Development of Blackout start Gas Heat Pump air conditioner

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Abstract : A Gas engine driven Heat Pump air conditioner (GHP) is the air-conditioning system that drives the compressors by the gas engine. GHP is the high efficiency, low electric power consumption and low running cost air-conditioning system. It is widely spread mainly in Japan, where more than 600,000 units have been installed so far.

Since the Great East Japan Earthquake, the concern about power shortage has been increased. The need for GHP, which operates not only air-conditioning but also power supply in a blackout, has been growing.

We commercialized the GHP in 2012 which can supply power to lighting and plug in a blackout by mounting a generator and a starter battery.

In this paper, we introduce the blackout start GHP (BOS GHP). In addition, we introduce the system which makes a further contribution to energy security by using a LPG (Liquefied Petroleum Gas) air mixing unit if the power grid and the city gas supply are stopped due to major disaster.

Key Words: Gas Heat Pump, blackout start, generator, battery

1 INTRODUCTION

A Gas engine driven Heat Pump air conditioner (GHP) has the excellent sales performance more than 25 years in Japan due to the high evaluated advantages, such as power saving and the electric-load leveling. We commercialized the GHP equipped with a generator as a more effective power saving product than the conventional GHP. 'Power self-consumption GHP' generates 1kW of electric power using the excess capacity of the gas engine during cooling and heating operation, and this power is supplied to the cooling fan motor and cooling pump, reducing the external power consumed by the outdoor unit. 'Grid-interconnection GHP' equiped with 4kW generator supplies generated power out of an outdoor unit through a grid interconnection. Electric power is generated using the excess power of the gas engine during cooling and heating operation. The accumulated shipment of GHP in Japan is shown in Figure 1. More than 600,000 GHP units have been installed in Japan.

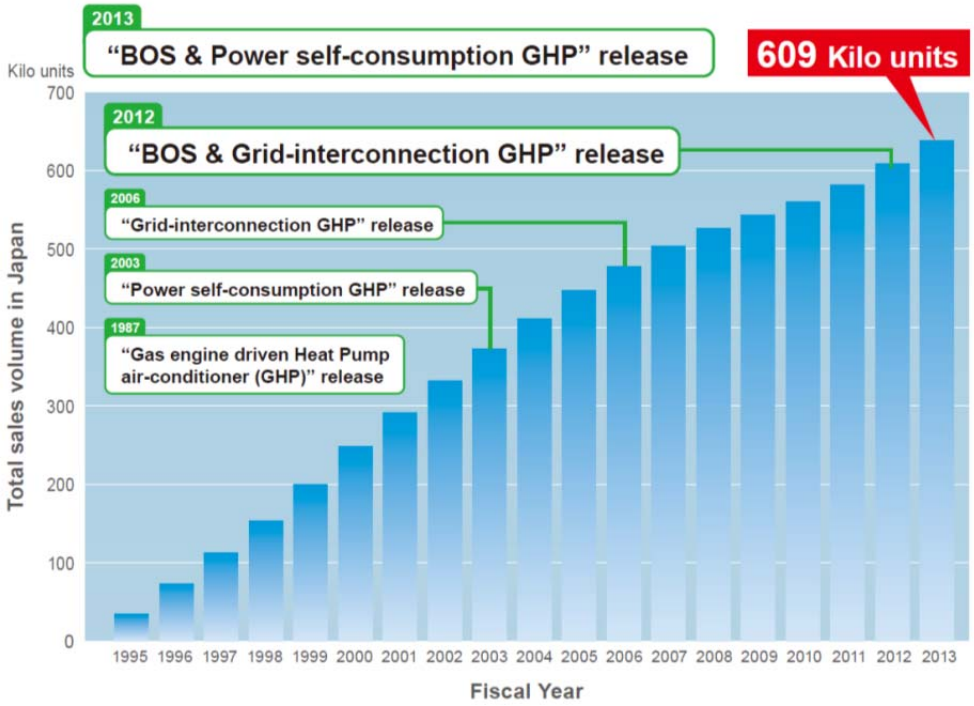

Figure 1: The acumulated shipment of GHP in Japan

After the Great East Japan Earthquake, the need for power-saving has been increased rapidly. Also custmer has requested us to make it possible to use air-conditioning and power usage, such as lighting or plug, even in a blackout.Therefore, we developed 'BOS & Grid-interconnection GHP (BOS-G GHP)' on the basis of the Grid-interconnection GHP which can supply power to lighting and plug in a blackout by a generator and a starter battery. This system was commercialized in April 2012. 'BOS & Power self-consumption GHP (BOS-P GHP)' on the basis of the Power self-consumption GHP was commercialized in April 2013.

