Assessing Load Uncertainty in the Optimal Allocation of Photovoltaic Distributed Generation in Radial Distribution Network

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Abstract

The transition toward renewable energy in the distribution network is hindered by demand fluctuations and voltage instability, posing risks to reliable and efficient operation. This paper investigates load uncertainty in determining the optimal size and placement of photovoltaic distributed generation (PVDG), while accounting for time-varying, voltage-dependent load models representing commercial, industrial, and residential sectors. A hybrid Backward/Forward Sweep–Grey Wolf Optimizer (BFS-GWO) method was developed to minimize power losses and improve voltage profiles in radial distribution systems. The proposed approach was validated in MATLAB on the standard IEEE 33-bus test system. The study compared the performance of networks with and without PVDGs under residential, commercial, and industrial load uncertainty, as well as comparing single and multiple PVDG configurations. Simulation results demonstrate that under uncertain conditions, the optimal integration of multiple PVDG significantly decreases total power losses up to 58.96% for residential, 54.51% for commercial, and 56.92% for industrial loads, and improves voltage profiles at critical buses to near 1.0 p.u.

Author keywords

Backward/Forward Sweep; Grey-Wolf Optimizer; Load Uncertainty; Photovoltaic Distributed Generation; Radial Distribution Network

Indexed keywords

Engineering controlled terms

Distributed power generation; Electric losses; Housing; IEEE Standards; Optimization; Photovoltaics; Renewable energy; Voltage control; Voltage distribution measurement

Engineering uncontrolled terms

Backward/forward sweep; Forward sweeps; Gray wolves; Gray-wolf optimizer; Load uncertainty; Optimizers; Photovoltaic distributed generations; Powerloss; Radial distribution networks; Voltage profile

Engineering main heading

Uncertainty analysis

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