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An integrated model for the design of air-cooled chiller plants for commercial buildings

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ABSTRACT

Cooling load calculation is the first step in designing the air-conditioning system of a building. The calculated cooling capacity with appropriate buffer is then used to select the number and size of chillers in the system. N + 1 is a common formula used by designers to size the chiller plants in Hong Kong buildings, where N is the actual number of chillers required and 1 is a redundant chiller provided to ensure reliability. This paper reviews the problem of excess capacity and discusses the risk exposure of chiller systems without redundant chillers. The cooling load profiles of the chiller plants of four medium-sized commercial buildings in Hong Kong are reviewed. The risk exposure of chiller systems without redundant chillers can be minimized by applying risk-based preventive maintenance. The just-in-demand design reduces capital cost of the building and frees up funds for continuous energy measurement and improving the energy efficiency of chiller plant systems. This paper presents a model for designing chiller plants that improves the energy efficiency of the plant in a cost effective and thoughtful manner. It is designed with consideration of the life cycle of the plant and real-time continuous commissioning, monitoring, measurement, comparison and execution for better energy management.

1. Introduction

The first step in designing a heating, ventilating and air-conditioning (HVAC) system of a building once the built environment and operational parameters have been taken into account is to calculate the cooling load. Electrical and mechanical (E&M) consulting engineers are responsible for calculating the cooling load capacity and specifying the equipment needed. In Asia, it is common for construction and design to occur at the same time. Compressed construction schedules mean that the design of cooling systems is usually quick and expedient, and often based on rules of thumb. Even with computer modeling, consulting engineers calculate the calculated cooling capacity with large safety margins for fear of liability should a shortage of cooling capacity occur due to changes in the practical operating situation. To ensure the reliability of cooling systems, redundant chillers are installed to safeguard the cooling capacity should one of the chillers fail at peak demand. Consequently, the chiller plant is frequently bigger than needed [1]. In fact, most the chiller plant is only operated at peak demand for a few months of the year. The provision of redundant chillers to increase the reliability of the chiller plant is comparatively expensive, and permits service and maintenance personnel to allow the chillers to break down. This means that only basic routine maintenance is carried out and limited resources are allocated to the maintenance and operation of the chiller plant. However, if redundant chillers were not supplied, then a stringent maintenance strategy would be necessary to maintain the reliability of the chiller plant. A more cost effective way than providing redundancy cooling capacity may be to upgrade the capacity of the independent refrigeration circuits of air-cooled chillers to an optimized level.

The operation of chillers creates peak electricity demand and accounts for about a quarter of the total electricity consumption of commercial buildings in sub-tropical climates [2,3]. It is essential to understand the energy efficiency or coefficient of performance (COP), of these chillers to reduce the electricity demand. However, without the installation of basic measuring equipment and chiller plant control (CPC) systems, carrying out energy audits is difficult and can be inaccurate.

Four medium-sized commercial buildings that use air-cooled screw chillers were studied to determine the extent of excess capacity in air coolant systems. Buildings with air-cooled screw chiller plants were chosen because of their prevalence in Hong Kong and the characteristics of the independent refrigeration circuits in air-cooled screw chillers. Although the Hong Kong government relaxed the restrictions on the use of fresh water for

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