

Investigation and Implementation of Silicone Conductor Cover for MV & HV Overhead Lines

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Abstract: *The energy sector has been developing at a rapid pace in the last 10 years or so. The need to replace internal combustion engines and the introduction of electric cars necessitates the need for strong energy production. But this is only the tip of the iceberg. More important is how the produced energy reaches the end user. The electricity transmission lines used need to be optimized to handle the loads.*

Keywords: Compact line design is the result of this space-saving strategy.

I. INTRODUCTION

Typically, 110-400 kV transmission lines are built very conservatively, with technology that is almost from the Stone Age. In normal overhead line construction, the insulation distances from phase to phase in the pole are determined by the need to maintain an acceptable level of insulation under certain climatic conditions. This means that the distance between the conductors in the poles of a conventional overhead line is significantly over-dimensioned from a purely electrical point of view.

When designing power lines, an important point is determining the transmitted power. Recently, many photovoltaic and wind power plants have been built. The electricity produced in these plants must be transported from the place of production (usually far from existing substations). Due to the large amount of electricity produced in Bulgaria, according to TSO data, about 500 MW are exported every day. For this purpose, four new 400 kV power lines had been built, and there are projects for another 2-3 more.

A. CAPACITY OF A POWER LINE

Regarding the transmission capacity of the power line: the amount of power transmitted depends largely on the wave impedance of the line, which can be achieved with the following solutions:

- Increasing the cross-section of the conductor. Unfortunately, the increase is carried out within certain limits according to the weight of the conductor. For comparison, medium voltage lines in Bulgaria use ACSR95 conductor (cross-section 95 sq.mm). However, in the Maritsa Iztok Mining Complex, due to the high power of the excavation machines, the cross-section of the conductor is now ACSR400 (cross-section 400 sq.mm). However, the large cross-section is very heavy, which necessitates the use of heavy poles. This is inefficient for utility companies, where the amount of power lines is large.
- Increasing the radius of the conductor surface –

increasing its cross-section. Since we cannot increase the radius of the conductor without increasing its cross-section for extra-high voltage power lines (750 and 1150 kV), this requires the use of hollow conductors;

- Increasing the number of conductors in a phase – this is a continuation of the above method, but is effective for voltages above 110 kV. Bundled conductors are used in 2-5 pcs. per phase;
- Increasing the voltage of the power line. In order to further increase the transmission capacity after the cross-section cannot be increased any further, the voltage of the line is increased from 20 kV to 400 kV (in Bulgaria). This method also has limitations due to the power losses caused by the length of the line. That is why power lines of 1150 kV are already being built in Russia and China and US.

Increasing the cross-section of the conductor, as well as increasing the voltage level on the power line, are costly operations. Increasing the cross-section of the conductor leads to an increase in its weight in the span and hence to an increase in the weight and size of the poles. After the war in Ukraine began, due to sanctions on Russian raw materials, price of steel and, accordingly, the cost of transportation increased 3-4 times. The possibilities for purchasing steel decreased, as delivery distances increased and hence the value of the final product. That is why companies began to think about other ways to increase the transmission capacity. Increasing the transmitted power above the permissible for a certain cross-section leads to heating of the conductor, as at a temperature of 100 °C, aluminum begins to soften and, due to its own weight, the sag in the span between lattice steel towers increases. This is dangerous because it can lead to a short circuit.

II. ALTERNATIVE

The limitations imposed by the above methods for increasing the transmission capacity of power lines are the reason for seeking new opportunities for this.

- A new possibility is the use of a high-temperature conductor with an increased operating temperature (150 – 240°C). The increased operating temperature level is achieved by adding zirconium to aluminum or replacing the steel wire with a composite one. For comparison, the permissible current load of a conductor type

ASCR95 is 320 A. On a high-temperature conductor 95-AT1-16-A20SA (from the Austrian company Lumpi-Berndorf) it is 429 A, without wind, with the same other parameters of the conductor (diameter and weight). The increase in current load increases by 34%. This is the same as using a conductor with a cross-section of 120 sq.mm.

