THE INNOVATIVE HIGH-EFFICIENCY WIRES OF POWER TRANSMISSION LINES ENERGY GRIDS

AUTORS:

V.N. KURYANOV,
NATIONAL RESEARCH UNIVERSITY «MOSCOW POWER ENGINEERING INSTITUTE», RU

M.M. SULTANOV,
NATIONAL RESEARCH UNIVERSITY «MOSCOW POWER ENGINEERING INSTITUTE», RU

V.A. FOKIN,
GENERAL DIRECTOR OF LLC "ENERGOSERVICE", RU

To meet the ever increasing power demand, we also needed the actions for development of new technology in the country with active participation of equipment manufacturers, research institutions etc. This paper gives information about the innovative high-efficiency wires of power transmission lines energy grids, parameters were determined based on simulation studies and laboratory evaluations.

Keywords: innovative wire, high-voltage power lines, loss of power and energy, economic efficiency, plastically deformed compacted messenger wire.

The cross section of the new Ground wire unidirectional twisted, with separate wires plastically deformed

INTRODUCTION

During several last decades, some new problems originated in Electric Power Transmission, that has led to a variety of novel trends in overhead lines projecting and construction, causing correspondingly major changes in the wires requirements and designs [1]. Power failure analysis of the Russian Overhead Lines' elements [2] shows that the violations related to failures of the conductors and ground wires are ranging from 40 % to 55 % of all violations registered, while they are increasing by ≈ 3–5 % annually. The main causes of damage are ice load (overweight, wind), fatigue wear due to Aeolian vibration and galloping, as well as damage from corrosion and the conductors' burns after flashovers and lightning strokes. Therefore, optimization of the wires structure is necessary through accounting not only the current-carrying capacity and operating loss (heating conductors due to their DC resistance, the cost of reversal magnetization of the steel core, eddy currents and corona losses), but also via their exploitation applicability and stability in a variety of the sharply different climatic conditions of Russia.

The practice of leading power grid companies suggests that a promising direction in solving the problem of increasing the capacity of transmission lines is the development of new structural materials for cores of wires and transmission lines capable of long-term operated at temperatures of 100-200 ºC.

WIRES BRANDS ASHT, ASHS

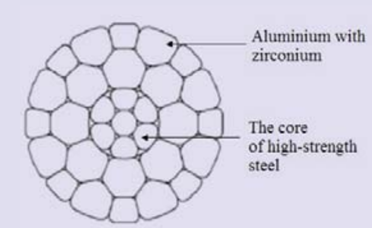

Figure 1

INNOVATIVE WIRES OF POWER TRANSMISSION LINES ENERGY GRIDS

Russian manufacturers have developed fundamentally new technology of producing wires with fill factor of capable of operation at high temperature — aluminum non-insulated high temperature wire, structurally consisting of a core and twisted wires made of heat resistant aluminum-zirconium alloy which shown on figure 1. The innovative design is the most promising for use in areas with high wind and snow and frost accretion. Different constructions of steel-aluminum wires brand ASHS (high strength) and ASHT (high temperature) is intended for transmitting electric power overhead transmission lines with high voltage lines 35-1150 kV.

The plastic deformation of the aluminum wire and wires of core allows for increasing the fill factor of the working section is much simpler and cheaper way. The disign is obtained with the use of such technology, as contributes, by increasing the fill factor of the working section to increase the useful current-conducting section of the wire. the obtained external surface more smooth and flat than that of wires made of round wires, can reduce the load against climatic influences, significantly reduce aerodynamic drag and the dance of wires [3].

WIRES BRANDS AERO-Z

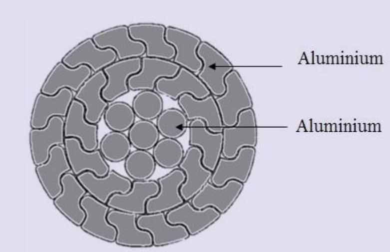

Figure 2

The wire has a high resistance to the effects of lightning impulse lightning discharge, the value of which is determined by the area of the suspension.

In addition, the wires resistant to thermal effects of short-circuit current arising in the process of operation of single-phase and two-phase earth fault. Experimentally confirmed operating temperature wire brand ASHT-150°C, the maximum allowable is 210°C.

