Impact Analysis on High-Permeability Distributed Power Access to Distribution Network Voltage

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Abstract. With massive access of distributed power, massive distributed power is connected for operation by grid connection. The grid-connected operation of intermittent distributed power will have important influence on the structure, voltage, power quality and others of power distribution network. This paper analyzes the influence of different places of access of distributed power with different capacities to power voltage through simulation, thereby providing the basis to play the effect of distributed power access better, and also providing an important reference direction for the rolling planning of distribution network.

Introduction

In recent years, the distributed power has been rapidly developed in domestic. The distributed power refers to the photovoltaic power generation facilities directly arranged on the power distribution network or distributed near the load, having economic, efficient and reliable power generation. When the distributed power is connected in the power distribution network, a big influence will be brought to the node voltage, power quality, protection, short circuit current and others, and the influence degree is closely related to the position and capacity of distributed power. Meanwhile, the access of distributed photovoltaic power generation inevitably affects the steady-state voltage distribution, and then, affects the quality of power supplied to the user.

Modeling

The power distribution network has many topological structure types. Most of power distribution systems in the city and countryside of China still rely on the radial chain structure, and in the following, all networks above the substation are equivalent to the voltage source. Several loads are distributed at the different positions in the feeder, and there are many load types in the power distribution network, therefore, the randomness is big, and it is quite difficult to express the load accurately. To facilitate studying, the load module provided by MATLAB software is uniformly adopted to express the load; and in the meanwhile, assume that the load has three-phase symmetry, the mutual inductance between the three-phase circuits is also not considered as the voltage grade is relatively low and the length of distribution line is relatively short; and all line impedances are converted into the voltage grade of the system.

Each concentrated load is regarded as a node along the feeder and numbered as 1, 2, ..., N successively from the busbar of substation. The resistance and reactance of each small section of line are R and X respectively, and the formed power distribution network is shown in Figure 1.

Figure 1. Multi-node chained power distribution network including DG.
Simulation Analysis

Influence of Distributed Power Connected at Different Places to Distribution Network Voltage

A distribution line model of 10kV planned DG built under MATLAB simulation software simulink environment and shown in Figure 1 is shown in Figure 2, wherein the distribution line is overhead line, and the parameters are as follows: $r_1=0.45\Omega/km$, $r_0=0.74\Omega/km$; $L_1=0.9337mH/km$, $L_0=4.1264mH/km$; $C_1=0.07074\mu F/km$, $C_0=0.0478\mu F/km$. The load node number is 7. To facilitate studying, 1 MVA load with power factor of 0.95 is uniformly distributed on the overhead line, and the length of overhead line between the loads is 1km. The ratio of main transformer is set as 110/10.5 kV.

The deviation of power voltage is an index of power quality. To reasonably determine this deviation is of great importance to the manufacturing and operation of electrical equipment, and safety and economy of electric power system. For the general electrical equipment, when the voltage deviation exceeds its design scope, the direct influence is to deteriorate the operating performance, its service life is affected, and even, the equipment is damaged in the short time; and the indirect influence is to possibly involve the production quality and quantity of corresponding product. Therefore, the determination of allowable deviation standard of voltage is a comprehensive technical and economic problem. In the following analysis, set that the allowable deviation of voltage of 10kV three-phase power supply network as $\pm 5\%$, the influence of access position of distributed power to the distribution line voltage is discussed.

The situations of accessing no distributed power on the distribution line and accessing the distributed power of which the capacity is 3MW and the power factor is 1 at the different loads points are simulated respectively. The simulation circuit is shown in Figure 3. The voltage distribution of load points on the line is shown in Figure 4.

![Figure 2. 10kV distribution line model.](image)

![Figure 3. Simulation circuit including DG.](image)

![Figure 4. Voltage distribution after 3MW DG is accessed to the load points.](image)
Voltage/kV
Load point of distribution line
No DG access
Access DG at the load point 7
Access DG at the load point 6
Access DG at the load point 5
Access DG at the load point 4
Access DG at the load point 3
Access DG at the load point 2
Access DG at the load point 1

By keeping that the total output of distributed power for 3mW is unchanged, 1MW distributed power is accessed at the load points 5, 6, 7, 1, 2 and 3 respectively. The voltage distribution of load points on the line is shown in Figure 5.

Figure 5. Voltage distribution after 1MW DG is accessed to the load points respectively.

Voltage/kV
Load points of distribution line
No DG access
Access 1MW DG at points 5, 6 and 7
Access 1MW DG at points 1, 2 and 3

It can be seen from Fig. 4 that, after 7 groups of 1MVA load with power factor of 0.95 are accessed on 10kV distribution line uniformly, the voltage on the distribution line is gradually reduced, and reduced below 9.5kV at the load points 6 and 7 at the end of line, which exceeds the lower limit of voltage of safe operation. When the distributed power is accessed at the load points, the voltage on the distribution line is obviously improved. It indicates that the voltage distribution of feeder can be obviously improved by accessing the distributed power on the power distribution network.

As well, it can be known from Figure 5 that, the distributed power generation having the same total output is distributed at the different positions, and there is big difference on the voltage distribution on the distribution line. The closer the node is, the bigger the voltage change ratio is, and the bigger the influence from injection power of distributed power generation is. On the contrary, the closer the distributed power generation is to the busbar of the system, the smaller the influence to the voltage distribution of circuit is. For example, the voltage at the load point 7 is still lower than 9.5kV after accessing 3MW distributed power at the load point 1. The voltage distribution on the distribution line is obviously improved after accessing 3MW distributed power at the load point 7, but the voltage change of the load point is too big. Therefore, from the angle of reducing the voltage change ratio, the distributed power generation is not suitable for accessing the system at the last node, and on the contrary, the position closer to the end in the middle of line or position combination can be selected.

