

A New Approach for the Analysis of Losses in Calculation of High-Voltage Transmission Networks

Ivica PETROVIĆ, Filip MIKULIĆ, Zoran BAUS, Srete NIKOLOVSKI, Dario GALIĆ

Abstract: By determining the losses in the power system, the aim is to determine the difference between the theoretical values and the actual losses obtained by measuring, to determine the reason for this difference, and to propose a theoretical method for selecting the calculation method that best corresponds to each type of transmission system. It is important to estimate the losses index for the expected level of loads, and thereby provide a basis for planning of system exploitation. The paper deals with the analysis of new methods used for the determination of losses in transmission network. New methods for determining losses that best suit the transmission system are presented, as well as a new method for determining losses in the transmission network, which is based on three elements. In conclusion, a comparison of individual methods tested on the real network model is shown with the aim of comparison of calculation, validation of results and evaluation of the analytical method of choice.

Keywords: calculations; loads; losses; new methods

1 INTRODUCTION

In order to increase energy efficiency in the power sector in the EU, one of the major goals becomes the reduction of losses in the network. The value of electricity losses depends largely on the network loads and in particular on the lines and transformers load.

The possibility of getting the necessary measured values for the determination of the losses is a significant problem in determining the same methods for the real time losses assessment, as mentioned in numerous studies [1, 2, 11].

Loads in power system are exposed to significant changes, so the theoretical calculation of the losses on the lines in the electricity network is carried out once a year and it is carried out on the basis of load curve of a typical day in the month with maximum loads, as described in [3, 12].

The calculation of losses in transmission networks requires many calculations that are based on power flow calculations and represent a loss of power that is the basis for many researchers [5-7].

Sometimes the objective of research is to evaluate the losses indexes on the expected level of load, and thus provide a basis for planning management of the power system and network development [9, 10, 13].

The article will present several common methods for theoretical determination of losses as well as a new method for determining losses in the transmission network, which is based on three features. At the end, there will be a comparison of some methods on real network model test with the aim of calculation and validation of certain methods comparison.

Chapter 2 provides an overview of the method for determining losses in real-time for high-voltage network.

Chapter 3 provides an overview of the standard method of equivalent power nodes to calculate losses.

Chapter 4 presents the calculation of losses in transmission networks based on three features.

Chapter 5 provides an example of calculation of transmission losses and comparison of the results for individual methods.

2 METHOD FOR MEASUREMENT OF LOSSES IN REAL TIME IN HIGH VOLTAGE NETWORKS

The method of computer calculation of loads and power flows, which was adopted for the calculation of energy losses in high voltage networks [4, 5] and on-line calculation should be run in accordance with the capabilities for processing of data. The calculation of the losses of transmission network required calculation of loads in individual branches, and necessary operating data are obtained from the SCADA system.

2.1 The Method Based on a Typical Day Measurements of Actual Load and the Estimated State

In order to realize the maximum load and load distribution, and determine the supply point and power transmission, various researchers and analysts determine the losses in the network at high loads. So, the actual measurement data obtained at high loads, methods of state estimation and load duration curves in the method for calculating losses based on a typical day are used. However, the operating mode, the amount of electricity transmitted and the conditions are not always standardized for the accounting period of big loads, so a variety of factors should be taken into account and the parameters for calculating losses with the selection of a particular method for the calculation of losses should be adjusted [11-13].

2.1.1 The Method of Choice Power and Quantity of Electricity

2.1.1.1 The Calculation of Losses Using Power Method

The current and voltage of each branch are obtained by analysis and calculations of power flows of active and reactive power output, load and data bus voltage for each hour [2]. Given the parameters of the power network, losses of active and reactive power of one branch can be calculated and represent the loss of electricity for each hour.

Such losses of electricity accumulated within 24 hours are losses on representative days. The first advantage of this method is that the reactive power losses are obtained at the same time, so that the distribution of reactive power

and voltage requirements is easily analysed. Another advantage is that thanks to the power flows, records in real time to calculate the losses of each branch can be easily checked.

