Study of coordinate Control method to Improve Stability on Multi–Infeed HVDC system

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Abstract—Recently, in particular, many of the coming hydro power projects in China are located far away from the load centers. As the use of HVDC transmission continues to develop situations have arisen where multiple HVDC links terminate in close proximity in a common AC system area. This paper refers to the methods to improve the stability of voltage on multi-infeed HVDC system, and using CRIEPI’s transient stability simulation tool (CAPT). Through the simulations, this paper find the better measurement to solve those faults cases. Make a model multi-infed system base on the China Southern Power Grid for system. We focused of the inverter side voltage, and compared this traditional control method with the rapid restart control method’s results. The control of constituent HVDC subsystems can be better coordinated by the consideration of the time of rapid restart control at inverter side.

Index Terms—Multi-Infeed HVDC system, AC/DC system, control systems of HVDC system, simulation, rectifier, inverter

Introduction

Recently, with the expansion of the demand scale, using the effectively resource of power system and saving the electricity power transfusion cost are necessary for power system. So, in order to transmit the bulk amount of electric power to the huge demands area of the big city, large scale HVDC system is used in long distance transmission line like HVDC system by means of the long distance HVDC is used all the more. Compared with the ac power transmission, it is easier for HVDC power transmission to connect between the systems which have different frequency, cut off a fault of the dc power transmission with high speed, to control power flow and so on. Moreover, it’s not necessary for HVDC system to consider synchronizing stability, and, its makes it possible to carry the power transmission to the remote area, and it well uses for BTB connect between the systems and the loop connect.

This paper deal with the Southern electricity power in China, where connected the closely multi HVDC inverter. We simulate the phenomenon of power system in case of the failure and the disturbance of ac/dc transmission line and prove the stabilizing control method.

1. Voltage stability of multi-infeed power system

With the increase in the use of HVDC systems, situation with two or more HVDC systems connecting to AC system locations that are in close proximity electrically, which is known as multi-infeed HVDC system, may arise. Since the conventional HVDC system absorbs reactive power on both its rectifier and inverter sides, the behavior of HVDC system may be a major factor concluding commutation failure, influences the voltage stability of AC/DC systems, and investigation and clarification of the voltage stability of multi-infed HVDC systems is required. Thus the analysis of power system voltage stability has become of great concern in the recent years [1][2].

To date, many methods have been proposed by power system researchers for power system voltage stability assessment, which can be generally divided into two types: Steady-state Method and Dynamic Method [2][3]. Dynamic method can investigate specific voltage collapse situations, including fast and transient voltage collapse, and for coordination of protection and controls. However, dynamic simulation results may strongly depend on the dynamic models of system equipments and these results do not readily provide sensitivity information or the degree of stability, and besides, they are also time consuming in terms of CPU and engineering information or the degree of stability, and besides, they are also time consuming in terms of CPU and engineering required for analysis of results [4].

In view of the importance of voltage stability assessment for multi-infeed HVDC power systems, a few researchers have been engaged in its study for several years. In the report by Aik and Andersson [5], an eigenvalue decomposition-technique-based method is used for analyzing the relationship between the voltage stability and some of the HVDC parameters, such as short-circuit ratio and coupling impedance between the constituent AC/DC subsystems. However, to date, few studies have been presented for illustrating the influence of control systems of HVDC system on system voltage stability.

Therefore, Simulation method that can take the control systems of HVDC system into consideration is proposed. Such control systems include an Automatic Power Regulator (APR) and an Automatic (DC) Current Regulator (ACR) on its rectifier side and a changeover between an Automatic (DC) Voltage Regulator (AVR) and an Automatic extinction advance angle Regulator (AeR) modes on its inverter side.

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High-voltage direct-current (HVDC) transmission has advantages over ac transmission in special situations. The following points are the typical applications for which HVDC transmission has been used:

1. HVDC System transmission is feasible for the large amounts of power transmission with long distance and it is competitive to AC System transmission for distances in excess of 400Km proximity.
2. HVDC systems have the ability to rapidly control the transmitted power. Therefore, they have a significant impact on the stability of the associated ac power systems.
3. A synchronous system link between two AC systems network would be feasible because of system stability problems.

A. The typical Multi-Infeed HVDC system

The power system where HVDC transmission lines are connected to multi-point of ac system in close proximity electrically is name as multi -infeed HVDC system.

The typical Multi-infeed HVDC system can classify two patterns. One of multi-infeed HVDC system is the ring-type configuration, where multi-terminal HVDC system connects to rings ring type of ac system. This is shown in Fig 1. Another multi-infeed system is the chain-type configuration, where HVDC system connects to fishbone type of AC power systems. This is shown in Figure 2.

