Research of Design and Choice of OPGW in UHV Transmission Line

Xie Shu-Hong, Li Hai-Quan
Zhongtian Hitachi Optical Fiber Cable Co., Ltd., Shanghai 200025, PR China
+86-21-64157800 lihq@chinaztt.com, xiesh@chinaztt.com

Abstract：There are fewer experience about using OPGW for UHV in China. The paper simply summarized a few applied experience of OPGW for UHV abroad, it is thought that UHV OPGW must have good characteristic about lightning protection, anti-vibration and anti-corona and so on. Based on it some design proposals and suggestions about UHV OPGW were brought forward, such as using bigger single wire diameter and aluminum clad steel wire OPGW; further studying the configuration method of ground wire(including OPGW) and using new inner compressed wire lightning protection OPGW. The study and analysis of OPGW type and series choice can provide the reference to adopt which kind of reasonable structure and good performance OPGW products for UHV network.

Keywords：UHV; OPGW; Design and Choice

1 Introduction

Electric power in China will maintain a swift growth in 15-20 years. In the direction of the power network development program “West-East power transmission project, South-North power supply mutually and national network” and considering our national condition and features of energy supply, State Grid Corporation of China decide to speed up building national power network whose core is Extra-High Voltage(UHV) power network, which is composed of 1000kV level alternating current and ±800kV direct current. A complete electric power transmission network and a complete optical communication network will be built. It is the most convenient and economical way to build a optical communication channel to composite communication ability in the UHV power transmission network. But with the development of the UHV power transmission network towards high capacity, great height, great length and extra-high voltage, we should consider the research of lightning strike resistance, anti-corona and so on.

2 The application of OPGW in UHV transmission line abroad

The developed countries in the world began their research on extra-high voltage electric transmission line techniques from 1960s. According to the data, USA, the former Soviet Union, Japan and Italy all built extra-high voltage experimental station and segment, focusing on extra-high voltages techniques and equipments.

The 900km 1150kv extra-high voltage transmission line was built in 1985 in the Soviet Union. According to the data, double earth wire is used instead of earth wire applying OPGW. The divide distance between the two earth wires are 400mm, and every phase earth wire is divided 70/72 steel-cored aluminum stranded line and the ratio of steel and Aluminum is < 1, this is because the weather in the places along the line is too heavy. They had to pursue the stronger mechanical performance. It is known that carrier communication was used on the line.

The 1000kv extra-high voltage trunk transmission line built in 1990s in Japan applied double OPGW earth wire (double circuit erect in the same tower) with earth’s 12^0 negative production angle. Japanese chooses the earth wire considering minimum diameter, short circuit current and mechanical strength in the corona of the earth wire. The south –north line-xinxiema trunk lines (111km) and qunmashanli trunk lines(138km) were built by Tokyo Electric Power Construction; 500mm^2 OPGW were designed and manufactured by Hitachi Cables, the construction is Aluminum loose tube framework 3 layers complete AS stranded, inner layer AS wires were scallop disposition. To strengthen the ability of resisting lightning strike, Φ4.2mm AS wire was used in the most outer layer as it showed in Table 1 . The east-west lines-Xinlimutrunk lines (240km) were built later. Considering the harmony of the lines and surrounding environment, low noise LN－OPGW 480mm^2 developed, designed and manufactured by Hitachi Cables were used as it showed in Table 2. All these OPGW were experimented in the Central Research Institute of the Electric Power Industry, such as wind tunnel, corona, and resisting radio also wind noise and corona noise test in Yanyuan and Chicheng, the two extra-high voltage research base.

The operation results of the experiments and practical projects indicate: there is no technical problem existing in the techniques of the extra-high voltage, and the results of electric power transmission

techniques and equipments can fulfill the need of the project.

Table 1 Structure and characteristic of OPGW 500mm^2 in Japan South-North UHV Line

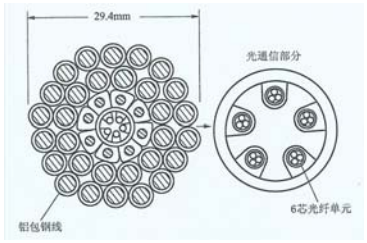
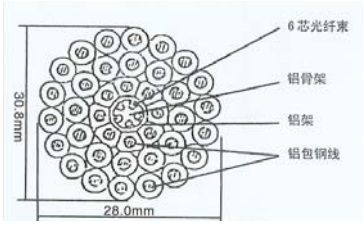
structure diagram		
Application section	Qunmashanli trunk line No.2～212 Xinxiequnma trunk line No.189～200	Xinxiequnma trunk line No.115～189
Number of optical fibers	30	30
Stranded wire structure	30/4.2 (40AC) 8/SB(eqv 3.62) (40AC) 1/6.5(OP-Unit)	30/4.2 (40AC) 8/SB(eqv 3.62) (30AC) 1/6.5(OP-Unit)
Calculated sectional areas	497.8 mm^2	497.8 mm^2
Cable diameter	29.4 mm	29.4 mm
Weight	2.431 kg/m	2.843 kg/m
Tensile strength	31370 kgf	38930 kgf
Electric resistance	0.0884 Ω/km	0.112Ω/km

