Optimal Solutions for Power Grid Development Problems

In the conditions of constant power consumption increase, the problem of optimizing long-distance energy flows transmission needs to be solved. One solution could be the creation of innovative conductors providing transmission capacity enhancement while reducing technical power losses, including corona losses.

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Products developed by "Energoservis", LLC and JSC “Severstal” are compacted conductors characterized by increased mechanical strength and current load. In comparison with ordinary conductors, the compacted conductors are twisted and constricted by means of plastic deformation. As a result, the compacted conductor has a higher density in the cross section and conductive electrical contacts between the wires. ASHS and ASHT conductors (high-strength and high-temperature steel-aluminum conductors) [2, 5, 7] are certified for use at power transmission lines by PJSC "FGC UES" interdepartmental commission [1, 2]. The conductors have passed tests on mechanical and electrical parameters, including on corona discharge and its intensity in accordance with IEC 61284:1997 recommendations ("Overhead lines – Requirements and tests for fitting") [3, 4, 5]. Comparative analysis of test results is considered below.

OPTIMAL SOLUTIONS FOR POWER GRID DEVELOPMENT PROBLEMS

Currently, the improvement of the power grid efficiency is one of the most topical issues. One solution is the implementation of innovative conductors with better characteristics in relation to standard steel-aluminum conductors. Among those characteristics are enhanced transmission capacity and mechanical strength, as well as resistance to high temperatures, aging and aggressive environmental influences.

Usually, the problems of power grids development around the world are solved by means of existing power lines reconstruction (preferably using old transmission towers). Sometimes, the reconstruction is performed with transmission capacity enhancement. If the reconstruction can't provide satisfactory result, new overhead lines construction is carried out. The use of new technologies is logical for any solution.

The conductors and overhead ground-wire cables produced with unique plastic deformation technology application allow to reduce price and have advanced characteristics (the first prize of PJSC "Rosseti" for the best implemented project in 2014). Taking into

Table 1. Wind loads for conductors with different cross-section contour depending on airflow speed

Airflow speed v_{AB}, m/s	Wind load acting on the following conductors, N/m					
	ASHS 128/37 (Ø15,2 mm)	ACSR 120/19 (Ø15,2 mm)	ASHS 216/33 (Ø18,5 mm)	ACSR 240/32 (Ø21,6 mm)	ASHS 277/79 (Ø22,4 mm)	ACSR 240/56 (Ø22,5 mm)
25	3,6	4,8	4,9	6,9	5,2	7,0
32	5,9	7,9	7,8	11,4	8,4	11,5
60	20,8	28,5	28,4	41,5	29,8	41,6

account the large-scale program of transmission lines constructions and reconstructions in Germany, France, Italy and other EEC countries, the use of afore-mentioned conductors can significantly reduce construction costs. "Rosseti" Group has already implemented 8 overhead line projects and has installed 18000 km of overhead ground-wire cables in Russia. In addition, 17 overhead line projects are under implementation.

Experimentally confirmed main advantages of ASHS/ASHT modern conductors in comparison with traditional steel-aluminum ones are listed below:

– wind loads reduction;
– less susceptibility to conductor galloping and vibrations self-damping;
– less probability of snow adhering;
– greater mechanical strength and, as a consequence, smaller sags and the possibility of increasing the distance between transmission towers;
– electrical resistance reduction;
– corona losses reduction;
– enhanced permissible current (for high-temperature conductor).

ASHS/ASHT conductor advantages are confirmed by the results of the research conducted by PJSC "FGC UES" science and technical center, National Research University "Moscow Power Engineering Institute", Volgograd State Technical University and other leading scientific centers.

The interactions of wind and conductors depending on wind speed and type of conductors cross-section have been compared. The following conductors with similar diameters have been used for comparison (Table 1): ASHS 128/37 and ACSR 120/19; ASHS 230/32 and AC 240/34; ASHS 277/79 and ACSR 240/56. There is the difference between calculated and standard wind loads, because wind pressure changes (depending on relief of the terrain), impact of span length on wind load and intermittent wind pressure along overhead transmission lines are not taken into account. Taken approach makes it possible to more clearly determine the contribution of conductor contours to wind load changes. The view of conductors contour after crimping was obtained by modeling steel-aluminum conductor plastic deformation process in the Abaqus/Explicit module of the SIMULIA/Abaqus software (Abaqus, Inc., USA). For all ASHS conductors aluminum wires of outer layer are tightly adjacent to each other without gaps. It provides a possibility to simulate the wind impact on a single conductor with one external contour by means of COMSOL Multiphysics.

