CONTROL ORIENTED DYNAMIC MODELING OF VAPOR COMPRESSION CYCLES FOR ELECTRONICS COOLING

By

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ABSTRACT

The increasing power density of high-performance electronics has created a need for advanced thermal management strategies. Vapor compression cycles (VCC) offer large heat transfer coefficients via low coolant temperatures and boiling heat transfer, and thus are attractive for electronics cooling. However, the high heat flux imposed by electronics requires new modeling and control techniques for VCC implementation. Challenges include transient heat loads, critical heat flux (CHF), refrigerant charge distribution, and multi-evaporator management. Previous efforts have sought to avoid CHF during transient heating conditions via actuating an electronic expansion valve (EEV) and variable-speed compressor with proportional-integral (PI) feedback control. Such strategies are temporarily effective, yet neglect the loop charge distribution dynamics that dominate long-term stability. To address this concern, the dynamics of a heated accumulator placed in the suction-line were added to a low-order, lumped element VCC model. The new model offers higher fidelity by accurately predicting refrigerant distribution throughout the VCC, and the inclusion of accumulator heating as an actuator provides a means for controlling charge distribution. Additionally, the model is expanded to handle multiple evaporator lines placed in parallel. Model simulations are validated against experiments, showing sufficient agreement to aid in model-based multi-input multi-output control design. Control strategies for steady-state efficiency optimization as well as transient heating CHF avoidance are discussed.