

2012

An Investigation of Refrigerant Oil Retention in an Air Conditioning System with Two Inverter Compressors in Parallel

Cheng-Shu Kuo
cshuo@itri.org.tw

Wei-Yueh Cheng

Wen-Der Hsieh

Yangguang Liu

Follow this and additional works at: <https://docs.lib.purdue.edu/icec>

Kuo, Cheng-Shu; Cheng, Wei-Yueh; Hsieh, Wen-Der; and Liu, Yangguang, "An Investigation of Refrigerant Oil Retention in an Air Conditioning System with Two Inverter Compressors in Parallel" (2012). *International Compressor Engineering Conference*. Paper 2142. <https://docs.lib.purdue.edu/icec/2142>

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

Complete proceedings may be acquired in print and on CD-ROM directly from the Ray W. Herrick Laboratories at <https://engineering.purdue.edu/Herrick/Events/orderlit.html>

An Investigation of Refrigerant Oil Retention in an Air Conditioning System with Two Inverter Compressors in Parallel

Cheng-Shu Kuo ^{1*}, Wei-Yueh Cheng ¹, Wen-Der Hsieh ¹, Yang-Guang Liu¹

¹Green Energy and Environment Research Laboratories, Industrial Technology Research Institute,
Chutung, HsinChu, 310, Taiwan

(886-3-5914252, 886-3-5820250, cskuo@itri.org.tw)

(886-3-5914211, 886-3-5820250, wycheng@itri.org.tw)

(886-3-5915386, 886-3-5820250, wdh@itri.org.tw)

(886-3-5915398, 886-3-5820250, ygliu@itri.org.tw)

ABSTRACT

A VRF (variable refrigerant flow) air conditioning, having a number of air handling units connected to an external condensing unit, commonly uses two or more compressors in the system. The complicated piping system of the VRF air conditioning causes difficulties for refrigerant oils to return back to each compressor, especially for compressors operating in different frequencies. Compressors need lubrication in operation process, otherwise the compressor will burn out because of wearing and overheating. Therefore, whether refrigerant oils can successfully return back to each compressor has become a key issue in the VRF air conditioning system. To this regard, this report studied refrigerant oil retention of each compressor operating in different frequencies in an air conditioning system with two compressors in parallel and proposed a simple strategy for the refrigerant oil retention of compressors to keep lubricants balanced in two compressors.

1. INTRODUCTION

Variable refrigerant flow (VRF) air conditioning systems with the advantages of energy-saving, comfortableness, and intelligent management have been widely applied in the buildings. The outdoor unit of the VRF air conditioning system is usually composed of two or more compressors in parallel to adjust the system for variable loadings. The advantages of applications of two or more compressors are to easily meet the requirement of drastic changes in working conditions, enhance cooling capacity of the system, lower starting current, and extend the life of the compressor. Compared to the traditional air conditioning systems, the VRF systems have longer connecting tubes with more severe problems of refrigerant oil accumulation. The excessive refrigerant oil accumulation in tubes may cause insufficient oil to back to the compressors, eventually leading the compressors to burn out due to ineffective lubrication. Therefore, the conditions of refrigerant oil returning to compressors greatly influence the performance and safety of the system. The common methods of refrigerant oil retention for compressor in parallel are (a) Oil/gas balancing method – applicable for two compressors with equal capacity in parallel, (b) Oil level control method – suitable for three or more compressors with different capacities in parallel.

For the oil/gas balancing method, the Hitachi company (Amada and Uchikawa, 1990) proposed an oil retention method for two compressors in parallel by connecting the discharge pipe of the first compressor to the high pressure chamber of the second compressor, and connecting the discharge pipe of the second compressor to the oil separator. The refrigerant oil returned back to the first compressor through the oil return pipe and then refrigerant oil of two compressors kept balanced via the oil level equalization pipe with the control by solenoid valves. The Mitsubishi company (Yamaguchi and Nakada, 1998) devised a solution for two compressors with equal capacity in parallel, modifying the refrigerant accumulator by inserting oil return pipes and suction pipes to both compressors for oil retention. The LG company (Song and Cho, 2008) filed a patent of air conditioner and controlling method for the same. Two compressors in parallel had its own individual oil retention piping system where each compressor was connected to the oil separator and then refrigerant oil returned back to the compressor via the oil return pipe. The oil

distribution pipe was installed to connect oil return pipes of these two compressors to control the oil retention of this system. The LG company (Zhang, 2009) proposed an oil-balancing system for double constant speed compressor of commercial air duct type air conditioner. The oil distribution pipes were installed at the bottom of each compressor. According to the internal pressures of compressors, refrigerant oil levels inside compressors were adjusted to keep oil retention of the system balanced.

