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Research paper

Fast design of the UMKW support structures for overhead power lines

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Abstract: Temporary support structures (UMKW) for power lines are used in emergency situations. Such system-based solutions require dedicated software that enables rapid design (model creation, calculations, and documentation generation). Achieving this goal involves adopting a data structure that minimizes the amount of input required from the designer while maximizing automation in each phase of the design process. This is made possible through the creation of a database of predefined and parameterized profiles for support structures. Design acceleration is enhanced by an advisory system that suggests and supervises the configuration of conductor suspension layouts, structure geometry (while maintaining electrical clearance requirements, both internal and external), structure height, etc. The declaration of load cases and their values is also fully automated. Based on data regarding conductors and insulators (retrieved from databases) and the line location within Poland territory (climatic zones), an analysis of conductors (cables) is performed, and all load cases required by standards, including variations leading to bending and torsion of support structures, are determined. The article presents two software variants differing in concept. The first variant involves a preliminary selection of structure imported from a database of pre-analyzed typical cases (UMKW-Base), while the second performs complete calculations (UMKW). The UMKW software system employs a dual data input module, enabling rapid design while achieving greater software versatility. Declaring the physical model of the structure and its automatic conversion to an analytical model allows structural calculations to be performed as well as preparation of design documentation without duplicate data entry.

Keywords: automated design, automated structure modeling, guyed towers, overhead power lines, software, temporary supporting structures

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1. Introduction

Electricity supply is classified by the Government Centre for Security as a priority element of the Critical Infrastructure System. Its continuous operation and the ability to restore in the shortest possible time are crucial for the reliability of a system [1]. A comprehensive review of the literature addressing various factors influencing the restoration of power line functionality has been provided in the publications [2, 3]. The importance of time is evidenced by commonly used reliability indices in the energy sector that define the duration (SAIDI) and frequency (SAIFI) of power supply interruptions [4, 5].

The basic elements of the power supply system are various types of structures, such as distribution gates and transmission towers. The diversity of towers makes it impossible to rely on identical structures for emergency situations, which could be directly replaced. An alternative are systems known as ERS (Emergency Restoration Systems) [6, 7], which must be characterized by versatility and the ability to be quickly deployed.

The pursuit of versatility and assembly considerations lead to ERS systems being designed as modular components used to build masts supported by guy wires. The use of guyed structures in power line supports has a long history, dating back to the 1930s [8, 9]. The use of guyed structures in power line temporary structures is dating back to the 1960s [10]. The most widely known systems [11] are the Lindsey (USA) [12] and SBB (Canada) [13], in which lattice modules are made of aluminum [14].

In many countries power lines are designed with use of the powerful PLS-CADD software [15]. Despite the popularity of PLS-CADD, companies offering ERS systems develop their own software specifically for selecting suitable structures. An example is ProSpot [16], a program offered by Lindsey Systems. Such specialized tools simplify the design of a given ERS system, contributing to its widespread adoption. However, it is important to note that this software is tailored to a specific ERS system, and to take full advantage of its features, the design principles applicable in the country where the system will be used must be implemented within it. It is worth noting that the principles of mast design vary greatly [17].

In recent years, with the growing trend of automating the design, construction and maintenance of building structures, BIM (Building Information Modeling) [18] has been gaining widespread popularity. Although primarily focused on buildings and structures, efforts are being made to standardize and extend the data structure to include information related to power infrastructure [19]. A key role is played by data management through the use of the Common Data Environment (CDE) platform and the extension of the IFC (*Industry Foundation Classes*) data format for power infrastructure objects [20].

This article presents our own experiences in developing specialized software for designing modular temporary support structures of the UMKW system. The limited functionality of the program prompted the use of a proprietary data format that represents the physical characteristics of structures and components of the line (physical model), with the ability to convert it into an analytical or drawing models. A well-designed data structure and software organization streamline the design process.

2. Brief characteristics of the UMKW system

The UMKW (Universal Modular Support Structures) system was developed as a comprehensive solution for the construction of energy infrastructure, including transmission and distribution supports. The main components of the system are three types of modules in the form of prefabricated spatial lattice steel elements with a cross-section of 0.5×0.5 m and lengths of 1M, 3M, or 6M, where M is the modular dimension of 0.5 m. The 3M and 6M modules are used to construct guyed towers and frames (Fig. 1). The 1M cubic module, which unlike the other two modules, is densely built, with only two of its six sides being open. It is used to form junctions (e.g., the connection between the beam and the columns), as well as to mount attach insulators. The system is also equipped with connecting elements for securing guy wires, insulators and ground anchors. All components are connected using bolts, creating support structures with an overall height of up to 50 m.