Additionally, in Octorber 2013, we added the variation of the BOS GHP by improvement of function of BOS-G GHP, such as power-generating system by multiple units and renewal type. The power-generating system by multiple units can supply high power capacity in a blackout by the combination of a BOS-G GHP and Grid-interconnection GHPs. Furthermore, renewal type can reuse the excisting refrigerant pipe.

In this paper, we introduce the outline and the features of BOS GHP', and further cotribution of energy security system.

2 SYSTEM OUTLINE

Figure 2 shows the system configuration of the BOS GHP. This system consists of the BOS GHP, the power switching board, the autonomous operation switch and so on. The BOS GHP is possible to operate not only air-conditioning but also power supply in a blackout because of the equipment of the starting battery, the circuit which supplies the DC of the battery and the improvement of the control for power generationg and air-conditioning.

Of course regardless of whether air-conditioning is used, the power can be used for lighting and so on in a blackout. The power switching board is necessary in order to change from the commercial power to the generated power. The indoor units and lightings are necessarry to connect the secondary side of the power switching board. If the 'autonomous operation switch' is pushed in a blackout, the autonomous operation starts. Also autonomous operation switch can be installed in any places such as an office or a control room.

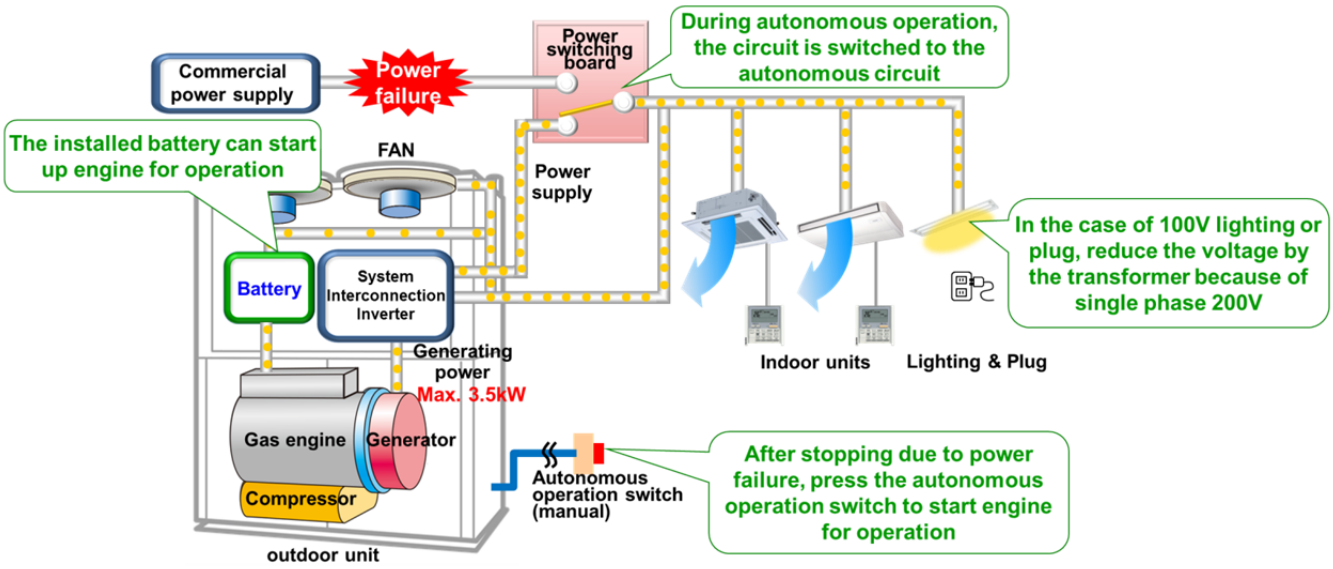

Figure 2: System image of 'BOS-G GHP'

3 SPECIFICATIONS

Table 1 shows specifications of BOS GHP. There are some cases of battery position depeding on the model. Some models installed a battery in the outdoor unit, the others installed a battery in a standalone box beside the outdoor unit.

