Development of the intelligent remote monitoring system for GHP

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Abstract: Gas engine driven heat pump (GHP) is the heat pump air-conditioning system which drives 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 150,000 units have been installed so far. Recently social needs for energy saving and visualization of energy consumption for air-conditioning become greater and greater. We developed the intelligent remote monitoring system for GHP which can operate GHPs at lower energy consumption remotely in order to meets these social needs. It has various functions to reduce energy consumption including “Energy-Saving Operation”,” Scheduling Management”, ”Daily Reporting”, and so on. We tested this intelligent remote monitoring system at various buildings in Japan. As a result, it was proven that it can reduce the energy consumption of GHPs by an average of about 20% a year. In this paper we reported the the system structure and features of the intelligent remote monitoring system for GHP and test result of its effect of energy saving.

Key Words: GHP, remote monitoring, energy saving

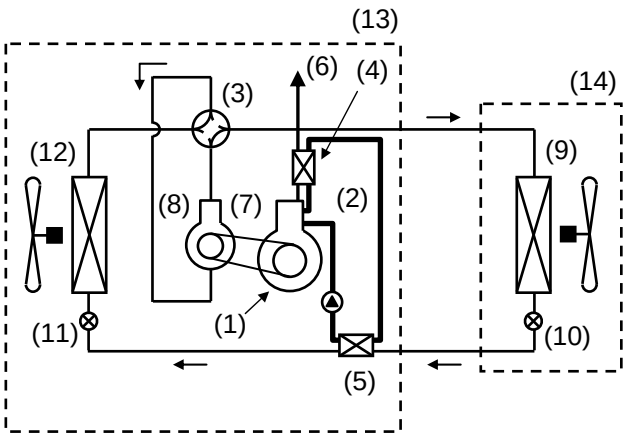
1 INTRODUCTION

1.1 The mechanism of GHP

Gas engine driven heat pump (GHP) is the heat pump air-conditioning system which drives compressors by the gas engine. Figure 1 shows the outward appearance of the typical GHPs and Figure 2 shows schematic of refrigerant and cooling water flow diagram of a typical GHP. Its refrigerant cycle is almost the same as that of the Electric heat pump (EHP). The biggest difference is that the EHP operates an electric motor to drive a compressor, while the GHP operates a gas engine instead of the motor. So the GHP consumes only one-tenth electricity of the EHP. In addition, the GHP has higher performance than that of the EHP in heating mode because it can utilize not only aerothermal heat from ambient air but also waste heat from gas engine at water-refrigerant heat exchanger.



Figure 1 Outward appearance of the typical GHPs



(1)Engine, (2)Cooling water line, (3)Four-way valve, (4)Exhaust gas heat exchanger, (5)Water-refrigerant heat exchanger, (6)Exhaust gas line, (7)Transmission, (8)Compressor, (9)Indoor unit heat exchanger, (10)indoor unit expansion valve, (11)Outdoor unit expansion valve, (12)Outdoor unit heat exchanger, (13)Outdoor unit, (14)Indoor unit

Figure 2 Schematics of refrigerant and cooling water flow diagram of a typical GHP (Heating mode)

1.2 Development background

Since release of the GHP in 1985, we have been improving performance of the GHP year after year. We have developed high efficiency gas engines, compressors, heat exchangers, and so on to improve its efficiency. The latest GHP series called “GHP XAIR” released in 2011 has top class APF (Annual performance factor) among big capacity VRF (Variable refrigerant flow) air-conditioners including the electric heat pump （EHP）.

On the other hand, VRF air-conditioners including the GHP are generally not optimized for different usages enough because it is difficult to operate optimally the outdoor-unit which has multiple indoor-units used in different conditions. Recently social needs for energy saving and visualization of energy consumption for air-conditioning become greater and greater. We developed the new intelligent remote monitoring system for the GHP which can optimize operation of GHPs to much various usages and reduce energy consumption remotely in order to meets these social needs.

