Voltage Deviation in Breaker-testing Station Study Using ADPSS

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Abstract

With the fast development of China power grid, more and more power system devices such as breakers are applied. Breaker testing also becomes very important. At the same time the testing procedure will cause voltage deviation around the breaker-testing station. Big voltage deviation can make severe damage for the power customers. Based on the power system simulation software ADPSS developed by China Electric Power Research Institute (CEPRI), this paper built up the simulation model using the electromechanical-electromagnetic transient hybrid method, and simulated the voltage deviation in a Henan breaker-testing station. The simulation results showed that with the higher testing breaker current level, bigger voltage deviation is caused. Finally this paper suggested a testing breaker current level for the breaker-testing station with Power Quality Criteria.

Keywords: power system, voltage deviation, ADPSS, electromechanical-electromagnetic transient hybrid simulation

1. Introduction

Breakers are widely used in power system. To ensure the breaker quality, testing of the power breakers is needed. At the same time, the testing procedure will cause voltage deviation around the breaker-testing station. Big voltage deviation can make severe damage for the power customers [1, 2]. Thus during the planning of the breaker-testing station, like the selection of common coupling point (CCP), the evaluation of voltage deviation is important [3, 4].

In Henan, a 420V-level breaker-testing station will be built in the southeast part of urban area. The CCP of the breaker-testing station is selected at the 10kV level of the nearby 110kV public substation. The 110kV public substation is connected with the upper 220kV public substation via two 110kV transmission lines. The power system geographical connection diagram is shown in Figure 1. So it is necessary to model the breaker-testing station and its surrounding area, and evaluate the voltage deviation when testing the breakers.
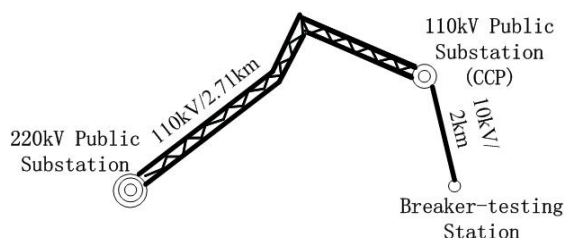

Figure 1. The Power System Geographical Connection Diagram

2. Simulation Enviroment and Criteria

In this paper the modeling and simulation work is done with Advanced Digital Power System Simulator (ADPSS) developed by CEPRI. ADPSS is based on high performance PC-cluster using multi-node structure and parallel computation technique [5, 6]. It is a powerful tool

for electromechanical-electromagnetic transient hybrid simulation of large scale power system up to 10000 buses [7]. With the increasing computer technology, the electromagnetic transient hybrid simulation is widely used in power system analysis [8, 9]. This paper built up the simulation model for the breaker-testing station and its surrounding area in ADPSS. Simulation diagram is shown in Figure 2. The breaker-testing station and 110kV public substation is built in electromagnetic simulation environment, shown in the square block. The Henan 220kV and up power grid is built in electromechanical simulation environment which is outside of the block.
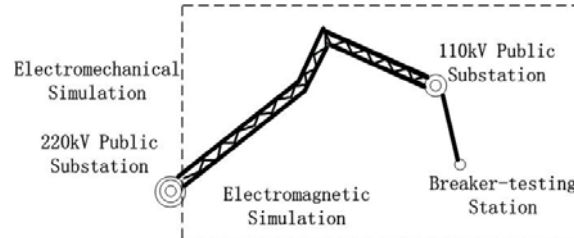

