Type of Material in the Pipes Overhead Power Lines Impact on the Distribution on the Size of the Overhang and the Tension

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Abstract. The article presents the material type from which the conductors of the overhead power lines are produced influences on the size of the overhang and the tension. The aim of the calculations was to present the benefits of the mechanics of the cable resulting from the type of cable used. The analysis was performed for two types of cables: aluminium with steel core and aluminium with composite core, twice span power line section. 10 different conductor-to-strand coil, wind, icing, and temperature variations were included in the calculations. The string description was made by means of a chain curve, while the horizontal component $H$ of the tension force was determined using the bisection method. The loads were collected in accordance with applicable Eurocode.

1. Introduction

Electricity is ubiquitous and at the same time essential in life. We live with all kinds of devices, without which we cannot often imagine everyday life, and only when there is power out, and especially when the battery in the mobile phone runs out, the horror reaches the zenith. The "current" has to be, and in order to get to the places where we are, we need adequate transmission lines. Electricity is supplied from the manufacturer to the receiver via overhead or underground power lines (Figure 1) Underground lines are used less often because of the high cost of assembly, but there are places (urban agglomerations) where there is no other power supply. The overhead lines are more common due to their smaller executive financial outlays and the ability to deliver energy at significantly longer distances and higher power.

Figure 1. The overhead power lines [2]

The overhead power line is a two- or multi-span engineering structure consisting of conductors (treated as tie rods), support structures (poles), single or multi-lane high and high voltage lines. The high
demand for electricity and its quality depends on the transmission line. Proper modelling of this type of construction is indispensable in its design and therefore safe and long-lasting work. This is why high reliability is required in electrical and mechanical (construction), safety and security [7].

The overhead power line is subject to multiple stresses due to static, wind, icing, temperature, during assembly and maintenance of exceptional lines (transverse, longitudinal and torsional icing along the route, short circuit, avalanches, and seismic shocks). It is therefore very important to adopt the right computational model, both for the modernization of existing facilities and for the construction of new ones.

2. A few words about the wires used in high voltage lines
Overhead power lines commonly use conductors in which the basic material is drawn with hard aluminium or its alloys containing magnesium and silicon. However, due to the insufficient durability of aluminium, non-ductile, bare, steel-aluminium conductors marked as AFL are used. The single cable consists of several dozens of aluminium conductor forming the outer part of the conductors and a core made of galvanized steel conductors (Figure 2).

![Figure 2. The AFL conductor](image2.png)

Current power lines that supply power are in very poor condition. Some even come from the 30's. They are constantly exchanging their individual episodes and building new ones. In addition, typical construction and material solutions of cables strongly restrict overhead power transmission capacity, which, due to the increasing demand for energy, can lead to a blackout energy crisis due to insufficient system throughput. These limitations may be due to, for example, the low temperature of the phase conductors, the environment, the spatial, economic and historical conditions, or the technical and structural parameters of the conductors and supporting structures. In order to increase transmission capacity, the current carrying capacity of lines should be increased using high temperature ACCC conductors [3].

ACCC conductors are made of carbon fibre and glass fibre composite core in the sheath of aluminium trapezoidal conductor (Figure 3).

![Figure 3. The ACCC cable](image3.png)

The lightweight and strong core of the ACCC conductor provides less weight, with the same diameter as the replacement AFL, and the conductor itself has improved tear strength and flat overhang characteristics at elevated temperatures (Figure 4).

The ACCC conductor manufacturers [8] ensure that the AFL replacement on the ACCC defers the need to build a new line by 20-25 years, and increases current carrying capacity without upgrading support structures.

