

Study on Effect of UHV Power Grid Construction Schemes on Short Circuit Current

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Abstract

The commissioning of Southern Hami-Zhengzhou ± 800 kV UHVDC transmission project has important significance to heighten operation reliability, transfer capability and supply electric ability of Henan power grid. However, short circuit currents of 500 kV buses in the Center of Henan are almost close to the operation upper limitation. In order to decrease the short circuit currents effectively, it's necessary to strengthen the network structure of Center of Henan power grid and calculate short circuit currents. Two schemes of strengthening the network structure of Center of Henan power grid are studied. The calculated values of short circuit currents of some important 500 kV buses in the two schemes are still bigger than expected. According to the latest Plan of State Grid, Yubei UHV substation and Zhumadian UHV substation located in Henan power grid. The calculated values of short circuit currents of some important 500 kV buses with the commissioning of Yubei UHV and Zhumadian UHV are qualified. So, reasonable network structure with UHV is suitable to heighten transfer capability and supply electric ability of Henan power grid.

Keywords

UHV, UHVDC, Construction Scheme, Short Circuit Current

1. Introduction

By the year of 2014, the main network structure of Henan power grid is a 500 kV trapezoid structure with two vertical and four horizontal lines. In 2013, peak load of Henan power grid is about 48,010 MW, while the generate ability of Henan power grid is only 46,260 MW. Therefore, there's a power shortage more than 3000 MW when considering reserved capacity. The installed capacity of coal-fired thermal power units accounted for 90 percent of the total installed capacity of Henan province. Considered from environment protection and sustainable development point of view, the commissioning of Southern Hami-Zhengzhou ± 800 kV UHVDC transmission project (*i.e.* Hami-Zhengzhou UHVDC) has important significance to heighten operation reliability, transfer capability and supply electric ability of Henan power grid.

The load center of Henan locates in the Center of Henan power grid, and the power comes from North of Henan,

West of Henan and South of Henan, so the suitable location of Henan power grid integrating Hami- Zhengzhou UHVDC is the Center of Henan power grid. However, short circuit currents of 500 kV buses in Center of Henan power grid are almost close to the operation upper limitation. In order to decrease the short circuit currents effectively, it's necessary to improve and strengthen the network structure of the Center of Henan power grid and calculate short circuit currents in the new network structure [1].

2. Effect of Short Circuit Current

Short circuit current calculation and control is one of the most important functions in power system analysis. Effect of short circuit current can be summarized as below [2]:

- 1) Short circuit is a kind of serious fault, it may break the stable operation of power system, break the power supply and even bring blackout.
- 2) It will decrease the voltage of power system greatly, damage industry equipment and product, and debase the quality of power energy.
- 3) The flaring electric arc may burn out the equipment, and if the short circuit current exceeds the interrupting ability of breaker, it may cause more serious fault.
- 4) It brings thermo effect and electromotive force effect, they may damage the equipment.
- 5) Short circuit current may disturb communication system and electronic system nearby.

However, short circuit current is far from having no benefit. Bigger short circuit current means stronger ability to tolerate serious short circuit fault for a certain power system. In order to ensure the security and stability of power system, it's necessary to keep a certain short circuit current level and control the short circuit current within an appropriate range.

3. Analysis of Short Circuit CURRENT

3.1. Calculation Conditions of Short Circuit Current

The calculation conditions of short circuit current in the paper are as below [3] [4]:

- 1) Calculating result is the effective value of industrial frequency current component injected into the short circuit point at the moment at which the short circuit arises.
- 2) The three-phase AC system is a symmetrical system, the structures of three phases of stator windings are symmetrical, and the spatial position differs by 120° electrical angle.
- 3) The short circuit is a bolted fault, and the short circuit impedance in the fault point has a value of zero.
- 4) To suppose the quadrature axis subtransient reactance is equal to the direct axis subtransient reactance. The model of synchronous generator with the direct axis subtransient reactance and constant subtransient electromotive force is used. The magnetic saturation effect of generator and the skin effect of conductor aren't considered.
- 5) Magnetic saturation effect of static components isn't considered, parameters of electric equipment won't change with the value of current.
- 6) The tap of transformer is used with the actual setting.
- 7) The operation mode of Henan power grid is with all generators and all lines operated, the load model of constant impedance load and induction motor is used.

3.2. Short Circuit Current of 500 kV System in Henan in 2013

The calculation results of three-phase short circuit current of some important 500 kV buses in Henan power grid in 2013 are shown in **Table 1**.

From the above table, if the induction motor model was considered, then three-phase short circuit current of some important 500 kV buses in Center of Henan power grid will exceed 63 kA. In fact the calculation conditions of short circuit current are somewhat conservative. In order to keep pace with the actual status in field, induction motor may be not taken into account in the succeeding study. Even if the induction motor isn't taken into account, the maximum value of three-phase short circuit current in Henan power grid is close to the limit breaking capacity of breaker. It's necessary to decrease short circuit current by some measures.

