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OPPORTUNITIES EVALUATION IN OPERATION OF THE TECHNICAL LOSSES UNDER LOAD FROM LOW VOLTAGE NETWORKS WHICH OPERATE IN SYMMETRIC STATE

BY

GH. GEORGESCU[*] and BOGDAN NEAGU

“Gheorghe Asachi” Technical University of Iaşi
Faculty of Electrical Engineering, Energetics and Applied Informatics

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Abstract. Some mathematical models and software application to evaluate power and energy losses of the low voltage (LV) public distribution networks elements are presented. Are reviewed classical mathematical models based on the typical load profiles of different consumer categories, the decomposition in Fourier series of these types of load profiles, longitudinal drop voltage, etc. Are also presented the results obtained using different mathematical models, accompanied by observations and conclusions.

Key words: technical power losses; typical load profile; Fourier series.

1. Introduction

The public distribution of electric energy is realized, in our country, through two voltage levels: MV (medium voltage – 6, 10, 20 kV) and LV (low voltage – 400 V). MV and LV public distribution networks are highly developed and through these networks are supplied with electric energy a total of about 8,358,500 small consumers, of which 8.35 million LV power contracted less than 100 kW, and the remaining 8,500 at MV with contracted power over 100 kW.

[*] Corresponding author: *e-mail*: georgescu@ee.tuiasi.ro

Regardless of the constructive structure, and the network layout respectively – radial, tree or meshed – LV public distribution networks work usually in trees or radial schemes, operating conditions due to simplifying and reducing the investment with switching, protection and automation devices. LV distribution systems consist, generally, of electrical networks with four conductors, characterized by the star connection, with null to earth as regards power sources (Albert *et al.*, 1997; Gavrilă, 1994; Georgescu, 2007; Ruduick, 1996; EDF, 1995).

It should be mentioned that in the National Power System structure are several thousand lines or LV distributors. Considering the main characteristics of these distribution networks, practical impossibility of storage and process of entire amount of topological and material information 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 (Albert *et al.*, 2000; Georgescu *et al.*, 1997; Georgescu, 2007; EDF, 1995).

2. The Main Ways to Obtain Information Needed to Assess Technical Losses under Load in Public LV 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 electric energy one LV network, through which are supplied 50…250 small consumers, having as purpose to determine loading different LV network components, can be used, in practice, the following main ways (Albert *et al.*, 2000; Georgescu, 2007; Neagu *et al.*, 2011): 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 the MV/LV station and its division in segments or sections of LV distribution network corresponding to the electric energy sold to consumers; the simultaneity factors usage for different consumer categories supplied from LV networks, depending on the number and characteristics of each consumer; the correlation usage between maximum power and daily or monthly active energy, consumed by different types of electrical receivers; measurement of difference between the energy injected into LV network and power recorded of energy meters installed at customers, LV recorder energy of MV/LV station bars and the voltage recorder both at LV substation feeders and customers which are supplied with electric energy, etc.

3. The Evaluation in Operation of Technical Losses Level under Load from Public LV Distribution Networks with Deterministic Methods

The energy losses estimation under load in operation process, which appear in LV, MV network components, can be made by using load curve parameters method (LCPM). For radial or tree configuration distribution networks, the obtained results by using LCPM are favourable for practical calculations made in operation.

In specialized literature (Albert *et al.*, 2000; Ionescu *et al.*, 1998), from the ranked load curves analysis, but also from the large number of records made by electronic three-phase metering ALPHA (Georgescu, 2007), for the public network has been determined dependencies as

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

where: P_* , Q_* are the active, respectively reactive power, in relative units, related to the maximum load; *α, β* – coefficients derived from regression processes for each consumer category supplied with electric energy through LV feeders.

By considering relation (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 corresponding of active and reactive power losses can be evaluated using the following expressions:

$$\tau_{P_*} = \left(0.7T_{P_*} + 0.3\right)T_{P_*}\,; \quad \tau_{Q_*} = \left(0.7T_{P_*}^{\beta} + 0.3\right)T_{P_*}^{\beta}\,. \tag{2}$$

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

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

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

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

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

Based on the above considerations, namely, by using the LCPM, active energy losses under load, in operation process, will be able to be evaluated, depending on the maximum loads considered (power/current), as follows:

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

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

To increase the precision of the results concerning the evaluation of energy losses that occur in public LV distribution networks in the literature (Albert *et al.*, 2000; Georgescu *et al.*, 1997; Georgescu, 2007; EDF, 1995), 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% (Albert *et al.*, 2000; Georgescu *et al.*, 1997; Neagu *et al.*, 2011).

