論 文 の 要 旨

Optimal Allocation of Multiple Distributed Generation Technologies in Distribution Systems

(配電系統における分散電源の最適配置)

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Recently, the penetration of renewable distributed generation (DG) technologies has dramatically increased in distribution systems. The most notable DG types are wind power, photovoltaic, and solar systems. These DG units are often distributed according to load centers in distribution systems. Renewable DG technologies are described as intermittent sources, for the reason that their output power varies depending on environmental conditions. Consequently, the performances distribution systems are greatly affected by these DG units. These resources may have positive or negative technical impacts on the grid, according to their selected sizes, locations, and types.

The main objective of this work is to perform comprehensive modeling, analysis of distribution systems and optimally install multiple DG technologies. The methodology of DG allocation must be generic, where different DG technologies are incorporates to the optimization process. In addition, the performance of the developed method must be efficient in terms of CPU time and accuracy. To represent the allocation problem from a practical view, distribution system constraints, such as voltage limits, line flow limits, and maximum DG penetration are required to be completely considered.

For this purpose, firstly, distribution system component models are developed using state of the art phase and sequence components frame of references. An efficient power flow method for analyzing distribution systems is presented. The proposed method utilizes efficient quadratic-based (QB) models for various components of distribution systems. The power flow problem is formulated and solved by a backward/forward sweep (BFS) algorithm. The proposed QBBFS method accommodates multi-phase laterals, different load types, capacitors, distribution transformers, and distributed generation (DG). The advantageous feature of the proposed method is robust convergence characteristics against ill conditions, guaranteeing lower iteration numbers than the existing BFS methods. The proposed method is tested and validated on several distribution test systems. The accuracy is verified using OpenDSS. Comparisons are made with other commonly used BFS methods. The results confirm the effectiveness and robustness of the proposed QBBFS with different loading conditions, high R/X ratio, and/or excessive DG penetration.

Secondly, an efficient analytical (EA) method is proposed for optimally installing multiple distributed generation (DG) technologies to minimize power loss in distribution systems. Different DG types are considered, and their power factors are optimally calculated. The proposed EA method is also applied

to the problem of allocating an optimal mix of different DG types with various generation capabilities. Furthermore, the EA method is integrated with the optimal power flow (OPF) algorithm to develop a new method, EA-OPF that effectively addresses overall system constraints. The proposed methods are tested using 33-bus and 69-bus distribution test systems. The calculated results are validated using the simulation results of the exact optimal solution obtained by an exhaustive OPF algorithm for both distribution test systems. The results show that the performances of the proposed methods are superior to existing methods in terms of computational speed and accuracy.

The thesis consists of seven chapters. The research topics are mainly distributing among the chapters as follows:

Chapter 1 presents the introduction to distribution systems, research objectives, scope of the research and organization of the thesis.

Chapter 2 provides comprehensive review about power flow analysis techniques, modeling and analysis of distribution systems.

Chapter 3 presents an improved Quadratic-based (QB) power flow method for solving the nonlinear iterative process in active distribution systems. The proposed method is validated via the OpenDSS software, and its performance is tested evaluated against existing methods.

Chapter 4 presents generic formulations for expressing the loss reduction with integrating multiple DG units in distribution systems. In addition, comprehensive analyses of several distribution systems are included, and the impacts of different DG units are deeply addressed.

Chapter 5 provides two new methods, namely EA and EA-OPF methods, for optimally allocating multiple DG units to minimize power loss in distribution systems. The proposed methods are tested on many test systems and compared with existing methods. The results demonstrate the effectiveness of the EA and EA-OPF methods.

Chapter 6 deals with allocating different DG types in distribution systems for reducing the losses. Different scenarios with different DG types to be allocated are studied and compared.

Chapter 7 provides a conclusion part, where contributions of the study are discussed. In addition, some recommendations for further research in the future are presented.