A lack of this method is that it does not use the measurement distribution quantity of electricity with heavy loads, and losses of electricity are not directly proportionate to the relative amount of electricity, which affects the reliability of the calculated losses of index values on typical days.

2.1.1.2 The Calculation of Losses Using Electric Energy Amounts Method

By displaying the distribution of the amount of electricity on representative days and displaying typical load curve for each load and node, the concept of the coefficient of the output load distribution is introduced [6]. Suppose there are n loads; the maximum value of the typical load curve of each load and node introduces the concept of the coefficient of the output load distribution. Suppose there are n loads; the maximum value of the typical load curve is $p_{i,max}$; load per hour is $p_{ij}(j = 1 - 24)$; the amount of electricity a day is A_i ; the total amount of the entire electricity in network is A_Σ . The coefficient of the output load distribution K_i can be calculated by the following formula:

$$K_{ij} = \frac{A_\Sigma}{\sum_{i=1}^n A_i} \frac{p_{ij}}{p_{i,max}} = k_A f_{ij} \quad (1)$$

where: $f_{ij} = \frac{p_{ij}}{p_{i,max}}$ - Current load factor; $k_A = \frac{A_\Sigma}{\sum_{i=1}^n A_i}$ -

where k_A is the ratio of the total amount of electricity in the whole network on representative days and the sum of the amount of electricity from n loads for typical day load curve.

To calculate the loss of a representative day based on the electricity load, each loaded node for 24 hours can be calculated according to the following formula:

$$\bar{p}_{ij} = k_{ij} p_{ij} \quad (i = 1 \approx n, j = 1 \approx 24) \quad (2)$$

2.1.2 The Analysis of the Real Time Topology and Complementing Parameters in Network Schemes

Typical day method needs a 24-hour calculation of power flows, but also the connection of network elements can vary within 24 hours. Theoretical calculation of losses should be shown for the losses with conditions with most often associated network elements so that network scheme adopted the method on typical day can be analysed in real time, including updating the data in real time depending on the operating mode and the automatic allocation of each newly formed network schemes. In general, there are three steps in the above analysis as follows.

2.1.2.1 Analysis of Connection Electricity Hub

According to the previously saved data on circuit breakers and table of on and off state circuit breakers collected by SCADA system, connecting node on both sides on circuit breakers based on the principles of the eponymous connection. Connected nodes are summed up in one node, and substations are ultimately reduced to a few nodes.

2.1.2.2 Analyses of Network Systems

According to previously stored information in tables about branches collected by SCADA system, connecting hubs at both ends of exchanging branches with the principle of the same name connection. Online hubs are simplified in the subsystem. The result of the analysis of the network system is divided with connected nodes in subsystems.

2.1.2.3 The Formation Of The Nodes Names

Common names junctions are formed for simplified nodes collected from these two steps across the network and serves as the basis of parameters of network structure and operational data.

2.1.3 Adjustment of Measured Configuration and Analysis of Calculation Results of Losses

For large systems with many nodes, measurement systems should be divided into subsystems and all nodes of each subsystem are to be analysed. Also nodes input power needs to be determined. When state assessment gives incomplete or incorrect information, it causes a lack of input power to more subsystems nodes. The power flow of the subsystem cannot be calculated then and its nodes should be reconfigured.

In calculation of losses for 24-hour power flow, calculation results can be compared with power flows recorded in real time [7]. If they are about equal, under maximal, minimal characteristics, results of the calculation method based on a typical day are considered more reliable. The greater the difference in the operating mode, real-time analysis of network schemes must be carried out again and the results of the calculations by the actual loads. The method based on a typical day requires a typical analysis for network connection. It shows that a 24-hour power flow calculation on a typical day has an impact on the three modes, and there are no problems and shortcomings. If we can define parts of three different characteristics, calculation of power flows in the three points is not problematic.

2.1.4 The Theoretical Calculation of the Line Loss Index for Three Comprehensive Methods

Three comprehensive line loss index values X which can be calculated according to the following formula:

$$X = W_1 X_1 + W_2 X_2 + W_3 X_3 \quad (3)$$

where: X_1, X_2, X_3 - Theoretical index of line loss, which is based on power flows, the theoretical index of line losses based on an assessment of the situation and statistical index of line loss, which is based on an electrical energy measurement system; W_1, W_2, W_3 - Marking three line loss indexes which can be determined by the following conditions.