Table 2 Structure of LN-OPGW 480mm^2 in Japan East-West UHV Line

structure diagram	
Stranded wire structure	Inner layer:8/SB (eqv 3.62mm) (AC) Neighboring inner layer: 12/4.2mm(AC) Outer layer: different diameter round single wires the AS linear diameter of jut 5.6mm OP-Unit: 1/6.5mm

3 Technical characteristic of OPGW in UHV transmission line of China

According to the industrial technical development and the accumulation of producing experience, overhead ground wire (no insulation) has not directly related to the voltage grade; and to the OPGW cable, served as lightningArc resistance wire in transmit electricity route, also has little to do with the voltage grade. However, we think that OPGW should be equipped with the following technical advantages when it is used in the transmit electricity route.

3.1 Good performance of lightning strike resistance

Because the distance between height of 1000kv extra-high voltage tower and ground wire is bigger than the parameter on 500kv route, high working voltage on conduct wire, easily occurred on the conduct wire and transmitted to the upper, increased probability of lightningstrike, so the volume of charge transmitted increasingly. In the tensile tower and corner tower, it suffered from lightning strike easily; those factors reduce the screen of avoiding lightning strike. By introduction of the material, in Former Soviet union, the lightning strike is not active and the 1150kV extra-high voltage line lightning strike trip-out rate reaches as high as 0.7/100km•a, but in Japan, the annual thunderstorm day number is about 25, 1000kV the west line extra-high voltage line also reaches as high as in the voltage dropping resistor 500kV movement period lightning strike trip-out rate 0.9/100km•a, this compares our country 500kV the line lightning strike trip-out rate statistical value 0.14/100km•a is much higher. Therefore we should consider the overhead static cable protection angle and the line pole tower high influence fully.

According to the computed result demonstrated that, in the same thunderstorm day situation, the extra-high voltage line OPGW electric charge shift quantity outdoes nearly a rank compared to the 500kV line (about 50C), moreover when the thunderstorm day is more than 50 days, DL/T 832-2003 standard regulation operating procedure highest 200C rank is somewhat low, corresponding 1000kV the line OPGW inspection needs 250-300C energy and can satisfy the project [3]. Therefore, it is necessary for us to set a higher request upon the thunder performance to extra-high voltage OPGW.

(1) In more than 110kV transmission lines of China, when there was no OPGW cable, it usually used the same material, specification double ground wire and the property of LightningArc Resistance was equal. Our country have used OPGW massively since the end of the 90's, the double ground wire used

OPGW+ to diverge the disposition way of the ground wire, the ground wire thunder protective performance equalization was broken. In recent years, repeatedly appeared the OPGW in the high thunderstorm area is to be broken; therefore, we must enhanced the ability of OPGW to bear lightning strike directly.

(2) The attention circle striking of the thunder to affect OPGW served as ground wire shielding properties.

3.2 Good performance of anti-vibration

Compared with the ultrahigh voltage transmission line with OPGW, because extra-high tension OPGW hangs the spot to be higher, the span is bigger, breeze vibration preventing and controlling is more difficult, therefore the extra-high tension transmission line ground wire's breeze vibration question is quite prominent. One is the OPGW vibration standard is stricter comparing with the ordinary conductor and the ground wire; The other is because the optical fiber is quite frail, the conventional anti-vibration hammer is the central incabloc, easily creates the local stress centralism to OPGW to damage the optical fiber, uses the pre-stranded wire clamp anti-vibration hammer, the spiral damping line and so on the allocation incabloc more suitable for OPGW anti-vibration.

3.3 Good performance of corona resistance

Extra-high tension rated voltage is 1000kV, the highest running voltage is 1100 kV, OPGW wire is highly high, OPGW and the wire are small in the span central mean distance, OPGW is in the wire of the strong electric field environment, OPGW superficial field intensity has been able to cause the OPGW comprehensive electronics corona, not only corona loss sharp growth, moreover can bring other many questions. Generally according to grounding surface field intensity (Em) and the grounding critical electric-field intensity (E。) ratio determined the grounding minimum diameter, certainly enhances the OPGW grounding diameter as far as possible to be advantageous in reducing the superficial electronics corona. Because the grounding diameter compares the wire to have to be small, the outer layer fold of yarn is also to be less than the wire, its surface roughness coefficient should be smaller than the wire, therefore should leave leeway certain allowance.