The paper attempts to estimate the effect of the type of material from which the conductors of the overhead power lines are made, the size of the overhang and the tension in the conductor. The analysis was made for two types of wires: aluminium with steel core and aluminium with composite core, single span of power line. The calculations included 10 different conductor-to-strand coil, wind, icing, and temperature variations. The influence of the conductor temperature on its resistance has not been taken into account.
3. Methodology of research

Overhead lines of high-voltage lines are modelled in the analysis as a tie, evenly distributed over the length of the conductor, for example deadweight, icing, wind and temperature changes or points: extraction isolators, vibration dampers, warning beams. The wire hung on the support structure is a burden on it. Due to the fact that the tie is a stretched element, therefore, only the force of the tension $N$ is influenced by the support, in example its components induced by the above types of loads. In design the necessary size is to determine the correct conductor length as well as overhang lines. The tow will be considered in Figure 5, which has a constant cross section $A$ (mm$^2$), is weighted with its deadweight $g$ (N/m) at length $l_{AB}$ and is suspended between points $A$ and $B$.

Figure 5. The curve of the suspension of the strut perfectly suited

The sequence search of the tension forces starts with finding the equation of the overhang curve (1) describing the course of the tendon in the coordinate system associated with the lowest line point.

$$y = k \cdot \left( \cosh \left( \frac{x}{k} \right) - 1 \right),$$

where: $k = \frac{H}{g}$.

Then the length of the conductor is calculated (2). The coordinates of the suspensions $x_A$ and $x_B$ (3) are

$$l_{AB} = \left( \sinh \left( \frac{x_B}{k} \right) - \sinh \left( \frac{x_A}{k} \right) \right),$$

Obviously only when the conductor is suspended at the same height, if the span is inclined, then the abscissa is offset from the center of the eccentricity $m$ (4).

$$x_A = -0.5 \cdot a + m \quad x_B = 0.5 \cdot a + m ,$$
The second necessary feature in the tendon analysis is the overhang function, describing the distance between the conductor and the chord connecting the suspension points $A$ and $B$, equation (5):

$$f(x) = \frac{b}{a} \cdot (x - x_a) + k \cdot \left[ \cosh \left( \frac{x_a}{k} \right) - \cosh \left( \frac{x}{k} \right) \right].$$

The horizontal component of the tension force $H$ is the most difficult to determine. It is based on the shape of the overhang line $k$ and other parameters necessary in the design. The numerical method of bisecting the conductor described by the chain curve was used in its calculation. This method has been presented in detail and used in the calculations by Z. Mendera [5]. Knowing the horizontal component $H$ and the course of the line $y(x)$ any argument $x$ by the vertical component $V(x)$ can be determined (6) and, consequently, the resultant force $N(x)$ (7) of the geometric relationships.

$$V(x) = H \cdot \sinh \left( \frac{b}{k} \right),$$

$$N(x) = \sqrt{H^2 + V(x)^2}.$$  

In addition to the vertical loads $q_v$ (deadweight, icing) for the tie, there is also a horizontal load $q_h$ (wind) which generates a force $W(x)$.

$$W(x) = 0.5 \cdot q_h \cdot l_{AB}.$$  

The maximum values of $V(x)_{\text{max}}, W(x)_{\text{max}}$ and $N(x)_{\text{max}}$, with $W(x)_{\text{max}}$.

4. Analysis of wires

A 110 kV high voltage line was analyzed in this paper. The span has dimensions: $a = 250$ m (Figure 5), $b = 0$ m. Two types of working conductor were adopted: aluminium and steel AFL – 6 240 mm$^2$ and high temperature of the ACCC. It was assumed that the projected section of the line is located 1 zone of wind load W1 and 2 zone of icing with S2, in the area below 300 m. In addition, the second level of tightening and reliability was assumed. The initial overhang of the conductor in the bays was selected to meet the durability of the conductors. Insulation distances and assembly and maintenance situations have not been checked.

4.1. Basic data

High Voltage Line - basic data:
- span: $a = 250$ m.
- Spall $b = 0$ m.
- Overhead starting at $T = + 10^\circ$C (determined with durability conditions): $f_0 = 6$ m - AFL conductor, $f_0 = 3.5$ m - ACCC.
- Height of working conductor suspension: $z = 21.9$ m.
- Height of lightning conductor: $z = 26.9$ m.