For oil level control methods, the Hitachi company (Amata and Uchikawa, 1992) developed the capacity controllable compressor apparatus by the means of oil distribution pipes and control valves between compressors to regulate the oil level in the compressors. Once one of these compressors was shut down, the corresponding control valve was closed to prevent other compressors from losing oil levels. A patent of common oil eliminator compressor system was created by the LG company (Yang, 2008), the outlets of inverter compressor and conventional single speed compressor connected to the common oil eliminator. One outlet of the common oil eliminator was towards accumulator, inverter compressor and conventional single speed compressor through the capillary tube via the controls of solenoid valves. This setup regularly supplied the refrigerant oil for the conventional single speed compressor and adjustably provided sufficient lubricant for inverter compressor according to its working frequency. The Haier company (Zhang and Mao, 2008) filed a patent of a multi-compressor oil equalizing system. The oil drain pipe and suction pipe of compressors were connected to the bottom and top of the oil receiver, respectively. One-way valve was installed on the oil drain pipe of each compressor to prevent entrance of refrigerant oil from other compressors. This can ensure redundant refrigerant oil of each compressor directly flow into the oil receiver wherein the oil receiver re-distributed the refrigerant oil for each compressor. Daikin company (Nakajima and Takeuchi, 2008) proposed a patent of refrigerating device and method of returning refrigerating machine oil. The principle is that when compressors reach the steady state, the specific control strategy is employed to periodically adjust expansion valves to increase refrigerant flow rate such that refrigerant oil flows with refrigerant from the evaporator back to the compressors.

Above previous works employed either complicated system piping or sophisticated control strategy, mainly maintaining refrigerant oil balanced for the system operating at the regular compressor speeds. However, when one compressor operates at the high compressor speed or system loading is higher, large amount of refrigerant oil of compressors accumulate in the system piping, greatly decreasing the lubricant of the compressor operating at the high compressor speed. To this regard, whether refrigerant oils can successfully return back to each compressor has become a key issue when some compressors in the VRF air conditioning system operated at the high speed or system is subjected to the large heat loading. In this report, a VRF air conditioning system with two compressors in parallel was established to observe the variations of oil retention of compressors under different compressor speeds and opening of electronic expansion valves. Based on these observations, a new oil retention mechanism for this system was proposed to demonstrate its feasibility for the condition of compressors working in large speed differences.

2. EXPERIMENTAL SYSTEM

This study is mainly conducted on a VRF system with two inverter compressors in parallel to observe the oil retention of the system. This system was composed of two inverter compressors, an outdoor unit and three indoor units, as illustrated in the Figure 1. The refrigerant leaves from each compressor to the individual oil separator, then separated refrigerant oil back to each compressor through the capillary tube and refrigerant with few refrigerant oils flowing into the condenser through the one-way valves. By the refrigerant distributor, high pressure liquid refrigerant of the condenser entered the individual electronic expansion valve to form the low pressure refrigerant. After the low pressure refrigerant in the indoor units (evaporators) absorbed the heat, the refrigerant converged together first and thereafter diverged into two streams to back to each compressor. The piping of this system was set to be symmetric to reduce the influence of the piping on the refrigerant oil accumulation in the system. Pressure gauges and temperature sensors were installed to record the variations of all parameters of system during operations. The observation window was created on each compressor to observe the oil level inside compressor. The photograph of this system is shown in the Figure 2. The capacity of major components of this system is: each inverter compressor 3430 W, the outdoor unit 8000 W and each indoor unit 2800 W.

