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Optimal Allocation method on Distributed Energy Storage System in Active Distribution Network

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Abstract

With distributed generations (DG) including the wind and photovoltaic power generations continually connected to the distribution network, reasonable allocation of energy storage system is extremely important to active distribution network (ADN). In this paper, a method to optimize the location and capacity of the embedded distributed energy storage system (DESS) is proposed to meet the needs of ADN and DGs. Firstly, the model of DGs is built according to the natural characteristics of wind and solar energy. Secondly, the model of allocating the DESS is established to achieve the best economical investment results with the constraints of ADN, DG and DESS themselves. Finally, a test ADN with wind and photovoltaic power generations is used to verify the efficiency of the method proposed in this paper.

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Keywords: Active Distribution Network; Distributed energy storage; Annual income of distribution network; Capacity optimization

1. Introduction

The distributed generations (DGs) including wind power (WG) and photovoltaic power (PV) can improve energy efficiency and reduce CO_2 emissions. However, the fluctuation and unpredictable characteristics of DGs may greatly

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affect the reliability and security of power system [1-3]. Active distributed network (ADN) is an intelligent distributed network which can automatically control and actively manage the abundant controllable resources within the network [4-5].

Energy storage system (ESS) can quickly adjust power flow. It can store energy when DG generation is sufficient, and output power to alleviate the shortcomings of intermittent DG generation, which is the key of AND's flexibility to adjust grid-connected DG and network's operation state [6-7]. But configuration and operation of ESS will directly affect AND's management of DGs and the economy of grid's operation. [8] proposed an optimized charging/discharging model of ESS unit in which the minimum fluctuation of active power is taken as objective function. [9] managed to plan the ESS's capacity aiming at achieving the best profits with tracking the estimation results and peak load shifting technology. [10] established a nonlinear constrained optimization model to formulate the optimal control strategy for the distributed energy storage system of intermittent grid-connected distributed power. But this model is computationally large, so it is not suitable for large-scale distribution network. [11] used a multi-objective algorithm to optimize the energy storage capacity. [12] proposed a multi-period mixed-integer nonlinear optimization model with the objective of minimum total investment and operation cost of DESS. Improved genetic algorithm (GA) is used to optimize the DESS allocation scheme, but the energy interval of ESS is slightly different from the actual situation. [13] proposed a novel bi-level optimization method for locating and sizing of DESS. Due to the time sequence matching of grid, load and ESS, the calculation period become longer.

This paper proposes a practical model of allocating distributed energy storage system (DESS) corresponding to DGs in the AND. The objective of the model is to achieve the best economical investment results with the constraints of ADN, DGs and DESS. The GA is used to solve the algorithm, and the power flow calculation is based on the former push back method.

2. Modeling of distributed generations and energy storage system in active distribution network

2.1. The advantage of distributed energy storage system

In AND with DGs, energy storage devices generally have two kinds of architectures: centralized architecture and distributed architecture [14]. The centralized architecture means that energy storage device will be installed in the same location, which can be used to balance the unstable output of all the DGs in ADN. While in the distributed architecture, every ESS is designed for each DG and it will only cooperate with the DG at the same location.

This paper chooses the DESS configuration method as the main research goal. The advantages of distributed configuration are not only that the storage capacity is less than the centralized, but also that it is cost-effective and can be flexibly installed. DESS can effectively solve the problems of planning and running of power generation.

2.2. The model of wind power

The number of wind power is closely related to the wind speed of the wind turbine. In this paper, Weibull Distribution is used to simulate the random fluctuations of wind [15-16]. The probability density function is

$$\mathrm{f}(v)=\frac{k}{c}\cdot(\frac{v}{c})^{k-1}\cdot\exp\left[-(\frac{v}{c})^{k}\right] \tag{1}$$

Where, k and c are the shape parameters and scale parameters in the Weibull distribution.

2.3. The model of photovoltaic power

The amount of PV generation is closely related to light intensity. According to the relevant statistics, the change of light intensity is basically consistent with the Beta distribution [17]. The probability density function is: