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CASE STUDY OF INVERTER AIR CONDITIONING LOGIC DURING OVERCHARGE REFRIGERANT

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Abstract

Preventative maintenance is a vital process for all mechanical machines. Known as routine or scheduled maintenance, it can be derived as a servicing and inspection activity aims to prevent equipment from malfunction. It is a critical process because it prevent any machines form facing a breakdown which will cause an operation interruption and disturbance. For residential air conditioning system, a routine maintenance must be performed based on the usage frequency where a higher usage means an increase in maintenance activity. There are several air conditioner system parameter need to be monitor during the maintenance activity which include refrigerant charge pressure (psi), operation current (amp), voltage (V), indoor unit supply and return temperature (°C). However, for an inverter air conditioner, additional parameter need to observing which is compressor discharge temperature (°C) and expansion valve opening value (pls). However, these additional two parameters often been neglected which cause an over-charge of refrigerant level during an invertor air conditioner system maintenance activity. An overcharge refrigerant in an air conditioning system will cause a drop in cooling capacity, increase energy consumption and shorten the lifespan of the equipment. Main objective for this study is to observe parameter changes that occur on inverter air conditioner during an overcharge refrigerant state. The observe parameter includes discharge temperature, expansion valve opening and operation current. Finding a suitable air conditioner capacity done prior of experiment start by calculating the cooling load requirements for the experiment area. Once cooling load was determined, the installation of R32 inverter air conditioner takes place and observation for overcharge refrigerant data is recorded. Based on the observations and recorded data, the compressor discharge temperature were reduced by 12%, 32% of the refrigerant flow were reduced due to the closure of the expansion valve and the compressor frequency drops by 17% when an extra 10% of refrigerant is added into the system.

Keywords: Overcharge refrigerant, inverter air conditioning, maintenance
JEL Classification: C8, Y8, O31

1. Introduction

Nowadays, air conditioning system is widely used in residential, commercial and industrial buildings as a means of treating air and to maintain and establish the require temperature (hot or cold), humidity (wet or dry), cleanliness and air motion in the building (Edward G. Pita-3rd ed., 1998). There are various type of air conditioner and the most popular among it is a split type air conditioner unit which is commonly used in residential building due to its simplicity and flexibility (M. A. S. S.A. Nada, 2017). However, due to its popularity, air conditioner has become one of the major electrical consumption appliances where it accounts of more than 50% of energy usage for a common household (Y. H. Jiangyan Liu Juanxin Chen, 2016). Since air conditioner has a high energy consumption among the household equipment (Mohsen Farzad, 1990), inverter air conditioner system was invented and introduced to reduce the energy usage for up to 40% by regulating the compressor motor speed based on room load demand. Purchasing cost of inverter air conditioner system is slightly higher compared to non-inverter unit due to several additional components such as intelligent sensor, outdoor printed circuit board (PCB), electronic expansion valve and multispeed compressor. However, the return on investment (ROI) can still be achieved by reduced electric consumption done by the inverter unit.

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In order to achieve the ROI for inverter air conditioner system a proper routine maintenance need to be conducted. There are various activites involved during an air conditioning system maintainance and one of it is to monitor the refrigerant charge level. This monitoring activity is importance because having an over-charge or under-charge level of refrigerent in air conditioning system will cause a reduction of 20% in efficiency compared to proper refrigerent level (Proctor,1996). Beside that, the efficiency of air conditioner system operate with improper charge will deteriorate from 10% to 20% (Downey and Proctor, 2002). Furthermore, according to research conduct by (Mohd Hazwan Yusof, 2018), overcharged of 20% refrigerant in air conditioning system will dropped the cooling capacity up to 11.4% and coefficient of performance 16.4% respectively. Even though monitoring the refrigerant charge level is an essential process during air conditioning system maintenance , this step is still being neglected. During the maintenance process, most of the air conditioner technician will usually pump in the refrigerant into the air conditioning system without emptying the trapped air and moisture inside the air conditioning component and piping route. As a result, the air conditioning system will produce an incorrect refrigerant pressure reading (psi), incorrect operation current reading (amp) and ultimately will shorten the lifespan of system. Furthermore, the operation of air conditioning system without going through the vacuuming process will reduce the cooling capacity, contaminate the compressor oil and leads to corrosion of air conditioning components.

