Performance of the Variable Refrigerant Volume Air-Conditioning System with Heat Recovery

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ABSTRACT

Different rooms in the same building have disparate heat/cool load because of diverse orientation and different indoor heat sources. Some rooms need to be cooled while the others need to be heated.

Conventional multi-system air-conditioners are limited to cool all of the indoor units or heat all of them. The common multi-system air-conditioners can not satisfy all of the users.

A multiple variable refrigerant volume (VRV) air conditioning system with heat recovery has been developed in this paper. A suitable operating mode can be selected for each indoor unit independently in this system, hence, concurrent heating and cooing is possible.

This paper describes the configuration, basic operating methods, and experimental results indicated a maximum one times higher coefficient of performance (COP) in the current heating and cooling mode compared to single-mode operations.

INTRODUCTION

With the development of national economy and the improvement of living standard, the requirement of air conditioner increases very quickly to make a comfortable environment for living and working. Some multi-system air conditioners have been developed to satisfy the need of several rooms (M.Masuda 1991, Gu Bo 1995). However, their operation is limited to a single mode--heating or cooling--at one time. The energy problem is urgent so that the performance of air conditioners must be improved. Thus, variable frequency compressor and EEV (Electronic Expansion Valve) are widely used (T.Q. Quieshi 1996, Shi Wenxing 2000). And some new Multi air conditioning systems were developed (Shi Wenxing 2000, Shao Shuangquan, 2001).

With the development of air conditioning technology, air conditioner is developed from the viewpoint of decreasing the energy consumption and increasing the human comfort. In modern buildings, some rooms need to be cooled, but some other rooms need to be heated simultaneously, even some rooms need not to be cooled or be heated, so the indoor units may be act as evaporators or condensers or be closed at the same time. Traditional air-conditioning system can only satisfy all the room to be cooled or be heated at the same time.

A new multiple VRF air conditioning with heat recovery has been developed in this paper. This system consists of several indoor units and one outdoor unit. Its capacity responds to the load of each room by using an inverter-aided compressor and electronic expansion valves that can automatically control the refrigerant flow for each indoor unit. The indoor unit in the heating room acts as condenser and the indoor unit in the cooling room acts as evaporator while the outdoor unit may act as evaporator or condenser.

Because both the condensing heat and evaporating heat are valuable in use, while in the traditional systems only the condensing heat or evaporating heat can be used, the energy efficiency ratio of this system is increased greatly and the capacity and energy consumption of outdoor unit is decreased remarkably. A typical system with two indoor units is analyzed based on the thermodynamics theory and computer simulation. Compared with the traditional air conditioning system, this system which provides higher human comfort with lower energy consumption can be used in the residential buildings or commercial buildings and can run in the heat pump mode, refrigeration mode or heat recovery mode throughout the year.

CONFIGURATION AND OPERATING MODES

The new multiple VRF air conditioning system consists of one outdoor unit and two indoor units. The configuration and the basic refrigerant circuit of this system are illustrated in Figure 1.

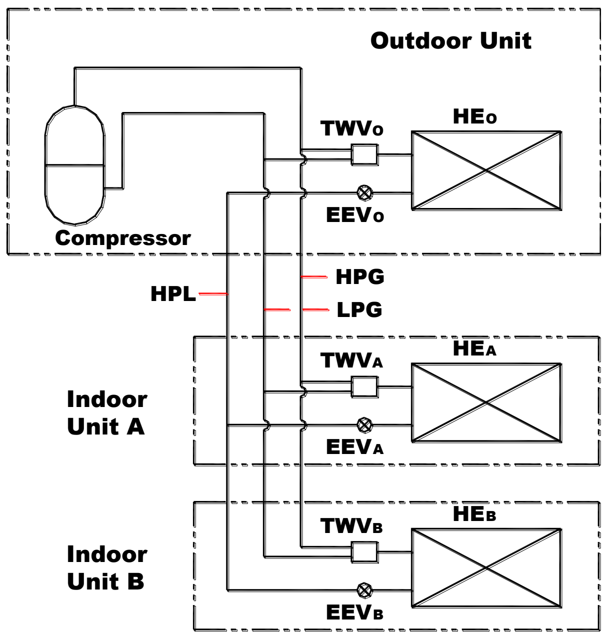

Figure 1 Configuration of the VRF system

This System has five different modes, as follows:

1. Cooling-only mode: All working indoor units are in the cooling operation;

2. Heating-only mode: All working indoor units are in the heating operation;

3. Cooling-principal mode: Cooling is the principal mode in the concurrent heating and cooling operation;

4. Heating-principal mode: Heating is the principal mode in the concurrent heating and cooling operation;

5. Heat recovery mode: heat balance between two indoor units and the outdoor heat exchanger does not work.

This VRF system has five operating modes, cooling-only, heating–only, cooling-principal, heating-principal, and heat recovery. Each operating mode is discussed below.

