Design and Analysis of Transmission Lines Connecting Power System Generators to the Grid

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Abstract

According to the actual requirements, it is necessary to design a line connecting the 150MW hydropower station and the 230KV hydropower station. The first is to plan the overall process of the project, by consulting the data, objectively evaluating the transmission line parameters, combining Matlab and Excel to calculate the transmission line parameters, including barrier current calculation and safety analysis, and finally combining power system simulation and cost calculation, the only one is selected from hundreds of scenarios. Rationale, power flow analysis, and power loss analysis are used to evaluate transmission lines, including series reactors and new transmission lines in parallel. The process reflects the continuous refinement of the initial design to create a transmission line that is both economical and safe.

Keywords

Hydropower Station; Transmission Line Parameters; Power System Simulation.

1. Introduction

In order to respond to the consistency of national economic development and environmental protection goals, so as to implement reasonable, safe, economical and environmentally friendly design goals, and promote the sustainable development of energy and low-carbon economy.[1] This design connects a 150MW generator to a 230KV grid. This requires the circuit to be designed when the line is not loaded and the voltage is within a reasonable range. At the same time, fault current analysis and safety analysis of the circuit need to be carried out to achieve the lowest possible cost and make the design circuit meet the requirements. Through system commissioning and verification, the performance and stability of the system are determined, so as to provide reliable clean energy for the power system and promote the sustainable development of energy and low-carbon economy.

2. Transmission Line Design and Analysis Project Plan

2.1. Overview of Hydropower Generation

Hydropower is the use of water to promote the rotation of hydraulic machinery (turbine), the potential energy of water into mechanical energy, if connected to the turbine, and another machine (generator) connected, can be with the rotation of the turbine to produce electrical energy.[2]

2.2. Calculation of Current

Assuming that the three-phase system is balanced, the power of each phase is 50MW. The line voltage of the circuit is 230kV, so the phase voltage is 132.79kv, and the power factor angle of the hydro-generator is 0.875 by consulting the data.[3] So the formula is as follows:

$$I_{\text{per phase}}=\frac{S_{\text{per phase}}}{V_{\text{line}-\text{natural}}}=\frac{\frac{150\text{MW}}{0.875\times 3}}{\frac{230\text{kV}}{\sqrt{3}}}=430.32\text{ A}$$

ISSN: 2688-8645

The current of the transmission line is 430.32A. Therefore, the total rated current of transmission lines selected in this project should be greater than 430.32A. It should be noted that the rated current of conductor in summer is less than that in winter, so the rated current in summer is used for calculation for safety reasons.

2.3. Project Construction

2.3.1. Initial Screening

A total of 180 design schemes were preliminarily selected. In this section, the 36 scenarios that best match are selected from 180 options. The table below shows the conductor diameters, current ratings, and costs available for this project

Table 1. Available conductor diameters, current ratings and costs

Conductor type/diameter	Current rating (summer, no wind)	Current rating (winter, wind < 2 ms-1)	Conductor cost
AAC 9.0 mm diameter	110 A	308 A	$4,300 per km
AAC 16.3mm diameter	216 A	636 A	$6,700 per km
AAC 21.0mm diameter	299 A	875 A	$9,000 per km
AAC 26.3mm diameter	405 A	997 A	$12,300 per km
AAC 31.5mm diameter	495 A	1224 A	$16,300 per km

Depending on the conductor bonding method, the corresponding optimal conductor can be found. The conditions are as follows: on the one hand, the total constant current of the conductor must be greater than the operating current, and on the other hand, the working current must not be too small. Finally, the bonding method is mapped to the type of conductor (mainly the difference in conductor diameter and unit resistance) and divided into four schemes:

(1) Wire type of No bundling;

(2) Wire type of Bundling Spacer-2 conductor;

(3) Wire type of Bundling Spacer-3 conductor;

(4) Wire type of Bundling Spacer-4 conductor.

So far, the screening from 180 to 36 species has been completed.

2.3.2. Secondary Selection

There are three tower types to choose from in this project.[4] They are horizontal phase (type A), vertical phase (type B), and triangle (type C). According to the long model and formula, Excel and MATLAB are used to calculate the transmission line parameters (R, C, L, G, A, B, C, D) and costs. The following parameter results are displayed.

