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ABSTRACT

A new type of digital water cooled multi-connected air-conditioning unit is researched and designed in this paper, combining pipe laying technology of heat pump with variable volume control technology, and the system get 4.2 for IPLV(C) (refrigerating integrated part load value), 4.0 for IPLV (H) (heating integrated part load value). This unit is connected to indoor units with refrigerant pipes. Due to controlling of electromagnetic valve and digital scroll compressor to adjust the refrigerant flow, it can be used in a wide range of working condition; and making use of ground water with constant temperature of cold and heat source to ensure the unit more energy-saved and environmental friendly. This system has heat recovery function, While cooling in indoor units, the system reclaims outdoor redundant energy to heat life water, heat recovery COP can arrive at 7.0. Finally, the application prospect of this system in residential buildings is given.

0. INTRODUCTION

Multi-connected VRV air conditioning system has been rapidly developed in recent years because of its advantages such as small occupancy, convenient installation, independently controlling the room and temperature, freeze-proofing in the winter etc. But the disadvantages of current air cooled VRV system exist in the following aspects, firstly, the ability of heat supply is lowered due to the defrosting outdoor unit; Secondly, it can’t run regularly or effectively in low ambient temperature; Finally, the cooling performance of outdoor unit directly depends on the ambient temperature, it’s ineffective and causes noise to the residents [9]. And the GSHP is deeply developed and widely used in North America and Europe. Comparing to the traditional air conditioning system, the efficiency of the system is 40%～60% higher and it can save more energy[1,3]. In the USA, GSHP occupies the entire heating and air-conditioning system 20%; In Europe, according to 1999 statistics, the proportion of GSHP in Switzerland was 96%, in Austria was 38%, in Denmark was 27%. Although in the domestic this technology has just started, it had Government department's strong support. In November 1997, the United States Department of Energy and China's Ministry of Science and Technology signed a Sino-US energy efficiency and renewable energy cooperation protocol, the main element of this is to vigorously promote this “green building” technology [2].
Therefore, based on the above theory and adapt to the requirements of sustainable energy development, the paper combines these two new technologies together and makes up for one's deficiency by learning from others' strong points. A new type of Multi-connected Digital Heat Recovery Ground Source Heat Pump has been developed here. With integrating the functions of central air-conditioning and hot water, the new system brings the ideal and cost-effective air conditioning and hot water unit select for the user.

1. THE PRINCIPLES OF THE UNIT

For making hot water via recycling heat from condenser, domestic and foreign manufacturers have conducted many research and application. The current application is tandem type, namely that connecting a hot water heat exchanger between the vent of compressor and air-cooled condenser. it produces hot water by recovering the sensible and latent heat of the high-pressure refrigerant , but this system can only partially reclaim heat and reclaim small amount of heat, with a 10 % ~ 30% [5] proportion recovery of the condensing heat.
The system design is different from conventional systems, it applies the parallel type: connecting a hot water generator parallel to the water-cooled heat exchanger and indoor air-cooled heat exchanger. The combination of every two of the three heat exchangers together with a common compressor and the corresponding throttling gear comprise a multipurpose and independent Multi-circuit heat pump. Total heat recovery of condensing heat can be realized in summer by this system. Figure 1 is the schematic of it.