- Another option is to reduce the distance between the phases. The transmitted power in conventional power lines (PL) is limited, depending on the nominal voltage and load current. At the same time, the PL generates inductance and capacitance, which depend on the distance between the phases. The greater the distance between them, the greater the inductance along the PL and, accordingly, the lower the active transmitted power. This requires the installation of additional expensive equipment, such as capacitor banks or static compensators STATCOM.

Reducing the distances between the phases changes the size of the power line, reducing it. The power lines obtained in this way are commonly called Compact ones. The creation of compact OHL with minimum permissible distances, optimal designs for the placement of the phases ensure an improvement in the parameters of the line at the expense of changing the parameters of the electromagnetic field between the phases and the magnetic field around the line itself. The strengthening of the electromagnetic field inside the line when reducing the distance between the phases allows to reduce the wave impedance of the OHL and thereby increase the active component of the power transited through the power line and improve the parameters of the OHL itself. It is as if we have connected capacitors between the phases in each inter-pole/pillar. Reducing the electromagnetic field in the external space leads to an improvement in the environmental performance of the line. The author has made calculations for a 20 kV line, on an ASCR95 conductor (cross-section 95 sq.mm), and by using a new type of cross-arm, the inductance is reduced and the line capacitance is increased by 15% (total 30%). With an allowable current load of an ASCR95 type conductor of 320 A, a current load of 400 A can be obtained, which is achieved by using a conductor with a cross-section one step up, without actual replacement with such a conductor or other costs for utility companies.

Reducing the distance between phases is achieved through several methods:

- Removal of long rod insulators and their replacement with station post ones. All intermediate links ensuring the swing of the conductor and the insulator chain are removed, and the conductor is fixed firmly to the new type of insulators. The reduction in distance in this way is limited by the minimum permissible ones to avoid arcing between live and grounded parts of the line.
- Use of covered conductors.

III. COVERED CONDUCTORS

XLPE and HDPE insulation are the most commonly used sheath materials for covered conductors. XLPE is preferred over HDPE because it has about twenty times the resistance to environmental stress cracking and about five times the impact and tensile strength of HDPE insulation. Covered conductors may have one, two or three sheath layers at medium voltage (6.6-33 kV), while at 66-132 kV the conductor may have up to five layers. Single sheath conductors typically use an aluminum alloy with an XLPE or HDPE sheath with a thickness of 2.3 millimeters (mm). These conductor systems are also manufactured with 1.6 mm and 1.8 mm sheaths for AC or aluminum alloy conductors, steel conductors and copper conductors. Thinner sheaths reduce the overall diameter and thus wind resistance, resulting in lower vibration levels and lower snow loads. Copper is used in highly salt-contaminated environments. To improve long-term phase-to-phase contact performance at 33 kV, sheath thicknesses of up to 3.3 mm can also be used. Single sheath sheathed conductors have some disadvantages, such as lower impulse strength compared to multi-sheathed conductors. In addition, electrical stress (distortion of the electric field) caused by trees on the line or cantilevered conductors can cause sheath erosion over several months depending on the system voltage. A typical three-layer sheathed conductor usually consists of a semiconducting sheath near the conductor, an insulating polyethylene sheath, and finally a hard, abrasion-resistant outer layer of HDPE. Ethylene propylene rubber (EPR) is another type of insulation used on sheathed conductors. It is resistant to heat, oxidation, ozone due to the stable, saturated backbone of the compound. Its advantages include lower thermal expansion compared to XLPE, reduced sensitivity, and higher flexibility. In general, EPR insulations retain their dielectric strength throughout the life of the installation, assuming proper storage and handling of the cable prior to installation. The superior flexibility of EPR insulated medium voltage cable is an important factor in larger areas where cables must be wound into vaults and other enclosures. In addition, EPR insulation offers high reliability and strong performance in rain, as well as improved fire resistance compared to XLPE insulations (APAR Industries, India, EHV/MV overhead covered conductors).



