ISSN 2616-5880 Vol. 4, Issue 1: 25-30, DOI: 10.25236/AJMC.2023.040105

Study on optimization of heat-resistant conductor in line capacity expansion

Lv Zhonghua, Liu Bing, Zhang Ruyu, Chen Youhui, Pan Qi, Hu Ruixue

State Grid Liaoning Electric Power CO, LTD., Power Electric Research Institute, Shenyang, 110015, China

Abstract: *Due to the low transmission capacity margin of overhead conductors of ACSR type in the existing grid structure, the large-scale grid connection of new energy is greatly limited. However, 60% of IACS heat-resistant conductors have low conductivity and high power loss in the transmission process. Therefore, 61.5% of IACS heat-resistant aluminum alloy conductors with high conductivity are developed for line capacity expansion and reconstruction. The feasibility of 61.5% IACS high conductivity heat-resistant aluminum alloy stranded conductor is analyzed in combination with the example of urban power line capacity expansion and transformation. Under the condition that the call height margin of the original line tower is sufficient, the use of this type of conductor can achieve obvious energy saving effect and effectively improve the transmission capacity and energy utilization rate of the line have been increased. Under the condition that the sag of the conductor and the bearing capacity of the tower do not increase compared with the original line, the capacity of the original line can be increased by at least 1.4 times by using this type of conductor. At the same time, because the conductor uses aluminum clad steel core as the reinforcing core, the corrosion resistance of the conductor is effectively improved to ensure the overhead transmission in coastal areas or heavily polluted areas safe operation reliability of electric lines.*

Keywords: *heat resistant aluminum alloy stranded conductor; capacity expansion and reconstruction*

1. Introduction

China's total energy resources are limited, the consumption structure is unreasonable, and the distribution of power resources and loads is seriously unbalanced. To ease this contradiction, the state has implemented a series of major transmission projects such as ultra-high voltage and ultra-high voltage to improve power transmission capacity and transmission distance,but the transmission capacity margin of ACSR overhead conductors in the existing grid structure is low, which greatly limits the large-scale grid connection of new energy. The conductivity of 60% IACS heat-resistant conductor is low, and the power loss is high in the transmission process.Therefore, the development of high-performance transmission conductor is a major technical problem that needs to be solved urgently in the power industry. Under this background, a 61.5% IACS high conductivity heat-resistant aluminum alloy stranded wire with large capacity and low loss came into being. This paper discusses the feasibility of the application of this new type of conductor in the line capacity expansion and transformation, taking a city network transformation project as an example.The original line of the urban network reconstruction project has a transmission capacity of 180MV·A rated voltage of 220kV, a rated transmission current of 497A, a single circuit and a single conductor, with a total length of 52.2km. The meteorological conditions of the line for site survey are shown in Table 1. In view of the need for capacity expansion to 324MV.A of the line, two capacity expansion and transformation schemes are preliminarily drawn up: a. Scheme 1, with 61.5% IACS high conductivity heat-resistant conductor used for capacity expansion and transformation under the condition that the tower height margin of the original line is sufficient. b. Scheme 2: When the original line is replaced with a new type of conductor, the ground distance and tower bearing capacity will not increase compared with the original conductor, and 61.5% IACS high conductivity heat-resistant conductor will be used for capacity increase reconstruction.With the sustainable development of China's economy, the demand for electricity has also risen significantly. In order to reduce the loss of lines, improve the transmission capacity, and effectively control the construction and operation costs of projects, heat-resistant conductors are gradually applied to new lines[1-2]. For developed areas, it is difficult to open new line corridors, and a large number of old lines need to be reconstructed. The capacity of the line is expanded by using old poles and towers. In order to meet the service conditions of the old line poles and towers, the old lines need to be reconstructed with