Fig. 1. An example of a frame made from UMKW system modules

The system's versatility, achieved while minimizing the number of modules and accounting for the wide variety of support structures used in power lines, led to the adoption of designs with guy-wire supports. This approach enables the creation of structures with different functions, heights, conductor arrangements, and load capacities tailored to withstand environmental forces in various wind and ice zones.

3. Why develop the own software for fast design?

The requirements for ERS systems are typically focused on three critical elements [1]: planning, emergency materials, and training. Planning includes assessing the importance of the line, gathering information about existing structures and determining the restoration method in case of line damage. Emergency materials involve maintaining readiness with, among other things, an adequate supply of guy wires and modules for constructing temporary structures. The third element pertains to a skilled workforce with experience in building temporary line segments, including towers installation techniques, wire tensioning, and anchoring with guy wires.

In addition to the aforementioned elements, a fourth can be identified: software designed to enable the rapid selection or design of supporting structures. The concept of developing software dedicated to designing a relatively narrow group of structures has practical justification. The following aspects highlight the specific nature of the issue, underscoring the need for a system to automate the design process:

- the need to minimize design time,
- the multidisciplinary nature of the issue,
- consideration of specific design principles for supporting structures,
- adaptation to national conditions due to the diversity of regulations in countries applying the EN 50341 standards [21–24].

The primary goal is to reduce design time, as the UMKW system is intended for creating temporary structures, including their use in emergencies. The time between a power line segment failure and its restoration should be minimized due to the severe and costly consequences of power supply interruptions. Therefore, a high level of automation is expected in the design and component assembly processes.

The second premise is the multidisciplinary nature of the issue. The software must integrate electrical requirements (such as selecting conductors, insulators, and maintaining electrical clearances) with structural considerations (including the configuration of the supporting structures and the ability to perform static and strength calculations).

Another premise is the dedicated set of standards for designing power lines (published by the independent standardization organization CENELEC), which is separate from the Eurocodes publisher (CEN). The distinct nature of designing power line structures relates both to safety and reliability principles and to the creation of load cases and combinations of actions, as well as the determination of the action values themselves. Even in the area of dimensioning steel structural elements, CENELEC standards propose separate principles that slightly differ from those in Eurocode 3.

Eurocode 0 is explicitly excluded as a source of principles for ensuring the safety of supporting structures. In power line design, the predominant actions come from the conductors and accessories, primarily resulting from environmental conditions (temperature changes, wind, and ice loading). Additionally, the method of determining climatic load values significantly differs from the principles defined in the various parts of Eurocode 1. In Poland, the approach used to determine the values of actions is partly empirical, meaning that previously applied rules are adapted, with the assumption that many years of their use confirm their validity. This primarily applies to determining ice loading on conductors. Only some elements of the approach are general and mainly concern wind actions. Even here, the rules differ slightly from those in EN 1991-1-4.

The challenges mentioned above contribute to the difficulties encountered in automating the design process. It is necessary to use several different programs and transfer results between them. In the widely used American power line design system, PLS-CADD [15], the principles for determining actions specific to Poland are not implemented.

4. Software for design UMKW support structures

4.1. Alternative versions of the software

The design of temporary supporting structures includes tasks such as performing full static and strength calculations (including conductors analysis) and partially preparing project documentation (includes, among other things, a complete list of materials necessary for the assembly of the structure and partial drawing documentation).

There are two different versions, with only the second one currently being developed. They are as follows (software name in parentheses):

– Version 1 (UMKW-Base): Software designed for browsing a database of previously calculated supporting structures, facilitating the selection of a structure that meets user-defined requirements.
– Version 2 (UMKW): Software system equipped with modules for free data generation and visualization, calculation modules (for conductors and supporting structures), and modules for visualizing results and preparing project documentation.

4.2. Software version 1 – UMKW-Base

Approximately 300 of the simplest single-shaft masts have been preliminarily analyzed. Several parameters characterizing the line and the supporting structure were varied (variable parameters), while others were treated as fixed (constant parameters). The variable parameters were:

– function of the power line support (suspension, angle-suspension, angle-tension or dead-end),
– total height of the structure,
– height of the lowest conductor suspension,
– spans of the line sections adjacent to the mast,
– deflection angle of the route direction.