Cooling-Only Mode

In this mode, the indoor units (for example, A and B) are in cooling operation, as shown in Figure 2. The gas refrigerant discharged from the compressor flows into the outdoor heat exchanger through connecting pipe HPG and is condensed there. The liquefied refrigerant flows into the indoor units through connecting pipe HPL and is depressurized by the indoor EEVs. The depressurized refrigerant is evaporated in the indoor heat exchangers and returns to the compressor through connecting pipe LPG. Thus, the indoor heat exchangers work as evaporators, and the outdoor heat exchanger works as a condenser.

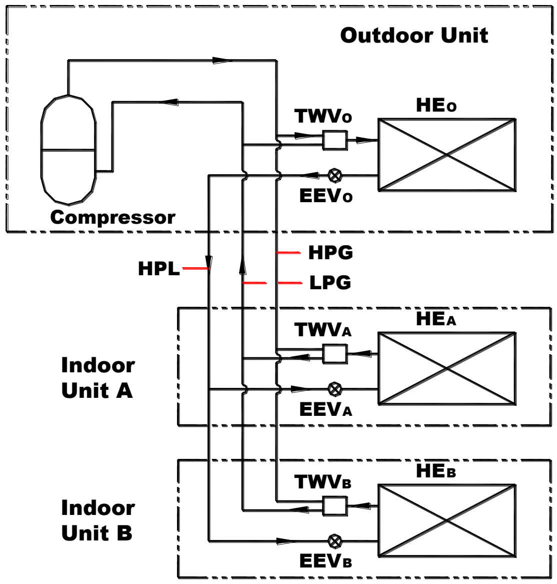

Figure 2 Cooling-Only mode

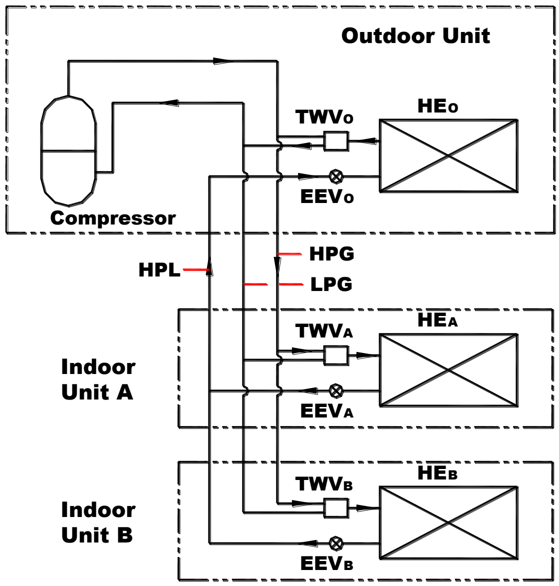

Figure 3 Heating-Only mode

Heating-Only Mode

In this mode, the indoor units (for example, A and B) are in heating operation, as shown in Figure 3. The gas refrigerant discharged from the compressor flows into the indoor heat exchangers through connecting pipe HPG and is condensed there. The liquefied refrigerant from each indoor heat exchanger flows into the outdoor unit through connecting pipe HPL and is depressurized by the outdoor EEV. The depressurized refrigerant is evaporated in the outdoor heat exchanger and returns to the compressor through connecting pipe LPG. Thus, the indoor heat-exchangers work as condensers, and the outdoor heat exchanger works as a evaporator.

Cooling-Principal Mode

In this mode, for example, indoor unit B is in cooling operation and indoor unit A is in heating operation. As shown in Figure 4, the gas refrigerant discharged from the compressor flows into the outdoor heat exchanger and the indoor heat exchanger A through connecting pipe HPG and is condensed there. The liquefied refrigerant from the outdoor heat exchanger and the indoor heat exchanger A flows into the indoor unit through connecting pipe HPL and is depressurized by the indoor EEVB. The depressurized refrigerant is evaporated in the indoor heat exchanger B and returns to the compressor through connecting pipe LPG. Thus, the outdoor heat exchanger and the indoor heat exchanger A work as condensers, and the indoor heat exchanger B works as a evaporator.