Figure 2. Simulation Diagram for the Breaker-testing Station

The interface between the electromechanical and electromagnetic parts is at the 110kV output of the 220kV upper substation, as shown in the Figure 2. Detailed simulation diagram is in Figure 3.
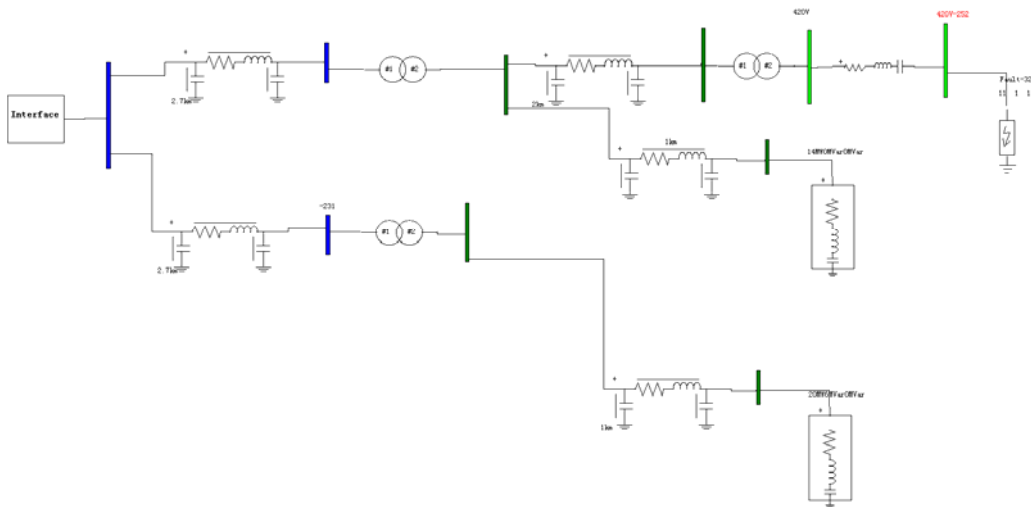

Figure 3. Detailed Simulation Diagram for Breaker-testing Station

According to China national criteria "Power quality – Deviation of supply voltage" (GB/T 12325-2008) [10, 11], for the 20kV and lower voltage level the voltage deviation compared with the standard voltage should be within ±7%. The voltage deviation equation is:

$$VD(\%) = \frac{V_{measure} - V_{s\tan dard}}{V_{s\tan dard}} \times 100\% \tag{1}$$

Where $V_{measure}$ is the measured voltage, $V_{s\tan dard}$ is the standard voltage.

3. Simulation Parameters

The simulation uses 2014 Henan 220kV and up power grid as electromechanical simulation environment. The 110kV public substation transformers' parameters are shown in Table 1.

Table 1. 110kV Public Substation #1 and #2 Transformers' Parameters

Transformer MVA	40MVA	Winding ratio	110kV/10kV YG/D
Short-circuit loss	158kW	Short-circuit voltage (%)	14.7%
No-load loss	28.8kW	No-load circuit (%)	0.12%

The breaker-testing station is connected at the #1 transformer of the 110kV public substation, as shown in Figure 3. The breaker-testing station, which simulation structure is shown in Figure 4, consists of 10kV distribution line, 10kV/420V short-circuit transformer, current-limiting resistor, and short-circuit fault point. The 10kV short-circuit transformer' parameters are shown in Table 2.
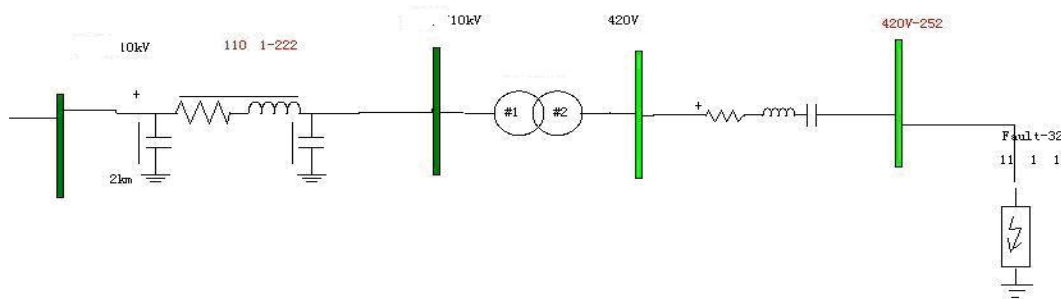

Figure 4. Breaker-testing Station Simulation Structure

Table 2. 10kV Short-circuit Transformer's Parameters

Transformer MVA	30MVA	Winding ratio	10kV/420V YG/D
Short-circuit loss	68kW	Short-circuit voltage (%)	7.5%
No-load loss	15kW	No-load circuit (%)	0.12%

The short circuit testing procedure is done using three-phase to ground fault. By changing the current-limiting resistor, different short-circuit current level and capacity is obtained. During the simulation the common coupling point (CCP), 10kV side voltage deviation of the 110kV #1 transformer is checked.

