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Research of Electricity Losses in Electric Networks

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***Abstract*—The production, transmission and distribution as well as the consumption of electrical energy are processes that are connected and simultaneous. The processes of transmission and distribution of electrical energy from the place of production to the place of consumption is a process associated with certain losses that can be provoked by various factors. Electrical loads are random in nature, but nevertheless they obey certain cyclicality in weekly, monthly, seasonal and annual aspects. In practice, it is necessary to determine and analyse them with sufficient accuracy. In this paper the error of electric power losses determination in distributed networks applying are analysed. An algorithm for calculate electric power losses with reading shape factor of load curves are made. For electrical networks differently configuration are applied the probability approach and investigate magnitude electric power losses.**

Keywords— distributed networks, electricity losses, load curves, shape factor, probability approach.

I. INTRODUCTION

The production, transmission and distribution as well as the consumption of electrical energy are processes that are connected and simultaneous. The processes of transmission and distribution of electrical energy from the place of production to the place of consumption is a process associated with certain losses that can be provoked by various factors.

Power losses and energy losses in distribution networks play a critical role in the overall efficiency of the electricity grid, affecting operational costs, reliability and sustainability of the grid. The introduction of the possibilities of reconfiguration of the electrical networks makes it possible to limit the losses of electrical energy on them [4,6], increase the reliability [1,2,3,4,5]. The use of real data on the power flows in the sections, and on the network as a whole, makes it possible to estimate the losses with greater accuracy and to take measures to limit them [7,8,11,12]. The introduction of a large number of decentralized energy sources in recent years has caused a change in the directions and sizes of the transmitted power on the sections. In a certain sense, a change in the freight schedules. In general, a change in the mode parameters (voltage level in the nodes, magnitude and direction of the transmitted powers, magnitude of short-circuit currents and other) [14] and the quality of the electrical energy [17,18] of the network is induced [9].

In practice, it is necessary to determine and analyse them with sufficient accuracy. Electrical loads are random in nature, but nevertheless they obey certain cyclicality in weekly, monthly, seasonal and annual aspects.

The determination of energy losses ΔW on an annual basis in electrical distribution networks can be carried out in the design stage or the operation process, when the configuration of the network, the lengths and sections of the wires in the individual sections, the transmitted powers on the branches and known loads in the nodes are known. In some isolated cases, there is insufficient information on the specified parameters, data on the annual commodity schedule in the nodes of the network.

Different methods can be applied to determine power losses and energy, each of which has a recommended area of application [13,15]. Their application leads in some cases to determining the result with an error exceeding 10%. Inaccuracy of information is the main difficulty in determining ΔW with sufficient accuracy [13,15].

In practice for approximate calculations of electricity losses with insufficient information, the following dependence is used [13,15,16]:

$$\Delta W = \Delta P_{max}.\tau \qquad (1)$$

Where ΔP_{max} are the active power losses in the maximum load mode; τ - the fictitious duration of power losses [13,15].

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The losses calculated in this way have a large error, even with a fully known network configuration, lengths and cross-sections of the wires in the sections, since the values τ are determined for a specific freight schedule, which introduces unavoidable inaccuracy.

The aims of the paper is to determine the error in the determination of power losses in distribution networks when applying deterministic methods, to propose an algorithm for the calculation of ΔW in a probabilistic approach with the average values ΔW of the loads in the nodes, in to investigate the magnitude of power losses for power networks with different configurations.

II. Materials and Methods

A. Electricity Losses In Radial Networks

The calculation expression for electricity losses contains the effective values of current Ie, active power Pe and reactive power Qe for time T, determined on an annual basis in [10,13,15].

$$\Delta W = 3.I_e^2.R.T.10^{-3} \quad (2)$$

The equation (2) can also be represented as (3).

$$\Delta W = \frac{P_e^2+Q_e^2}{U^2}R.T \quad (3)$$

Where R is the active resistance of the conductors, and U is the nominal voltage of the distribution network.

