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"A REVIEW OF VARIABLE REFRIGERANT FLOW SYSTEM AN EMERGING TECHNOLOGY IN HVAC"

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ABSTRACT

The Variable Refrigerant flow technology is rising as the advanced and promising option to the conventional systems. The concept of the VRF has been generated since the early 1990s the general idea behind that was the system should operate on one large outdoor unit and will have several indoor units. Variable refrigerant flow (VRF) is a multi-split air-conditioning system configuration where there is one outdoor condensing unit and multiple indoor units are present. The arrangement of this system can provide the zonal comfort and simultaneous heating and cooling. This technology uses the smart integrated controls, variable speed drives (VSD), refrigerant piping and heat recovery to provide more thermal comfort in the less energy consumption.
The variable refrigerant flow control is the key to many advantages as well as the major technical challenge of VRF system. The conventional refrigerant systems turn OFF or ON completely in response to one central controller, whereas the VRF systems continually adjust the flow of refrigerant to each indoor evaporator. Hence the variable refrigerant flow system is providing the energy and space-saving solution to the existing system.

Keywords: *Coefficient of performance (COP),Electronic Expansion Valve (EEV), Four-way valve, HVAC.*

I. INTRODUCTION

The thermal comfort and healthy atmosphere in the commercial and residential building is the need of the modern society. Also, the zonal comfort is necessary with less consumption of electricity and space. The field of air conditioning is gradually developed from the one unit for the one house to the independent unit for the separate zones in the same house [1].The multi-split air conditioning system that includes variable refrigerant flow (VRF) or variable refrigerant volume (VRV) technology, so-called multi-split VRF/VRV.The Variable Refrigerant Flow System is the emerging technology of this era which can satisfy the same demands of the modern society [2]. The VRF system uses only one outdoor unit to run the multiple indoor units. The VRV i.e., Variable Refrigerant Volume is the trademark of the majorVRF system manufacturer Daikin and the VRF is the common name used by the all other VRF manufacturers [3].

Generally, this system work by varying the flow rate of the refrigerant by changing the speed of the compressor and opening of the Electronic Expansion Valves (EEVs) to maintain the air temperature of the zone at the indoor set temperature. The EEV islocated in every indoor unit which operates electronically by the response of the sensors which are present in each zone to match the required cooling or heating load [10].

II. CONSTRUCTION

Variable refrigerant flow (VRF) is a multi-split air-conditioning system where there is one outdoor condensing unit and multiple indoor units are present.Commonly the VRF system consists offour indoor units as shown in fig. 1.1. As we see in the fig 1.1the indoor units are connected with the outdoor unit in parallel arrangement with the refrigerant pipes.The VRF system can be used the both cooling or heating of the space.The path of the refrigerant is adjusted by the four-way valve present in the outdoor unit setupto obtain the simultaneous cooling and heating of the zone as per the requirement. There is an electronic expansion valve located in each indoor unit. This system uses the refrigerant R-410a which is themost suitable refrigerant for this system [18].

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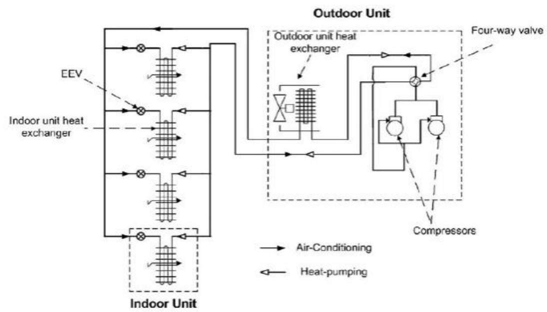

Fig.1.1 The layout of the typical VRF system

Outdoor Unit

The outdoor unit of the VRF system consists of two to three compressors based on the capacity of the system where the one compressor between them is variable speed. This variable speed compressor is inverter driven which gives the wide variation in the speed according to the part load conditions.By varying the frequency of the inverter the variable speed compressor changes its speed results into the change in the mass flow rate of the dischargedrefrigerant.This feature of the VRF enables the system to work efficiently on the part load conditions.The outdoor units of the VRF system are available upto 240,000 Btu/h[5].

