DEVELOPMENT OF GHP FEATURING A GENERATOR CAPABLE OF SERVING EXTERNAL LOADS

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Keywords: 1. Heat Pump; 2. Air Conditioner; 3. Gas Engine; 4. Save Energy; 5. Gas utilization

1. Introduction

The gas heat pump (GHP) air conditioner is a gas air-conditioning system that drives the compressor of the outdoor machine with the gas engine, and does the air conditioning by the heat pump driving. The number of GHP installed is growing every year due to increased awareness of their advantages such as energy efficiency, small power consumption and low running cost.

The installed capacity of GHP air conditioners within the Osaka Gas service area reached approximately 4.11 million kW at the end of FY2008 (105% compared with the previous fiscal year).

In April 2003, we released the “High-power MULTI” GHP air conditioning system, which featured a small generator. Figure2 shows the structure of High-power MULTI. The generator generates 1 kW of electric power using the excess capacity of the gas engine during space cooling and heating operations, and this power is supplied to the cooling fan motor and cooling pump, reducing the external power consumed by the outdoor unit. In the case of 56kW type, the electric power consumed by this GHP air conditioning system is just 1/150 of that by an electric heat pump (EHP) air conditioner of the same class.

Figure1. Spread of GHP in the Osaka Gas service area

Figure2. System Outline of High-power MULTI

Figure3. Comparison with other 56kW type
We launched the sale of High Power MULTI with the variation of the type from 35.5kW to 56kW type in 2003. All GHP manufacturers are going to commercialize High Power MULTI in the FY2004, a variation is due to be expanded to 35.5kW – 85kW type. By the end of March 2009, some 12,700 of these GHP air conditioning systems had been installed within the Osaka Gas service area.

Furthermore, we were also tackling development of GHP with a power-generating function that enlarges power generation capacity of High Power MULTI, and supplies generated power out of an outdoor unit through a grid interconnection. This system named “High-Power EXCEL” was released in April 2006.

In this paper, we show the development and spread of GHP featuring a small generator. Finally a future prospect is described.

2. System Outline

Figure 4 shows the structure of our latest “High-power EXCEL” GHP air conditioning system. In this new system, the generator and the grid interconnection are additionally installed in conventional GHP. Its generator is driven with the same engine that drives the compressor. High-frequency AC power produced by the generator is converted into DC power by the converter, and its DC power is converted by the inverter in the same voltage and frequency as a grid power. The generated power and the grid power are connected by the grid interconnection by AC power.

High-power EXCEL combines the high air conditioning efficiency of conventional GHP with the capacity for simultaneously and efficiently generating about 4 kW of electric power. The generated electricity covers all electricity consumed by the outdoor unit, and also lowers the grid power consumed by indoor units, lighting and other loads inside the building because the generated electricity is fed into the building through a grid interconnection. As a result, the High-power EXCEL GHP air conditioning system achieves even higher energy efficiency and lower running cost than conventional GHP.

Figure 4. System Outline of High-power EXCEL

Figure 5. Appearance of High-power EXCEL
3. Major Specifications

The major specifications of the 56kW type are shown in Table 1. Although High Power EXCEL has the same dimensions and cooling capacity as conventional GHP, they differ in electric power and gas consumption. Since High Power MULTI generates 2.3kW electricity under rated conditions, the power consumption has been reduced to 0kW, and gas consumption has increased by 5.7 kW compared with the conventional GHP.

<table>
<thead>
<tr>
<th></th>
<th>Conventional GHP</th>
<th>High-Power EXCEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cooling Capacity kW</strong></td>
<td>56.0</td>
<td></td>
</tr>
<tr>
<td><strong>Heating Capacity kW</strong></td>
<td>63.0</td>
<td></td>
</tr>
<tr>
<td><strong>Power Source</strong></td>
<td>3-phase 200V</td>
<td>1-phase 200V</td>
</tr>
<tr>
<td><strong>Power Consumption (Cooling Rated)</strong></td>
<td>1.36</td>
<td>0.1.36’</td>
</tr>
<tr>
<td><strong>Power Consumption (Heating Rated)</strong></td>
<td>1.12</td>
<td>0.1.12’</td>
</tr>
<tr>
<td><strong>Gas Consumption (Cooling Rated)</strong></td>
<td>38.3</td>
<td>44.0 38.3’</td>
</tr>
<tr>
<td><strong>Gas Consumption (Heating Rated)</strong></td>
<td>43.0</td>
<td>48.7 43.0’</td>
</tr>
<tr>
<td><strong>Generator Capacity kW</strong></td>
<td>2.3 Max3.95’</td>
<td>Permanent magnet type</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td>1800 ~ 1000 ~ 2228</td>
<td></td>
</tr>
<tr>
<td><strong>Net Weight kg</strong></td>
<td>810</td>
<td>860</td>
</tr>
<tr>
<td><strong>Noise dB (A)</strong></td>
<td>56</td>
<td>58</td>
</tr>
</tbody>
</table>

Table 1. Specifications of the Conventional GHP and High-power EXCEL (56kW type)

(‘*’ mark indicates the data in the case where electricity is not generated.)

