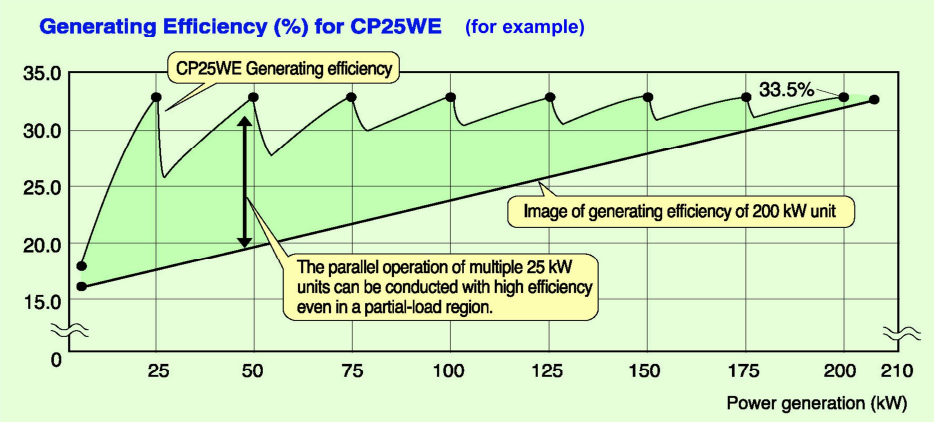
Table 2 : Specifications of 35kW CP unit

Model			CP35VC-TN (Standard)	CP35VCZ-TN (BOS)
Rated electrical power output		kW	25	
Voltage		V	200	
Frequency		Hz	50 / 60	
Overall efficiency (LHV)		%	85 <84>	
Electrical generation efficiency (LHV)		%	34	
Heat recovery rate (LHV)		%	51 <50>	
Hot Water Temperature (Outlet)		℃	85 (max 88)	
Fuel consumption (LHV)		kW	103	
Rated power consumption	Radiator fan stopped	kW	0.51 / 0.56	0.53 / 0.59
	Radiator fan operating	kW	0.89 / 0.95	0.92 / 0.98
Dimension	Width	mm	2000	
	Depth	mm	1100	
	Height	mm	2000	
Net weight (including water and lubricant)		kg	1470	1530
Operating sound pressure level		dB(A)/1m	62.0	
IP classification		-	IP44	
Maintenance interval		Hours	10000	

Note : The number in parenthesis < > is the value operated with hot water temperature 88 ˚C

Control of Multiple-unit Operation

The system controller (sold separately) enables the use to control the operation of multiple units (up to 8 units). High-efficiency operation on partial load is possible by controlling the number of units in operation.



Rotation operation balances the operating hours of each unit, this enables the maintenance costs are reduced by being able to do maintenance on all the units during the same maintenance period.
The appropriate number of units for the required load operate, and units are operated on a rotation basis in order to keep the operating hours of each unit nearly equal.