Other manufacturers use Z-shaped wire which shown on figure 2 and used in the wire of the brand AERO-Z.

A new class of compacted conductors with increased strength and bandwidth. These are plastically deformed high- strength conductors types ASHT, ASHS [3, 4], certified of JSC "FGC UES" and have a significantly higher mechanical strength and current carrying capacity. The cross section of the new Ground wire unidirectional twisted, with separate wires plastically deformed shown on figure (see p. 4). Compacted conductor of harness type differs from the classical constructions, because after twisting the core, it is subjected raising its density over the cross section by compression, and then the similar procedure is applied to the conductive lays after their blending and twisting, see an example of such design in figure 4.

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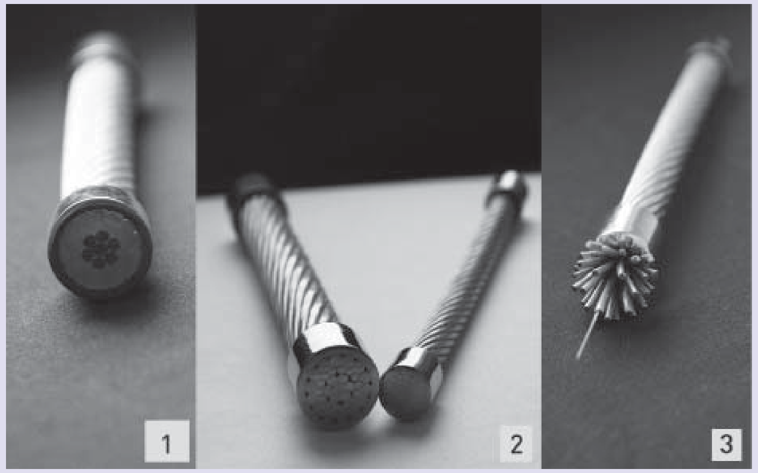
THE RANGE OF PRODUCTS FOR OPTICAL LINES



1. Plastically deformed wire (ASVP-ASVT); 2. Old design (bigger diameter) and new design (smaller diameter with the same lighting resistance qualities) ground wire; 3. OCGT (optical cable built into ground wire)

Figure 3

A MODEL OF THE NEW WIRES UNIDIRECTIONAL TWISTED (THE THREE CONDUCTIVE LAYERS, CORE)

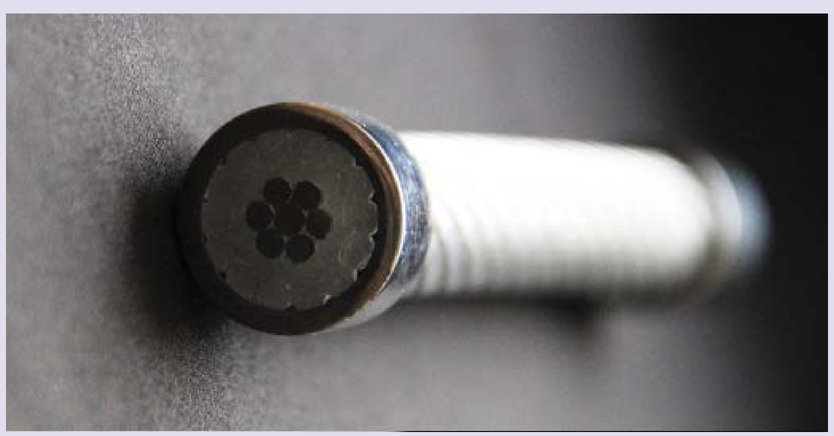


Figure 4

Plastic deformation with a reduction rate of the cross-section calculated for each of the materials prevents unwinding of the conductor and the mutual displacement of its elements under tensile forces, and due to mechanical hardening, the strength of the aluminum wires increases up to 1,5–2 times. The costs of conductors ASHT, ASHS and refurbishment of overhead line with these conductors are no more than similar costs of the ordinary conductors and in calculating the life cycle is even lower, but increasing the capacity (a few tens of percent for ASHS, up to 80–100 % for ASHT) covers any additional costs, reduces the load on the towers, reduces tensile force, wind and sleet loads and, eventually, it should increase the reliability of the Overhead Line, as far as the fatigue strength of the new conductors improves considerably. The smaller diameter of the conductors ASHS, ASHT compared to the same of ordinary conductors ACSR with lower strength would provide reduction: aerodynamic drag and, consequently, wind-induced loads; the level of internal corrosion in the conductor; the intensity of ice and snow build-up on the conductors outer surface; galloping amplitudes of wires.