As a counter measure, Department of Environment under Malaysian Ministry of Natural Resources, Environment and Climate Change has developed a training manual and Standard Operating Procedure (SOP) for air conditioning technician to cater this issue. According to the training manual, the air and moisture must be pump out from the refrigerant line (500 microns for HCFC and 200 microns for HFC) by using a vacuum pump before inserting the refrigerant into the air conditioning system. In addition, air conditioner manufacturer also provide an installation guideline on refrigerant pre-charge level for newly installed air conditioner split unit type which cater a piping system with length up to 7.5 metres. For a piping system that exceed the pre-charge length, an additional refrigerant is required and must be measured using a weighting scale to avoid over filling. The air conditioning performance is linked directly with refrigerant charge level in the system (H. M.-T. F. Poggi D. Leducq, 2008). Therefore, this study will observe the changes in parameter of compressor discharge temperature, expansion valve opening and operation current for inverter air conditioning unit during over-charge refrigerant level from 100% to 140%. The result of air conditioning parameter observe will be tabulate in table and presented for references.

The objective for this study as below:

a. To study the logic for compressor discharge temperature, expansion valve opening and operation current for residential inverter air conditioner system while running in overcharge refrigerant level.
b. To tabulate new table of data that presented inverter data parameter during overcharge for troubleshooting guidance at site and also for teaching and learning references.

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2. Methodology

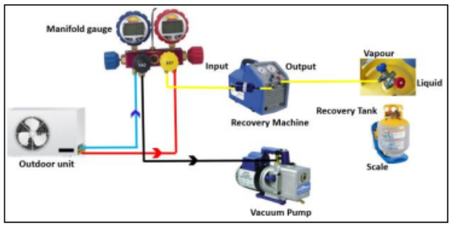

Figure 1. Recovery refrigerant setup

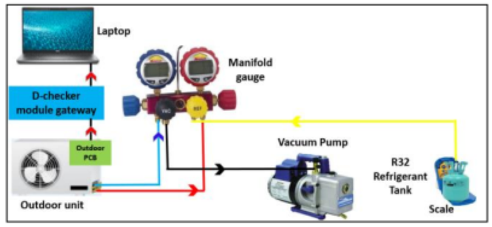

Figure 2. Refrigerant charging setup

The experiment was setup by using R32 inverter split unit air conditioner type, together with others relevant accessories and equipment as shown in figure 1 and figure 2. The study was performed by regulating the refrigerant charge level from 100% until 140% within 15 minutes. Air Conditioning & Refrigeration Institute (ARI) 210/240 standard is being applied during conducting this experiment (A.-C. & R. I. (ARI), Stand. 210/240, 2006). Prior to the experiment start, the cooling capacity requirement for the experiment's location (Metallurgy Laboratories, Politeknik Kuching Sarawak, Malaysia) was determined by using the following calculation:

Rule of thumb = Width (W) x Length (L) x Coefficient for laboratories
= 10ft x 12ft x 75btu/hr/ft2
= 9000Btu/hr @ 2.63kW

As a cooling load required for the laboratory is 9,000Btu/hr (2.63kW), the 9,100Btu/hr (2.67kW) inverter split unit air conditioner (model 2019) is selected and installed for this study. The air conditioner is using R32 refrigerant as the working refrigerant. D-checker module input wire is connected to outdoor printed circuit board (PCB) at outdoor unit of air conditioner and input wire was connected to the laptop for data collection. As shown in Figure 1,in order to get an accurate data, all the refrigerants, air and moisture inside the air conditioner system components and pipelines were pumped out using recovery machine and vacuum pump until it reach 200 microns as R32 is an HFC refrigerant type. As shown in Figure 2, by referring to manufacturer standard, 0.55kg of new R32 refrigerant will be charged into the air conditioner system while being monitored by using weighting scale and manifold gauge. In this study, five different refrigerant charges level will be tested and three fixed parameter setting is being used as shown in Table 1:

