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Analysis of 750 kV Conductors in 750 kV Substations

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Abstract: Two-bundled conductors are generally used in the design of 750 kV substations. Compared to two-bundled conductors, multi-bundled conductors have higher load capacity and greater start-up voltage. This paper investigates the possibility of using multi-bundled conductors instead of two-bundled conductors in 750 kV substations from both technical and economic aspects.

1. Introduction

During the evaluation of the preliminary design of the 750 kV Yongdeng-Jinchang transmission project and 750 kV Jinchang-Jiuquan-Anxi transmission project, researcher Sun Zhusen of the Infrastructure Department of State Grid Corporation attended the meeting and instructed that a thematic study should be carried out in 750 kV substations and lines to optimize the study of substation fittings and conductors for reducing corona and noise. At present, the 1000 kV substation has been operating through the optimization of the calculation of the fittings and connection conductors. The results are remarkable, and the audible noise is even smaller than that of the 500 kV substation.

Gansu Electric Power Company carried out the 750 kV substation fitting optimization study in the 750 kV Yongbai project, and optimized the equipment fixtures and equal voltage shield rings of the substation except for the connecting wires. Since the connection wire is in the form of two bundles, the effect of reducing the corona and noise of the wire is very limited by optimizing the connection fixture and spacer bar, which can only be improved by increasing the number of conductor bundles. According to the initial calculations of the professor of Western Jiaotong University, if the 750 kV conductors use four bundles, the field strength on the surface of the conductors will be improved by more than 50% compared to that of the two bundles. Therefore, it is necessary to conduct an in-depth study on the conductor bundle of the 750 kV substation and propose a reasonable conductor bundle scheme.

2. Status of 750 kV conductors in 750 kV substations

At present, China has already commissioned several 750 kV substations, and there are more than a dozen 750 kV substations soon to be built. In these substations, the 750 kV busbar and 750 kV intra-string conductors are designed as one type of JLHN58K-1600. JLHN58K-1600 is a new type of conductor specially developed by Xinjiang TBEA Cable Factory for a 750 kV substation according to the research results of the 750 kV substation project. As JLHN58K-1600 is only used in the 750 kV substation and 1000 kV substation, it has less consumption, fewer manufacturers and a higher price [1].

The two-bundled conductors used in 750 kV transmission lines are derived from China's current 330 kV substation and 500 kV substation conductor program. The difference between them is that the conductor cross-section is increased, and the intra-bundle distance is increased from 200 mm to 400 mm. However, the problem of corona noise in the two-bundled conductors has fundamentally unchanged.

In the 750 kV substation fitting optimization project conducted by Gansu Provincial Electric Power Company, all the substation fittings of 750 kV substation were simulated and optimized, and the optimized fittings will significantly reduce the corona and noise of the substation. However, for the two-bundled conductors, the corona and noise generated by the conductors can not be reduced only by optimizing the connection fittings and spacers. In this way, the main source of noise in the whole substation will be the two-bundled conductors, which can be completely solved only by increasing the number of conductor bundles.

Based on the weaknesses above, the two-bundled conductor scheme was abandoned in the three 1000 kV substations in China. All three substations used a four-bundled conductor, which was successful.

Due to the superiority of three-bundled and four-bundled conductors compared with two-bundled conductors, together with the successful use of the four-bundled conductors in 1000 kV substations, this study explores the possibility of using three-bundled or four-bundled conductors for 750 kV conductors in 750 kV substations through calculations, and gives conclusions and recommendations.

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At present, the Baiyin 750 kV substation is under construction, and the following discussion takes Baiyin 750 kV substation as an example.

3. 750 kV conductor design

The 750 kV conductors are mainly controlled by the corona inception voltage and the load capacity of the conductors. We compared various conductors from these two aspects, selected the conductors that can meet the requirements, and calculated the forces of various conductors under the frame.

3.1. Calculation of the minimum diameter of 750 kV conductors with different bundles.

Through the calculation of different conductor's starting corona voltage, the minimum diameters of 750 kV conductors in the case of two bundles, three bundles and four bundles were calculated to ensure that the conductors can not develop a comprehensive corona under a clear sky, and the calculation results are shown in the following table [2].