COMPARISON OF THE MAIN CHARACTERISTICS

Parameters of the new wires important for the overhead lines designed do exceed greatly than those for ordinary ones. But the new wires are little heavier, they would fit excellent for the new Line to be built in the regions with excessive wind or ice loads or for long River crossings. Comparison of the main characteristics is presented in tables 1, 2, 3.

In the case of the new wires application at large crossings, it is possible to reduce the height of the terminal anchor supports of the crossing up to 25–30 %, subject to the standardized dimensions of the support Towers; this in turn will lead to considerably lower cost of all the crossing. In addition, with a reduction in height of the support Towers their inductance decreases, correspondingly reduces probability of direct lightning strokes and proba-

COMPARISON OF AS, AERO-Z, ASHS, ASHT WIRES A DIAMETER OF 22.4 MM

Type	Diameter, mm	Breaking force, kg	Weight,Kg/km	Permissible continuous current, A
Standard AL-Steel 240/56	22,4	98253(100%)	1106 (100%)	610 (100%)
AERO-Z 346-2Z	22,4	111320 (113%)	958 (87%)	852 (140%)
Lumpi -TACSR	22,4	86260 (113%)	957 (87%)	861 (141%)
J-Power Systems GATACSR	22,4	110000 (113%)	1100 (100%)	860 (140%)
ASHS 277/79 Energoservise	22,4	163940 (167%)	1399 (127%)	861 (141%)
ASHS 258/73 Energoservise	21,6	151553 (154,2%)	1296,5 (117%)	812,72 (133%)
Standard AL-Steel 400/93*	29,1	173715 (100%)	1851 (100%)	860 (100%)
ASHS 371/106 * Energoservise	26,0	225001 (122,79%)	1872(113%)	1059,9 (123%)
ASHT 277/79 **Energoservise	22,4	163940 (167%)	1399(127%)	1199 (197%

The values for Standard AL-Steel 240/56 conductors (serially used now) are assumed as 100 %.
* — Comparison AS400 / 93 and ASVP371 / 106;
** — The high temperature cable (ASHT by Energoservis).
The advantages of ASHS and ASHT conductors are more than twice stronger; ASHS conductor's current is almost as high as AERO-Z's current; and ASHT conductors offers capacity almost twice higher than AS conductor and 1.5 times higher than AERO-Z conductors of similar diameters. It supposes that the new ASHS and ASHT conductors expand designing of high voltage power lines and allow dealing with the goals that used to be unpractical or used to require great efforts.

Table 1

TECHNICAL COMPARISON OF WIRES FOR A PROMISING USE IN THE DEVELOPMENT OF POWER TRANSMISSION LINES ENERGY GRIDS

№	Company manufacturer	Conductor	Ø, mm	Weight, kg/km	AC Continuous carry, A	Breaking load, кN	Resistance, Ohm/km	Conductors sag at T_{max}
Traditionally used wires								
1	Standard steel-aluminum conductor	ACSR 240/32	21,6	921	605	72,7	0,121	13,2
2		ACSR 300/39	24,0	1 132	710	89,2	0,098	11,5
3		ACSR 400/51	27,5	1 490	825	115,4	0,075	11,7
Innovative types of wires (with improved performance)								
4	Energoservise	ASHT461/64 high temperature	26,9	1 802	1668	170,5	0,063	9,3
		ASHT 371/106	26	1882	1476	220,4	0,0776	7,8
		ASHT 277/79	22,4	1400	1199	163,9	0,1040	7,7
		ASHS 277/79 ** high-strength	22,4	1400	862	163,9	0,1040	7,9
5	Lumpi-Berndorf	TACSR/HACIN 212/49	21	939	861	95,4	0,1283	10,5
6	Lumpi-Berndorf	TACSR/ACS 212/49	21	914	871	95,4	0,1283	11,6
7	J-Power Systems	GTACSR 217/49	20,3	1015	840	110,7	0,136	9,1
8	Nexans	AERO-Z 366-2Z	23,1	1014	732	116,2	0,092	9,9
9	ZM	ACCR 405-T16	20,1	684	1059	70,0	0,129	8,2

