

# Measurement and Simulation of Induced Voltage and Current on 110 KV Crossing Transmission Lines under UHV AC Transmission Lines

Weiwei Pan<sup>1</sup>, Shoucheng Miu<sup>1</sup>, Guangkai Yu<sup>2</sup>, Tian Wu<sup>2</sup>, Bo Zhang<sup>3</sup>

<sup>1</sup>State Grid Jinhua Power Supply Company, Jinhua, China

<sup>2</sup>China Electric Power Research Institute, Wuhan, China

<sup>3</sup>School of Electrical Engineering, Wuhan University, Wuhan, China

Email: yarchergk@163.com

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## Abstract

The induced electricity of 110 kV transmission lines which cross the UHV AC transmission lines may threaten personal safety of the maintenance staff. In this paper, field measurement of the induced voltage and induced current on a 110 kV crossing line inside Jinhua in Zhejiang province is performed. The electrostatic induced voltage on the measured line is 12.24 kV. The power frequency electromagnetic field simulation model is established, and the calculation results are consistent with the measured. Influence factors analysis shows that the electrostatic induced voltage on the 110 kV line is 12.78 kV, the electromagnetic induced voltage is 12.3 V, the induced current through ground wire is less than 1A when the UHV lines operate at full load. The induced voltage and current decrease while the crossing distance increases. Parallel lines induction is much higher than crossing lines. The electromagnetic induced voltage after ground knife-switch shut down would exceed the human safety voltage 36 V while the crossing angle is less than 30°, so the temporary ground wire must be hanged to ensure safety of the maintenance staff.

## Keywords

UHV AC Transmission Lines, Crossing, Induced Voltage, Induced Current, Field Measurement, Simulation Calculation

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## 1. Introduction

Ultra-high-voltage AC power transmission has outstanding advantages of high transmission capacity, long distance of power transmission, low line loss, small

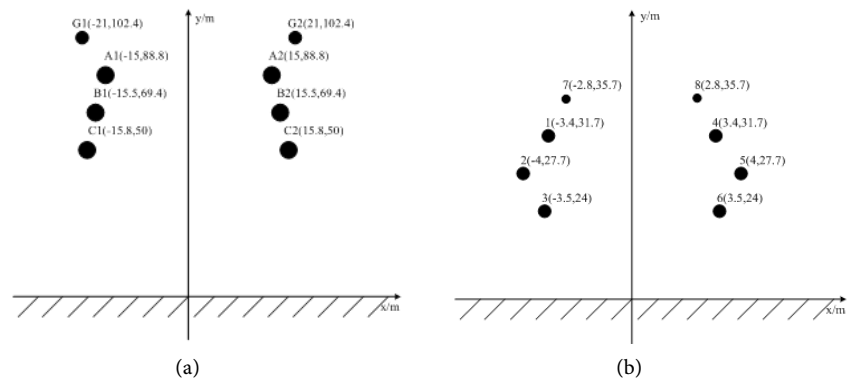
coverage, etc., which is an energy-saving and eco-friendly advanced power transmission technology. At present, China has three 1000 kV AC UHV projects completed in operation in total [1] [2]. As construction of UHV lines is underway, it is inevitable that power transmission lines in other voltage classes may parallel or cross with UHV lines in construction due to space limitation of power transmission corridor [3] [4] [5]. While high-voltage lines are running, electromagnetic fields may arise in space surrounding the lines. As a result, induced voltage and current may arise in nearby low-voltage lines, triggering potential safety threats in low-voltage line shutdown overhaul [6] [7] [8]. As UHV lines have high running voltage and transmission power, it is more necessary to focus on their induced power on low-voltage lines.