Figure 1 : Control of Multiple Operation 1

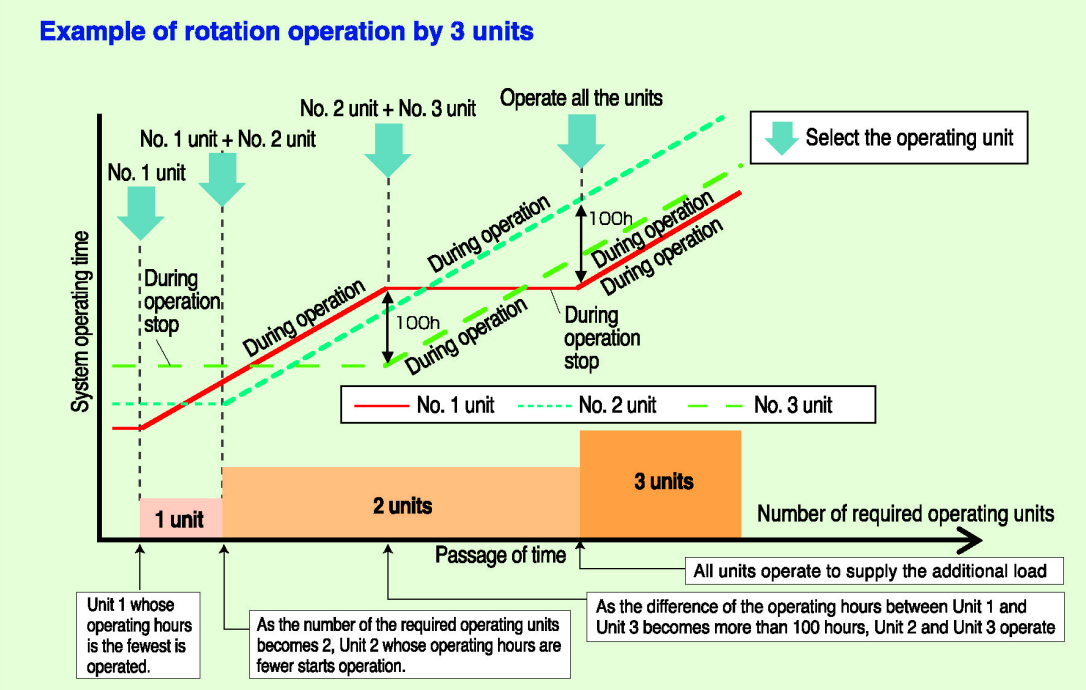


Figure 2 : Control of Multiple Operation 2

Figure 3 : External appearance of 35kW CP unit

