A COMPARATIVE STUDY REGARDING THE EFFICIENCY OF TECHNICAL LOSSES EVALUATION METHODS IN LOW VOLTAGE ELECTRICITY NETWORKS

Eng. **Bogdan-Constantin NEAGU,** PhD Student[1], Prof. Eng. **Gheorghe GEORGESCU** PhD[1],

[1]"Gheorghe Asachi" Technical University of Iaşi, Electrical Engineering Faculty.

REZUMAT. Reducerea pierderilor tehnice de putere reprezintă o problemă majoră în planificarea şi exploatarea reţelelor de distribuţie cu importante implicaţii tehnico-economice. Ţinând seama de volumul mare de informaţii necesar metodelor clasice pentru evaluarea pierderilor tehnice de putere şi energie din reţelele publice de joasă tensiune, în lucrare sunt prezentate modele matematice şi programe de calcul ale acestora utilizând profilele tip de sarcină. În final, pentru a sublinia precizia metodologiei descrise este analizată o reţea reală de joasă tensiune.

Cuvinte cheie: pierderi tehnice, profile tip de sarcină, serii Fourier, metode deterministe.

ABSTRACT. In distribution networks, the reduction of technical power losses represents an major issue during planning and operation with important technical and economical implications. Taking into account the high volume of required information used for technical power losses evaluation with traditional methods from low voltage (LV) public distribution networks, in the paper, some mathematical models and application to power and energy losses computation using typical load profiles, are presented. Finally, to emphasize the methods described accuracy a real LV networks are analysed.

Keywords: technical losses, typical load profiles, Fourier series, deterministic methods.

1. INTRODUCTION

The distribution network is the most visible part of the supply system, and as such the most exposed to the critical observation of its users. Every element for power network offers resistance to power flow and consumes some energy while allowing current to flow through it. The energy consumed by all these elements is named as *technical losses* [1], [2].

The distribution network in developing countries suffers from the problem of low voltage (LV) with high energy losses. The problem of the losses and voltage drop in distribution feeders dependent on each other and varies with the pattern of loading on the feeders [1].

A permanent policy for reduction of energy losses implies not only the technical improvement of the network (by introduction of modern equipments and circuit components), but also requires the use of software tools to facilitate the operation process [2].

Considering the main characteristics of distribution networks, practical impossibility of storage and process of entire amount of topological and material data relating to LV distribution networks and their low monitoring process in current operation, it was necessary the elaboration of mathematical models which can allow determination and evaluation of technological consumption and technical active and reactive power losses under load for a given area, based on the lowest possible volume of information, ensuring, at the same time, from practically point of view, a sufficient accuracy of results. Thus, the goal of this paper is to describe some mathematical models to determine the levels of the power/energy losses using the typical load profiles in LV distribution networks.

For LV public distribution networks, the necessary information for analytical computation to evaluate technical losses under load are more difficult to obtain in exploitation than MV repartition and distribution networks. For this reason, in LV distribution systems in which MV/LV station supplies with electricity one LV network, through which are supplied 50÷250 small consumers, having as purpose to determinate the different loading of LV network components, can be used in practice, the following main ways [3], [4], [5]:

- Power flows measurement in a sufficient number of points or nodes along the distributors and, in particular, of their derivation points;
- Energy measurement, recorder and storage in station and its division in segments of LV distribution network corresponding with the electricity sold to uers;
- Simultaneity factors usage for different consumer categories supplied from LV networks, depending on the number and characteristics of each consumer;

o The correlation usage between maximum power and daily or monthly active energy consumed by different types of electrical receivers;

o Difference measurement between energy injected into LV network and power recorded of energy meters installed at users;

o LV recorder energy of MV/LV station bars and the voltage recorder both at LV substation feeders and customers which are supplied with electricity, etc.

2. TECHNICAL LOSSES IN LV NETWORK USING DETERMINISTIC METHODS

The estimation of energy losses under load in operation process, which appear in LV distribution network components (lines) can be made by using load curve parameters method. In current operation, for radial or tree configuration distribution networks, the obtained results by using this method are favorable for practical computations.

In literature [3], [6], [8], from the ranked load curves analysis, but also from the large number of records made by electronic three-phase metering ALPHA, for public network has been determined dependencies as:

$$Q_* = \alpha \cdot P_*^{\beta} \tag{1}$$

where: P_*, Q_* - active and reactive power, in relative unit, related to the peak load; α, β - coefficients derived from regression processes for each consumer category supplied with electricity through LV feeders.