In the case of public LV distribution networks, evaluation with acceptable accuracy of percentage power losses can be achieved by using percentage values of measured voltage loss ($M\Delta U$) 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 written the following equality (Georgescu *et al.*, 2001; Poeată *et al.*, 1987):

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

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

According to (7) it results 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 voltage losses occurring in the LV network associated, and theirs mean values, respectively, are measured, can be assesed the percentage and absolute active energy losses, ΔW, that occur in LV network, using the following relations:

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

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 relation

$$\Delta U,[\%] = \frac{U_{PT}^{jt} U_{\text{cap.ret.}}}{U_{PT}^{jt}} \cdot 100, \tag{10}$$

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

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

$$\Delta P,[\%] = k \Delta U,[\%], \tag{11}$$

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 (Albert *et al.*, 2000; Gavrilă, 1994; Georgescu, 2007).

Energy losses under load, which appear in normal optimized scheme of LV public distribution networks, can be determined by calculating 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_{zreg}), for daily operating states (Albert *et al.*, 1997; Georgescu, 2007).

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

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

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

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

where: n_{lk} is the number of k type standard days in monthly state, l; $\Delta W_{\text{day}_{lk}}$ – 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 utilize this power/energy losses calculation method (ELCM) 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: the load type profiles of various consumer categories for different months of the year and standard days, the standard structure of consumption from network nodes and a small number of informations obtained through direct measurements in distribution network, such as the measured current in node at any hour of day, the daily active energy which flows through node (Georgescu *et al.*, 2001).

When a part of the load curves associated with network nodes were established by described methodology in order to improve the load curves modelling accuracy, 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 calculations of the regime, using load curves mathematical modeled (MCMM) (Georgescu, 2007; Neagu *et al.*, 2011).

In the LV distribution networks developed case, the methodology presented above provides the energy losses evaluation with good precision, having the disadvantage that it requires the calculation of a large number of hourly operating states. This drawback can be reduced through decomposition of the load curves from network nodes in a Fourier series (DLCFS), such as (Georgescu *et al.*, 2001; Georgescu, 2007)

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

where: N is 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.

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

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

where

$$\overline{\Delta P} = R \frac{\overline{P}^2 + \overline{Q}^2}{U^2}$$

is the active power losses due to active and reactive average loads flows;

$$\Delta P^{'} = \frac{R}{U^2}\left[\left(\frac{A_k^P}{\sqrt{2}} \right)^2 + \left(\frac{A_k^Q}{\sqrt{2}} \right)^2 \right]; \;\; \Delta P^{"} = \frac{R}{U^2}\left[\left(\frac{B_k^P}{\sqrt{2}} \right)^2 + \left(\frac{B_k^Q}{\sqrt{2}} \right)^2 \right]$$

– power losses associated with k harmonic in two stationary state of the network nodes considering the following loads: $P_{ik}^{'} = A_{ik}^{P} \big/ \sqrt{2}$; $Q_{ik}^{'} = A_{ik}^{Q} \big/ \sqrt{2}$; $P_{ik}^{"} = B_{ik}^{P} \big/ \sqrt{2}$; $Q_{ik}^{"} = B_{ik}^{Q} \big/ \sqrt{2}$, respectively; ε_W – the error caused by neglecting the Fourier series harmonics with rank greater then N.

According to the mathematical model above described (DLCFS), 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 and twin stationary states for each harmonic considered.

From performed 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 (Georgescu, 2007).

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 and reactive power of the daily load curves in characteristic days

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

where: n is 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.

By using this method of technical active energy losses calculation by thermal or Joule effect (MWβ), in LV distribution network elements, requires knowledge of relative dispersion values for active and reactive load of different consumer categories supplied from electricity distribution systems, in standard four days for each month of the year (Georgescu *et al.*,2001; Georgescu, 2007).

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

Using this methodology (MWβ), the energy losses under load, for a year, which appear in 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: $W_{a_{lk}}$, $W_{r_{lk}}$ are 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 (Georgescu *et al*., 1997, 2001) 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%.