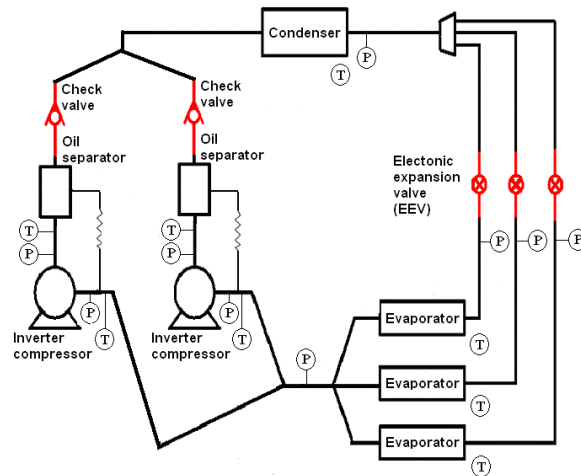


Figure 1: Experimental system for study of oil retention of a VRF air conditioning system with two inverter compressors in parallel



Figure 2: The close-up pictures of experimental system

3. EXPERIMENTAL RESULTS

The experiments for oil retention of this dual-compressor system were conducted to observe the oil levels of the compressor via CCD camera under different compressor speeds. Through the observations and analysis of experimental results, a new oil retention mechanism for this system was proposed to overcome the problems of refrigeration oil returning back to the compressors. Figures 3 to 11 illustrate the experimental observations of oil levels of the compressors under different compressor speeds (30, 60 and 80 Hz) and electronic expansion valve openings. The outdoor unit was applied by 1000 W heat load during experiments. The initial oil level of each compressor was kept the same as each other, around 4.5 centimeters high. The stable oil levels of compressors were found after the operation of 30 minutes.

Figures 3 to 5 present the experimental results of two compressors at the same speed of 30 Hz with openings of electronic expansion valve of 200, 250 and 300 pulses respectively. Figures 6 to 8 are oil variations of two compressors when the system works at the condition: two compressors at the same speed of 30 Hz and openings of electronic expansion valve at 1500, 200 and 300 pulses. Figures 9 to 11 are experimental results for two compressors at the same speed of 80 Hz with openings of electronic expansion valve of 200, 300 and 400 pulses respectively. The heat loads of the outdoor unit for those experimental tests are 1000 W. These results represent the variations in relative oil levels of compressors at different compressor speeds and electronic expansion valve openings. The oil levels at compressor speeds of 30, 60 and 80 Hz are around 3 to 4, 2 to 3 and 1 to 2 centimeters, respectively. When the compressor speeds are higher, more refrigerant oil accumulate in the system. From the observations, oil levels of two compressors were almost the same when system was kept at the compressor speed of 60 Hz under different openings of the electronic expansion valve. It is inferred that the current system piping is suitable for the compressor speed of 60 Hz. When openings of electronic expansion valve are larger, oil levels of compressors are maintained at the higher observed measurement positions. The reason for this condition is that the pressure of the low pressure side increases to assist the refrigerant oil to easily back to the compressors.

Figures 12 to 17 show the experimental observations of the system operating at the condition of two compressors at different speeds under different openings of the electronic expansion valve. The openings of electronic expansion valve for compressor speed 80, 60 and 30 Hz are combinations of 400, 300 and 200 pulses where the third opening of electronic expansion valve is maintained at 300 pulses. The heat loads of the outdoor unit for all test cases were 1000 W. The initial oil level of each compressor was about 4.5 centimeters and after half hour operation, oil level of the system reached the stable state. The test matrix for observations of oil retention of system at different unequal compressor speeds and openings of electronic expansion valves is indicated in the Table 1.

As can be seen in the Figures 12 and 13, when compressor speeds were the combination of 30 and 60 Hz, the oil levels of these two compressors can stay at the relatively higher position about 2 to 3 centimeters, less likely to lose the lubrication. The oil level of the compressor with a speed of 60 Hz was higher. It is deduced that the compressor with a speed of 60 Hz has the exceptional performance and the best operation efficiency to have the better oil retention. Figures 14 to 17 show the evident differences (more than 2 centimeters) of oil levels of compressor with larger different speed were observation during operations. The reason for the compressor speed at 80 Hz with less than 1 centimeter of oil level is that compressor speed is too high such that the refrigerant oil tends to accumulated in the system.