ISSN 2616-5880 Vol. 4, Issue 1: 25-30, DOI: 10.25236/AJMC.2023.040105

various heat-resistant conductors.The heat-resistant conductor is a special conductor used on overhead transmission lines. It is the general name of several types of conductors that can deliver more electric energy than the traditional ACSR under the condition of equal conductor cross-sectional area.So far, there have been many kinds of capacity increasing conductors in the world, which can be summarized into two categories: one is to increase the transmission capacity of the conductor, the temperature of the conductor increases, but the strength of the material used as the conductive part does not decrease, and the total tensile force at room temperature is still similar, such as the series of conductors with heat-resistant aluminum alloy as the conductor; The other type focuses on the energy conservation of the conductive part, that is, it has high conductivity, and the overall mechanical properties of the conductor are borne by the load-bearing core. Even after the current carrying capacity of the conductor increases and the temperature of the conductor increases, the operation of the conductor is still safe, such as the series of conductors with organic composite materials as the reinforcing core.The power consumption in China has been significantly increased, and the demand for power resources is growing, which has led to the contradiction between the backward power equipment and the increasing power consumption. However, the transmission capacity of the established transmission lines has an upper limit due to the wire section. Therefore, the power sector generally chooses to use the original line tower resources to replace the inherent conductors with aluminum clad invar core high conductivity ultra heat resistant conductors, To achieve the purpose of line capacity expansion, this method can effectively reduce the investment and construction cycle of the line when applied. However, the traditional aluminum clad invar core super heat-resistant aluminum alloy strand has significant capacity increasing and low sag application characteristics, but the conductivity of the super heat-resistant aluminum alloy wire as the main conductive unit is only 60%. This leads to a very serious loss of power lines due to the high temperature operation of the line. With the development of electric power industry and the continuous improvement of power grid users' requirements for energy conservation and environmental protection of overhead transmission lines, the concept of aluminum clad invar steel core high conductivity super heat-resistant conductor came into being.

2. Preliminary draft of line capacity expansion and reconstruction scheme

The proposal of line capacity expansion and reconstruction scheme 1 is based on the fact that the margin of tower height call of the original line is sufficient, and there is no need to add new towers or reconstruct the tower strength. Using the original line corridor resources,only 61.5% IACS high conductivity heat-resistant capacity expansion conductor is replaced to achieve the line transmission capacity of 324MV.When evaluating the feasibility of line capacity expansion and reconstruction scheme 1, the main concern is whether the sag performance, resistance loss performance and economy of the conductor after capacity expansion and reconstruction with 61.5% IACS high conductivity heat-resistant capacity expansion conductor meet the line erection requirements. The structures and technical parameters of JL/G1A-400/35 ACSR conductor, JNRLH1/G1A-400/35 ACSR conductor (ordinary heat-resistant conductor) and JNRLH61.5/G1A-400/35 ACSR conductor (high conductivity heat-resistant conductor) erected on the original line are compared.So Compared with the JL/G1A-400/35 steel cored aluminum stranded wire which is concentric twisted by galvanized steel core and 61% IACS aluminum wire erected on the original line, the JNRLH1/G1A-400/35 ordinary heat-resistant wire which is concentric twisted by galvanized steel core and 60% IACS heat-resistant aluminum alloy wire increases the allowable service temperature by using 60% IACS heat-resistant aluminum alloy wire, However, in order to achieve high temperature resistance, alloy elements added to the aluminum matrix reduce the conductivity of the material (lower than 61% IACS of conventional electrical duralumin)[3-4], which will undoubtedly increase the line loss of the modified line. b. Compared with the JL/G1A-400/35 conductor erected on the original line, the JNRLH61.5/G1A-400/35 high conductivity heat-resistant conductor, which is made of galvanized steel core and 61.5% IACS high conductivity heat-resistant aluminum alloy wire, is concentrically twisted. The allowable service temperature is increased by using 61.5% IACS high conductivity heat-resistant aluminum alloy wire. In order to increase the conductivity of the heat-resistant aluminum alloy wire from 60% IACS to 61.5% IACS, and maintain the mechanical properties and allowable continuous use temperature of the wire compared with the ordinary heat-resistant wire, the process of the high conductivity heat-resistant wire was optimized in the production process. The optimization measures include selecting remelting aluminum ingots from different manufacturers, controlling the impurity element content of raw materials, effectively removing vanadium, titanium and other elements through boronizing during the manufacturing process, and increasing the heat treatment process of rod materials with a new heat treatment processp[5-6].In actual operation, the active power loss of the transmission line is proportional to the square ratio of the current, and is linearly related to the conductor resistance. When the current is in the normal operation state, there is no obvious difference between the resistance of the invar core wire and the ordinary resistance, so the loss can be increased when the invar core wire is used for double capacity transmission as shown in figure1. When analyzing from the perspective of asset life cycle, the increase of energy loss cost will also affect its promotion and application.

