# Claims

1. A multi-sensor monitoring system for electrical power distribution and cooling infrastructure, comprising:

    - a partial discharge sensor comprising an interdigitated electrode strip disposed adjacent to a high-voltage busbar, and a supporting circuit configured to detect high-frequency transient pulses indicative of partial discharge events on the busbar;

    - an impedance sensing module comprising a printed circuit board with at least one pair of interdigitated electrodes connectable across an electrochemical energy storage device, a signal generator that applies multi-frequency AC excitation (in a range of about 10 Hz to 10 kHz) to the device, and a measurement circuit that determines the device's equivalent series resistance and capacitance from the electrical response;

    - a dielectric fluid purity probe comprising a substrate with interdigitated conductor traces arranged to be immersed in a dielectric coolant, and a sensor circuit configured to measure a capacitance and conductance of the coolant between said traces, thereby detecting changes in coolant dielectric constant and ionic contamination;

    - a central processing node communicatively coupled to the partial discharge sensor, the impedance sensing module, and the fluid purity probe, the central node being configured to aggregate and time-stamp sensor data, apply calibration corrections and threshold criteria to the data, and transmit status information or alerts to an external management system.

2. The system of claim 1, wherein the central processing node comprises a network interface for communicating sensor measurements and alarm notifications to a building management or data center infrastructure management (DCIM) system.

3. A partial discharge monitoring device for a high-voltage DC busbar, comprising:

    - a flexible insulating substrate carrying an interdigitated electrode pattern, the substrate being shaped to attach along a surface of the busbar and the electrode pattern being capacitively coupled to the busbar to pick up partial discharge signals;

- an amplifier and filter circuit connected to the interdigitated electrode pattern, the circuit being tuned to amplify high-frequency current or voltage pulses generated by partial discharge activity;

- a processing unit configured to receive a filtered signal from the amplifier and to detect partial discharge events based on the signal, the processing unit further computing an indicator of partial discharge magnitude or repetition rate;

- an output interface to communicate partial discharge data or alarms to a central monitor.

4. The device of claim 3, wherein the flexible substrate is a polyimide film and the interdigitated electrodes are metal traces on the film, the device further comprising an adhesive or clamping means to secure the film to the busbar such that the electrode traces lie in close proximity to the busbar's surface.

5. The device of claim 3, wherein the amplifier and filter circuit includes a band-pass filter centered in the MHz-range to isolate partial discharge pulses, and wherein the processing unit is a microcontroller programmed to count discharge pulses and calculate an anomaly score over time.

6. An impedance monitoring module for an electrochemical capacitor bank or battery, comprising:

   - a pair of terminals or interdigitated contacts arranged to connect across a cell or module under test;

   - a frequency sweep generator configured to apply an AC test stimulus across the pair of terminals at a plurality of frequencies between approximately 10 Hz and 10 kHz;

   - a measurement circuit that senses the voltage and current through the cell or module in response to the test stimulus at each frequency;

   - a controller that calculates the cell's impedance spectrum from the measured responses and determines at least an equivalent series resistance value and a capacitance value of the cell, and that compares those values to predetermined baseline values to assess a state-of-health of the cell;

   - a communication interface for reporting the impedance or state-of-health data to a central system.

7. The module of claim 6, wherein the controller triggers a fault indication if the measured equivalent series resistance exceeds a threshold indicative of end-of-life (approximately

a 100% increase over an initial ESR) or if the measured capacitance falls below a threshold (approximately 80% of an initial capacitance) .

8. A dielectric coolant purity sensor, comprising:

    - a probe including a non-conductive body and a set of interdigitated electrode traces exposed on a surface of the body, the probe being adapted to be submerged in a liquid cooling fluid;

    - a sensor excitation and readout circuit coupled to the electrode traces, the circuit applying an electrical signal to the traces and measuring an electrical property of the fluid between the traces, wherein the measured property includes a capacitance corresponding to fluid permittivity and a conductance corresponding to ionic content in the fluid;

    - a monitoring unit that generates an output indicative of coolant purity based on the measured capacitance and conductance, wherein changes in the output beyond calibrated limits signify the presence of contaminants or moisture in the coolant.

9. The sensor of claim 8, wherein the monitoring unit is configured to issue an alert when the fluid's measured conductivity exceeds a predetermined safe threshold (indicating ionic contamination reaching an unsafe level) or when the measured dielectric constant deviates from a normal range (indicating ingress of a high-permittivity substance such as water).

10. The system of claim 1, wherein the central processing node stores calibration data for each said sensor module and applies said calibration data to incoming measurements to correct for baseline offsets and environmental influences, and wherein the central node evaluates the corrected measurements against said threshold criteria such that an alarm is generated only when a true deviation in sensor readings corresponding to a fault condition is observed.

11. A leakage-current monitoring device for a power-transmission or distribution conductor, comprising: • a clamp-on or wrap-around insulating body supporting an interdigitated-electrode array capacitively coupled to the conductor; • a trans-impedance amplifier and filter network configured to measure displacement current over a bandwidth of 10 Hz – 10 kHz; • a processing unit that derives at least root-mean-square leakage current and time-rate-of-change, compares the values to calibrated thresholds, and issues an alert when a ground-fault or insulation-leakage condition is detected; and • a communication interface operable to transmit leakage-current data or alarms to the central processing node of claim 1.