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Multi Point Distributed Intelligent Power Distribution Technology

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In order to solve the adverse effects caused by multi point distributed power grid on the feeder steady voltage, power quality of power supply and relay protection, a distributed power triangle load distribution model is put forward, and according to the circuit superposition theorem, the voltage distribution calculation method based on this model is proposed. The verification of this model shows that the triangle load distribution model with distributed power is much better than the uniform load distribution model. Under the condition that the the access position is not changed, the output force is determined by the support function of voltage. The more the output force is, the greater the voltage support function is, and the higher the overall voltage level is. When the output force is unchanged, the closer the access position to the end of the line is, the greater the impact on voltage is. In conclusion, this result provides a theoretical basis for voltage regulation analysis.

1. Introduction

At present, the research and practice of smart grid has been paid more and more attention to by the government and the whole society. One of the fundamental characteristics of smart grid different from the traditional grid is to support a large number of access to distributed power supply. Distributed generation (DG) technology is an ideal way for full development and utilization of renewable energy. It has the advantages of small investment, environmental protection, reliable power supply, flexible powering method and so on, which can provide powerful support and effective supplement of the future power grid (Iván et al., 2015). The emerge of DG has changed the one-way mode of trend of the distribution system, and makes the trend cannot be predicted. At the same time, it will produce a series of power quality problems and affect the reliability of the system operation (Roldán-Blay et al., 2017). As a result, the issues related to distributed generation access to grid has become a topic to be studied.

As more and more distributed energy resources penetrate into the distribution system infrastructure, it is required that the future distribution systems have new flexible reconfigurable network topology, new protection schemes, new voltage control and new measurement methods (Tao et al., 2017). When DG is connected to the distribution network and operated, it will have some impact on the distribution network in some cases. For the distribution network which needs high reliability and highpower quality, the access of distributed generation must be careful. Aiming at a typical load distribution model, namely the triangle model, and based on circuit superposition theorem, the voltage distribution calculation of the established model is carried out. Through the study and analysis of distributed generation output force and distribution power system voltage change caused by access position change, it is necessary to make a correct assessment of the impact of distributed power on the distribution system so that the distribution system can safely and stably operate.

2. Establishment of distribution network model

2.1 Distribution system overview

Traditionally, the power system is divided into three major systems: generation, transmission and distribution. The voltage level of the distribution network is generally selected as 110kV (or 35kV) and below, which covers various voltage levels of low voltage (220-380V), medium voltage (6-10kV) and high voltage (35-110kV).

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The primary wiring diagram of distribution network adopts radiation connection, trunk type connection and ring network connection mode (Olival et al., 2017), and its form mainly depends on the requirement of power supply reliability. For a long time, most of the distribution network connections in China adopt the power supply mode based on overhead lines. When the DG is introduced, the distribution network will change from a radial network into a network which is connected with the power supply and the user. The feeder flow is always unidirectional without DG, and the active power flow decreases gradually as the distance from the substation increases (Meirinhos et al., 2017). However, when the feeder is connected to the DG, the power flow in the unidirectional mode of the distribution system has changed. And the power flow along the feeder line may increase or decrease with the change of the position and capacity of the DG access (Ali et al., 2017). As the last link of the power system, the distribution system is directly facing the end users, and its perfection is directly related to the reliability and power quality of the majority of users, so it plays an important role in the power system.

2.2 Triangular load distribution model containing DG

The basic unit of the distribution network is the feeder, and the feeder voltage level in China is mostly 110kV. On each feeder line, the lines are distributed as a tree. Figure 1 is the radial connection mode of simple distribution network containing DG.

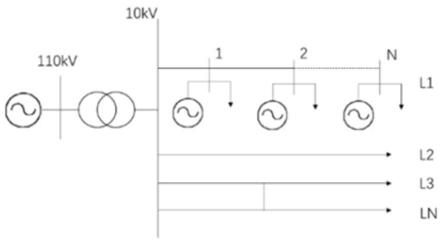

Figure 1: Connection mode of simple radial distribution network with DG

In order to analyze the voltage distribution of distribution network with distributed grid, a typical load distribution model is adopted, namely the triangle model. In that the uniform load distribution model will bring greater error for distribution uneven situation on the line load, and in fact, the load distribution on the line are rarely uniform, the triangle model is used (Oytun et al., 2017). The area of triangle represents the load size, so as to reduce the error, as shown in figure 2. Suppose that the feeder length is m, the distributed power is accessed at k, and the total active power and reactive power of the load are expressed by P_L and Q_L, respectively. The area of the triangle in the figure represents the total power of the load, and the resistance and reactance of the unit length are represented by r and x, respectively, and d is any point in the distribution line.

