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# Software for calculation of technical losses in transmission network

***Abstract**. Technical losses arise by known physical electricity effects and it is not possible to eliminate them effectively. The paper deals with the 1st version of software tool for technical losses of transmission system lines calculation. The inputs are line parameters and measured data databases from control system of the Czech transmission system operator (ČEPS company). Outputs are Joule's losses, corona losses and leakage losses for each transmission line. The paper also includes description of input databases structure, calculation result files and computing algorithms.*

***Streszczenie.** Straty techniczne powstają przez znane efekty fizyczne związane z energią elektryczną i nie ma możliwości aby je skutecznie wyeliminować. W artykule opisano pierwszą wersję oprogramowania do obliczania strat technicznych w liniach systemowych. Wejściami są parametry linii oraz zmierzone dane z bazy danych systemu kontroli czeskiego operatora systemu przesyłowego (spółka CEPS). Wyjściami są straty Joule'a, straty ulotu i straty nieszczelności dla każdej z linii przesyłowych. Dokument zawiera również opis struktury bazy danych wejściowych, pliki wynikowe obliczeń i algorytmów obliczeniowych.(**Oprogramowanie do obliczania strat technicznych w sieciach przesyłowych**)*

**Keywords:** Transmission network, Technical losses, Joule's losses, Corona losses, Leakage losses.
**Słowa kluczowe**: Sieci przesyłowe, straty techniczne, straty Joule, straty ulotu, straty z tytułu nieszczelności.

## Introduction

The issues of electricity losses on the lines of the transmission system greatly influence the operation of electricity network. Electricity losses arise in all the components of the network. They cannot be totally eliminated, only reduced. The costs of reducing the losses cannot exceed the cost of electricity savings.

The below described computing software solves the issues of the technical losses on the VHV and HV lines. Such losses constitute a portion of produced electricity which is wasted and cause further costs. The losses are:

- *Joule's losses* – arise due to the active resistance of the $R$ conductors,
- *Corona losses* – are caused by inefficient electrical insulation of conductors,
- *Leakage losses* – their cause is inefficient insulation against the potential of the earth.

Modern power-producing companies control the electricity system with the help of high-quality computing technology and control systems. These systems operate with the quantities which are estimated, measured (voltage, current, rated power, temperature), and stative. All these data are processed by the control system of the energy dispatching and used to control the electricity system efficiently. The methodology of technical losses calculations has to build upon the mathematical and physical relations. The current version of the program does not allow the prediction of the losses with respect to the atmospheric influence.

## Calculations of technical losses on transmission system lines

*Joule's losses*

For the calculation of the Joule's losses the equation (1) has been devised which is valid providing zero leakage.

(1)

$$\Delta P = 3 \cdot R \cdot \left[ \frac{\sqrt{P_1^2 + \left( Q_1 - \frac{U_1^2 \cdot B}{2} \cdot 10^{-6} \right)^2}}{\sqrt{3} \cdot U_1} \right]^2$$

where: $\Delta P$ [MW] are Joule's losses on the whole line, $P_1$ [MW], $Q_1$ [Mvar], $V_1$ [kV] are measured values related to node 1, $R$ [Ω], $B$ [μS] are line parameters.
When so calculating the Joule's losses, the error is up to 1 %.

*Corona losses*

The expert literature gives many methodologies for the their calculation [1]. However, none of them is universal. Atmospheric influences affect greatly the corona losses. For the real calculations the Russian methodology seems to be the most appropriate.

The calculation of the corona losses proceeds from the Peterson's relation (2) [2]:

(2) $$\Delta P_{Crn/km} = \frac{0{,}0168 \cdot U_{Ph}^2 \cdot L \cdot F}{\left( ln \frac{d}{r} \right)^2}$$

The modified Peterson's relation for the corona losses is then:

(3) $$\Delta P_{Crn/km} = k_{cor} \cdot \left( \frac{U_{Delta}}{\sqrt{3}} \right)^2 \cdot F_U$$

where: $k_{cor}$ is a coefficient taking into consideration the factors affecting the corona formation described in literature [1], $F_u$ is a coefficient taking into consideration the ratio of the phase voltage and effective intensity of the field on the surface of the conductors. The used coefficients for individual voltage values were chosen according to the measurement.

*Leakage losses*

Leakage losses in practice are most frequently measured on the real lines. In [3], resulting relations for the calculation of the leakage currents and leakage losses are devised, and in [4], influence of the fouling of insulators on the leakage is elaborated.

(4) $$I_{Lkg} = \sqrt{3} \cdot U_{Delta} \cdot c$$

(5) $$\Delta P_{Lkg} = U_{Delta}^2 \cdot c$$

$c$ coefficient includes many factors, e.g. the thickness of the fouling on the insulators, composition, and number of the insulation suspenders.

## Structure of input databases

The computing program is designed to be flexible and open. Currently, it is able to compute with the exports of databases of the control system of the energy dispatching [5], i.e. off-line. The input databases are sets of three categories:

- classification tables of line names and abbreviations
- the tables with the line parameters
- quarter-hour P, Q, V, I measurements.