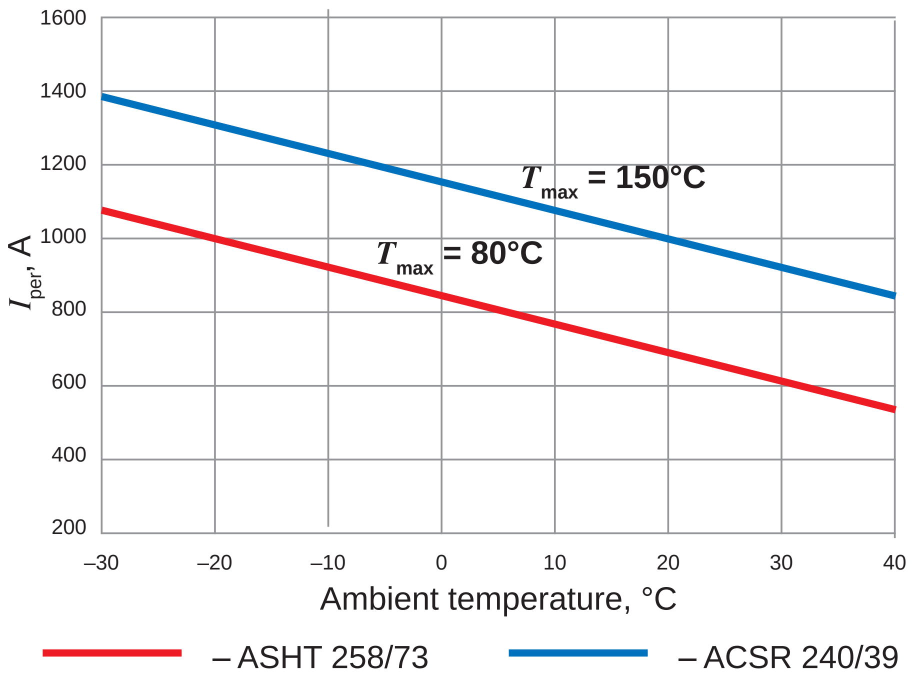

Figure 1. Dependence of permissible current load on ambient temperature

As can be seen from the data above, wind load on ASHS conductors having streamlined design is lower by 33% on the average. Reduction of wind load makes it possible to reduce the load on power transmission structures and to mount conductors with greater transmission capacity to existing towers during capital repairs. Plastically crimped wires have a number of advantages, which are usually inherent in more expensive wires from profiled wires. According to reference data, the loads from ice coating action on compacted conductors with smooth outer surface and reduced diameter are decreased by 3-9% compared to standard steel-aluminum conductors of the same section [6].

It should be noted that, according to regulatory documentation, standard conductors are allowed to operate when their temperatures is up to 80-90 °C. The permissible temperature for ASHT conductors is 150 °C.

Figure 1 represents the dependence of permissible current load on the air temperature (wind speed is 1.2 m/s) for AC and ASHT conductors in conditions of a maximum operating temperature of 80°C and 150°C, respectively. Continuous permissible current for high-temperature conductor is 30-35% higher than the value for standard conductor of the same diameter. This characteristic (Figure 1) allows innovative conductor application when significant increase of transmission capacity, without increasing the cross-section, is required. Also, the innovative conductor can be used in areas with high ambient temperatures.

THE STUDY OF CORONA DISCHARGE OCCURRENCE AS A FUNCTION OF VOLTAGE

An important point when using conductors with less diameter is the risk of corona losses and noise levels enhancement. JSC "STC FGC UES" conducted two studies for testing this problem. At the first stage, two conductors of the same diameter (18.8 mm) were taken for comparing and studying corona discharge. In total, 4 conductors have been used within the experiment (Table 2 and Figure 2).

