Current Status of Relay Protection Technology Development at Home and Abroad



Overview

IEC Trend Report Relay protection for PEDGs:2025 | IECRecognizing the dire need for advanced relay protection, this report presents a comprehensive analysi.

Key Takeaways

Relay protection technology is rapidly evolving worldwide, driven by smart grid integration, digitalization, AI, and renewable energy challenges, with China and other countries actively advancing intelligent, adaptive, and communication-based protection systems.Technological Evolution

Relay protection has transitioned from electromechanical relays to digital and intelligent systems. Early systems relied on simple current and voltage comparisons, while modern devices incorporate semiconductor-based logic, microprocessors, and digital communication, enabling faster response, higher accuracy, and multi-device coordination . The integration of smart grids and distributed energy resources has necessitated adaptive protection strategies, wide-area monitoring, and automated coordination to maintain grid stability .

Emerging Technologies

Key innovations include:

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• AI-driven adaptive protection: Uses machine learning to adjust relay settings dynamically based on grid conditions .

• Digital twins and simulation: Enables scenario-based testing and predictive maintenance .

• Communication-based protection: Incorporates optical fiber, 5G, phasor measurement units, and software-defined networking for real-time fault detection and coordinated control .

• Collaborative fault identification: Enhances reliability by integrating control and protection systems . These technologies address challenges posed by low-inertia grids, distributed generation, and complex fault characteristics introduced by renewable energy sources .

Domestic and International Development

• China: By 2024, over 10,000 smart substations were built, with smart meter coverage exceeding 90%, enabling real-time monitoring and management . State Grid and Southern Grid have implemented wide-area protection and digital relay coordination.

• United States: Initiatives like GridWise have enhanced grid intelligence and adaptive protection capabilities .

• Europe and Asia-Pacific: Focus on upgrading aging infrastructure, integrating IoT-enabled digital relays, and adopting international standards like IEC 61850 .

Market Trends

The global protective relay market was valued at USD 2.8 billion in 2024 and is projected to reach USD 3.9 billion by 2030, growing at a CAGR of 5.7% . Growth drivers include:

• Increasing demand for reliable power supply in industrializing regions.

• Expansion of renewable energy requiring sophisticated protection.

• Adoption of digital and smart relay systems with IoT capabilities.

• Regulatory emphasis on grid reliability and energy efficiency .

Challenges

Despite advancements, relay protection faces several challenges:

• Reduced fault currents in inverter-dominated grids weaken protection sensitivity .

• Coordination issues due to distributed generation and decentralized grids .

• Cybersecurity threats in digital systems .

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• Cross-regional standardization and communication delays affecting protection reliability .
Future Directions
• Adaptive and self-healing protection systems leveraging AI and big data .

• Enhanced standardization for AI-based and communication-enabled relays .

• Integration with predictive maintenance and lifecycle services to optimize grid reliability .

• International collaboration to share innovations and harmonize standards for power electronic-dominated grids . In summary, relay protection development is moving toward intelligent, adaptive, and communication-oriented systems globally, with China, the U.S., and Europe leading in smart grid integration, digital relay deployment, and AI-enabled adaptive protection. These advancements are critical to ensuring grid stability, accommodating renewable energy, and supporting the global energy transition.

Article Content

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