All the tables are in Excel format, so they can be easily enlarged, reached and the databases can be completed and unified. For the work with the computing system these exports do not need any specific adjustments. In future, this program can be connected onto the dispatching databases on-line. The size of the input databases is limited only by the Excel format itself, all the databases can be changed and completed within it.

If program is to function correctly:

- all the used abbreviations for lines must have their assigned and valid line names
- quarter-hour P, Q, V, I measurements must be taken within the same time intervals
- databases can contain redundant information, as all the needed quantities in them are searched for and therefore any preset structure is unnecessary.

Table 1 gives an example of abbreviations assigned to the names of lines, Table 2 shows line parameters and Table 3 is an example of the quarter-hour voltage and current measurements.

Table 1. Abbreviations and line names

| Abbreviation | Name |
|---|---|
| BEZ2 | Bezděčín |
| CHT2 | Chotějovice |
| CST2 | Čechy Střed |
| HRA2 | Hradec |
| LIS2 | Lískovec |

Table 2. Line parameters

| Line number | Substation A | Substation B | Imax [A] | Length [km] | R [Ω] | X [Ω] | B [μS] |
|---|---|---|---|---|---|---|---|
| V207_ | Tábor | Sokolnice | 656 | 168.918 | 10.73 | 72.45 | 426 |
| V208_ | Čechy střed | Milín | 580 | 86.236 | 6.92 | 34.3 | 213 |
| V209_ | Čechy střed | Bezděčin | 723 | 68.437 | 4.82 | 28.69 | 190 |
| V210_ | Bezděčin | Chotějovice | 656 | 97.945 | 6.46 | 38.1 | 243 |
| V211_ | Chotějovice | Vyškov | 656 | 30.374 | 1.98 | 11.69 | 76 |

Table 3. Quarter-hour current and voltage measurements

| Date | Time | cBEZ2: V209:I [A] | cBEZ2: V209:V [kV] | cBEZ2: V210:I [A] | cBEZ2: V210:V [kV] | cCHT2: V211:I [A] | cCHT2: V211:V [kV] |
|---|---|---|---|---|---|---|---|
| 1 Mar | 0:00:00 | 18.46 | 242.34 | 16.92 | 242.27 | 143.52 | 240.48 |
| 1 Mar | 0:15:00 | 19.56 | 241.82 | 19.12 | 241.76 | 162.48 | 239.99 |
| 1 Mar | 0:30:00 | 13.85 | 241.82 | 14.07 | 241.76 | 176.28 | 240.02 |
| 1 Mar | 0:45:00 | 13.19 | 241.82 | 13.19 | 241.76 | 177 | 239.99 |
| 1 Mar | 1:00:00 | 9.45 | 241.82 | 9.45 | 241.76 | 162.48 | 240.18 |

## Calculation of "Losses on TS Lines" program

Microsoft Visual Basic Professional has been chosen as the development environment of the program, as it is possible to create the graphical user interface quickly, easily and in a well arranged manner. It also supports all the currently available programming technologies, includes necessary modules for working with Microsoft Office files and is fully functional in all the operating Microsoft systems.

The overall conception makes the work with the system intuitive, the individual steps are logically arranged and their number is, if possible, minimized. The speed of performed calculations and operating with the downloading of the input databases has been optimised as well.

Of course, the results can be displayed either in tables or graphically with the option of saving and printing.

