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Energy Distribution Planning Models Taxonomy and Methods of Distributed Generation Systems

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Abstract

Current passive distribution systems are converted into active networks by introducing distributed generation. This can lead to increased short-circuit currents in electricity network components. Another important issue is that distributed generation may have affect on the state of electrical system voltage and network losses. Power losses are important for reliable operation of a distribution network and thus should be minimized. Deployment of distributed generation in a non-optimal location may cause a variety of problems, such as increase in system losses and costs, voltage fluctuations, as well as problems of reliability and stability. This article discusses how, compared to initially proposed numerical (conventional) power distribution planning models, the modern ones result to be more integrated and are mostly aimed at multiple goals. Comparison of optimization methods to identify the optimal location for distributed generation is presented.

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Keywords: Distributed generation; distribution network; optimization methods

1. Introduction

Power distribution networks are faced with the ever-growing load demand and (or) large fluctuations in value. Although the equipment is usually distributed evenly between phases, imbalances in phase loads is formed due to

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load growth and the changing needs within a day. The need to balance the load and minimize the loss of power led to exploring the issue of load balancing and scheduling. Scientific studies present two main methods for phase load balancing: at system level – the reconfiguration of power lines, whereas at power line level – phase swapping [1]. Distributed generation and existing controlled resources, such as direct load control, reactive power compensation and demand integration, are good potential controlled (managed) resources for smart grids. Distributed generation and integration of flexible loads into the distribution network is useful only if there is good management [2]. Voltage control is traditionally performed by means of reactive power management, using a synchronous generator, capacitors and, at the latest, devices of flexible alternating current transmission system (FACTS) [3]. In electrical power systems, balancing electricity is used for faster restoration of a balance in the supply and demand. Energy demand increases by extracting energy from intermittent renewable energy sources such as wind or solar energy [4]. Production of distributed energy from renewable sources and the reduction of loss will reduce the demand of energy produced by traditional power plants, which in turn will help reduce the greenhouse effect. As distributed generation sources are installed near the load center, their relevant layout may help reduce power losses [5].

The main problem, the optimization of a real network, allows for a relatively large amount of configurations due to the number of connected devices. In general, it may be impossible to check all the options available and to make the necessary calculations for each of them, for example, to determine the optimal flow in order to find the best performance configuration. To solve this problem, the methods of optimization are commonly used, which reduces the search range and helps you to find the optimal solution [6].

This article provides the most advanced taxonomy and methods of power distribution scheduling models that enable to establish a unified definition of a relatively large number of works dealing with this topic [7].

2. Taxonomy of power distribution scheduling models

The objective of power transmission development scheduling is to promote competition among market participants and ensure high system performance and reliability standards. Eventual overloads restrict competition and increase the end-user price [8]. Distributed power generation increasingly requires active distribution networks, which allows electric current to flow in two directions – either for power users or business use, or to the network when the user exports the excess amount of generated electricity.

Automatic Generation Control (AGC) is especially important for large-scale systems, which ensure the system frequency and nominal powers in tie-lines. Where active power production is insufficient due to unexpected interferences or other reasons to meet the demand for energy, the frequency generally decreases and vice versa. In order to restore quickly the frequency and ensure the required power to be transferred through this line, the automatic production control is used. It is therefore necessary to use a control system that eliminates the impact of sudden load changes and maintains the nominal frequency [9]. Automatic Generation Control takes place in two modes, namely: very fast primary control and slow secondary control. Restrictors are used for primary control, and controllers are used for secondary control [10]. After the emergence of current technological innovations, traditional controllers are being replaced by smart controllers. This ensures a more rapid, effective and dynamic solution of frequency management problems [11].

Traditional optimization methods intended to integrate the distributed generation into the electricity grid may vary depending on their goals, for example, to minimize power loss, to minimize system cost, to improve voltage profile, to increase power loads and local marginal costs [12]. Individual and joint systems use a variety of smart methods such as classical optimal fuzzy logic, artificial neural networks, genetic algorithm, bacterial foraging, particle swarm optimization, firefly algorithm, most of which are used in automatic production control. The most commonly invoked method is a trial and error method, but the results may not be optimal; moreover, these studies require a lot of time. Modern metaheuristic algorithms have been developed to carry out a full search that is not possible using classical techniques [13].

3. Power distribution scheduling models

Balancing energy in integrated power systems is used in cases where there is a need to stabilize the active power balance provisionally (from a few seconds to a few hours). Alternating current transmission systems must have a