Domestic and foreign studies on UHV AC power transmission line induction are more concerned with parallel construction. In Literature [9] [10], computation and field measurement are made on induced voltage and current in 500kV one-tower two-circuit parallel line; in Literature [11] [12] [13], simulated computation and analysis are made on induced voltage and current in two-circuit UHV line with one line in power and one line in shutdown and 1000kV UHV and 500 kV/220 kV lines parallel with each other on the same tower respectively; in Literature [14] [15], computation is made on induction of UHV AC power transmission lines on low-voltage power distribution lines below. Concerning line crossing, in Literature [16] [17], methods of computation of power-frequency electromagnetic fields in crossing areas of AC power transmission lines are introduced; in Literature [18], theoretical computation is made on electrostatic induction of crossing and elongating conductors below 500 kV power transmission line. Few systematic domestic and foreign studies are concerning power transmission line crossing induction.

In this paper, field measurement is made on induced voltage and current of 110 kV crossing lines below UHV line in Jinhua, Zhejiang, simulated model is set up by CDEGS software to compute and analyze fluctuations in induced voltage and current of 110 kV lines under different transmission currents of UHV line, different crossing distances and crossing angles between UHV and 110 kV lines, precautions in shutdown overhaul of low-voltage lines under UHV line are presented, and reference basis is offered for layout design of crossing lines.

## 2. System Overview and Simulation Model

Put into operation at the end of 2014, Zhebei-Fuzhou 1000kV UHV AC Power Transmission Project is constructed in two circuits all the way. Line Jianglian I, Line Jianglian II and 110 kV Line Xianchi 1555 (construction in two circuits on the same tower) cross in Jinhua. Their crossing distance is 18.3 m and crossing angle is 60°. **Figure 1** shows layout of conductors and ground wires at the crossing location of two lines. G1 and A1-C1 refer to ground wire and three-phase conductor of Line Jianglian I; G2 and A2-C2 refer to ground wire and three-phase conductor of Line Jianglian II. Conductor 1-3 and Conductor 4 - 6 refer to Line Xianchi 1555 Circuit I and Line Xianchi 1555 Circuit II respective-



**Figure 1.** Layout of conductors and ground wires at the crossing location. (a) Line Jianglian; (b) Line Xianchi 1555.

ly; 7 and 8 refer to ground wires. Parameters of conductors and ground wires of crossing lines are shown in **Table 1**.

The simulated model of induced power of crossing lines is set up in the HIFREQ module in the simulation software of CDEGS as shown in **Figure 2**. Since induction is weaker somewhere farther from the crossing point, 2 km is taken as line length in simulated modeling, the crossing point is located in the center of line and line is deemed as a straight line by omitting the angle of rotation of line at the tension support; while power-frequency voltage and current are inflicted on three-phase conductor of Line Jianglian in normal operation, induction is computed in shutdown of Line Xianchi 1555.

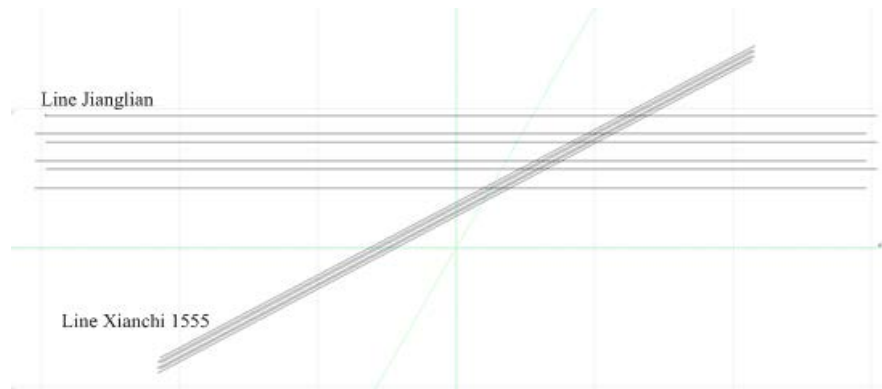
### 3. Measurement of Induced Voltage and Current of 110 KV Line

In order to study and master effects of UHV line on induced power of power transmission lines below, field measurement is made on 110 kV Line Xianchi 1555 in Jinhua as shown in **Figure 3**. In measurement, 110 kV line is in shutdown due to substation overhaul. In the state of test run, UHV line has lower load and its running load is as shown in **Table 2**.