Location - basic data:
- Reliability level: 2.
- Location: Kielce, 272.81 m above sea level (below 300 m above sea level).
- Wind load zone: W1.
- Land category III, terrain factor $k_r = 0.214$, roughness parameter $z_0 = 0.3$.
- Height factor $c_{ALT} = 1.0$, wind speed: $v_{h,0} = 22 \cdot c_{ALT} = 22$ m/s.
- Air density $\rho = 1.25$ kg/m$^3$.
- Ice loading zone: S2, ice density $\rho_{L} = 700$ kg/m$^3$.
- Level of sharpening: II, dirt zone: II.

Phase conductor AFL – 6 240 mm$^2$ - basic material data:
- Rated wire strength of the AFL - 6 240 mm$^2$ tensile $RTS = 84.65$ kN (Nan).
- Modulus of elasticity of aluminium and steel: $E_{AL} = 69$ kN/mm$^2$, $E_{Fe} = 205$ kN/mm$^2$.
- Coefficients of thermal expansion $\alpha$ and $Fe$: $\alpha_{T,AL} = 23 \cdot 10^{-6}$ 1/K, $\alpha_{T,Fe} = 11.5 \cdot 10^{-6}$ 1/K.
• Overall characteristics: diameter $d = 21.7$ mm, cross section $A = A_{Al} + A_{Fe} = 236.1 + 40.08 = 276.2$ mm$^2$, unit weight $m = 977.8$ kg/km (with grease), nominal weight $g_L = 9.6$ N/m, average modulus of elasticity $E = 88.730$ kN/mm$^2$, average coefficient of thermal expansion $\varepsilon_T = 19.14$ 1/K.

Table 1. The values of the impact of icing and wind on working lines

| CONDUCTOR’S TYPE | AFL | ACCC |
|------------------|-----|------|
| **ICING IMPACT** |     |      |
| Extreme icing load | $I_K$ | N/m | 25.994 | 26.07 |
| Nominal icing load | $I_{K,0.37}$ | N/m | 9.62 | 9.65 |
| Equivalent diameter of the icing conductor under extreme icing load $D$ | $D = \sqrt{d^2 + \frac{4 \cdot I_K}{9.81 \cdot \pi \cdot \rho_1}}$ | mm | 72.8 | 72.9 |
| Equivalent diameter of the icing conductor under nominal icing load $D_{0.37}$ | $D_{0.37} = \sqrt{d^2 + \frac{4 \cdot I_{K,0.37}}{9.81 \cdot \pi \cdot \rho_1}}$ | mm | 47.5 | 47.6 |
| Extreme icing load – computational value $I_d$ | $I_d = \gamma_1 \cdot I_K$ | N/m | 32.49 | 32.58 |
| Nominal icing load – computational value $I_{d,0.37}$ | $I_{d,0.37} = 0.37 \cdot I_K$ | N/m | 9.62 | 9.65 |
| **WIND IMPACT** |     |      |
| Extreme wind speed at the height of conductor suspension | $v_h = k_v \cdot \ln \left( \frac{z}{z_0} \right) \cdot v_{h,0}$ | m/s | 20.199 | 20.199 |
| Wind speed pressure at the conductor suspension height | $q_h = \frac{D \cdot v_h^2}{2}$ | N/m$^2$ | 255 | 255 |
| Intensity of turbulence $I_v$ (Orographic factor $c_0 = 1.0$) | $I_v = \left( c_0 \cdot \ln \left( \frac{z}{z_0} \right) \right)^{-\frac{3}{5}}$ | - | 0.233 | 0.233 |
| Peak pressure of wind speed in the gust $q_p$ | $q_p(z) = q_h \cdot (1 + 7 \cdot I_v)$ | N/m$^2$ | 670.91 | 670.91 |
| Span factor $G_C$ | $G_C = 0.6 + \frac{80}{a}$ | - | 0.92 | 0.92 |
| Aerodynamic drag factor $C_C$ | not icy wire | - | 1.0 | 1.0 |
| ice wire | - | 1.1 | 1.1 |
| The angle of wind rake $\phi$ - measured relative to the normal to the conductor | $\phi = 0^\circ$ $\Rightarrow \cos \phi = 1$ | - | 1.0 | 1.0 |