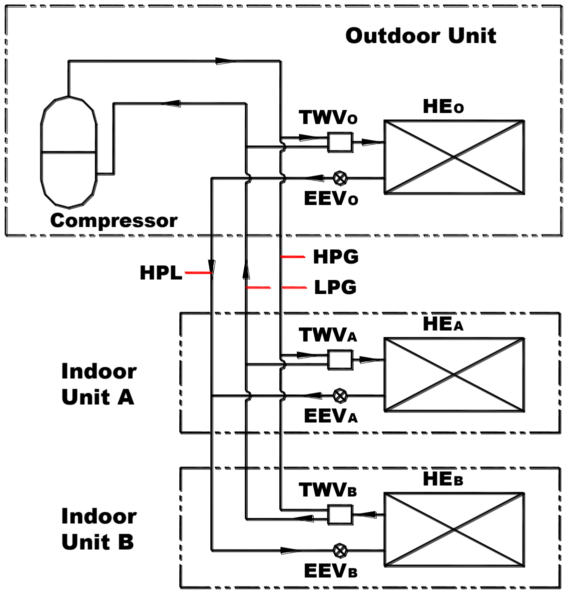

Figure 4 Cooling-Principal mode

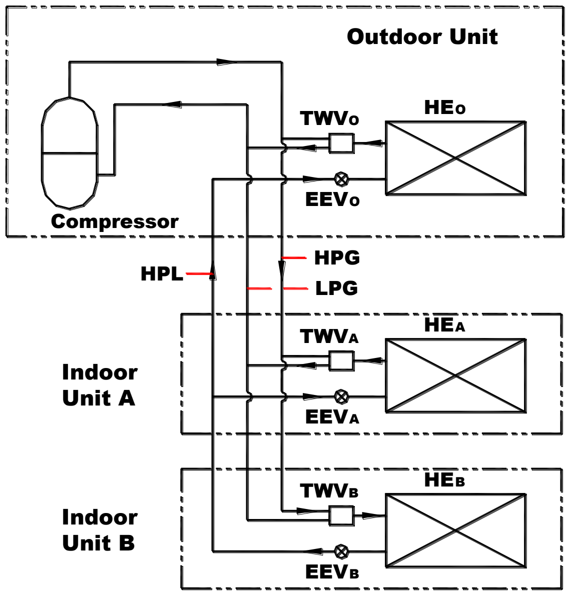

Figure 5 Heating-Principal mode

Heating-Principal Mode

In this mode, for example, indoor unit A is in cooling operation and indoor unit B is in heating operation. As shown in Figure 4, the gas refrigerant discharged from the compressor flows into the indoor heat exchanger B through connecting pipe HPG and is condensed there. The liquefied refrigerant from the indoor heat exchanger B flows into the indoor unit A and the outdoor unit through connecting pipe HPL and is depressurized by the indoor EEVA and EEVO. The depressurized refrigerant is evaporated in the indoor heat exchanger A and the outdoor heat exchanger and returns to the compressor through connecting pipe LPG. Thus, the outdoor heat exchanger and the indoor heat exchanger a work as evaporators, and the indoor heat exchanger B works as a condenser.

Heat Recovery Mode

In this mode, for example, indoor unit B is in cooling operation and indoor unit A is in heating operation. As shown in Figure 2e, the gas refrigerant discharged from the compressor flows into the indoor heat exchanger A through connecting pipe HPG and is condensed there. The liquefied refrigerant from the indoor heat exchanger A flows into the indoor unit B through connecting pipe HPL and is depressurized by the indoor EEVB. The depressurized refrigerant is evaporated in the indoor heat exchanger B and returns to the compressor through connecting pipe LPG. Thus, the indoor heat exchanger A work as a condenser, and the indoor heat exchanger B works as an evaporator and the outdoor heat exchanger does not work. The heat is transmitted from the room B to the room A.