The objective function is: $a^2W_1^2 + b^2W_2^2 + c^2W_3^2 = \min$ with restrictions: $W_1 + W_2 + W_3 = 1$ and $W_1, W_2, W_3 \geq 0$ where a, b, c are the differences (relative value) between the three indexes of line losses on the last day, respectively the current day. Upon attaining, the importance of a comprehensive index of line loss X can be calculated by a Eq. (3). This is the theoretical percentage of line loss whose reliability is higher than any index of line loss. This shows that the index loss was calculated by the method of power flows perhaps the closest to the actual value in the nominal conditions. This method gives the most information in real-time and comprehensively offers highly reliable values of losses in real time based on the calculated three theoretical indexes of line losses. Such losses are assessed as sufficiently reliable from the perspective of mathematical processing. In conclusion, this method is effective in the short term for the theoretical calculation of the line loss in order to evaluate, but not suitable for calculations of line losses over a longer period.

3 EQUIVALENT METHOD OF NODES POWER FOR CALCULATION OF LOSSES

Equivalent method of nodes power to calculate the losses in the transmission network was explained in detail in reference [1]. In the past 20 years, this method is widely used in power systems.

3.1.1 Two-Dimensional Order for Calculation of Losses in Power Grids

Suppose the transmission network has n units for losses calculation, accounting periods, and the time interval between measurements. Losses of the largest piece of the network within the measuring interval can be obtained by summing up the energy losses of each unit within intervals or by summing up the total of electricity losses of all units within each measurement interval.

The expression of two-dimensional order then is described in Fig. 1 as follows:

	unit (n) \longrightarrow			
time (i) \downarrow	ΔA_{i1}	ΔA_{i2}	\cdots	ΔA_{ij}
	\vdots	\vdots	\vdots	\vdots
	ΔA_{i1}	ΔA_{i2}	\cdots	ΔA_{ij}

Figure 1 Two-dimensional row

Losses in the transmission network within the interval T can be calculated by the following formula:

$$\Delta A_{\Sigma} \Big|_0^T = \sum_{j=1}^n \left[\sum_{i=1}^{i=T/t_0} (\Delta A_{ij}) \right] = \sum_{i=1}^{i=T/t_0} \left[\sum_{j=1}^n (\Delta A_{ij}) \right] \tag{4}$$

where: ΔA_{Σ} - Total loss of electricity; $\sum_{j=1}^n (\Delta A_{ij})$ - Total amount of electrical energy in n loads.

3.1.2 Calculation of Electrical Energy Losses in the Network

If the period of calculation of energy losses is one day (i.e. 24 hours), electricity losses in the network can be calculated in two ways:

1) We multiply the average power losses of each accounting unit over time, and then summarize:

$$\Delta A = \sum_{i=1}^n \Delta(P_{ij})_j T \tag{5}$$

where: ΔA - Electrical energy losses; T - The period of electrical energy losses calculation.

Fig. 2 provides an overview of nodes with transformer loads and loads with no losses.

2) With summarizing electricity losses in the network within each hour:

$$\Delta A = \sum_{i=1}^{24} (\Delta A_{ij}) = \sum_{i=1}^{24} \left(\sum_{j=1}^n \Delta P_{av} T \right) \tag{6}$$

where P_{av} - the average active power.

