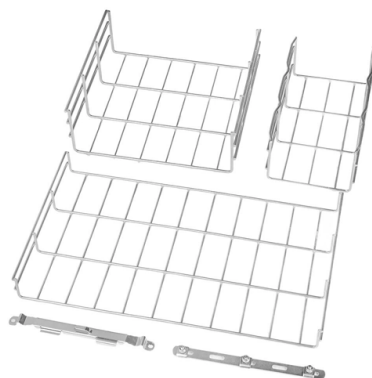


Principle of Photovoltaic Cluster Control Module



Overview

Photovoltaic (PV) devices contain semiconducting materials that convert sunlight into electrical energy.

Key Takeaways

A Photovoltaic Cluster Control Module manages distributed PV units by coordinating inter-cluster and intra-cluster operations to optimize voltage, power flow, and system stability.

Overview
A Photovoltaic Cluster Control Module is designed to regulate and optimize the operation of multiple PV units grouped into clusters, particularly in high-penetration distributed PV systems. Its main goal is to maintain voltage stability, prevent over-limit conditions, and ensure efficient power utilization while responding to the variability of solar generation and load demand .

Hierarchical Control Structure

The control module typically operates using a two-layer strategy:

- Inter-Cluster Coordination (Upper Layer):
- This layer manages the interaction between different PV clusters.
- It selects dominant nodes within each cluster based on network observability, controllability, and spatial metrics such as node centrality.

- Multi-objective optimization is applied to minimize voltage deviations or network losses across the system.
- Advanced algorithms, such as particle swarm-gray wolf coupling (PSO-GWO) or improved community algorithms, are used to generate output indicators for each cluster .
- Intra-Cluster Autonomy (Lower Layer):
 - This layer distributes the control commands from the dominant node to downstream and upstream nodes within the cluster.
 - It ensures local voltage regulation and power flow optimization, even in cases of communication failure.
 - The intra-cluster strategy prioritizes minimum voltage deviation and reduced network losses within the cluster .

Key Functions

- Voltage Regulation: Maintains node voltages within safe limits, preventing over-voltage or under-voltage conditions caused by high PV penetration .
- Power Flow Management: Coordinates active and reactive power outputs of PV inverters to balance supply and demand within the cluster and across the network .
- Node Selection and Optimization: Identifies key nodes for control to reduce the number of control points while maximizing regulation efficiency .
- Autonomous Operation: Ensures clusters can operate independently if communication with the central controller is lost, maintaining system stability .

Benefits

- Enhanced Stability: Reduces voltage fluctuations and power reversal issues in distribution networks.
- Improved PV Consumption: Optimizes the use of generated solar energy, increasing the effective integration of distributed PV systems.
- Scalability: Supports large-scale PV deployment by dividing the network into manageable clusters.
- Robustness: Combines centralized coordination with local autonomy to handle variability in solar generation and load demand . In essence, the Photovoltaic Cluster Control Module integrates hierarchical control, optimization algorithms, and autonomous cluster management to ensure safe, efficient, and stable operation of distributed PV systems in modern power networks.

Article Content

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Photovoltaic (PV) devices contain semiconducting materials that convert sunlight into electrical energy. A single PV device is known

Composition and Working Principle of The Photovoltaic Power

Regardless of the form, the working principle is that the photovoltaic module will convert light energy into direct current,

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