

The Research on Optimal Location of Distributed Generation Considering the Line Power Flow of A Grid

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Abstract: As we all know, the access of distributed generations(DGs) will change the structure of the power grid. Different access locations have different impacts on the power grid. Therefore, the site selection of DGs is the top priority of current research. This paper is based on the theory of complex network, the second-order Kuramoto-like model is used to model the dynamic of a power grid, utilize the change of the line power flow after a distributed generation(DG) is connected to the power grid, and combine the relationship between the line capacity and the initial power in the cascading failure study of the power grid to determine the number of overload lines after the DG is connected to the grid. In principle, the grid-connected node with the least number of overload lines is regarded as a reasonable grid-connected location of the DG. After verification, the research method in this paper can be used as a reference for the site selection of the DG and has certain practical value.

Keywords: DG, The line power flow, The power grid.

1. Introduction

Recently, more and more scholars use the dynamic characteristics of complex networks to study how to connect DG to the power grid. The access of distributed generations(DGs) will change the structure of the power grid. Different access locations have different impacts on the power grid. Therefore, the site selection of DGs is the top priority of current research. Reference [1-2] proposed two methods for DGs to connect to the power grid. The first method is to connect the newly added DG to the load nodes with small degree in the original network(called SDJ method), and the second method is to connect the newly added DG to the load nodes with big degree in the original network(called LDJ method). It is found that the DG is connected to the small load nodes in the original power grid, which is more conducive to the synchronization of the power grid and can enhance the anti-interference ability of the network. In Ref [3], through the analysis of the dynamic characteristics of the power grid, proposes that the connection of DGs to the power grid from the load node is more conducive to the improvement of the synchronization ability of the power grid.

2. The Power Grid Model and Experimental Conditions

Simulation is carried on IEEE 14 and IEEE 30 standard test grids [5]. The power grid consists of two types nodes: generator nodes and load nodes. The IEEE 14 test system contains 9 load nodes and 5 generator nodes, a total of 14 nodes; the IEEE 30 test system contains 24 load nodes and 6 generator nodes, a total of 30 nodes. In this paper, the fourth-order Runge-Kutta integration method [6] is used to write the second-order Kuramoto-like model program for simulation experiments. The integration step is taken $h=0.001$, and the simulation time t is the product of the integration step h and the number of evolution steps i , that is $t = h \times i$. The initial phase deviation of each node in the system is among $[-\pi/2, \pi/2]$, and the initial frequency offset of each node is uniformly valued on $[-0.1, 0.1]$. In addition, because the power of each

DG connected to the power grid is different, the critical coupling strength of the power grid K_C is also different.

3. Method

3.1. The Line Power Flow

For the line power flow of the grid, generally speaking, its size reflects the ability of the line to undertake power exchange tasks throughout the power grid. Therefore, the change of the grid topology or the change of the transmission line capacity will influence the line power flow of the entire grid. The change will have a certain impact on the synchronization stability of the power grid. The Line power flow from node i to node j can be rewritten as Eq. (1):

$$F_{ij} = K_{ij} \sin(\phi_i - \phi_j) \quad (1)$$

In Eq.(1), $K_{ij} = K * a_{ij}$, K is the synchronous coupling strength and a_{ij} is the adjacency matrix.

3.2. The Method For Grid Access Location of DG Based on Line Power Flow

According to the previous research, it's better to connect to the grid from the load node than that from the generator node [5]. This paper analyzes the change of the line power flow after the DG is connected to the grid from different load nodes to judge the reasonable access position of the DG. In order to ensure that the change of the line power flow before and after the DG is connected to the grid is only related to the access position of the DG, the coupling strength K is taken as the value that can synchronize the grid before and after the DG is connected to the grid at any power, that is $K \geq K_C$, and the corresponding phase skew will be recorded. In the IEEE14 system, the critical synchronous coupling strength of the system after a single DG is connected to the power grid from each load node with a power of 1 and 1.5 is shown in Tab. 1 and Tab. 2:

Table 1. The K_c corresponding to DG access power of 1

DG's access node number i	4	5	7	9	10	11	12	13	14
K_c	4.2	4.3	4.0	3.9	3.4	3.2	3.0	3.0	3.0

Table 2. The K_c corresponding to DG access power of 1.5

DG's access node number i	4	5	7	9	10	11	12	13	14
K_c	4.2	4.6	4.1	3.6	3.0	3.9	2.6	2.8	2.9

Through experiments and comparisons, K can be 5 and 40 in the IEEE 14 and IEEE 30 standard test grids; then the line power flow of each line F_{ij} and F_{ijDG} before and after DG access to the grid is calculated according to Eq. (1). According to the relationship $F_{ijL} = (1 + \alpha)F_{ij}$ between the line capacity and its initial power in cascading failure study of the grid (usually $\alpha = 0.2$), if the power flow of a branch line of the power grid is greater than the line capacity after the DG is connected, that is $F_{ijDG} > (1 + \alpha)F_{ij}$, then think the line is overloaded, if the overload time is too long, the line will be easily damaged. The number of overloaded lines caused by DG connecting to the power grid from different load nodes is also different. In principle, the less number of overloaded lines caused by DG connecting to the power grid from a certain load node, the more beneficial to the safe operation of the entire network. Therefore, the load node is the best access location for a single DG.