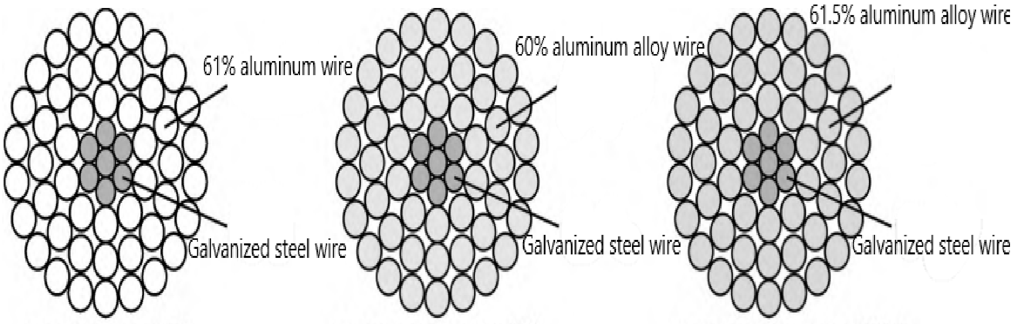

Figure 1: Conductor Structure Comparison

3. New heat resistant conductors overview

The design positioning temperature of the original line is 40℃and the calibration temperature is 70 ℃, so the sag of JL/G1A-400/35 conductor erected on the original line is calculated according to the operating temperature of 70℃.Under the condition of meeting the target transmission capacity of 324MV and current carrying capacity of 895A after line capacity increase,the operating temperature of 400/35 conductor is 95.6 ℃ and 94.6 ℃ respectively, so the conductor sag is calculated accordingly. Compares the calculation results of each conductor sag.It can be seen that the sag of each representative span conductor of JNRLH1/G1A-400/35ordinary heat-resistant conductor and JNRLH61.5/G1A-400/35 high conductivity heat-resistant conductor has increased compared with the JL/G1A-400/35 conductor erected on the original line,however[7], the sag of the latter is calculated according to the target transmission capacity of 324MV current carrying capacity of 895A and average ambient temperature of 15℃after the line capacity increase.The resistance loss of JNRLH1/G1A-400/35 conductor and JNRLH61.5/G1A-400/35 conductor are compared. It can be seen that compared with JNRLH1/G1A-400/35 ordinary heat-resistant conductor, the conductor resistance loss of JNRLH61.5/G1A-400/35 high conductivity heat-resistant conductor is 97.47%, a decrease of 2.53%. The cost of resistance loss per kilometer of transmission line can be saved by 9200 yuan/year, and the energy-saving effect is obvious on the premise of meeting the requirements of line capacity increase. Assuming that the annual costs are consistent, the unit prices of JNRLH1/G1A －400 / 35 conductor and JNRLH61.5 / G1A －400 / 35 conductor are calculated according to the power engineering recovery rate of 8%, the operation and maintenance cost rate of 1.4% and the economic service life of 30a, and the correlation between the unit prices of JNRLH1/G1A－400 / 35 conductor and the line economy during the line life is shown. It can be seen that compared with JNRLH1 / G1A －400 / 35 ordinary heat-resistant conductor, the annual cost of the line can be effectively reduced as long as the unit price increase of JNRLH61.5 / G1A－400 / 35high conductivity heat-resistant conductor is controlled within 22%,which is feasible and economical.Line capacity increase transformation scheme 1 is adopted (i.e. only 61.5% IACS is replaced when the call height margin of the original line tower is sufficient conductivity heat-resistant capacity increasing conductor), which can achieve the goal of line capacity increasing (transmission capacity 324MVA). Compared with JNRLH1/G1A-400/35 ordinary heat-resistant conductor, 61.5% IACS heat-resistant capacity increasing conductor with high conductivity has better sag performance, resistance loss performance and economy, and can meet the requirements for line erection[8-9].The aluminum clad invar steel core high conductivity super heat-resistant wire is a kind of carrier fluid, which can ensure the normal operation of the system when the wire is operating in a high temperature environment. In addition, under the same temperature conditions, the current carrying capacity of the aluminum clad invar steel core high conductivity super heat-resistant wire is greater than that of the ordinary wire with the same section. Therefore, when designing, it is necessary to measure the characteristics of the wire according to the actual requirements of the design, Through in-depth sharing of the whole situation, we can find that there is no problem between Aiyou's aluminum clad invar steel core high conductivity super heat-resistant conductor and ordinary conductor in current carrying capacity. Therefore, when designing, we can choose the original transmission line for design, strictly control the quality of the conductor, and do not need to change the high requirements and standards of the tower pole, so that we can realize the replacement of the conductor for capacity increase, In this way, the cost can be reduced. In terms of heat resistance and sag properties, aluminum clad invar steel core high conductivity super heat resistance conductor has significant advantages, but this conductor is expensive in application, but it can reduce the cost of construction and operation, and can save construction costs, so as to reduce costs. It is beneficial to comprehensively consider the use of aluminum clad invar steel core high conductivity super heat-resistant conductor for construction, to ensure the stable supply of power resources in China and to ensure the economic benefits of power enterprises themselves.