By considering (1), it results that between the active and reactive peak load durations, in relative units, there is a connection having considering this hypothesis $T_{P_*} = T_{Q_*}^{\beta}$. Losses duration for active and reactive power losses can be evaluated using the following expressions:

$$\begin{aligned} \tau_{P_*} &= \left(0.7 \cdot T_{P_*} + 0.3\right) T_{P_*} \\ \tau_{Q_*} &= \left(0.7 \cdot T_{P_*}^{\beta} + 0.3\right) T_{P_*}^{\beta} \end{aligned} \tag{2}$$

When the maximum active and reactive power values coincide in time, so the two loads vary accordingly, characteristic fact for LV public networks, losses duration for apparent load is:

$$\tau_{s_*} = \tau_{P_*} \cdot \cos^2 \varphi_{\max} + \tau_{Q_*} \cdot \sin^2 \varphi_{\max} \tag{3}$$

For the general case of inaccurate variations, losses duration for apparent load will have the following form:

$$\tau_{s_*} = \tau_{P_*} \cdot \cos^2 \varphi_{\max} - k_q \cdot \tau_{Q_*} \cdot \sin^2 \varphi_{\max} \tag{4}$$

where k_q is non-lapping over coefficient of maximum active and reactive power from daily load curve.

In operation process, based on the above considerations, namely, by using the load curve parameters method, active energy losses under load will be able to evaluate, depending on the maximum loads considered (power/current), as follows:

$$\Delta W = \frac{R}{U_n^2} \cdot S_{\max}^2 \cdot T \cdot \tau_{S_*} = \frac{R}{U_n^2} T\left(P_{\max}^2 \cdot \tau_{P_*} + Q_{\max}^2 \cdot \tau_{Q_*}\right) \tag{5}$$

$$\Delta W = 3 \cdot I_{\max}^2 \cdot R \cdot T\left(\tau_{P_*} \cdot \cos^2 \varphi_{\max} + \tau_{Q_*} \cdot \sin^2 \varphi_{\max}\right) \tag{6}$$

To increase the results precision on the energy losses evaluation, in the literature [2], [3], [5], [8], based on a large number of measurements in a several networks in our country, have been established the correlations between the losses duration of apparent loads and fill factor of the load curve for the transformers from substation, LV feeders and distributors, maximum active power utilization period respectively, fill factor (K_{UP}) of active load curve and power factor at peak load, if households and tertiary consumers are supplied from public LV networks.

According to the presented methodology, the energy losses evaluation in public LV networks can be performed separately or combined, using the apparent load, when the active and reactive powers vary accordingly or inadequately. The accuracy of the obtained results is relatively good in this computation variant, errors values hovering around 2.5 … ± 5% [6].

In the public LV distribution networks case, the evaluation with acceptable accuracy of percentage power losses can be achieved by using percentage values of measured voltage loss in the distribution network analysed. Considering that the inductive reactance of the lines in these networks, especially when they are made in cable, is much smaller compared to resistance ($X << R$) and reactive loads which flows by LV feeders are relatively small ($\cos \varphi \approx 1$), can be writed the following equality [4], [5]:

$$\Delta U,[\%] = \frac{\sqrt{3} \cdot R \cdot I_a}{U} \cdot 100 = \sqrt{3} \cdot I_a \cdot \sqrt{3} \frac{R \cdot I_a}{\sqrt{3} \cdot I_a \cdot U} \cdot 100 = \frac{\Delta P}{P} \cdot 100 \tag{7}$$

where: R - is the resistance of LV distributor/section; I_a – active current that flow through LV distributor.

According to (7) shows that the percentage of active power losses is approximately equal to the percentage of voltage losses, namely:

$$\Delta P,[\%] \cong \Delta U,[\%] \tag{8}$$

If active energy W distributed through a substation is also recorded by metering and also are measured voltage losses occurring in associated LV network, and their mean value respectively, can be assesed the percentage and absolute active energy losses, ΔW, in LV network, using the following relations:

$$\Delta W,[\%] \cong \Delta P \cdot \frac{\tau_P}{T_P} \;\; ; \; \Delta W \cong \Delta W \cdot W \; , \qquad (9)$$

It must be noted that for public LV networks, the ratio $\tau_P / T_P \approx 0.3$ and the fill factor of the load curve K_U has values usually ranged between 0.3 and 0.5.