Figure 3 shows the conventional and the new remote monitoring system for the GHP. The conventional system is consisted of GHPs, the adopter which have wireless communication function, the remote monitoring center of gas companies, and so on. For example, it was able to send information to the monitoring center when GHPs break down automatically and to provide simple remote control. So it had been mainly used to find failures of devices, inform failures to maintenance companies, and repair speedily. However the new intelligent system has almost the same constitution as that of the conventional system, we added various functions to reduce energy consumption including “Energy-Saving Operation”, ”Scheduling Management”, ”Daily Reporting”, and so on to the new adopter. These enable customers to set schedule, set energy-saving, get daily reports on the internet. Furthermore, the new adopter is able to predict failures of some parts and inform before the occurrence of failure.

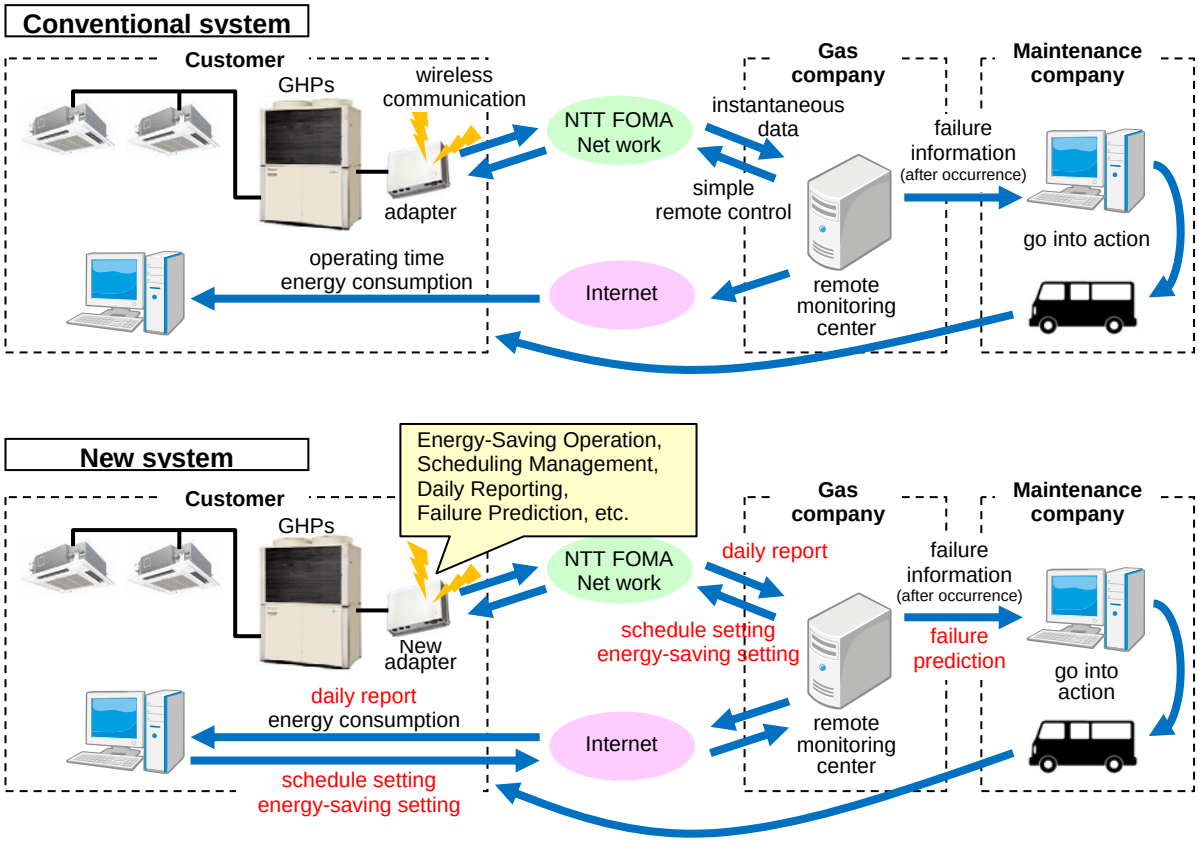


Figure 3 Outline of the conventional and the new remote monitoring system for the GHP

2 DEVELOPMENT ITEMS

2.1 New adopter

Figure 4 shows appearance of the new adopter. In the new system, a large data handling capacity and a large data saving capacity are required to provide the intelligent control. We improved the data processor and the data storage device of the new adopter in comparison with that of the conventional adopter.