Characteristic values of wind load

| Wind load calculation values |     |      |
| Extreme wind - $w_{d}$ load taken into account in the situation without icing | $w_{d} = q_p \cdot G_C \cdot C_C \cdot d \cdot \cos^2 \phi$ | N/m | 13.39 | 13.45 |
| Unlikely wind – load $w_{d,L}$ ($B^2 = 0.56$) considered in combination with nominal icing | $w_{d,L} = B^2 \cdot q_p \cdot G_C \cdot C_C \cdot D_{0.37} \cdot \cos^2 \phi$ | N/m | 18.06 | 18.1 |
| Very likely wind – load $w_{d,H}$ ($B^2 = 0.33$) considered in combination with extreme icing | $w_{d,H} = \gamma_w \cdot q_p \cdot G_C \cdot C_C \cdot D \cdot \cos^2 \phi$ | N/m | 16.30 | 16.33 |

ACCC phase line - basic material data [6]:

- Rated ACCC tensile strength $RTS = 103.5$ kN (NRK).
- Modulus of elasticity of aluminium and steel: $E_{Al} = 69$ kN/mm$^2$, $E_{komp} = 181$ kN/mm$^2$. 


• Coefficients of thermal expansion $A_l$ and $F_e$: $\varepsilon_{T,A_l} = 23 \times 10^{-6}$ 1/K, $\varepsilon_{T,komp} = 2.3 \times 10^{-6}$ 1/K.

• General characteristics: diameter $d = 21.79$ mm, cross section $A = A_l + A_{komp} = 315.5 + 39.7 = 355.2$ mm$^2$, $m = 946.7$ kg/km unit weight (with grease), nominal weight $g_k = 9.29$ N/m, average modulus of elasticity $E = 81.518$ kN/mm$^2$, average coefficient of thermal expansion $\varepsilon_T = 17.86$ 1/K.

4.2. The determination of tension force influence on conductors

Values derived from deadweight, icing, wind and temperature were calculated according to PN - EN 50341-2-22-2016[6]. Two combinations of icing and winding ($P_{3a}$ and $P_{3b}$) should be considered in the conductor calculation. In the situation of the combined effect of icing and wind, it is necessary to determine the replacement diameter $D$ of the icy pipe.

4.3. Cases of impact systems

Based on characteristic and computational load values, the load components of 1 m cable length will be determined under various operating conditions, vertical components $q_v$, horizontal components $q_h$ and $q_{tot}$ accidents. Conductors cases have been designated according to standard [6] and table. 3.8 [5] and is shown in Table 2. The wind effect in $P_1$, $P_{3a}$, $P_{3b}$ cases was analysed for three different directions of operation: perpendicular to the line direction, parallel to the line direction and to the line direction perpendicular to the span, the remaining directions are considered only for the supporting structures.

### Table 2. List of cases of conductor systems [5].

| Case interactions | Deadweight | Temperature $T_X$, °C | Icing | Wind |
|-------------------|------------|-----------------------|-------|------|
| Initial state of the conductor – conductors suspension determination | | | | |
| $P_0$ | 1.0 | +10 | none | none |
| Cases for conductors used in conductors and poles | | | | |
| $P_1$ | 1.0 | +10 | none | 1.0 |
| $P_{3a}$ | 1.0 | -5 | 1.0 | none |
| $P_{3b}$ | 1.0 | -5 | 1.0 | $\psi_w = 0.33$ |
| $P_{3b}$ | 1.0 | -25 | 1.0 | $\psi_t = 0.37$ |

The resultant $q_{tot}$ loads determined for the conductors are necessary to determine the tension and overhang of the conductors under different atmospheric conditions. As the initial state, the load was assumed only by the weight of the conductor suspended at +10°C. Table 3 a), b) summarizes the effect values for AFL-6 240 mm$^2$ phase conductors and ACCC.