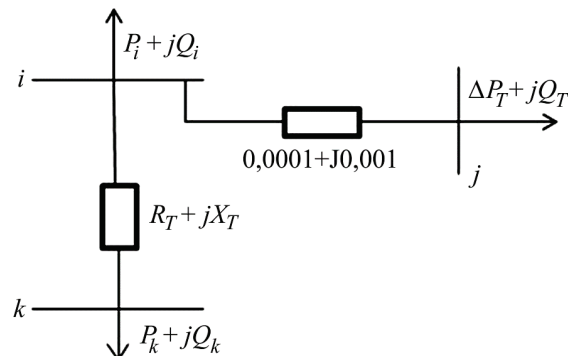


Figure 2 Transformer loads node and lossless loads

According to the first method, the amount of energy in the network is:

$$A = \left[\sum_{j=1}^n (P_{av} + \Delta P_{av}) \right] T \tag{7}$$

Then, the line losses index is:

$$\Delta A \% = \frac{\sum_{j=1}^n (\Delta P_{av})_j}{\sum_{j=1}^n (P_{av} + \Delta P_{av})_j} \tag{8}$$

4 CALCULATION OF LOSSES IN TRANSMISSION NETWORK BASED ON THREE POINTS

Calculation of flows with typical loads is carried out in three points or three features, to obtain the corresponding average loss of power under typical daily loads [10]. Obviously, the three types of daily average losses of the power may represent the total energy losses within the three operating modes. Line loss index on three points integrated to obtain an index of loss throughout the entire period is the basic concept of loss calculation in high-voltage grids based on the power losses in three points.

Theoretical calculation of losses for a long period that serves as a check is described in the next steps.

1) Application of the long period determined from the amount of energy in order to obtain the average load and the application of the measured maximum load to obtain factors of active power loads in long period f_p , and the minimum load index β_p which gives the index of changes $1/X$. Permitted medium power for three selected points is P_{1*} , P_{2*} , P_{3*} , and then $P_{1*} = (\beta_p + P_{s,m})/2$, $P_{2*} = f_p$, $P_{3*} = (P_{m,b} + 1,0)/2$.

2) It is necessary to choose the typical curve of daily load for the three points, and provide them with daily maximum load, or P_{1max} , P_{2max} , P_{3max} . We also need to multiply real maximum load for the entire period up to the value per unit of average power. Compare the daily maximum load with the product and take $(P_{\Sigma,max}P_{1*})/P_{1max}$, $(P_{\Sigma,max}P_{2*})/P_{2max}$, $(P_{\Sigma,max}P_{3*})/P_{3max}$, as coefficients of proportionality for adjusting to get a new distribution of the three points on typical daily load.

3) Performing calculated 24-hour power flows adjusted by distribution of three points on typical daily load, to obtain the average daily energy losses $\Delta P_1\%$, $\Delta P_2\%$ and $\Delta P_3\%$.

4) Using typical daily load curve for network in three ways to calculate the coefficients K_1 , K_2 , K_3 and using the Eq. (4), we calculate the losses indexes $\Delta A_1\%$, $\Delta A_2\%$ and $\Delta A_3\%$ according to three points of division.

5) With a combination of coefficients of low load factor that appears in most of the longer periods, we get the ratio between the electrical quantities of three shared characteristics $A_1 : A_2 : A_3$ and the ratio between the electrical quantities in three points of division of the total quantity of electricity $\alpha_1 : \alpha_2 : \alpha_3$.

6) Calculation of losses index for an entire period is obtained by the following formula:

$$\Delta A_{\Sigma} \% = \frac{\Delta A_{\Sigma}}{A} = \frac{(\Delta A_1 \% A_1 + \Delta A_2 \% A_2 + \Delta A_3 \% A_3)}{(A_1 + A_2 + A_3)} \quad (9)$$

where ΔA_1 , ΔA_2 and ΔA_3 are indexes of losses divided into three parts.

The replacement of ratios of the average load gives:

$$\Delta A_{\Sigma} \% = 0,233\Delta A_1 \% + 0,660\Delta A_2 \% + 0,107\Delta A_3 \% , \quad (10)$$

According to formula (10), total losses divided into three parts have a different degree of influence on the overall index of losses: the normal mode has the most effect, which follows from the minimal mode, and finally the least impact has the maximum mode.