In the measurement, three-phase conductors of Circuit I and Circuit II at the No.15 Support below the crossing point or Conductor 1 - 6 in **Figure 1(b)** are selected. Measured results are shown in **Table 3**.

- 1) Induced voltage of all phase conductors is measured before earthing switches on both ends of line are closed following substation shutdown;
- 2) After earthing switches on both ends of line are closed, induced voltage of all phase conductors is re-measured;
- 3) Temporary ground wires are attached to locations near both sides of a measuring point to measure induced current of temporary ground wires.

It is known by measured results that while earthing switches in the substation are not closed, higher electrostatic induced voltage arises on the 110 kV line and induced voltage of Conductor 1 that is the closest to UHV line attains as high as 12.24 kV; while earthing switches on both ends of substation are closed, induced voltage on the line is almost zero; due to lower running load of UHV line in



**Figure 2.** Simulated model.



**Figure 3.** Induced voltage and current of crossing lines in field measurement.

**Table 1.** Parameters of conductors and ground wires of crossing lines.

Line type	Line Jianglian	Line Xianchi 1555
Conductor	8 × JL/G1A-630/45	1 × LGJ-240/30
Ground wire	LBGJ-185-20AC	LGJ-50/30

**Table 2.** UHV line load.

Load Parameter	Name of UHV line	
	Line Jianglian I	Line Jianglian II
Active power/MW	246 - 275	241 - 271
Reactivepower/Mvar	405 - 416	11 - 21
Current/A	261 - 271	127 - 154

**Table 3.** Measured results of induced voltage and current.

Conductor No.	Induced voltage of conductor/kV		Induced current of ground wire/A
	Earthing switches are unclosed	Earthing switches are closed	
1	12.24	0.002	0.07
2	10.47	0.002	0.06
3	8.70	0.002	0.02
4	12.22	0.001	0.07
5	10.47	0.001	0.06
6	8.70	0.001	0.02

measurement, after temporary ground wires are attached to both ends of the crossing point, the measured induced current flowing through the ground wires is very low as well, which is lower than 0.07A.

#### 4. Simulated Computation and Analysis of Influence Factors

The maximum value in **Table 2** is taken as load of UHV line to make simulated computation on results of induced voltage of all conductors and induced current of temporary ground wires as shown in **Table 4**.

It is known by table that results of simulated computation and field measurement are close to each other, proving the accuracy of simulated model. Different transmission currents of UHV line, crossing distances and crossing angles are taken to make simulated computation and analysis on induced voltage and current of 110 kV line.

##### 4.1. Effects of Transmission Current of UHV Line

The maximum transmission capacity of the UHV line is 6000 MW in one circuit. However, since it is put into operation lately and experiences no peak of power consumption, it keeps running in a lower load. In order to ensure personal safety in shutdown overhaul of 110 kV line below, it is necessary to study induction in the state of high load. While UHV line is in the transmission powers of 2000 MW, 4000 MW and 6000 MW respectively, transmission current of each phase conductor is 1.15 kA, 2.31 kA and 3.46 kA respectively. Crossing distance of 18.3 m and crossing angle of 60° are taken to compute induced voltage and current of 110 kV line under different transmission currents as shown in **Table 5**.

While earthing switches in the substation are not closed, induced voltage of 110 kV line is generally electrostatic coupling component and electrostatic induction is irrelevant with transmission current. Therefore, induced voltage of conductors is almost unchanged; after earthing switches on both sides of station are closed, induced voltage of 110 kV line is generally electromagnetic coupling component and electromagnetic coupling voltage rises as transmission current rises in direct proportion and induced voltage is 12.3 V while UHV line is in

**Table 4.** Results of simulated computation on induced voltage and current.

Conductor No.	Induced voltage of conductor/kV		Induced current of ground wire/A
	Earthing switches are unclosed	Earthing switches are closed	
1	12.77	0.0016	0.067
2	11.08	0.0013	0.057
3	9.58	0.0014	0.044
4	12.76	0.0016	0.067
5	11.07	0.0013	0.057
6	9.58	0.0014	0.044

**Table 5.** Computing results of UHV line under different transmission currents.

Transmission current/kA	Induced voltage of conductor/kV		Induced current of ground wire/A
	Earthing switches are unclosed	Earthing switches are closed	
1.15	12.77	0.0047	0.20
2.31	12.78	0.0085	0.38
3.46	12.78	0.0123	0.56

full-load operation; induced current flowing through temporary ground wires is very low, which is lower than 1A.