When the LV distribution network has a tree configuration, showing portions/sections with different number of phases, the percentage power losses may be determined with the following relation:

$$\Delta U[\%] = \frac{U_{PT}^{jt} - U_{cap.ret.}}{U_{PT}^{jt}} \cdot 100 \qquad (10)$$

where: U_{PT}^{jt} - is the voltage phase value at the LV substation bar; $U_{cap.ret.}$ - the lowest voltage phase value at the end of distribution network (single or three phase).

Having in view the aforementioned, the percentage technical losses of active power under load can be assessed as:

$$\Delta P\,[\%] = k \cdot \Delta U\,[\%]. \qquad (11)$$

As regards the proportionality coefficient k from (11), depending on the structure of the analysed network and non-uniform load, can be considered approximately 0.75, in the case of approximate evaluation of power losses [3], [5], [6], [7].

Energy losses under load, which appear in normal optimized scheme of LV public distribution networks, can be determined by computing their characteristic seasonal summer and winter states, in working and rest days. Also, to increase the accuracy in losses determination, can be analysed the characteristic states for each month of year in four standard days.

In this case, the energy losses under load are determined for characteristic days, considered constant when they periodically repeated. The influence of irregularity factor due to connecting or disconnecting and load curve deviations of consumer from one day to another can be considered using the irregularity coefficients ($k_{z\,\mathrm{reg}}$), for daily operating states [2], [5].

The determination with good precision of power ($\Delta P(t)$) and energy (ΔW_{day}) losses is obtained by state repeated calculations, considering the active and reactive daily load curves in network nodes, as 24 hourly levels, for characteristic states analysed, namely:

$$\Delta W = \sum_{t=1}^{24} \Delta P(t) \qquad (12)$$

In the situation of the energy losses determination for a longer period of time (such as a year) is necessary monthly states analysis, in four standard days, respectively, and the annual energy losses are:

$$\Delta W_{\mathrm{year}} = \sum_{l=1}^{12}\sum_{k=1}^{4} n_{lk}\,\Delta W_{\mathrm{day}_{lk}} = \sum_{l=1}^{12}\sum_{k=1}^{4} n_{lk} \sum_{t=1}^{24} \Delta P_{lk}(t), \; (13)$$

where: n_{lk} - the number of k type standard days in monthly state l; $\Delta W_{\mathrm{day}_{lk}}$ – energy losses associated with k type standard day in monthly state l; $\Delta P_{lk}(t)$ – power losses on t level from k standard day, in monthly state l.

To use this power/energy losses calculation method it is necessary a simultaneous recording of active and reactive daily load curves, for all network nodes analysed, in characteristic daily states.

If in operation process is not possible for all network nodes these recordings, the daily load curves can be modelled using a database which contain [4]:

- ✓ the typical load profiles of various consumer categories for different months of the year and standard days;
- ✓ the standard structure of consumption from network nodes;
- ✓ a small number of information obtained through direct measurements in distribution network, such as: the measured current in node at any hour of the day and the daily active energy which flows through node.

In order to improve the load curves modelling accuracy, by using above described methodology, when a part of the load curves associated with the network nodes were established, they can be corrected to achieve the balance of hourly powers in a portion or whole distribution network analysed, and for the power and energy losses determination will be used the method of power/energy losses computation by repeated computations of the state, using load curves mathematical modeled [5], [7].

In the LV distribution networks developed case, the methodology above presented provides the energy losses evaluation with good precision, having the disadvantage that requires the calculation of a large number of hourly states. This drawback can be reduced through decomposition of the load curves from network nodes in a Fourier series, such as [4], [5]:

$$\begin{cases} P_i(t) = \overline{P}_i + \sum_{k=1}^{N} A_{ik}^{P} \sin\left(\frac{2k\pi}{T}\cdot t\right) + \sum_{k=1}^{N} B_{ik}^{P} \cos\left(\frac{2k\pi}{T}\cdot t\right), \\ Q_i(t) = \overline{Q}_i + \sum_{k=1}^{N} A_{ik}^{Q} \sin\left(\frac{2k\pi}{T}\cdot t\right) + \sum_{k=1}^{N} B_{ik}^{Q} \cos\left(\frac{2k\pi}{T}\cdot t\right), \end{cases} \qquad (14)$$

where: N - the number of harmonics taken into account in series development; t – number of hourly level from daily load curves; $\overline{P_i}$, $\overline{Q_i}$ – average values of active and reactive power from the i node daily load curve; A_{ik}^P, B_{ik}^P, A_{ik}^Q, B_{ik}^Q – Fourier coefficients corresponding to k harmonic, for active and, respectively, reactive power of node i.