4. Results and Discussion

The simulation running time is 2 seconds. At one second the three-phase to ground fault is applied. The fault lasts for 0.5s. Two short-circuit current level: 50kA and 25kA, is tested.

4.1. Short-circuit Current Level is 50kA

The station's short-circuit current is shown in Figure 5. Its magnitude is 0.51 in p.u., which in physical unit is 50kA (RMS value). The calculating equation is:

$$I_{sc} = S_{sys} / \sqrt{3} / U_{L-L} * I_{pu} / \sqrt{2}$$

(2)

Where S_{sys} is simulation system MVA rating (100MVA), U_{L-L} is line to line RMS voltage (420V).
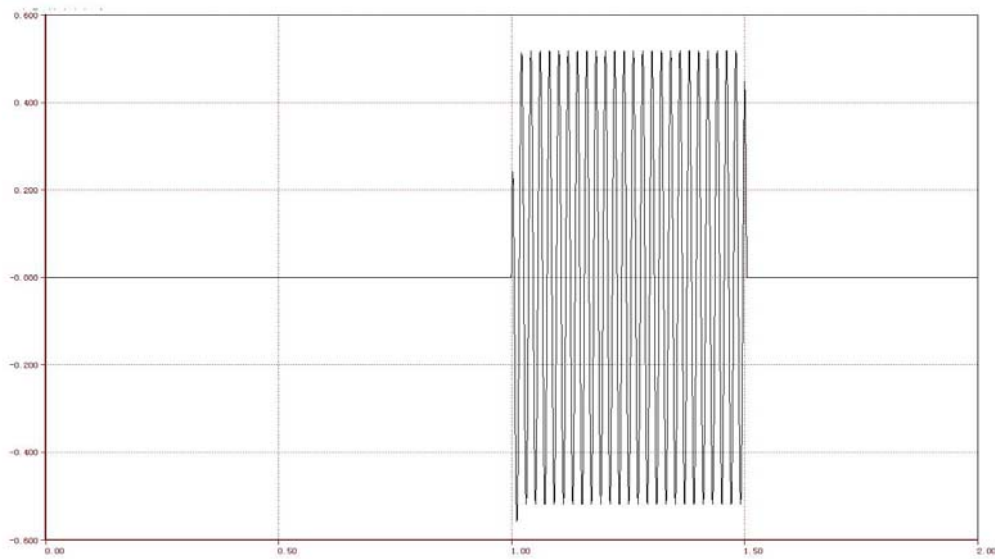
Figure 5. The Station's Short-circuit Current during the Test Procedure (50kA)