Table 1. Experiment setup parameter

Refrigerant charge (%)	100, 110, 120, 130, 140
Observe parameter	1. Compressor discharge temperature (°C) 2. Expansion valve opening (pls) 3. Operation current (A)
Temperature setting (°C)	24
Fan mode	High
Outdoor air temperature (°C)	30

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4. Result and Discussion

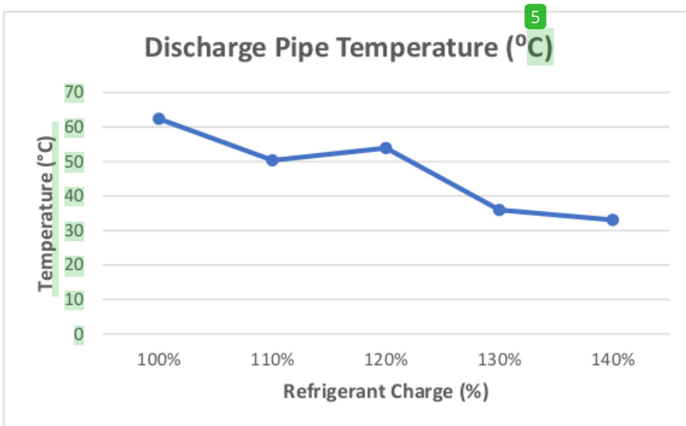

Figure 3. Compressor discharge temperature (°C) data

Figure 3 shows the average data of compressor discharge temperature (°C) in a duration of 15 minutes. The compressor discharge thermistor was located at the compressor outlet line approximately 5 cm from the compressor housing. Based on the observation, the initial temperature recorded is 62°C where it is on the optimum refrigerant charge level. The temperature keep decreasing when the refrigerant charge level is increase by 10% until it reach a value of 140%. At this level, the temperature is reduced by 46.77% with a temperature value of 33°C. Normal operating temperature for the compressor is between 60°C to 70°C. This descending temperature reading occur due to increase in refrigerant flow through the compressor. During the air conditioner system operation, the increase in refrigerant flow will result in excessive refrigerant. This excessive refrigerant will not be transform into gas phase during evaporation stage, thus it remain in liquid form. This liquid form will enter the compressor and consequently will affect the compressor suction valve function.

This negative affect from this experiment is expected as according to (Woohyun Kim, 2010), the overcharge refrigerant will reduce air conditioner lifespan, capacity for cooling or heating and overall efficiency. The increase in refrigerant volume will also reduce the superheating process in the evaporator (John Houcek, 1984). Next, based on study conducted by (John Houcek, 1984), the overcharge refrigerant will cause a slugging, motor overheating and liquid flood back which reduce oil dilution and lubrication of the components in compressor. In addition, the situation will become worse if the outdoor temperature is low and no routine maintenance is performed. Plus, liquid compression may also transpire if the capacity of air conditioner is larger than a required capacity

To counter this issue, modern residential air conditioner is equipped with accumulator at the compressor inlet that act as a temporary storage for refrigerant and to separate the liquid and vapour refrigerant. However in this experiment, it still unable to cater the excessive volume of refrigerant which indicate inserting excessive amount of refrigerant into the air conditioner is not recommended.

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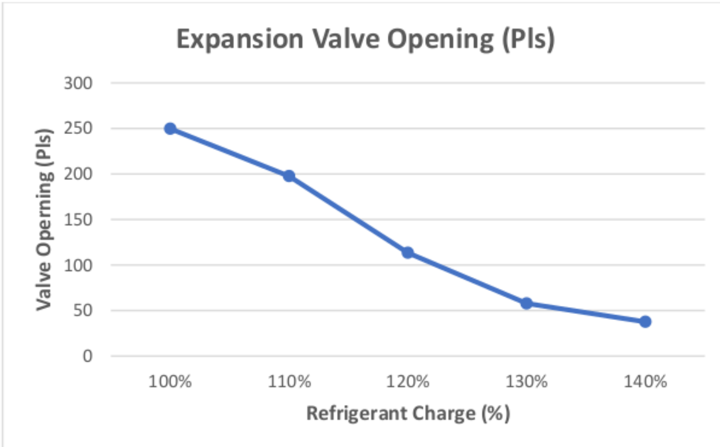