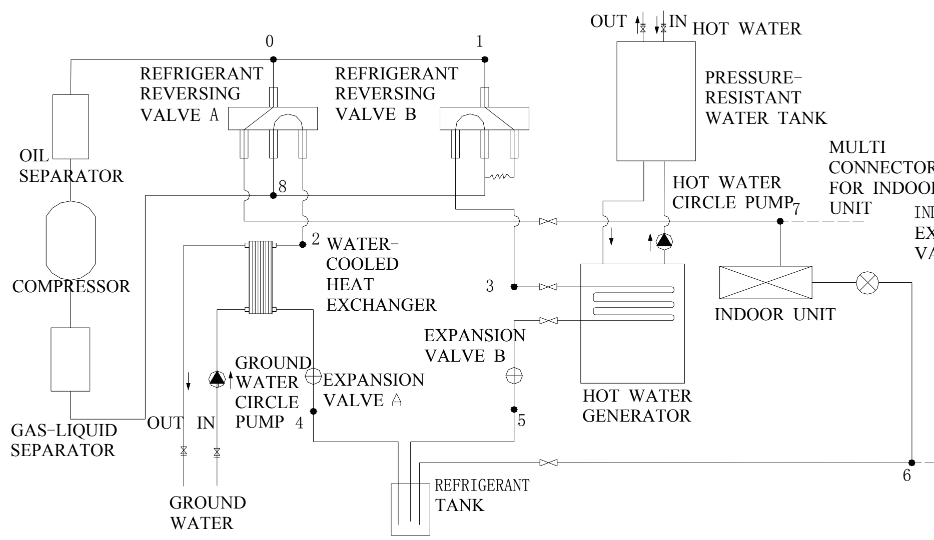

Figure 1 The schematic of multi-connected digital heat recovery ground source heat pump

The operating principle is to use the buried pipes to absorb heat from the soil or give off heat to the soil so as to control indoor temperature and generate life hot water, it can't be affected by the external environmental. In summer, the indoor air is cooled and dehumidified by evaporator; meanwhile, free life hot water can be got from the condensing heat, if the hot water is not needed or its temperature achieves set-value, the redundant heat can be transferred to the ground by the water-cooled heat exchanger. In other seasons, the unit can absorb the heat from ground source and get 55 ℃ water directly. The units can be controlled by temperature sensor for sensing the temperature of the water, only need a pre-set temperature.

2. SYSTEM STRUCTURE AND RUNNING MODE

2.1 System Introduction

This new developed system by author is a new Multi-connected Digital Heat Recovery Ground Source Heat Pump with cooling capacity of 15kW. It is composed of a oudoor unit, several indoor units, a hot water generator and a pressure-resistant water tank. As shown in Figure 1, outdoor Systems is made up of a digital scroll compressor, a gas-liquid separator, an oil separator, a water-cooled heat exchanger, a refrigerant tank and two refrigerant reversing valve. The system can run in four kinds of mode and change running mode by switching valves, for better control and switch, expansion valves are mounted in different circuits. The EXV controls refrigerant flow of hot water generator and every indoor unit. The refrigerant is R22.

2.2 Running Modes

This new system includes following 4 kinds of running mode, cooling only, heating, cooling and making hot water and making hot water only . Below is the table of the status of valves and circle pump in 4 running modes.

Table 1 The status of valves and circle pump in 4 running modes

Running Modes	Refrigerant flowing direction	Refrigerant reversing valve A	Refrigerant reversing valve B	EXVA	EXVB	Ground water circle pump	Hot water circle pump
Cooling	0->2->4->6->7->8	Power-off	Power-off	on	off	on	Off
Cooling and Making hot water	0->2->4->6->7->8 1->3->5->6->7->8	Power-off	Power-on	on	on	off	on
Making hot water	1->3->5->4->2->8	Power-on	Power-on	on	on	on	on
Heating	0->7->6->4->2->8	Power-on	Power-off	on	off	on	off

Note: EXV stands for expansion valve.

2.3 System Design and Analyses

The layout of the system is as Figure 2 below, the outline dimension of GMV outdoor unit is 621 mm x 450 mm x 850 mm(L×W×H).The outline dimension of hot water generator is 580 mm x 590 mm x 1350 mm (L×W×H).The water tank has the dimension of ø560 mm x 1280 mm(D×H), the volume of 200L and refrigerant filling amount of 10Kg.The hot water generator is designed in a special vertical way, it makes great contribute to the small occupation and convenient installation. The heating capacity is the key benchmark of hot water generator, so the axial heat exchanger applied here can highly improve its performance, ability of freeze-proofing and reliability.

Figure 2 The layout of new multi-connected digital heat recovery ground source heat pump

3. PERFORMANCE ANALYSES

During the process of design and development of this new system, various experiments have been implemented. The experimental devices include one GMV－Rs150W/AS (outdoor), four ducted air handlers (indoor) GMV-R25P/H (2 units) and GMV-R50P/H (2 units) and a heat pump water heater SXVD200LCJ. The results and analyses of the experiments are listed below.

