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Name of the topic: Energy Efficiency Enhancement Through Demand Response in Smart Grid

Findings:

Key Words: Electric Vehicle, Smart Grid, Microgrid, Particle Swarm Optimization, Genetic Algorithm, Jaya Algorithm, Demand Response, Energy Efficiency, IEC 61850, Renewable Energy Resources.

This research proposes a comprehensive framework for the seamless integration of Electric Vehicles (EVs) into Renewable Energy Resource (RER)-based hybrid microgrids, emphasizing efficiency, stability and cost optimization. The developed small-scale microgrid model incorporates solar panels, pole-mounted transformers and battery controllers, with detailed computational analyses such as load flow estimation, impedance characterization and steady-state evaluation using MATLAB R2022a. The framework utilizes Distributed Energy Resources (DERs) to enhance power distribution, minimize energy losses and improve operational resilience.

A central contribution is the development of an advanced Energy Management System (EMS) that employs the Multi-Objective Jaya Algorithm (MOJA) for real-time scheduling and optimization of EV charging/discharging operations. The EMS dynamically responds to load demand, photovoltaic (PV) generation variability, electricity pricing and user participation in Demand Response (DR) programs, effectively balancing V2G and G2V operations to ensure grid reliability and flexibility.

To further improve operational efficiency, a hybrid Particle Swarm Optimization–Grey Wolf Optimization (PSO-GWO) algorithm is introduced, outperforming conventional techniques such as Mixed Integer Linear Programming (MILP), Ant Colony Optimization (ACO) and the Jaya Algorithm (JA) in minimizing costs and maximizing energy utilization. Validation through integrated MATLAB/Simulink and RTDS co-simulations confirms its superior performance.

Moreover, an IEC 61850-compliant communication architecture is developed to enable secure, low-latency and interoperable coordination among EVs, microgrid controllers and roadside units. Evaluations using Riverbed Modeler 18.5 demonstrate efficient real-time communication and control signal exchange. Collectively, the proposed framework ensures enhanced grid resilience, economic efficiency and scalable EV integration within future smart grid infrastructures.