4. Feasibility assessment

The proposal of line capacity expansion and reconstruction scheme is based on the fact that the ground distance and tower bearing capacity of 61.5% IACS high conductivity heat-resistant capacity expansion conductor are not increased compared with the original conductor after the original line is replaced, so as to meet the requirements of line erection ask. Comparing the safety and operation maintenance of each conductor, it is found that the operation stability of carbon fiber composite core conductor is poor, and the construction of gap type conductor is difficult. The details are as follows: operation and maintenance experience of ACSR.It is rich and safe, and can be used in important crossing and dancing areas such as "three spans", but its capacity is limited; The operation and maintenance experience of carbon fiber composite core conductor is less, and it is designed according to the state grid ultra-high voltage grounding electrode line, etc.Based on experience, it can not be used for important crossing such as "three spans", nor for galloping area, multiple broken lines and other accidents. It has poor operation stability. Its disadvantage is that it can not be used as a jumper, and other conductors need to be used as jumpers; Aluminum clad invar core heat-resistant aluminum alloy stranded wire has less operation and maintenance experience, and has good safety. It can be used in important crossing and galloping areas, but its disadvantage is that it is expensive; The gap type conductor has less experience in operation and maintenance, and has good safety. It can be used for more important crossing. The disadvantage is that the construction is difficult.When evaluating the feasibility of the line capacity expansion and reconstruction scheme, the main concern is whether the transmission capacity of the line after capacity expansion and reconstruction with 61.5% IACS high conductivity heat-resistant capacity expansion conductor meets the target transmission capacity of 324MVA after capacity expansion.Compare JL/G1A-400/35 ACSR conductor and JNRLH61.5X/LB14-340/35 aluminum conductor erected on the original line the structure and technical parameters of the steel clad high conductivity heat-resistant aluminum alloy stranded conductor (high conductivity heat-resistant conductor) can be seen that compared with the JL/G1A-400/35 conductor erected on the original line, 14% IACS aluminum clad steel core and 61.5% IACS high conductivity heat-resistant aluminum alloy stranded conductor are concentric twisted combined JNRLH61.5X / LB14-340 / 35 high conductivity resistance.The allowable operating temperature of hot wire is increased by using 61.5% IACS high conductivity heat-resistant aluminum alloy profile wire.The design positioning temperature of the original line is 40℃and the calibration temperature is 70℃, so the sag of JL/G1A − 400 / 35 conductor erected on the original line is calculated according to the operating temperature of 70℃.

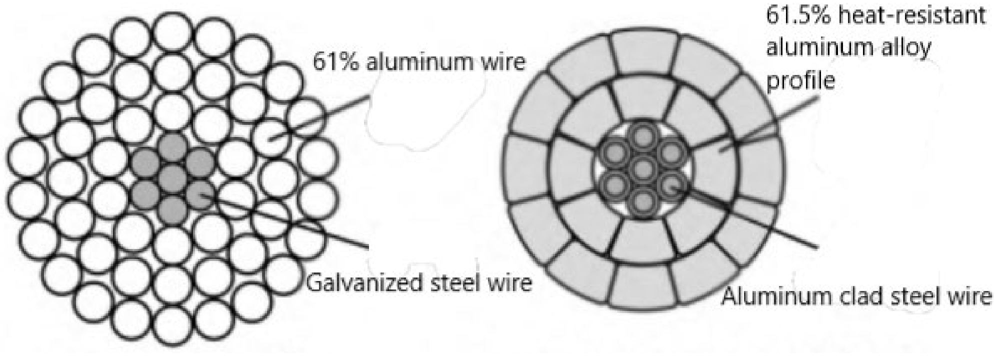

Figure 2: Conductor structure comparison

As shown in figure2, the maximum allowable operating temperature of JNRLH61.5X / LB14 − 340 / 35 high conductivity heat-resistant conductor can be calculated as 94℃without increasing the conductor sag after the line capacity is increased, Therefore, the current carrying capacity of the conductor is calculated. compares the calculation results of sag and current carrying capacity of the two