** — If the increase in the support load is not desirable, it is suitable to replace the ACSR 300/67 conductor ASHS 317/47, has less weight and heat losses, higher bandwidth compared with the ACSR300/67 with almost equal tensile strength (125 kN) . With the new construction of overhead lines with increasing distance between the supports and the low current loadings on line is possible to use ASHS 277/79, and when it is necessary to significantly increase the capacity of the line - that ASHS 389/59. Conductor ASHS295/44(116 kN) is more suitable for the replacement of AS240/56(98 kN) conductors for overhead lines, where a slight increase in weight and load on the bearing is permissible, with the need to increase bandwidth, while lowering heat loss.
So using innovative wires may be considerably increasing the capacity of high voltage lines as compared with standard conductors.

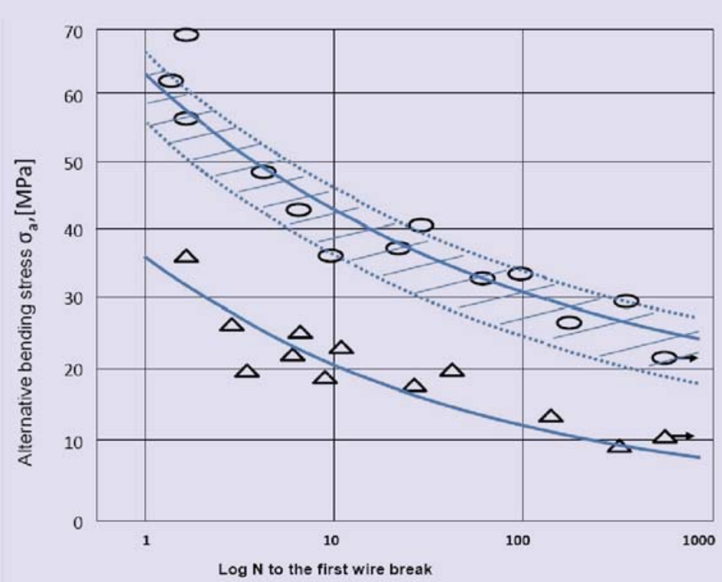
Table 2

COMPARISON OF CONVENTIONAL TYPE AND THE NEW PROPOSED

Parameters of the conductors to be compared	ACSR 150/24	ASHT, ASHS 162/47	
	value	value	Change in percent to ACSR
Core cross section, mm²	24,2	47,3	+90
Al part cross section, mm²	149	162,3	+8,9
Diameter, mm	17,1	17,1	0,0
Rated Breaking strength, daN	5227,9	9882,4	+89,0
Max current load, A	554	590,5 (822)	+6,6 (+48,4)
Span length of OHL at one and the same sag, m	280	364	+30
Towers on the 10 km of OHL	37	27	–27
Specific losses of electricity at the same current load (150 A), MWh/km per year	41,7	36,4	–12,7
Conductor temperature expansion coefficient, 10-6 1/ °C	19,2	16,7	–13
Conductor elasticity modulus, E*10⁻³, N/mm²	82,5	88	+ 6,7
Sag at the highest air temperature (+40 °C), m, for the spans: 250 m / 300 m	6,29 9,26	3,32 4,87	–47,2
Sag at ambient temperature –5 ° C in the 3rd region of the wind and ice load, m: 250/300	6,66 9,63	4,41 6,04	–33,8
The electric field of the corona onset at dry weather, kV/cm	34,04	40,0	+17,5
DC Resistance (20 °C), O hm/km	0,2039	0,1780	–12,7
Preliminary conductors' relative costs estimation	100 %	110-120 %	

Table 3

PROGNOSIS OF FATIGUE BEHAVIOR FOR THE ASVP, ASVT CONDUCTORS (SHADED AREA)



The test results as a function (N) for single-layer (ellipses) and multi-layer (triangles) conductors ACSR are reproduced on the basis of data [7]. N in Megacycles

Figure 5

bility of back flashover to the overhead line. Moreover, it is necessary borne in mind that the unique technological solutions in the production of new wires allow to offer a significant reduction in price relative to other wires with the same characteristics.