BOS-G GHP can supply the building with up to 3kW by grid-interconnection for normal operation. Then BOS-G GHP has profound effect on power-saving and cutting peak power compared with BOS-P GHP. However, BOS-G GHP may be needed for dedicated board for grid-interconnection. The board is equipped with protection relays such as OVGR (over voltage groud relay) etc, for protecting power grid, outdoor unit and reverse power flow.

On the other hand, BOS-P GHP is not needed the dedicated board, because it supply only power the accessories such as fans in the outdoor unit for normal operation. BOS-P GHP supplies power the accessories such as fans in the outdoor unit for normal operation.

Table 1: Main specifications

Type		BOS & Grid-interconnection GHP (BOS-G GHP)	BOS & Power self-consumption GHP (BOS-P GHP)	
Grid-interconnection		Able	Unable	
Appearance (outdoor unit)				
Dimension H*W*D [mm]		2228×1800×1060	1660×2077×880 (battery box : 276×746×649)	2170×1890×800
Weight		920kg	785kg (battery box : 45kg)	1,010kg
Cooling capacity	Normal	56kW	56kW	56kW
	Blackout	56kW(※1)	45kW(※2)	45kW
Heating capacity	Normal	63kW	63kW	63kW
	Blackout	63kW(※1)	50kW(※2)	50kW
Generated power	Normal	Max. 3.95kW (supply building with grid interconnection)	Approx. 0.7kW (used in the outdoor unit)	Approx. 0.7kW (used in the outdoor unit)
	Blackout	3.5kW	4.5kW	3.0kW
Kind of connectable loads		Lighting(incandescent lamp, rapid-start fluorescent lamp, LED), TV, PC, cell-phone battery charger, and so on		
Connectable load capacity	Power supply only	2.5kVA	3.0kVA	2.1kVA
	Power supply and air-conditioning	1.2kVA ＋ indoor units	2.0kVA ＋ indoor units(※2)	1.1kVA + indoor units
Kind of Connectable indoor unit		ceiling mounted cassette ceiling suspended built-in cassette built-in duct	ceiling mounted cassette ceiling suspended	ceiling mounted cassette ceiling suspended

(※1) The air-conditioning capacity may becomes lower in order to give priority to the power generating.
(※2) The air-conditioning control is limited to all indoor units simultaneous work/stop.

4 OPERATION FLOW DURING BLACKOUT

In this section, we describe the operation of BOS-G GHP. (See Figure 3 ~ Figure 5)

4. 1 Normal operation (during interconnected)

When BOS-G GHP is in the interconnected grid, BOS-G GHP operates the engine and generates power. The generated power is supplied to the building. The engine performs start/stop with air-conditioning load. Also the power generation stops when the engine stops. And it resumes when the engine starts. It may be needed for dedicated board which is equipped with protection relays.
The air-conditinong is operated by the remote cotroller as well as the conventional air-conditioner. Also, the battery is automatically charged from a charging circuit.

4. 2 Start up in a blackout (during power failure)

BOS-G GHP starts up in a blackout, when a user pushes the autonomous operation switch. The battery supplies a control circuit and a starter with electric power by pushing the switch. After that, the engine starts to generate power. In response, the circuit in power switching board changes from the commercial power side to the autonomous circuit side. And BOS-G GHP starts power supply to indoor units and lightings and so on. At this time, it does not start air-conditioning immediately . After the power is supplied to the remote cotrollers of indoor units, the air-conditioning can be started by a user pushes the remote controllers. The start up of BOS-G GHP is manual-start in order to prevent unintended operation in a blackout. Also as above-mentioned, the autonomous operation switch can be installed in any places.

4. 3 Autonomous operation

The engine continues runinng regardless of air-conditioning load at autonomous operation in a blackout. And the power supply to lighting and so on is continued. When air-conditiong load is lost, it becomes operation of only power generation.