The effective values I_e, P_e and Q_e, for an annual load schedule of I(t), P(t), Q(t) are determined by the average values of the corresponding regime parameters I_c, P_c and Q_c with (4), (5) and (6), respectively.

$$P_e = K_{\Phi}.\mathrm{P_c} \quad (4)$$

$$Q_e = L_{\Phi}.Q_c \quad (5)$$

$$I_e = G_{\Phi}.I_c \quad (6)$$

Where $K_Ф$, $L_Ф$, $G_Ф$ are respectively the coefficients of the shape of the graph of I(t), P(t) and Q(t), which characterize the degree of its unevenness.

If electrical networks with higher nominal voltages are considered, to determine the effective values values I_e, P_e and Q_e, through the average I_c, P_c and Q_c, data on the voltage in the relevant node and the static characteristic of the load, which is known with sufficient accuracy, are used [13].

At a minimum value of $K_Ф = 1$, then $P_e = P_c$ and P(t) = const and the unevenness of the load schedule is minimal. The (7) or (8) follows from equation (2), (4), (5) and (6).

$$\Delta W = 3.10^{-3}.R.T.G_{\Phi}^2.I_c^2 \quad (7)$$

$$\Delta W = \frac{R.T}{U^2}.\left(K_{\Phi}^2.P_c^2 + L_{\Phi}^2.Q_c^2\right) \quad (8)$$

The limits of variation of electrical loads are determined by $\alpha = Pmax_{min}$ and $\beta = Qmax_{min}$.

The maximum value of the shape factor Kf can be determined by $K_{\phi\,\max} = \frac{1+\alpha}{2\sqrt{\alpha}}$ and $L\frac{1+\beta}{2\sqrt{\beta}}_{\phi max}$

For more accurate calculations of $K_{o\phi}^2$, expression (9) is used. the expression for $L_{o\phi}^2$ can be written by the same logic.

$$K_{o\Phi}^2 = \frac{1}{2} + \frac{1}{8.\alpha}.(1+\alpha)^2 = f(\alpha) \quad (9)$$

the allowed error is determined by (10) for$|\delta_\alpha|$ and by a similar approach for $|\delta_\beta|$

$$|\delta_\delta| = \frac{K_{o\Phi}^2-1}{K_{o\Phi}^2} = \frac{(1+\alpha)^2-4.\alpha}{(1+\alpha)^2+4.\alpha} = \varphi(\alpha) \quad (10)$$

B. Determination Of Electricity Losses In Distribution Networks

In electrical networks with a large number of branches and nodes to determine the power loss using a deterministic approach, the is usually used (11).

$$\Delta P = \sum_{k=1}^{N}\frac{(P_k^2+Q_k^2).R_{kk}}{U_k^2} + \\ +2\sum_{j<k}^{1,N}B_{jk}\frac{(P_jP_k+Q_jQ_k).R_{jk}}{U_jU_k}.cos\theta_{jk} - \\ -2\sum_{j,k}^{1,N}\frac{(P_jP_k+Q_jQ_k)}{U_jU_k}.sin\theta_{jk} \quad (11)$$

Where P_k and Q_k are the active and reactive power at the node k-th; U_k – the voltage in the node k-th of the network; ; θ_{jk} - the phase shift (dephasing) between the voltages U_j and U_k in the corresponding node j and k; R_{kk} , R_{jk} - the own and mutual active resistances of the network for the respective nodes j and k;

The use of the statistical approach is more appropriate when determining losses in distribution networks [13]. The input parameters are U_j and U_k; R_{kk}, R_{jk} and θ_{jk}. The average values of the active power P_{kc} and reactive power Q_{kc} are determined and:

$$\Delta P_c = \sum\frac{R_{kk}}{U_{kc}^2}(P_{kc}^2+Q_{kc}^2) + 2\sum\frac{R_{jk}.cos\theta_{jkc}}{U_{jc}U_{kc}}\left(P_{jc}P_{kc} + \right. \\ \left. +Q_{jc}Q_{kc}\right) - 2\sum\frac{R_{jk}.cos\theta_{jkc}}{U_{jc}U_{kc}}\left(P_{jc}P_{kc} - Q_{jc}Q_{kc}\right) \quad (12)$$

The load schedules of the nodes captured at the minimum mode P_1 (t) and maximum mode P_n (t), respectively, are the smallest and largest value in the set of realizations of the random process. All other possible cases are included in these limits [13].