Figure 4 Appearance and internal structure of the new adopter

2.2 New functions

Table 1 shows new major functions which we developed.

Table 1: New major functions

No	Name	Outline
1	Energy-Saving Operation	It reduces energy consumption by optimizing operation depending on the usage and the installation conditions of a GHP.
2	Scheduling Management	It schedules start-stop, set back the temperature settings, turn off GHPs when users forget to turn off them, and so on.
3	Daily Reporting	It provides operating condition and energy consumption data on a day-to-day basis.
4	Failure Prediction	It predicts failures of some parts and informs before the occurrence of failure.

2.2.1 Energy-Saving Operation

"Energy-Saving Operation" enhances operational efficiency of GHPs by optimizing engine speed and temperature of supply air for usage environment. For example, in cooling mode, it slows down engine speed of GHPs when indoor temperature is in comfortable range to reduce energy consumption.

Figure 5 shows image of indoor temperature transition under Energy-Saving Operation. Energy-Saving Operation has three energy saving levels. The higher the Energy -Saving level, the larger reduction of gas consumption becomes. When indoor temperature is high, the level is zero or low. Then, with drop of indoor temperature, the level gradually gets higher. If indoor temperature rises and exceeds the predetermined rage, the level is lowered step by step to maintain amenity. It is possible to change the range in which each level operates. In Figure 5, level 3 operates when indoor temperature is lower than 27 degree, level 2 operates when indoor temperature is 27 to 28 degree, level 1 operates when indoor temperature is 28 to 29 degree, and Energy-Saving Operation is canceled when indoor temperature is higher than 29 degree.

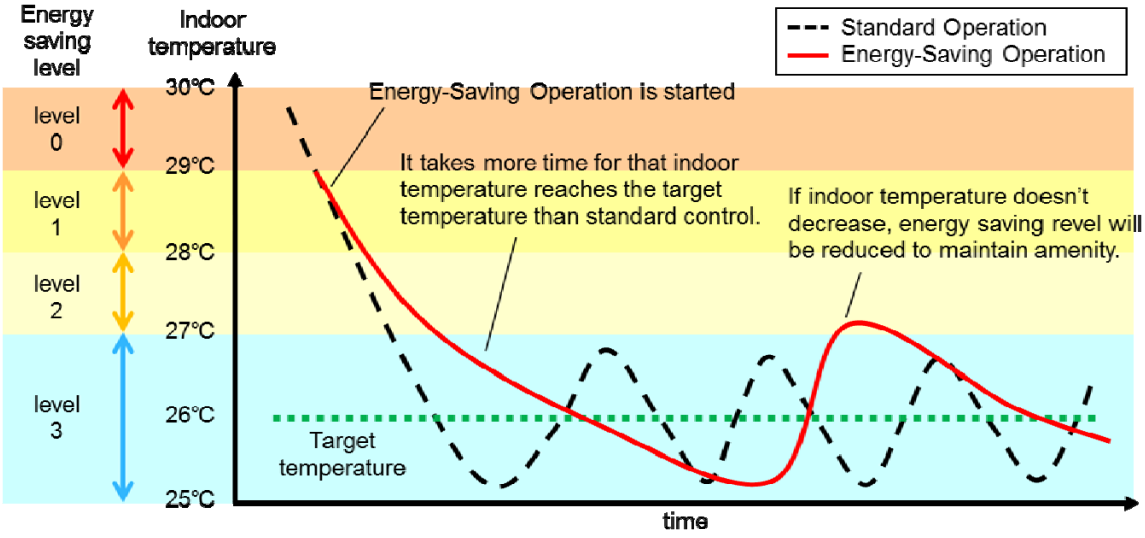


Figure 5 Image of indoor temperature transition under Energy-Saving Operation

It is also possible to thin out the GHP which is operating at low load and low efficiency if several GHPs are installed in one large room space. It is called thinning operation. Figure 6 shows image of this thinning operation. In the case of standard operation, all GHPs are operating at low load. In general, efficiency of air conditioners containing GHP drops when these operate at lower than about 50% load. On the other hand, in the case of thinning operation, low load and low efficiency operation is avoided by stopping one unit. During thinning operation, the adopter increases and decreases number of GHPs to stop according with indoor temperature to maintain amenity.

