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Fault Detection and Diagnosis Process for Oversizing Design on Multiple Packaged Air-conditioning Units

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Abstract

Heating, ventilation, air-conditioning and Refrigeration (HVAC&R) systems are seldom designed or commissioned properly. The situation leads to abrupt or degradation faults resulting in inefficient energy uses, excessive energy consumption and high service costs. To solve these aforementioned problems, fault detection and diagnosis (FDD) is utilized to firstly detect any abnormal conditions of a system and then diagnoses and determines their causes. In order to apply this concept in HVAC oversizing designs, this paper proposes the state-of-art procedure of a FDD procedure for analyzing the inherently faulty design (oversizing) of multiple packaged air-conditioning units used to supply cooling for an open space in light commercial buildings. A generic process of FDD for a packaged unit is briefly introduced to efficiently design FDD algorithms and to illustrate an overview picture for new researchers in FDD areas. In the procedures, compressor statuses, time-on and time-off operations and outdoor air temperatures are recorded by means of the on-board controller of each machine unit. These physical and electrical monitoring data are applied to diagnose and evaluate oversizing level in terms of runtime fraction (RTF) and cycling rate (N). Eventually, an adaptive control is designed and implemented to enhance process recovery for soft-repairing and permanently reducing fault effect caused by oversizing without intervening system operations (non-invasive technology).

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Keywords: Fault Detection and Diagnosis; Multiple Packaged Air-conditioning Units; Oversizing, Process Recovery; Runtime Fraction

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1. Introduction

Packaged air-conditioning units or rooftop units (RTUs) are intensively used to provide heating or cooling for thermal comfort purpose in the U.S. At least around 2 problems occur in routine operations of each unit [1]. These mentioned fault examples are caused by routine operations, field commissioning, installation and maintenance. To prevent these happenings, automated fault detection and diagnosis (FDD) has been intensively developed as embedded intelligence for two main reasons: improved safety (e.g. nuclear power plant, aircraft and chemical process plant) and decrease of operational cost in terms of service and utility costs (HVAC&R). In the first objective, safety is mainly concerned, so expensive sensors and electronics can be utilized within FDD to achieve this goal. Meanwhile, ensuring safety is not the first priority in HVAC&R applications; it is mainly used to improve productivity in terms of equipment efficiency and better thermal comfort and to reduce operating costs and potentially schedule maintenances. Conducting the second goal on HVAC&R systems, low-cost sensors, on-board controller data and manufacturers' data are used to efficiently develop virtual sensors for extending limited measurement data and for physical reducing sensor costs to monitor the health of equipment, diagnose problems, and recommend service. FDD are multi processes performing as a series of three distinct functional procedures including: fault detection, fault diagnosis and process recovery, in which fault diagnosis is combined fault identification with fault isolation, and process recovery is involved with fault evaluation, decision and action as shown in Fig.1.

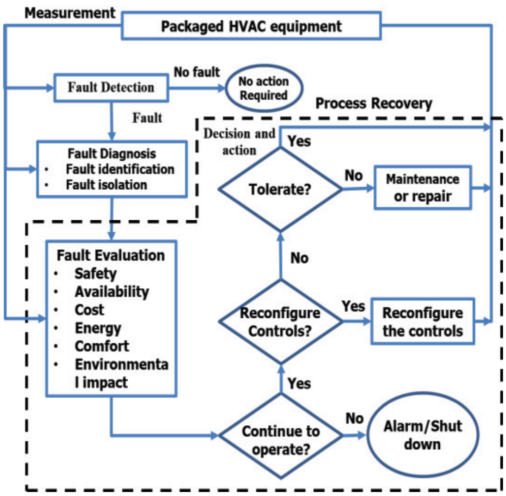

Fig. 1 Generic procedure of FDD to unitary HVAC equipment

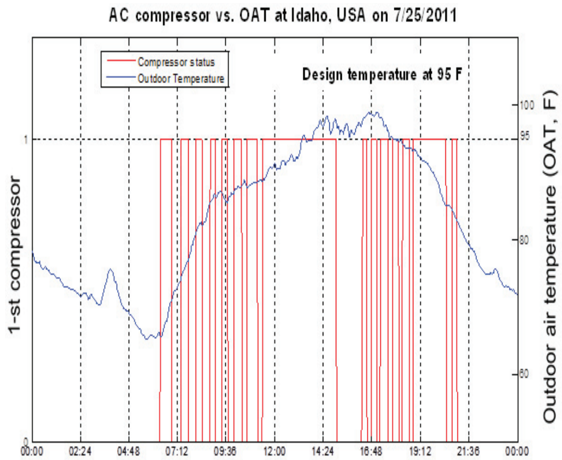

Fig. 2 Oversizing characteristics of a single-stage oversizing RTU compressor

Generally, faults in a packaged air-conditioning unit can be classified into abrupt faults (hard faults or failure) and degradation faults (soft faults). The first type happens immediately without system warning from conventional sensors; it is required to stop a process for an immediate repair such as compressor failure, control related faults and electrical faults. Meanwhile, soft faults are caused by non-optimal design and fault operations; they are not cost effective to be repaired immediately if the severity level is not high enough resulting in degraded system performance, but allow continued operation of the system. For example, there are oversizing, faulty control and typical hardware faults (e.g. incorrect refrigerant charges, drifted sensors, non-condensable, liquid-line restriction, evaporator fouling and condenser fouling). The impact of non-optimal design and faulty operations can be minimized or mitigated by adaptive controls called "soft-repair" before they are physically repaired. Most previous researchers have been continuously considering the typical hardware faults to protect later catastrophic equipment failure. Literature indicates that a few researches considered faults occurred by unsuitable design or oversizing design which is inherent behavior because at least 25% of actual cooling load are acceptably over designed to ensure adequate cool and heat in the hottest and coldest period by HVAC designers [2]. However, from field data analysis, oversizing can reach to around 100% [3]. This paper systematically presents the state-of-art process of a FDD