Indoor Unit

The indoor unit of the VRF is equipped with the heat exchanger, electronic expansion valve, temperature sensor, and the blower fan.Various indoor units can be installed to the outdoor unit of the VRF system. The installation of the indoor units with various configuration is also possible in the VRF systemas shown in fig 1.2. The indoor units with the cooling or heating capacity between 4777 Btu/hr to 59713 Btu/h.The conception of using the more indoor unit is gradually developed with 4 units to 8 units in the late 1980s, to 16 units in the early 1990s, to 32 units were employed in 1999. Now the today's advanced VRF system can have as many as 60 or more indoor units operate on the single outdoor unit enabling the application in the large residential and commercial buildings [4].

The temperature sensors are located in the indoor unit which gives the comparison between the actual temperature in the zone and set temperature of the thermostat. The EEV adjusts the flow of the refrigerant according to the temperature difference. By this way the indoor units are operated.

The refrigerant pipes are used to connect the indoor and the outdoor unit of the VRF system. Because of the advances in the VRF system the total piping length of the system is increased up to 1000m [4].

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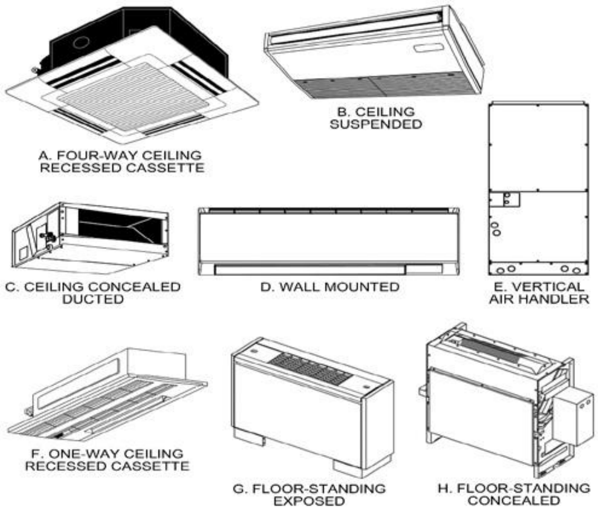

Fig. 1.2 Various types of indoor units

III. WORKING

The multi-spit VRF system is the advanced version of the ductless multi-split system provides the multiple indoor units connected to the single outdoor unit by giving the feature of the simultaneous heating and cooling [3]. Normally this system uses the scroll type compressor in the outdoor unit. The function of the evaporator is depending on the mode of the operation of the system either cooling or heating.

Cooling mode

In the cooling mode, the indoor units of the system function as the evaporators. The pressure of the discharged refrigerant is increased while entering into the outdoor unit by four-way valve shown in fig 1.1. At this stage, the temperature of the refrigerant is lower. Then refrigerant with high pressure and the low temperature is then throttled via EEV to the low pressure. This low pressure and low-temperature refrigerant enter the indoor unit to absorb the heat from the indoor zone. This refrigerant is superheated and returns to the compressor by completing the cooling cycle.

Heating mode

In the heating mode, the indoor units of the system function as the condenser. The four-way valve as shown in fig 1.1 present in the system reverses the path of the refrigerant in this mode. The compressor discharges the refrigerant to the high temperature before entering the indoor unit heat exchanger. Hence the indoor units heat up space by rejecting heat. Then the refrigerant with high pressure and low temperature is throttled by the EEV to the low pressure. This refrigerant with low pressure and low temperature enters the outdoor unit heat exchanger. Refrigerant superheated in the outdoor unit and completes the heating cycle by returning to the compressor [7].

IV. MODES OF OPERATION

The multi-split VRF system can be operated in different heating and cooling combinations according to the requirement of thezone.

Heating only mode

In theheating only mode,the indoor unit will work as the condenser and the outdoor unit work as the evaporator. In this heating mode, the multi-split VRF system will increase the temperature of the zone or space by rejecting the heat. In this mode, all of the indoor units perform the same function of heating the space[2].

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This modeoperates on the two-pipe system. This two-pipe configuration has the two refrigerant pipes in which one is low-pressure liquid pipe and other is high-pressure gas pipe.