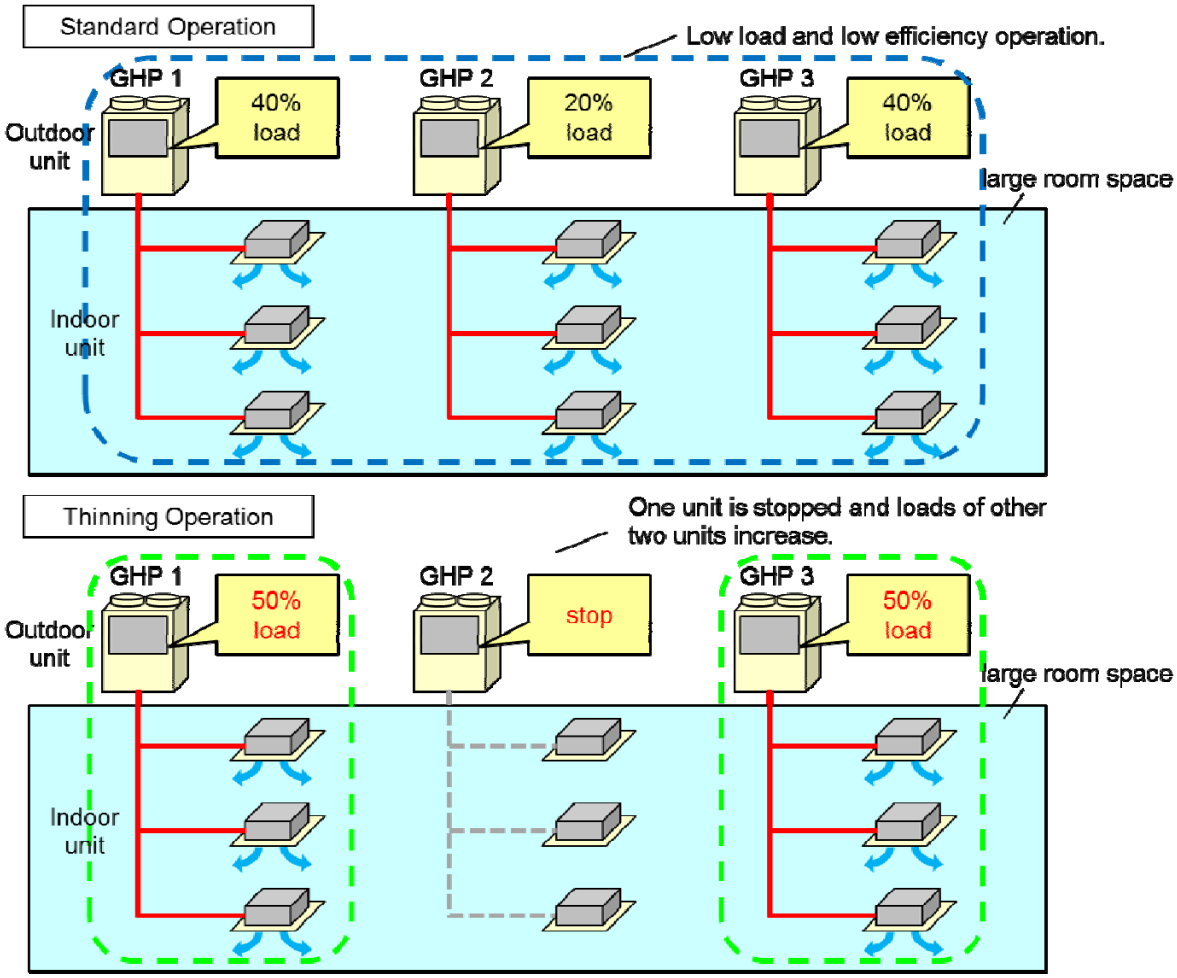


Figure 6 Outline of thinning operation

2.2.2 Scheduling Management

It is possible to schedule start-stop, operation mode (Cooling or Heating), temperature setting, air volume, and so on via the Internet. Additionally, it can automatically set back the temperature settings when these are changed by users and turn off GHPs when users forget to turn off them. It decreases waste of energy even if GHPs are used wasteful manner by various users.

