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COMPUTATION OF SAG AND TENSION IN MEDIUM-VOLTAGE AERIAL BUNDLED CONDUCTOR (MV ABC) USING MICROSOFT EXCEL

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Abstract: *This study presents an applied methodology for calculating the sag and tension of medium-voltage self-supporting cable bundles (SN-SKS) using Microsoft Excel. Based on input parameters – voltage, cross-sectional area, additional load coefficient, suspension height on the pole, horizontal span between poles, temperature, and maximum allowable conductor stress – Excel automatically calculates the sag length and tension force. The results are visually presented on a separate chart sheet, allowing dynamic analysis of different scenarios. The study demonstrates that this approach enables quick verification of design solutions, optimization of the cable system design, and assessment of cable bundle safety under various operating conditions.*
Keywords: medium-voltage cable bundle, sag, tension, Microsoft Excel and applied analysis.

1. INTRODUCTION

Contemporary life, accompanied by rapid technological advances, brings new challenges to the application of computing across various fields of science and engineering. In power systems engineering, the use of computers has become an indispensable component of system design and operation. Their application enables more efficient planning, analysis, and control of complex power networks.

Computer support in this area is particularly important for several key activities:

- development of design concepts.
- preparation of technical and graphical documentation.
- management and monitoring of project execution.
- implementation of standardized procedures in real-world power systems.

In this way, computer-aided design contributes to greater accuracy, reliability, and efficiency in the operation of power systems, thereby significantly improving the quality of the engineered solutions.

Modern engineers employ software tools such as Microsoft Excel for rapid, accurate calculations that enable analysis of different parameter combinations. This paper presents an approach that, based on the input data—

- voltage level,
- cross-sectional area of the MV ABC (self-supporting bundled conductor),
- additional load factor,
- attachment height of the MV ABC on the pole,
- horizontal span length,
- temperature, and
- maximum allowable tension in the MV ABC—

automatically computes the conductor sag and tensile force. The resulting values are

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plotted as a chart on a dedicated worksheet in Excel.

2. PROGRAM DEVELOPMENT

The development of a Microsoft Excel–based computational tool for calculating sag and tensile stress in a medium-voltage aerial bundled cable (MV ABC; srp. SN-SKS) is founded on defining input parameters, formulating the governing mathematical relations, and creating visual representations of the results.

2.1 INPUT PARAMETERS DEFINITIONS

In the first development phase, a worksheet named” Proračun” (Calculation) is created in Microsoft Excel, where the user enters the parameters shown in Figure 1.

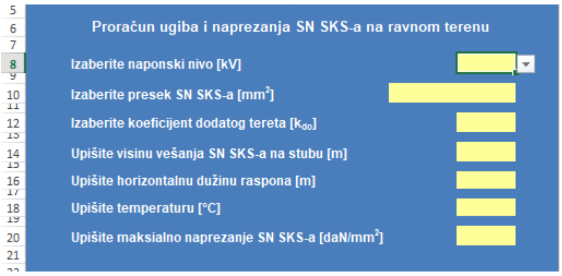

Figure 1. Input fields for entering the calculation parameters

To ensure a straightforward and readable data entry process, the first three parameters—voltage level, MV ABC cross-section, and additional load factor—are selected from drop-down lists.

All remaining parameters are entered as free-form numeric values. This approach provides sufficient flexibility for the tool to be applicable across a wide range of scenarios, while maintaining control over the key parameters.

The drop-down lists are created using the Data Validation feature, with a predefined set of allowable values. Figure 2 shows an example in which the voltage level of the MV ABC is specified.

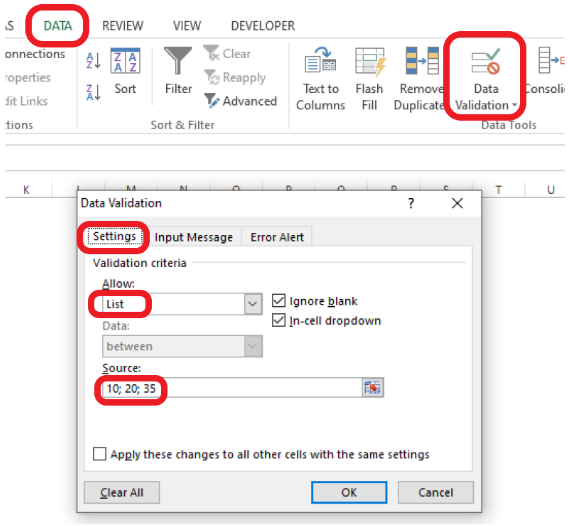

Figure 2. Data validation

This ensures that only standardized, permissible values are used, thereby reducing the likelihood of error.

2.2 FORMULATION OF THE COMPUTATION

For calculating sag and tensile force in medium-voltage aerial bundled conductors (SN-SKS / MV ABC), dedicated Excel worksheets were created containing the physical properties of cables for the voltage levels 10 kV, 20 kV, and 35 kV. Each worksheet provides a table of key parameters required for accurate calculations.