Figure 4. Expansion valve opening (Pls) data

Figure 4 shows the effect of overcharge refrigerant on the expansion valve opening pulse value (pls). As illustrated in figure above, the expansion valve pulse value (pls) shows a declining trend as the quantity of refrigerant increase. At the optimum refrigerant level (100%) setting, the expansion valve opening pulse value (pls) is at the peak with a value of 250 pls while during the highest refrigerant level (140%) setting, the pulse value drop significantly by 84.8% with just 38 pls. An increase of 10% of the refrigerant volume into a system will reduce the valve opening approximately by 50-60 pls. There are also a correlation between compressor discharge temperature with the expansion valve opening pulse value, where the value of compressor temperature is directly proportional with expansion valve value. At 100% charge setting, the compressor temperature was at 62ºC with a greater valve opening value (250 pls) and at 33ºC compressor discharge, the opening of the expansion valve is 38 pls. This phenomenon occur because expansion valve is adjusting its opening to match the target temperature and the actual discharge temperature.

Beside over charging the refrigerant level, there are other factor that contribute in a reduce value of expansion valve opening. Improper maintenance on the interior air filter and evaporator, over-sizing capacity of the air conditioner and faulty procedure during the air conditioner installation also contribute to the decrease value of expansion valve opening. Furthermore, if this conditions is still continue to exist, it will reduce the superheat value in which will reduce the lifespan of the compressor due to liquid compression phenomenon.

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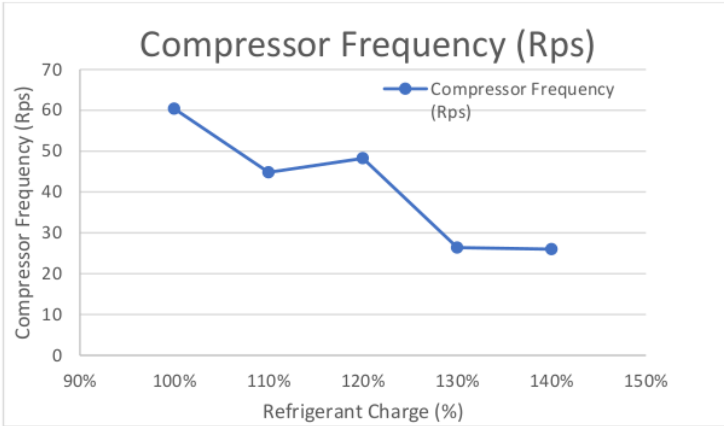

Figure 5. Compressor frequency (Rps) and temperature difference data

Figure 5 illustrate the value of compressor frequency (rps) recorded within 15 minutes for multiple refrigerant charge level. The lowest frequency recorded is at 26rps where refrigerant charge level was at 140%. The compressor frequency value will drop due to increase in pressure in the air conditioning system. During refrigerant overcharge condition, the liquid refrigerant is not vaporized completely by the evaporator. Therefore, the air conditioner system is force to operate in wet mode, where the liquid refrigerant flows through the compressor suction and damages the compressor valve. During the experiment observation, the frequency of the compressor was automatically adjusted according to the temperature differences between ambient temperature and the temperature set by the user. In other word, bigger temperature gap between ambient temperature and the set temperature will result in higher compressor frequency value and it is applicable vice versa. In addition, the same phenomena as overload refrigerant conditions also occur when there are insufficient condensation occur in the condenser, a malfunction expansion valve and a reduction of the heat load inside a room.

5. Conclusion

The current research focuses on determining the value of three different parameters of the split unit inverter system. These data can provide some information to the air conditioner technician on air conditioner characteristic during overcharge refrigerant and could be act as a guidance for troubleshooting work on the inverter system. Increasing and decreasing of refrigerant charge will give impact on the reading for each component. The summary for this case study is tabulated in Table 2:

Table 2. Case study summary

Refrigerant Charge (%)	Compressor discharge temperature (°C)	Expansion Valve Opening (pls)	Compressor (rps)
100	62	250	60
110	50	198	45
120	54	113	48
130	36	58	26
140	33	38	26

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