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Robotics for electricity generation, transmission and distribution systems – Part 1-2: State-of-the art and standardization roadmap for electric power system robots

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IEC TR 63439-1-2 has been prepared by IEC technical committee 129: Robotics for electricity generation, transmission and distribution systems. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
129/59/DTR	129/64/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 63439 series, published under the general title *Robotics for electricity generation, transmission and distribution systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

INTRODUCTION

With the continuous advancement of automation, digitalization, and artificial intelligence, more than 20 countries worldwide - including Canada, China, Japan, New Zealand, the United States, etc. - have actively pursued research and application of power robotics technologies. The global demand for robotic solutions in the power sector is substantial and presents significant growth potential.

Currently, robots carrying out tasks such as patrol, inspection, detection, and maintenance are already widely adopted across power generation, transmission, substation, and distribution systems. Meanwhile, specialized robots - such as those for gas-insulated switchgear (GIS) diagnostics and live working in substations - are under development. These applications have driven new technical requirements for robotic systems designed to assist or replace manual field inspections.

However, the absence of unified international standards has led to significant variations in robot functionality and performance across different countries, resulting in limited interoperability and compatibility. There is a clear need to establish international standards to achieve consensus on functionality, performance, safety, and operational efficiency.

This report encompasses the entire power system workflow and addresses applications such as inspection, maintenance, operation, and emergency response. Both indoor and outdoor high-voltage environments are considered, as well as diverse geographical and climatic conditions. Key factors in adopting power robotics are investigated, including safety issues, human-machine collaboration, system reliability, and cybersecurity. The report also analyses standardization needs based on current applications and proposes a roadmap for standardization. The purpose of this report is to offer guidance for advancing related technologies and products while serving as a reference for developing international standards in the field of power robotics.

This document mainly consists of five parts. Clause 4 provides an overview of power robotics, covering their current applications, technical status, classification methods, system architecture, key components, and operating modes in electric power systems. Clause 5 outlines the key technologies of power robotics, including mobile platforms, positioning/navigation systems, communication networks and cybersecurity. Clause 6 details the core functional technologies of power robots, covering multi-modal inspection capabilities and critical maintenance operations for electric power systems. Clause 7 presents testing frameworks for power robots, ensuring operational effectiveness across all critical system parameters. Finally, Clause 8 outlines the standardization framework for power robotics, reviews existing standards and organizations, and presents the IEC/TC129 structure with a comprehensive roadmap and implementation plan for future standardization efforts.

Further reading:

IEC 60050-191:1990, International Electrotechnical Vocabulary (IEV) - Part 161: Electromagnetic compatibility IEC 60050-161:1990 [1]

IEC 60050-192:2015, International Electrotechnical Vocabulary (IEV) - Part 192: Dependability IEC 60050-192:2015 [2]

IEC 60050-195:2021, International Electrotechnical Vocabulary (IEV) - Part 195: Earthing and protection against electric shock IEC 60050-195:2021 [3]

IEC 60050-300:2001, International Electrotechnical Vocabulary (IEV) - Part 300: Electrical and electronic measurements and measuring instruments - Part 311: General terms relating to measurements - Part 312: General terms relating to electrical measurements - Part 313: Types of electrical measuring instruments - Part 314: Specific terms according to the type of instrument IEC 60050-300:2001 [4]

IEC 60050-651:2014, International Electrotechnical Vocabulary (IEV) - Part 651: Live working IEC 60050-651:2014 [5]

IEC TR 62210:2003, Power system control and associated communications - Data and communication security IEC TR 62210:2003 [6]

ISO 12100:2010, Safety of machinery - General principles for design - Risk assessment and risk reduction ISO 12100:2010 [7]

ISO 18257:2016, Space systems - Semiconductor integrated circuits for space applications - Design requirements ISO 18257:2016 [8]

ISO 19092:2008, Financial services - Biometrics - Security framework ISO 19092:2008 [9]

ISO/TS 27790:2009, Health informatics - Document registry framework ISO/TS 27790:2009 [10]

1 Scope

This part of IEC 63439, which is a Technical Report, specifies a comprehensive study of the robotic technologies in power systems, including generation, transmission, and distribution. The primary objectives are:

a) System overview and classification

Analyze current robotic applications across all power system segments (generation, transmission, and distribution), developing a comprehensive classification framework that categorizes robots by operational scenarios (substations, power lines), functional roles (inspection, repair), and environmental conditions (high-voltage zones, confined spaces).

b) Core technology assessment

Evaluate fundamental robotic technologies encompassing mobility platforms (ground robots, drones, remotely operated vehicles (ROVs)), navigation systems (GPS, LiDAR, vision-based), and communication networks (wired/wireless/hybrid); assess functional capabilities through multi-sensor inspection (visual, thermal, ultrasonic) and maintenance operations (live-line work, cleaning, debris removal), and examine integration aspects with power grid management systems including data protocols and cybersecurity requirements.

c) Testing and validation framework

Establish performance benchmarks for core robotic functions including autonomous navigation, inspection accuracy, and operational efficiency, while developing reliability testing methods that incorporate failure mode analysis (FMEA/FMECA) and environmental stress testing under extreme conditions.

d) Standardization roadmap

Conduct a gap analysis of current power robotics standards (including IEC/TC129) to identify deficiencies, while systematically mapping stakeholder requirements to prioritize standardization needs across hardware, software interfaces, and safety protocols; develop the roadmap with clear timelines for creating new standards, facilitating adoption, and ensuring compliance verification across the industry.

2 Normative references

There are no normative references in this document.

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[3] IEC 60050-195:2021, *International Electrotechnical Vocabulary (IEV) - Part 195: Earthing and protection against electric shock*

[4] IEC 60050-300:2001, *International Electrotechnical Vocabulary (IEV) - Part 300: Electrical and electronic measurements and measuring instruments - Part 311: General terms relating to measurements - Part 312: General terms relating to electrical measurements - Part 313: Types of electrical measuring instruments - Part 314: Specific terms according to the type of instrument*

[5] IEC 60050-651:2014, *International Electrotechnical Vocabulary (IEV) - Part 651: Live working*

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