In symmetrical normal steady state, for public distribution networks operating on radial or tree configuration, considering the load curves decomposed in Fourier series, the power losses under load on a network element with the resistance R can be computed using only loads average values or the Fourier coefficients of the different harmonics according to the relation:

$$\Delta W = \overline{\Delta P} \cdot T + \sum_{t=1}^{N} \left(\Delta P_k^{'} + \Delta P_k^{''} \right) \cdot T + \varepsilon_W \qquad (15)$$

where: $\overline{\Delta P} = R \dfrac{\overline{P}^2 + \overline{Q}^2}{U^2}$ is the active power losses due to active and reactive average loads flows; $\Delta P^{'} = \dfrac{R}{U^2}\left[\left(\dfrac{A_k^P}{\sqrt{2}}\right)^2 + \left(\dfrac{A_k^Q}{\sqrt{2}}\right)^2\right]$; $\Delta P^{''} = \dfrac{R}{U^2}\left[\left(\dfrac{B_k^P}{\sqrt{2}}\right)^2 + \left(\dfrac{B_k^Q}{\sqrt{2}}\right)^2\right]$ – power losses associated with k harmonic in two stationary state of the network nodes considering the following loads: $P_{ik}^{'} = A_{ik}^P / \sqrt{2}$; $Q_{ik}^{'} = A_{ik}^Q / \sqrt{2}$; $P_{ik}^{''} = B_{ik}^P / \sqrt{2}$; $Q_{ik}^{''} = B_{ik}^Q / \sqrt{2}$, respectively; ε_W – the error caused by neglecting the Fourier series harmonics with rank greater then N.

According to decomposition of load curves in Fourier series method, in LV distribution network, for computing the energy losses under load it is necessary to analyse the $2N+1$ operating states:

- ✓ One state for active and reactive loads from network nodes;
- ✓ Two stationary states for each harmonic considered.

From the made studies has been found that the error in losses evaluation under load is kept fewer than 2.5%, if in Fourier series development is considered only two harmonics [5].

Another methodology to compute the energy losses under load, which occur in public networks, supposes the knowledge or monitoring of active and reactive power flows in various elements of LV distribution network in analysed period. Also, it is necessary to know the relative dispersions $\beta^2(P)$ and $\beta^2(Q)$, compared with the average value, for active/reactive power of the daily load curves in standard days:

$$\begin{cases} \beta^2(P) = \dfrac{\frac{1}{n}\sum_{t=1}^{n}\left(P_i - \overline{P}\right)^2}{\overline{P}^2} = \dfrac{1}{n}\sum_{t=1}^{n}\left(P_i^* - 1\right)^2 \\ \beta^2(Q) = \dfrac{\frac{1}{n}\sum_{t=1}^{n}\left(Q_i - \overline{Q}\right)^2}{\overline{Q}^2} = \dfrac{1}{n}\sum_{t=1}^{n}\left(Q_i^* - 1\right)^2, \end{cases} \qquad (16)$$

where: n - the number of measurements during the analysed period; P_i, Q_i – active and, respectively, reactive power measured in i range; $\overline{P}$, $\overline{Q}$ – the P_i and Q_i average values measured during the analysis.

The use of technical active energy losses computation method through thermal or Joule effect, in LV distribution network elements requires the knowledge of relative dispersion values for active and reactive load of different consumer categories supplied from electricity distribution systems, in four standard days (Monday – Friday; Tuesday – Wednesday – Thursday; Saturday; Sunday and legal holidays) for each month of the year [4], [5].

By using the databases which contain daily curves or typical load profiles of different consumer categories, according with (16), the relative dispersion values for active and reactive load in annual characteristic state for different consumers were determined.