Table 1 Calculation results of losses in one region

Time (hour)	1	2	3	4	5	6	7	8	Total
Load (MW)	195	191	189	190	193	205	212	220	
Losses (MW)	1,35	1,25	1,25	1,25	1,30	1,55	1,65	1,85	
Time (hour)	9	10	11	12	13	14	15	16	
Load (MW)	229	240	234	214	223	233	236	239	
Losses (MW)	2,15	2,50	2,45	1,75	2,00	2,30	2,40	2,50	
Time (hour)	17	18	19	20	21	22	23	24	
Load (MW)	237	222	229	237	232	222	209	212	5243
Losses (MW)	2,47	1,97	2,17	2,45	2,25	1,95	1,65	1,30	45,71

5 EXAMPLES FOR THE CALCULATION OF TRANSMISSION LOSSES

In Tab. 1, load and measured losses are listed and shown by hours of a typical day in one region. Three ways of calculating losses based on the total weight and measure for 24 hours in one region.

Checking the accuracy of calculation of losses, the method of division into three elements should be used.

1) Calculation of parameters of the curve of the total load. Load points are:

$$A = \sum_{i=1}^{24} P_i t = 5243 \text{ MW} \quad (11)$$

$$P_{av} = \frac{A}{24} = 218,45 \text{ MW}, \quad P_{max} = 240 \text{ MW} \quad (12)$$

$$f = \frac{P_{av}}{P_{max}} = \frac{218,45}{240} = 0,91 \quad (13)$$

$$\beta = \frac{P_{min}}{P_{max}} = \frac{189}{240} = 0,79 \quad (14)$$

$$\frac{1}{\lambda} = \frac{(1-f)}{(f-\beta)} = \frac{(1-0,91)}{(0,91-0,79)} = 0,75 \quad (15)$$

where: f - Load factor, β - Minimum load index, $1/\lambda$ - Index of load changes.

The index of the daily power loss is:

$$\Delta P \% = \frac{\sum \Delta P_i}{A} = \frac{45,71}{5243} = 0,87\% \quad (16)$$

2) Calculation of power points in three points: $f = 0,91$
Using the formula for the combination of high load factor, we get:

$$P_{s,m*} = 0,008 \left(\frac{1}{\lambda} \right)^2 - 0,1266 \left(\frac{1}{\lambda} \right) + 0,9043 = 0,81385 \quad (17)$$

$$P_{s,m} = P_{s,m*} \times P_{max} = 0,81385 \times 240 \times 10^6 = 195,32 \text{ MW} \quad (18)$$

$$P_{m,b*} = 0,0052 \left(\frac{1}{\lambda} \right)^2 - 0,0456 \left(\frac{1}{\lambda} \right) + 0,9918 = 0,9605 \quad (19)$$

$$P_{m,b} = P_{m,b*} \times P_{\max} = 0,9605 \times 240 \times 10^6 = 230,52 \text{ MW} \quad (20)$$

3) Calculating the average load of each of the divided points.

Minimum point

$$P_{s,av} = \frac{(\beta + P_{s,m*})}{2} \times P_{\max} = \frac{(0,79 + 0,81385)}{2} \times 240 \times 10^6 = 192,46 \text{ MW} \quad (21)$$

Maximum point

$$P_{b,av} = \frac{(P_{m,1} + 1)}{2} \times P_{\max} = \frac{0,9605 + 1}{2} \times 240 \times 10^6 = 235,26 \text{ MW} \quad (22)$$

4) Diversification of the loss of power index corresponding to an average load in three points

a) $P_{s,av}$ with minimal point of operation responds to power at 3h, and the change of power losses index is:

$$\Delta P_s \% = \Delta P_{3*} \% \times \left(\frac{P_{s,av}}{P_{3*}} \right)^2 = 0,686 \% \quad (23)$$

where: ΔP_{3*} - Ratio of power losses and load in 3 hours, $P_{s,av}$ - Average load minimal point, P_{3*} - Measured loads in 3h

b) P_{av} in normal conditions of operation corresponds to power at 8 hours, so it follows:

$$\Delta P_m \% = \Delta P_{8*} \% \times \left(\frac{P_{av}}{P_{8*}} \right)^2 = 0,8295 \quad (24)$$

where: ΔP_{8*} - Ratio of power losses and load at 8h, P_{8*} - Measured load in 8h

c) $P_{\max,av}$ at maximum point of the operation corresponds to the 15 h, so it follows:

$$\Delta P_b \% = \Delta P_{15*} \% \times \left(\frac{P_{b,av}}{P_{15*}} \right)^2 = \frac{2,40}{236} \times \left(\frac{235,26}{236} \right)^2 = 0,98 \% \quad (25)$$

where: $P_{b,av}$ - Average load for maximal point, P_{15*} - Measured load in 15h

