Simulation analysis of distribution network with distributed generation based on ADPSS

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Abstract—In this paper, the steady-state and transient models of distributed generation are modeled and simulated based on ADPSS system. Through the analysis of the simulation results, the fault characteristics of the distribution network with distributed generation are extracted. Through the analysis of the steady-state and transient models with distributed generation and the impact of the access of distributed generation on the power quality of the distribution network, the fault characteristics of the distribution network with distributed generation are extracted, which lays a theoretical foundation for the location and capacity determination of distributed generation.

1. Introduction
Advanced digital power system simulator (ADPSS) is an all digital simulation system based on high-performance PC cluster developed by China Electric Power Research Institute. The simulation device uses the multi node structure of the cluster and the high-speed local communication network, uses the network parallel computing technology to decompose the computing tasks, and carries out real-time and synchronous control of the process, so as to realize the real-time and super real-time simulation of electromechanical and electromagnetic transients of large-scale complex AC / DC power system and the test of external physical devices. The simulation device can be used for electromechanical transient simulation and electromechanical electromagnetic transient hybrid simulation of large-scale AC / DC power system with 3000 units and 20000 nodes, can be connected with dispatching automation system to obtain online data for simulation, and can be connected to relay protection, safety automatic device Facts control device, DC transmission control device and other actual physical devices are subject to closed-loop simulation test. Commercial software such as MATLAB can be accessed for local and sub task calculation, and user-defined model can be accessed to complete the functions and tasks specified by the user.

It lays a foundation for establishing the constraints of distribution network planning with distributed generation, and can also verify and verify the accuracy and effectiveness of the planning scheme. Through the analysis of the steady-state and transient models with distributed generation and the impact of distributed generation on the power quality of distribution network, the model is established based on ADPSS system, and the corresponding simulation is done. Through the analysis of simulation results, the fault characteristics of distribution network with distributed generation are extracted, which lays a theoretical foundation for the location and capacity of distributed generation.
2. Modeling and analysis of distributed generation

2.1. Photovoltaic cell

The power generated by the photovoltaic panel and inverter can be illustrated in Fig. 1, and can be given by:

$$P_{PV} = I_{irr} \times P_{mpp} \times F_T$$

(1)

where $P_{mpp}$ is the reference value of the output power of the photovoltaic array at a certain temperature and the radiance is 1 kW/m$^2$, $I_{irr}$ is the current radiance, $F_T$ is the current output power factor.

Circuit model of photovoltaic cell can be shown in Fig. 2 to Fig.5 with 3 basic models.

![Photovoltaic cell model](image)

Fig.1 Photovoltaic cell model

![Ideal model of photovoltaic cell](image)

Fig.2 Ideal model of photovoltaic cell

![Single diode model of photovoltaic cell](image)

Fig.3 Single diode model of photovoltaic cell

![Double diode model of photovoltaic cell](image)

Fig.4 Double diode model of photovoltaic cell
In the steady-state simulation, the energy storage device can not only operate independently, but also be controlled by the energy storage controller, and the SOC of the battery can be given by:

\[
SOC(t) = SOC(t_0) + S_{ymb} \times i_d \times t \times (3600C_M)^{-1}
\] (2)

where \(SOC(t_0)\) is the initial value of battery energy storage, \(i_d\) is current, \(t\) is charge/discharge time, \(C_M\) is the change capacity, \(S_{ymb}\) is the marked value of charge/discharge.

2.2. Wind power
For different grid connected wind power generation systems, the shafting model has a unified structure, which generally includes three mass blocks: Fan mass block, gearbox mass block and generator mass block (no gearbox mass block for direct drive wind power generation system). The inertia of fan mass is generally large, while that of gearbox is small. Its main function is to mesh the fan and generator through low-speed rotating shaft and high-speed rotating shaft. Due to the large difference of mass inertia, the mass composition of different wind power generation systems is not completely consistent. Different shafting models have different applications. In the modeling and Simulation of wind power generation system, the two mass model is more commonly used. The two mass model is taken as an example.

