STUDYING THE VARIABLE REFRIGERANT VOLUME (VRV) SYSTEM AND DETERMINING THE ROOT CAUSE OF ITS PROBLEM IN BUILDING 37, AGENSI NUKLEAR MALAYSIA

PEMAHAMAN TENTANG SISTEM VARIABLE REFRIGERANT VOLUME (VRV) DAN MENGKAJI PUNCA MASALAH DI BANGUNAN 37, AGENSI NUKLEAR MALAYSIA

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Abstract

Variable Refrigerant Volume (VRV) system is one of the Heating, Ventilation and Air Conditioning (HVAC) type in the building. VRV system is a multi-split type air conditioner that uses variable refrigerant flow control to provide customers with the ability to maintain individual zone control in each room and floor of a building. VRV used in Building 37 is made by Mitsubishi Heavy Industries that was completely installed in 2011 with two pipes system format. The objectives of this study are to understand the Variable Refrigerant Volume (VRV) system and also to study the root cause of its problem in Building 37, Agensi Nuklear Malaysia. The result of the study study suggests poor workmanship during installation process and insufficient electrical grounding are suspected as the causes of on-going and repeating problems occurred. Hence, Bahagian Kejuruteraan (BKJ) has worked out with the service contractor to identify the main problem and leaking area before proceeding with repair and commissioning activities.

Abstrak

Sistem Variable Refrigerant Volume (VRV) adalah salah satu sistem untuk pemanasan, pengudaraan dan penyaman udara (HVAC) di dalam bangunan. VRV adalah jenis penghawa dingin berasingan yang menggunakan kawalan aliran bahan pendingin yang boleh ubah untuk membolehkan pengguna mempunyai kemampuan mengawal suhu di bilik secara berasingan. VRV yang digunakan di Bangunan 37 dibuat oleh Mitsubishi Heavy Industries dan telah siap dipasang pada tahun 2011 dengan menggunakan sistem dua (2) paip. Objektif kajian ini adalah untuk memahami sistem Variable Refrigerant Volume (VRV) dan mengkaji punca masalah VRV yang berlaku di Bangunan 37, Agensi Nuklear Malaysia. Hasil kajian ini mendapati kelemahan dalam mutukerja di peringkat pemasangan sistem ini dan pembumian elektrik yang tidak mencukupi adalah punca masalah yang berlanjutan serta berulangkali berlaku. Oleh yang sedemikian, BKJ telah berkerjasama dengan pihak kontraktor servis untuk mengenal pasti masalah utama dan kawasan kebocoran sistem ini sebelum aktiviti pembaikan dan mengujilari semula sistem ini dilakukan.

Keywords : Variable Refrigerant Volume (VRV), Variable Refrigerant Flow (VRF), Fan Coil Unit (FCU), Heating Ventilation Air Conditioning system (HVAC)

INTRODUCTION

Variable Refrigerant Volume (VRV) system is a heating, ventilation and air conditioning (HVAC) technology that relatively new to the Malaysian market. Theoretically, VRV has a lot to offer in terms of efficiency, running costs, flexibility in use and control. As with any system, it suits some buildings, applications and climates better than others. In Nuclear Malaysia, VRV has been installed in Building 37 and 57 (Rumah Tamu) and been serviced monthly by service contractor.

The objectives of this study are to understand the Variable Refrigerant Volume (VRV) system and also to study the root cause of its problem in Building 37, Agensi Nuklear Malaysia

BACKGROUND

Building 37 or namely as Pembangunan Teknologi dan Kualiti (PTK) Building consists of 4 main floors as a part of facilities in providing public services, conducting research and consultation that related with nuclear technology in Malaysia. There are 6 units of VRV outdoors to serve 56 units of VRV indoors. Besides VRV system, there are several numbers of air-cooled split unit and air-cooled split ducted that have been installed in Building 37 as a part of HVAC system. VRV Indoors unit that have been used are wall mounted, ceiling concealed, ceiling suspended and cassette type. VRV system used in Building 37 made by Mitsubishi Heavy Industries which completely installed in 2011 by NIATGA SDN BHD with 2 pipe system format.