When the commercial power becomes restoration, BOS-G GHP detects power restoration and stops automatically. Stopping power generation is detected, and the power supply automatically change from the autonomous circuit side to the commercial power side. In this condition, the autonomous operation switch is returned (pushed again) and a remote controller of indoor units is turned on, the normal operation is started.

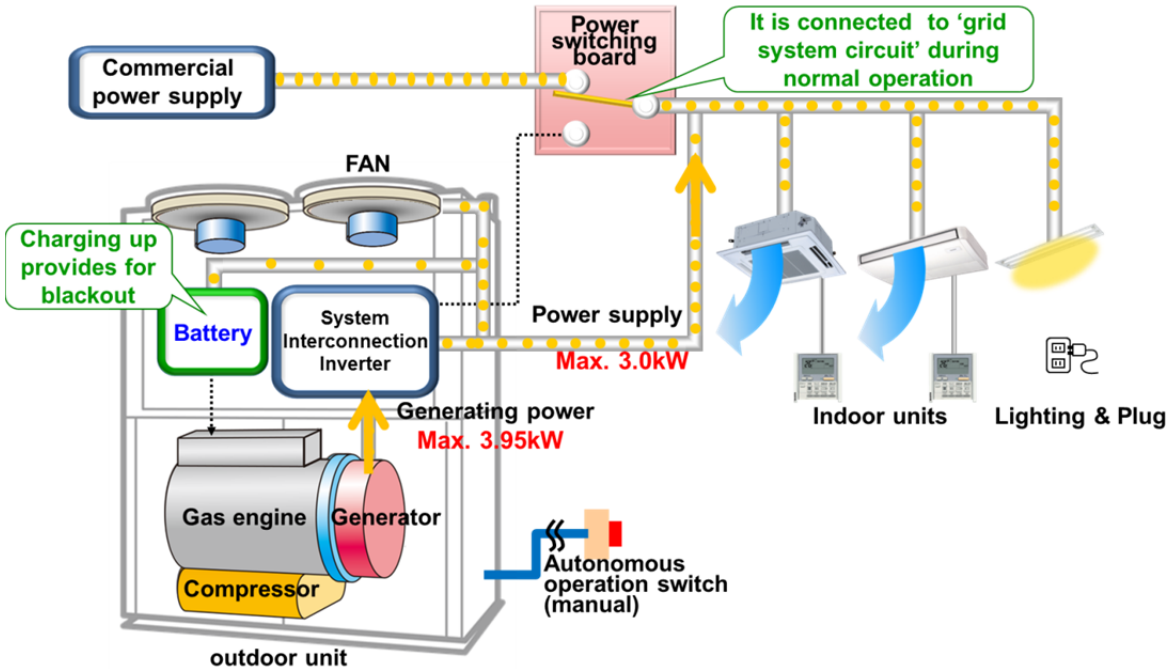

Figure 3: Outline of 'Normal operation'