The tests were carried out in accordance with IEC 61284 recommendations.

Based on comparative tests results obtained at PJSC "FGC UES" science and technical center, it was established that ASHS 197/55 conductor manufactured by "Energoservis", LLC has corona discharge voltage (142.2 kV) by 5.7% higher than ACSR 185/29 conductor (134.5 kV) with the same diameter 18.8 mm.

Similar tests were carried out for ASHS 216/33 and ACSR 240/32 conductors with different diameters. Based on comparative tests results AC 240/32 conductor (Ø21.6 mm) and ASHS 216/33 conductor (Ø18.5 mm) have the same corona discharge voltage. However, continuous permissible current of the conductors being compared differs significantly (510 A for ACSR 240/32 conductor, 689 A for ASHS 216/33 conductor (t = 70 °C), and 1040 A for ASHT 216/33 conductor (t = 150°C)).

ASHS conductors have advantages in terms of smaller corona losses in comparison with ACSR conductors of the same diameter. Also, ASHS conductors have comparable corona losses in regard to

Table 2. Technical data of the tested conductors

Conductor model	Conductor external diameter, mm	Number of aluminum wires in the conductor, pcs	Diameter of outer layer wires, mm	Continuous permissible current
ACSR 150/19	16,8	24	2,8	450
ACSR 185/29	18,8	26	2,98	510
ASHS/ASHT 197/55	18,8	28	3,45	561/943*
ACSR 240/32	21,6	24	3,6	605

** t_{max} = 70 °C — high-strength steel-aluminum conductor and t_{max} = 150 °C — high temperature steel-aluminum conductors*