The diverse combinations of these few parameters result in an innumerable number of configurations. 300 of them were selected for which full calculations were performed and a database was created. All the preliminary configurations were adjusted for use in 110 kV power lines. In the analyses, the constant parameters were: the type of conductors (phase AFL-6 240 mm^2, earth wires AFL-1.7 70 mm^2) and their initial tension (σ = 100/165 MPa for phase/earth wire conductors, respectively), the type of insulators (adapted to the support function), the shape of the support head (vertical conductor suspension layout and the distance between them), wind and icing zones, levelled or slightly sloped conductor span (the coefficient for the weight span was 1.20), and the design standard (EN 50341-2-22:2010 [22]). Only the most significant constant parameters were listed above.

Each of these supporting structures has been calculated, taking into account the combinations of actions defined in the standard [22]. For each structure, a guying system (with assumed pre-tension forces) has been selected, ensuring compliance with the ULS and SLS conditions. In emergency situations, the selection of the UMKW system structure involves the user entering a list of data regarding the aforementioned variable parameters (the program interface is shown in Fig. 2). The UMKW-Base software searches the database and identifies one mast with characteristics that ensure compliance with the user-defined requirements. The variable parameters used as selection criteria are:

– height of the lowest conductor suspension: $h_{\text{con}} \le h_{\text{con,db}}$,
– span of the longer power line span: $\max(L_1, L_2) \ge \max(L_{1,\text{db}}, L_{2,\text{db}})$,
– difference in span lengths: $\Delta L = L_{\max} - L_{\min} \ge \Delta L_{\text{db}} = L_{\max,\text{db}} - L_{\min,\text{db}}$,
– angle of deflection of the route from the straight line: $\gamma \ge \gamma_{\text{db}}$.

The index “db” in the above symbols indicates the parameters selected from the database records.

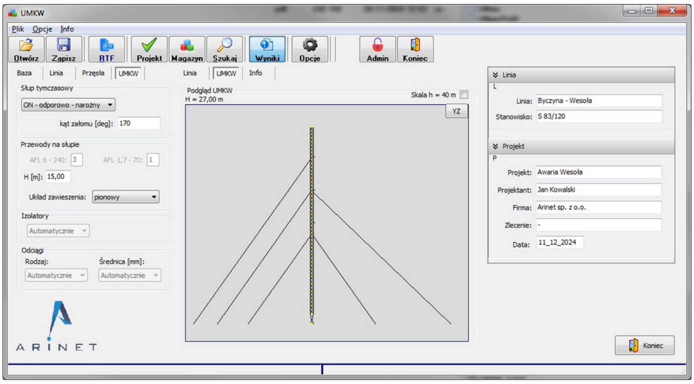


Fig. 2. UMKW-Base interface for selecting a structure from the database

The use of selected structure is limited by the adherence to all the previously listed constant parameters. A single record in the database contains over 100 fields with information about the structure itself (e.g., module arrangement, placement and pre-tensioning of the guys) as well as selected calculation results (such as minimum and maximum forces in the guys, maximum stress in the angle sections, etc.). Based on the information from the database, documentation can be generated in the form of a materials list in rich text format (*rtf*) and a sketch of the structure, saved in the popular drawing exchange format *dxf*, commonly used in CAD programs.

The program in this version has some limitations and is not entirely versatile. These limitations stem from the large number of variables that determine the selection of the appropriate supporting structure for a given situation. The constraints are related to the numerous possible scenarios (such as terrain formation and neighboring objects) that influence the positioning of the supporting structure and the available space for anchoring the guy wires.

4.3. Software version 2 – UMKW

The limitations of software version 1 (UMKW-Base) became a catalyst for developing more universal software for the fast design. The concept was upheld that modeling and analysis of structures could be performed quickly, while simultaneously preserving the ability to design also complex structures built from system modules.

It is worth noting that the versatility of the software somewhat contradicts ease of use and, consequently, the speed of design. Increasing the software's versatility necessitates the introduction of more data and a more complex data structure. Maintaining the desired design speed depends on the development of user communication mechanisms that expedite the creation of line and structure models, as well as data management systems that ensure data consistency.

The UMKW software is a desktop application consisting of several modules launched from a management program. The modules are interconnected, enabling the automation of the design process and seamless data transfer. This article focuses primarily on the issues of modeling UMKW system structures and data management, while issues related to performing calculations are omitted due to the limited scope of the article.

The general structure of the modules comprising the UMKW program is shown in Fig. 3. At the top of the pyramid are two modules used for data editing (UMKW-Wizard and UMKW-TextEditor). Their functionality is described in the following section.