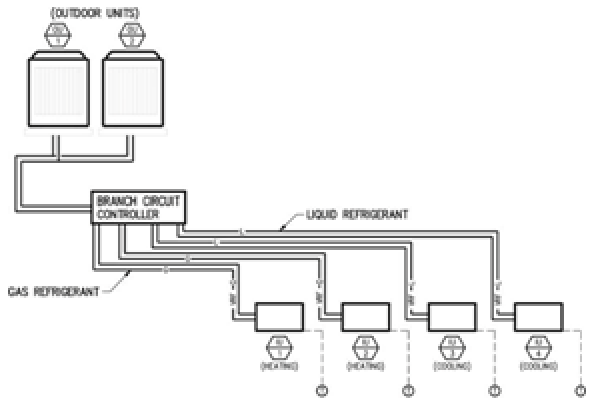

Fig 1.3 Two pipe VRF system

Cooling only mode

In the cooling only mode, the indoor unit functions as the evaporator and the outdoor unit of the system functions as the condenser.In this cooling, only mode of the multi-split VRF system the indoor unit will reduce the temperature of the zone by absorbing the heat from the zone.In this mode, all of the indoor units will perform as the same functioni.e., cooling the space. The cooling only mode operates on the two-pipe system.

Heat Recovery mode

The heat recovery mode is also called the three-pipe system as shown in fig. 1.4. In this mode of operation, the indoor units can functionas the evaporator and the condenser simultaneously .As per the need, this system can be operated for simultaneous cooling and heating of the zone. In this mode, the heat is managed in the indoor units and the outdoor is closed.

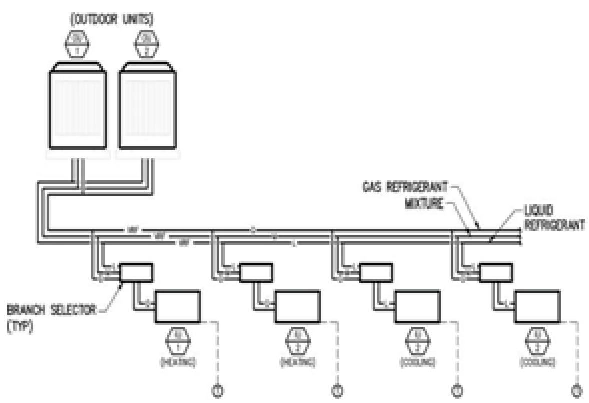

Fig 1.4 Three pipe VRF system

This system uses the three-pipe system in which the three pipes are high-pressure gas pipe, a low-pressure gas pipe and, the low-pressure liquid pipe.

V. PERFORMANCE OF THE SYSTEM

The variable refrigerant flow system is known for the energy efficient solution over the conventional system This system can become the emerging technology in the field of air conditioning as the energy saving technology but its energy saving capability largely depends on the time span when it operates at part load. When working at full load VRFsystem does not work as an energy saving option [4].

The efficiency and energy saving capacity of the system depends on many parameters. The VRF system can save energy from 10% to 40% [16].

The performance rating is having the vital role to know the scope of the improvement and to have a complete understanding of the technology. The VRF systems which are less than the 65000 Btu/h capacity Heating/Cooling Seasonal Performance Factor is used to rate the cooling or the heating performance of the system. And the systems which are greater or equal to the 65,000 Btu/h the Coefficient of Performance or COP is used to rate the cooling or heating capacity of the system [9].

VI. APPLICATIONS

The multi-split VRF system is having a large scale of applications. The VRF system can be installed where the multiple zones are to be maintained at the required temperature. This system is versatile because it gives the individual control to the individual zones. This system can be installed where space is the constraint because the extra ducting work and conditioning needed for the ventilation is not needed for the system [17].

The other most appropriate application of the VRF system is where the individualized thermal comfort is needed like in office buildings, strip malls, hotels and motels, hospital, banks, and schools. The offices and the strip malls have the different zonal requirement of the conditioned space so that VRF become interesting for these applications [2].

VII. LITERATURE REVIEW

Rahul Khatri et al [4] studied the energy performance of the inverter-based variable refrigerant flow system with the help of constant volume unitary AC. This study mainly focused to find out whether the variable refrigerant flow system is energy efficient solution or not. The field performance testing is used to compare the performance of inverter based VRF unitary AC with the constant volume unitary AC. By the observations, it is found that the VRF technology is efficient only in the part load conditions. While working on the full load conditions the VRF technology does not give the energy efficient solution.

