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A comprehensive study on the important faults in heat pump system during the warranty period

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ABSTRACT

The heat pump market has become mature in many countries. There are millions of heat pumps installed worldwide. So any improvement in the installation, operation, and maintenance of heat pump systems can save a considerable amount of energy and cost, and reduce Green House Emissions to a large extent. The present study suggests a Smart Fault Detection and Diagnosis (SFDD) mechanism as the essential part of the next generation of heat pumps. A SFDD mechanism can minimize the installation and control errors, decrease the performance degradation during operation, avoid unnecessary visual inspections and components replacement, and reduce the maintenance cost and down-time of the system. To develop a SFDD mechanism, the first essential step is to obtain knowledge about the most common and expensive faults experienced by heat pumps. The heat pump manufacturers are one of the best sources to find out the most common and costliest faults occurring in heat pump systems during the first few years of their life. The present paper, as the first part of two, describes the results from a comprehensive study done on the most recent faults which were reported to some of the heat pump manufacturers in Sweden during the warranty period. The most common and the costliest faults in the Air/Air, Air/Water, Brine/Water, and exhaust air heat pumps are presented. Some of the faults such as faulty pressure switches or fans are only related to the heat pump unit, i.e. the thermodynamic cycle which facilitates the heat pumping cycle. Some of the common and expensive faults such as faulty shuttle or shunt valve are related to the faulty components in the heating systems. Generally, the results show that faults in Control and Electronics are almost the most common and costliest faults in all types of heat pumps. Faults in Control and Electronics include any fault related to control unit, electrical faults (such as short circuit, etc.), Printed Circuit Board (PCB), display, soft starter, overcurrent and motor protection relay, etc.

Une étude inclusive des défauts importants dans le systéme de pompe á chaleur pendant la période de garantie

Mots clés : Pompe á chaleur ; Défaut ; Défaillance ; Détection des fautes ; Diagnostic

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1. Introduction

Heat pump technology provides an efficient and sustainable solution for heating and cooling of the buildings which could be otherwise heated by oil or gas boilers or pure electrical heater. When the heat pump operates in a healthy condition, there is great opportunity to save a large amount of energy and cut the global CO_2 emissions. Bettgenhäuser et al. (2013) predicts that the CO_2-eq emissions will be reduced by 40% if 50% of all new buildings and 30% of retrofitted buildings are equipped with heat pumps in 2030.

There are millions of heat pumps installed worldwide. In Sweden alone, it is estimated that over one million heat pumps have been installed. The market value of the heat pumps insta lled in Sweden alone is estimated to be approximately 1 billion euro, excluding the maintenance cost (Forsen, 2012). The market share of heat pumps for the current and newly built single family houses in Sweden is 50% and 90%, respectively (Ibid). So any improvement in the installation, operation, and maintenance of heat pump system can save a considerable amount of energy and cost, and reduce Green House Emissions to a large extent.

However, it is not uncommon for the heat pump systems to operate with lower system efficiency than the typical efficiencies measured at standard conditions in manufacturers' laboratories. Sometimes, a poor installation or control error can lead to the performance degradation of the whole system to a large extent.

Furthermore, there have been several heat pump faults reported to the insurance companies or heat pump manufacturers during 2010–2012. A considerable number of these faults are associated with confusion for the servicemen, long down-time for the system and unnecessary component replacement. These consequently might end up with some unnecessary costs for the end-customer, heat pump manufacturer, and insurance company which could have been avoided if smart procedures were used.

Therefore, a Smart Fault Detection and Diagnosis procedure (SFDD) is suggested by the author as the solution to the problems mentioned. A SFDD system as the heart of a smart heat pump is able to minimize the installation and control errors, decrease the performance degradation during operation, avoid unnecessary visual inspections and components replacement, and reduce the maintenance cost and down-time of the system.

Fault Detection and Diagnosis for heat pumps or vapor compression chiller were investigated by Zogg (2002); Zogg et al. (2006); Chen and Lan (2009); Kim et al. (2009, 2008); Navarro-Esbri et al. (2006); Choi et al. (2012); Rossi and Braun (1997); Li and Braun (2007). For example, Zogg (2002) and Zogg et al. (2006) presented a FDD system for heat pumps based on a gray-box process model whose parameters are identified online. The faults are classified from the parameters using "vector clustering" technique. Chen and Lan (2009) developed a PCA-based (Principal Component Analysis) fault detection method to detect the faults in air-source heat pump. Kim et al. (2009) implemented seven artificial faults on a R410A residential unitary split heat pump operating in the cooling mode. The study monitored several fault detection features and identified the most sensitive features for each fault (Ibid).

To develop a SFDD mechanism, the first essential step, which is usually missing in the previous studies, is to obtain knowledge about the most common and costliest faults in the heat pumps. To design an efficient SFDD system, it is very important to know what usually cause the faults in the heat pump system and what kind of faults are expected be detected and diagnosed by SFDD system. The heat pump manufacturers are one of the best sources to find out the most common and costliest faults occurred recently in the heat pump systems. The present paper, as the first part of two, describes the results from a comprehensive study done on the most recent faults which were reported to some of the heat pump manufacturers in Sweden.

2. Methodology

Approximately, 68,000 fault reports which were sent to several heat pump manufacturers during the warranty period are collected and processed (see Table 1). Some of these reports were real fault in the system and some of them were some complaints, for example about the noise in the system. About 8600 fault reports are not clear enough to be analyzed; about 4300 fault reports do not mention the type of the heat pump which makes it hard to interpret; so these unclear and uncompleted fault reports are excluded from the study. It is very important to know the faults in the most recent models of heat pumps. The old fault reports usually refer to the problems which are already known and solved during the recent years; so approximately 18,000 faults which were reported before 2010 are also excluded from this study. Therefore, about 37,000 faults reported to the Heat Pump Manufacturers, called OEMs, from the beginning of 2010 to the end of 2012 are analyzed and the results are presented in the following section.

While the number of Brine to water heat pumps i.e. Ground Source Heat Pumps (GSHPs) which are sold in Sweden between 2010 and 2012 are considerably higher than the Air/Air or Air/Water heat pumps, the number of fault reports in the present study is the highest for the Air/Water heat pumps. It should be mentioned that the number of fault reports studied in the present paper cannot give any indication about the quality of different types of heat pumps. Due to the fact that the present study does not cover all the faults reported to the heat pump manufacturers in Sweden, it is not possible to say in general which type of heat pump has the highest or lowest number of faults.

3. Results

3.1. *Air/Air heat pump system*

Only in Sweden, over one hundred thousand air/air heat pumps are sold during 2010–2011 (two years). This type of

Table 1 – Number of faults analyzed in the present study.

Total number of fault reports received	Number of fault reports with missing key info	Number of fault occurred before 2010	Total number of faults analyzed in this study
67,952	12,984	17,895	37,037