

PATENT SPECIFICATION

Low-Temperature Battery Management System

Patent No. PDR-2021-0147

Filing Date: March 15, 2021

ABSTRACT

A system and method for managing battery performance in extreme cold environments, specifically designed for autonomous mobile robots operating in sub-zero temperatures. The invention comprises an intelligent thermal regulation system that maintains optimal battery temperature and performance through a combination of active heating elements, passive insulation, and predictive power management algorithms.

BACKGROUND OF THE INVENTION

[0001] Autonomous mobile robots operating in cold storage environments face significant challenges related to battery performance and longevity. Traditional lithium-ion batteries experience severely reduced capacity and charging capabilities at temperatures below -20 C, limiting their practical application in cold-chain logistics and frozen storage facilities.

[0002] Existing solutions typically rely on basic heating elements that consume excessive power and provide inadequate temperature regulation, resulting in inefficient operation and reduced battery life.

SUMMARY OF THE INVENTION

[0003] The present invention provides a comprehensive battery management system specifically designed for low-temperature environments, comprising:

- a) An advanced thermal envelope incorporating phase-change materials and vacuum-sealed insulation layers;
- b) Microprocessor-controlled heating elements with distributed temperature sensors;
- c) Predictive power management algorithms that optimize heating cycles based on operational parameters;
- d) A regenerative thermal recovery system that captures waste heat during operation.

DETAILED DESCRIPTION

Thermal Management System

[0004] The primary thermal management system consists of:

A multi-layer insulation system comprising:

- Outer layer: Impact-resistant composite shell
- Middle layer: Vacuum-sealed aerogel insulation
- Inner layer: Phase-change material containment system

Heating element configuration:

- Carbon fiber heating elements (0.5W/cm)
- Precision temperature sensors (0.1 C accuracy)
- Distributed placement optimized for uniform heat distribution

Control System Architecture

[0005] The control system implements:

Real-time temperature monitoring across 16 discrete zones

Predictive heating algorithms based on:

- Historical temperature data
- Current draw patterns
- Planned robot operations
- Ambient temperature conditions

Power Management

[0006] The system incorporates:

Dynamic power allocation between:

- Core robot functions
- Heating elements
- Sensor systems
- Control electronics

Efficiency optimization through:

- Predictive pre-heating cycles

- Waste heat recovery
- Load balancing algorithms

CLAIMS

A battery management system for low-temperature environments comprising:

- a) A multi-layer thermal insulation system
- b) Distributed heating elements
- c) Temperature sensors
- d) A microprocessor-based control system
- e) Predictive power management algorithms

The system of claim 1, wherein the thermal insulation system includes vacuum-sealed aerogel insulation maintaining an R-value of at least 40 per inch at temperatures between -40 C and 25 C.

The system of claim 1, wherein the heating elements are carbon fiber-based and capable of providing 0.5W/cm of heating capacity while maintaining uniform temperature distribution across the battery surface.

The system of claim 1, wherein the control system implements machine learning algorithms to optimize heating cycles based on operational parameters and environmental conditions.

DRAWINGS

[0007] Figure 1: System Architecture Diagram

[0008] Figure 2: Thermal Layer Configuration

[0009] Figure 3: Control System Flow Chart

[0010] Figure 4: Power Management Schema

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FIELD OF INVENTION

[0011] This invention relates to battery management systems for autonomous mobile robots operating in extreme cold environments, specifically addressing the challenges of maintaining optimal battery performance in sub-zero temperatures.

PRIOR ART REFERENCES

US Patent 9,876,543: "Thermal Management System for Electronic Devices"

US Patent 10,234,567: "Battery Heating System for Cold Environments"

International Patent WO2019/123456: "Smart Battery Temperature Control"