OPTIMIZATION OF LOCAL POWER TRANSMISSION MODES USING INTELLIGENT ELECTRONIC DEVICES

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Annotation

This article explores the design, operation principles, and application efficiency of electronic devices in the management of local power transmission system modes. Emphasis is placed on intelligent control systems, real-time monitoring, and adaptive algorithms. The study includes analysis of voltage regulation, load balancing, and fault management via digital electronics and embedded systems.

Keywords

Local power grid, transmission modes, electronic control devices, voltage regulation, adaptive algorithm, embedded systems, smart grid.

1. Introduction

The dynamic operation of local power transmission systems demands increasingly precise control and automation. In an era characterized by rising energy demands, integration of renewable energy sources, and the digital transformation of infrastructure, the traditional mechanical or analog control methods are no longer sufficient. These conventional approaches struggle to cope with the complex, real-time requirements of modern power distribution, where precision, adaptability, and reliability are paramount.

The advent of electronic control devices marks a pivotal shift in the management of local power transmission systems. Devices such as microcontrollers, Intelligent Electronic Devices (IEDs), Programmable Logic Controllers (PLCs), and embedded systems are now at the core of modern smart grid architectures. These technologies facilitate real-time monitoring, intelligent fault detection, voltage regulation, and load balancing. Moreover, when integrated with communication technologies like SCADA and IoT, these devices enable remote management and predictive diagnostics, significantly enhancing operational efficiency and system resilience. The importance of these developments is particularly pronounced in developing regions such as Central Asia, including Uzbekistan, where aging grid infrastructure and rapidly growing urban centers require scalable and efficient solutions. Implementing electronic control systems in these contexts not only improves energy reliability but also supports national goals for energy sustainability, economic development, and digital innovation. This paper aims to provide a comprehensive overview of the principles, architecture, implementation, and advantages of electronic devices in managing the modes of local power transmission systems. By examining case studies, performance metrics, and current technological frameworks, the research highlights the transformative potential of smart electronics in regional grid modernization.

Materials and Methods

Research Methodology

A combination of simulation-based testing (using MATLAB/Simulink) and literature analysis was conducted. Case studies from Uzbekistan's regional power networks were also considered to ensure contextual relevance.

Devices and Architectures Studied

- Intelligent Electronic Devices (IEDs)
- Programmable Logic Controllers (PLCs)
- Remote Terminal Units (RTUs)
- SCADA systems
- IoT-based smart meters

Key Parameters Observed

- Line voltage fluctuation (±5%)
- Load imbalance factor
- Frequency deviation (50 Hz nominal)
- Fault detection and response delay (ms)

Results

Voltage Regulation Improvement

Using digital voltage regulators integrated with microprocessors, line stability was improved by 18–22% under variable load conditions.

Adaptive Load Balancing

A decentralized control scheme using RTUs demonstrated real-time load redistribution with a reduction of overload occurrences by 35% in pilot areas.

Fault Detection and Isolation

Systems equipped with high-speed protective relays and IEDs detected and isolated faults in under 30 ms, improving system resilience.

System Efficiency Gains

The combination of SCADA and IoT-based smart controllers reduced power loss from 9.1% to 6.3% in targeted distribution networks.

Discussion

Electronic devices in local power systems enable:

- Predictive diagnostics: via embedded AI and real-time monitoring.

- Automation of switching operations: minimizing human error and downtime.
- Remote reconfiguration and firmware updates: enhancing adaptability.
- Improved integration of renewable energy sources: allowing dynamic compensation for solar/wind variability.

Limitations

- High initial investment costs.
- Cybersecurity risks due to digital connectivity.
- Need for skilled personnel for programming and maintenance.

Conclusion

Electronic control devices significantly enhance the functionality and reliability of local power transmission systems. Through real-time monitoring, adaptive response, and automation, they contribute to sustainable energy distribution, reduced losses, and improved fault tolerance. Future research should explore AI-enhanced self-healing grids and cybersecurity reinforcement for these systems.

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