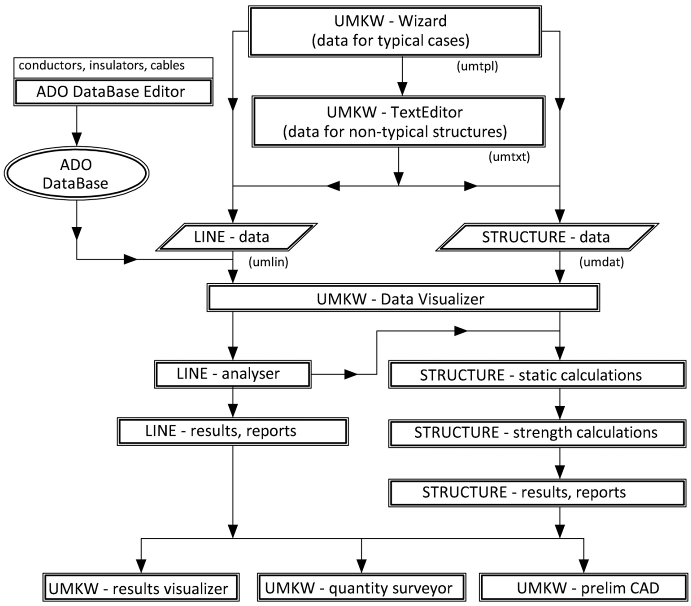


Fig. 3. Diagram of dependencies between UMKW software modules

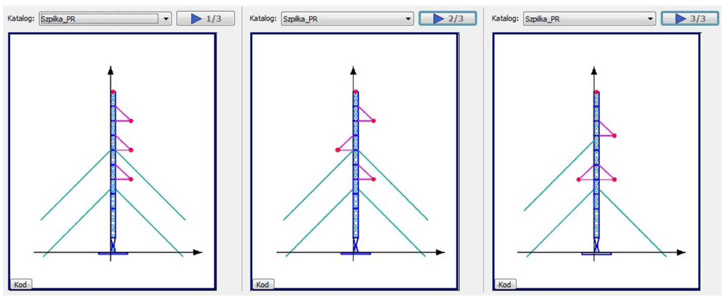
The analysis of forces in conductors is performed in an independent module (*Line-Analyser*), with its results passed to the module responsible for structural static calculations. Another independent module handles strength calculations and monitors forces in the guy wires. Although there is mutual interaction between the conductors and the structure, in practical design, these two aspects are commonly decoupled, assuming a unidirectional relationship. Calculations for conductors and structures are conducted independently. The omission of the influence of tower deformability on the forces in the conductors can be considered as a form of implicit safety margin. The UMKW software is complemented by modules for reporting and data/result visualization. The next section discusses mechanisms that facilitate structural modeling.

5. Software UMKW automation

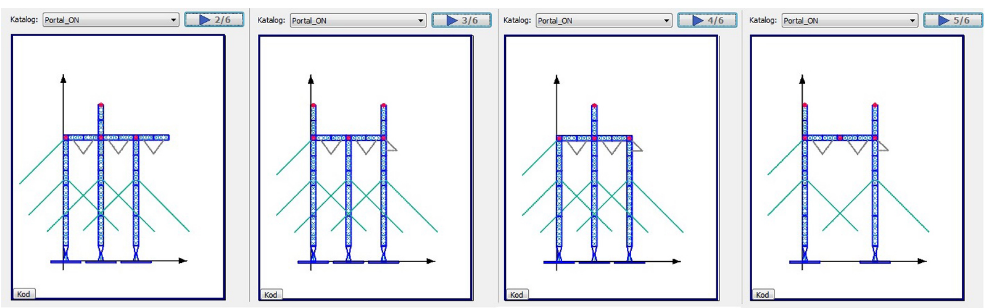
The UMKW program was developed using object-oriented programming techniques. Each component of the structure and power line is represented as an object containing comprehensive information about its properties. Since the properties of these elements are readily available without requiring user input, it is possible to automatically generate both analytical and geometric models. This database information on conductors, insulators, wires, and modules is also used to assist the designer in shaping the structure and verifying electrical requirements.

5.1. Parameterization

From the user perspective, an essential component of the UMKW software is the UMKW-Wizard module. Its main function is the quick modeling of typical line-structure configurations with predefined guyed tower profiles and suggested conductor suspension layouts, while minimizing the amount of data that needs to be defined. The predefined tower profiles are organized into a catalog consisting of eight groups, sorted by four tower functions (suspension, angle-suspension, angle-tension, dead-end) and two tower structure types (single-shaft masts and frames). The designer first selects a group of structures and then chooses the tower profile along with the conductor layout. Example of some support structure profiles are shown in Fig. 4.