4. Simulation and Discussion

In this paper, several simulation experiments are carried out on the research method of the network access position of the DG based on the line power flow on multiple IEEE test systems. Specifically, take IEEE14 and IEEE30 standard test systems as examples to analyze.

4.1. The Analysis of the Best Access Location for A Single DG

A single DG is connected to the power grid from each load node with different power. It can be seen from the above analysis that the IEEE14 network coupling strength is $K=5$, and the access power is taken as an example of 0.25 and 0.5. The power of the generator node is 1.75 and 0.5. 1.7; IEEE30 network coupling strength takes $K=40$. The access power is taken as 0.6 and 1.2, respectively, the generator node power is 3.9 and 3.8. The number of overloaded lines caused by DG connecting to the power grid from each load node with different power is shown in Figure 1.

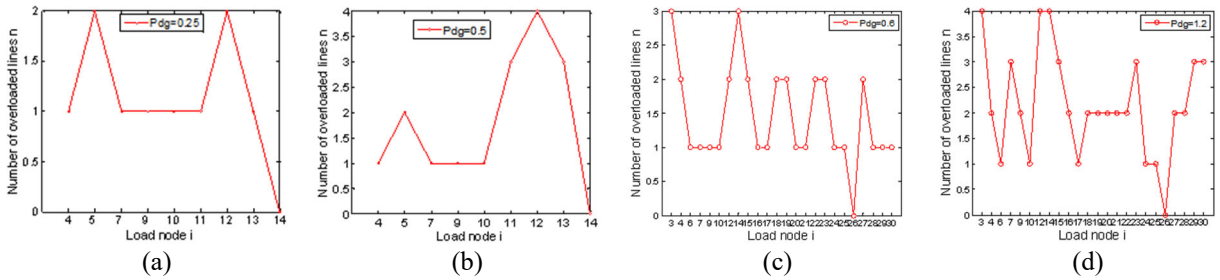


Figure 1. The relationship between the number of overloaded lines and the power of DG
(a) (b) IEEE14 test system; (c) (d) IEEE30 test system;

It can be seen from the above figures that the number of overloaded lines is the least when DG is connected to the power grid from 14 nodes and 26 nodes on IEEE 14 and IEEE 30 standard test grids respectively. Therefore, it is considered that DG connecting to the power grid from 14 nodes and 26 nodes is the most beneficial to the safe operation of the entire system. To sum up, for accessing a single DG, node 14 of the IEEE14 system and node 26 of the IEEE30 system are the

best access locations for the DG of the IEEE14 and the IEEE30 network.

4.2. Verification

In order to verify the rationality and reliability of the method based on the line power flow for the grid connection location of the DG in this paper, the following two aspects will be analyzed through the critical synchronous coupling strength and the network D value, as shown in Figure 2.

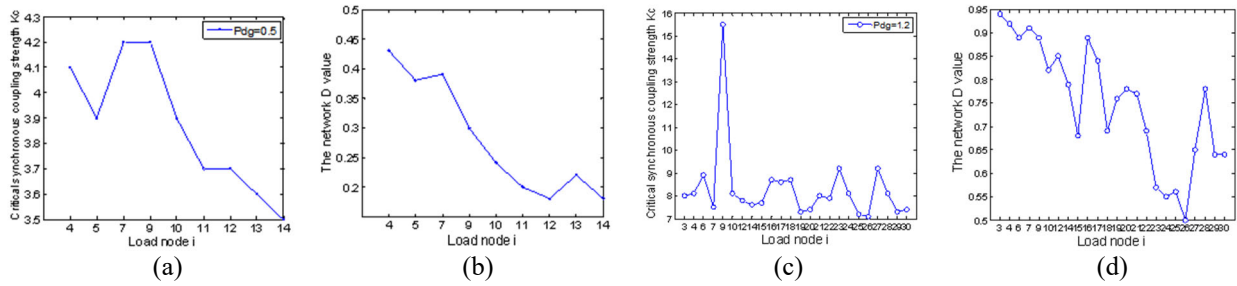


Figure 2. (a) (b) IEEE14 test system; (c) (d)IEEE30 test system

The smaller the critical synchronization coupling strength, the better the network synchronization ability; and the network D value quantifies the difference between the average distance between each load node and the generator node after the DG is connected to the grid [7]. The more uniform the distribution of load nodes around the generator node, the more conducive to the synchronization of the power network [11]. As shown in the figure, through the verification of the critical synchronous coupling strength and the network D value, it shows that the No. 14 node of the IEEE14 system and the No. 26 node of the IEEE30 system are the best DG nodes. This is consistent with the result of using the change of the power flow of the grid line after the DG is connected to the grid to determine the optimal grid-connected position of the DG. It shows that the use of the method in this paper to determine the grid-connected position of the DG is beneficial to the synchronization of the power network and the enhancement of the anti-interference ability. It also proves that the rationality and reliability of the research method in this paper.

5. Conclusion

In this paper, the optimal DG connection position is determined by the change of the line power flow after DG is connected to the grid. The experimental simulations show that the DG should be connected to the power grid from the load node with the least number of line overloads caused by its grid connection, and the two indicators of critical synchronous coupling strength and network D value are used for verification, indicating that the method in this paper is used to determine the grid connection of DG. The location is beneficial to the synchronization of the power network and the enhancement of the anti-interference ability. It also shows the rationality and reliability of the method for researching the grid-connected site selection of DG in this chapter.

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