These tables serve as reference data that are automatically linked to the formulas on the calculation worksheet corresponding to the selected voltage level. The user selects the cable’s voltage level, and Excel automatically loads the appropriate physical characteristics from the respective worksheet (“10 kV,” “20 kV,” or “35 kV”).

Based on these data, the program computes the sag magnitude and tensile force for the specified span length and conductor height above ground, while accounting for additional loading and temperature conditions.

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Table 1. Physical properties of the MV ABC type XHE 48/O-A (10 kV) and the standard additional load (icing)

Fizička svojstva SN SKS-a tipa XHE 48/O-A, 10 kV i normalno dodato opterećenje (obled) - tabela 6.6.v iz TP 10b				
Naznačeni presek SN SKS-a, S_n [mm^2]		3x(1x50)+50	3x(1x70)+50	3x(1x95)+50
Materijal i presek za noseće uže		č 50	č 50	č 50
Ukupan presek nosećeg užeta, S_u [mm^2]		48,32	48,32	48,32
Spoljašnji prečnik nosećeg užeta, d_{unu} [mm]		9	9	9
Računska silakidanja nosećeg užeta, F_{ku} [daN]		6013	6013	6013
Temperaturni koeficijent linearnig širenja nosećeg užeta, α_u [10-6/°C]		11	11	11
Modul elesticnosti nosećeg užeta, E_u [daN/mm2]		17500	17500	17500
Ukupan prečnik (ceo snop), d_u [mm]		58	62	66
Podužna masa SN SKS-a (ceo snop), G_u [kg/m]		2,25	2,57	2,89
Specifična masa SN SKS-a, $\gamma_u = G_u / S_u$ [daN/m·mm^2]		0,0466	0,0532	0,0598
	k_{do} = 1	1,3708	1,4173	1,4623
Normalno dodato opterećenje, N_{do} [daN/m]	k_{do} = 1,6	2,1933	2,2677	2,3397
$N_{do} = k_{do} \cdot 0{,}18 \cdot \sqrt{d_u}$	k_{do} = 2,5	3,4271	3,5433	3,6558
	k_{do} = 4	5,4834	5,6693	5,8493
	k_{do} = 1	0,0749	0,0825	0,0901
Specifična masa SN SKS-a sa dodatim opterećenjem, γ_{du} [daN/mm^2]	k_{do} = 1,6	0,0920	0,1001	0,1082
$\gamma_{du} = \gamma_u + N_{do} / S_u$	k_{do} = 2,5	0,1175	0,1265	0,1355
	k_{do} = 4	0,1600	0,1705	0,1809

Proračun | Grafik | 10 kV | 20 kV | 35 kV | Funkcije

In determining the conductor tension as a function of operating temperature, the conductor state equation is employed. This equation links the fundamental mechanical and thermal parameters of the conductors, such as initial tension, span length, thermal expansion and elastic modulus.

From the state equation, the tension values are obtained for different operating regimes and climatic conditions (e.g., nominal temperature, elevated temperature, additional loading due to wind or icing). The resulting calculations provide the basis for selecting conductor dimensions and specifying their permissible tension limits under real operating conditions.

To obtain an accurate solution of the conductor state equation, a numerical iterative method was used. In this case, the Newton–Raphson method was applied, enabling rapid root-finding of $f(x)$and thus the conductor tension corresponding to a given temperature.

The following data are shown in Table 2. for each iteration:

- x— the initial guess or the newly computed value of the unknown.
- $f(x)$— the function value at the chosen x;
- $f'(x)$— the first derivative of the function at x;
- **New** $x = x - \frac{f(x)}{f'(x)}$— the correction of the previous value according to the algorithm.

Table 2. Application of the Newton–Raphson method to solve the conductor state equation.

x	f(x)	f'(x)	Nova x=x-(f(x)/f'(x))
20,000	3465,000	1733,035	18,001
18,001	285,130	1451,815	17,804
17,804	2,589	1425,485	17,802
17,802	0,000	1425,242	17,802
17,802	0,000	1425,242	17,802
17,802	0,000	1425,242	17,802
17,802	0,000	1425,242	17,802
17,802	0,000	1425,242	17,802
17,802	0,000	1425,242	17,802
17,802	0,000	1425,242	17,802

From the table, it can be observed that the initial value $x = 20.000$ converges over several iterations to $x = 17.802$, which represents the desired solution of the state equation. The obtained value corresponds to the mechanical tension in the conductor for the specified temperature and loading parameters.

Table 3. X-values for plotting the conductor sag curve

x	f(x)
-20	9,00
-18	8,80
-16	8,63
-14	8,47
-12	8,34
-10	8,23
-8	8,13
-6	8,06
-4	8,01
-2	7,98
0	7,97
2	7,98
4	8,01
6	8,06
8	8,13
10	8,23
12	8,34
14	8,47
16	8,63
18	8,80
20	9,00

On the same worksheet, “Functions”, Table 3. presents the distribution of conductor sag as a function of thae position (x) along the span. The (x) column ranges from (-20) to (+20), while the (f(x)) column

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gives the corresponding sag values in meters. Based on these data, a symmetric sag curve can be constructed: the minimum sag in the middle of the span (x = 0), and the values increase toward the span ends (x = -20) and (x = 20)). This representation enables a graphical interpretation of conductor deformation under operating conditions.