Using the losses computation methodology by thermal or Joule effect, the energy losses under load, for a year, which appear on a network element with R resistance, can be evaluated with the expression

$$\Delta W = \frac{R}{24U_n^2}\sum_{l=1}^{12}\sum_{k=1}^{4} N_{lk}\left\{W_{a_{lk}}^2\left[1+\beta_{lk}^2(P)\right] + W_{r_{lk}}^2\left[1+\beta_{lk}^2(Q)\right]\right\}10^{-3}, \qquad (17)$$

where: $W_{a_{lk}}$, $W_{r_{lk}}$ - the active and reactive energy flows in k type standard day, of the month l expressed in kWh and kVArh respectively; N_{lk} – number of k type standard days in month l, $\beta_{lk}^2(P)$, $\beta_{lk}^2(Q)$ – relative dispersion toward the average value of active and, respectively, reactive loads for k type standard day, in month l.

For the consumers supplied with electricity from public distribution networks through statistical processing of a large number of daily load curves, in the specialized literature [3], [4] are presented the relative dispersions corresponding to the urban/rural household and tertiary consumption (hotel, school, hospital, etc.). The presented method leads to satisfactory results in the accurate assessment of energy losses in public distribution networks, with percentage errors situated in the range ±3%…±3.5%.

3. CASE STUDY

In this paragraph, by using different mathematical models and methods in LV public networks a relatively large number of electrical networks, aiming to establish the level of these losses and to compare the results accuracy provided by different considered methods were analysed. For technical losses computation were used a specialised software application for each method specified in detail previously [3], [4], [5].

Thus, for LV networks analysed, depending on the available data obtained by monitoring the loads (*I, P, Q*) and energies, which are recorded by existing meters or by ALPHA three phase electronic meters installed in certain points of the network, and current intensity and voltage level at the LV substation bars, measured at a certain hour of analysed day, and at the niches of consumers supplied with electricity, the following variants for technical losses computation were considered:

A) Daily load curves of current, active and reactive power on each LV substation bars and each consumer niches supplied with electricity. These curves *(I(t), U(t), P(t), Q(t))* and daily energy W_{day} are recorded and stored using, generally, ALPHA three phase electronic meters. Having available, for computing, the daily load curves in the form of 24 hourly levels, technical losses were calculated with a specialized computer program, representing the most precise analysis variants from the results point of view, namely A_I and $A_{P,Q}$ variants.

B) Installation of active and reactive energy meters on each LV substation bars, on each consumer niches supplied with electricity and the current intensity measurement at a certain hour of the day, in the same points above mentioned. In this way, were available for computation, the active and reactive energies in 24 h and current intensity values for certain hour of the day, of each departure from substation and each consumer niches supplied from LV distribution networks.

The daily load curves for each network node were modelled using the typical load profiles of consumers; the structure consumption of nodes and daily active energy which flows through node was studied using variant B_{PTW}. Also, another B_{SFW} study variant was considered, when the daily load curves of the nodes were developed in Fourier series. Similarly, using intensities values were created two other versions of analysis, B_{PTI} and B_{SFI}. The load curves modelled in the four specified variants have been corrected to meet the balance of current, active and reactive power on each LV feeder, and on a whole distribution network analysed, respectively.

C) The installation of energy meters, in similar way as in *B* variant, where daily active and reactive energy on the consumer niches supplied from LV distribution network are available for computation. In this study (variant C_W) the losses in the network are determined according to available data and relative dispersions toward the average value of active and reactive loads, for each consumer categories.

D) The installation of voltage levels measuring and recording installations of the LV substation bars and every niche of consumers, and for computation was available the longitudinal voltage drops that occur on sections of LV distribution network. Using these voltage drops in percentage values and considering (8), were calculated daily technical losses of analysed network ($D_{\Delta U}$ variant).

E) By using the daily load curves parameters method, when the power losses at peak load duration were considered as indicated in a) variant, correspond to the exact variant of the input data. For the maximum load duration and for losses duration of different categories of household and tertiary sectors, have been used updated values for the year 2010 and these is the E_{MPCS} variant.

