Research on Development Technology of AC / DC Hybrid Distribution Network Construction in Smart Grid

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Abstract. At present, the flexible interconnection of flexible power grids based on flexible DC and the combination of AC and DC distribution networks in smart grids will bring great changes and challenges to the operation of traditional power distribution systems. The AC / DC hybrid distribution network can better accept distributed power and DC loads, alleviate the contradiction between limited corridors and high load density in urban power grid stations, and provide dynamic reactive power support at the load centre, which can effectively improve the urban distribution system. Power quality, reliability and operating efficiency. This article summarizes and analyses key technical issues such as the topology, optimization planning, dispatch control, and economic evaluation of AC-DC hybrid distribution networks. Finally, the application prospects of AC-DC hybrid distribution networks are prospected.

1. Introduction

The interconnection between the feeders of the traditional power distribution system is usually researched based on the segmented contact switch. In actual operation, a closed-loop research and an open-loop power supply are often used. With the widespread implementation and application of new technologies such as distributed power, energy storage, electric vehicles, and microgrids, as well as active power distribution, self-healing control, and demand-side response, conventional network connection methods based on contact switches have become the main bottlenecks restricting the further improvement of the operation economy, flexibility and reliability of the power distribution system [1]. The future intelligent power distribution system aims to achieve a flexible, reliable and efficient distribution network architecture and flexible scheduling and control of power flows. Intelligent soft switching technology based on back-to-back voltage source converters can replace traditional circuit breaker-based feeder contact switches to achieve flexible interconnection between feeders, thereby greatly improving the flexibility, speed and accuracy of power distribution network power flow control. This technology has recently received widespread attention from academic and industrial circles at home and abroad. This paper will summarize the existing network research results, including the grid structure, optimal planning, dispatch control, and economic evaluation of AC-DC hybrid distribution networks [2].
2. Grid Structure and Control of AC / DC Hybrid Distribution Network

2.1. AC / DC Hybrid Distribution Network Grid Structure

The structure of the DC distribution network grid mainly includes radial, two-end power supply and ring-shaped DC distribution networks. 1. Radiated DC distribution network is composed of DC buses of different voltage levels. The backbone network is composed of distributed power sources, AC loads and DC loads connected to the DC bus through power electronic devices. Its structure is simple, control requirements are low, but power supply is reliable. Compared with the radiating DC power distribution network, when the power supply on one side is faulty, you can operate the contact switch to supply power from the other power source to realize load transfer and improve Overall reliability [3]; 3. Compared with the DC power distribution network at both ends, the ring-shaped DC power distribution network can quickly locate and isolate faults. Its operation mode is like the DC power distribution network at both ends, and its power supply reliability higher. According to different application requirements, AC / DC hybrid power distribution networks can be divided into AC / DC hybrid power distribution networks with flexible DC devices and AC / DC hybrid power distribution networks with DC networks. The former is suitable for situations where the DC source load is small. This is more suitable for the case of high-density DC source-load access. The AC / DC hybrid power distribution network with DC network connection mode mainly includes radiant AC / DC hybrid power distribution network (no communication between AC and DC lines), multi-segment moderate connection AC / DC hybrid power distribution network (connected between AC and DC lines), As shown in Figure 1 for the radiation type AC and DC hybrid distribution network structure.

2.2. Hierarchical operation control framework of DC distribution network

The DC distribution network usually adopts a hierarchical operation control framework as shown in Figure 2. Aiming at the DC distribution network of different topologies, according to the different system operation modes and control objectives, a reasonable local controller algorithm and a system-level coordinated optimization control strategy should be selected. In the local control layer, one of the key control objectives is the DC voltage stability control. The topology and operation mode have a greater impact on the DC voltage control mode. For system-level control, a simple DC distribution network can use centralized optimization control. For complex DC distribution networks, in order to ensure high reliability and flexibility of multi-scale coordinated control, distributed collaborative optimization is a feasible solution [4].