Table 1: Test matrix for the system operating at different compressor speeds and openings of electronic expansion valve

	Speed of left compressor	Speed of right compressor	Opening of electronic expansion valve
Figure 12	60 Hz	30 Hz	200,300,300 pulse
Figure 13	30 Hz	60 Hz	300,200,300 pulse
Figure 14	80 Hz	60 Hz	300,400,300 pulse
Figure 15	60 Hz	80 Hz	400,300,300 pulse
Figure 16	80 Hz	30 Hz	200,400,300 pulse
Figure 17	30 Hz	80 Hz	400,200,300 pulse

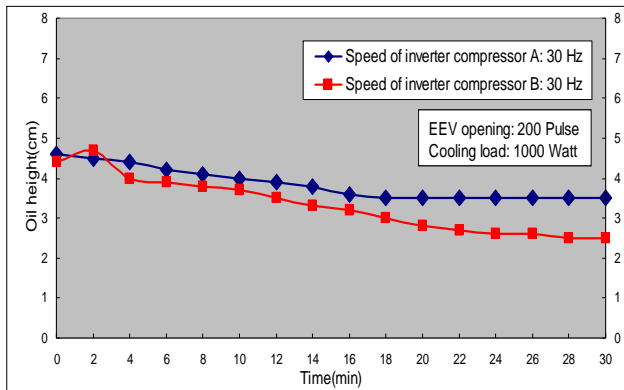


Figure 3: Experimental result: compressor speed 30Hz and opening of electronic expansion valve 200 pulse

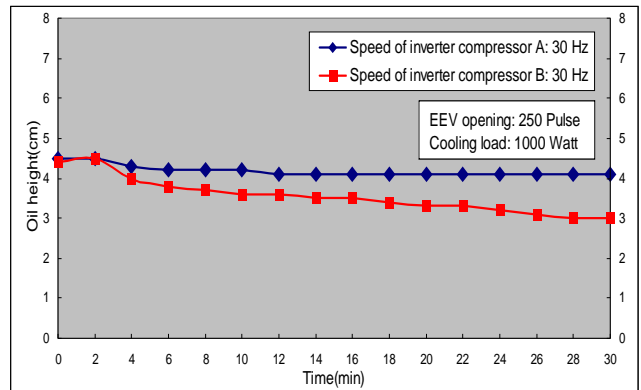


Figure 4: Experimental result: compressor speed 30Hz and opening of electronic expansion valve 250 pulse

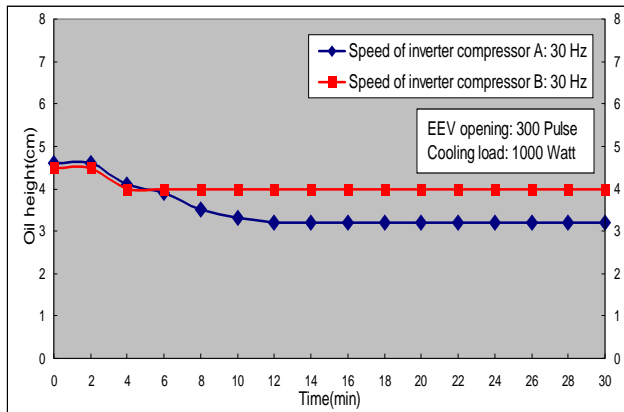


Figure 5: Experimental result: compressor speed 30Hz and opening of electronic expansion valve 300 pulse

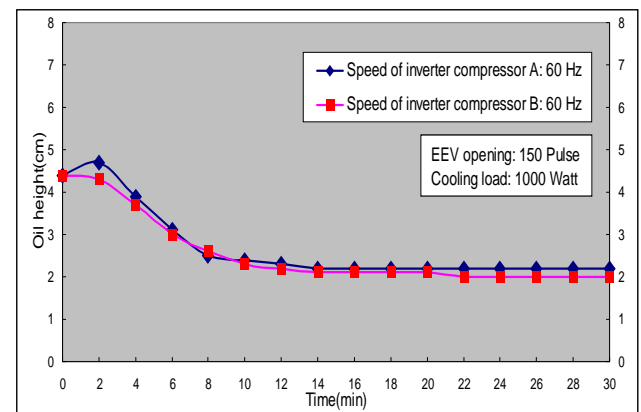


Figure 6: Experimental result: compressor speed 60Hz and opening of electronic expansion valve 150 pulse