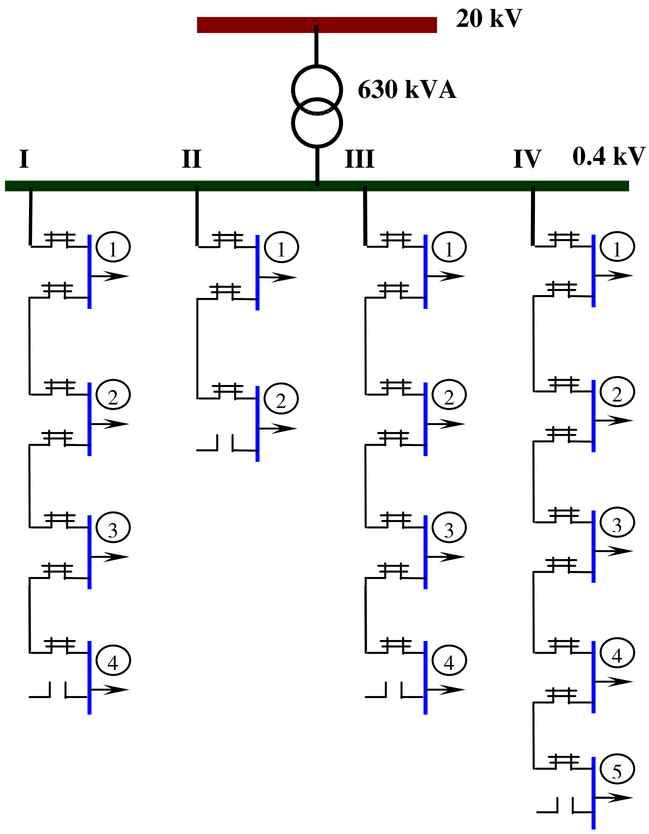

Fig. 1. Single line diagram of the analysed low voltage distribution network.

Must be mentioned that the database with the typical load profiles for different categories of households and tertiary consumers supplied with electricity from public distribution systems, in standard day, during a year, was updated in the 2009, 2010 and 2011 years.

In the following lines, the obtained results by using the software application developed to assess the power and active energy technical losses under symmetrical load, for all variants aforementioned are presented.

For this purpose a real LV public distribution network from Iasi county, corresponding to a 20/0.4 kV substation, with a rated apparent power of 630 kVA, which supplies with electricity a large number of urban households (309 apartments situated in blocks of flats) were analysed.

The single line diagram of the LV network is represented in Fig. 1. The power cables used at LV feeders' are ACYY with 3x150 mm^2 + 70 mm^2 and 3x240 mm^2 + 120 mm^2 sections.

LV distribution network power supplies 15 blocks of flats, each niches provided with four or eight floors, all apartments of these buildings are of A variant of endowment, after utilities namely: receivers equipped with appliances for lighting, food preservation, audio-visual, household activities and provide hot water, heating and cooking, through their central heating or with gas connection to the kitchen.

Public network analysed is carried out underground version, but operate in permanent normally steady-state in radial configuration and has four LV distributors.

For the power loss and daily energy losses computation of maximum daily load duration, by all methods previously mentioned, one simplified assumption for transversal active power losses which appear in LV power or force cables was adopted, neglecting also their variation with the voltage level in different hourly state.

From the power losses at peak load and daily energy losses point of view, these were computed for all standard days of June 2011. Below, for lack of space, are presented only the obtained results for a working day (Thursday) in all methods of computation above presented and for all options mentioned according to obtained data by measurements/recordings from analysed distribution network (A_I, $A_{P,Q}$, B_{PTW}, B_{SFW}, B_{PTI}, B_{SFI}, C_W, $D_{\Delta U}$, E_{MPCS}), which are the input data for each computation method.

In this way, in operation, by analysing the real and modelled daily load curves, it is possible to found easily that the differences between these load curves are relatively small and can be used, in practical calculation of power and energy losses.

By using as input data the real load curves recorded (A_I and $A_{P,Q}$ variants), the mathematical modelled daily load curves using typical load profiles (B_{PTW}, B_{SFW}, B_{PTI} and B_{SFI} variants), and active energies measured at each consumer niche (C_W variant), and using specialized software the power and daily energy losses for all sections of the network and for the total LV distribution network were determined.

For daily energy losses determination with the parameters of load curves method (E_{MPCS} variant), power losses at peak load were considered to be at 21 o'clock, from analysed day (Thursday) and as regards the losses duration have considered the specified values in the regulations of our country, for household consumers.

Table 1 presents the obtained results using the our software application, regarding the active power losses of the peak load, through thermal effect, from all sections of LV feeders, and for the entire network analysed, for a working day (Thursday) from June 2011, for all study variants above presented. Active power losses in peak load duration over a day are presented both in absolute (kW) and percentage (%) size reported to the maximum load of each feeder or to the entire LV distribution network analysed.