In short, the local control layer of the DC distribution network mainly solves the problem of fast power balance and stability control after the system is disturbed (such as new energy output or load...
fluctuations, system operating mode changes, etc.); system-level control is mainly Solve the problem of optimal operation of DC distribution network in long time scale.

3. Scheduling and Control Technology of AC / DC Hybrid Distribution Network

3.1. Scheduling Scheme of AC / DC Hybrid Distribution Network

The dispatching plan of the AC-DC hybrid power distribution network should be formulated in conjunction with distributed power sources, energy storage equipment, and actual load characteristics. Because AC / DC hybrid distribution networks have different topologies and operating methods compared to traditional distribution networks, the scheduling methods of the two are also different. Flexible interconnection devices can be used in AC / DC hybrid distribution networks to achieve multi-regional power flow.

This paper studies the multi-source cooperative hierarchical distributed optimal scheduling scheme for AC-DC hybrid distribution networks, and its structure is shown in Figure 3. The strategy uses hierarchical dispatching and distributed optimization theories and methods to optimize the dispatching of AC / DC hybrid active power distribution networks with multiple types of distributed generation to achieve efficient production and use of electrical energy. In the local dispatching layer, the joint output optimization of renewable distributed power generation combined with energy storage devices is performed; in the regional dispatching layer, based on the optimization results of the local dispatching layer, controllable distributed power generation within the distribution network area and inter-area exchange Power scheduling to optimize the power supply mode of the distribution network. Through simulation research, the feasibility and effectiveness of this hierarchical distributed optimization scheduling strategy can be proved. In the local scheduling layer, renewable energy can be fully utilized and energy storage can be used to stabilize fluctuations. In the regional scheduling layer, distributed optimization scheduling is used. We can get the optimal power supply scheme for the overall AC-DC hybrid distribution network, and verify that by constructing the AC-DC hybrid distribution network, we
can make better use of the different load characteristics of each AC distribution network area, and realize wide-area dispatching of energy.

**Figure 3.** Hierarchical and Distributed Optimal Scheduling Strategy for AC-DC Hybrid Distribution Network

### 3.2. Control technology of AC / DC hybrid distribution network interface converter

As the interface unit of the AC distribution network and the DC distribution network, the VSC converter enables multiple AC feeders to form a closed-loop decoupling structure, which lays the foundation for flexible regulation of the distribution network trend. The topology of the three-phase VSC converter is shown in Figure 4 [5].

**Figure 4.** Topology structure of three-phase voltage source converter
Let the AC grid phase voltage be $u_{a}, u_{b}, u_{c}$; the converter output voltage is $u_{a}, u_{b}, u_{c}$; the converter output current is $i_{a}, i_{b}, i_{c}$; the connection inductance and resistance are $L$ and $R$, respectively, and the voltage equation of VSC in the three-phase stationary coordinate system is

$$
\begin{align}
L \frac{d i_d}{dt} &= -R i_d + \omega_{s} L i_q + u_{sd} - u_d \\
L \frac{d i_q}{dt} &= -R i_q + \omega_{s} L i_d - u_q
\end{align}
$$

Where: $i_d$ and $i_q$ are the d and q axis currents of the converter; $\omega_s$ is the electrical angular frequency of the grid; $u_{sd}$ is the d axis component of the grid voltage $u_s$, and $u_{sd} = u_s$; $u_d$ and $u_q$ are the d of the converter output voltage Axis and q axis components. The power equation is

$$
\begin{align}
P &= \frac{3}{2} u_s i_d \\
Q &= \frac{3}{2} u_s i_q
\end{align}
$$

According to equation (1), there are coupling terms $\omega_{s} L i_q$ and $\omega_{s} L i_d$ between the d-axis and the q-axis. In order to realize the decoupling control of PQ, Divide the coupling between the two.