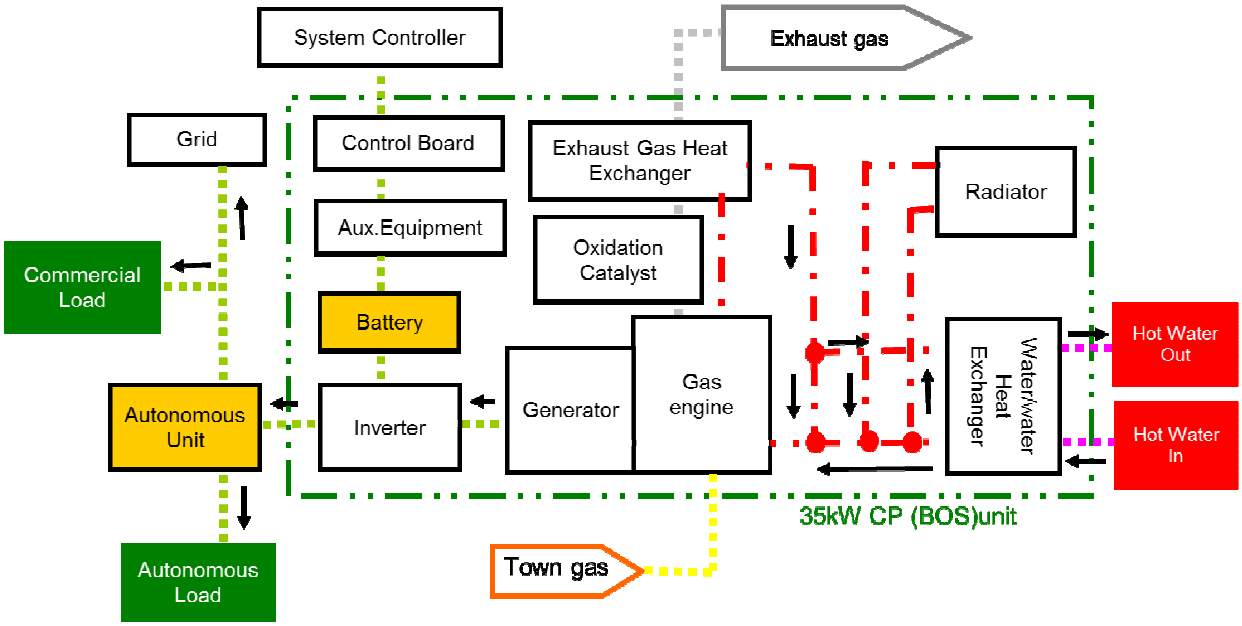


Figure 4 : 35kW CP (BOS) system flow

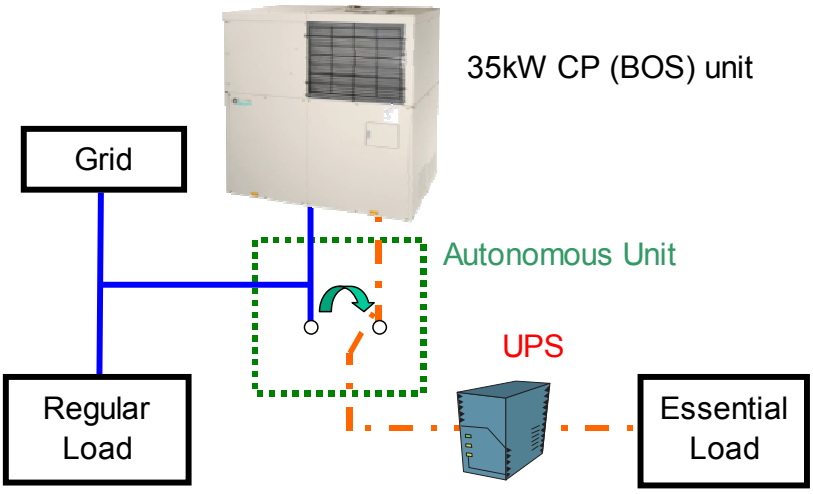
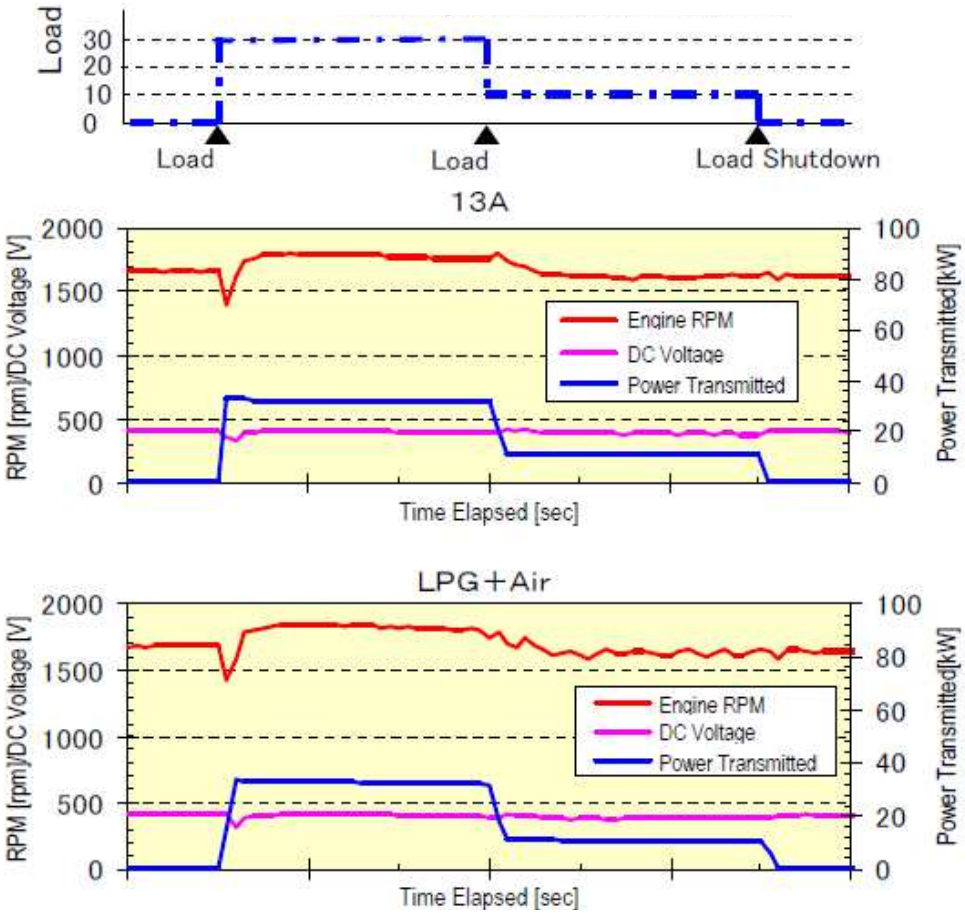