The common coupling point (CCP), 10kV side voltage waveform of the 110kV #1 transformer in p.u. is shown in Figure 6, the amplified voltage deviation waveform is shown in Figure 7.
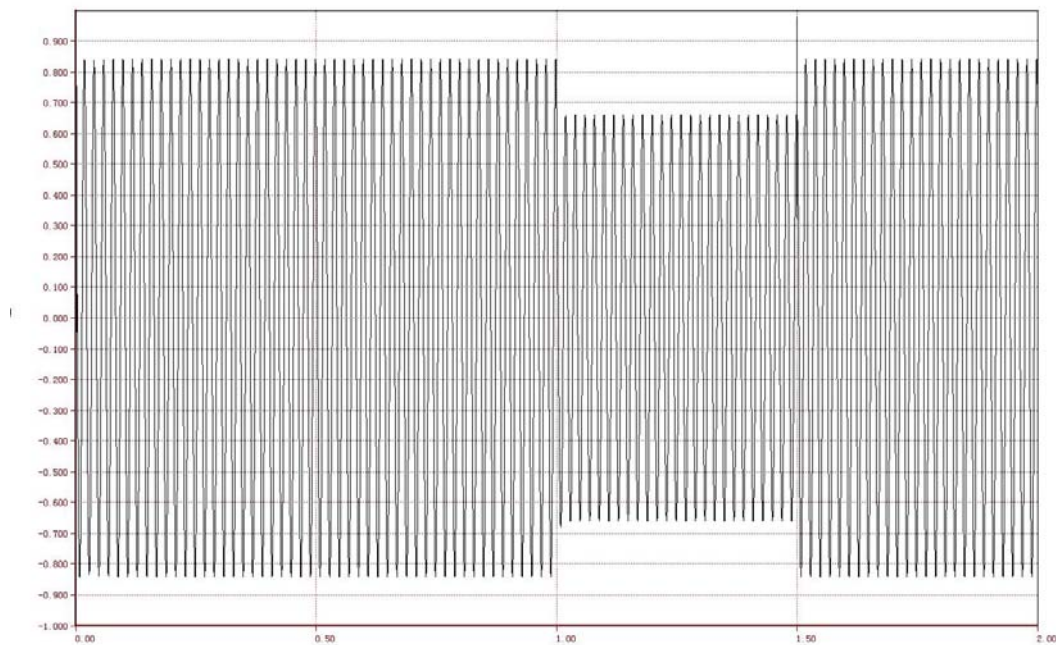

Figure 6. 110kV #1 Transformer's 10kV Side Voltage Waveform (p.u.) when Short-circuit Current is 50kA
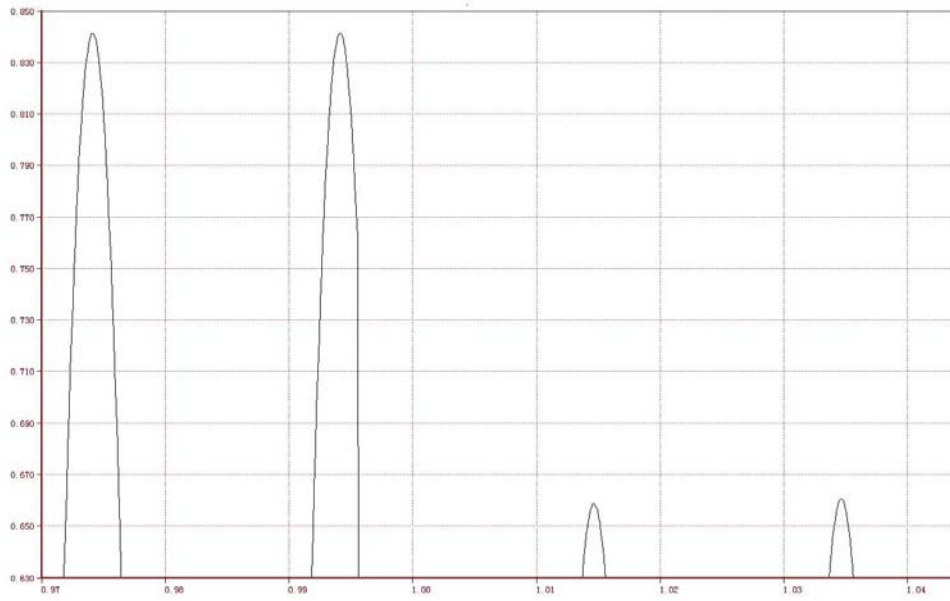
Figure 7. Amplified Voltage Deviation Waveform when Short-circuit Current is 50kA

From Figure 7 when short-circuit current is 50kA, the CCP voltage deviation percentage calculated by Eq. 1 is (0.84-0.66)/0.84*100%=21%. This results beyond the limit of the national criteria (GB/T 12325-2008). So the 50kA short-circuit current level can't be accepted.

