Simulation and Analysis on ±800KV Jinpin-Suzhou UHVDC Mono-Polar Block Fault on June 17

Da-Jiang WANG\textsuperscript{1,a,*}, Ye-Feng JIANG\textsuperscript{2}, Chen-Guang QIU\textsuperscript{2}, Liang-Liang SONG\textsuperscript{1}, Hao-Ming HU\textsuperscript{1}, Xiao CHEN\textsuperscript{3}, Gang LI\textsuperscript{2}, Jin-Min CHENG\textsuperscript{2}, Jie LI\textsuperscript{2}, Tao ZHU\textsuperscript{2} and Yu-Chen HAO\textsuperscript{2}

\textsuperscript{1}State Grid Jiangsu Electric Power Research Institute, Nanjing 211103, China
\textsuperscript{2}State Grid Jiangsu Electric Power Dispatching and Control Center, Nanjing 210024, China
\textsuperscript{3}State Grid Jiangsu Electric Power maintenance branch company, Nanjing 211102, China
\textsuperscript{a}Email:wangdj1983@163.com
\textsuperscript{*Corresponding author

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Abstract. Mono-polar block or bipolar block is common fault for high voltage direct current (HVDC) transmission system, which will result in serious problems and have severe effect on security and stability of power system. The Jinpin-Suzhou ultra-high voltage direct current (UHVDC) transmission project has effectively alleviated the power shortage of Jiangsu province that with receiving-end power grid, in order to simulate the operation status of Jiangsu power grid after mono-polar block of Jinpin-Suzhou UHVDC system in June 17,2016,the online dynamic security assessment system (DSA) is adopted, the frequency characteristics, bus voltage, transient response of the unit, and the power flow of transmission lines are analyzed from three moments: pre-fault time, fault time and steady state after fault, and the simulation results are compared with the actual recorded values by PMU, the actual failure process is successfully reappeared, the results can provide technical support for improving the safe operation level of Jinpin-Suzhou UHVDC system.

Introduction

Due to the reverse distribution of power resources and load centers in China, ultra high voltage long distance transmission with the advantages of large transmission capacity, long transmission distance and low transmission loss is an effective way to optimize the power allocation [1-3]. Jiangsu province is located in the economy and load center of China's east coast, with the increasing demand for electricity, Jiangsu power grid, as the receiving-end power grid, the proportion of accepting power from outside area is getting higher and higher, receiving power from the southwest, central China and other regions by ultra high voltage transmission lines, Jinpin-Suzhou UHVDC transmission project with transmission capacity of 7200 MW, play a significant role in meeting the demand for electricity in Jiangsu, but blocking of HVDC will lead to a wide range transfer of power flow, resulting in overload of transmission lines, the drop of bus voltage, frequency deviation or even splitting caused by out-of-step separation, thus, block fault of Jinpin-Suzhou UHVDC system is a serious threat to the safe operation of Jiangsu power grid[4-9].

In order to simulate the block fault of Jinpin-Suzhou UHVDC system in June 17, 2016, the operating state of Jiangsu power grid before occurrence of block fault and the frequency characteristics, bus voltage, transient response of the units, and the power flow of transmission lines after occurrence of block fault are introduced, the fault is simulated and analyzed based on the online dynamic security assessment system, and the results are compared with the actual recorded values by PMU, the reliability of the simulation model and method are verified.
Basic Analysis on Jinpin-Suzhou UHVDC System Mono-Polar Block Fault

±800kV Jinping-Suzhou UHVDC Transmission Project which start from Jinping converter station in Sichuan province and end in Suzhou converter station in Jiangsu province, the abundant hydroelectric power resource of Southwest China can be transmitted to the load center of Southern Jiangsu province directly via Jinpin-Suzhou UHVDC project, which has effectively alleviated the power insufficiency of southern Jiangsu province.

The diagram of 500KV grid structure of Suzhou converter station and surrounding area is shown in Fig. 1, the power transmitted by Jinping-Suzhou UHVDC system is connected to the power grid of Jiangsu by six 500kV transmission lines including Suzhou-Wujian three lines, Suzhou-CheFang line and Suzhou-Mudu double lines.

Figure 1. The 500kV grid structure in southern Suzhou.

Pre-Fault Jiangsu Power Grid Operation Mode.