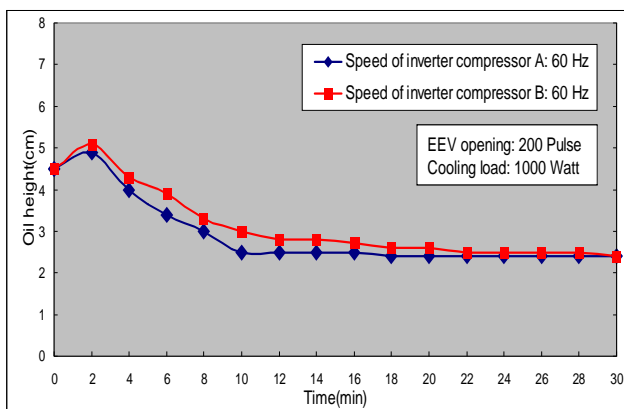


Figure 7: Experimental result: compressor speed 60Hz and opening of electronic expansion valve 200 pulse

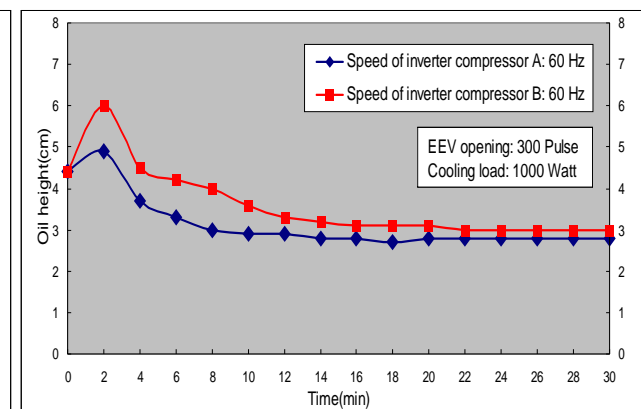


Figure 8: Experimental result: compressor speed 60Hz and opening of electronic expansion valve 300 pulse

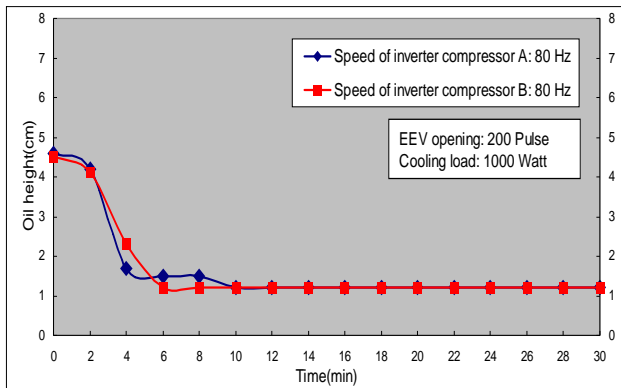


Figure 9: Experimental result: compressor speed 80Hz and opening of electronic expansion valve 200 pulse

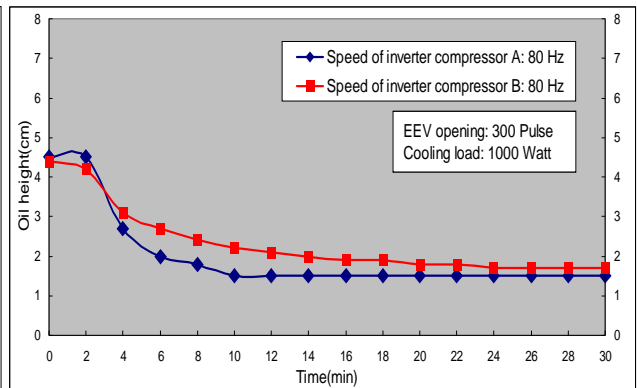


Figure 10: Experimental result: compressor speed 80Hz and opening of electronic expansion valve 300 pulse

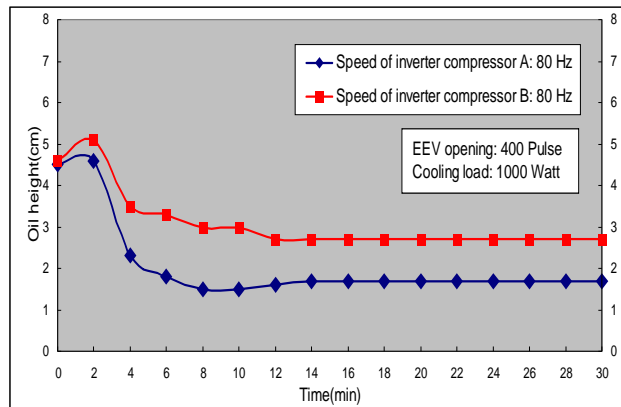


Figure 11: Experimental result: compressor speed 80Hz and opening of electronic expansion valve 400 pulse