By using new wires is increased breaking strength and decreased Specific loss of electricity at the same current load, aerodynamic loadings (till 35%) and formation of ice (till 25%), conductor temperature expansion coefficient (15%) only due the constructional design. In case of application for repair or upgrading works at the old overhead lines some other (less weighty — with the thinner core) new wires may be advised [6].

EXPERIMENTAL TEST RESULTS ON CREEP

The correct definition of the conductors creep has recently become one

CREEP RESULTS FOR THE WIRES PRODUCED ON THE BASIS OF THE NEW TECHNOLOGY OF UNIDIRECTIONAL TWISTING (Ø11,0 MM)

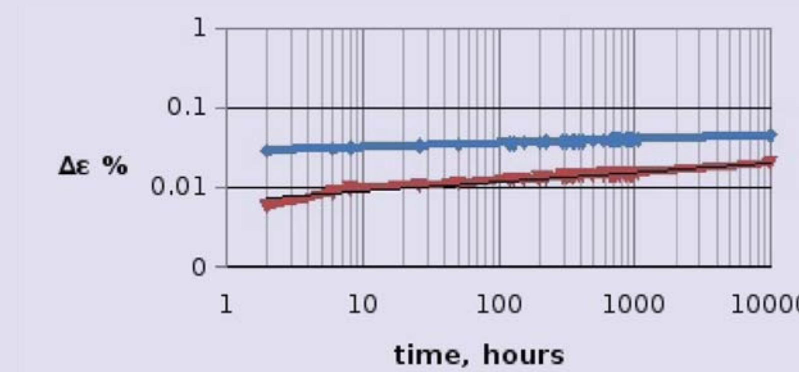


Figure 6

THE RESULTS OF TESTS ON STABILITY TO LIGHTNING DISCHARGE OF THE GROUND-WIRES OF DIFFERENT TYPES OF ONE AND THE SAME DIAMETER

№	Design, Material	Impulse value Coulombs	The Percent of all Discharges[9]	Mech. strength after Stroke	The Sample condition
Competitor 1	7 wires of Al-clad Steel, usual design	80	≈85%	0,4…0,5 RTS	Fig. 7
Competitor 2	19 galvanized wires, usual design	85	≈90%	0,5…0,6 RTS	Fig. 8
Competitor 3	19 galvanized wires, unidirectional twist, compacted	110…140	> 99 %	1,0 RTS	Fig. 9

Table 4

of the important requirements arising from the Exploitation organizations in Russia, as it turned out that the capacity of many of the overhead Lines may not be fully utilized due to increased, after many years of service, sag of the wires [8]. Figure 5 shows the forecast for the fatigue characteristics of wires ASHT and ASHS.

To avoid this problem with our products in future, special attention to the creep tests is addressed. Quite recently, tests of creep (hood) of the OPGW type have been initiated, to provide the normalized input data for the Project engineers. The tests were carried out under a constant load of Teds = 20% of RTS (Rated Tensile Strength)in the experimental stand.

The results of the tests performed at «R&D Center @ FGS», JSC showed:

- Elasticity modulus of plastic deformed unidirectional twisted Ø11,0 mm ground wire is about 7% higher than Elasticity modulus of conventional Ø15,5 mm ground wire.
- Ø11,0 mm ground wire stretched over 0,0150% of the initial value for 1040 hours, while Ø15,5 mm ground wire stretched 0,0532% over the same period. It means, that Ø11,0 mm ground wire creep is almost four times less than Ø15,5 mm ground wire creep. Prognosis of fatigue behavior for 25 year period differs by almost 4–5 times in favor of the Ø11,0 mm ground wire.

The results obtained at 20 ± 2 0C are shown in the graph of figure 6. So far, the test was carried out at constant and strictly controlled conditions, and the results obtained may be described in rather a simplified form. By this moment, we have an approximate expression for creep as: $\varepsilon_{creep} = at^b$; where a = 0,0278, b = 0,0511.

In the future, by extending the baseline of our tests, we expect to obtain more reliable creep characteristics of the samples. By changing tension and temperature during experiments, we would have chances to generate a more comprehensive polynomial digital description of new wires creep.

In General it can be concluded that the use of new technology lay in combination with plastic deformation of layers of wires in the manufacturing process significantly reduces the elongation, reduces the intensity of their growth over time, regardless of material (steel, aluminum-steel or copper).