Fig.1. XLPE insulated conductors

Covered conductors with XLPE insulation are the cheaper alternative to underground cables and are therefore widely used in 20-35 kV power lines and have some advantages over bare conductors:

- Easier installation – supplied as a bundle of three conductors on rolls;
- Fault detection is facilitated because there is no excavation;
- Right-of-Way is less for the power line to pass

through wooded and mountainous areas. The operation of the power line is not affected by damage related to tree branches swaying in the wind.

- Reduced risk of forest fires – in a power line with bare conductors passing through a wooded area, with a large length, when a ground short circuit occurs, the current is very small and cannot trigger the relay protection to turn the power line off. At the same time, the electric arc continues to burn, which is already causing a forest fire..
- The risk of falling on the power line, especially in the terminal - insulator section, where birds can receive an electric shock, is reduced;
- The power line equipped with insulated conductors is not affected by Highly polluted atmosphere or areas with intense lightning activity.

A prototype of a high voltage 110 kV line with covered conductors is in operation in Finland. The use of XLPE covered LMF SAX is a high-voltage overhead conductor system for power lines, where LMF stands for Low Magnetic Field and SAX is a type of covered conductor. The conductor is made of a compacted aluminum alloy, which is covered with one or more layers of cross-linked polyethylene (XLPE) insulation. This design allows for closer tower spacing, reduces electromagnetic fields, and improves reliability by preventing outages that could be caused by conductors touching.

For power lines with voltages above 35 kV, the use of XLPE insulated conductors is not effective due to the high weight per linear meter of insulation. This requires increasing the size and load capacity of the poles, reducing the distances between them and thereby increasing construction and maintenance costs. The increase in costs can reach up to 50% of the cost of a power line with bare conductors, and this is just for flat terrains.

The alternative to XLPE insulation can be regular silicone insulation for wires.

IV. SILICONE COVERED CONDUCTORS

To protect wildlife from electric shocks caused by contact with wires, as an element of the insulation system of low and medium voltage power lines, insulating coatings are widely used, which are placed on existing bare wires. Silicone coatings for wires are designed to provide protection for both equipment and birds. They are made of silicone, specially designed for the strict requirements of the electrical industry for nominal voltages up to 66 kV.



Fig. 2 Silicone coatings from 3M, Rauchman, Changchun, Envertec

Silicone coating for conductors for voltages up to 36 kV is much more effective than XLPE insulated conductors for the following reasons:

- XLPE insulation is applied to the conductor only in the factory, which means that it can only be used in the construction of new power lines. Placing such conductors on an existing power line means total replacement of the bare conductor with insulated one, which reduces the efficiency of its use.
- XLPE insulated conductors are not safe to touch and must be treated as bare conductors;
- The silicone coating is supplied in rolls of a certain length and can be installed on an existing 11 – 35 kV overhead line conductor;
- Silicone coating has a much lower weight per linear meter than XLPE insulation, which means that poles do not need to be replaced;
- The silicone coating protects people and animals from electric shock and is an insulator up to 36 kV (Envertec). This means that birds and animals that for some reason have landed or climbed onto the power line poles, in the border area between the insulator and the conductor, will not be injured. This also applies to the service personnel, who are 100% protected.

V. ADVANTAGES OF IMPLEMENTING THE COVER ONTO OHL

Envertec's silicone coating was applied to bare conductors and equipment at the Biovet-Peshtera 110/6 kV substation and can be used to coat conductors in power lines and substations with voltages of 11 – 400 kV.

- Narrowed conditions in big cities, resort areas, the presence of the forests of first group (stocks of forests with valuable species of trees, national, city parks and green areas), where, for one reason or another is a necessary passage for Overhead Lines.