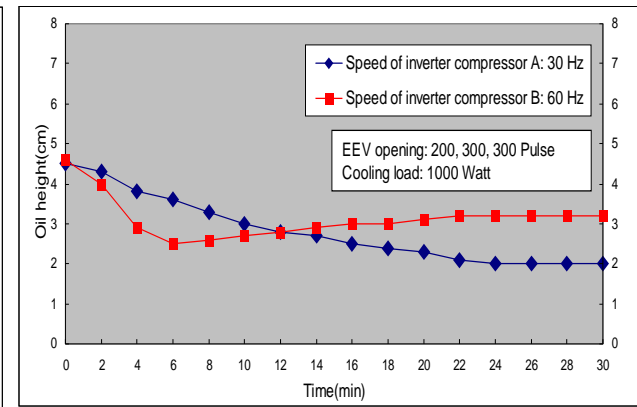


Figure 12: Experimental result: compressor speed 30Hz (right) and 60Hz (left) and opening of electronic expansion valve 200,300 and 300 pulse

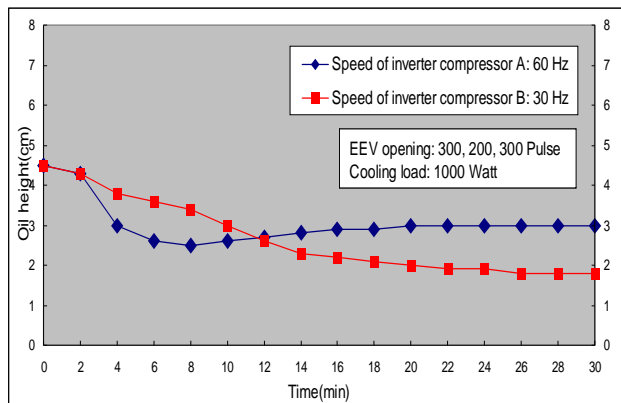


Figure 13: Experimental result: compressor speed 60Hz (right) and 30Hz (left) and opening of electronic expansion valve 300,200 and 300 pulse

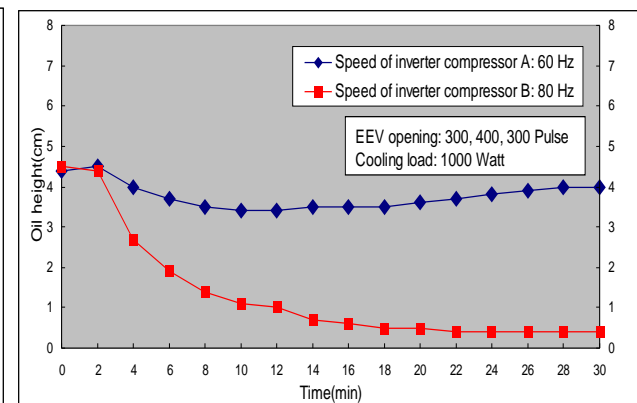


Figure 14: Experimental result: compressor speed 60Hz (right) and 80Hz (left) and opening of electronic expansion valve 300,400 and 300 pulse

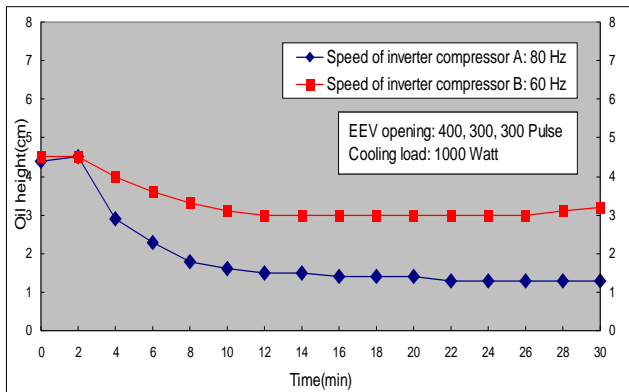


Figure 15: Experimental result: compressor speed 80Hz (right) and 60Hz (left) and opening of electronic expansion valve 400,300 and 300 pulse