B. The joint plan of China and fact of MIDC system

Statistically, the amount of the power to which the water energy resources converted in China theoretically equals to 67604 million kW. And the amounts of electrical power of southwest and northeast area are 55748 million kW, which is account for 82.46% of the total electricity. On the other hand, the east coast area tends to increase the demands for power yearly. In order to harmonize with these opposite situation, the power system of all over China mean to change considerably as follows. Entire China has seven power networks now, and then this will have three separated area, north, central and south part of the whole country, through the plan to use resources efficiently until 2010. Finally, the power will be carried from east from west.

Generally, the long distance HVDC and BTB cooperation along the systems is usually used as tie-line. This paper is based on the southern fact power system in Fig.3. Point A is Sanxia, point B is Guizhou and point C is Yunnan respectively. Using the transmission line of HVDC which is three root and 500kV of the 1000km class from this three point, this system provide the 9GW electrical power to Guangzhou, huge consumer. The transformer substation of three receive side is connected on AC transmission line of the 100km class and 500 kV.

C. Simply System model
Result Analysis:

Fig.5 and fig.8 to fig.11 indicate the result of transient stability simulation by CPAT. Fig.5 (a) is commutation failure cause by the lack of margin angle for increasing overlap angle and early voltage zero point. In case that the AC voltage drop equally in each three phases, only the increasing of overlap angle lead to the lack of margin angle. We detected this phenomenon and restarted the inverter immediately for its stabilizing.

1. In case of the AC-DC combined system, because the phase angle between generator and receive terminal bus of ac transmission system is not decrease, the system could not keep in stability.
2. In case of the MIDC system, because the generator of the remote area and the AC system of demand area are independent from each other. The system could keep in stable operation.

Voltage Stability:

Because the control response speed of DC is fast, it is often that the voltage fluctuation of load bus is getting bigger in a few second after the cutting off disturbance.

• Synchronizing Stability

Rapid restart control method

It is important that the AC/DC substation establish the AC voltage by the utilize the rapid control performance of DC system. The decrease of transmission power during fault of AC system is inevitability in AC transmission as well as DC. The restoration of AC voltage by cutting off the fault and rapid startup of AC transmission power is important. Hence, a rapid phase control method is developed to keep the ignition pulse time point and to synchronize the phase angle of AC voltage. When the DC voltage is less than specific level on the phase control circuit, PLO (phase lock oscillator), is changed to keep advance pulse and this circuit returns to the system voltage immediately after the restoration of AC voltage.

The merits of phase control method are stability improvement of AC/DC parallel transmission system, and the restriction of the short time over voltage occurred in DC system.
1. Both of the transformer comes commutation failure for fault of AC transmission line, because the inverter of each DC transmissions of MIDC is closely to each other.
2. Because it occurs the over voltage exceeded 120% of capacity of voltage transmission line of ac bus at this time, I carried out the rapid restart control to decrease this.
3. Then, unsteadiness occur at light power flow be cause of wobble of voltage for control and synchronizing stability occur at heavy power flow.
4. To add the control of time lag restart for unsteady phenomenon, it is possible to stabilize.

Result Analysis on the coordinate control

- Make the restart time lag of rapid restart control, in order to keep the voltage stability for the system.

From Fig.8 to Fig.11 are the voltages simulated figures of inverter side based on the System in Fig.6.

Fig.8 (b) shows the result with the rapid restart control method in Fig.7.

Fig.9 (b) and (c) shows the result by means of the rapid restart control and time lag restart control method on light power flow of MIDC.

Fig.10 (b) and (c) shows the result by means of the rapid restart control and time lag restart control method on heavy power flow of MIDC.

Fig.11 (b) shows the figure with the optimized time lag restarts control method.

1. Traditional control method
2. Rapid restart control method
3. Time lag restarts control method

Fig.9 Light power flow of MIDC system

Fig.10 Heavy Flow of MIDC System
E. Optimized of the gain

![Electric diagram]

Fig.11 optimized time lag restarts control method

Tab.1 Optimized of the restart time

<table>
<thead>
<tr>
<th>Restart time of 100 side</th>
<th>01</th>
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<th>01</th>
<th>01</th>
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<tr>
<td>Restart time of 400 side</td>
<td>01</td>
<td>02</td>
<td>03</td>
<td>04</td>
<td>05</td>
<td>06</td>
<td>07</td>
<td>08</td>
<td>09</td>
</tr>
<tr>
<td>Peak Voltage (pu)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
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<td>1.5</td>
</tr>
<tr>
<td>Re-stabilize time (s)</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
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</tr>
</tbody>
</table>

(a) Peak voltage of the system inverter side

(b) Re-stability time of the system inverter side

Fig.12 Figure described with Tab.1

Result Analysis on the coordinate control

Form the fig.11, we can see the voltage depend on adjustment of the inverter restart time.

Because the fault point is nearby the inverters, it restarts the inverter 100 far from its fault point, then adjust then inverter 400 times of restarts, and it could improve the voltage of the system.

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IV. BIOGRAPHIES

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