4. Features

(a) No electric power consumed for air conditioning

Equipped with a 4-kW generator and using the generated electricity for powering auxiliary mechanisms in the outdoor unit, the outdoor unit consumes no grid power during cooling and heating operations.

(b) Cutting the grid power consumption and lowering the contract demand by feeding generated electricity into the building

About 1 kW of the peak generation capacity of about 4 kW is consumed by the outdoor unit, but each outdoor unit can supply the balance of about 3 kW to loads inside the building. Feeding this electricity to indoor units, lighting and other loads inside the building, the customer can cut the grid power consumption and lower the contract demand.

Figure 6. Comparison of power consumptions between 56kW type

Figure 7. Visual presentation of how the contract demand is reduced
(c) Efficient electric power generation system using the excess capacity of the gas engine

Electric power is generated using the excess power of the gas engine during cooling and heating operations. As a result, the generation efficiency* during the rated cooling/heating operation is about 45% (in terms of low calorific value (LHV)), and during partially loaded operation is about 45–55% (LHV), surpassing the average demand-end generation efficiency of domestic fossil-fired power stations, which is approx. 40%.

* The power-generating efficiency of a generator installed in an outdoor unit is obtained by the following equation:

\[
\text{Generating efficiency} = \frac{\text{Generated output (kW)}}{\text{Gas consumption increased by power generation (kW)}}
\]

5. Technological Development

(a) Development of a high power engine

Since it was planned to generate electric power of 2–4 kW, the engine of the conventional model would have been insufficient to cope with the excess power, making it difficult to achieve lean-burn operation and increasing NOx emissions. The high power engine we developed allows lean-burn operation of the level achieved by the conventional model even under the higher load, attaining both low NOx emissions and highly efficient operation.

(b) Development of a highly efficient generator

The system features a bearing-less type of high-frequency generator. The 16-pole design and larger rotor diameter help maintain efficiency and output at low speed, and when directly coupled with the engine, the generator achieves sufficient output at low speed and sustained voltage at high speed. With a thickness of 100 mm or less, the generator can be contained in a housing no larger than conventional GHP. Moreover, additional grooves in the rotor (generator rotator) improve cooling. The rated generation efficiency is as high as 93% or more.

![Figure8. Newly Developed Elements](image)
(c) Development of generation control

In case two or more units are installed, the incoming electric power signal cable is led to the master unit alone, and the slave units recognize the incoming electric power level by means of inverter-to-inverter communication. This wiring scheme simplifies the wiring between the cubicle (lead-in point) to the outdoor units.

Depending on the number of units and power feeding style, protective relays may need to be installed external to the inverters. We therefore provide seven types of grid interconnection boards with built-in protective relays as options. The installation of a grid interconnection board with required protective relays enables a suitable configuration to be set up in view of the number of outdoor units and the power feeding style.

6. Benefits from the Development and Implementation

(a) Gas sales

Compared with a GHP air conditioner without a generator, High-power EXCEL consumes approximately 20% more gas, resulting in higher annual gas sales to the customer.

(b) Environmental benefits

$\text{CO}_2$ emissions are cut by approximately 27% compared with an EHP air conditioning system of the same class running on grid power.

(c) Running cost

Compared with a GHP air conditioner without a generator, the High-power EXCEL will cut the customer’s fuel cost by approximately 20% (lower running cost).

Assumed conditions:
- Floor area 5,000 $\text{m}^2$, air conditioning capacity 200HP, office
- Annual operation hours converted to full-load hours: 1,000 h (cooling 650 h + heating 350 h)
- $\text{CO}_2$ emission intensity from electricity: 0.69 kg-$\text{CO}_2$/kWh (average of fossil-fired generation)
- $\text{CO}_2$ emission intensity from gas: 2.288 kg-$\text{CO}_2$/m$^3$ (city gas type 13A)

7. Future Prospects

Since High Power EXCEL has been put on the market in April 2006, the total installation number of the end of the FY2008 is 2019 units in only 3 years. During the FY2008, a variation will be also expanded 45kW to 71kW type.

Moreover, when the engine torque for power generation is added to engine in addition to torque for air-conditioning, the engine load increases and the amount of engine waste heat also increases. We will work in the development of the GHP that may be able to use the waste heat effectively and the improvement of more highly efficient GHP in the near future.