Table 1. Summary of VRV system in Building 37

Floor	**Outdoor Unit**	**Outdoor Unit Model**	**Power (HP)**	**No. Indoor Unit**	**Total Cooling Capacity (BTU/HR)**
1st Floor	CU-06	FDC560KXRE6	20	6	198,800
1st Floor	CU-05	FDC900KXRE6	32	8	319,200
Basement 1	CU-04	FDC1010KXRE6	36	14	357,800
Basement 1	CU-03	FDC850KXRE6	30	12	301,100
Basement 2	CU-02	FDC504KXRE6	18	10	198,800
Basement 3	CU-01	FDC504KXRE6	18	6	178,900
Total				56	1,554,600

BKJ has observed VRV systems in building 37 which experience on-going problems, seeming to go from bad to worse. Furthermore, the problems keep reported in Helpdesk system although the same problems have been resolved before. Most faults experienced on a VRV system will result in the complete system being out of action. With systems serving 6-14 indoor units, a fault on one unit could affect many people. As noted above, this adds severe pressure to get the problem fixed and the system operational as soon as possible.

THEORY

Variable Refrigerant Volume (VRV) system is a multi-split type air conditioner. VRV has also been referred as Variable Refrigerant Flow (VRF) that uses variable refrigerant flow control to provide customers with the ability to maintain individual zone control in each room and floor of a building. The compressor unit is controlled by a variable-speed drive, which may operate more efficiently than conventional compressors of similar size. VRV technology was invented in Japan by Daikin company in 1982. Nowadays, most of HVAC system manufactures have offer VRV systems to be used in mid and large size buildings. Figure 1 shows a typical layout of VRV system.

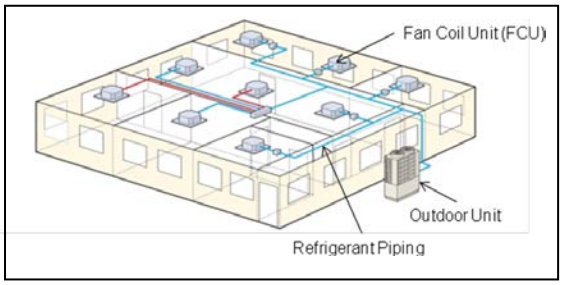

Figure 1. Typical layout of VRV System

VRV use refrigerant as the cooling and heating medium. This refrigerant is conditioned by a single outdoor condensing unit, and is circulated within the building to multiple fan-coil units (FCUs). Come in two system formats, two pipe and three pipe systems. In a two pipe system which commonly referred as heat pump system, all of the zones must either be all in cooling or all in heating. A three pipe Heat Recovery (HR) systems has the ability to simultaneously heat certain zones while cooling others. That is means VRV systems have a unique ability to extract heat out of areas requiring cooling and put it into zones requiring heating. In both two-pipe and three-pipe systems with refrigerant heat recovery, one or more heat recovery units are included between the compressor unit and the fan coil units. This unit controls the flow of liquid and vapour refrigerants between the fan coil units in heating or cooling mode, and minimizes the load on the compressor. Methods vary by manufacturers who provide their own valves, heat exchangers, controls and other components. Figure 2 includes simplified diagrams of two configurations with heat recovery.

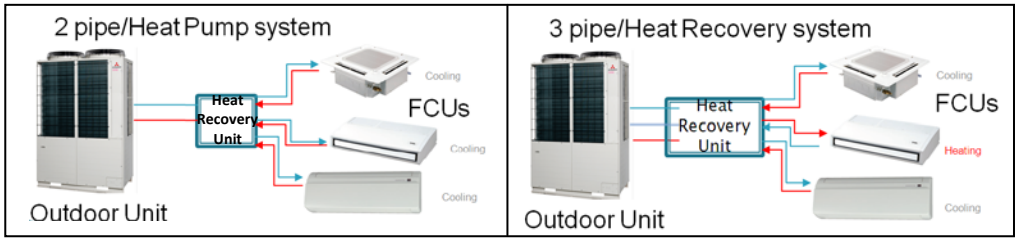

Figure 2. VRV Heat Recovery System Configuration Options

METHODOLOGY

The process flow chart of the study is described in fig. 3. Process 1 is the definition of the problem and objectives of the study. Then process 2 is the detail study of the basic understanding of the Variable Refrigerant Volume (VRV) system and collects the relevant data from service report that had been prepared by contractor service. The next process is the analysis on the possible root cause with necessary evidence and theory before concluding the study.

