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Optimal location and sizing of distributed generation for distribution systems: An improved analytical technique

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ABSTRACT
Distributed generation (DG) significantly improves power system reliability and voltage profile, and reduces power losses. These benefits can be maximized by optimizing the DG utilization, which greatly depends on adequate number, size, and placement of DG. This study proposes a high-convergence optimization technique for optimal DG placement in distribution networks, aiming to reduce power losses and improve voltage profile and voltage stability index. The technique is tested on a 7-bus system before being verified on the IEEE 33-bus system. After validation, it is tested on a 71-bus distribution network (DN). The estimated ideal size for a single DG is used as a limit for determining the optimal placement and size of multiple DG units. The results show that there is a loss reduction of 70.09%, 61.43%, and 71.15% for the 7-bus, IEEE 33-bus, and 71-bus systems, respectively, from their base case loss. The average absolute error of voltage of the aforementioned buses also shows similar enhancement, decreasing from 0.0144, 0.0561, and 0.0527, to 0.0058, 0.0209, and 0.0184, respectively. The voltage stability index of each DN has increased significantly in comparison to the base case. The comparison demonstrates that the proposed technique can provide better results for any size of distribution network.

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Distributed generation (DG); loss sensitivity factor (LSF); optimal location and size; power losses; radial distribution network (RDN)

1. Introduction

The amount of electricity generated from renewable energy sources (RES) has grown significantly in the recent past because of its potential to address the challenges of energy demand and global warming. Distributed generation (DG) has provided a significant share of the total power produced by RES due to its advantages like close to load center, easy, and short duration of installation and using the existing roofs for photovoltaic (PV) systems. DGs might be considered as one of the potential solutions to some of the difficulties that power systems confront, such as excessive power loss, poor power quality, low reliability, and transmission system congestion, in addition to fulfilling energy requirements (Nagaraju et al. 2012). DGs can provide improved performance of DN, but their inappropriate deployment can result in issues like reverse power flow (RPF), poor protection coordination, voltage imbalance, and increased losses (Shafiullah, Arif, and Oo 2018). The improper location, type, and size of DG can also affect the power quality and level of fault current at the point of common coupling (PCC) (Mohapatra, Babu, and Mohanty 2016). As a result, the optimal use of DG sources should be explored in order to maximize their benefits. The optimal DG placement may be considered as optimal active power compensation, similar to the optimal positioning of the capacitors for reactive compensation used to reduce the power loss and to minimize the voltage deviation while simultaneously enhancing reliability and voltage stability. As a consequence, DG deployment is a multi-objective optimization issue, and optimizing many objectives at the same time is difficult due to the importance of each objective at various units and scales. Therefore, a precise multi-objective formulation is required due to the possibility of conflicting purposes. By assigning different weights or multiplying them with a penalty factor, many multi-objective formulations with separate objectives are reduced to single-objective problem. As a result, a workable solution requires a trade-off.

In the past few years, researchers have examined the effects of DG position and size on power flow, power losses, voltage profile, reverse power flow, and other parameters (Bawazir and Cetin 2020). Numerous optimization techniques, which may be numerical, heuristic, or analytical, and can be single or multi-objective, have been implemented to optimize the DG placement and size. The optimization techniques include a variety of unique algorithms, with differences in the problem formulation, methodology, and assumptions used. All techniques have benefits and drawbacks that are based on the data and system under examination. As an objective function, the DG allocation problem is typically nonlinear or stochastic. The primary goal of all formulations is to decrease the power losses and enhance voltage profile while complying with all the voltage and power constraints. Apart from these, optimization benefits include increased loading margin and critical clearing time, voltage stability index (VSI) enhancement, improved load factor, and power quality (Naderipour and Abdul-Malek 2020). Numerous optimization algorithms inspired by

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