Basim ALbaaj and Orhan Kaplan, 2025, Operational cost assessment using IGDT considering uncertainty in wind and solar power with battery integration, 14th International Conference on Renewable Energy Research and Applications 27–30 October 2025, Vienna, Austria.

"Abstract The increasing penetration of renewable energy sources has introduced significant uncertainty into modern power systems, creating challenges in maintaining reliable and economic operation. To address this issue, this study proposes an optimal power flow (OPF) framework based on Information-Gap Decision Theory (IGDT). The framework is designed to handle severe uncertainty in renewable power generation while ensuring robust and stable system performance. The IEEE 30-bus test system, integrated with 4 MW of wind generation and 1 MW of solar generation, is used as the test platform. To enhance flexibility and reliability, a Battery Energy Storage System (BESS) is incorporated, enabling the system to effectively mitigate fluctuations in renewable output. The optimization problem is solved using the Binary Differential Evolution (BDE) algorithm, which efficiently identifies the best compromise among conflicting objectives such as fuel cost, system losses, emissions, and voltage deviation. Simulation results demonstrate that the inclusion of BESS consistently improves performance across all metrics compared to the no-BESS case. The findings indicate substantial reductions in generation cost, system losses, and emissions, while simultaneously enhancing overall system stability. Furthermore, analysis of the percentage error between the BESS and non-BESS scenarios reveals that the most favorable outcome occurs at $\beta = 0.2$, corresponding to a daily profit of \$139.2152. These results confirm that the integration of IGDT with BESS and BDE provides a resilient, efficient, and economically viable strategy for operating renewable-dominated power systems under uncertainty."

Keywords optimal power flow; renewable energy; battery; information gap decision theory.

Highlights

"The key contributions of this study can be outlined as follows:

"1. The uncertain nature of wind and solar energy is modeled using the IGDT framework.

"2. Unlike probabilistic methods such as Monte Carlo Simulation, IGDT does not rely on predefined probability distributions for uncertain variables. It also provides greater flexibility than Robust Optimization (RO), since it does not require specifying a maximum uncertainty level in advance.

"3. The integration of BESS enhances voltage stability, mitigates operational risks, and improves the overall ability of IGDT to manage renewable uncertainties effectively.

"4. In this work, the Binary Differential Evolution (BDE) algorithm is employed to solve

the multi-objective OPF problem under renewable uncertainty. BDE ensures efficient exploration of the solution space, enabling convergence toward optimal trade-offs between cost, losses, emissions, and voltage performance."