Table 1. Minimum diameter of 750 kV conductors

Bundle number	Altitude (m)	Interphase distance (m)	Intra-bundle distance (cm)	Minimum diameter of conductor (mm)
2	2000	11	40	60.0
3	2000	11	40	41.6
4	2000	11	40	24.4

According to Table 1 together with the diameter of various conductors, it is known that if the three-bundled conductors are used, the wires need to be above LGJK-630 or NRLH58GJ-1000/125; if the four-bundled conductors are used, the wires need to be above LGJ-630/80 or NRLH58GJ-630/80[3].

3.2 Calculation of the conductors meeting the load capacity requirements

3.2.1 750 kV busbar conductor selection

According to the system design, the maximum power penetration of the 750 kV bus is 5700 MW and the power factor is 0.9, which means the maximum current of the 750 kV bus is 4875 A[4].

Table 2. 750 kV busbar load capacity comparison

	2X(JLHN58K-1600)	3X(LGJK-1000)	3X(LGJK-1250)	3X(NRLH58GJ-1000/125)	4X(LGJ-630/80)	4X(LGJ-800/100)	4X(NRLH58GJ-630/80)
Load capacity	6500 A	4836 A	5499 A	6690 A	4360 A	5176 A	6792 A
Can the load capacity be met	Yes	No	Yes	Yes	No	Yes	Yes
Corona inception voltage	912 kV	——	928 kV	824 kV	——	1115 kV	1031 kV

3.2.2 750 kV intra-string conductor selection

The maximum power penetration in the 750 kV interval string is 3000 MW, which means the maximum current in the 750 kV string is 2567 A[5].

Table 3. Comparison of the load capacity of the 750 kV intra-string conductor

	2X(JLHN58K-1600)	3X(LGJK-630)	3X(NRLH58GJ-1000/125)	4X(LGJ-630/80)	4X(NRLH58GJ-630/80)
Load capacity	6500 A	3741 A	6690 A	4630 A	6792 A
Can it meet the requirements	Yes	Yes	Yes	Yes	Yes
Corona inception voltage	912 kV	880 kV	928 kV	1031 kV	1031 kV

3.3 750 kV conductor schemes

According to Table 2 and Table 3, the 750 kV conductor schemes can be derived.

Table 4. 750 kV conductor schemes

Conductor scheme	750 kV Busbar	750 kV in-string conductor
Two-bundled conductor	2X(JLHN58K-1600)	2X(JLHN58K-1600)
Three-bundled conductor	3X(LGJK-1250)	3X(LGJK-630)
	3X(NRLH58GJ-1000/125)	3X(NRLH58GJ-1000/125)
Four-bundled conductor	4X(LGJ-800/100)	4X(LGJ-630/80)
	4X(NRLH58GJ-630/80)	4X(NRLH58GJ-630/80)

4. Comparison of various schemes of conductor forces

We calculated the forces corresponding to each of the aspects in Table 4 to determine the substation configuration[6].

1) Comparison of busbar force calculation with a busbar span of 42 mm.

Table 5. Calculation of force on busbar frame for various schemeswith a span of 42 meters

		Maximum load	Maximum wind speed	Minimum temperature	Construction and Installation	Three-phase human live maintenance	Single-phase human live maintenance	Lateral wind pressure
2X(JLHN58K-1600)	Horizontal	3502	3140	2736	2718	2969	3155	214
	Vertical	2229	1984	1769	1773	1873	1948	
3X(LGJK-1250)	Horizontal	4112	3648	3246	3227	3483	3671	153
	Vertical	2507	2213	2004	2007	2107	2182	
3X(NRLH58GJ-1000/125)	Horizontal	3594	3171	2828	2810	3061	3247	134
	Vertical	2271	1996	1813	1816	1916	1991	
4X(LGJ-800/100)	Horizontal	3894	3449	2997	2982	3233	3420	115
	Vertical	2413	2126	1891	1895	1995	2070	
4X(NRLH58GJ-630/80)	Horizontal	3539	3128	2709	2694	2942	3127	105
	Vertical	2250	1979	1758	1761	1861	1936	

2) The calculation and comparison of the force within the span show that the span is 98 mm.