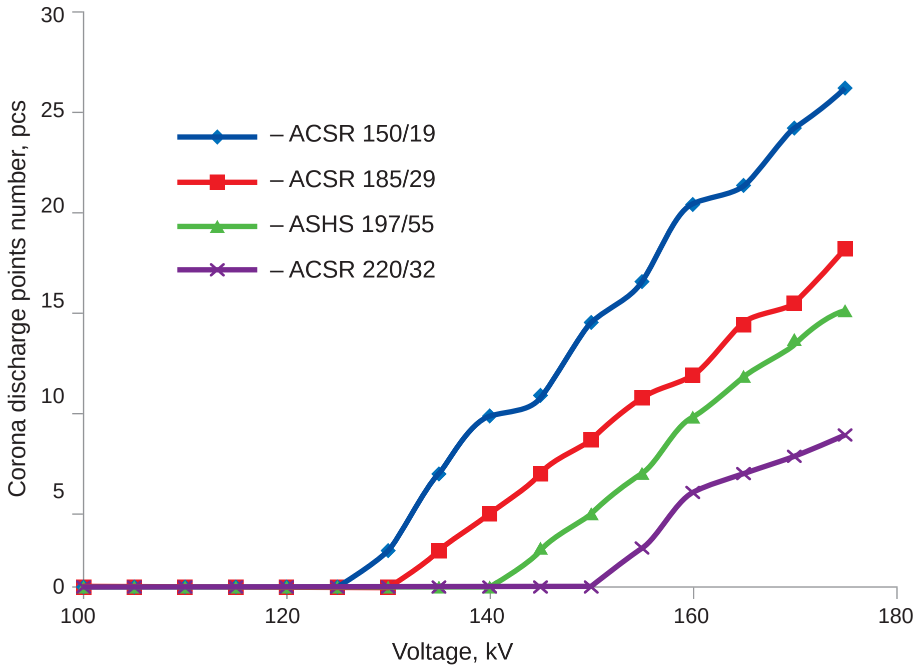

Figure 2. Dependence of corona discharge points number on voltage

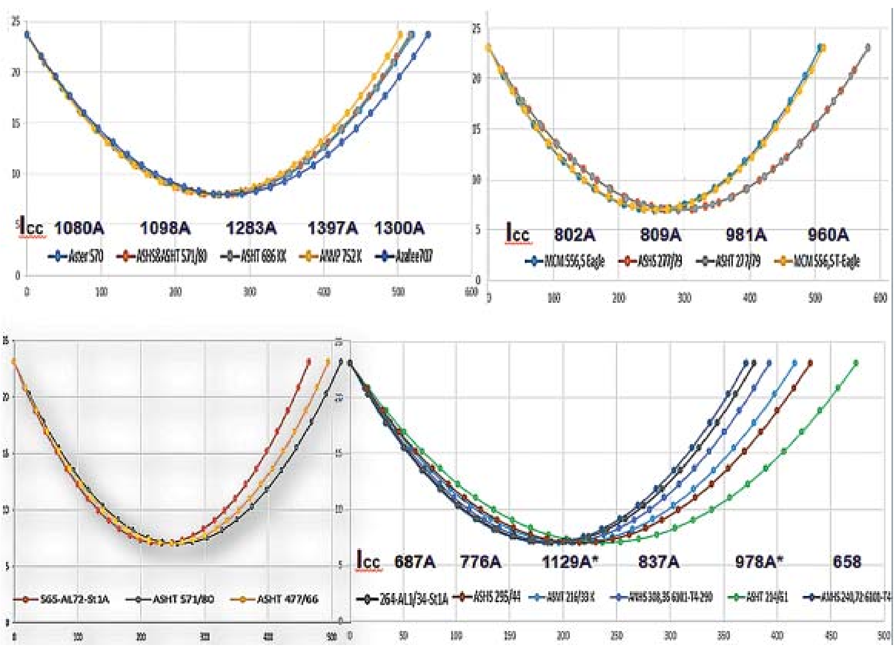

Figure 3. Span length with allowable clearance spans for OHL

Calculated specific corona losses in good weather (220 kV overhead line)

Phase construction (conductor model; conductor radius r_0, cm)	Annual average losses change, %
ACSR 240/32; Ø 21,6 mm	+ 26,67%
ACSR 300/39; Ø 24,0 mm	0,00%
ACSR 330/43; Ø 25,2 mm	–13,33%
ASHS 317/47; Ø 22,3 mm	–13,33%
ASHS 295/44; Ø 21,5 mm	–6,67%

Calculated specific corona losses in good weather (330 kV overhead line with split phase consisting of 2 conductors with 40 cm spacing)

Phase construction (conductor model; conductor radius r_0, cm)	Annual average losses change, %
2 × ACSR 300/39; Ø 24,0 mm	+ 18,52%
2 × ACSR 400/51; Ø 27,5 mm	0,00%
2 × ASHS 317/47; Ø 22,3 mm	–7,41%
2 × ASHS 295/44; Ø 21,5 mm	+ 3,70%

ACSR conductors with larger diameter and similar electrical and mechanical characteristics.

The examples of design solutions (Figure 3) illustrate significant expansion of optimization possibilities.

CONCLUSION

As a result of numerical experiments, a study of ASHT modern high-temperature conductors application efficiency in electrical grid has been made. The data on the ultimate loads, the reduction of heat release and magnetization of the conductors in operation have been obtained. Based on comparative tests results it was established that ASHS conductors have corona discharge voltage higher, than ACSR conductors with the same diameter.

The relative decrease of ASHT high-temperature conductor magnetization in comparison with AC conductor is 3-7%. The obtained results show that innovative conductor application is justified when significant increase of transmission capacity without increasing the cross-section is required. Also, the innovative conductor can be used in areas with high ambient temperatures. When reconstructing 110 kV and above electrical networks, the economic effect of ASHT conductors application is achieved by reducing magnetization, heat and corona losses as well as increasing network capacity and improving power supply reliability. Considering the fact that currently existing power transmission lines have been in operation for more than 25-40 years and have depleted their resources, it is extremely necessary to replace them with new ones.

On a per 1 km basis of 110 kV conductor in the Volgograd Region, the discounted payback period for the replacement of a standard conductor with ASHT high-temperature conductor (manufactured by "Energoservis", LLC) does not exceed 5 years. It changes the approach to high-temperature conductors application.

Average characteristics of overhead lines in Russia

Voltage, kV	220	330	500	750
Average length of overhead line, km	59	88	187	250
Average diameter of ACSR conductor, mm	25,6	25,6	27,4	26,1
Possible ASHT / ASHS conductor diameter in terms of corona discharge	22,4	22,4	24,5	24

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