Customization Process for Energy-Saving Passive Components for IDC Data Centers



Overview

Towards energy-efficient data centers: A comprehensive review of. In summary, this paper provides an overview and guide to DC energy-consumption issues.

Key Takeaways

Customizing passive components for energy-efficient IDC data centers involves selecting materials, testing for thermal and chemical compatibility, and integrating advanced cooling designs like two-phase or immersion systems.

Material Selection and Compatibility Testing

The first step in customization is selecting materials that can withstand the operational environment of the data center. For immersion cooling systems, passive components must be compatible with non-conductive coolant liquids to prevent chemical reactions and maintain electrical reliability over prolonged exposure. Companies like TDK conduct conformity and compatibility tests to ensure components such as capacitors, resistors, and inductors remain stable in immersion liquids, providing test reports to guide customer-specific customization requests.

Thermal Management IntegrationEnergy-saving passive components are often integrated into advanced thermal management systems. Intelligent Data Centers (IDCs) use digital twin platforms to monitor real-time temperature distributions and optimize cooling strategies. Passive components can be customized to work with Deep Q-Learning Network (DQN)-based thermal management, ensuring hotspots are efficiently cooled while minimizing Power Usage Effectiveness (PUE),.

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This integration allows components to contribute to overall energy efficiency without active power consumption.

Advanced Cooling Designs

Customization also involves designing passive components for specific cooling methods: Two-phase cooling: Components are designed to facilitate phase-change heat transfer, removing heat without pumps or fans. 3D-printed passive cooling elements have been developed to achieve high cooling capacities (e.g., 600 W) while enabling heat reuse for district heating or industrial applications. Immersion cooling: Components must be chemically and electrically compatible with immersion fluids, and their geometry may be optimized for direct contact with coolant to maximize heat transfer.

Cold plates and direct-to-chip solutions: Passive components can be integrated into cold plate assemblies or thermal interface materials (TIMs) to enhance heat dissipation at the micro-level, supporting high-TDP chips like GPUs and AI accelerators.

Testing and Validation

After design, rigorous testing ensures reliability and energy efficiency: Thermal cycling and stress tests simulate operational conditions. Chemical compatibility tests verify long-term immersion stability. Performance benchmarking evaluates energy savings and cooling efficiency against standard metrics like PUE.

Iterative Customization Process

The customization process is iterative: Define operational requirements (power density, cooling method, environmental conditions). Select materials and passive component types. Design geometry and integrate with cooling systems.

Conduct compatibility and thermal performance tests. Refine design based on test results and digital twin simulations.

Deploy in ID

C prototype and monitor real-time performance for further optimization.

Conclusion

Customizing energy-saving passive components for IDC data centers requires a holistic approach combining material science, thermal design, and intelligent system integration. By leveraging immersion or two-phase cooling, digital twin simulations, and rigorous testing, data centers can achieve significant energy efficiency improvements while maintaining component reliability and supporting high-performance computing workloads.

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