Table 2. Values of Parameters R, L, C, Z, Y, Zc and γ

Type	Bundling	R (Ω/km)	L(H/km)	C(F/km)	z	y	Zc	γ
type A	1 conductor	0.0493	1.06E-03	1.10E-08	0.049300 + 0.333009i	0.000000 + 0.000003i	311.269620 + -22.915938i	0.000079 + 0.001076i
	2 conductors	0.0915	8.42E-04	1.36E-08	0.091500 + 0.264522i	0.000000 + 0.000004i	252.411196 + -42.422250i	0.000181 + 0.001078i
	3 conductors	0.061	7.30E-04	1.56E-08	0.061000 + 0.229336i	0.000000 + 0.000005i	218.193469 + -28.522239i	0.000140 + 0.001069i
	4 conductors	0.14475	6.58E-04	1.72E-08	0.144750 + 0.206717i	0.000000 + 0.000005i	206.104472 + -64.986454i	0.000351 + 0.001114i
type B	1 conductor	0.0493	1.08E-03	1.08E-08	0.049300 + 0.339292i	0.000000 + 0.000003i	317.056878 + -22.914275i	0.000078 + 0.001076i
	2 conductors	0.0915	8.61E-04	1.33E-08	0.091500 + 0.270491i	0.000000 + 0.000004i	257.950842 + -42.447551i	0.000177 + 0.001078i
	3 conductors	0.061	7.49E-04	1.52E-08	0.061000 + 0.235305i	0.000000 + 0.000005i	223.809626 + -28.538268i	0.000136 + 0.001069i
	4 conductors	0.14475	6.77E-04	1.67E-08	0.144750 + 0.212686i	0.000000 + 0.000005i	211.631505 + -65.184136i	0.000342 + 0.001110i
type C	1 conductor	0.0493	1.11E-03	1.05E-08	0.049300 + 0.348717i	0.000000 + 0.000003i	325.944628 + -22.926297i	0.000076 + 0.001075i
	2 conductors	0.0915	8.84E-04	1.30E-08	0.091500 + 0.277717i	0.000000 + 0.000004i	264.192829 + -42.401073i	0.000173 + 0.001079i
	3 conductors	0.061	7.72E-04	1.47E-08	0.061000 + 0.242531i	0.000000 + 0.000005i	230.943328 + -28.597444i	0.000132 + 0.001067i
	4 conductors	0.14475	7.00E-04	1.62E-08	0.144750 + 0.219911i	0.000000 + 0.000005i	217.876235 + -65.270032i	0.000332 + 0.001109i

By observing the relationship between the parameters, it is found that the tower type has little influence on the parameters, and after the cost comparison, the tower type A can be selected as the starting point to obtain 12 schemes. This is shown in the table below.

Table 3. 12 schemes

	Bundle conductor		**Bundle conductor**		**Bundle conductor**
	No bundling (31.5mm)		No bundling (31.5mm)		No bundling (31.5mm)
	Bundling Spacer-2 conductor (16.3mm)		Bundling Spacer-2conductor (16.3mm)		Bundling Spacer-2conductor (16.3mm)
Bus4	Bundling Spacer-3 conductor (16.3mm)	**Bus6**	Bundling Spacer-3 conductor (16.3mm)	**Bus8**	Bundling Spacer-3 conductor (16.3mm)
	Bundling Spacer-4 conductor (9.00mm)		Bundling Spacer-4 conductor (9.00mm)		Bundling Spacer-4 conductor (9.00mm

2.3.3. Triple Screening

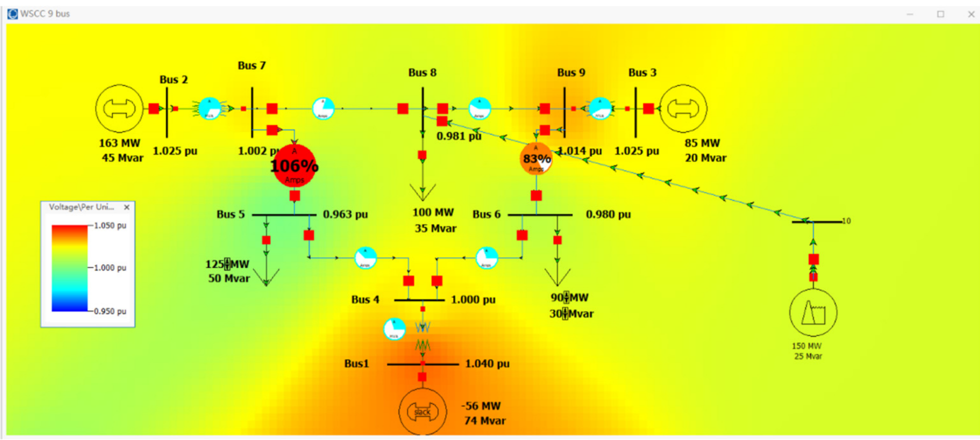

Figure 1. Line overload simulation

From 12 scenarios to 4 scenarios. There are three buses to choose from for this project, BUS4, BUS6 and BUS8. Through the simulation of 12 schemes, it is found that only when BUS 4 and BUS 6 are connected, the transmission line will be overloaded when it is working normally, and when BUS 8 is connected, the transmission line will be overloaded and will be overloaded when it is working normally, as shown in the figure 1.

After meeting the safety requirements, four more reasonable solutions were finally selected through different prices, namely the A-type tower and the four bundling when connected to the BUS 4.

2.3.4. Final Screening

The prices of the last four plans are almost identical, with the only difference being the bundle model. Since the larger the number of harnesses, the smaller the reactance, the greater the admittance, and the greater the difficulty of construction.[5] The scheme of bundling spacer-2 conductors or bundling spacer-3 conductors should be selected. Since the operating current of the bundled gasket-2 conductor is closer to the total constant current, the price is also the cheapest.

Therefore, the final solution consisted of a transmission line connected to bus 4 tower A, bundled with a Spacer-2 conductor, corresponding to a conductor with a diameter of 16.3 mm.

3. Conclusion

The final design of the transmission line connecting the hydropower station and the original line is the result of the objective evaluation of the transmission line parameters, safety analysis and cost consideration. The conductors are of 16.30mm diameter and connected to bus 4 using Tower A, and the transmission lines are evaluated using reasonableness, power flow analysis and power loss analysis, including series reactors and parallel new transmission lines. Finally, improvements were made to the initial design to create a transmission line that was both economical and safe.

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