National Institute of Technology Rourkela

Synopsis Seminar

Seminar Title	: Optimized Load Frequency Control in Renewable-Energy-Based Microgrids with Electric Vehicle Integration
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Venue	: Seminar Room No. 401 EE Department
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Abstract :

The modern power system is undergoing a paradigm shift driven by growing electricity demand, depletion of conventional resources, and the large-scale integration of renewable energy sources (RES). While RES and electric vehicles (EVs) offer significant sustainability benefits, their variability and uncertain behavior introduce critical challenges to frequency regulation and grid stability. Traditional proportional&ndashintegral&ndashderivative (PID) controllers, though widely employed in load frequency control (LFC), have proven inadequate under nonlinear, renewable-rich, and multi-source environments.

This thesis examines advanced control strategies and the synergistic role of energy storage systems in enhancing LFC in interconnected and hybrid microgrid frameworks. Internal Model Control (IMC)-based PID and Fractional Order PID (FOPID) controllers are developed and optimized using metaheuristic techniques such as Particle Swarm Optimization (PSO). Their performance is assessed in diverse system configurations, including thermal&ndashhydro networks, multi-source systems with thermal, hydro, gas, and wind units, and hybrid microgrids with high renewable penetration. To address reduced inertia and dynamic uncertainties, the study integrates fast-acting storage devices such as superconducting magnetic energy storage (SMES), capacitor energy storage (CES), redox flow batteries (RFB), and EVs operating in vehicle-to-grid (V2G) mode.

Simulation studies reveal that IMC&ndashPID and PSO-tuned FOPID controllers significantly outperform conventional controllers by reducing frequency deviations, damping oscillations, and improving tie-line power stability. Among storage units, EVs demonstrate superior adaptability as a distributed storage system, actively supporting system balance during peak demand. Reduced-order modeling and sensitivity analyses further validate the robustness of the system under varying load conditions and system parameters.

The findings highlight that combining advanced control strategies with coordinated storage and EV integration offers a reliable and sustainable solution for frequency regulation in smart grids. The thesis concludes with recommendations for future research, emphasizing artificial intelligence (AI)-driven controllers, large-scale V2G frameworks, and cyber-physical resilience to support the transition toward intelligent, sustainable, and resilient power systems..