PhD Dissertation Defense Announcement
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ASSESSMENT OF CONTAMINANT FLOWPATHS IN AIRSIDE ECONOMIZATION AND ANALYSIS OF THERMAL PERFORMANCE AT TANK AND SERVER LEVEL FOR SINGLE-PHASE IMMERSION COOLED DATA CENTERS

By

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Teams Link

Abstract

The last two decades of 2000 have seen a remarkable increment in utilization and reliance on digital technologies and platforms. During this time, electronic devices have undergone intense miniaturization and a corresponding rise in power densities. The primary bottleneck, however, due to extensive device miniaturization and data center proliferation has always been thermal management. Air-cooling has been the most popular method of data center thermal management but is limited to low power processors since the cost and energy consumption to pump air for high power density racks becomes very large. As a result, data center administrators have resorted to energy-efficient air-cooling techniques like Direct/Indirect Airside Economization and Free Air-cooling. Although these technologies aid in alleviating the concerns of high energy consumption they also have an inherent risk of exposing the IT equipment to harmful airborne particulate and gaseous contaminants.

The first part of this research investigates the distribution of these airborne particulates inside the IT equipment and data center space with the help of particle tracking using Computational Fluid Dynamics. This investigation aims at carrying out simplified modeling 3-D and 2-D models of data center space and IT Equipment with known boundary conditions of the airflow. Particle tracking models of a commercial CFD code are used to simulate the behavior of a known particle mass in the airflow. Analysis of the most vulnerable locations of particle deposition is made by assessing the regions with higher particle concentrations. Similarly, regions of high particle concentration are identified inside the IT Equipment for different server configurations and different inlet boundary conditions. The CFD methodology presented in this study can be leveraged during the data center infrastructure design phase and also during the server mechanical design phase to minimize the particulate accumulation inside the servers.

The second part of this study focuses on the design optimization of heat sinks and the analysis of the thermal performance of servers at the tank level in single-phase immersion cooling. An in-depth numerical study on different multi-parametric and multi-objective optimization methodologies for heat sinks is conducted using OptiSLang for forced and natural convection for an open compute server design. The optimization results quantify the dependency of each of the geometric parameters of the heat sink on the objective functions. It is observed that this dependency varies for both natural and forced convection and also on the heat sink material. The impact and participation of mixed convection heat transfer for optimized and baseline heat sink are also analyzed in pure natural to highly forced flow. At the tank level, a numerical study is proposed to analyze the impact of flow boundary conditions inside the immersion tank on the thermal performance of the immersed servers. This is done by designing and analyzing various possible distribution manifold configurations for an immersion tank and monitoring the ability of the manifold design in providing a uniform flow rate to each server in the tank. To analyze the impact of the manifold design on server thermal performance, a detailed model of a single server and manifold is numerically analyzed. The manifold configurations assessed at the tank level are used to observe the influence of flow distribution inside the server. Conclusions on which manifold configuration is superior are made by determining the CPU thermal performance.