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Name of the topic: Operation Management of Microgrid for Maximum Energy Security

Findings:

Key Words: PMU Protection Scheme, Power system, Renewable Energy, Hybrid GJOA and Gradient Descent Algorithm, Real Time Digital Simulator, Isolated Microgrid, Loadability, Microgrid, Faults Analysis, Distribution Generation

This research comprehensively addresses microgrid operation management strategies to achieve maximum energy security by integrating renewable energy sources, energy storage systems, and advanced control mechanisms. The study begins with a detailed analysis of photovoltaic (PV) and wind energy models, evaluating their efficiency, reliability, and performance under varying conditions. The one-diode PV model demonstrated superior accuracy in simulating real-world behavior, especially under high solar irradiance. A Maximum Power Point Tracking (MPPT) method was proposed for fixed-speed wind energy systems using a Permanent Magnet Synchronous Generator (PMSG), with an optimized converter topology ensuring efficient power extraction and grid synchronization.

The study further introduces a dynamic protection scheme utilizing Phasor Measurement Units (PMUs) for real-time fault detection and location. The proposed Positive Sequence Impedance Angle (PSIA)-based method effectively distinguishes between internal and external faults, enhancing microgrid resilience and reliability. Simulations using Real-Time Digital Simulator (RTDS) validate the scheme's accuracy in various fault scenarios.

Real-time microgrid operation under dynamic generation conditions were also explored, with a Master-Slave (MS) strategy proposed to optimize distributed generator placement, minimizing power losses across variable load demands. A novel hybrid optimization algorithm combining Golden Jackal Optimization (GJO) and Gradient Descent Optimization (GDO) was developed, offering faster convergence and superior performance compared to existing methods.

Additionally, the concept of loadability was introduced, supported by Bayesian Sparse Polynomial Chaos Expansion (BSPCE) analysis to evaluate and enhance microgrid capacity under fluctuating conditions. Overall, this research delivers robust strategies to improve microgrid efficiency, resilience, and sustainable energy management for future decentralized energy systems.