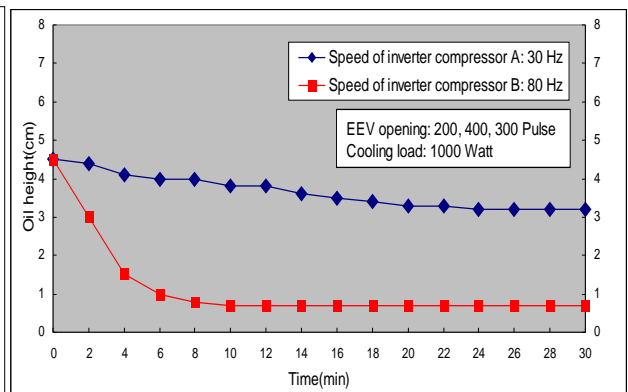


Figure 16: Experimental result: compressor speed 30Hz (right) and 80Hz (left) and opening of electronic expansion valve 200,400 and 300 pulse

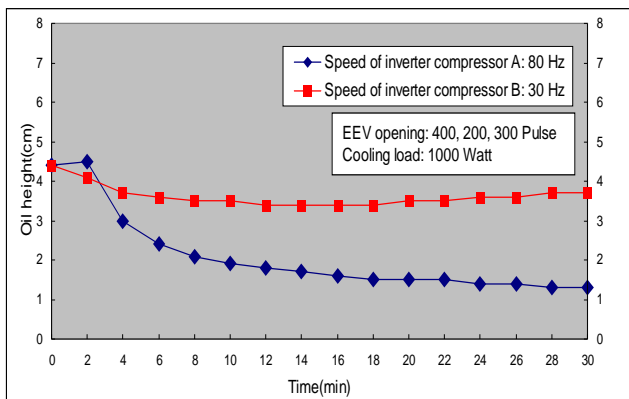


Figure 17: Experimental result: compressor speed 80Hz (right) and 30Hz (left) and opening of electronic expansion valve 400,200 and 300 pulse

Figure 18 shows the schematic of the current oil retention system design for the dual compressor. Each compressor in this dual compressor system was individually connected with an oil separator, a large amount of refrigerant oil accumulated in the oil separators and then through the capillary tubes to back to the compressors. In order to accelerate the retention of refrigerant oil to the compressors, the new oil retention apparatus was proposed by using the additional larger capillary tube between the compressor and oil separator as the oil return pipe, controlled by the solenoid valve to regulate the amount of oil retention. Figure 19 illustrates the experimental result of current oil retention system design working at the condition: speeds of the compressors of 60 Hz (right) and 80 Hz (left), openings of electronic expansion valve of 300, 400 and 300 pulses respectively. From the observation of the figure, when system worked after 10 minutes, the oil level of the left compressor was nearly 0 centimeter. At this moment, oil retention mechanism was applied to reduce the speed of left compressor to 60 Hz and open the solenoid valve. After 10 minutes, the oil level of the left compressor reached the appropriate height (about 3 centimeter) and then closed the solenoid valve, followed by increasing the speed of the left compressor to 80 Hz. This oil retention mechanism was periodically applied to control the oil retention of the compressors, maintaining the system at the normal working condition.

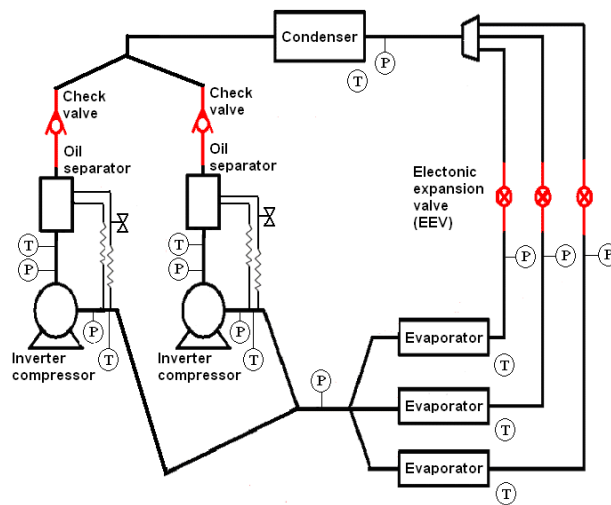


Figure 18: A new setup of oil retention system for the VRF air conditioning system

