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Computational simulations and optimization of flow and temperature distributions in a large-scale power plant building

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Research Article

Abstract

For reduced carbon dioxide and pollutant emission, it is often as effective, if not more, to minimize energy use on the consumption side, as to maximize the efficiency on the power supply side. In this study, we seek to fully characterize and optimize the heating, ventilation, and air conditioning (HVAC) electrical energy use in a large-scale structure: a power-plant building that houses boilers, turbines and other operating equipment. We use a fully three-dimensional computational fluid dynamics (CFD) model of this building, measuring 80 m in width, 120 m in length and 60 m in height, replicating the complex internal and external geometries, in order to simulate the flow and temperature distributions under a wide range of ambient and HVAC operating conditions. The flow patterns and temperature distributions in this building structure are computationally simulated in detail, wherein the computed temperatures are validated through spot measurements. The detailed understanding of the flow patterns and temperature distributions then allows for optimization of the HVAC configuration. Identification of the problematic flow patterns and temperature mis-distributions, leads to some corrective measures, for optimization of the temperature distributions. The basic principles of fluid mechanics and heat transfer, applied in conjunction with CFD simulation results, can result in substantial improvements under both hot- and cold-weather conditions, in most cases with relatively simple, implementable modifications.

Keywords

CFD,
HVAC,
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optimization,
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1 Introduction

For reduced carbon dioxide and pollutant emission, it is important to develop or improve upon the electrical power generation methods. As important is the energy conservation on the consumption side. Roughly, one-third of the United States energy consumption occurs in the residential and commercial buildings (United States Global Change Research Program 2010), most of it in the heat, ventilation, and air conditioning (HVAC). Nearly all of this energy consumption is in the electrical power. Due to a number of reasons, such as the age and degradation, off-design operations, and poor insulation, the HVAC operation in many instances is less than optimal. In some large-scale buildings, such as a power plant considered in this study, the internal electrical energy use can add up to a significant amount, frequently occupying a large fraction of the operational cost. For the Coronado Generating Station (located at St. Johns, Arizona, USA) under consideration in this study, the internal electrical energy use is 11% out of the 435 MW gross generation capacity. During operational planning, optimization of the HVAC is often overlooked, adding to the overall system inefficiency. In this work, we use a fully three-dimensional model of the power plant building by reproducing its internal and external geometries, in order to computationally simulate the flow and temperature distributions under a wide range of ambient and HVAC operating conditions. The detailed understanding of the flow patterns and temperature distributions then allows for optimization of the HVAC configuration (vent location, flow direction and vent airflow rates and temperatures).

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