4.2. Short-circuit current level is 25kA
The station's short-circuit current is shown in Figure 8. Its magnitude is 0.26 in p.u., which in physical unit is 25kA (RMS value) by Equation (2).
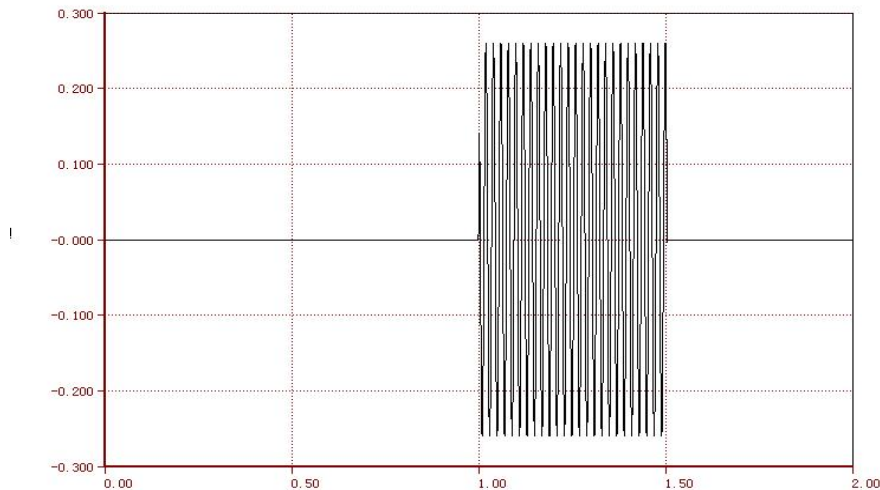

Figure 8. The Station's Short-circuit Current during the Test Procedure (25kA)

The common coupling point (CCP), 10kV side voltage waveform of the 110kV #1 transformer in p.u. is shown in Figure 9, the amplified voltage deviation waveform is shown in Fig ure 10.
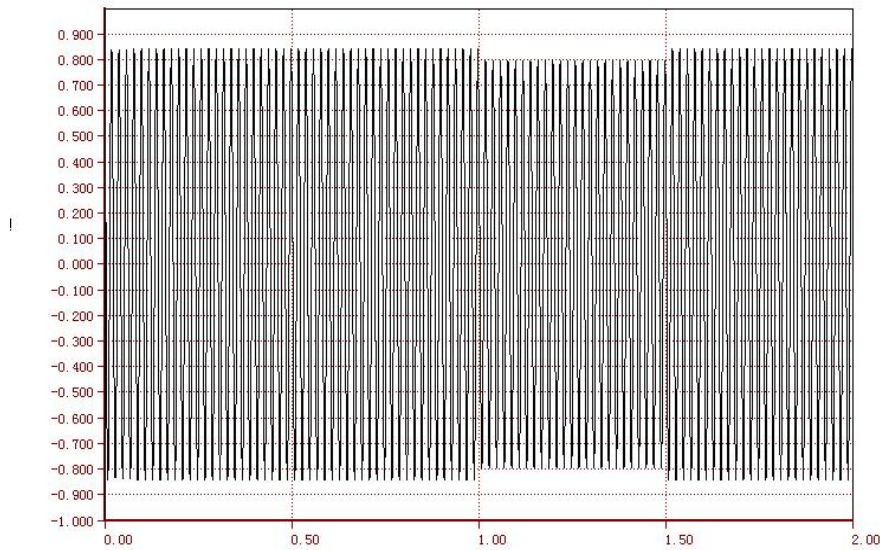
Figure 9. 110kV #1 Transformer's 10kV Side Voltage Waveform (p.u.) when Short-circuit Current is 25kA
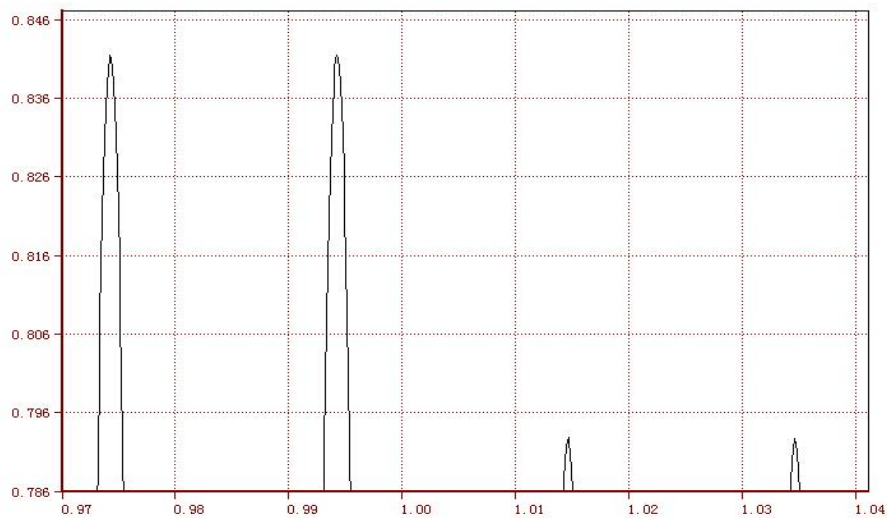