Sun Tingting et al. [15] studied the existing problems faced by the VRF technology. This paper gives the detail idea about the disadvantages of the system. The listed disadvantages of the system are the properties of the system are affected by the outdoor temperature, this system has the lower COP and the cooling capacity with an expansion of the scale. On the basis of these advantages, they have introduced the new technology called as water loop variable refrigerant flow(WLVRF). This new system overcomes the disadvantages of the VRF system. By taking the office building as a sample the simulation for the WLVRF is carried out. It is found in the analysis that when this system is working in the heating condition then half of the heat energy is recovered from the inner zone.

Prabudh Tiwari et al. [14] given the modeling and the CFD analysis of the VRF system. Stated that the experimental testing consumes more time and the cost. As there is a substitute to the experimental testing method is the application of the computational fluid dynamics (CFD) to predict the thermal features of the system. The analysis is done by the ANSYS fluent 14.5. After the analysis, this study stated that the comfort level of the occupants can be enhanced by regulating the flow of the air coming out of the evaporator.

Ali Alamer et al. [5]performed the case study of the hotel in Amman, Jordan the sensitivity analysis is done in the selected area according to the heating and cooling load.Stated that the VRF technology is the advanced and the alternative solution to the centralized HVAC system. This study showed that the system gives the energy efficiency at the partial load instead of being costly. This study is mainly done to optimise the heating and the cooling load to improve the human thermal comfort.

This study also gave the criteria to select the indoor and the outdoor units for the VRF system. This paper also gives that by controllingrelative humidity, cooling supply temperature and bypass factor along with dry bulb temperature the can reach to the comfort zone temperature efficiently instead of controlling the temperature solely.

Zhiqiang (John) Zhai et al. [8]this paper gives brief overview of the VRF system and also states a brief analysis of the technical barriers of the system. This study also gives that there is a need to develop the tool which will give the energy consumption of the system without the building design data. This tool is analysed experimentally and numerically by comparing the results to the existing tool which are present already. This tool also suggests that the VRF system have the ability to save the energy where the percentage of the energy saving is highly depending on the climate and local energy cost.

Abdullah Yildiz et al. [6]This paper deals with the finding of the optimum insulation thickness of installed inside the building pipe network of the VRF (variable refrigerant flow) systems. In this study, the pipe network of the three-pipe system working on both heating and the cooling mode is considered. There are many studies are on the optimum thickness of the pipe network of the VRF system mainly considering the heating mode and the other parameters like efficiency, the material of insulation, the lifetime etc.

The results of this study given that, the optimum thickness of the insulation increases as the heat load on the pipe increases. The energy saving values of the system in increases from the 19.07% to 58.50% for the pipe sections of thehigh-pressure gas pipe and for the low-pressureliquid pipe these values vary from 40.00% to 56.41% in the heating mode of the VRF system. The optimum thickness of the insulation for the low-pressure liquid pipe and the high-pressure gas pipe varies from 7 mm to 8 mm under the cooling mode. In the heating mode, the optimum insulation thickness varies for the high-pressure gas pipe and the low-pressure liquid pipe from 16mm to 20mm and 11mm to 13mm respectively.

Roba Saab et al. [9]studied the performance of the VRF system under the various operating situations such as hot and humid climates. This study is done in the Engineering Equation Solver (EES) while the input data obtained by the specification of the VRF system. The results have shown that the coefficient of performance (COP) of the system is highly depends on the evaporator and condenser pressures as well as the type of refrigerant used.

It is noted that the COP of the system varies with the effect of the condenser and the evaporator pressures, the COP of the system increases non-linearly with an increase in evaporator pressure and/or decrease in the condenser pressure. Different types of refrigerants were modeled in the system and it is found that refrigerant R-410a seen to be a second most efficient refrigerant after ammonia.

Ziai Li et al. [12] given the model of the multi-split variable refrigerant flow system with the subcooler and also validated the system. The nine cases were considered with different length of the pipes and the subcooling heat exchanger also the cooling performance of the system has been studied by simulation.

The results have shown that the subcooler enhances the performance of the system by improving the coefficient of performance of the system with short pipelines. The COP of the system can also be improved by increasing the length of the subcooler heat exchanger. The COP of the system can be improved by 1.7%.