5) Calculated ratio of the amount of electricity for the three points. According to the integral operation of load curves for a combination of the parameters of the index higher loads when the $1/\lambda = 1$ ratio amounts of electricity for the three points. In Table 3.4 from the literature [1] there is $\alpha_1 : \alpha_2 : \alpha_3 = 1 : 2,56 : 0,52$; when $1/\lambda = 2$ $\alpha_1 : \alpha_2 : \alpha_3 = 1 : 2,79 : 0,507$. According to the calculation using

interpolation when $1/\lambda = 1.625$ ratio of the amount of electricity three features $\alpha_1 : \alpha_2 : \alpha_3 = 1 : 2,62 : 0,51$.

6) Calculation of electricity losses shared on three points. Minimal point:

$$\Delta A_s = \frac{A_\Sigma \times \alpha_1}{\alpha_1 + \alpha_2 + \alpha_3} \Delta P_s \% = \frac{5243 \times 10^3}{1 + 2,62 + 0,51} \times 0,68 \% = 8632 \text{ kW} \cdot \text{h} \quad (26)$$

Normal point:

$$\Delta A_m = \frac{A_\Sigma \times \alpha_2}{\alpha_1 + \alpha_2 + \alpha_3} \Delta P_m \% = \frac{5243 \times 10^3 \times 2,62}{1 + 2,62 + 0,51} \times 0,829 \% = 27573 \text{ kW} \cdot \text{h} \quad (27)$$

Maximal point:

$$\Delta A_b = \frac{A_\Sigma \times \alpha_3}{\alpha_1 + \alpha_2 + \alpha_3} \Delta P_b \% = \frac{5243 \times 10^3 \times 0,51}{1 + 2,62 + 0,51} \times 0,98 \% = 6345 \text{ kW} \cdot \text{h} \quad (28)$$

where: $\Delta P_s \%$, $\Delta P_m \%$ and $\Delta P_b \%$ - Indexes of power losses at a minimal point, normal and maximal point.

6) Calculated total losses considering loss index for the entire period.

The index of power loss for the entire period is:

$$\Delta P_\Sigma \% = \frac{45,71}{5243} = 0,8718 \% \quad (29)$$

Loss factor calculated using the coefficients f and β

$$F = 0,639f^2 + 0,361(f + f\beta - \beta) = 0,8319 \quad (30)$$

Coefficient of curve shape of the total load is:

$$K = \frac{\sqrt{F}}{f} = \frac{\sqrt{0,8319}}{0,91} = 0,88 \quad (31)$$

Using the formula for calculating the index of energy losses for the full period, we get:

$$\Delta A_\Sigma \% = K \Delta P_\Sigma \% = 1,002 \times 0,8718 \% = 0,873 \% \quad (32)$$

$$\Delta A_\Sigma = A \Delta A_\Sigma \% = 5243 \times 10^6 \times 0,873 \% = 45771,39 \text{ kW} \cdot \text{h} \quad (33)$$

7) Calculation with errors method. An error occurred between energy losses by dividing in three points and the results obtained by measuring the loss index, and follows

$$\Delta A'_\Sigma = \Delta A_s + \Delta A_m + \Delta A_b = 42,5 \text{ MW} \cdot \text{h} \quad (34)$$

where: ΔA_s , ΔA_m , ΔA_b - Losses of electrical energy for minimum, normal and maximum points.

The relative error is:

$$\delta \Delta A_{\Sigma} = \frac{(\Delta A_{\Sigma} - \Delta A'_{\Sigma})}{\Delta A_{\Sigma}} \times 100\% = 4,55\% \quad (35)$$

where: $\Delta A'_{\Sigma}$ - Total electricity losses divided into three elements.

If the coefficient form in three points is greater than 1.0, the relative error in the calculation of energy losses can be reduced. In our case it is 0.88, which shows that the coefficients of shape of the curve and total losses are very well presented.

There is no special difficulty in choosing the typical load curves for a long period at the minimum, normal and maximum point, and three calculated coefficients have the form of stable characteristics.

The division of three periods coincide with three working points, and the average loss of three parts varies in a small range. Line loss index is great at maximum point, small at minimal point, and average under normal operation. The loss index is calculated on the basis of the principle amount of electrical balance during a long period and is considered to be very reliable in terms of statistics and probability.

5.1 Comparison of Measured Values with Results From Losses Calculations Methods

In order to fully comprehend and evaluate the network losses calculations methods, we need to compare them with measurement results. It should be noted that the methods based on the measurements also have errors due to quality and class of measuring devices' differences. Table 2 illustrates a comparison of losses using certain method.

Table 2 Losses and deviations of individual methods

	Method	Losses (%)	Losses deviation (%)		
			1-2	1-3	2-3
1	Calculated the entire period	0,873	0,0012	0,015	0,0138
2	Calculated by 3 features	0,8718			
3	Measured	0,858			

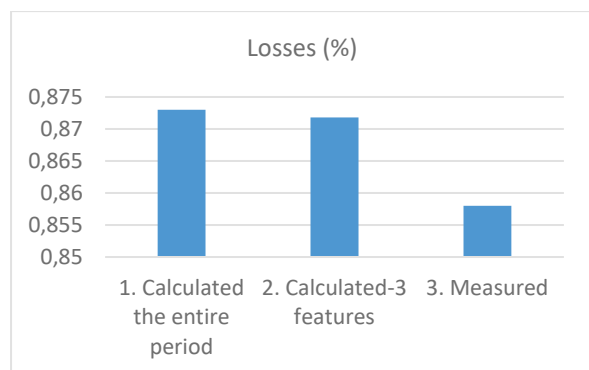


Figure 3 Losses depending on the method of calculation or measurement

From Tab. 2 it is evident that the method with three features gives better results than the method of calculation

for the entire period and brings deviation of relative losses in the amount of 0.0138%.

Fig. 3 gives a comparative overview of losses for all three methods.

From the above, it can be said overall that both calculation methods of losses correspond perfectly with the measured results and values that are used in practice.

6 CONCLUSION

In this article, the application of most common methods for calculating the losses in the case of high-voltage transmission network of one Croatian area is analysed. The new method for calculating the loss on power transmission lines takes advantage of the principle of "multiplication of probability" to solve the problem by dividing the load curves on three working points.

Results of analysis that are obtained by calculations using the proposed methods were compared with the results of measurements in practice, which enabled a proper evaluation of the proposed methods.

A new approach for the calculation of the losses of the transmission network has demonstrated the advantages of the new methods for solving calculation and valorisation of network losses, and has especially emphasized the advantages of solving the problem by dividing the load curve on three points.

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Authors' addresses

Ivica PETROVIĆ, PhD,
Croatian Transmission System Operator Ltd.
Information Technology Osijek
Osijek, Croatia
ivica.petrovic@hops.hr

Filip MIKULIĆ, m.sc.ee,
Faculty of Electrical Engineering, Computer Science and Information
Technology Osijek
Kneza Trpimira 2B, 31000 Osijek, Croatia
filip.mikulic1@gmail.com

Zoran BAUS, PhD
Faculty of Electrical Engineering, Computer Science and Information
Technology Osijek
Kneza Trpimira 2B, 31000 Osijek, Croatia
zoran.baus@efos.hr

Srete NIKOLOVSKI, PhD
Faculty of Electrical Engineering, Computer Science and Information
Technology Osijek
Kneza Trpimira 2B, 31000 Osijek, Croatia
srete@efos.hr

Dario GALIĆ, PhD
Faculty of Medicine
Josipa Huttlera 4, 31000 Osijek, Croatia
dario.galic@mefos.hr