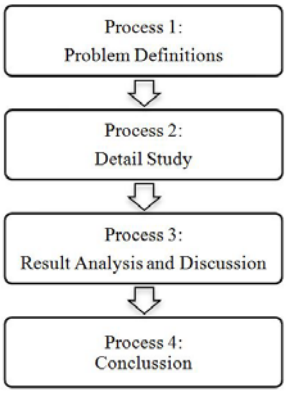

Figure 3. Flowchart of the methodology

RESULTS AND DISCUSSION

Advantages

VRV system in the building can conserve space for installation. The space efficiency is enhanced by the compact size of the individual units, the long maximum piping length, and the ability to utilize a large scale air conditioning system with a single piping circuit.

Besides that, the system provides superior design flexibility especially in changing of layout that can be made easily. New compressor technology eliminates the need for piping calculations, which shortens the time needed for design. Outdoor units can be placed on the roof where they have no effect on the design of the building interior.

The lightweight and compact units of VRV components can be transported using a regular lift. The pipes are few in number, making layout simpler. Hence, the technology in VRV system simplifies the installation process in term of time and cost. The figure 4 below shows an advantage of VRV system as compared with centralized air conditioning that using chilled water.

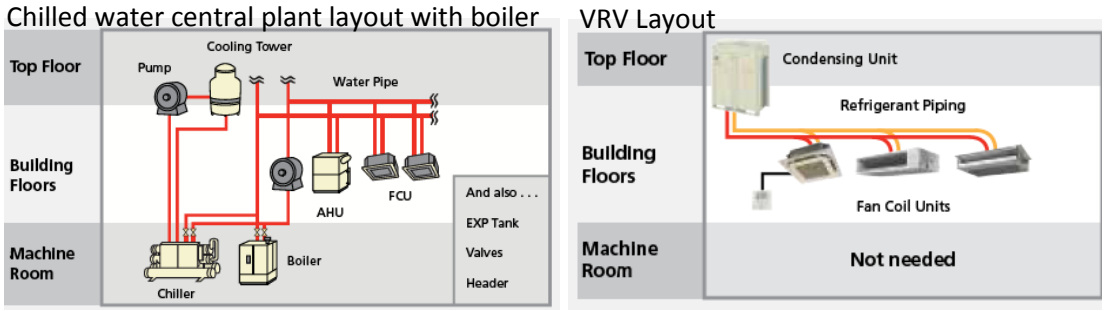

Figure 4. Comparison of Chilled water central plant with VRV layout

VRV delivers ultimate reliability of HVAC system in the building. VRV comes with self-diagnostic system that can identify problems within the system quickly and accurately. Thus, it will help the maintenance worker in troubleshooting the right way.

Figure 5. Error code shown on remote controller of VRV system

VRV systems enable individual climate control settings for each zone to provide the utmost in comfort to commercial building settings. For empty room, the system can be switched off individually as compared with centralized air conditioning system that use chilled water from chiller. Hence, the operational cost of the building will be reduced.

Precise individual control and inverter technology minimize energy consumption to deliver optimum energy savings. VRV can achieve about 30% or higher energy cost saving relatively with other conventional HVAC system.

In addition, VRV offers adaptable design that beneficial to the building designer in selecting the matching unit in order to suit with their requirements. Modular design of outdoor units and wide selection of indoor units ensure system designs that are ideally suited to the environments where they are installed.

The noise level of VRV system is also very low. Units are designed to operate quietly and are also equipped with a function for silent operation that gives advantage to operate at night without disturbing people. In addition, the lesser number of compressors that can serve a lot number of FCU will contribute towards low level of noise for the entire building.

Types of Failure

The leaks especially on joints which may involve re-purging the lines with nitrogen or re-assembling flared joints. The systems must then be thoroughly evacuated, to remove all air and moisture that may take several days.

Figure 6. Leaking detected during pressurized test

Electrical, electronic and control component failures can and do occur. These can be exacerbated by vibration from fans & compressors, excessive temperatures and poor quality power supplies. Obsolescence of control boards has been an issue with some brands with early generation equipment.

A compressor failure is the most common serious problem and generally classified as electrical (compressor motor) or mechanical (compressor) failure. Assessment of the system's oil condition and physical inspection of the failed compressor provide the clues as to what may have contributed to the failure.

Root Cause

After a problem being reported in HelpDesk system, BKJ's staff with service contractor will investigates the problem on site. Among the problems reported was indoor unit is not functioning which leading the room not being cool. Most of problem occurred is due to leaking on pipe work which roots causes stemming from poor installation, poor workmanship and also poor maintenance practices. As per record, the repair cost of system leakage in Building 37 is RM7,800 in early 2015. The cost included pressurized with dry nitrogen, brazing work, retighten, vacuum work, and recharge refrigerant R-410A and also testing and commissioning.