3.1 Calculation Equations

3.1.1 Integrated Part Load Value (IPLV) Equations [7,8]

A method to calculate the IPLV(C) is given in Equation (1).

$$\mathrm{IPLV(C)} = (\mathrm{PLF_1} - \mathrm{PLF_2})(\mathrm{EER_1} + \mathrm{EER_2})/2 + (\mathrm{PLF_2} - \mathrm{PLF_3})(\mathrm{EER_2} + \mathrm{EER_3})/2 + (\mathrm{PLF_3} - \mathrm{PLF_4})(\mathrm{EER_3} + \mathrm{EER_4})/2 + (\mathrm{PLF_4})(\mathrm{EER_4}) \quad (1)$$

Where

PLF1, PLF2, PLF3, PLF4 are load efficiencies in 100 %,(75±10%), (50±10%), (25±10%) percentages in rated load condition which are determined by Figure 3.

EER1, EER2, EER3, EER4 are EER in 100 %,(75±10%), (50±10%), (25±10%) percentages in rated load condition.

The IPLV (H) can be calculated referring to IPLV(C).

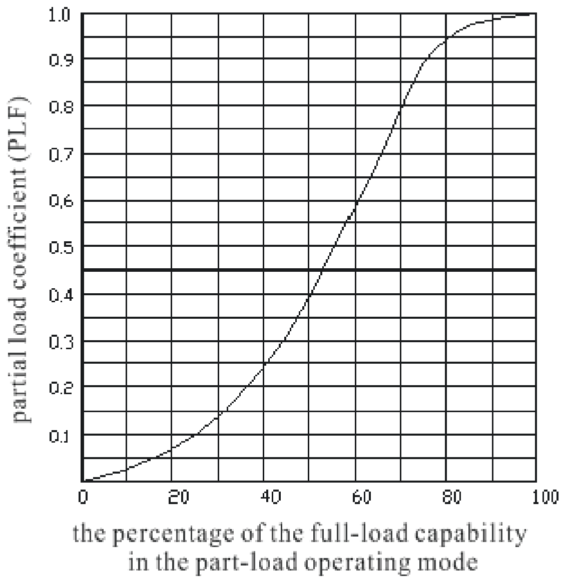

Figure 3 Charts of efficiencies in various loads

3.1.2 HCOP（cooling and making hot water） and COP（making hot water） Equations[3,4,6,7,8]

A method to calculate the heating capacity is given in Equation (2).

$$Q_h = C \times G \times (t_2 - t_1)/(3600 \times H) + Q_x + Q_l \quad (2)$$

Where

Qh ——Heating capacity of heat pump, kW;

C ——specific heat capacity of water in average temperature, kJ/（kg • ℃）;

G —— mass of heating water, kg;

t1 ——Initial temperature of water (the average temperature of water in tank when starting to time), ℃;

t2 ——Termination temperature of water (the average temperature of water in tank when finishing time), ℃;

H —— Duration of heating (duration form the beginning of heating to the end of heating), h;

Qx —— Standard heat storage of piping and water tank, kW;

Ql ——Standard heat leakage of piping and water tank, kW.

Qx can be calculated from (3):

$$Q_x = \sum_{i=0}^{i=n} C_i G_i \times (t_2 - t_1) \tag{3}$$

Where

Ci ——specific heat capacity of water tank and piping in average temperature, J/（kg・℃）;

Gi ——mass of piping and standard parts of water tank, kg.

The unit power consumption is written as

$$E = N_o / H \tag{4}$$

Where

E ——unit power consumption, kW;

N0 —— Total consumption during a heating cycle, kW・h.