It can be seen from Figure 5 that, the voltage supporting effect on distribution line by accessing three groups of distributed power with capacity of 1MW to three load points is superior to that of accessing one 3MW distributed power to one load point. This indicates that the distribution power
generation having the same total output is distributed at the different position combination, and the voltage distribution obtained is superior to the situation of accessing DG to the distribution line concentratedly. And the voltage supporting effect in the distribution line after accessing to the load points 1, 2 and 3 is weaker than that of accessing to the load points 5, 6 and 7. Thus, it can be said that, the distribution line shall be dispersedly accessed when accessing to the distributed power, and DG is distributed at the node closer to the end in the middle of line.

**Influence of Output of Distributed Power to Voltage of Distribution Line**

2MW, 4MW and 5MW distributed power is accessed to the load point 6 successively, and the voltage distribution at the load points on the line is shown in Figure 6.

![Figure 6. Voltage distribution of distribution line when accessing DG with different capacities.](image)

| Voltage/kV | Distribution line |
|-----------|------------------|
| No DG access | Access 2MW DG | Access 4MW DG | Access 5MW DG |

It can be known by observing Figure 6 that, the distributed power is accessed at the same load point, and the total capacity of distributed power generation is in proportion to the voltage of these points. It indicates that, the support of the distributed power to the voltage of distribution line is related to its capacity. With the increase of capacity of DG, the voltage of these points is continuously increased, and when DG is 5MW, the voltage of some points on the distribution line is more than 10.5kV. While the distributed power generation planning, the voltage of some points may be higher than the rated voltage or the busbar voltage of sending end system due to the voltage support of distributed power generation if the capacity of DG is not properly selected. When DG exits the operation, the voltage change range on the line will also be too big.

**Influence of Power Factor of Distributed Power to Voltage of Distribution Line**

It can be known from Figure 6 that, the voltage of some points on the feeder exceeds 10.5kV after 5MW distributed power is accessed at the load point 6. The power factor of DG is adjusted at 0.95, namely, DG makes 4.75kW active power, and absorbs the reactive power from the system. The simulation result is shown in Figure 7.

![Figure 7. Influence of power factor of DG to voltage distribution of distribution line.](image)
Voltage/kV
Distribution line
No DG access
The power factor of DG is 0.95
The power factor of DG is 1

According to the above discussion, it can be found that, the voltage on the feeder can be changed by accessing a certain capacity of DG to the power distribution network, but the specific effect is closely related to the site selection and capacity of DG. If it is not properly selected, DG would enable the voltage of some points on the feeder to exceed the permissible range. In addition, for the distributed power end, the general installation position can be deemed to be fixed due to the national policy and provision as well as special geographical position. In this case, the possibility that the voltage of some points on the feeder exceeds the specified range is bigger due to the access of distributed power generation. The problems of enabling the voltage of some points on the feeder to exceed the limit due to the access of DG by adjusting the power factor of DG to enable DG to absorb a certain reactive power from the power distribution network can be improved. A shown in Figure 7, after 5MW DG is accessed at the load point 6, the voltage of some points on the feeder is more than 10.5kV. After the power factor of DG is adjusted from 1 to 0.95, the voltage at the load point is fully reduce within the safe range, which indicates that the problem that the voltage of distribution line exceeds the limit can be well solved by adjusting the power factor of DG. To maximize the environmental protection and resource utilization rate, the active power made by DG is usually maximized through the different operation principles of distributed power with different types, and then, it can guarantee that the voltage of distribution line does not exceed the permissible range by adjusting the voltage with the static var generator (SVG) and other reactive compensation devices. But, the addition of reactive compensation device means to add the investment, which needs to comprehensively consider the economic problem of investment and operation for planning.

We draw the following conclusions in combination with the above simulation analysis and in regard to the influence of DG to the steady state voltage distribution of power distribution network:
1) The voltage distribution on the feeder will be changed by accessing a certain capacity of DG to the power distribution network, but the specific effect is closed related to the access position and capacity of DG.

2) When the relative network load of distributed power generation is relatively big, the voltage of some points on the feeder will exceed the specified range, and such problem can be solved by adjusting the power factor or DG or by virtue of reactive compensation device, but normally, the distributed power generation shall generate more active power and less reactive power, so as to keep the operation of high power factor.

3) It is favorable for the voltage control to spread the distributed power generation with the same capacity on the feeder, rather than concentrating on the same position.

4) Due to the limit of specific geographical position and other some reasons, the general installation position is relatively determined, therefore, the planning content of distributed power generation is mainly concentrated on the constant volume.

Conclusion
This paper verifies the influence of access of DG with different capacities to the power distribution network at different places to the voltage at the user side through simulation, and obtains that the voltage distribution of distribution network line can be adjusted by adjusting the power factor of distributed power by contrasting the influence of access of DG with different power factors to the power distribution network to the voltage distribution of power distribution network, thereby providing a certain reference basis for the distributed power to participate in the voltage regulation of power grid, and also providing a beneficial reference for rolling planning of distribution network.
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