Aluminum coating of rods allows additional reduction of temperature, but its use is associated with a number of negative factors: low corrosion resistance of aluminized coating in the area of contact with stainless tube of optical module; low resistance of ground wires with aluminum coating. When selecting a type of protective coating for steel rods it is necessary to consider not only possible change of temperature field in wires at similar values of short-circuit current, but also dependence of its value on specific resistance of ground wire, as well as resistance, corrosion resistance and rod bearing capacity.

CALCULATION OF WIRES PARAMETERS

Calculation of wires parameters and final selection of optimal wires for part of the overhead line calculated automatically by the special research program named SOWfPOL (figure 10).

MESSENGER WIRES FOR OVERHEAD CONTACT SYSTEM OF RAILWAYS

The Russian developers have created the products having at the same time high mechanical durability, slightly changing length at fluctuations of temperature, resistance to corrosion, electric conductivity of copper, the having best aerodynamic characteristics, standard diameters rather technological by a mass production. At the same time products are compatible to standard fittings. The compacted, plastically deformed bearing CC brand wires, are capable to carry out functions not only the bearing

THE SAMPLE CONDITION OF COMPETITOR 1

Figure 7

THE SAMPLE CONDITION OF COMPETITOR 2

Figure 8

THE SAMPLE CONDITION OF COMPETITOR 3

Figure 9

wires, but also the strengthening wires, electric connectors of a contact suspension bracket and wires of feeding lines. Copper compacted wire CC brand. It consists of 36 condensed copper wires of various diameters and has at the same time the bigger section, the increased explosive effort and lower specific resistance. It is an example of the copper cable carrying a contact network of railways is most clearly illustrates the advantage of plastically deformed products, increasing the mechanical strength to the level of bronze, but the conductivity of pure copper or alloys without using expensive technologies.

CONCLUSION

The innovative technology of plastic deformation Patents awarded in Germany and Russia and provides important and prospective advantages of the new innovative wires — greater

WINDOW OF CALCULATION PROGRAM FOR CHOICES THE CORRECT WIRES WITH THE BEST PARAMETERS AND FINAL SELECTION OF OPTIMAL WIRES FOR PART OF THE OVERHEAD LINE

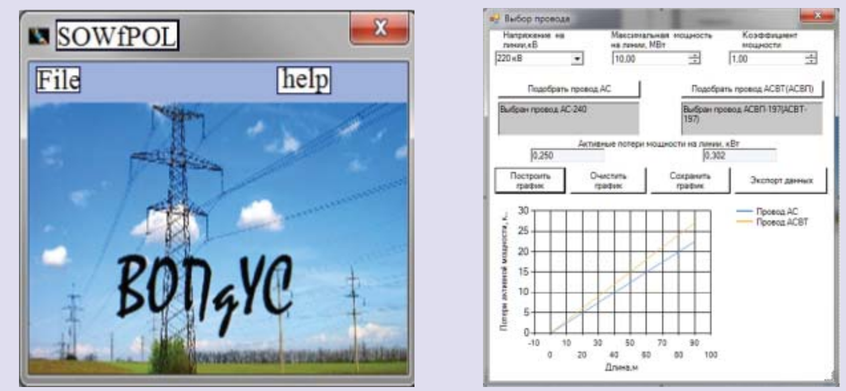


Figure 10 windows of software

much strength and the higher current of Power transmitted. In addition to the advantages enumerated above, the new wires have already revealed the superior stability at lightning strokes; also, all the new products would surely have a very promising feature — the good fatigue stability at Aeolian vibrations and other kinds of dynamic impacts.

Comparative estimation of parameters of steel-aluminum wires of various types and mechanical durability calculations in various modes of environmental conditions demonstrated that steel-aluminum plastic swaged ASHS wires allow to flexibly solving designer and construction problems of power transmission lines energy grids.

Mathematical modeling techniques with subsequent series of experiments were used to demonstrate the falsity of the established opinion on that it is necessary to apply steel-aluminum wires with even number of lays of aluminum wires, twisted in the opposite directions in order to decrease electric power loss due to magnetic reversal of steel cores.

The transmission capability of high voltage lines energy grids of power lines can be increased due to application of ASHS wires by a magnitude of several tens up to several hundreds of percent in comparison with standard wires [3].

Smaller diameter of ASHS, ASHT wires as compared to standard wires with the same transfer capability allows reducing support load and slack of wires.

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