ISSN 2616-5880 Vol. 4, Issue 1: 25-30, DOI: 10.25236/AJMC.2023.040105

types of conductors. It can be seen that compared with the JL/G1A-400/35 conductor erected on the original line, the capacity of the line with JNRLH61.5X/LB14-340/35 high conductivity heat-resistant conductor is increased to more than 1.4 times without increasing sag and tower bearing capacity.There is no difference between the construction method of aluminum clad invar steel core high conductivity super heat resistant conductor and ordinary conductor, and no special tools are needed during construction. The construction can be carried out by referring to the tension setting out method of ordinary conductor during design. Therefore, the aluminum clad invar steel core high conductivity super heat-resistant conductor can be constructed in the bottleneck area of overhead transmission line capacitance by using the original line corridor, and does not need to reform the tower. The power grid company can use the original line corridor to increase the capacity of the line to more than double, which can effectively reduce the cost and construction time, thus leading to no increase in sag after capacity increase, and ensuring the stable operation of the system.

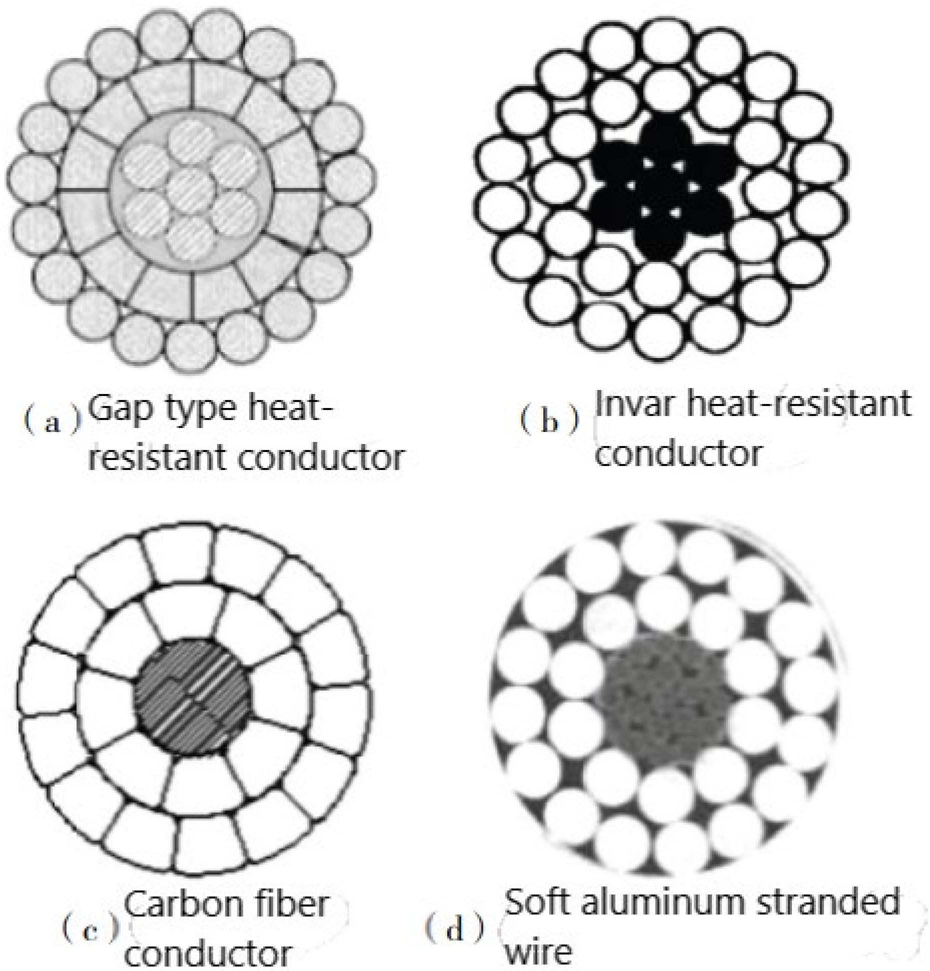

Figure 3: Cross sections of several heat-resistant conductors

In figure3 we can see that it can be seen from Joule's Law, because of the existence of resistance, the temperature of the metal wire will rise after being energized, and its mechanical properties will decrease, leading to the reduction of the transmission capacity. In order to improve the transmission capacity of the wire, American scholars found that the appropriate addition of zirconium (Zr) to the aluminum of the wire can greatly improve the heat resistance of the aluminum, making the wire have a higher transmission capacity when operating at a higher temperature. The reason why the heat-resistant wire has high heat resistance is that the addition of zirconium increases the recrystallization temperature of the wire, resulting in lattice defects and plastic deformation of metal materials during cold working. The high temperature during metal material processing increases the atomic heat energy of the material, and the lattice defects in the metal material are easy to move, so that part of the heat energy is converted into mechanical energy, which consumes part of the heat of the material, and ultimately improves the heat resistance of the metal material. In the power system, the working temperature of overhead transmission conductor is generally not more than 200 ℃, but the working temperature of heat-resistant conductor can be much higher than this value, and its heat-resistant performance is very good. The initial softening

ISSN 2616-5880 Vol. 4, Issue 1: 25-30, DOI: 10.25236/AJMC.2023.040105

temperature is an important index to measure the heat resistance of conductor. Through experimental comparison, some scholars found that the softening initial temperature of the improved heat-resistant aluminum alloy conductor was 100 °C higher than that of the ordinary duralumin conductor, indicating that the heat-resistant capacity of the heat-resistant conductor was significantly higher than that of the ordinary duralumin conductor.