3.3. Short Circuit Current of 500 kV System in Henan in 2014

The calculation results of three-phase short circuit current of some important 500 kV buses in Henan power grid

in 2014 are shown in **Table 2**.

From the above table, short circuit current level of the Henan power grid is increasing accordingly year by year because of the growth of economy, and short circuit current problem is more obvious. Even if the induction motor isn't taken into account, the three-phase short circuit current in Henan power grid is enlarged and closer to the limit breaking capacity of breaker. So it's urgent necessary to decrease short circuit current by some measures.

4. Two Schemes of Strengthening the Network Structure

To heighten the breaking ability of breaker is a directional way, but now the breaker with breaking ability above 63 kA is too much expensive. In general, it's not economical to use breaker with breaking ability above 63 kA widely. In order to ensure the security of power system, to strengthen and improve the network structure is a better choice by far now.

According to the characteristic of Henan power grid and source of short circuit current in some important 500kV buses, the network structure can be improved and optimized. The strengthening measures can't do much harm to the security and stability of power system. When considering all-round, two schemes of improving and strengthening the network structure of Center of Henan power grid are studied as below [5].

4.1. Scheme No. 1.

The network structure of Center of Henan power grid of strengthening scheme 1 is shown in **Figure 1** as below.

The 1st scheme is to connect one of Songshan-Zhengzhou double circuit 500 kV transmission lines and one of Zhengzhou-Guandu double circuit 500 kV transmission lines in series outside the 500 kV Zhengzhou Substation. Calculation verified that the strengthening measures won't do much harm to the security and stability of power system. The network structure meets the requirement of *Guide on Security and Stability for Power System (DL 755 - 2001)*. The calculation result of three-phase short circuit current of strengthening scheme 1 is shown in table 3 as below.

Table 1. Short circuit currents of some important 500 kV buses in 2013.

Bus	short circuit current (kA)	
	With motor	Without motor
YU_Songshan50	67.42	60.03
YU_Zhengzhou50	66.42	59.31
YU_Huojia50	62.51	55.14
YU_Zhengbei50	62.44	56.15
YU_Zhengnan50	50.68	47.06

Table 2. Short circuit currents of some important 500 kV buses in 2014.

Bus	short circuit current (kA)	
	With motor	Without motor
YU_Songshan50	68.91	61.23
YU_Zhengzhou50	66.63	59.33
YU_Huojia50	62.70	55.31
YU_Zhengbei50	62.41	55.96
YU_Zhengnan50	50.74	47.08
YU_Xiangshan50	59.21	54.04

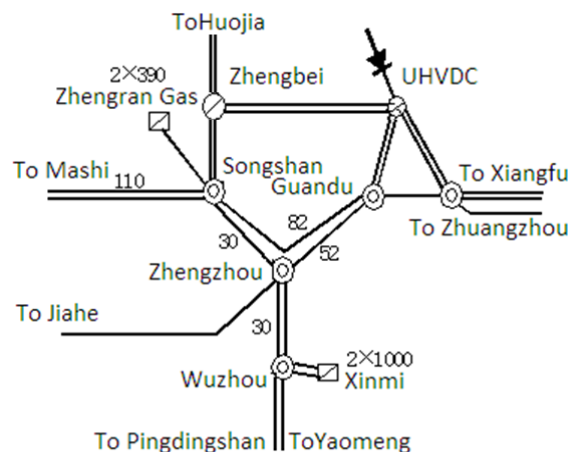


Figure 1. Scheme 1 of strengthening the network.

4.2. Scheme No. 2

The network structure of Center of Henan power grid of strengthening scheme 2 is shown in **Figure 2** as below.

The 2nd scheme is to open the Songshan-Zhengzhou 500 kV double-circuit transmission lines, so as to enlarge the ring network in Center of Henan power grid. The new 500 kV ring network in Center of Henan is comprised by lines of Songshan-Mashi-Gongyi-Mudan-Jiahe-Zhengzhou-Guandu-Zhengzhou UHVDC convertor substation-Zhengbei-Songshan. Calculation verified that the measures won't do much harm to the security and stability of power system. The network structure meets the requirement of *Guide on Security and Stability for Power System (DL 755 - 2001)* [6]. The calculation results of three-phase short circuit current of some important 500 kV buses in strengthening scheme 1 and scheme 2 are shown in **Table 3** as below.

From the above table, it's obvious that the calculated values of short circuit currents are still bigger than expect. They are still close to the limit breaking capacity of breaker. The two strengthening schemes only have obvious effect on relative substations, and have little effect on other substations.