Figure 7. Improper installed pipe due to poor workmanship

The most common cause of an electrical or compressor motor failure is due to the system's oil becoming acidic. This can happen due to undiagnosed refrigerant leaks, poor system evacuation or previous compressor failures. The acidic oil damages the electrical insulation on the motor windings and causes an electrical short. The service report is likely to say that the compressor motor is down to earth or has an earth fault. On 2014, there is a report shows that grounding on outdoor unit which connected to the building is not sufficient. Thus repair work to make grounding direct to the ground which result no more problem on electrical short that can protect Printed Circuit Board (PCB) from failure. The cost for repair work on grounding was RM18,500.

The most common cause of a mechanical or more specifically a compressor failure is lack of oil at the compressor, usually caused by sludge and blocked strainers and oil-ways within the outdoor unit. As a result, that cause mechanical damage to the compressor bearings, suction and discharge valves. The service report is likely to say 'compressor failure'. Mechanical or valve damage can only be confirmed if a compressor is cut-open for diagnosis. As per record in Nuclear Malaysia, 1 unit of compressor has been replaced with cost of RM14,400 in 2015. There is one unit of compressor that shown symptom of failure that needs to be replaced. Since that unit is rarely used due to that serviced floor which is Basement 3 is still vacant, BKJ has decided to postpone the replacement of unit.

Figure 8. The replacement work on VRV compressor in Building 37

Challenges

Physical leak detection is difficult as the refrigerant pipes are insulated, and is even harder where they are run in inaccessible or difficult to access spaces. Also leaks on internal parts of equipment, such as indoor units, can be difficult to locate without disassembly. It is almost impossible to determine how much refrigerant has been lost.
If the oil has become acidic it must be virtually completely removed from the system. To achieve this, the suction accumulators should be replaced along with failed compressors. The piping and indoor units should also be cleaned out, but this is very difficult and time-consuming. Consequently the new compressor starts out life in an acidic environment, which is likely to lead to another premature failure. If this process is allowed to repeat, a runaway trail of compressor failures is likely to result.

Mechanical damage due to chronic lack of oil or foaming oil due to low refrigerant levels will result in metal fines being released as metallic components wear excessively. These fines will block strainers within the refrigeration system which are generally non serviceable and inaccessible, causing a further lack of oil return to the compressor. As mentioned above if this process is allowed to repeat, further compressor failures are likely to result.

Precaution

During Installation of VRV system, some precaution action need to be considered as listed below:

a. The system shall be designed by a competent, experienced professional air conditioning engineer.
b. Use a supplier-approved qualified installer.
c. Use corrosion-treated outdoor units, to maximize their life.
d. Ensure isolating valves with service-ports are fitted for every indoor unit.
e. Make sure all brazing is done using nitrogen purging and at least some joints are witnessed.
f. Make sure pipework pressure tests are undertaken in accordance with the manufacturer’s recommendations and are witnessed.
g. Make sure proper system evacuations are undertaken to remove all moisture and are witnessed.
h. The system shall be commissioned by a supplier-approved agent.

Pressure testing is often omitted or carried out lower than recommended levels due to time constraint. Pressure testing pipe work and joints stresses the metals in different directions than achieved by system evacuation procedures.

Proper triple evacuation procedures must be followed and will ideally be left until a specific level of vacuum is attained rather than by time alone. Sufficient time must be allowed, particularly in cold weather for all of the moisture to be drawn out of a system. There is no short-cut to this process. It will take as long as it takes and on a large system, it could sit under vacuum for 3-5 days before acceptable results are achieved.

If a system requires repairs such as a compressor replacement or alteration work such as relocation of an indoor unit, all of the measures relating to a new installation must be followed.

CONCLUSION

VRV system requires the same level of care and attention to detail as afforded to large chillers or industrial refrigeration systems. As a conclusion, poor workmanship during installation process and insufficient electrical grounding are suspecting the causes of on-going and repeating problems occurred in Building 37, Agensi Nuklear Malaysia. Hence, Bahagian Kejuruteraan (BKJ) has worked out with service contractor to identify the main problem and leaking area before proceed with repair and commissioning activities. One of the major repair activities done was replacing the piping especially at joint area.

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