Modular Management of Photovoltaic Power Generation Equipment

Overview

Coordinated operation and multi-layered optimization of hybridThe coordinated operation of hybrid photovoltaic (PV) and Small Modular Reactor (SMR) microgr.

Key Takeaways

Modular management of PV systems enables scalable, efficient, and fault-tolerant operation through module-level control, integrated power electronics, and smart monitoring.Overview of Modular PV Management

Modular management in photovoltaic systems involves breaking down the PV array and energy storage into smaller, autonomous units that can be independently controlled and monitored. Each module typically includes a PV cell, a storage battery, power switches, and a dedicated controller. This architecture allows flexible operation modes, independent connection/disconnection, and optimized energy flow, improving system efficiency and reliability while reducing the impact of shading or battery imbalance on overall performance .

Module-Integrated Power Electronics

Module-integrated power electronics (MIPE) are key to modular PV management. These include microinverters or DC/DC converters attached directly to individual modules, enabling maximum power point tracking (MPPT) at the module level. MIPE simplifies cabling, enhances energy yield, and allows reactive power support for grid stabilization. Advances in MIPE technology have progressed from low-frequency transformers to high-frequency and fully laminated in-module designs, which can reduce system costs and improve compactness .

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Hierarchical System Topology

A modular PV system is often organized hierarchically:

• Module (Basic Unit): Autonomous PV cell and battery with independent control.

• Series String: Multiple modules connected in series to match voltage requirements.

• System Level: Parallel connection of series strings converging through DC/DC converters to a common DC bus, which can supply DC loads or feed AC loads via inverters . This topology eliminates shading and battery balancing issues, allows PV cells to operate near their maximum power point without complex MPPT circuits, and reduces reliance on traditional battery management systems (BMS), .

Smart Monitoring and Management

Modern modular PV systems integrate smart monitoring platforms that provide real-time diagnostics, fault detection, and performance optimization. For example, Huawei's Smart PV management system uses AI algorithms, I-V curve analysis, and drone-assisted inspection to identify faulty modules with over 96% accuracy, optimize tracker angles, and improve operation and maintenance efficiency by up to 80% . Open interfaces allow third-party systems to access operational data, supporting scalable and interoperable PV plant management.

Advantages of Modular Management

• Scalability: Easy expansion by adding modules or strings.

• Fault Tolerance: Failure of a single module does not affect overall system operation.

• Efficiency: Module-level MPPT and smart tracking maximize energy yield.

• Reduced Costs: Simplified MPPT and BMS reduce hardware and maintenance costs.

• Grid Support: Module-integrated electronics can provide reactive power and stabilize voltage .

Conclusion

Modular management of photovoltaic power generation equipment combines module-level control, integrated power electronics, and intelligent monitoring to create flexible, efficient, and reliable PV systems. This approach addresses traditional challenges such as shading, battery imbalance, and complex maintenance, making it particularly suitable for large-scale, building-integrated, and distributed PV applications.

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Studies of large-scale DC connected photovoltaic power system

DC collection and transmission is one of the major development directions of large-scale photovoltaic (PV) power

Modular PV system design and evaluation

Inverters The main element of a PV system is an inverter, which converts the direct current from PV modules to

(PDF) Application of Module Level Power Electronics Technology in ...

Distributed photovoltaic power generation system usually adopts series wiring scheme, which has problems such as

(PDF) MODULAR PHOTOVOLTAIC SYSTEM DESIGN

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The recent increase in demand for solar power systems is due to enhancements in manufacturing crystalline panels,

Review on photovoltaic with battery energy storage system for power ...

Abstract Photovoltaic (PV) has been extensively applied in buildings, adding a battery to building attached photovoltaic

Solar Photovoltaic System

A solar photovoltaic system or PV system is an electricity generation system with a combination of various components such as PV

Solar Photovoltaic System Design Basics

Solar photovoltaic modules are where the electricity gets generated, but are only one of the many parts in a complete photovoltaic

Solar Photovoltaic Technology Basics

Solar Photovoltaic Technology Basics What Is Photovoltaic Technology? Photovoltaic (PV)

Solar energy harvesting technologies for PV self ...

First, the PV power generation and scenarios of PV self-powered applications are analyzed. Second, analysis of

Modeling and integration of rooftop photovoltaic systems for ...

In the context of photovoltaic, a specific focus has been placed on Rooftop PV (RPV) systems, which indicate

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Modular multilevel converter for large-scale photovoltaic generation ...

A modular multilevel converter (MMC) topology for high-scale three-phase photovoltaic power generation and its

A Modular Grid-Connected Photovoltaic Generation System Based on

During power generation, only one modular dc–ac inverter is operating with nonfull load, and the other modular dc–ac inverters are

Integrated design of solar photovoltaic power generation technology and ...

The most important thing is to monitor the power quality of the inverter. The introduction of the Internet of Things makes

Design and Engineering of Photovoltaic Power Generation System

Photovoltaic power generation systems have emerged as a viable alternative for renewable energy production. This

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Photovoltaic systems operation and maintenance: A review and future ...

Gaps and future research directions for PV O&M management are proposed. The expansion of photovoltaic systems

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The integration of IoT technologies in smart energy management systems (SEMS) for PV power generation has

A Comprehensive Assessment on Modular Technologies,

Many engineers view MMCs as highly appropriate for major PV plants because they can be installed modularly, are galvanically

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