#### 4.2. Effects of crossing Distance between 110 KV Line and UHV Line

Transmission current of 3.46 kA of each phase conductor and crossing angle of  $60^\circ$  are taken to compute induced voltage and current of 110 kV line under different crossing distances as shown in **Table 6**.

The farther UHV line is away from 110 kV line below, the lower electrostatic induced voltage and electromagnetic induced voltage of 110 kV line will be. As crossing distance rises from 20 m to 50 m, electrostatic induced voltage falls from 12.43 kV to 8.93 kV and electromagnetic induced voltage falls from 12.2 V to 11.0 V; induced current of temporary ground wires slightly declines as well.

#### 4.3. Effects of crossing Angle between 110 KV Line and UHV Line

Transmission current of 3.46 kA of each phase conductor and crossing distance of 18.3 m are taken to compute induced voltage and current of 110 kV line under different crossing angles as shown in **Table 7**.

While crossing angle changes from  $0^\circ$  (parallel construction) to  $90^\circ$  (vertical crossing), induced voltage and current of 110 kV line show greater change. In parallel construction of two lines, electrostatic induced voltage attains 100.84 kV, electromagnetic induced voltage attains 358 V, and induced current of ground wires attains 16.3 A, much higher than those in the situation of line crossing. Even though crossing angle is only  $30^\circ$ , electrostatic induced voltage falls 59.3%, electromagnetic induced voltage and induced current of ground wires fall as much as 89.7% and 89.4% respectively.

**Table 6.** Computing results under different crossing distances.

Crossing distance/m	Induced voltage of conductor/kV		Induced current of ground wire/A
	Earthing switches are unclosed	Earthing switches are closed	
20	12.43	0.0122	0.56
30	10.84	0.0118	0.54
40	9.755	0.0114	0.53
50	8.930	0.0110	0.51

**Table 7.** Computing results under different crossing angles.

Crossing angle	Induced voltage of conductor/kV		Induced current of ground wire/A
	Earthing switches are unclosed	Earthing switches are closed	
0°	100.84	0.358	16.3
30°	41.02	0.0367	1.72
60°	12.78	0.0123	0.56
90°	10.94	0.00088	0.039

## 5. Conclusions

- While 1000 kV Line Jianglian is in liveoperation in Jinhua, Zhejiang, field measurement is made on induced voltage and current of conductors of 110 kV Line Xianchi 1555 that is 18.3 m below the above line and in a crossing angle of 60° with the above line. The electrostatic induced voltage attains 12.24 kV. Due to lower line load in measurement, the electromagnetic induced voltage is lower than 2V and induced current of ground wires is lower than 0.07A.
- Results of simulated computation show that while UHV line is in full-load operation, electrostatic induced voltage is 12.78 kV, electromagnetic induced voltage is 12.3 V and induced current is lower than 1 A in the 110 kV line below; as the crossing distance rises, the induced voltage and current gradually fall; while two lines are in parallel construction, the electrostatic induced voltage is 100.84 kV, electromagnetic induced voltage is 358 V and induced current of ground wires is 16.3A, much higher than those in the situation of line crossing. The higher the crossing angle is, the lower induced voltage and current will be.
- Though induced voltage and current of the crossing line below the UHV line are lower than those in parallel construction, greater electrostatic induced voltage may arise. In shutdown overhaul, it is necessary to ensure that earthing switches on both sides of line in the substation are closed. While crossing angle of lines is lower than 30°, electromagnetic induced voltage of lines will be higher than human safety voltage of 36 V after earthing switches are closed. Thus, in line overhaul, it is also necessary to attach temporary ground wires on both sides of a working point to ensure personal safety.

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