- Reducing Right-of-way when passing through forest and mountain area is one of the biggest advantages of silicone covered conductors

- Economic impact: in a class of 20 - 220 kV voltage construction of compact Overhead Lines is cheaper than construction with normal dimensions. It means the economic component directs the client to the modern, and now more increasingly worldwide technical solution.

- Another advantage of the Compact Overhead Lines is its design, which allows to increase the reliability, safety and transiting ability of power line. For upgrading existing 110 kV power lines to 220 kV. The insulation distances for a 220 kV power line are 1800 – 2200 mm. When insulating the conductors with Envertec Silicone Coating, the potential between two isolated phases of the power line can be reduced to 140 kV, which means that an existing 110 kV power line can be converted to 220 kV.

VI. APPLICATION



FIG.3 ENVERTEC'S CLAMP SILICONE COVERS

Silicone coating for ACSR would solve some problems such as:

- Reducing clearances when passing overhead power lines in Urban areas, eliminating the possibility of electric shocks to people and animals at break of wire;
- Eliminates the need for large tracts when passing through wooded and mountainous areas – reducing the Right-of-way;
- Used as bird-protection in areas with intense movement of birds and causing short circuits bird feces.
- Put in tensioning poles and structures to cover the wire connecting tensioning chains of the same phase, to avoid contact with it to the earthed parts of the pole in the wind.
- Avoid icing of the conductor due to the hydrophobic features of silicone thereby preventing "playing" of the conductor.
- Protects wire from corrosion by salt spray, prevents ingress of water in the wire rain and prevents corrosion of the steel in the ACSR;
- Can be used on high-temperature wires with operating temperatures up to 155 °C
- Once installed no maintenance is needed for the whole operating life of min 30 years.
- Better cooling performance than the bare conductor, due to the outstanding Thermal conductivity of the silicone material.
- Protects the power line working in harsh environments such as tunnels, culverts, bridges, etc. against oxidation and erosion damage caused by dust devils, moist air, acid rain, etc.
- Reliable protect against short circuits and power outages due to careless overlapping terminals.
- Protect electrical equipment from fire due to their non-combustible features (V0) and do not support combustion.
- Possibility of electrical shock to personnel manipulations;
- Effective prevention of major accidents caused by reptiles or small animal centered the installations of the substation;
- Prevents accidents caused by forgotten tools when repairmen is done in Switchgear;

TABLE I DIMENSIONS & WEIGHT

| | | | | |
|-----------------|------|------|------|------|
| Dimensions (mm) | Ø 12 | Ø 16 | Ø 22 | Ø 38 |
|-----------------|------|------|------|------|

| | | | | |
|---------------|------|------|------|------|
| Weight (kg/m) | 0.24 | 0.31 | 0.42 | 0.95 |
|---------------|------|------|------|------|

VII. CONCLUSIONS

Silicone Conductor Cover could be widely used by Utility Companies for preventing Bare Conductors of MV & HV Overhead Lines from Icing due to the hydrophobicity of the silicone, thus avoiding effect of "playing conductors".

The cover could be used in the Infrastructure Railway Companies as an insulation of the messenger wire when lines are passing through tunnels and under bridges with decreased clearance

VIII. REAL APPLICATION

Biovet Peshtera 110/6 kV substation fully equipped with Silicone Conductor Covers.



Fig. 4 Envertec's silicone coating completely covers equipment at the Biovet Peshtera substation

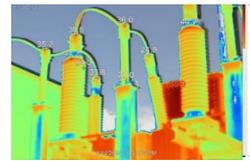


Fig.5 Thermal camera photo and the covered wires and equipment at the Biovet Peshtera substation

REFERENCES

- [1] Commercial Information provided by Envertec, Spain, Cantega Technologies, Canada and Izoelektro Slovenia.
- [2] laboratory researches by Ivan Handjiev at ERP North HV laboratory, Varna, Bulgaria