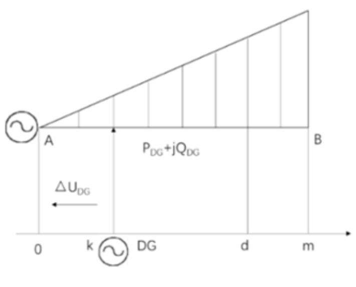

Figure 2: Model of triangle load distribution with distributed power

When the distribution system has only the system power supply alone, the active and reactive loads before and after the d point are represented by P_{0-d}, Q_{0-d},P_{d-m}, and Q_{d-m}, respectively. Then, there are:

$$P_{0-d} = \frac{d^2}{m^2}P_L, \qquad P_{d-m} = (1-\frac{d^2}{m^2})P_L$$
$$Q_{0-d} = \frac{d^2}{m^2}Q_L, \qquad Q_{d-m} = (1-\frac{d^2}{m^2})Q_L \tag{1}$$

3. Voltage distribution calculation

According to the model built in Figure 2, the voltage of A point at the beginning of line is U_0, the line rated voltage is U_N. And d is any point in the line, and then the voltage of d point is 0:

$$U_d = U_0 \quad \Delta U \quad U_0 \quad \Delta U_{sd} \quad \Delta U_{DG} \tag{2}$$

The established model in Figure 2 is a simple distribution line with distributed power. Based on the superposition theorem of circuit, considering the role of system power and distributed power on distribution lines, respectively, so the voltage loss △U includes two parts of ΔU_{sd} and delta ΔU_{DG}. ΔU_{sd} is caused by system power function alone, including two parts: ΔU_{sd1} is due to the equivalent load after d point (Iromi, et al., 2017), and ΔU_{sd2} is caused by the load with triangular form distribution; ΔU_{DG} is caused by the single function of DG (Amin, et al., 2017).

3.1 Node voltage of distribution network with DG

When 0＜d≤k, we can calculate the voltage of d point:

$$U_d = U_0 \quad \frac{d}{U_N}(1 \quad \frac{d^2}{3m^2})(rP_L + xQ_L) \quad (rP_{DG} + xQ_{DG}) \tag{3}$$

When k＜d≤m, we can calculate the voltage of d point:

$$U_d = U_0 \quad \frac{d}{U_N}(1 \quad \frac{d^2}{3m^2})(rP_L + xQ_L) + \frac{rkP_{DG} + xkQ_{DG}}{U_N} \tag{4}$$

3.2 Node voltage of distribution network with uniform load distribution

When 0＜d≤k, we can calculate the voltage of d point:

$$U_d = U_0 \quad \frac{d}{U_N}(1 \quad \frac{d}{2m})(rP_L + xQ_L) + \frac{d}{U_N}(rP_{DG} + xQ_{DG}) \tag{5}$$

When k＜d≤m, we can calculate the voltage of d point:

$$U_d = U_0 \quad \frac{d}{U_N}(1 \quad \frac{d}{2m})(rP_L + xQ_L) + \frac{k}{U_N}(rP_{DG} + xQ_{DG}) \tag{6}$$

4. Model simulation results and analysis

In accordance with the triangle load distribution model with DG, for a 10kV distribution line, the line parameters are: the line length is m=12km, the total number of load is 12, the resistance per unit length within the lines is r+jx=0.082+j0.247, the line voltage per unit value at the beginning is U_0=1.05, rated voltage per unit value is U_N=1.0, the power base value is 10MVA, the medium voltage value is 10kV, and the total load of line is: P_L=5MW and Q_L=3Mvar. DG active power is P_{DG}=3MW, and the power factor cosΦ=0.9 (lag). In the example, the load data of the node is shown in Table 1.

Table 1: Loads date

Node	Active power(MW)	Reactive power(Mvar)
1	0.03472	0.2083
2	0.10417	0.0625
3	0.17361	0.10417
4	0.24306	0.14582
5	0.3125	0.1875
6	0.38194	0.22917
7	0.45139	0.27083
8	0.52083	0.3125
9	0.59028	0.35417
10	0.65927	0.39583
11	0.72917	0.4375
12	0.79861	0.47917

4.1 Model validation

According to the above data, the voltage distribution calculation is carried out for distribution network of triangle load distribution model and the uniform load distribution model. The formulas are shown as (3), (4), (5) and (6), respectively. The calculation results are compared with the strict trend calculation to verify the correctness and effectiveness of the method. The data are shown in Table 2 and Figure 3 is the node access verification diagram.

Table 2: The result with DG at node 6

Node	Node voltage standard value		
	Strict trend calculation	Triangle load model	Uniform load model
1	1.05	1.05	1.05
2	1.04425	1.0446	1.045
3	1.03858	1.0393	1.041
4	1.03316	1.0343	1.0379
5	1.02813	1.0299	1.0358
6	1.02366	1.026	1.0347
7	1.01989	1.023	1.0345
8	1.01108	1.0149	1.0292
9	1.00334	1.0079	1.0249
10	0.99684	1.0021	1.0215
11	0.99173	0.9978	1.0192
12	0.98816	0.9951	1.0177

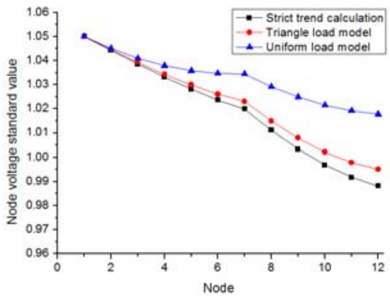

Figure 3: Model validation of DG at node 6

Through the above calculation of voltage after DG access, the voltage distribution calculation results based on triangle load model are consistent with strict flow calculation results, and are much better than voltage distribution calculation results of the uniform load distribution model. Thus, it verifies the correctness and validity of the triangle load distribution model in voltage analysis of distribution network with DG.