Figure 7 shows image of setting temperature transition under schedule management. In the case of Standard Operation, low setting temperature continues and indoor units continue to operate if users forget to turn off. On the other hand, in the case of Schedule Management, setting temperature is returned at every fixed time if users lowered setting temperature than

target temperature. In addition, Indoor units are automatically turned off at every fixed time if these are used outside of predetermined operation hours.

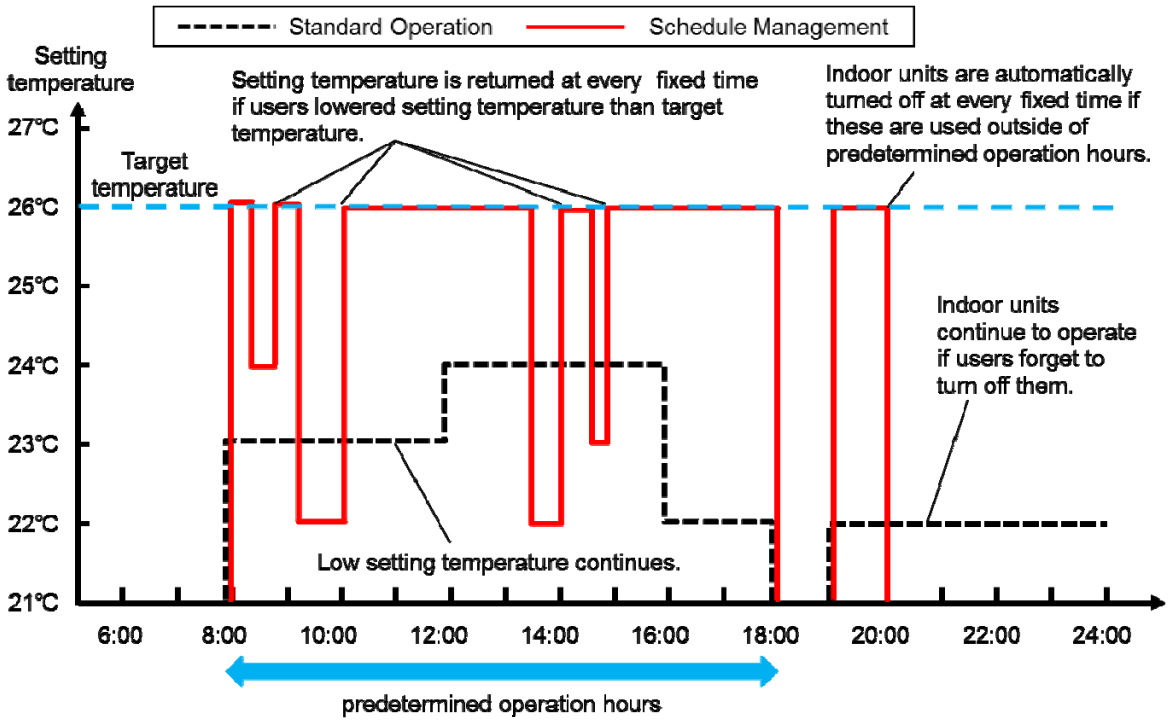


Figure 7 Image of setting temperature transition under Schedule Management

2.2.3 Daily Reporting

"Daily Reporting" is the function that provides operating condition and energy consumption data on a day-to-day basis through the Internet. Data preservation interval can be changed 15 to 60 minutes. The adaptor processes various data at predetermined time interval and sends day-to-day basis data to the remote monitoring center once a day. It can help facility managers to find useless operations and make operations more efficient. See Table 2 for examples of data available in Daily Reporting.

Table 2: Major data available in Daily Reporting

No	Data type	Items
1	Operation data of outdoor units	Operation time, Engine speed, Refrigerant pressure, Refrigerant temperature, Cooling water temperature, Energy-Saving level
2	Operation data of indoor units	Operation time, Setting temperature, Suction air temperature, Status of schedule management
3	Energy data	Power consumption, Gas consumption

2.2.4 Failure Prediction

The adopter monitors outdoor units and indoor units appropriately and predicts failures of some parts. If it detects a sign of trouble, it sends that information to the remote monitoring

center automatically. Trouble stops can be avoided by carrying out preventive maintenance such as the part exchange based on foresight information that the center received. It can predict failures of the engine starter motor, the refrigerant system sensors, and so on.