Knowing the load distribution law allows one to calculate the missing elements in the set. This law is determined by statistical processing of a given daily commodity chart.

The uniform density distribution has the form shown below:

$$f(P,t) = \begin{cases} \frac{1}{P_n(t)-P_1(t)}, P_1(t) \le P(t) \le P_n(t); \\ 0, P(t) < P_1(t); P(t) > P_n(t). \end{cases} \quad (13)$$

The Individual realizations in the random process are calculated at the boundary values with:

$$P_k(t) = P_1(t) + (k-1)\frac{P_n(t) - P_1(t)}{n-1}$$

$$P_k(t) = P_1(t) + (k-1)\Delta P(t); \quad (14)$$

$$k = 1,2,\ldots,n; t = 1,2,\ldots,24/\Delta t$$

Where n is the duration of the random process; Δt - the diskette interval of the load schedule.

The estimation of the coefficient of variation of the load schedule for active power is used in the modeling of the capacities in the nodes.

$$\tilde{v}_P(t) = \frac{\sqrt{\tilde{D}[P(t)]}}{\tilde{M}[P(t)]}. \quad (15)$$

Considering the law of uniform density of load distribution, for the coefficient of variation is obtained:

$$\tilde{v}_P(t) = \frac{\sqrt{n(n-1)}[P_1(t)-P_n(t)]}{\sqrt{3}(n-1)[P_1(t)+P_n(t)]} \quad (16)$$

The rms value of the load is determined by:

$$\tilde{M}[P^2(t)] = \tilde{M}[P(t)]^2 + \tilde{D}[P(t)]$$

$$\tilde{M}[P^2(t)] = \tilde{M}[P(t)]^2[1 - \tilde{v}_P^2(t)] \quad (17)$$

With the obtained mathematical expressions, the mode parameters in the distribution networks are determined.

Loads are considered to be uncorrelated due to their physical independence:

$$\frac{1}{T}\int_0^T P_j P_k dt = M(P_j P_k) = MP_j MP_k = P_{jc} P_{kc} \quad (18)$$

The dependencies for the reactive fats in the nodes of the distribution network are analogous.

If the coefficients of the shape of the load schedules are used, (9) is transformed into the form (19).

$$\Delta P_c = \Delta P_{oc} + \sum \frac{R_{kk}}{U_{kc}^2}\left[\left(K_{k\phi}^2 - 1\right)P_{kc}^2 + \left(L_{k\phi}^2 - 1\right)Q_{kc}^2\right]$$
(19)

Where the first term of is the main and the second term is the dispersion component of the power losses.

III. RESULTS AND DISCUSSION

The results of the calculations for $K_{o\phi}^2$ and $|\delta_\alpha|$ for radial electrical networks, depending on α are presented in fig.1 and fig.2.

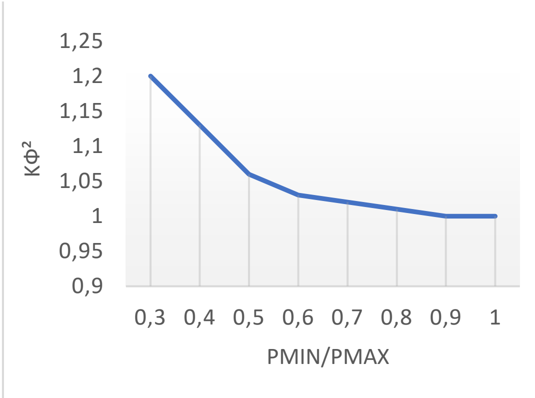

Fig. 1. Dependence of the form factor and limits of variation of electrical loads.

The error |δ| when calculating the electricity losses in radial lines for the real load schedules for a specific load type, it reaches even higher values, especially for industrial loads.