Before the block fault, the total load of Jiangsu power system was 66017MW, and a generation of 52730MW. East China power grid has a consumption load of 166813MW, the load of Suzhou area was 17936MW. The power transmitted by Jinping-Suzhou UHVDC system was 3066MW. The frequency of East China power grid was at 50.05HZ, 500kV bus voltage of Suzhou converter station was 505.93kV, 500kV bus voltage of Wujian substation was 506.2kV.

At 13:39:10, June 17, 2016, the block fault of polar I in Jinpin-Suzhou UHVDC transmission system was caused by the lighting strike at the DC transmission lines while polar II was being maintenance, and 3070MW DC power was lost. The power output of units located in Jiangsu province and other provinces were increased after the block fault, without removal of the load, the loss of load caused by this fault is 0.

System Frequency Characters Recorded by PMU

The block fault occurred at 13:39:10, the frequency curve of power system recorded by PMU in Suzhou converter station is shown in Fig. 2. It can been seen that the system frequency dropped rapidly after the fault, and dropped to the lowest value of 49.86HZ after the fault about 5 seconds, with the drop range of 0.145HZ. Then, under the common action of load characteristics and primary frequency modulation characteristics of the units, the system frequency began to recover and rose to about 49.926HZ at about 20s after the fault.
The Power Fluctuation of Generators

The output fluctuation characteristics of some units in Jiangsu are shown in the following table.

Table 1. The power output characters of generators.

| Units       | Pre-fault(MW) | Fault time(MW) | After-fault(MW) |
|-------------|---------------|----------------|-----------------|
| Huasu3#     | 554           | 651            | 563             |
| Huasu4#     | 559           | 636            | 568             |
| Changshu1#  | 494           | 566            | 625             |
| Wangting11# | 257           | 303            | 260             |

The power system was disturbed and lead to the electromagnetic transient process after the block fault, the power output of units started to fluctuate due to disturbance, the power output of units at fault time may more than or equal to the rated value, the fluctuation process was end, and the power output of units tends to stabilize about 7 seconds after the fault.

Voltage Characters Recorded by PMU

Voltage is another important index of power system after fault. PMUs have been installed in Suzhou converter station and 500KV substations of Suzhou area, such as Wujiang, Mudu and Shipai. So, bus voltage data recorded by PMUs can be obtained. Because the trend and shapes of bus voltage curves are similar, 500KV AC bus voltage of Suzhou converter station is selected as a representative, and its bus voltage curve recorded by PMU is shown in the Fig. 3.

The 500KV AC bus voltage of Suzhou converter station raised instantaneously after the fault, and then gradually decreased with the removal of the filter one by one; the voltage decreased to the lowest point about 1 minute later. With gradually rise of system frequency, the voltage slowly recovered to the steady value, which is slightly lower than initial value.

After the fault, voltages of all buses maintain above an acceptable level and the fault doesn’t affect the voltage stability.
**Power Flow of Key Transmission Lines**

After the fault, the power flow of 500kV transmission lines in Suzhou area changed dramatically due to lost a significant power source, and power flow of part lines even reversed, however, there was no stability limits of line be exceeded. Power flow changes on part of transmission lines are shown in Table 2.

| Section                  | Pre-Fault(MW) | Post-Fault(MW) | Power Limit(MW) |
|--------------------------|---------------|----------------|-----------------|
| Mudu-Suzhou double-lines | -31           | 1440           | /               |
| Suzhou-Wujiang triple-lines | 2710       | 1818           | 3750            |
| Chefang-Suzhou single-line | -390        | 380            | /               |
| Yushan-Chefang double-lines | -1130       | -490           | 2000            |
| Shipai-Chefang single-line | 470         | 1150           | 1700            |
| Changshu-Shipai double-lines | 1320        | 1850           | /               |
| Meili-Mudu double-lines  | 1720          | 2760           | 3000            |
| Shipai-Huangdu double-lines | 18          | -550           | /               |

**Simulation and Analysis on Jinpin-Suzhou UHVDC Block Fault Based on DSA**

**The Basic Simulation Data and Fault Setting**

In order to further investigate this block fault after the fault, safety analysis engineers of Jiangsu dispatching and control center carried out fault simulation analysis on the basis of DSA system which is based on the intelligent scheduling system of D5000 and can get the data of whole east China power system every 15 minutes [10-12].

In order to ensure the correctness of simulation, power system state estimation data from DSA system at the time of 13:30, June 17 that only 9 minutes ahead of fault time is taken and on which the simulation is processed, the difference between online data and real data measured by SCADA can be ignored, the selected basic data can reflect the real system operation mode before the fault properly.