4 Suggestion of UHV OPGW design and choice

The OPGW optical cable shaping is an important content in an extra-high tension engineering design. The grounding (including the OPGW optical cable) is the first barrier of extra-high tension transmission line anti-thunder. However, the OPGW optical cable while undertakes the grounding to guard against the lightning strike duty, but also is undertaking the extra-high tension transmission line information system "the nerve center" the role, needs to have the very high movement reliability. The extra-high tension project line is long, the spanning meteorological region are many, the meteorological condition is changeable, the terrain is complex, having the high elevation, the mountain high mountains, the knoll mire, the big river lake, the movement condition is harsh, to the OPGW optical cable design shaping, we must consider these topographical condition and the meteorological condition fully.

4.1 Suggesting design all aluminum clad steel wire stranded type OPGW, and the diameter of the outside layer wires is about φ4.0mm.

We use all aluminum clad Steel stranding structure, also increase the outer layer single wire diameter as far as possible, and it is the best way to promote OPGW performance of resisting lightning strike. According to Japan's experience, in 275kV and in the 500kV ultrahigh voltage line widespread use entire aluminum clad Steel structure OPGW 260mm² is extremely reliable, its outer layer uses 40% IACS φ4.2mm aluminum clad Steel single wire and through the Central Research Institute of the Electric Power Industry the direct current arc fuse experiment appraisal also is very good. Therefore, Japanese request extra-high tension line OPGW outer layer single wire anti-direct current arc fuse ability is at least not lower than 40% IACS φ4.2mm aluminum clad Steel single wire. Our country recent years requested 500kV line OPGW to bear the thunder ability to achieve 150-200 coulomb (the 300A-400A electric current), the outer layer single wire diameter was not smaller than a 3.0mm aluminum clad steel wire. 1000kV the line OPGW inspection needs 250-300C (the 500A-600A electric current) energy according to the above. According to our country's lightning the experimental statistics, 40% IACS φ3.0mm aluminum clad steel wire breaks 2.75-4 equally under 150-200 coulomb lightning strike energy, cannot satisfy the extra-high tension line's requirement. Therefore, we suggested the extra-high tension design uses the entire aluminum clad Steel stranding OPGW, also the outer layer single wire diameter aboutφ4.0mm can satisfy the project to bear the thunder need.

4.2 Recommending further studying the configuration method of ground wire(including OPGW) inside and outside of industry.

(1)Research influence on lightning resistance of the grounding method of OPGW and diffluent ground

wire.

In our country double-ground wire transmission system, there is little lightning striking off phenomenon because of applying of double galvanized steel wire or Al-clad steel wire when OPGW has not been applied. But in the OPGW double ground wire system, the structure and electromechanical properties of the other diffluent ground wire coordinating with this system approximates to the OPGW, and fusion point of the outer layer aluminum wire is not higher than the outer Al-alloy wire of OPGW, though the strike off wire because of lightning are almost OPGW but not diffluent ground wire. According to current typical lightning theory，OPGW and diffluent ground wire in double ground wire system are equal in suffering from lighting, but why OPGW is easier? Lightning has a trend of looking for the way where impedance is little impedance to discharge lightning charge to neutrialize with ground charges of different polarity. The grounding method of the current designed OPGW and diffluent ground wire has no obvious discrepancy. We should study the influence of OPGW and the grounding method of diffluent ground wire to cause lighting, and study coordination of diffluent ground wire and OPGW from grounding method to cease the probability suffering from lighting.

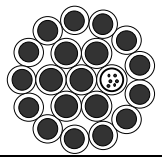
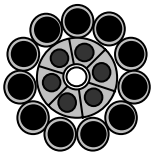
(2) Discuss the aptness of the configuration method of OPGW and good conductivity diffluent ground wire

Considering OPGW and diffluent ground wire configuration method designed in our special high voltage cause the lightning proof characteristic disequilibrium and easily strike off from lighting. And the design of tension-sag matching, short –circuit current and other electric property for OPGW and good conductivity diffluent ground wire come to unification. So we can investigate the possibility of adopting double OPGW instead of OPGW and good conductivity diffluent ground wire in ground wire design.

4.3 Recommend developing and designing the new inner compressed wires lightning resistant type OPGW

Ground wire homocentric stranding type OPGW is used in our country commonly. From lightning resistance point, Compressed Wires Lightning Resistant Type OPGW has the better lightning resistance characteristic. This type adopt inner layer compressed sector stranding structure which makes the whole OPGW structure compact, raise the filler coefficient of cross section so that increase cross section of OPGW, enhance its holding power to weight ratio and decrease sag. And the most important feature is to raise diameter of outer layer wire obviously and uplift its lightning resistance performance greatly.

