PATENT SPECIFICATION

Thermal-Electric Hybrid Power Management System for Cold Environment Robotics

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ABSTRACT

A thermal-electric hybrid power management system for autonomous mobile robots operating in extreme cold environments, comprising an integrated thermal recovery circuit, adaptive power distribution modules, and temperature-compensated battery management system. The invention enables sustained robotic operation in sub-zero environments through intelligent heat recapture and dynamic power allocation.

BACKGROUND OF INVENTION

[0001] Autonomous mobile robots operating in cold storage and industrial freezer environments face significant challenges related to power efficiency and battery performance degradation. Conventional battery systems experience severely reduced capacity and operational life in sub-zero temperatures.

[0002] Prior attempts to address cold environment power management have relied primarily on battery insulation or heating elements, resulting in significant power consumption overhead and reduced operational efficiency.

SUMMARY OF INVENTION

[0003] The present invention provides a novel thermal-electric hybrid power management system that integrates:

- Thermal energy recovery from robot actuator operations
- Dynamic power distribution based on component-level thermal states
- Adaptive battery charging and discharge algorithms optimized for cold environments
- Integrated thermal management circuitry for critical electronic components

DETAILED DESCRIPTION

[0004] Referring to Fig. 1, the thermal-electric hybrid power management system (100) comprises:

[0005] A primary thermal recovery circuit (110) containing:

- Heat exchanger manifold (111)
- Thermoelectric generator array (112)
- Thermal transfer fluid circulation system (113)
- Temperature sensor network (114)

[0006] Power distribution module (120) including:

- Microprocessor-controlled power routing matrix (121)
- Component-level power monitoring system (122)
- Adaptive power allocation algorithm (123)
- Emergency power reserve circuit (124)

[0007] Battery management system (130) comprising:

- Temperature-compensated charging controller (131)
- State-of-charge optimization logic (132)
- Cell balancing circuitry (133)
- Thermal protection system (134)

CLAIMS

A thermal-electric hybrid power management system for cold environment robotics, comprising:

a) A thermal recovery circuit configured to capture and convert waste heat from robot actuator operations into supplemental electrical power;

b) An adaptive power distribution module capable of dynamically routing power based on component thermal states;

c) A temperature-compensated battery management system optimized for sub-zero operation.

The system of claim 1, wherein the thermal recovery circuit comprises:

a) A heat exchanger manifold connected to robot actuator assemblies;

b) A thermoelectric generator array for converting thermal differentials to electrical power;

c) A closed-loop thermal transfer fluid system.

The system of claim 1, wherein the power distribution module implements:

a) Real-time power routing based on component temperature feedback;

b) Predictive power allocation using thermal state modeling;

c) Emergency power reserves for critical systems.

The system of claim 1, wherein the battery management system provides:

a) Temperature-optimized charging algorithms;

b) Dynamic cell balancing;

c) Thermal protection controls.

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GOVERNMENT INTERESTS

[0008] This invention was made with government support under contract SBIR-2019-CR157 awarded by the Department of Defense. The government has certain rights in the invention.

PRIOR ART REFERENCES

- US Patent 10,724,852
- US Patent 10,891,227
- US Patent Application 2018/0157211
- "Advanced Power Management for Cold Environment Robotics" (IEEE Robotics and Automation, 2018)

FIELD OF INVENTION

[0009] This invention relates to power management systems for autonomous mobile robots, specifically addressing the challenges of sustained operation in extreme cold environments through integrated thermal and electrical power optimization.