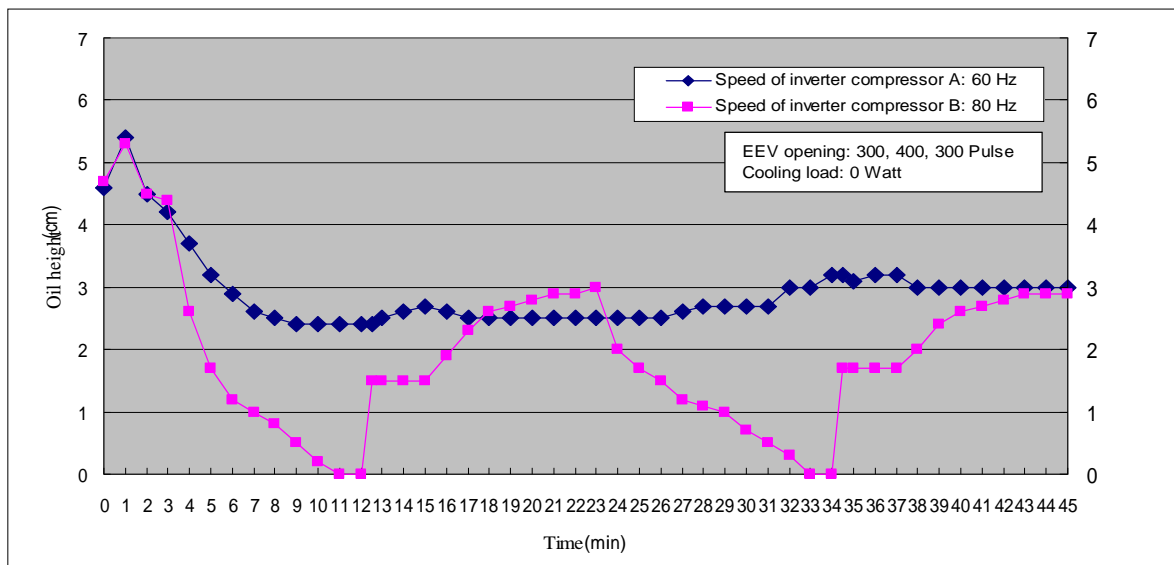


Figure 19: Experimental result of the new setup of oil retention system for the VRF air conditioning system

4. CONCLUSIONS

A VRF system with two compressors in parallel had been established to observe the oil retention of compressors under the same/different compressor speeds and different openings of electronic expansion valves. It is found that the system operating at the compressor speed of 80 Hz had the lowest refrigerant oil level, tending to lose the lubrication. Based on these observations, a new oil retention strategy was proposed by using the additional larger capillary tube between the compressor and oil separator as the oil return pipe, controlled by the solenoid valve to

regulate the amount of oil retention. The experimental results showed that this oil retention mechanism can periodically control the oil retention of the compressors, maintaining the system at the normal working condition.

REFERENCES

- Amada, A., Uchikawa N., 1990, Refrigerating device, Patent no.: JP2227570. Hitachi Ltd.
Yamaguchi, T., Nakada, H., 1998, Refrigerator, Patent no.: JP10073330. Mitsubishi Electric Corp.
Song, C.W., Cho, N.J., 2008, Air conditioner and controlling method for the same, Patent no.: WO2008044807. LG Electronics Inc.
Zhang, B., 2009, Oil-balancing system for double constant speed compressor of commercial air duct type air-conditioner, Patent no.: CN101532497. LG Electronics Inc.
Amata, A., Uchikawa, N., 1992, Capacity controllable compressor apparatus, Patent no.:US5094598. Hitachi Ltd.
Yang, Z., 2008, Common oil eliminator compressor system, Patent no.: CN101236036. LG Electronics Inc.
Zhang, X., Mao, S., 2008, Multi- compressor oil equalizing system, Patent no.: CN101290006. Haier Group.
Nakajima, H., Takeuchi, T., 2008, Refrigerating device and method of returning Refrigerating machine oil, Patent no.: JP2008138914. Daikin Ind Ltd.

ACKNOWLEDGEMENT

The authors would like to thank the Bureau of Energy of the Ministry of Economic Affairs of Taiwan for sponsoring this research work.