### Table 3a. Values of interactions on phases conductors AFL-6 240 mm$^2$ and ACCC.

| Conductor type | AFL-6 240 mm$^2$ | ACCC |
|----------------|-----------------|------|
| Case $P_0$ (deadweight of the conductor at the mounting temperature $T_{0}=+10^\circ$C) | | |
| Vertical load: | $q_v$ N/m | 9.60 | 9.29 |
| Case $P_1$ (temperature $T_{v}=+10^\circ$C + maximum wind (1.0)) | | | |
| Deadweight: | $g_k$ N/m | 9.60 | 9.29 |
| Wind load: | $w_{cd}$ N/m | 16.07 | 16.14 |
| Vertical load: | $q_v$ N/m | 9.60 | 9.29 |
| Horizontal wind: | $q_h$ N/m | 16.07 | 16.14 |
| Resultant load (diagonal): | $q_{tot}$ N/m | 18.72 | 18.62 |
| Case $P_{3a}$ (deadweight + extreme icing (1.0) + temperature $T_{i}=-5^\circ$C) | | | |
| Deadweight: | $g_k$ N/m | 9.60 | 9.29 |
Table 3b. Values of interactions on phases conductors AFL-6 240 mm² and ACCC.

| Conductor type | AFL-6 240 mm² | ACCC |
|----------------|--------------|------|
| Icing load: | | |
| Vertical load: | | |
| Resultant load (horizontal): | | |
| Temperature change: | | |

Case P₀ₐ (deadweight + extreme icing (1.0) + very likely wind (0.33) + temperature T₁=-5°C)

| Load | gₑ | N/m | 9.60 | 9.29 |
|------|----|-----|------|------|
| Vertical load: | | |
| Horizontal wind: | | |
| Resultant load (diagonal): | | |
| Temperature change: | | |

Case P₀₆ (deadweight + nominal icing (0.37) + unlikely wind(0.56) + temperature T₁=-5°C)

| Load | gₑ | N/m | 9.60 | 9.29 |
|------|----|-----|------|------|
| Vertical load: | | |
| Horizontal wind: | | |
| Resultant load (diagonal): | | |
| Temperature change: | | |

Case P₄ (deadweight + temperature T₁=-25°C without wind and icing)

| Load | gₑ | N/m | 9.60 | 9.29 |
|------|----|-----|------|------|
| Vertical load: | | |
| Temperature change: | | |

The calculation values for the bender method for determining the tension and overhang lines are given in Table 4a and 4b.

Table 4a. Values of interactions on phases conductors AFL-6 240 mm².

| Calculation case | Deadweight | Temperature | Ice | Wind |
|------------------|------------|-------------|-----|------|
| | gₑ | N/m | ΔT | °C | Iₑ,i,0.5 | wₑ | qₑ | N/m | qₑ | N/m | qₑ | N/m |
| P₀ | 9.60 | 0 | 0.00 | 0.00 | 9.60 | 0.00 | 9.60 |
| P₁ | 9.60 | 0 | 0.00 | 16.07 | 9.60 | 16.07 | 18.72 |
| P₃ (φ = 45°) | 9.60 | 0 | 0.00 | 8.04 | 9.60 | 8.04 | 12.52 |
| P₃ (φ = 0°) | 9.60 | -15 | 32.49 | 0.00 | 42.09 | 0.00 | 42.09 |
| Analogical case to P₀ | | | | | | |
| P₂₀ | 9.60 | -15 | 32.49 | 16.30 | 42.09 | 16.30 | 51.64 |
| P₃₀ (φ = 45°) | 9.60 | -15 | 32.49 | 8.15 | 42.09 | 8.15 | 42.87 |
| Analogical case to P₂₀ | | | | | | |
| P₃₀ (φ = 0°) | 9.60 | -15 | 32.49 | 0.00 | 9.60 | 0.00 | 9.60 |
| P₀₆ | 9.60 | -15 | 9.62 | 21.67 | 19.22 | 21.67 | 28.97 |
| P₂₆ (φ = 45°) | 9.60 | -15 | 9.62 | 10.84 | 19.22 | 10.84 | 22.07 |
| P₃₆ (φ = 0°) | 9.60 | -15 | 9.62 | 0.00 | 19.22 | 0.00 | 19.22 |
| P₄ | 9.60 | -15 | 0.00 | 0.00 | 9.60 | 0.00 | 9.60 |
Table 4b. Values of interactions on phases conductors ACCC.

