

Automation Design of Photovoltaic Power Plant Distribution Network



Overview

Research and application of the impact of distributed photovoltaic. Several key areas represent potential opportunities for further research in the futur.

Key Takeaways

Optimizing a PV power plant distribution network involves strategic placement of PV modules, inverters, and energy storage using multi-objective optimization and power flow tracking to enhance efficiency, reduce losses, and improve voltage stability. Key Design Considerations



1. **PV and Inverter Placement:** The location and sizing of PV modules and inverters are critical for minimizing cable lengths, reducing losses, and improving overall system efficiency. Heuristic and algorithmic approaches, such as Python-based simulations, can generate multiple inverter placement combinations to identify the optimal configuration that minimizes total cable length and maximizes energy delivery efficiency .

2. **Energy Storage Integration:** Incorporating energy storage allows for better utilization of PV generation, smoothing power fluctuations, and increasing the PV consumption rate. Studies show that energy storage can raise PV consumption from 85.6% to over 96%, though it may slightly increase network losses due to multidirectional power flows .

3. **Multi-Objective Optimization:** Designing a PV distribution network often involves balancing multiple objectives, including voltage stability, economic efficiency, and network loss minimization. Multi-objective genetic algorithms (MOGA), fractional-order particle swarm optimization, and Archimedes optimization algorithms are effective for determining optimal PV and storage placement and sizing .

4. **Power Flow Tracking:** Power flow tracking technology is used to analyze the impact of distributed PV and storage on the network. It helps identify voltage deviations, repetitive power flows, and areas where energy storage placement can optimize load sharing and reduce congestion .

5. **Cable Sizing and Network Configuration:** Optimizing cable sizes and network paths is essential to reduce resistive losses and improve system reliability. Automated design tools can calculate the shortest feasible cable paths for all inverter locations, ensuring minimal material usage and cost while maintaining voltage profiles within acceptable limits .

6. **Environmental and Grid Considerations:** Optimal PV distribution reduces dependence on conventional power plants, lowers greenhouse gas emissions, and enhances grid stability. Voltage profile improvements and loss reductions are achieved by carefully selecting PV system locations and sizes based on load sensitivity and network topology .

Implementation Workflow

- **Data Collection:** Gather network parameters, load profiles, and PV generation potential.
- **Candidate Site Selection:** Identify feasible locations for PV modules and inverters.
- **Optimization Modeling:** Apply multi-objective algorithms to determine optimal placement and sizing of PV modules, inverters, and storage.
- **Power Flow Analysis:** Simulate network operation using power flow tracking to validate voltage stability and loss reduction.
- **Iterative Refinement:** Adjust placements and capacities based on simulation results to achieve Pareto-optimal solutions.
- **Final Design:** Implement the configuration with optimized cable routing, inverter allocation, and storage integration.

Conclusion

Automated design of PV power plant distribution networks leverages optimization algorithms, power flow tracking, and heuristic methods to achieve high efficiency, reduced losses, and improved voltage stability. Integrating energy storage and carefully sizing inverters and cables ensures maximum utilization of PV generation while maintaining grid reliability and economic feasibility. This approach is essential for modern grid-connected PV systems aiming for sustainable and cost-effective energy delivery.

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