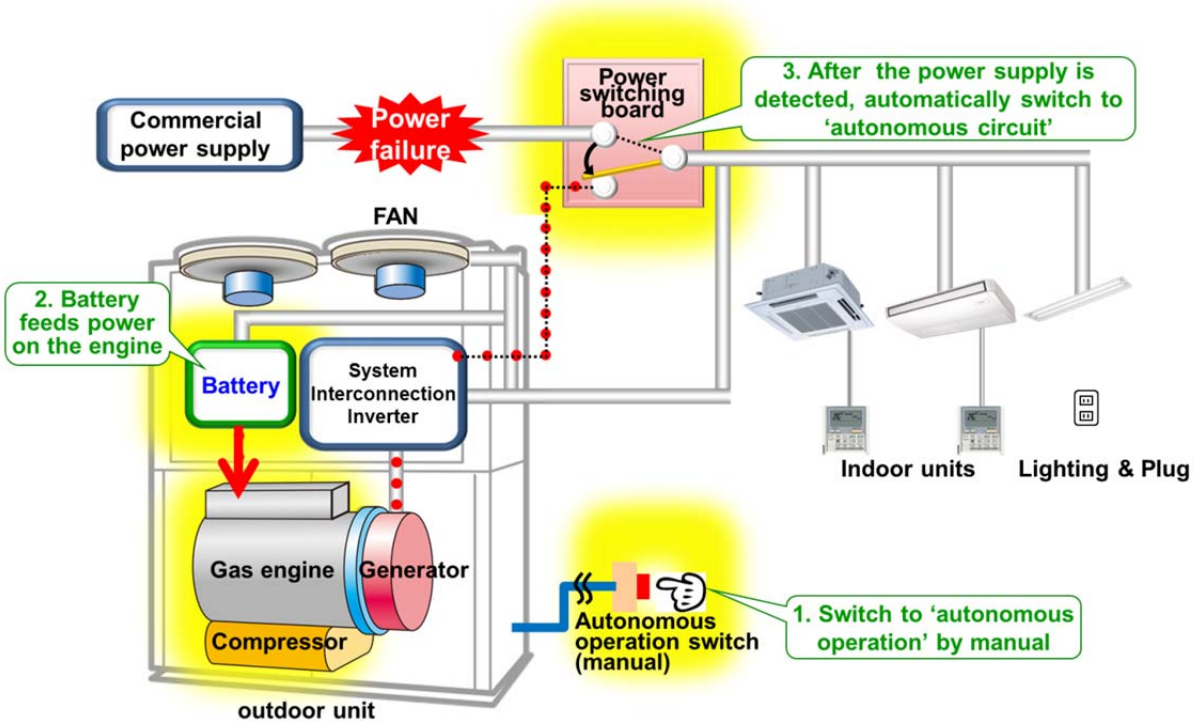

Figure 4: Outline of 'Start up in blackout'

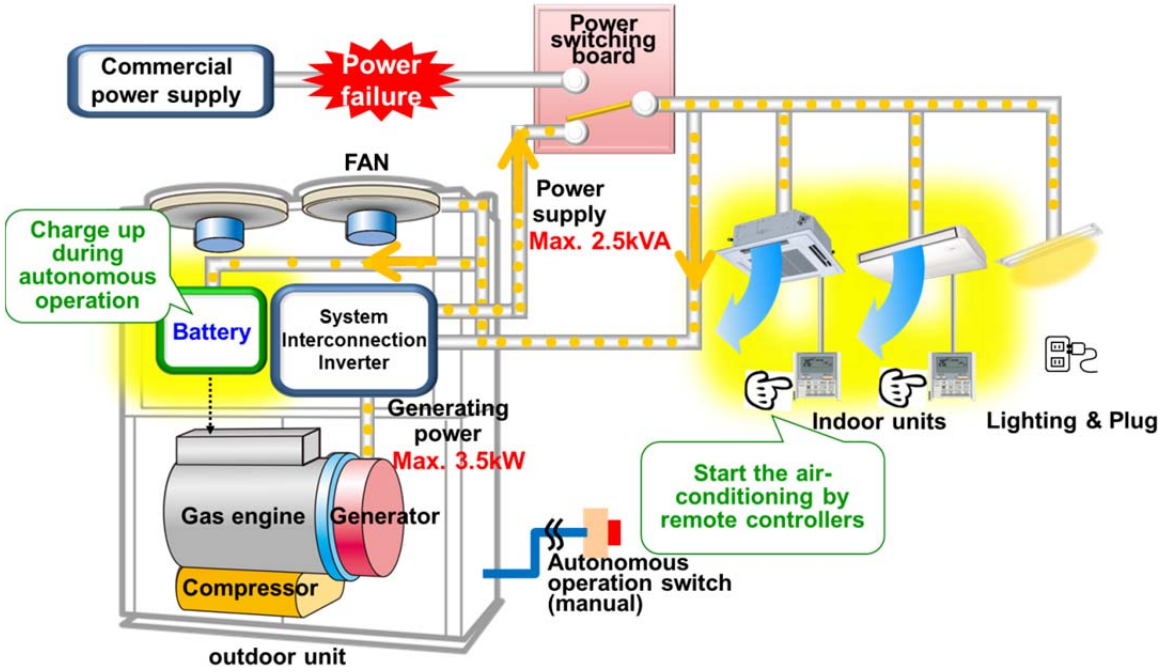

Figure 5: Outline of 'Autonomous operation'