| Calculation case | Deadweight | Temperature | Ice | Wind | Load |
|------------------|------------|-------------|-----|------|------|
|                  |            |            |     |      | Vertical | Horizontal | Resultant |
|                  | $q_v$ | $\Delta T$ | $I_{x,y,z}$ | $w_c$ | $q_v$ | $q_a$ | $q_{tot}$ |
| $P_0$            | 9.29      | 0          | 0.00 | 0.00 | 9.29 | 0.00 | 9.29 |
| $P_1$            | 9.29      | 0          | 0.00 | 16.14 | 9.29 | 16.07 | 18.72 |
| $P_1 (\phi = 45^\circ)$ | 9.29 | 0          | 0.00 | 8.07  | 9.29 | 8.04  | 12.52 |
| $P_1 (\phi = 0^\circ)$ | Analogical case to $P_0$ |
| $P_{2a}$         | 9.29      | -15        | 32.49 | 0.00 | 41.88 | 0.00 | 42.09 |
| $P_{2a}$         | 9.29      | -15        | 32.49 | 16.33 | 41.88 | 16.33 | 51.64 |
| $P_{3a} (\phi = 45^\circ)$ | 9.29 | -15 | 32.49 | 8.16  | 41.88 | 8.16  | 42.87 |
| $P_{3a} (\phi = 0^\circ)$ | Analogical case to $P_{2a}$ |
| $P_{3a}$         | 9.29      | -15        | 9.62  | 21.72 | 19.84 | 21.72 | 28.97 |
| $P_{3b}$         | 9.29      | -15        | 9.62  | 10.86 | 19.84 | 10.86 | 22.07 |
| $P_{3b} (\phi = 45^\circ)$ | 9.29 | -15 | 9.62 | 0.00  | 19.84 | 0.00  | 19.84 |
| $P_{3b} (\phi = 0^\circ)$ | Analogical case to $P_{3a}$ |
| $P_4$            | 9.29      | -15        | 0.00  | 0.00  | 9.29 | 0.00 | 9.29 |

5. Results and discussions

5.1. Equation states

For each phase conductor, from the equation of states solved using the bisection method, the values of the tension force, the conduction force on the posts and the shape of the overhang line were determined for 12 different load cases. For the analysis of the line overhang, the chain curve equation was used. For the calculation of the aforementioned size was written by the co-author of M. Pawlak program in Mathematica. The results are summarized in Table 5 for AFL and ACCC:

Table 5. State equations for phase conductor AFL-6 240 mm² and ACCC.