Figure 5 : UPS connected 35kW CP system flow



Load Input/Shutdown Patterns

Figure 6 : 13A and LPG-air loading and unloading test comparison

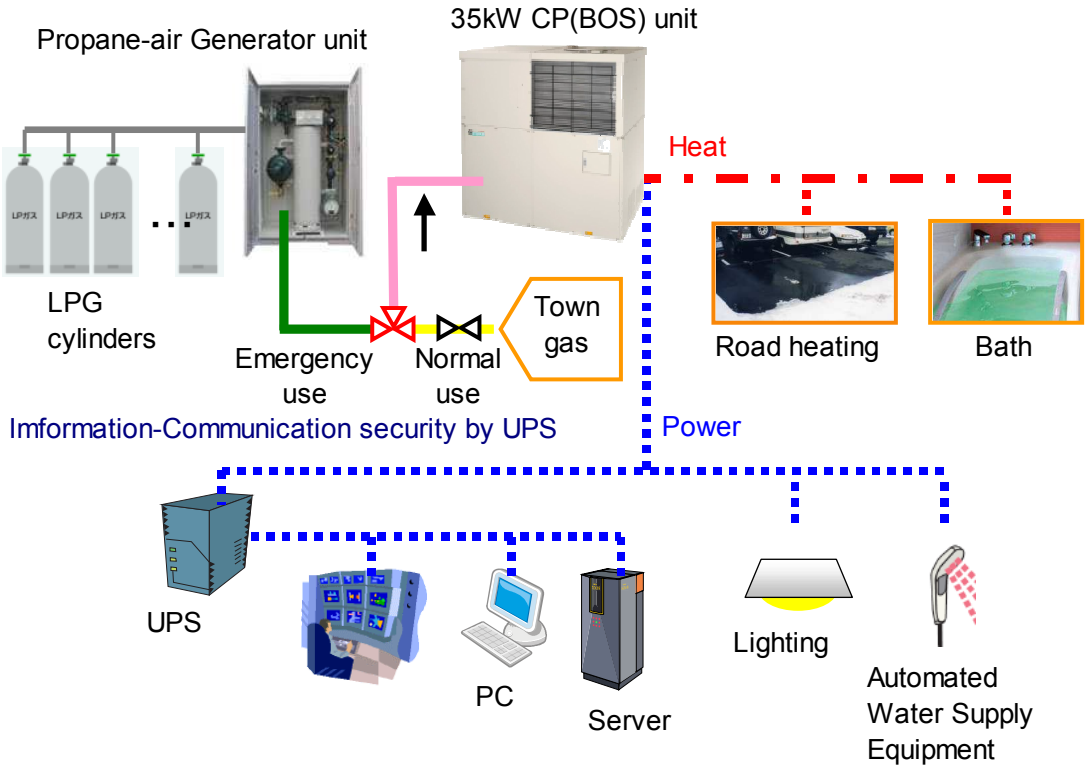


Figure 7 : System flow in the Hikone Gas Building

Figure 8 : External view of Hikone Gas Building