VIII. CONCLUSION

This review gives the detail working, configuration, modes of operating of the system and the applications. Besides the detail of the studies related to the variable refrigerant flow (VRF) system are also given.

The variable refrigerant flow technology is becoming the new emerging technology in the field of air conditioning because of its large applications and very efficient way of operation. This technology refers to the ability of the system to control the mass flow rate of the refrigerant by using the inverter-driven compressor of variable speed and the electronic expansion valve. The variable refrigerant flow system gives the energy efficient and the flexible operation, ease of installation, zonal comfort.

REFERENCES

1. Y.C. Park, Y.C. Kim, M.K. Min, Performance analysis on a multi-type inverter air conditioner, Energy Conversion and Management 42 (13) (2001) 1607 1621.
2. A. Amarnath, M. Blatt, Variable refrigerant flow: An Emerging Air conditioner and Heat Pump Technology, ACEEE Summer Study on Energy Efficiency in Buildings (2008).
3. C. Wu, Z. Xingxi, D. Shiming, Developmentof control method and dynamic modelfor multievaporator air conditioners (MEAC), EnergyConversion and Management 46 (3) (2005) 451–465.
4. Rahul Khatri, Anant Joshi, Energy performance Comparison of Inverter based Variable Refrigerant Flow Unitary AC with Constant Volume Unitary AC, Energy Procedia, 109 (2017) 18 - 26.
5. Ali Alahmer, Sameh Alsaqoor, Simulation and optimisation of multi-split variable refrigerant flow systems, Ain Shams Engineering Journal, 203 (2017) 175 - 185.
6. Abdullah Yildiz, Mustafa Ali, Determination of the economical optimum insulation thickness forVRF (variable refrigerant flow) systems, Energy, 89 (2015) 835 – 844.
7. Je Hyeon Lee, Pil Jae Im, Young-hak Song, Field test and Simulation Evaluation of Variable Refrigerant Flow Systems Performance, Energy Buildings, 2017.
8. Zhiqiang (John) Zhai, Jessica Rivas, Promoting Variable Refrigerant Flow System with A SimpleDesign and Analysis Tool, Building Engineering, 2017.
9. Roba Saab, Mohamed I. Hasan Ali, Variable refrigerant flow cooling system performance at Different Operation Pressures and types of refrigerants, Energy Procedia, 119 (2017) 426 – 432.
10. Tolga N. Aynur, Yunho Hwang, Reinhard Radermacher, Simulation comparison of VAV and VRF air conditioning systems in an existingbuilding for the cooling season, Energy and Buildings,41 (2009) 1143–1150.
11. Qiu Tu, Lina Zhang, Wei Cai, Xiujuan Guo, Xiaojun Yuan, Chenmian Deng,Jie Zhang, Controlstrategy of compressor and sub-cooler in variable refrigerant flow airconditioning system for high EER and comfortable indoor environment, Applied Thermal Engineering 17 (2018).
12. Ziai Li, Baolong Wang, Xianting Li, Wenxing Shi, Simulation on effects of subcooler on cooling performance ofmulti-split variable refrigerant flow systems with different lengths ofrefrigerant pipeline, Energy and Buildings 126 (2016) 301 – 309.
13. TolgaN. Aynur, YunhoHwang, ReinhardRadermacher,Simulation comparison of VAV and VRF air conditioning systems in an existing building for the cooling season, Energy and Buildings 41 (2009) 1143 – 1150.
14. Prabudh Tiwari Ajeet Bargaley, Modelling and Analysis of Variable refrigerant flow system through CFD, International Journal for Scientific Research & Development, IJSRD, Vol. 5, Issue 04, 2017.
15. Sun Tingting et al. Issue and Improvement Measure of Multi-split Air-Conditioner, International Conference on Computer Distributed Control and Intelligent Environmental Monitoring. 2011.
16. Tolga N. Aynur, Variable refrigerant flow systems: A review, Energy and Buildings 42 (2010) 1106 – 1112.
17. Kartik Patel, Prof. Pushpendra K. Jain, Prof. Dinesh K. Koli, A review of a HVAC With VRF System, International Journal for Innovative Research in Science & Technology, vol. 1, Issue 10, 2015.
18. R. Afify, Designing VRF systems, ASHRAE Journal 50 (6) (2008) 52 – 55.