4. Case Example, Results and Comparisons

Using different mathematical models and methods for computing technical losses in LV public networks were analysed a relatively large number of electrical networks, aiming to establish the level of these losses and to compare the results provided by different considered methods. For technical losses computation were used a software application for each method specified in detail previously (Georgescu *et al*., 1997, 2001; Georgescu*,* 2007; Poeată *et al.*, 1987).

In this way, for LV networks analysed were considered the following variants for technical losses computation, 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:

a) Daily load curves of current, active and reactive power, respectively, on each LV substation bars and each consumer niches supplied with electric energy. These curves ($I(t)$, $U(t)$, $P(t)$, $Q(t)$) and daily energy (W_{day}) were recorded and stored using, generally, ALPHA three phase electronic meters. Having available, for computing, the daily load curves (*I, P, Q*) 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 electric energy 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_{PT}. Also, another B_{SF} 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 relation (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.

It must to underline that the database containing the typical load profiles for different categories of households and tertiary consumers supplied with electric energy from public distribution systems, in standard day, during a year, was updated in the years 2009 and 2010.

In what follows are presented 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. For this purpose were analysed an existing LV public network, 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). The single line diagram of the LV network analysed with topological and material parameters is represented in Fig. 1. The power cables used at LV feeders realization are ACYY with 3×150 mm^2 + 70 mm^2 and 3×240 mm^2 + 120 mm^2 sections.

LV distribution network power supplies a number of 15 blocks of flats, each with 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 in underground version, but operate in permanent normally steady-state in radial configuration and has four LV distributors.

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

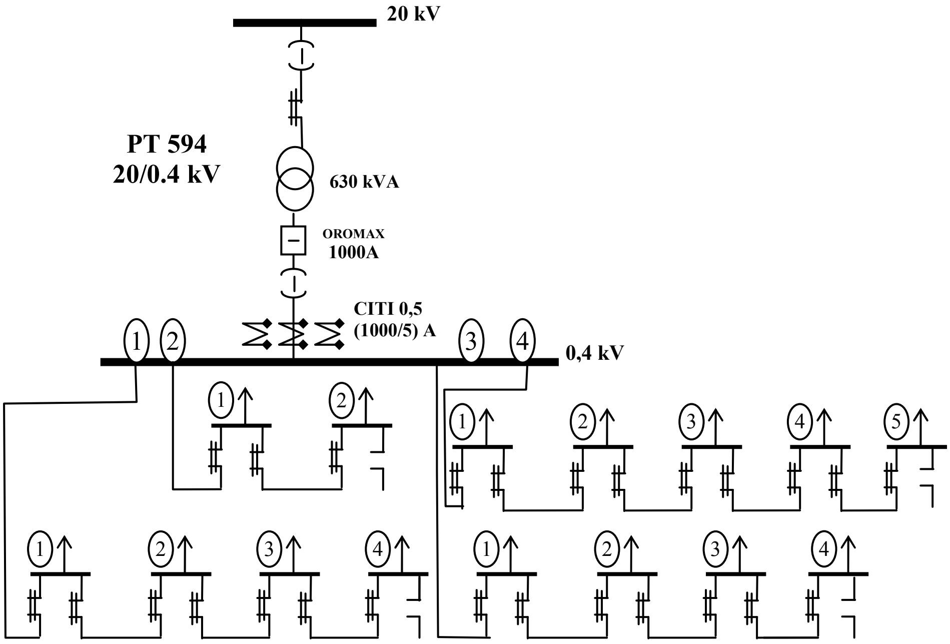

Fig. 1 – Single line diagram of the analysed LV distribution network.

As regards the power losses at peak load and daily energy losses, these were computed for all standard days of June 2011. For lack of space, below are clearly presented only the obtained results for a working day (Wednesday) 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.

For example, in Fig. 2 are represented the real P (Fig. 2 *a*), Q (Fig. 2 *b*) and I (Fig. 2 *c*) daily curves recorded on 24 hourly levels for a single LV distributor, namely 954 departures. However, the same figures presents daily load curves (I, P and Q) which were mathematically modelled using consumer typical load profiles, consumption structure of nodes and direct measurements made in the network: the current of certain hour of day or daily energy through the node.

Analysing the real and modelled daily load curves (Fig. 2), it is possible to found easily that the differences between these load curves are relatively small and can be used, in this way, in practical calculation of power and energy losses in operation.

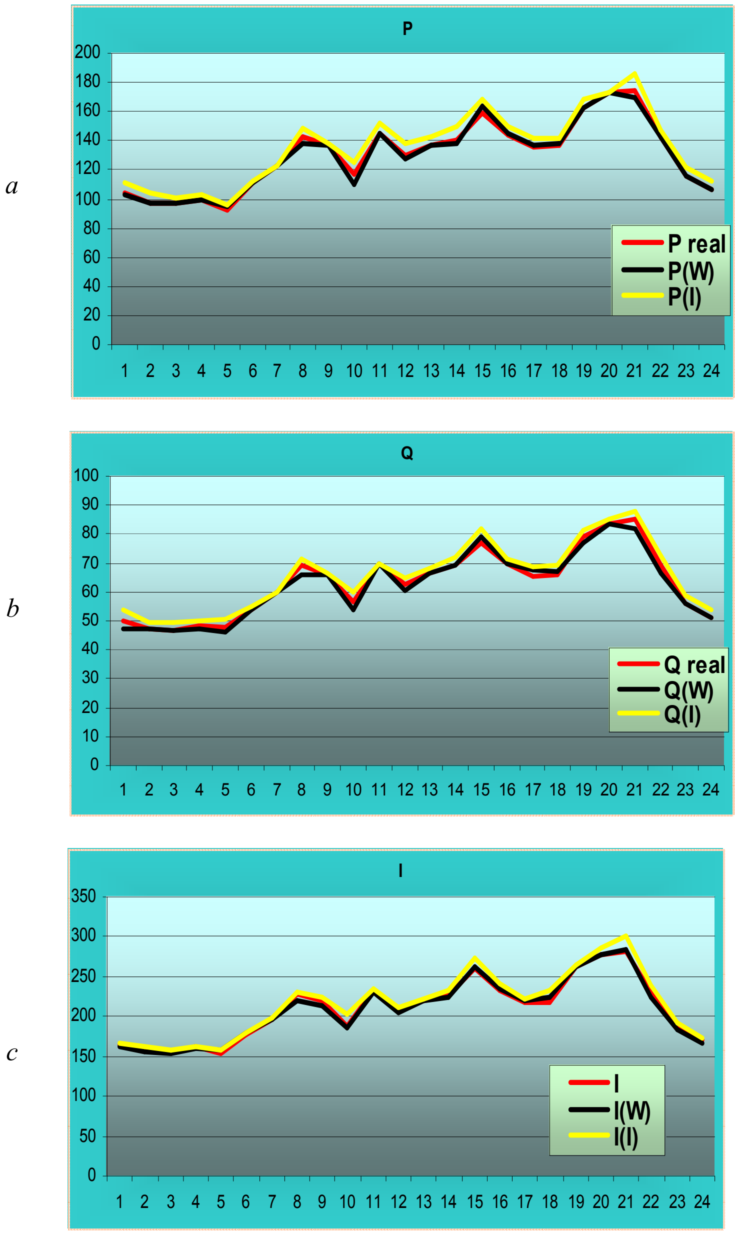

Fig. 2 – Real daily load curves (*P, Q, I)* obtained by recordings for 954 feeders (departure).

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 were determined the power and daily energy losses for all sections of the network and for the total LV distribution network. To 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 and as regards the losses duration were considered values specified in the regulations of our country, for household consumers.