(a)



(b)

Fig. 4. Examples of predefined guyed tower profiles: (a) suspension single-shaft, (b) angle-tension frame

The height of tower, crossarm spans, cantilever projections, tower tops length, and conductor locations are examples of parameters defined by the user. Based on the specified numerical values, the system automatically suggests a module arrangement to construct the desired tower. UMKW-Wizard also allows flexible definition of data related to line sections adjacent to the tower, including their directions and lengths. User can also select any type of conductor and equipment suitable for the nominal voltage of the line. The UMKW software communicate with ADO databases containing information about the characteristics of conductors, insulators, and guy lines. One of the software modules is an external database editor, which enables both the selection of appropriate record and the addition of user-defined records with complete geometric and material characteristics. ActiveX Data Objects (ADO) technology is used to perform operations on databases. The geometric and material characteristics enable the automation of calculations, e.g., assigning values for self-weight, wind, and icing loads, as well as defining the points of application of these loads.

In the UMKW-Wizard module, users also define climatic conditions (wind and icing zones), terrain characteristics (altitude above sea level and terrain category), and the line restriction level. Additionally, the selection of one of the three most recent editions of the standards serves as the basis for defining the method of determining the values of actions, their combinations, and the load configurations for supporting structures.

One of the key features of the UMKW-Wizard is the ability to freely define guy wires. Typically, four or two guy wires are used on one level. Lower levels incorporate stabilizing guy wires (usually four), while higher levels include balancing guy wires, typically two per level. The user has full flexibility in configuring the guy wires by specifying the type of cable and the level and location of attachment, the pre-tension force, and the angles in both the vertical and horizontal planes. In the current version of the software, the guy wire configuration is not automatically optimized, but work on this issue is planned.

The UMKW-Wizard module is responsible for quick and easy modeling of the structure. In order to simplify the use of this module as much as possible, certain simplifying assumptions have been made. These include: the use of a single type of phase conductor, uniform directions for all conductors reaching the tower, positioning the supporting structure walls along the bisector of the angle of the route deflection, the absence of bracing and struts stiffening the structure, and the occurrence of only standard loads.

The concept of fast and versatile modeling of the line-structure system is implemented through the existence of two modules for data declaration: UMKW-Wizard (Fig. 5) and UMKW-Editor (Fig. 6).

The first module (UMKW-Wizard) is equipped with a graphic editor and limited functionalities (mainly for simplifying model generation). The second module (UMKW-Editor) is used for editing the text file containing data in the native *umtxt* format. Files in the *umtxt* format are intended for data storage in a hierarchical structure divided into sections and subsections, with a structure and syntax that are user-friendly. UMKW-Editor allows the introduction of data that enhances the software's versatility, eliminating the limitations of the UMKW-Wizard module (such as a variety of conductors, insulators, additional bracing elements, individually defined guy wires, terrain profile input, and additional (non-standard) load cases and combinations.

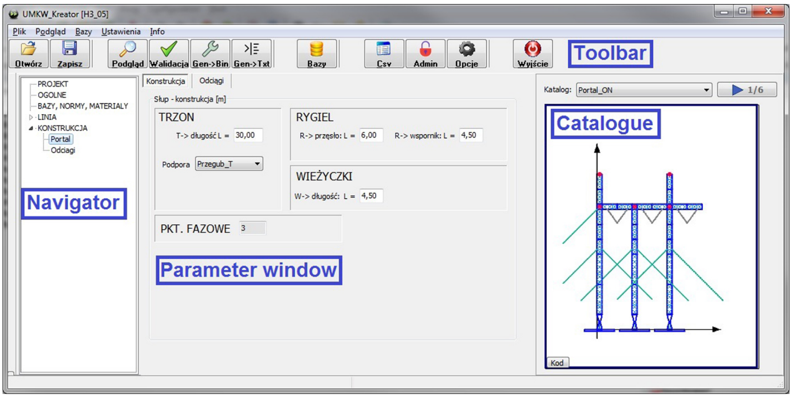


Fig. 5. Interface of the UMKW-Wizard module

UMKW-Editor has been equipped with additional tools that facilitate the editing of text data. Mechanisms commonly used in integrated development environment (IDE) have been implemented. These include the ability to edit individual subsections with hints for the structure used in the key-value schema. Due to the possibility of full user intervention in the content of *umtxt* files, an integral part of this module are procedures that control the correctness of the file in terms of syntax (validation for proper interpretation of the entry) and logic (ensuring the construction model can be correctly built). The result of these control procedures is a list of errors with the ability to trace their location, which helps the identification of any issues in the text file.