Table 6. Calculation of force on busbar frame for various schemeswith a span of 98 meters

		Maximum load	Maximum wind speed	Minimum temperature	Construction and Installation	Three-phase human live maintenance	Single-phase human live maintenance	Lateral wind pressure
2X(JLHN58K-1600)	Horizontal	7016	6240	5451	5107	5821	6215	347
	Vertical	2776	2489	2165	2170	2270	2345	
3X(LGJK-1250)	Horizontal	6331	5691	4712	4518	5109	5479	235
	Vertical	2668	2397	2021	2026	2126	2201	
3X(NRLH58GJ-1000/125)	Horizontal	7114	6216	5577	5252	5945	6331	216
	Vertical	2831	2497	2221	2225	2325	2400	
4X(LGJ-800/100)	Horizontal	6708	5892	5035	4805	5422	5796	171
	Vertical	2773	2450	2112	2116	2216	2291	
4X(NRLH58GJ-630/80)	Horizontal	6808	5965	5134	4869	5511	5887	171
	Vertical	2788	2461	2126	2131	2231	2306	

According to Table 5 and Table 6, if the bus adopts 3X(LGJK-1250), the forces of the frame will increase by about 20%. If the bus adopts 3X(NRLH58GJ-1000/125), the forces of the frame will increase by about 5%. If the bus adopts 4X(LGJ-800/100), the forces of the frame will increase by 10%. If the bus adopts 4X(NRLH58GJ-630/80), the forces of the frame are basically the same.

If busbar 3X(LGJK-630), 3X(NRLH58GJ-1000/125), 4X(LGJ-630/80) and 4X(NRLH58GJ-630/80) are used for the intra-string conductors, the forces of the frame are basically the same.

Through the frame force calibration, if the 750 kV substation adopts a three-bundled conductor or four-bundled conductor, the 750 kV conductor forces will be slightly increased or remain the same, yet within the frame tolerance range, and the 750 kV frame does not need to be replaced[7].

5. Economic and technical comparison of conductors

The costs of the technology schemes are listed below.

Table 7. Comparison of costs for various technical solutions

Conductor type		Length (m)	Cost (million yuan)	Cost savings (million yuan) (relative to the two-bundled conductors)
Busbar	2X(JLHN58K-1600)	2800	102	
	3X(LGJK-1250)	4200	51	51
	3X(NRLH58GJ-1000/125)	4200	68	34
	4X(LGJ-800/100)	5600	49	53
	4X(NRLH58GJ-630/80)	5600	61	41
Intra-string conductors	2X(JLHN58K-1600)	7000	240	
	3X(LGJK-630)	10500	72	168
	3X(NRLH58GJ-1000/125)	10500	153	87
	4X(LGJ-630/80)	14000	78	162
	4X(NRLH58GJ-630/80)	14000	134	106

According to Table 7, if the 750 kV conductors are replaced by other conductors, the maximum saving of the 750 kV Baiyin substation in this period is 2.21 million yuan (64%), and the minimum saving is 1.21 million yuan (35%). Considering the best situation of the corona, the bus bar is selected 4X (LGJ-800/100), and the intra-string conductor is selected 4X (LGJ-630/80), by which savings of 2.15 million yuan (63%) can be achieved. As there is no precedent of using multi-bundled conductors in 750 kV substations, and the four-bundled conductors are much higher than the three-bundled conductors in terms of corona inception voltage, for insurance purposes, it is recommended that 4X (LGJ-800/100) conductors be used for 750 kV busbars[8]. At the same time, in order to reduce the types of fittings, it is recommended that 4X (LGJ-800/100) conductors are also used in 750 kV intra-string conductors. If 4X(LGJ-800/100) conductors are used for both 750 kV busbar and 750 kV intra-string conductors, the whole Baiyin 750 kV substation can save 1,755,000 yuan investment, with a saving ratio of 51%.

6. Conclusion

Through the calculation and analysis above, using three-bundled conductors or four-bundled conductors, the 750 kV substation 750 kV conductor can be completely feasible economically and can meet the requirements technically, therefore it can be applied in the construction.

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