5 DEVEROPMENT OUTLINE OF BOS GHP

BOS GHP is defferent from the conventional generator in a blackout. BOS GHP is necessary to have the only power generating mode and the air-conditioning and power generating mode. These modes are achived by means of following.

i) BOS GHP is equipped with the clutches for disconnect the compressors from the engine. The only power generating mode is accomplished with connecting the generator and the engine by the clutche.

ii) In the air-conditioning and power generating mode, BOS GHP is needed 2 things. FIrst is that the refrigerant circulating volume is controlled according to the air-conditioning load. Second is that GHP can run without the engine stall by overload when the power load rapidly increase.The control image of this autonomous operation shows Figure 6. The small or large compressor is used, the minimum engine rotation speed is higher than the normal operation case. Also, when the air-conditioning is operated, the power needs to supply not only the outdoor unit but also the indoor units. As previously described, this is accomplished with starting with only power generating mode, continuing with supplying the power to the indoor units.

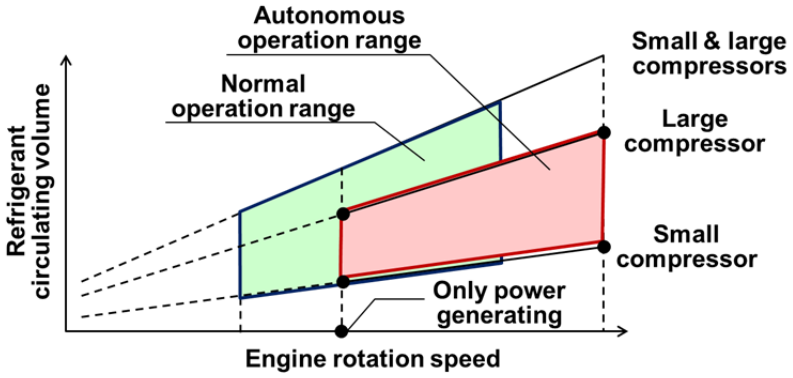

Figure 6 : Control image of 'Autonomous operation'

6 FUNCTIONAL ADVANCEMENT OF BOS-G GHP

Functional advancement of BOS-G GHP was released on October 2013 such as the power-generating system by multiple units and renewal type. The renewal type is suited for the case in which the air-conditioners are replaced. The excisting refrigerant pipe can be reused without cleanup by changing the strainer and adding pressure switch in the outdoor unit.

In this section, the power-generating system by multiple units is mainly described.

6.1 Sequence of Power-generating system by multiple units

The power-generating system by multiple units can supply Max. 10kVA in a blackout by the combination 'BOS-G GHP' and 'Grid-interconnection GHP's.

Figure 7 shows starting up sequence of this system.In a blackout, BOS-G GHP starts by the battery and supplies generated power to Grid-interconnection GHPs. Grid-interconnection GHP is started up by the power in turns.

6.2 Features of Power-generating system by multiple units

The followings are the features of this system.

i) Only one BOS-G GHP is needed in this sysytem, therefore, the cost of this system is lower than installing 4 BOS-G GHP units. Figure 8 shows installation cost and maintenance cost.

ii) It takes about one minute to start BOS-G GHP, and after that, three Grid-interconnection GHPs start in turns. Therefore It takes 4 or 5 minutes from pushing the autonomous operation switch to supplying power to indoor units or lightings and so on.

iii) If the BOS-G GHP cannot be worked by anything wrong, All Grid-interconnection GHPs cannot be worked, and the autonomous operation is stopped .If Grid-interconnection GHP cannot be worked by anything wrong, the units except the trouble unit can be worked.