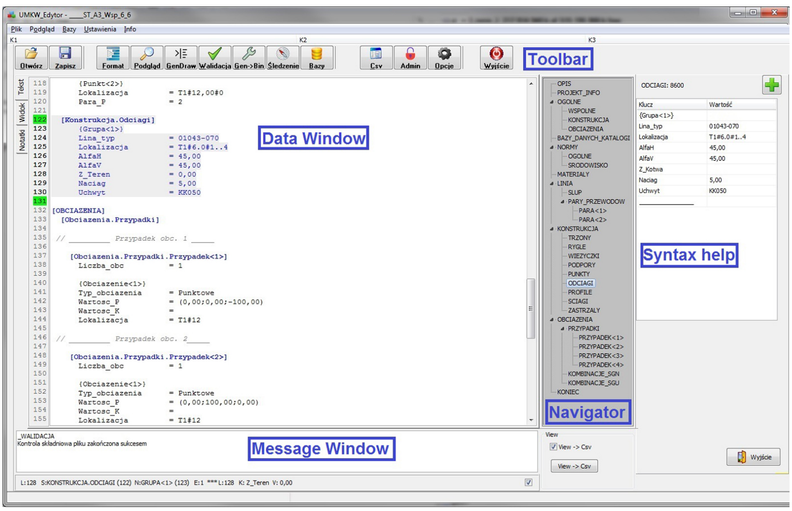


Fig. 6. Interface of the UMKW-Editor module

The model generation used by subsequent modules of the design software can proceed in a one-step process (using only the UMKW-Wizard module, transforming *umtpl* file → binary files *umlin, umdat*) or a two-step process (UMKW-Wizard → UMKW-Editor → binary files *umlin, umdat*). In the two-step modeling scheme, the data entered in the UMKW-Wizard module are converted into a more general text format (*umtxt*), and after supplementation or modification, are saved into the binary files *umlin, umdat*.

An additional component of the UMKW software is a module that allows for the visualization of the physical model, illustrating the structure's configuration, the layout and location of guy wires and insulators, as well as the values and directions of the loads, etc.

5.2. Advisory system

The UMKW system software is primarily intended for the structural design of supporting structures. However, due to its specific application, it is closely aligned with the requirements of power transmission lines. Structural requirements (selection and configuration of the supporting structure) and electrical requirements (selection and positioning of conductors and insulators) are interdependent. Power line design must adhere to standards regarding internal and external clearances and proper lightning protection.

Depending on the nominal voltage, pollution zone and restriction level, the internal clearances (distances between conductors and between conductors and the structure) are determined. The UMKW software monitors the shape of the supporting tower head to ensure that these clearances are maintained, suggesting its configuration (crossarm span L_s, cantilever length L_c) based on the selected tower profile and the aforementioned parameters. Example of the angle-tension frame head satisfying internal clearances $D_{\min}$ is shown in Fig. 7.

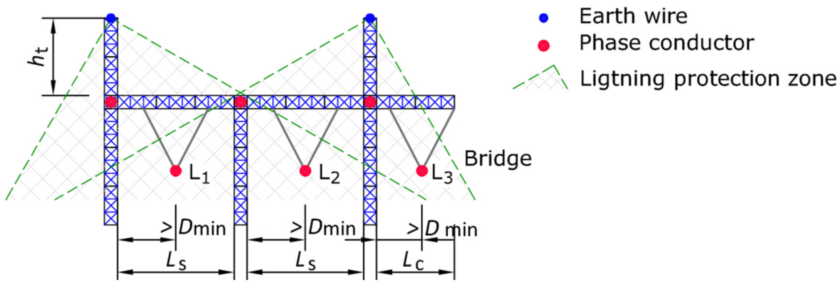


Fig. 7. An angle-tension frame head configuration

The software also controls external clearances by suggesting the height of the lowest conductor, based on the terrain profile and the location of special objects (e.g., roads, railways) provided in the data. Combined with the spacing between conductors, this determines the overall height of a single-shaft structure. For configurations where the supporting system is a frame, the program suggests the lowest possible elevation of the frame beam (crossarm). The basis for these analyses includes factors such as: nominal voltage, terrain profile with the location and type of adjacent objects, insulator geometry, conductor type, span lengths, conductor suspension height on neighboring towers, and the initial tension of conductor H_0 (at $T = +10°\text{C}$). Based on these inputs and the calculated shape of the catenary for two critical conditions (maximum temperature and extreme icing), the minimum elevation z_1 (Fig. 8) of the conductor is determined, followed by the elevation of the crossarm considering the insulator geometry.