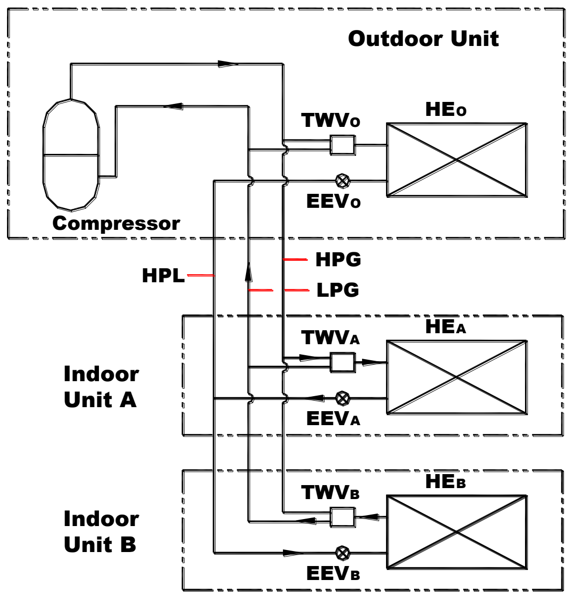

Figure 6 Heating-Recovery mode

ANALYSIS OF PERFORMANCE

From the analysis, we can find both the condensing heat and evaporating heat are valuable in use in the mode such as cooling-principal, heating-principal and heat recovery. The coefficient of performance (COP) of the VRF system increases markedly. The COP can be calculated by the following equation:

$$COP = \frac{|Q_A| + |Q_B|}{P} \qquad (1)$$

where

Q_A -----heat exchanged in indoor unit A, (W)

Q_B -----heat exchanged in indoor unit B, (W)

P -----electricity energy consumed by the system. (W)

When the indoor unit is in heating operation, the heat exchanged in it is positive number, and when the indoor unit is in cooling operation, the heat exchanged in it is negative number.

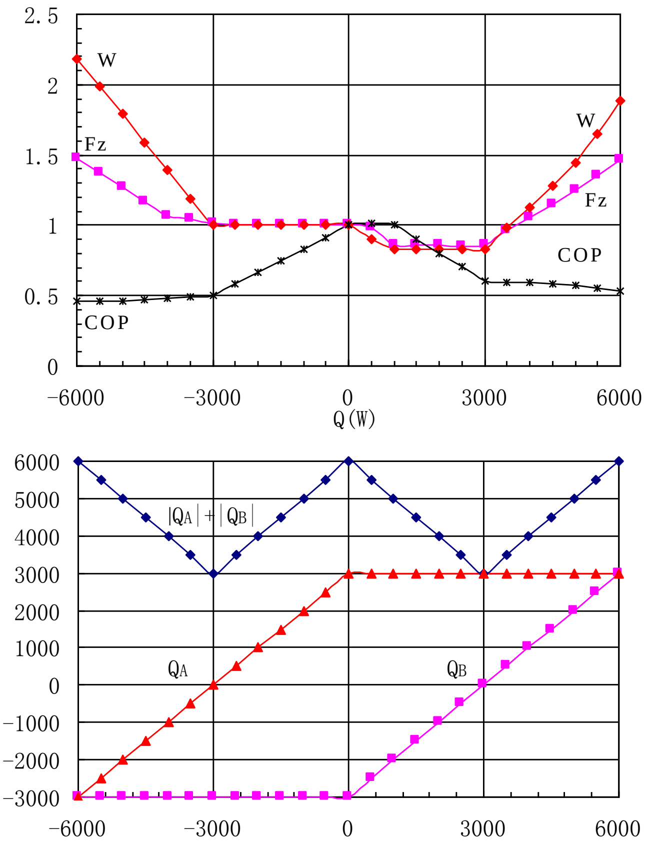

Figure 7 Performance of the system

The value of each variable is shown in Table 1 when the system is operating in standard condition. Taking the value of P, Fz and COP in this condition for one, the ratios of them in other conditions are shown in Figure 7.

From Figure 7, we can find that when the COP in heat recovery mode is about two times of the COP in cooling-only mode or heating-only mode.

For both the condensing heat and the evaporating heat are made use of, the COP of this multiple VRF air conditioning system increases markedly. On the other hand, for the heat transferred from indoor environment to outdoor environment is decreased largely, thus the pollution to the outdoor

Table 1 Standard condition

Condensing Temperature (^{o}C)	48
Evaporating Temperature (^{o}C)	1
Q_A (W)	-3000
Q_B (W)	3000
P (W)	1030
Fz (Hz)	51
COP	5.78

environment is reduced accordingly.

CONCLUSIONS

A new multiple VRF air conditioning system with heat recovery has been developed. The basic concept and performance are summarized as follows.

The capacity of this system responds to the load of each room by using a variable frequency compressor and electronic expansion valves (EEV) that can control the refrigerant flow for each indoor unit and changing the airflow rate of each heat exchanger.

This new VRF system can operate concurrent heating and cooling that can satisfy the heating or cooling of several rooms.

Both the condensing heat and evaporating heat are value in use, the coefficient of performance of this system increases markedly, about two times of in the cooling-only mode or heating-only mode.

For the heat transferred from indoor environment to outdoor environment is decreased largely, thus the pollution to the outdoor environment is reduced accordingly.

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