3 MONITOR TEST

We tested this new intelligent monitoring system at various buildings in Japan. In this paper, we report the result measured at a certain office building (office A) as an example.

3.1 TESTING SITE

Figure 8 shows pictures of office A. It is on the second floor of the 4-story building in Tokyo. One 16HP GHP and one 20HP GHP installed for that floor. The area of the floor is 400 m^2.



Figure 8 Pictures of office A

3.2 TESTING METHOD

We tested the operations shown in the table 3. We repeated a day to use these operations (Energy-Saving Operation day) and a day not to do (Standard Operation day). Then we compared the gas consumption of both to confirm the energy saving effect of these operations. We also compared the indoor amenity by Predicted Mean Vote (PMV) which is an index to evaluate comfort.

The operation data of GHPs was collected by Daily Reporting function. The data of outdoor temperature, indoor temperature, indoor humidity and gas consumption were measured and collected by sensors and data loggers installed in the site.

The test was carried out from July, 2012 to February, 2013.

Table 3: Operations used in this study

No	Name	Outline
1	Energy-Saving Operation	✓ To optimize engine speed of GHPs
2	Scheduling Management	✓ To schedule start-stop ✓ To set back the temperature settings (Cooling mode : 26 degree / Heating mode : 22 degree) ✓ To turn off GHPs when users forget to turn off them

3.3 TEST RESULT

The test result shown in Figure 9 and 10. In Figure 9, the horizontal axis shows the average outdoor temperature a day, and the vertical axis shows the gas consumption per day. In comparison with the gas consumption of Standard Operation day based on linear approximation, the gas consumption of Energy-Saving Operation day downed about 30% in cooling mode, downed about 10% in heating mode and downed about 20% in a year.

In Figure 10, the horizontal axis shows the average outdoor temperature a day, and the vertical axis shows the average PMV a day. The PMV of Energy-Saving Operation day was kept in comfortable range, so it was proved that this Energy-Saving Operation can reduce energy consumption without spoiling comfort.