5. Conclusion

The capacity increase of the line can be achieved to 1.4 times by adopting the line capacity increase transformation scheme 2 (that is, there is no need to transform or reinforce the existing iron tower, save space and land resources, and only replace 61.5% IACS high conductivity heat-resistant capacity increase conductor), but it can not meet the requirements of the line capacity increase transformation to 1.6 times (i.e., the target transmission capacity after capacity increase is 324MVA). For the capacity expansion and reconstruction of the urban power grid, under the condition that the call height margin of the original line tower is sufficient, 61.5% IACS steel core high conductivity heat-resistant aluminum alloy stranded wire is used to replace the 60% IACS steel core heat-resistant aluminum alloy stranded wire in service. The energy-saving effect is obvious on the premise that the capacity expansion is more than 1.6 times, which effectively improves the transmission capacity and energy utilization rate of the line, and saves the area of the transmission line corridor, Protect the ecological environment; When compared with the original line, the sag of the conductor and the bearing capacity of the tower do not increase, using 61.5% IACS aluminum clad steel core high conductivity heat-resistant aluminum alloy stranded wire can increase the capacity of the original line by at least 1.4 times. At the same time, because the aluminum clad steel core is used as the reinforcing core of the conductor, the corrosion resistance of the conductor is effectively improved, which can ensure the safe operation reliability of overhead transmission lines in coastal areas or heavily polluted areas.

References

[1] Xue Tianshui. Comparative study on ultra long distance transmission modes[D]. Shanghai: Shanghai Offshore Electric Power Institute, 2015

[2] Zhu Zhixiang, Han Yu, Chen Xin, et al. High conductivity heat-resistant aluminum for overhead lines Development of alloy conductor[J]. China Electric Power, 2014, 47 (6): 66 − 69

[3] Li Jing, Yang Sheng, Cai Bin, et al Microstructure and properties [J]. Metal heat treatment, 2015, 40 (11): 25-28

[4] Wan Jiancheng, Xi Yongping, Liu Long, et al. New energy-saving conductor resistance temperature system Experimental study of the number[J]. China Electric Power, 2014, 47 (6): 70-74

[5] Qi Donghui. Research on energy-saving application of high-temperature heat-resistant conductor [D]. State: South China University of Technology, 2012

[6] Zhang Yinglu. Calculation of tension sag characteristics of double capacity conductor [J]. Power Construction, 2006, 27 (9): 7-8

[7] Gu Junjie, Yuan Qi, Ge Qingtian. Technical characteristics and application of aluminum clad invar steel core heat-resistant conductor[J]. Electricity and Energy, 2014, 35 (5): 594-596

[8] Dong Gang. Research on the properties of aluminum coated carbon fiber composite core conductor [J]. Shandong Electric Power Technology,2017: 44(11)65-68

[9] You Chuanyong. Research on the application of capacity increasing conductor on overhead transmission lines[J]. Electric power equipment B, 2006, 7 (10): 1-7