| Conductor types | Working conductor AFL-6 240 mm² | Working conductor ACCC |
|-----------------|--------------------------------|-----------------------|
|                  | $P_1$ | $P_{2a}$ | $P_{3a}$ | $P_{3b}$ | $P_4$ | $P_1$ | $P_{2a}$ | $P_{3a}$ | $P_{3b}$ | $P_4$ |
| Interactions values | $g_v$ N/m | 9.60 | 9.60 | 9.60 | 9.60 | 9.60 | 9.29 | 9.29 | 9.29 | 9.29 |
|                  | $\Delta T$ °C | 0 | -15 | -15 | -15 | -35 | 0 | -15 | -15 | -35 |
|                  | $I$ N/m | 0.00 | 32.49 | 32.49 | 9.62 | 0.00 | 0.00 | 32.58 | 32.58 | 9.65 | 0.00 |
|                  | $w_c$ N/m | 16.07 | 0.00 | 16.30 | 21.67 | 0.00 | 16.14 | 0.00 | 16.33 | 21.72 | 0.00 |
|                  | $q_v$ N/m | 9.60 | 42.09 | 42.09 | 19.22 | 9.60 | 9.29 | 41.87 | 41.87 | 18.94 | 9.29 |
|                  | $q_a$ N/m | 16.07 | 0.00 | 16.30 | 21.67 | 0.00 | 16.14 | 0.00 | 16.33 | 21.72 | 0.00 |
|                  | $q_{tot}$ N/m | 18.72 | 42.09 | 45.14 | 28.96 | 9.60 | 18.62 | 41.87 | 44.95 | 28.81 | 9.29 |
| Bisecting solution | $k$ m | 1121 | 1022 | 1004 | 1123 | 1622 | 1602 | 1333 | 1296 | 1551 | 3300 |
|                  | $m$ m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
|                  | $I_{xy}$ m | 250.52 | 250.62 | 250.65 | 250.52 | 250.25 | 250.25 | 250.37 | 250.39 | 250.27 | 250.06 |
| Tension forces (components and resultant) | $H$ kN | 20.99 | 43.03 | 45.30 | 32.54 | 15.58 | 29.83 | 55.81 | 58.26 | 44.70 | 30.65 |
|                  | $V_{max}$ kN | 1.20 | 5.27 | 5.28 | 2.41 | 1.20 | 1.16 | 5.24 | 5.24 | 2.37 | 1.16 |
|                  | $W_{max}$ kN | 2.01 | 0.00 | 2.04 | 2.71 | 0.00 | 2.02 | 0.00 | 2.04 | 2.72 | 0.00 |
|                  | $N_{max}$ kN | 21.22 | 43.35 | 45.70 | 32.85 | 15.63 | 29.99 | 56.06 | 58.56 | 44.93 | 30.68 |
| Maximum conductor overhang in the plane of the V and W resultant forces | $f_{max}$ m | 6.97 | 7.65 | 7.79 | 6.96 | 4.82 | 4.88 | 5.86 | 6.03 | 5.04 | 2.37 |
5.2. The weld strength calculations
The weld strength calculations were performed for all 5 cases defined in Table 1 according to standard [8]. The control of the limit-load capacity of the analysed cables was carried out for the tension forces given in Table 6 in accordance with formula (9),

\[ \frac{N_{\text{ed, max}}}{N_{\text{Rd}}} \leq 1, \]  

where:

\[ N_{\text{Rd}} = \frac{\text{RTS}}{\gamma_{\text{MC}}}. \]  

\( \gamma_{\text{MC}} \) - (partial safety factor) for II case of tightening [6].

| Table 6. Checking of the conductor capacity limits. |
|---------------------------------------------------|
| Conductor type | Working wire AFL-6 240 mm² | Working wire ACCC |
| Calculation case | \( P_1 \) | \( P_{2a} \) | \( P_{3a} \) | \( P_{3b} \) | \( P_4 \) | \( P_1 \) | \( P_{2a} \) | \( P_{3a} \) | \( P_{3b} \) | \( P_4 \) |
| \( N_{\text{ed, max}} \) kN | 21.22 | 43.35 | 45.70 | 32.85 | 15.63 | 29.99 | 56.06 | 58.56 | 44.93 | 30.68 |
| \( \gamma_{\text{MC}} \) | 1.25 | 1.82 | 1.25 | 1.25 | 2.50 | 1.25 | 1.82 | 1.25 | 1.25 | 2.50 |
| \( N_{\text{Rd}} \) kN | 67.72 | 46.51 | 67.72 | 67.72 | 33.86 | 82.8 | 56.87 | 82.8 | 82.8 | 41.4 |
| Checking of the conductor capacity limits | \( N_{\text{ed, max}} / N_{\text{Rd}} \) | 0.313 | 0.932 | 0.675 | 0.485 | 0.462 | 0.362 | 0.986 | 0.707 | 0.542 | 0.741 |

6. Conclusions
The cable analysis carried out at work shows that:
- the material from which the conductor is built has a small (approx. 0.2%) impact on the length of the \( L_{\text{AB}} \),
- The tension of \( N(x) \) is smaller for the AFL than for the ACCC, resulting in less impact on the support structure,
- The maximum overhang \( f_{\text{max}} \) is smaller for ACCC than for AFL,
- The larger security supply has an AFL cable.

From the point of view of the conductor’s mechanics and supporting structures, it is more advantageous to use such conductors in overhead high voltage lines of standard aluminium conductors. However, considering the high demand for electricity and the reduction of transmission losses, the use of high temperature conductors should be considered.

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