4.3. Scheme No. 2 with Yubei UHV and Zhumadian UHV

According to the latest Plan of State Grid, Henan UHV power grid will be an important constituent part of the national UHV power grid. There are 2 vertical transmission passageways and 1 horizontal transmission passageway go across Henan UHV power grid. The 1000-kV Yubei UHV substation locates in North of Henan, and it has 4 outgoing lines of 500 kV. And, the 1000-kV Zhumadian UHV substation locates in South of Henan, and it also has 4 outgoing lines of 500 kV.

The calculated values of short circuit currents of some important 500 kV buses with the commissioning of Yubei UHV substation and Zhumadian UHV substation based on the scheme 2 are shown in **Table 4**.

From the above table, it's obvious that the calculated values of short circuit currents with the commissioning of Yubei UHV substation and Zhumadian UHV substation are smaller than the foregoing two strengthening schemes. It can effect on more substations than the scheme without Yubei UHV substation and Zhumadian UHV substation.

In order to integrate Hami-Zhengzhou UHVDC project, the network structure of Center of Henan power grid has to be strengthened. In the future, the commissioning of Yubei UHV substation and Zhumadian UHV substation also will strengthen the Henan power grid.

It's all known that if a power network is strengthened, in general the short circuit current will be enlarged accordingly. So it's interesting that why the short circuit current be decreased in Henan power grid.

4.4. The Venin Equivalent Reactance of the Power System

In order to verify the above simulation and analysis, the The venin equivalent reactance of the power system is calculated [7]. In the Scheme No. 2 without Yubei UHV and Zhumadian UHV, the 1st 500 kV bus in Zhengzhou substation is selected as the short circuit point. The venin equivalent reactance is about in the range of 0.015621

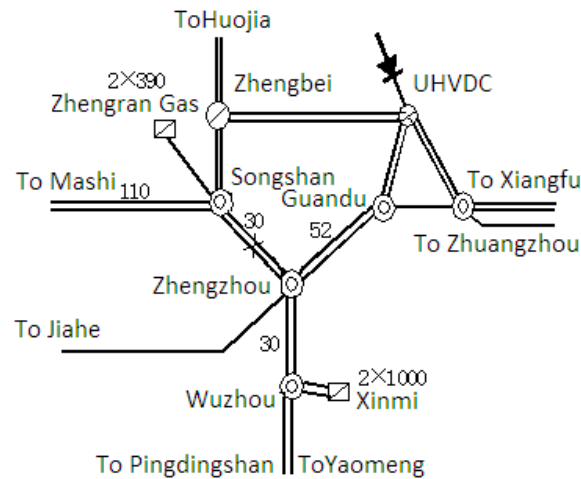


Figure 2. Scheme 2 of strengthening the network.

Table 3. Short circuit currents of strengthening scheme in 2014.

Bus	short circuit current (kA)		
	Original	Scheme 1	Scheme 2
YU_Songshan50	61.23	58.94	58.91
YU_Zhengzhou50	59.33	50.24	48.93
YU_Huojia50	55.31	54.83	54.66
YU_Zhengbei50	55.96	54.73	55.20
YU_Zhengnan50	47.08	46.62	46.09
YU_Xiangshan50	54.04	53.75	53.72

Table 4. Short circuit currents of some important 500 kV buses with UHV in 2014.

Bus	short circuit current (kA)	
	Original	Scheme 2 with UHV
YU_Songshan50	61.23	45.62
YU_Zhengzhou50	59.33	44.48
YU_Huojia50	55.31	50.25
YU_Zhengbei50	55.96	46.21
YU_Zhengnan50	47.08	44.16
YU_Xiangshan50	54.04	52.36

- 0.015722. In the Scheme No. 2 with Yubei UHV and Zhumadian UHV, the venin equivalent reactance is about in the range of 0.015685 - 0.015791. With the commissioning of Yubei UHV substation and Zhumadian UHV substation and other relational improvements in Henan power grid, the venin equivalent reactance of the power system is enlarged in some degree, so the short circuit current is decreased.

The network structure of Henan power grid has been optimized so as to integrate Hami-Zhengzhou UHVDC project. Though the network structure is strengthened, the Center of Henan power grid is simplified and sparser, so the venin equivalent reactance of the power system is enlarged. It's the reason of the short circuit current was decreased obviously. The calculation results of the venin equivalent reactance and the short circuit current can

verify the simulation and analysis from two aspects.

5. Conclusions

After the calculation and analysis, conclusions can be obtained as below.

1) There's a big power shortage in Henan power grid and the power-receiving ratio will be higher in the future. And the short circuit current will grow continuously. So, it's necessary to take appropriate measures to decrease short circuit current.

2) According to the operating characteristic of power grid and source of short circuit current, it's feasible to decrease short circuit current by improving and optimizing the network structure while not to do harm to the security and stability of power system.

3) If a network is strengthened, whether the short circuit current will be enlarged or not can be verified by the venin equivalent reactance.

4) Reasonable network structure with UHV is suitable to heighten operation reliability, transfer capability and supply electric ability of Henan power grid, and the short circuit current problem can be solved in a certain degree.

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