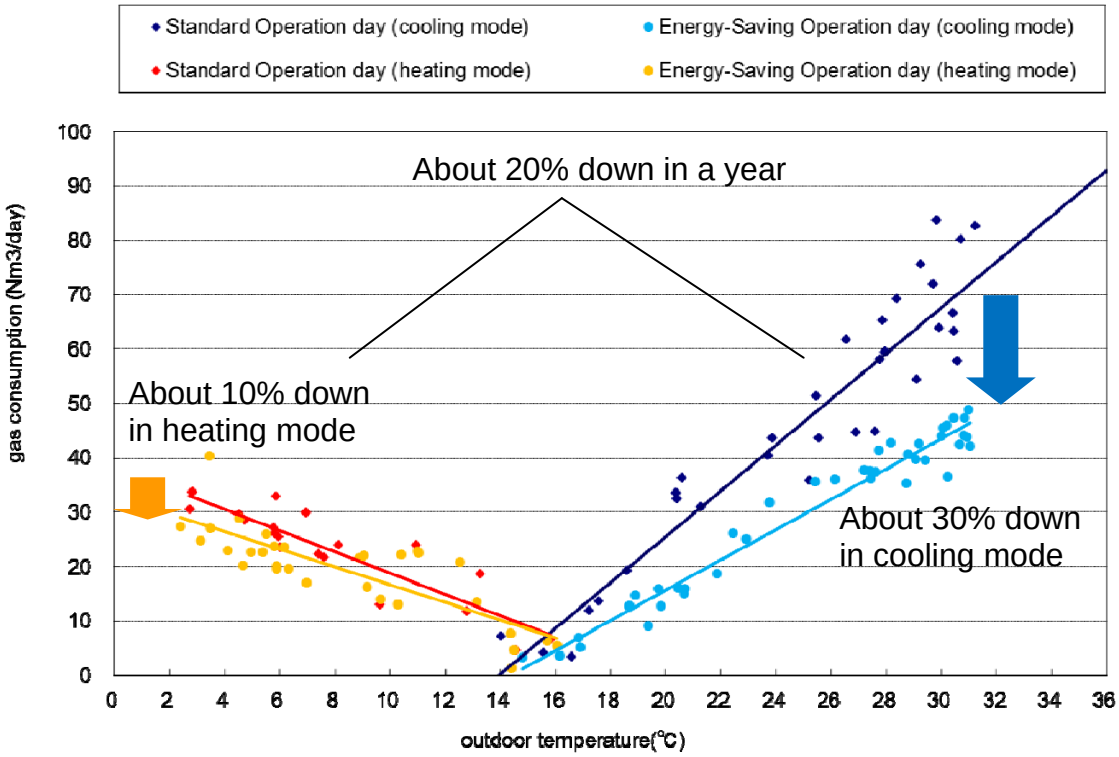


Figure 9 Gas consumption data of Standard Operation day and Energy-Saving day

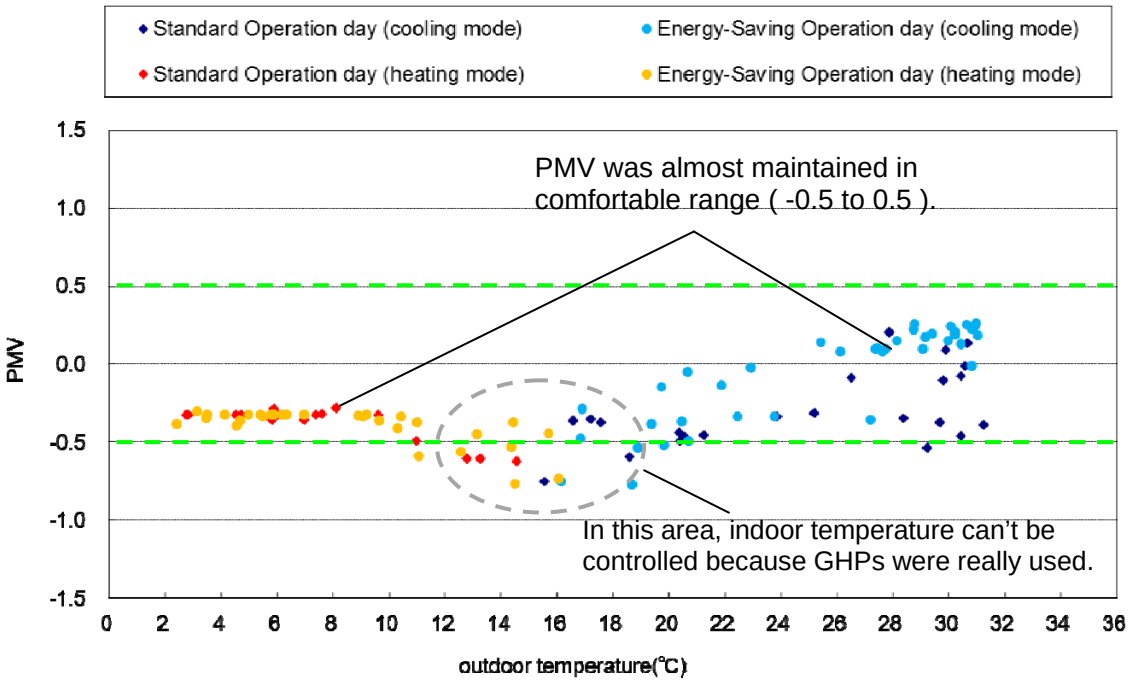


Figure 10 PMV data of Standard Operation day and Energy-Saving day

4 CONCLUSION

We developed the new intelligent remote monitoring system for GHP. It has four new major functions described below:

- Energy-Saving Operation: It reduces energy consumption by optimizing operation depending on the usage and the installation conditions of a GHP.
- Scheduling Management: It schedules start-stop, sets back the temperature settings, turns off GHPs when users forget to turn off them, and so on.
- Daily Reporting: It provides operating condition and energy consumption data on a day-to-day basis.
- Failure Prediction: It predicts failures of some parts and informs before the occurrence of failure.

Then we tested this new system at various buildings in Japan. In this paper, we described the result measured at office A in Tokyo as an example. As a result, the following things were proven:

- It can reduce the energy consumption of GHPs by an average of about 20% a year.
- It can reduce the energy consumption without spoiling comfort.

5 REFERENCE

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