Figure 10. Amplified Voltage Deviation Waveform when Short-circuit Current is 25kA

From Figure 10 when short-circuit current is 25kA, the CCP voltage deviation percentage calculated by Equation (1) is (0.84-0.79)/0.84*100%=6.0%. Compared with Figure. 5-7, these results satisfy the limit of the national criteria (GB/T 12325-2008). So the 25kA short-circuit current level can be accepted.

5. Conclusion

With the breakers widely used in power system testing of the power breakers is needed. The testing procedure will cause voltage deviation around the breaker-testing station. Big

voltage deviation can make severe damage for the power customers. Based on the power system simulation software ADPSS developed by China Electric Power Research Institute (CEPRI), this paper built up the evaluation model using the electromechanical-electromagnetic transient hybrid method, and simulated the voltage deviation in a Henan breaker-testing station. The simulation results showed that with the higher testing breaker current level, bigger voltage deviation is caused. Finally this paper suggested a testing breaker current level for the breaker-testing station with Power Quality Criteria.

References

[1] Tao Shun, Xiao Xiangning, Liu Xiaojuan. *Study on distribution reliability considering voltage sags.* Proceedings of the Chinese Society for Electrical Engineering. 2005; 25(21): 63-69.
[2] Wang Bin, Pan Zhencun, Xu Bingyin. Analysis of voltage sags in distribution system. *Power System Technology.* 2004; 28(2): 56-59..
[3] Li Wei, Li Yuchun, Li Xiangyang. *Simulation of effect of breakers short circuit test on system voltage.* Journal of North China Electric Power University. 2006; 33(5): 25-28.
[4] Zhang Wei. The Electromagnetic Interference Model Analysis of the Power Switching Devices. *TELKOMNIKA Indonesian Journal of Electrical Engineering.* 2013; 11(1): 167-172.
[5] Tang Yong. *Present situation and development of power system simulation technologies.* Automation of Electric Power Systems. 2002; 26(17): 66-70.
[6] China Electric Power Research Institute. *Technical Summary Report on Development of Advanced Digital Power System Simulator.* 2004.
[7] Fang Tian, Chengyan Yue, Zhongxi Wu and Xiaoxin Zhou. *Realization of Electromechanical Transient and Electromagnetic Transient Real Time Hybrid Simulation in Power System.* Proc. of the IEEE/PES Transmission and Distribution Conference and Exhibition Asia Pacific, Dalian, China. 2005.
[8] Shadreck Mpanga, Wang Feng, Chen Chun. Electromagnetic Field Evaluation of a 500kV High Voltage Overhead Line*. TELKOMNIKA Indonesian Journal of Electrical Engineering.* 2013; 11(2): 789-796.
[9] Ding Shuye, Zhang Ning. Analysis of Electromagnetic Properties of Doubly-fed Turbine Generator*. TELKOMNIKA Indonesian Journal of Electrical Engineering.* 2013; 11(2): 783-788.
[10] China national criteria. *Power quality – Deviation of supply voltage.* (GB/T 12325-2008).
[11] State Grid Corporation of China. *Technical guide for power quality assessment.* Q/GDW651. 2011.