4.2 Influence of DG output variation on voltage distribution

The same network data and load, DG accesses to node 6. According to the DG output of 0, 30%, 65%, and 100% four programs, the test is conducted (Calvillo et al., 2015). According to the triangular load distribution algorithm given in this paper, we calculate the voltage distribution, and the results are shown in Figure 4.

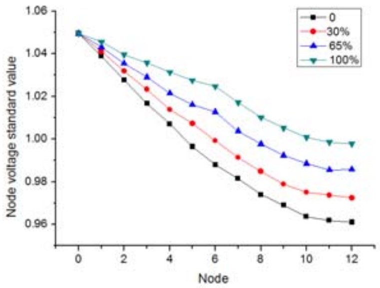

Figure 4: Voltage profiles according to the change of DG output

The above results show that the voltage level will increase with the increase of DG access capacity when the position of DG remains unchanged. It can be concluded that the voltage supporting effect of DG is determined by its output when the position is fixed, and the premise is to consider the type of distributed power supply (Liu et al., 2017).

4.3 Influence of position change of DG on voltage distribution

Keep the output unchanged, and for the output, only change its position in the network, which are points 4, 6, 8, and 11, respectively, and the results are shown in Figure 5.

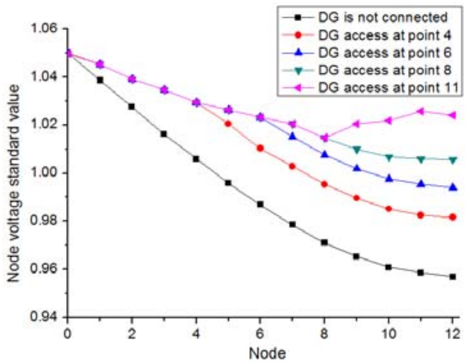

Figure 5: Voltage profiles according to the change of DG interconnecting location

We can see from Figure 5 that, when DG output is not unchanged, we change the access position, then the voltage will change. The closer to the load side is, the more obvious the voltage amplitude change is. When the access point is 11, the voltage level is significantly higher than the voltage level when the access point is the other. When the access point is 11, DG position is closer to the load side, and for the access point 4, the location is close to the bus. It can be seen that the closer the access location of DG to the end of the line is, the greater the impact on voltage is.

4.4 Voltage regulation of DG

Because the generator of distributed generation has excitation system and it can adjust the reactive power to a certain extent, it has the ability of voltage regulation. In actual operation, when the DG is away from the substation, the substation bus voltage regulation ability is very weak (Liviu et al., 2017). As in Figure 5, the access point 11 illustrates this point. Some generators use induction motor (such as wind turbines), which may also absorb reactive power, and does not apply to voltage regulator. The inverter itself does not produce reactive power, so in this case, we must have the corresponding reactive power compensation devices (Ahmad et al., 2017). The power companies tend not to expect the distributed generation to adjust the voltage at the public connection point, worrying about the interference for the reactive power regulation device of its own. Between a plurality of distributed generations, sometimes there will produce interference at modulation (Rahman et al., 2017). The distributed generation with small capacity is usually incapable of voltage regulation, and often runs at a constant power factor or constant reactive power mode. Although large capacity distributed generation can be used to regulate the voltage at the common junction point, the relevent signal and information must be transmitted to the dispatching center of the distribution system, so as to coordinate the scheduling and control (Rasmus et al., 2017). The problem is that the start and stop of distributed generation is often controlled by the user. If it is required to undertake the voltage adjustment task at the common connection point, once the outage occurs, the voltage regulation at the common junction point may become a problem (Joel et al., 2016).

5. Conclusions

In the future, the combination of large power grid with distributed power grid is a main way to save investment, reduce energy consumption, and improve the stability and flexibility of power system. Based on the background of smart grid, taking the achievement of large-scale distributed power access to the grid as the goal, and change of voltage of distribution network with DG as the research object, we study the pressure regulation of distributed power access to the grid. The research results indicate that the triangle load distribution model is better than the load uniform distribution model. Without changing the access position, the output voltage is decided by the support function. The more the output force is, the greater the voltage support effect is, and the higher the overall voltage level is. In the case of the output unchanged, the closer the location to the end of the line is, the greater the impact on voltage is, and when it is away from the substation, the weaker the ability to regulate the bus voltage of substation.

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