Another aspect of shaping the supporting structure is ensuring the lightning protection of the conductors. For the selected configuration, after confirming the crossarm span and cantilever extension, the computer system checks the height of the tower top to maintain the appropriate angle between the ground wires and the phase conductors. The method for verifying tower top height h_t in the context of lightning protection zone is illustrated in Fig. 7.

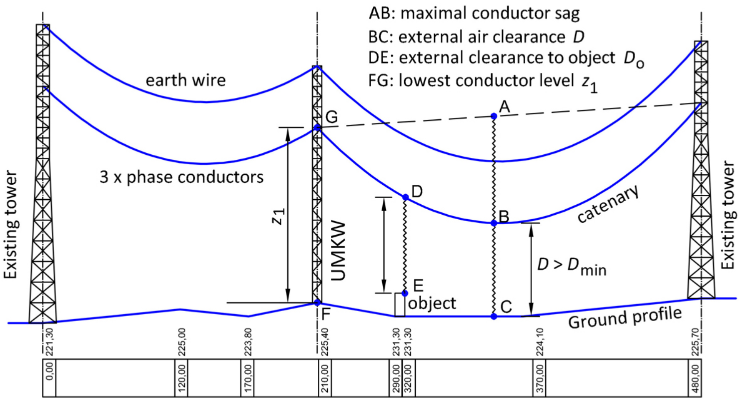


Fig. 8. Determining the elevation of conductor suspension point

5.3. Automation of determining loads on tower

An element of the UMKW software that significantly shortens the design time is the automation of determining the loads on the towers coming from the conductors. Taking into account the location (wind and icing zones), the version of the standard, the height of conductor suspension, and the properties of the conductors and insulators, the program sequentially: determines the magnitude of the loads on the conductor, performs the cable analysis, calculates the reaction forces, and returns a set of resultant forces acting on the tower at all points where the conductors are suspended. There are two alternative options for proceeding with this:

– using a single-span cable model with an equivalent span in the tension section (while simultaneously considering the length of the span adjacent to the tower),
– using a multi-span cable model that takes into account the swing of insulators on suspension towers (the procedure for this approach is described in [25]).

It is important to note that for angle-tension towers, the total number of load cases can exceeds 50. These cases are related to considering the possibility of any conductor breaking, different configurations arising from the uneven icing of the conductors, or effects from various wind directions. It is assumed that up to 12 potential wind directions are considered. Eight of these are related to the tower's orientation (4 directions perpendicular to the structure's walls, 4 directions along the diagonals), and four are related to wind blowing perpendicularly to the conductors on the left and right sides of the support structure. Depending on the assumed wind direction, the corresponding forces coming from the wind acting directly on the lattice structure are also automatically determined.

In the analysis, it is helpful to adopt and consistently apply a global coordinate system in which the directions of the line segments, wind directions, and tower rotation are defined. Although the plane of one of the tower's walls typically aligns with the bisector of the deflection angle of the route, there is an option (using UMKW-Editor) to deviate from this assumption.

The process of automating the declaration of load cases takes into account the following: the profile of the tower and the conductors layout. When evaluating the possibility of uneven icing of the conductors, layout of differential icing are analyzed, leading to bending (transverse or longitudinal) or torsion of the structure. This requires that in each load case, the resultant forces are automatically assigned to the individual attachment points of the conductors.

6. Conclusions and further work

The development of the UMKW software dedicated to designing temporary power line support structures enables the creation of a comprehensive ERS system tailored to local conditions. A fundamental aspect is adopting a proprietary object-oriented data structure that encompasses complete information about the power line and UMKW structures. Equally important is a method of software communication with a user that minimizes the amount of data input required, simultaneously maintaining the software's versatility. Predefining parameterized profiles of guyed towers and combining with data on steel modules, conductor characteristics, insulators, and hardware relieves designers of the need to declare these data, facilitating the automation of subsequent design stages. Integrating a set of electrical requirements into the software enables the implementation of an advisory system to support the designer's work. Through data processing, complete computational models can be generated, and documentation created without user's effort. The current version of the software requires the designer to manually define the guys layout and pre-tensioning. Future development of the UMKW software will focus on automating the guys selection, followed by the automation of tower geometry.