Table 1

Active Power Loss at Peak Load on a Working Day from June 2011

Disponible data variant calculation method	Distribution network elements	LV distributors (departures) of 594 substation								Total LV distribution network	
		Departure Bl 954		Departure Bl 957		Departure Bl 980		Departure Bl 679			
		kW	%	kW	%	kW	%	kW	%	kW	%
$A_{P,Q}$	Feeder sections	3.35	1.91	0.1378	0.45	0.4098	0.776	0.6099	1.104	4.5075	1.434
A_I	Feeder sections	3.35	1.91	0.1379	0.45	0.4101	0.777	0.6101	1.104	4.5081	1.434
B_{PTW}	Feeder sections	3.34	1.89	0.1372	0.45	0.4032	0.764	0.6049	1.095	4.4853	1.427
B_{SFW}	Feeder sections	3.33	1.89	0.1368	0.44	0.4005	0.758	0.6016	1.089	4.4689	1.422
B_{PTI}	Feeder sections	3.36	1.91	0.1386	0.45	0.4109	0.778	0.6111	1.106	4.5206	1.438
B_{SFI}	Feeder sections	3.35	1.91	0.1378	0.45	0.4096	0.776	0.6098	1.104	4.5072	1.434
E_{MPCS}	Feeder sections	3.35	1.91	0.1378	0.45	0.4098	0.776	0.6099	1.104	4.5075	1.434
$D_{\Delta U}$	Feeder sections	3.02	1.71	0.1298	0.42	0.3965	0.751	0.5976	1.082	4.2121	1.340

Thus, in Table 1 are presented the obtained results using the 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 (Wednesday) from June 2011, for all study variants above presented. Active power losses in peak load duration over a day are presented both in absolute size (kW) and in percentage (%) reported to the maximum load of each feeder or to the entire LV distribution network analysed.

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

Table 2

Daily Active Energy Losses through Thermal Effect, in Public Distribution Elements for a Working Day (Wednesday) from June 2011

Disponible data variant calculation method	Distribution network elements	LV distributors (departures) of 594 substation								Total LV distribution network	
		Departure Bl 954		Departure Bl 957		Departure Bl 980		Departure Bl 679			
		kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
$A_{P,Q}$	Feeder sections	44.25	1.414	2.212	0.248	4.397	0.539	7.2201	0.811	58.079	1.015
A_I	Feeder sections	44.26	1.415	2.211	0.248	4.401	0.540	7.2203	0.811	58.092	1.015
B_{PTW}	Feeder sections	44.12	1.410	2.210	0.248	4.392	0.539	7.2199	0.811	57.942	1.012
B_{SFW}	Feeder sections	44.01	1.407	2.206	0.248	4.389	0.538	7.2188	0.811	57.823	1.010
B_{PTI}	Feeder sections	44.31	1.416	2.218	0.249	4.408	0.541	7.2211	0.811	58.157	1.016
B_{SFI}	Feeder sections	44.25	1.415	2.211	0.248	4.399	0.540	7.2203	0.811	58.080	1.015
C_W	Feeder sections	40.11	1.282	2.002	0.225	4.202	0.515	6.9071	0.776	53.116	0.928
E_{MPCS}	Feeder sections	39.95	1.277	1.998	0.224	4.187	0.514	6.8212	0.766	52.956	0.925
$D_{\Delta U}$	Feeder sections	36.81	1.177	1.865	0.209	3.985	0.489	6.7481	0.758	49.408	0.863

5. Conclusions

Considering the low level monitoring in LV public distribution networks of the load (*I, P, Q*) or load curves which currently exists in our country, 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.

From the analysis of the results presented in Tables 1 and 2, concerning the technical power losses computation at maximum load (peak load) and energy losses for a day in a public LV distribution network, the following conclusions may be drawn:

a) Small errors 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 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.

b) Acceptable error in technical power and energy losses determination, practically, can be obtained using C_W variant.

c) Between all options examined regarding the technical power and energy losses determination, the less accurate 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 ($D_{\Delta U}$).

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POSIBILITĂŢI DE EVALUARE ÎN EXPLOATARE A PIERDERILOR TEHNICE ÎN SARCINĂ ÎN REŢELELE DE JOASĂ TENSIUNE ÎN REGIMURILE SIMETRICE

(Rezumat)

În funcţie de datele disponibile sunt prezentate o serie de modele matematice şi programe de calcul destinate evaluării pierderilor de putere şi energie în sarcină, care apar în elementele componente ale reţelelor publice de distribuţie de joasă tensiune. Sunt trecute în revistă atât modele matematice tradiţionale, cât şi modele matematice recente, bazate pe utilizarea curbelor sau profilelor tip de sarcină ale diferitelor categorii de consumatori, precum şi descompunerea în serii Fourier a acestor profile tip de sarcină etc. Totodată, sunt prezentate în detaliu rezultatele obţinute cu ajutorul diferitelor modele matematice, toate fiind însoţite de observaţii şi concluzii.