2.3 RESULTS GENERATION AND VISUALIZATION

Based on the previously entered parameters and the computations carried out in the Excel environment, all results required for the final analysis of sag and tensile force in SN-SKS/MV ABC conductors are obtained. The program automatically produces the numerical outputs, which are clearly shown in Figure 3, and then uses the same values for the graphical representation.

Figure 3. Excel-based tool for calculating sag and tensile force of the MV ABC (SN-SKS).

The graphical output in Figure 4. enables a visual interpretation of the relationship between operating temperature, tensile stress, and sag, highlighting critical points along the span. In this way, engineers are provided with a reliable tool for assessing the stability and safety of the MV ABC (SN-SKS) and for selecting optimal design parameters. The user receives not only numerical results but also a graphical representation that facilitates a deeper understanding of the MV ABC conductor's behavior under varying operating conditions.

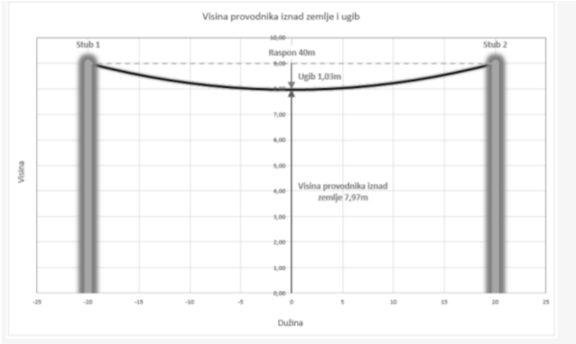

Figure 4. Sag curve and conductor height above ground (clearance).

2.4 VBA MACRO FUNCTIONALITY IN THE TOOL

To streamline use of the developed Excel application, VBA macros were implemented to automate the most frequently performed tasks. On the main calculation worksheet, control buttons are provided for straightforward user operation, as shown in Figure 5.

Figure 5. Control buttons for simplified operation.

- **Chart** — pressing this button opens a dedicated worksheet **"Grafik"**, where the sag–tension diagram is generated automatically from the previously entered data. This provides a visual display of the results without any additional manual setup.
- **Clear** — this button deletes all initially entered parameters from the worksheet, returning the tool to its initial state and enabling entry of new data for the next calculation.

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This significantly speeds up the analysis and prevents errors that could arise from leaving stale inputs in place.

- **Save** — clicking this button automatically creates a file saved to the user's Desktop, named

  "**Proračun**" with the current date appended. This facilitates archiving and later review of completed calculations.
- **Print** — pressing this button activates **Print Preview**, displaying a document ready for printing. The user can review and then print the complete calculation with all entered parameters and results.

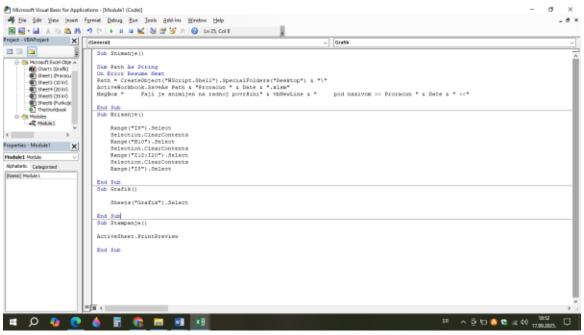

Figure 6. Implemented VBA macros.

Through the implementation of these VBA macros, the tool attains a high degree of automation and an intuitive workflow in Excel. Users do not need to understand advanced Excel functions or VBA programming; the clearly labeled buttons are sufficient. This substantially enhances the practical value of the tool and its applicability in engineering practice.

3. CONCLUSION

The calculation of sag and tension in medium-voltage aerial bundled conductors (MV ABC; SN-SKS) is a critical aspect of designing and operating overhead power lines. Accuracy directly affects safety, reliability, and service life: excessive sag or impermissible tension can damage insulation and lead to supply interruptions.

This paper demonstrates how all required computations can be performed in Microsoft Excel by applying the conductor state equation together with numerical methods. Emphasis is placed on the use of the Newton–Raphson method to solve the nonlinear equation, enabling rapid and accurate determination of conductor tension as a function of temperature and additional loading.

Beyond basic tabulation, Excel proves to be a viable platform for complex engineering analyses. Automation via VBA macros further streamlines the workflow, allowing users to generate plots, save files, clear inputs, and print results with minimal effort. The result is a fast and intuitive process.

The graphical representation of sag provides clear insight into conductor ground clearance under varying temperatures and tensile forces. This visualization helps identify critical points and validates the computation, which is essential for both design and operation.

In conclusion, although often perceived as a simple tool, Excel can fully support sophisticated calculations in power engineering and offers valuable assistance to engineers and students alike. The presented methodology is applicable to multiple voltage levels (10 kV, 20 kV, 35 kV) and forms a solid foundation for further enhancements, such as integration with databases and relevant standards.

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