Jinpin-Suzhou UHVDC system mono-polar block fault is settled in DSA system, and particularly, the elimination scheme reactive power compensator in Suzhou converter station is settled in accordance with actual situation. It should be noted that the Auto Generation Control (AGC) model has not been established in Jiangsu DSA system yet, thus its dynamic control performance is not available for the simulation.

**Simulation and Analysis on System Frequency**

The comparison between the simulation curve of system frequency and the curve of system frequency recorded by PMU is shown in the Fig. 4.
The system frequency dropped rapidly after the fault due to the active power imbalance caused by mono-block fault, under the synergistically action of primary frequency control characteristics of the units and load-frequency characteristics after the fault, system frequency keeps rising to the steady state, which is about 20 seconds after the fault.

From the Fig. 4, it can be seen that there is little difference between the two system frequency curves. simulation curve based on DSA drops to the minimum value of 49.89HZ at about 3 seconds after the fault, and curve recorded by PMU drops to 49.86HZ at about 5 seconds after the fault. The PMU curve drops deeper than the simulation curve, with slower frequency recovery rate. The possible reasons are that the models and parameters of generators and loads of DSA are not completely accord with the actual, which is needed to be improved in the further [13].

**Simulation and Analysis on Bus Voltage**

The removal method of filter is settled accord with the actual mode when the voltage is simulated, which is removed seven times at different time. Simulation curve based on DSA and PMU curve of 500kV bus voltage of Suzhou converter station are plotted and compared in the Fig. 5.

From the Fig. 5, it can be seen that, the 500kV bus voltage of Suzhou converter station rises instantaneously and then falls by stage with the filters are eliminated by steps after the fault. The instant rise is caused by the time difference between DC block fault and elimination of on-site compensating filters in Suzhou converter station. The comparison results show that the simulation results are very coincides with the actual results recorded by PMU.

**Simulation and Analysis on Generator Power Output**

A comparison between DSA simulation curve and PMU curve of #3 generator of Huaneng Taicang Power Plant is made, as shown in the Fig. 6.
From the Fig. 6, it can be seen that the power output of #3 unit of Huaneng Taicang Power Plant starts to weakening oscillate after the fault, the oscillation time lasts about 6 seconds, then the power output of generator is sustained as a steady state, the DSA simulation curve fitted well with the PMU curve according to the curve comparison.

**Simulation and Analysis on Power flow of Key Transmission Lines**

The simulation results of power flow of key transmission lines in Suzhou area is shown in Table 3.

| Section                  | Pre-Fault(MW) | Post-Fault(MW) | Power Limit(MW) |
|--------------------------|---------------|---------------|-----------------|
| Mudu-Suzhou double-lines | -35           | 1433          | /               |
| Suzhou-Wujiang triple-lines | 2695       | 1825          | 3750            |
| Chefang-Suzhou single-line | -340         | 392           | /               |
| Yushan-Chefang double-lines | -1123       | -481          | 2000            |
| Shipai-Chefang single-line | 481          | 1186          | 1700            |
| Changshu-Shipai double-lines | 1298       | 1868          | /               |
| Meili-Mudu double-lines | 1755         | 2821          | 3000            |
| Shipai-Huangdu double-lines | 23          | -538          | /               |

There is little difference between the simulation results and the recorded results by comparing Table 2 and Table 3.

**Summary**

The Jinping-Suzhou UHVDC transmission system has subjected to mono-polar block fault due to bad weather in June 17, 2016. The fault was quickly subsided, and did not have a greater impact on the Jiangsu power grid, owing to the strong structure of Jiangsu power grid and appropriate measures adopted by dispatchers after the fault.

The influence of “6.17” Jinping-Suzhou UHVDC mono-polar block fault on Jiangsu Power Grid are analyzed from aspects such as system frequency drop, generator power output fluctuation, bus voltage drop and power flow changes of key transmission lines in this paper. This fault is simulated based on DSA, and the simulation results are compared with the recorded results by PMU, the comparison results show that the accuracy of simulation is high, but some details need to be further improved, the model, parameters of Jiangsu DSA system should be optimized in the aim of simulating the dynamic
characteristics of the whole power system accurately. Through the analysis of the fault, it is helpful to further understand the development process of the fault and the corresponding treatment measures, and provide decision support for the dispatchers, help in transforming to intelligent scheduling.

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