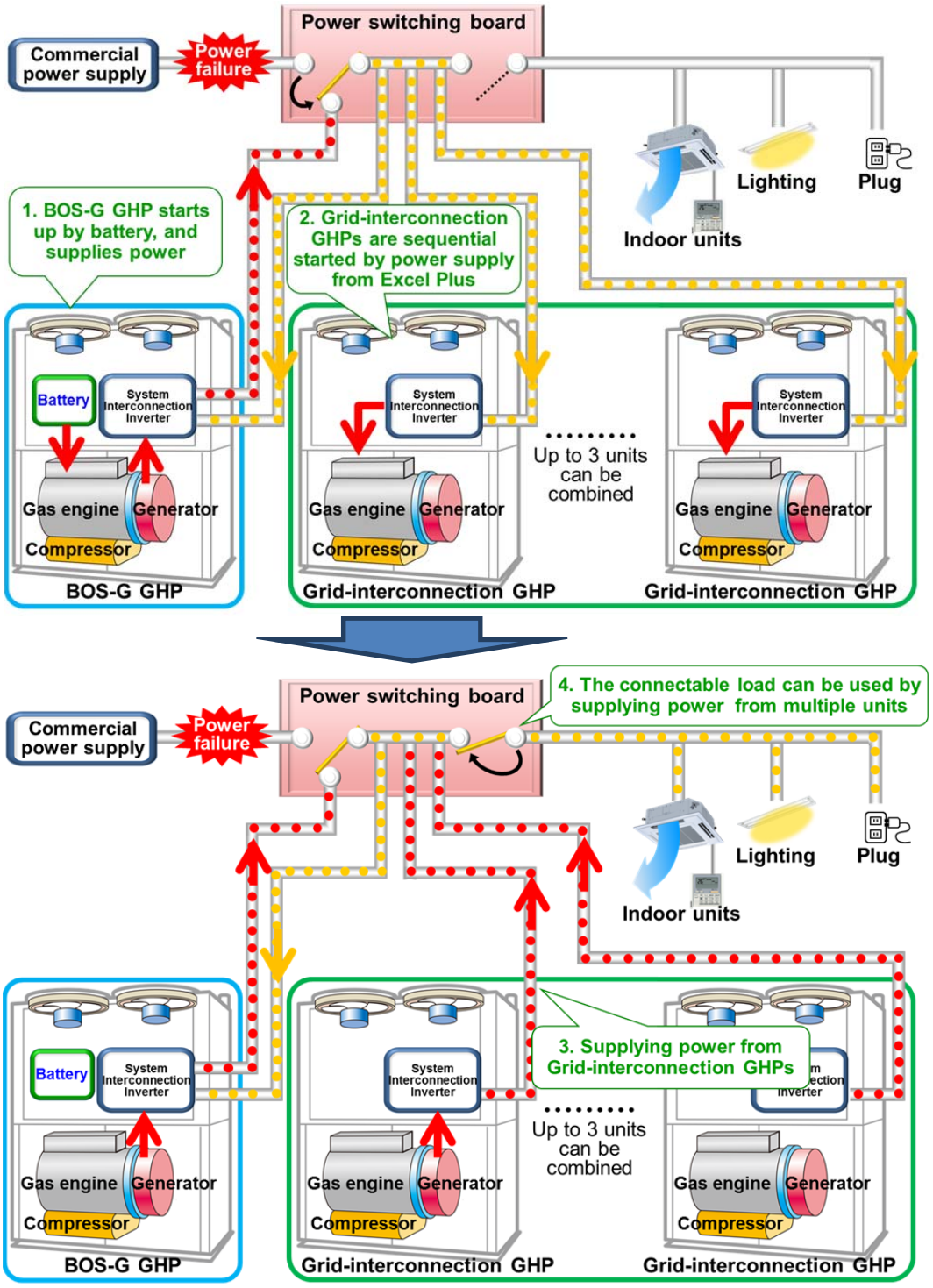

Figure 7: Outline of the power-generating system by multiple units

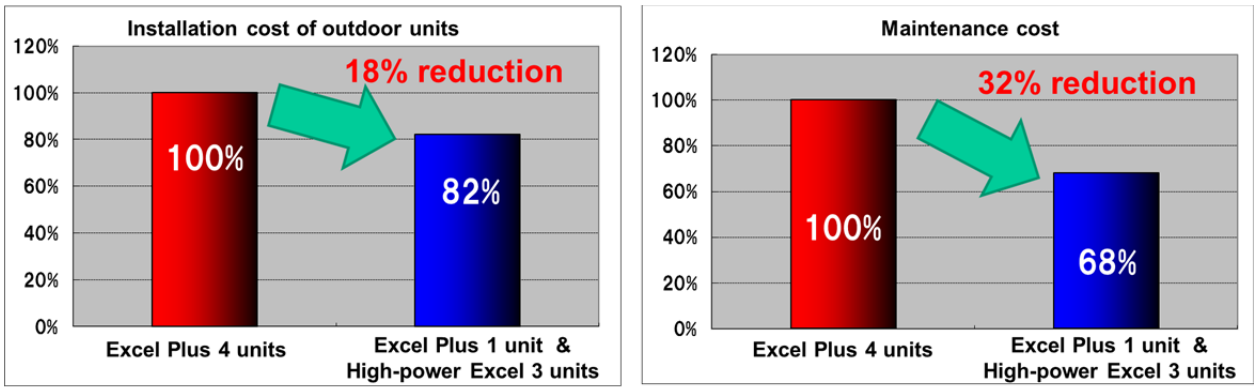

Figure 8: Installation and maintenance cost of the power-generating system by multiple units

7 FURTHER ADVANCEMENT TO ENERGY SECURITY

In this section, we introduce the system which makes further contribution to the advancement of energy security. The BOS GHP with LPG(Liquefied Petroleum Gas) air mixing unit can use in the disaster such as city gas and power outage. The system outline which connected LPG air mixing unit to BOS GHP is shown in Figure 9. When the city gas outage, This system can supply gas from LPG air mixing unit by operating a three-way valve manually. The LPG air mixing unit supply comparable city gas which is diluted the concentration of generating gas from LPG cylinders with air. Therefore, this system provides air-conditioning and power supply in disaster.

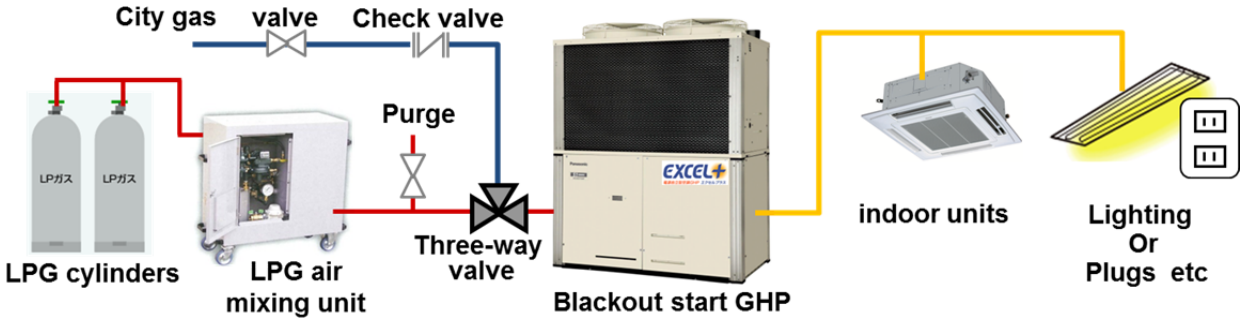

Figure 9: System image of LPG air mixing unit

8 CONCLUSION

In this paper, we introduced the blackout start GHP which has large effects for power saving and improvement of energy security. The blackout start GHP is accomplished with the stable operation by achieving balance between air-conditioning and power generating in a blackout. Also, we developed the power-generating system by multiple units that can supply maximum 10kVA in a blackout. In the future, we aspire for widespread of the blackout start GHP by means of followings.

i) The maintenance cost becomes lower by extension of battery life.
ii) The variation of blackout start GHP is expanded by development of the renewal type and 2 units combination type.

9 REFERENCES

Hiroshi Kanai. (Dec 2013). “Stand-alone power system type gas engine heat pump”, BE architectural equipment p.64-71

Takashi Murakami. (Dec 2012), “Stand-alone power system gas heat pump”, The society of Heating, Air-Conditioning and Sanitary Engineers of Japan: 86 p.1102-1105

Toshinari Sakai, Takashi Murakami, Satoshi Niigawa. (Oct 2011), “Spread of GHP and future development”, International Gas Union Research Conference2011 No.P3-06