Abstract

The electrical distribution network serves as a crucial infrastructure, connecting loads and generation, distributed storage, electric vehicles, and adaptable demand. Distributed Energy Resources contribute significantly to local capacity, bolstering support for a fully renewable energy system. Analyzing distribution systems involves various methodologies, such as power flow analysis, loss calculation and allocation, and loss sensitivity analysis, to model, analyze, and enhance the efficiency of the system. This dissertation presents findings on the analysis of three-phase balanced and unbalanced radial distribution systems. It introduces a novel method to calculate the sensitivities of total losses concerning the shunt node current magnitude for both balanced and unbalanced systems. The relationship between these sensitivities and the losses assigned to system nodes under various operating conditions, including scenarios with reverse power flow, is also explored. A new smart charging strategy for electric vehicles (EVs) operating in grid-to-vehicle mode is proposed, utilizing K-means clustering techniques and fuzzy weights. This approach leverages blockchain technology with a Proof-of-Authority consensus protocol to enhance network security and achieve decentralization, ensuring complete transparency and traceability of EV charging activities and grid status monitoring over time. Additionally, new indicators for avoided PV power reduction and energy curtailment are established, derived from a Monte Carlo-based evaluation of three-phase power flow results to address EV-related uncertainties. The performance of the proposed methods is evaluated in terms of network losses, applying the novel concept regarding the sign of the product of allocated losses and the net load power to the "IEEE 123 bus Test Feeder" to assess the robustness of the proposed method in the presence of EVs. A new approach to PV power curtailment integrates fairness-based strategies to construct the Pareto front, ranked by TOPSIS, focusing on reducing system losses and optimizing grid performance. This strategy adjusts PV power curtailment to minimize total system losses while encompassing fairness of the PV curtailment as a future conflicting object.