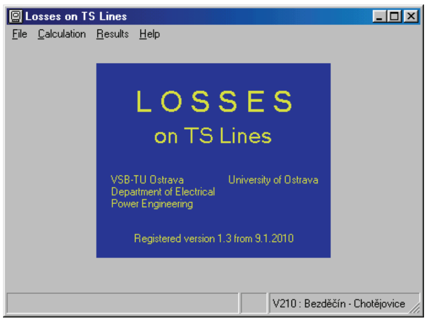


Fig.1. The main program window

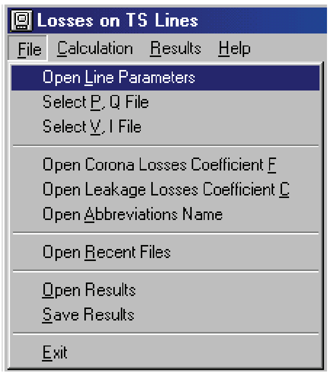


Fig.2. Menu „File“

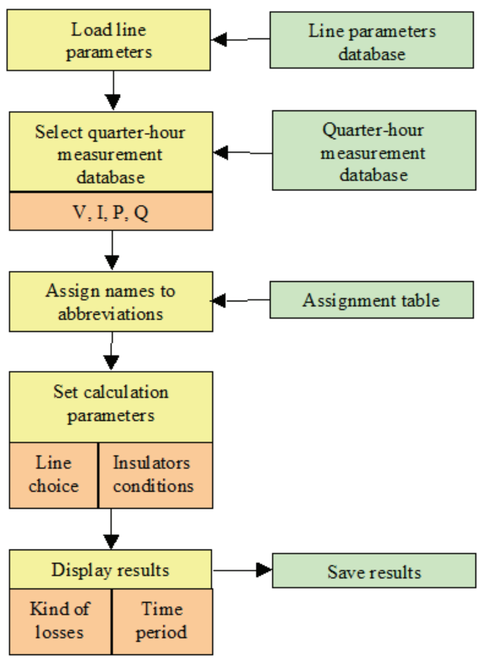


Fig.3. Program flow chart

## Program description

The main program window with the welcome screen is in Fig.1. At the start of work all the input databases need to be downloaded in the menu “File“ (Fig.2). This window corresponds with the logical inner program structure, which is, including the sequence on the input databases, shown in Fig.3.

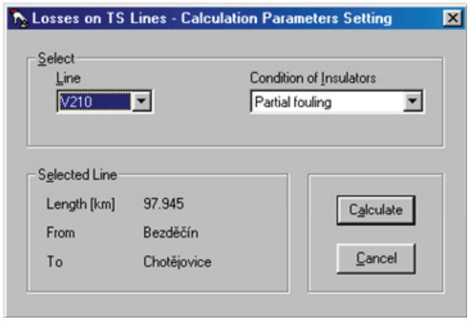


Fig.4. Calculation parameters setting

At the start the database of the line parameters must be downloaded, then the tables with the 15-minute measurements are matched. After that, the used abbreviations are completed with the names of substations and $c$ and $F_u$ coefficients are read.

The titles of all the opened files are downloaded into the Windows system register. Faster reading is possible with the help of the option "Open Recent Files".

Before running the calculations, the particular line and corresponding condition of insulators are chosen - Fig.4.

### Calculation results

The calculation results may be viewed in a well arranged graphic manner and in a table (Fig.5). Firstly, the whole period of time is shown from the quarter-hour measurement file. It is possible to enlarge it arbitrarily and analyse in more detail. Another switch allows us to choose, which of the technical losses we wish to view. Further option allows re-calculation on the line of 1 km length. Finally, the last switch gives the option of showing the results in nodes 1, 2, or their average value respectively. The graph itself is printable.

If we wish to repeat the calculation for a different line, reading all the input databases is unnecessary – the required line must only be chosen and the calculation is run.

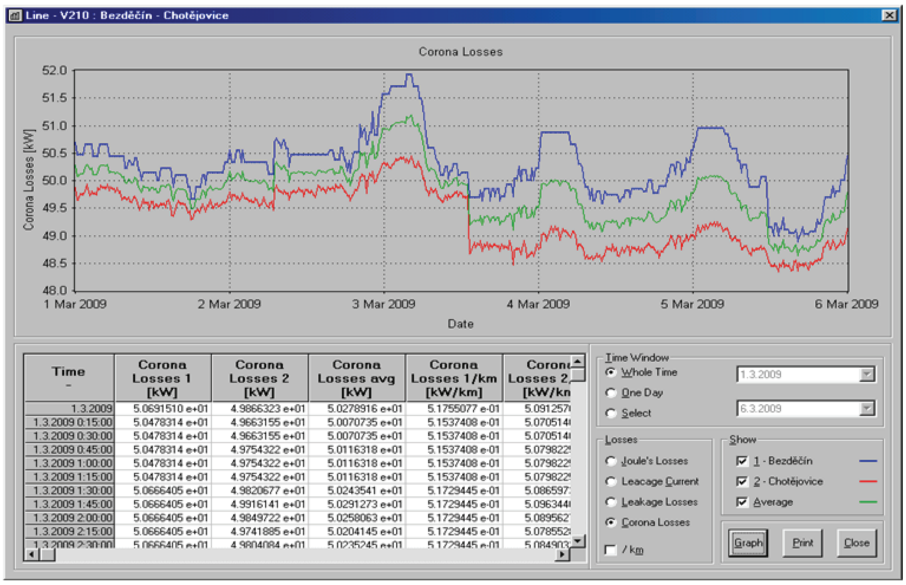


Fig.5. Technical losses calculation results

Such a procedure may be used to go through all the lines included in the database.

The results of every calculation may be saved in the menu "File", and later read for further processing. The file with the results contains all the calculated technical losses in both nodes and their average. A list with all the parameters included in the calculation is a part of the file.

### Conclusion

This paper describes the first version of a program, which comprehensively solves the calculations of the technical losses in the transmission network. Inputs are the line parameters and exports of the ČEPS, a.s. measurement databases.

Currently we have been working on the possibility to include the prediction of the losses with respect to climate conditions (namely the temperature) into the program.

This software has been checked on a real database of the TRIS control system at the ČEPS, a.s. dispatching. The program itself and its results have been used in practice.

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[5] Measurements database, ČEPS, a.s.

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