Table 1

Active Power Losses at Peak Load through thermal effect for a Working Day (June 2011)

Calculation Method	LV distributors (departures) of 20/0.4 kV substation								Entire LV network	
	Feder I		Feder II		Feder III		Feder IV			
	kW	%	kW	%	kW	%	kW	%	kW	%
$A_{P,Q}$	3.35	1.91	0.1378	0.45	0.4098	0.776	0.6099	1.104	4.5075	1.434
A_I	3.35	1.91	0.1379	0.45	0.4101	0.777	0.6101	1.104	4.5081	1.434
B_{PTW}	3.34	1.89	0.1372	0.45	0.4032	0.764	0.6049	1.095	4.4853	1.427
B_{SFW}	3.33	1.89	0.1368	0.44	0.4005	0.758	0.6016	1.089	4.4689	1.422
B_{PTI}	3.36	1.91	0.1386	0.45	0.4109	0.778	0.6111	1.106	4.5206	1.438
B_{SFI}	3.35	1.91	0.1378	0.45	0.4096	0.776	0.6098	1.104	4.5072	1.434
E_{MPCS}	3.35	1.91	0.1378	0.45	0.4098	0.776	0.6099	1.104	4.5075	1.434
$D_{\Delta U}$	3.02	1.71	0.1298	0.42	0.3965	0.751	0.5976	1.082	4.2121	1.340

Table 2

Daily Active Energy Losses through Thermal Effect in LV public distribution network for a Working Day (Thursday) from June 2011

Calculation Method	LV distributors (departures) of 20/0.4 kV substation								Entire LV network	
	Feder I		Feder II		Feder III		Feder IV			
	kW	%	kW	%	kW	%	kW	%	kW	%
$A_{P,Q}$	44.25	1.414	2.212	0.248	4.397	0.539	7.2201	0.811	58.079	1.015
A_I	44.26	1.415	2.211	0.248	4.401	0.540	7.2203	0.811	58.092	1.015
B_{PTW}	44.12	1.410	2.210	0.248	4.392	0.539	7.2199	0.811	57.942	1.012
B_{SFW}	44.01	1.407	2.206	0.248	4.389	0.538	7.2188	0.811	57.823	1.010
B_{PTI}	44.31	1.416	2.218	0.249	4.408	0.541	7.2211	0.811	58.157	1.016
B_{SFI}	44.25	1.415	2.211	0.248	4.399	0.540	7.2203	0.811	58.080	1.015
C_W	40.11	1.282	2.002	0.225	4.202	0.515	6.9071	0.776	53.116	0.928
E_{MPCS}	39.95	1.277	1.998	0.224	4.187	0.514	6.8212	0.766	52.956	0.925
$D_{\Delta U}$	36.81	1.177	1.865	0.209	3.985	0.489	6.7481	0.758	49.408	0.863

Similarly, in Table 2, the daily active energy losses by thermal effect for working day (Wednesday) from June 2011 are presented. These energy losses values are presented both in absolute (kWh) and percentage (%) values reported to active energy which flow on each feeder of network in a day or the daily active energy which flows across the LV network analysis.

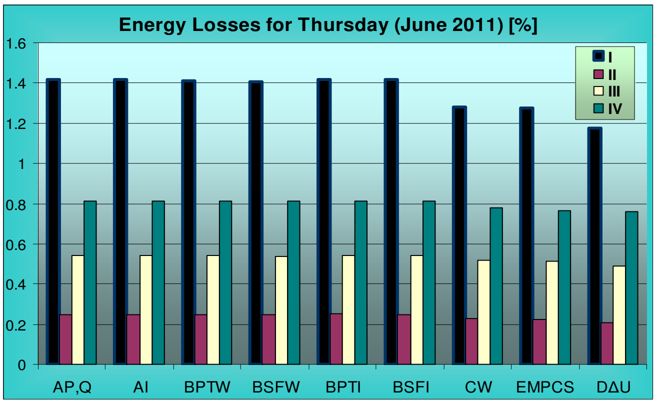

Fig. 2. The Daily Energy Losses for Thursday (June 2011) using Different Mathematical Models for the LV network (Fig. 1)

For a comparative analysis of all the computation methods (small, acceptable or large errors) described in the previous paragraph, in Fig. 2 are presented the percentage values of the daily energy losses, for the four feeders (I, II, III and IV) of the LV network from Fig.1. These values are for a working day (Thursday).

4. CONCLUSIONS

In the paper is performed a comparative analysis between different mathematical models and computation methods, based on available data for each node of the LV distribution network analysed, taking into account the currently low level monitoring in LV public distribution networks of the load or load curves in our country.