Since the inertia of the gearbox is smaller than that of the fan and generator, sometimes the inertia of the gearbox can be ignored and the quantities of the low-speed shaft can be converted to the high-speed shaft. In the transient simulation of permanent magnet motor, the control system components are used to simulate the characteristics of permanent magnet motor with undamped winding more simply and effectively. The transient time domain solution of the control system is obtained by solving the component characteristics of each basic link, and the accurate simulation results can also be obtained, which can be shown in Fig. 5.

![Fig.5 Permanent magnet synchronous motor model described by transfer function](image)

3. Fault characteristic analysis of distribution network with distributed generation
Based on the modeling and analysis of distributed generation and energy storage equipment in the previous part, a typical distribution network system with split generation or energy storage equipment is constructed in Fig. 6. Through these simulations, the fault characteristics of distribution network with distributed generation and energy storage equipment are intuitively analyzed. In the model, the fault start time is set as 1.6s, the duration is 0.3s, the active rated power of distributed generation is 1000kW, and the reactive rated power is 100kvar.

![Fig.6 Distribution network system diagram with distributed generation](image)
Before the fault, the distributed power supply outputs active power according to the rated capacity, and the reactive power output is 10kvar. Take the electromotive force of the power supply as the phase reference, and the current reference direction is shown in the figure. The simulation results of phase to phase fault and three phase short circuit at C are given in turn below. In the simulation diagram of positive sequence, negative sequence and zero sequence amplitude and phase, the yellow line represents the curve of positive sequence component, pink represents the curve of negative sequence component, and cyan represents the curve of zero component.

In order to clearly see the change of voltage during fault, the time window length of 0.5s is selected here, that is, the fault start time corresponds to 0.1s in the Fig. 7 to Fig. 10.

Fig. 7 Current waveform when interphase fault with the fault point at C

Fig. 8 Voltage waveform when interphase fault with the fault point at C

Fig. 9 Phase diagram of current positive, negative and zero sequence waveform

Fig. 10 Phase diagram of voltage positive, negative and zero sequence waveform
Several conclusion can be listed according to the simulation results above.

(1) When the phase to phase fault occurs in the distribution network, the current of the two phases will increase instantaneously, and then gradually decrease to a stable value, which changes within a certain range; The voltage of fault phase will decrease to a certain voltage value and operate stably, and the voltage of other two phases will increase for a short time; The residual phase current and voltage remain basically stable.

(2) After the fault is eliminated, the three-phase current and voltage will immediately return to the initial value.

(3) During the fault process, the amplitudes of the positive and negative sequence voltage and current components of the fault phase will change greatly. The positive sequence current component increases rapidly and the negative sequence current component decreases accordingly. When it reaches a certain value, it will oscillate near a certain current value; The positive voltage component will first decrease and then increase, and finally oscillate up and down around a value. The negative sequence voltage component will quickly increase from 0, and then gradually decrease.

(4) The positive sequence current, voltage component and negative sequence current and voltage will reach 180 degrees within 0.2S after the fault, and then oscillate.

(5) In the phase to phase short circuit, a short circuit circuit circuit can be formed between phases. Therefore, the phase difference can be 180 degrees by detecting whether the current directions of the two fault phases are opposite.

4. Conclusion
In this paper, the steady-state and transient models with distributed generation and the impact of distributed generation on power quality of distribution network are analyzed. The modeling is based on ADPSS system, and the corresponding simulation is done. Through the analysis of simulation results, the fault characteristics of distribution network with distributed generation are extracted, which lays a theoretical foundation for the location and capacity of distributed generation.

References
[1] Chan, E., Markushevich, N. (2016) Justification and Planning of Distribution Automation., CEPSI, 11: 796-803.
[2] Markushevich, N. (2014) Modeling Distribution Automation, 4th International Symposium on DA/DSM, 1:59-67.
[3] Jensen, C., Markushevich, N., Berman, A. (2018) Optimizing Feeder Sectionalizing Points for Distribution Automation. DistribuTech, 1:147-150.
[4] Markushevich, N., Clemmer, J., Berman, A. (2018) Analysis of Capacitor Control Under Conditions of Distribution Automation at OG&E, DistribuTech, 1:143-146.
[5] Wei, G., Weili, W., Danyun, H., Zhihua, L. (2007) Distributed Generation and Effects of Its Parallel Operation on Power System. High Voltage Engineering, 33:36-39.