Fig.2 shows that at α<0.4, the error in determining ΔW exceeds 10%. The error is between 5 and 10%. At α>0.52, the error in calculating the power losses remains within the permissible limits

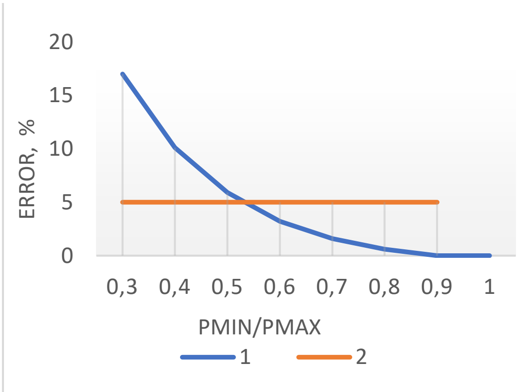

Fig. 2. Dependence of the error and limits of variation of electrical loads - 1 and Limit value - 2.

According to the proposed algorithm, software was developed for determining power losses in a distribution network. The power range in the nodes varies from 2.5 to 4.5 MW, cos φ e in the interval from 0.9 to 0.95. Calculations are carried out for electrical networks with two types of configurations:

- a lightly loaded network with a large total branch length.
- A highly loaded network with a small total branch length.

The average values of power losses in distribution networks are presented in Fig.3. The summarized results of the calculations show that as the number of nodes increases, the dispersion component of the losses decreases

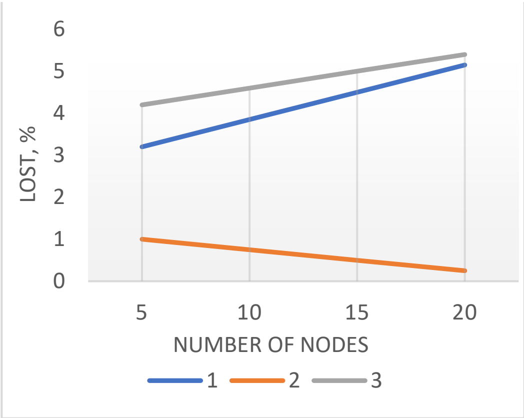

Fig. 3. Average values of power losses in a distribution network: 1 – main component; 2 – dispersion ingredient; 3 – total value.

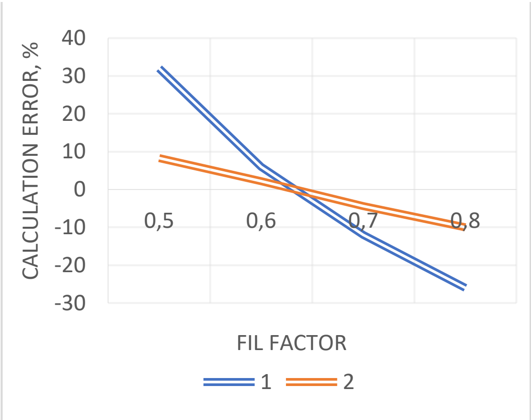

Fig. 4. Error in determining the electricity losses depending on the filling factor: 1 – with the fictitious duration method; 2 – with a probabilistic approach.

Fig. 4 shows the change in electricity losses depending on the load factor of a known load schedule, determined respectively by the fictitious duration method and the probabilistic approach. The error is calculated relative to the case of applying a stepwise load schedule approximation with a very small sampling step.

IV. Conclusions

The error in the determination of ΔW exceeds 10 % at $\alpha<0.4$. When $0,4<\alpha<0,5$ the error is between 5 and 10%. At $\alpha>0.52$, the error in calculating the electricity losses remains within the permissible limits.

A probabilistic approach to determining electricity losses combined with determining the shape factor of the load schedule is recommended for distribution networks.

From the conducted calculations of power losses in distribution networks, it is found that as the number of distribution network nodes increases, the dispersion component of losses decreases.