According to different control purposes, the outer loop control method of the interface converter is divided into PQ control, V/ f control and droop control, and PQ control has VQ control (constant DC voltage and constant reactive power control) and converter output voltage Control and other deformation methods. The main control methods adopted by the AC / DC interface VSC in this paper are PQ control, VQ control, and V/ f control. The control block diagram of PQ control is shown in Figure 5. Its main function is to change the power flow between AC and DC, and then realize functions such as power flow optimization.
Figure 5. Control block diagram of PQ control

VQ control is mainly to provide voltage support for medium voltage DC distribution network. Replace the active power control in PQ control with DC bus voltage control to change to VQ control, and the PI parameters need to be modified accordingly. In fact, the stabilization of DC voltage is achieved by controlling the energy transmission between the converter and the grid. V / f control is mainly used to realize the uninterrupted power supply of AC load. When a line fails somewhere and trips, V / f control can continue to provide voltage and frequency support for the downstream branch load of the breakpoint. After returning to normal, if you want to switch from island mode to grid-connected mode, you can add phase difference control in the frequency loop. When you want to connect to the grid, use the frequency and amplitude of the AC grid voltage as reference signals, and put phase-difference control at the same time [5].

4. Economic Evaluation of AC / DC Hybrid Distribution Network
The economic evaluation link is an important means to reduce and avoid decision-making errors in AC-DC hybrid distribution network construction projects and improve project economic benefits. Traditional AC / DC hybrid economic evaluation methods mainly include deterministic evaluation methods and uncertainty evaluation methods. Deterministic evaluation methods mainly include static evaluation methods and dynamic evaluation methods [6]. The static evaluation method does not consider the time value of funds when evaluating the economic effect of investment in engineering projects. It is relatively simple and intuitive, but it also does not take into account the benefits and changes in costs and differences in the service life of various schemes; the dynamic assessment method considers the time factor of funds and is more in line with the dynamic law of funds, so the economic evaluation given is more in line with reality, mainly including the net present value method and the internal rate of return method. Dynamic payback period method and cost present value comparison method. In the economic evaluation of AC-DC hybrid distribution networks, static assessment can be used to make preliminary estimates of the economics of AC-DC hybrid distribution networks, but the results cannot be used for practical demonstration. Although the dynamic evaluation method considers the time value of funds, the uncertainty of the technical and economic variables in the AC-DC hybrid distribution network is large, and the dynamic evaluation method cannot guarantee the accuracy of the evaluation results.
In the economic evaluation of AC-DC hybrid distribution networks, the interval-based analysis method is simple and easy to handle, and can better handle uncertainty information. It is more suitable for economic evaluation of uncertainty. However, although this method considers the uncertainty of technical and economic variables to a certain extent, the evaluation result provided is an interval number and cannot provide probability distribution information on the interval [7].

In the economic evaluation of AC-DC hybrid distribution networks, the traditional economic evaluation algorithms have been difficult to adapt to the new economic evaluation requirements. It is necessary to consider the uncertainty of technical and economic variables and the time value of funds during the entire life cycle to evaluate the economics of AC-DC hybrid distribution networks. Some scholars have proposed an economic evaluation method based on the probabilistic full life cycle. This method is based on the full life cycle method, considering the uncertainty of the economic evaluation variables, and is suitable for the economic evaluation of AC-DC hybrid distribution networks [8].

5. Conclusion
Flexible DC equipment brings new controllable means to the operation of the distribution network, which can continuously adjust the active and reactive power flow in the distribution network. In the new form of power grid, such as AC-DC hybrid power distribution network, how to perform coordinated control of a variety of continuous regulating equipment and discrete regulating equipment, and maintain good control results under normal operation and fault conditions, is worthy of further study. In addition, in AC / DC hybrid distribution networks, there are large fluctuations in distributed power and load power, which will cause a wide range of system operating points. Research on robust control methods for AC / DC hybrid distribution networks it still has good control ability when transferring, which will bring great help to its operation.

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