HCOP is given as

$$\mathrm{H}COP = (Q_h + \mathrm{Q}) / E \tag{5}$$

Where

Q—— refrigeration capacity, kW

E ——unit power consumption, kW

COP is calculated by equation:

$$COP = Q_h / E \tag{6}$$

3.2 Performance Testing

In order to get IPLV, testing on cooling/ heating performance were given when indoor unit is 16.7%, 50%, 66.7%, or 100% loaded. The test data is listed in table 2 below. According to the test data, Figure 3 and equation 1.1, IPLV（C）equals 4.2 and IPLV（H）is 4.0.

Table 2 Test data and calculation result in air conditioning mode

Cooling (Heating) Rate	4	3	2	1
Indoor unit variable load	16.7%	50%	66.7%	100%
Cooling capacity（kW）	2.47	7.45	9.78	14.7
Heating capacity（kW）	2.55	7.86	10	15.9
Cooling consumed power（kW）	0.93	1.65	1.99	3.68
Heating consumed power（kW）	1.02	1.81	2.1	3.89
EER	2.660	4.515	4.915	3.995
COP	2.500	4.343	4.762	4.087
PLF	0.05	0.4	0.8	1
IPLV（C）	4.2			
IPLV（H）	4.0			

Note:

(*)At the nominal cooling conditions: indoor ambient air temperature 27℃(DBT),19℃(WBT); outdoor ambient air temperature 27℃(DBT);entering ground water temperature 25.04℃ with Δt5℃;

(**).At the nominal heating conditions: indoor ambient air temperature 20℃(DBT),15℃(WBT); outdoor ambient air temperature20℃(DBT);entering ground water temperature 10.05℃,the water flow is same to the cooling conditions.

3.3 Testing on Heat Recovery and Making Hot Water

In terms of equations （2），（3），（4），（5），（6） , the results are listed below in table 3.

Table 3 Calculation matrix of COP when system runs in heat recovery and making hot water mode

	Parameter options	Unit	Cooling and making hot water	Making hot water
Test parameter	C	kJ/（kg • ℃）	4.2	4.2
	G	kg	225.5	225.5
	Gi	kg	50	50
	Ci	kJ/（kg • ℃）	0.46	0.46
	t1	°C	15	15
	t2	°C	48	48
	H	h	0.466	0.66
	N0	kW • h	1.96	2.00
	Q	kW	14.65	0
Calculated value	Qh	kW	14.25	11.20
	E	kW	4.20	3.03
	HCOP/COP	W/W	7.0	3.7

Note:
(*)At the cooling and making hot water test conditions: indoor ambient air temperature 27℃(DBT),19℃(WBT); outdoor ambient air temperature 27℃(DBT);entering ground water temperature 25℃ with △t5℃;
(**)At the making hot water test conditions: entering ground water temperature 10°C, the water flow is 3.0 m^3 /h..

The experimental results indicate that the new system get 4.2 for IPLV(C), 4.0 for IPLV (H) and 7.0 for heat recovery COP. Comparing to the traditional air conditioning system or hot water system, it presents a more energy save trend of heat pump.

4. CONCLUSIONS

Finally, as we know, with the development of economy and achievement of society, human beings' life step into higher quality stations, more and more middle and high level income domestic economies have ability to get big-area housing or villa as their home. Because of this, hot water in daily life have been confirmed to be a big requirement in the future, also be clear to us that the related energy consume will take up a big proportion in the full use of society. But even now, inefficient energy consume, serious pollution problem still can't be solved by traditional air -conditioning and thermal water technologies. So, a kind of unit system with cooling, heating and hot water functions has been stepped into research and gotten a broad application in practice. Compared to the traditional ones, this new unit not only solve the condensation heat pollution problem, but also save considerable energy consume which was used to produce daily hot water for user. Even more, it has changed the conditions of unsafety using oil boiler or gas boiler, inefficient use of energy, and polluted ejection which is not in the requirement of environment protection and safety, is injured to human's healthy even body. In this paper, the brand new thermal recovery system combines 3 functions (cooling, heating, hot water) together, of which, the HCOP value comes to 7.0, controller system is very simple, structure is compact, and requirement for huge space and special technologies of construction isn't in need. Anyway, the application of this kind of system will become high frequency in residential building and be well known broad.

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