Table 3 Technique comparison of two kinds of OPGW

Typical Parameter			Conventional round wire stranding type	Compressed wires lightning resistant type
Structure Drawing				
Struc-ture	Outer layer	Nos/mm	27AS 13/3.0	27AS 9/4.0
	Inner layer	Nos/mm	30AS 6/3.25 + SUS 1/3.2	30AS 6/SB 2.3
	center	Nos/mm	30AS 1/3.5	SUS 1/3.4
Max. number of fibers		Nos	36	36
Cable diameter		mm	16.0	16.0
Weight		kg/km	850	840
Rated tensile strength		kN	137	137
Short circuit Current capacity		$kA^2.s$	146	152
Lightningresistant		C	150-200	250-300

4.4 Recommend study and analysis of OPGW type and series choice in UHV transmission line

There is little OPGW work experience in UHV abroad and it is almost not exist in our country. In viewing of our never touching the relevant test and the equipment and specification not being established, selection of design and series study analysis of special high voltage applied in OPGW will play an important role.

Construction special voltage in our country means that the line has a long range and high power transmission capacity, the line also cross Yangtze River, Huang River and other rivers and lakes, so it has a high command for OPGW. Especially when the power transmitted to east area, the range of Yangtze River becomes wide gradually. The long span becomes from 2000m to about 2500m, and single OPGW wire rises to approx. 4000m. Because of OPGW having high demand of strength and considering its short circuit current and lightning resistance performance, OPGW

surely develops to big cross section. With more information transmitted, fiber amount of OPGW will increase form 24 cores to 48 cores.

In viewing of the importance of long span and high strength OPGW applied in the projects, the special high voltage construction adopts homemade OPGW symbolizing Zhongtian when the long span is general (thousand meters), but use imported OPGW when it's a special long span such as Jiangyin long span, Jiangzhou Yangtze river long span, Wuhu Yangtze river long span in Longzheng line and Mt. Ma'an long span, etc.. In reality, from application achievement of homemade long span OPGW, we have capability to produce series of OPGW with high strength, big cross section, good sag performance and great amount of fiber cores, and we also get a good application effectiveness of the anti-vibration design and test proof of long span OPGW. If we can produce special long span OPGW which adjust to high strength, big cross section, great amount of fiber cores, ordinary span(thousand meters) OPGW and routine line OPGW, so that it helps conform series and provide benefit condition for special high voltage design specifications and references and consultation for inner special high voltage project design and OPGW selection design and product.

5 Perorations

Compared with the EHV transmission line, the UHV transmission line's characteristics are high rated voltage, long transmission line, large conveying capacity, high iron tower and wide area power network. Although the OPGW of UHV also has double function of the overhead earth wire and optical communication, it is stricter in the operating ambient, effect of lightning strike and fault, the request of mechanical property, electrical specification and the fiber, the cooperation of fittings. Besides that, it is stricter in the engineering construction and the request of operating safety. All of these are related to the design and selection of the OPGW.

The OPGW of UHV must have characteristics of good lightning proof; shake proof, corona resistance etc. According to the mechanical property, short circuit capacity, lightning characteristic and the minimum diameter under the control of the corona, we believe that when design and select the OPGW we must consider the following factors:

(1) design and use all-ACS stranding stainless tube type OPGW, and the diameter of the outside layer wires is about 4.0mm.

(2) further studying the configuration method of ground wire(including OPGW).

(3) developing and designing the newly inner compressed wire lightning protection OPGW.

(4) developing the study and analysis of OPGW type and series choice.

Reference

[1] Liu Zheng-Ya. Extra-High Voltage Power Network [M].Beijing: China Economy Press, 2005.11.

[2] Itochi (Japanese). Development of OPGW in UHV Transmission Lines [C]. Symposia of Applied Technique Forum of New Generation OPGW, 2001.11.

[3] Sun De-Dong. Analysis of OPGW Performance of Lightning Resistance in UHV Transmission Lines[C]. Electrical Power System Communication，2005，27(6)：17-19.

[4] Fu Jun-Feng, Xie Shu-Hong, Li Hai-Quan. Research of design instance using OPGW for UHV in China[C]. Telecommunication for Electric Power System，2005，27(6)：12-16.

Authors

Xie Shu-Hong (Aug., 1970) Male, B.E., MBA and senior engineer. Engaged in the technical development and applied research of the overhead transmission line and special optical power cable for many years, and involved in the research and application of a wide range of national key projects. Now is ZHC's chief engineer.

Li Ha-Qquan (Jun., 1973) Male, B.E., master of engineering, and senior engineer. Engaged in the producing, technique, quality, management of the OPGW for many years, and involved in the lightning arc test and short circuit test of OPGW in Kinectrics Labor, Canada, moreover published many papers about special optical cable. Now is ZHC's general manager.