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Szybkie projektowanie konstrukcji wsporczych napowietrznych linii elektroenergetycznych systemu UMKW

Słowa kluczowe: napowietrzne linie elektroenergetyczne, tymczasowe konstrukcje wsporcze, maszty, zautomatyzowane projektowanie, zautomatyzowane modelowanie konstrukcji, oprogramowanie

Streszczenie:

Artykuł dotyczy systemu UMKW służącego do budowy tymczasowych konstrukcji wsporczych pod napowietrzne linie elektroenergetyczne w sytuacjach awaryjnych i remontowych. Jest to rozwijany w Polsce system, którego głównymi elementami są stalowe przestrzenne moduły kratowe umożliwiające budowę masztów oraz układów ramowych podpartych przy użyciu odciągów linowych. Głównym tematem jest automatyzacja projektowania konstrukcji wsporczych systemu UMKW pozwalająca na wydatne skrócenie czasu potrzebnego do określenia właściwej konstrukcji wsporczej i stworzenia dokumentacji. Przedstawiono dwa różne warianty autorskiego oprogramowania. Pierwszy wariant (UMKW-Base) pozwala na dobór konstrukcji z bazy danych zawierającej skończoną liczbę wstępnie przeliczonych układów linia-słup różniących się wysokością słupa, układem przewodów, rozpiętością przęsełitp. Drugi wariant (UMKW) pozwala na zautomatyzowane projektowanie z możliwością dowolnego ukształtowania konstrukcji wsporczej, swobodnego rozmieszczenia odciągów i przyjęcia sił naciągu wstępnego i zadeklarowania niezbędnych danych dotyczących linii elektroenergetycznej. W artykule zaprezentowano własne koncepcje zaimplementowane w oprogramowaniu dające możliwość skrócenia czasu projektowania. Pod pojęciem projektowania rozumie się: tworzenie modelu, automatyczną generację oddziaływań, analizę przewodów (cięgien), obliczenia statyczne i wytrzymałościowe konstrukcji oraz generację dokumentacji. W tekście skoncentrowano się wyłącznie na kwestiach odnoszących się do szybkiego modelowania konstrukcji, pomijając zagadnienia związane z obliczeniami. W artykule wskazano zalety wynikające z opracowania wyspecjalizowanego oprogramowania przeznaczonego do projektowania wąskiej grupy konstrukcji. Z jednej strony są one związane z dostosowaniem do obowiązujących warunków krajowych, a z drugiej ze zminimalizowaniem liczby danych wprowadzanych przez użytkownika oraz automatycznym przenoszeniem danych i wyników pośrednich między modułami oprogramowania realizującymi kolejne etapy obliczeń. Przedstawiono również koncepcję parametryzacji geometrii konstrukcji wsporczych. Możliwe było to dzięki stworzeniu bazy predefiniowanych sylwetek słupów z kilkoma definiującymi je wymiarami (parametrami). Dodatkowo, przez zintegrowanie wymagań elektrycznych z oprogramowaniem, przyspieszono proces kształtowania konstrukcji. Powstały w ten sposób *system doradczy* sugeruje lub nadzoruje takie rozmieszczenie przewodów lub przyjęcie wymiarów konstrukcji, aby zachowane były odstępy izolacyjne wewnętrzne (między przewodami lub przewodami a konstrukcją) i zewnętrzne (między przewodami i terenem lub obiektami infrastruktury). Opisano również autorski pomysł na zdublowanie modułu służącego do edycji danych. Przyjęcie tego rozwiązania sprawia, że oprogramowanie może być proste w obsłudze, a z drugiej strony uniwersalne. Krótko scharakteryzowano pełną automatyzację deklaracji układów i kombinacji oddziaływań. Na podstawie danych dotyczących przewodów i izolatorów (odczytywanych z baz danych) oraz lokalizacji odcinka linii na terenie Polski (stref klimatycznych) wykonywana jest analiza przewodów (cięgien) i określane są wszystkie wymagane przez normy przypadki oddziaływań przewodów (układy sił działających na konstrukcję) wraz z różnymi wariantami prowadzącymi do zginania i skręcania konstrukcji wsporczej. Deklaracja modelu fizycznego konstrukcji oraz automatyczna konwersja do modelu analitycznego pozwalają na przeprowadzenie obliczeń konstrukcji i przygotowanie dokumentacji projektowej bez konieczności dwukrotnego wprowadzania danych. Prace rozwojowe systemu UMKW zostały sfinansowane w ramach grantu nr POIR.01.01.01-00-0792/17 Narodowego Centrum Badań i Rozwoju, Program Operacyjny Inteligentny Rozwój 2014–2020, działanie 1.1/poddziałanie 1.1.1.

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