When applying the probabilistic approach, the calculation error is within the permissible limits for values of the load factor of the load schedule in the interval from 0.6 to 0.75

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References

[1] N. Tsygulev, V. Khlebnikov, and Y. Voronina, "Specific aspects of calculating electrical energy losses in electricity networks". VIII International Scientific Conference Transport of Siberia – 2020, In IOP Conference Series: Materials Science and Engineering (Vol. 918, No. 1, p. 012156). doi:10.1088/1757-899X/918/1/012156

[2] A. Augugliaro, L. Dusonchet, and E. Riva Sanseverino, "Voltage drop and power losses fast evaluation through equivalent models of feeders for optimal operation of automated distribution networks". European transactions on electrical power, 217-225, 1999 https://doi.org/10.1002/etep.4450090401.

[3] S. W., Wang, C. Y. Hung, and D. C. Lin, "Loop-type feeder models for fast distribution system calculations",10th International Power & Energy Conference (IPEC 2012), pp. 611-615.

[4] T. H. Chen, and S. W.Wang, "Simplified bidirectional-feeder models for distribution-system calculations". IEE Proceedings-Generation, Transmission and Distribution 1995, 142(5), pp. 459-467.

[5] M. Todorovski, "A reduction method for radial distribution feeders: ensuring parity in voltages and losses". IEEE Transactions on Power Systems2024, 39(2), pp. 4759-4762, DOI:10.1109/TPWRS.2024.3351490

[6] T. H. Chen, and S. W. Wang, (1995, November). "Applications of simplified bi-directional feeder models for accelerating the voltage-drop and power-loss calculations", International Conference on Energy Management and Power Delivery EMPD'95 (Vol. 2, pp. 708-713).

[7] A. R., Manito, U. H. Bezerra, T. M. Soares, J. P Vieira, M. V Nunes, M. E. Tostes, and R. C., de Oliveira, "Technical and non - technical losses calculation in distribution grids using a defined equivalent operational impedance". IET Generation, Transmission & Distribution, 13(8), pp. 1315-1323

[8] C. E. M.Rodrigues, M. E de Lima Tostes, U. H Bezerra, T. M. Soares, E. O. de Matos, L. S. Soares Filho, and C. J. da Silva Moura, "Technical Loss Calculation in Distribution Grids Using Equivalent Minimum Order Networks and an Iterative Power Factor Correction Procedure". Energies 2021., 14(3), pp. 1-23

[9] Y. Ma and G. Fu, "Analysis of the Impact of Power Grid Structure and Equipment Types on Distribution Losses", 6th International Conference on Energy, Power and Grid (ICEPG 2024), pp. 775-779,

[10] M. I. Fursanov, A. A. Zalotoy, and V. V. Makarevich, "Calculation of technological consumption (loss) of electricity in modern 0.38–10 kV electrical distribution networks", Energetika. Proceedings of CIS higher education institutions and power engineering associations 2018, 61(5), pp. 408-422, https://doi.org/10.21122/1029-7448-2018-61-5-408-422

[11] M. Junxia, G. Binqing, L. Fuchao, and D. Peidong, "Study on power loss of distribution network with distributed generation and its reactive power optimization problem", International Conference on Power System Technology 2014, pp. 1213-1216

[12] S. Totalov, V. Zlatanova, V. Garbeva, N. Paunkov, P. Katsarova, "Comparative analysis of electrical energy measurement errors with commercial measurement tools", Conference of the Union of Scientists in Bulgaria 2011, vol. B – IX

[13] St. Nedeltcheva, "Electrical networks and systems with decentralized generating sources", TU – Sofia Publishing house, Sofia, April 2018, ISBN 978-619-167-348-3

[14] S. Petrov, "Monitoring of mode parameters in distribution electric networks", Announcements of TU-Sliven №4, 2019, ISSN1312-3920

[15] P. Notov and St., Nedeltcheva, "Electroenergetics", Vol. 2, TU – Sofia Publishing house, Sofia, 2009.

[16] Nedelcheva S., "Application of mathematical models for determining the losses of electricity in CH and HV power lines. Anniversary scientific conference", Conference Sliven'97.

[17] R. Simionov, K. Seymenliyski, G. Georgiev, and other, "Studying the Impact of PV Plants on Power Quality", Communications in Computer and Information Science, DOI:10.1007/978-3-031-23226-8_6

[18] Ordinance No. 3, Ministry of Energy and Energy Resources, Republic of Bulgaria, 2004