Mechanical Engineering Doctoral Defense

Modeling, Experimentation, and Analysis of Data Center Waste Heat Recovery and Utilization

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abstract

Increasing computational demands in data centers require facilities to operate at higher ambient temperatures and at higher power densities. Conventionally, data centers are cooled with electrically-driven vapor-compressor equipment. This paper proposes an alternative data center cooling architecture that is heat-driven. The thermal source is heat produced by the computer equipment.

This dissertation details experiments investigating the quantity and quality of heat that can be captured from a liquid-cooled microprocessor on a computer server blade from a data center. The experiments involved four liquid-cooling setups and associated heat-extraction, including a radical approach using mineral oil. The trials examine the feasibility of using the thermal energy from a CPU to drive a cooling process. Uniquely, the investigation establishes an interesting and useful relationship simultaneously among CPU and system temperatures, thermal power, and utilization levels. In response to the system data, this project explores the heat, temperature and power effects of adding insulation, varying water flow, tasking the CPU, and varying the cold plate-to-CPU clamping pressure. The aim is to provide an optimal and steady range of temperatures necessary for a chiller to operate. Results indicate an increasing relationship among CPU temperature, thermal power and CPU tasking. Since the dissipated heat can be captured and removed from the system for reuse elsewhere, the need for electricity-consuming computer fans is eliminated. Thermocouple readings of CPU temperatures as high as 93 °C and a calculated CPU thermal energy up to 67 Wth show a sufficiently high temperature and thermal energy to serve as the input temperature and heat medium input to an absorption chiller.

This dissertation performs a detailed analysis of the exergy of a processor and determines the maximum amount of energy utilizable for work. Exergy as a source of realizable work is separated into its two contributing constituents: thermal exergy and informational exergy. The informational exergy is that usable form of work contained within the most fundamental unit of information output by a switching device within a CPU. Exergetic thermal, informational and efficiency values are calculated and plotted for our particular CPU. The dissertation concludes with a discussion of the work's significance.

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