From the analysis of results shown in Tables 1 and 2, concerning the active technical power losses and energy losses computation at peak load for a day in a public low voltage distribution network, the following conclusions may be drawn:

- In technical power and energy losses determination compared with the ideal situation when knowing the real load curves (current, active power, reactive power) appropriate $A_{P,Q}$ and A_I variants small errors are obtained by mathematical modelling of daily load curves from distribution network nodes, using typical load profiles of consumers, as hourly levels or decomposed in Fourier series, namely B_{PTW}, B_{SFW}, B_{PTI} and B_{SFI} variants (Fig. 2).
- Practically, acceptable error in technical energy losses evaluation can be obtained using C_W study variant (Fig. 2).
- Between all options studied regarding the technical power and energy losses evaluation, the less accurate (Fig. 2) have been proved the daily load curve parameters method (E_{MPCS}) and the method by which the percentage values of technical active power losses are considered approximately equal with the percentage of longitudinal voltage drops ($D_{\Delta U}$).

BIBLIOGRAPHY

[1] **Ramachandra Murthy**, **Ramalinga Raju**, *Electrical Energy Loss in Rural Distribution Feeders – A Case Study*, ARPN Journal of Engineering and Applied Sciences, vol. 4, no. 2, pp. 33-37, 2009.

[2] **Georgescu Gh., Gavrilaş M., Rădăşanu Daniela**, *Calculul şi reducerea pierderilor de energie în reţelele electrice*, Edit. Spectrum, Iaşi, 1997.

[3] **Albert H**. et al., *Pierderi de putere şi energie în reţelele electrice*, Edit. Tehnică, Bucureşti, 2000.

[4] **Georgescu Gh.**, **Poeată A.**, **Brumă N.**, *et al.*, *Analiza statistică-probabilistică a sarcinilor din nodurile reţelelor de distribuţie.Bază de date. Programe software specializate*, Rev. Prod. Transp. şi distr. ener. el. şi term., 8-9, 30-36, (2001).

[5] **Georgescu Gh.**, *Sisteme de distribuţie a energiei electrice*, Vol. *1*, Edit. Politehnium, Iaşi, 2007.

[6] **Neagu B.**, **Georgescu Gh.**, **Guşă M.D.**, *Mathematical Methods for Technical Active Power and Energy Loss Evaluation in Operation Using Typical Load Profiles of the Consumers from Repartition Systems,* 4th International Conference on Power Systems – MPS 2011, Cluj-Napoca, 2011.

[7] **Neagu B.**, **Georgescu Gh.**, **Guşă M.D.**, *Load Curves Characteristics of Consumers Supplied From Electricity Repartition and Distribution Public Systems,* Bul. Instit. Politehnic Iaşi, *LVII*(*LXI*), fasc. 1, 2011.

[8] **Ionescu T.-G., Pop Olga**, *Ingineria sistemelor de distribuţie a energiei electrice*, Edit. Tehnică, Bucureşti, 1998.

About the authors

Eng. **Bogdan-Constantin NEAGU,** PhD Student
”Gheorghe Asachi” Technical University of Iaşi, Electrical Engineering Faculty.
email:bogdan.neagu@ee.tuiasi.ro

He was born in Roman, Romania, on July 4, 1984. He graduated the “Vasile Sav” High School in Roman, in 2003, and the Technical University “Gheorghe Asachi” of Iasi, Faculty of Electrical Engineering, Power Systems study program, in 2008. Currently he is Ph.D. student in the same faculty and his research interests are in power system optimization, electric energy transmission and distribution, design and operation of power system, load profiling and forecast.

.

Prof. Eng. **Gheorghe GEORGESCU**, PhD.
”Gheorghe Asachi” Technical University of Iaşi, Electrical Engineering Faculty, Power Department, Iaşi, România.
email:georgescu@ee.tuiasi.ro

He was born in Romania, on January 13, 1949. He received the M.Sc. and Ph.D. degrees from the Technical University “Gheorghe Asachi” of Iasi, Romania, Faculty of Electrical Engineering, in 1971 and 1983 respectively. Currently he is Professor in the Electrical Engineering Faculty of Technical University “Gheorghe Asachi” of Iasi. His research interests are power systems structure and exploitation states optimization, artificial intelligence techniques in power system, power quality, load modelling and forecast, electric energy transmission and distribution networks.