

Abstract

A multi-sensor monitoring system is disclosed for proactive electrical and thermal infrastructure management in high-density computing environments and in utility-scale power-transmission and distribution assets.

. The system integrates three interdigitated electrode (IDE) based sensor modules and a central processing node. A flexible IDE strip sensor attaches to high-voltage DC busbars to detect incipient partial discharges in the pico-coulomb range, using built-in amplification, filtering, and scoring to flag insulation degradation. An impedance-sensing module with IDE pairs on a PCB performs multi-frequency sweeps (approximately 10 Hz–10 kHz) to measure the equivalent series resistance (ESR) and capacitance drift of energy storage elements (such as UPS supercapacitors or battery cells), enabling early detection of performance degradation. A dielectric purity probe, shaped like a bookmark with IDE traces, immerses in the coolant of liquid-cooled data-center equipment to monitor dielectric constant and ionic contamination (e.g. water ingress or dissolved ions) via changes in capacitance and conductance. A central processing node aggregates time-stamped data from all sensors, applies calibration corrections and threshold algorithms, and communicates health status and alerts to building management or Data Center Infrastructure Management (DCIM) systems. A fourth IDE-based leakage-current module clamps non-invasively around energized conductors or ground shields to measure sub-milliamp stray currents (50 / 60 Hz AC or \pm HVDC) and incipient ground faults on overhead lines, underground cables, pad-mounted transformers and switchgear.

The invention provides a comprehensive, real-time monitoring solution to improve the reliability and safety of power distribution, energy storage, and cooling systems in mission-critical facilities.