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THE EVALUATION OF ACTIVE POWER LOSSES IN LOW VOLTAGE DISTRIBUTION SYSTEMS OPERATED IN DISTORTING STEADY STATE

BY

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Abstract. Low voltage public distribution systems supply large numbers of residential consumers and a much lower number of industrial consumers, which draw relatively low power quantities. Generally, these consumers are non-linear and with an unbalanced distribution on the three circuit phases. In this paper, after analyzing metered data and computed results following an extended measurement campaign carried out on a large number of low voltage feeders, it was confirmed that in this type of network, the real operating conditions are distorted and unbalanced. The most frequent voltage and current harmonics were computed as percent values from the fundamental wave amplitude. Also, the quality of the supply for these types of network was assessed, together with the added power losses due to the distorted state in transformers and feeders, and the increasingly higher neutral wire currents.

Key words: electricity distribution networks; distorted states; power losses.

1. Introduction

In Romania, the electricity distribution networks are operated at two voltage levels, namely at medium voltage (MV) – 6, 10, 20 kV and low voltage

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(LV) – 400 V. In today's operating conditions, brought by the deregulated electricity market, the development and upgrading of distribution networks and the restructuring of existing networks, is becoming increasingly necessary, after the pronounced shift of consumption seen in the last years from the MV to the LV level. The estimate number of final consumers supplied by the public distribution networks is impressive (around 9,000,000), according to the data published by ANRE: 8,380,000 residential consumers; 20,000 public or big non-residential consumers; 600,000 medium and small non-residential consumers (Georgescu *et al.*, 2001; Georgescu *et al.*, 2008). On the other hand, requirements regarding the quality of the supply service, increasing the transmission capacity, reducing active power losses and increasing delivery efficiency have become tougher.

The active power losses inevitably occur in any network element and increase together with the network delivery capacity. Loss reduction is a primary concern for a rational or optimal operation of distribution networks, being a key concern for both regional distribution utilities and consumers.

The local distribution systems consist mainly from three-phase underground or overhead lines, using in general the four wire technology, with three active phases and one neutral wire. Also, these network use a star connection, with grounded neutral.

By adopting simplifying assumptions, most theoretical studies and analyses consider ideal conditions for network operation, electricity being generated, delivered and used with constant frequency and perfectly sinusoidal voltage and current waves. However, because of physical, structural, technological and economic limitations, these operation conditions are not achievable. The real operating state is a distorting state, in which harmonic components are present besides the fundamental wave (Chicco *et al.*, 2011; Golovanov *et al.*, 2003; Hanzelka *et al.*, 2004; Neagu *et al.*, 2012).

On the other hand, LV distribution systems supply a significant number of three-phase and two-phase unbalanced consumers, with relatively large consumption, and a very large number of single phase consumers with low consumption, usually with an unbalanced distribution on the three active phases.

Taking into account these aspects, it becomes certain that electricity distribution networks are operated in real or distorted states and, at the same time, unbalanced. For these reasons, in steady operation conditions, the cureewnts on the three phases are unbalanced and distorted, while the neutral wire current is a magnitude greater than zero. Actually, the neutral wire current is the sum of the three phase currents.

In such distorted and unbalanced states, several negative effects will certainly appear, which have been thoroughly studied in the literature. It is considered that the neutral wire current flows are "the meeting place of all negative consequences" which occur in these operating states of electricity distribution systems (Chicco *et al.*, 2011; Eremia *et al.*, 2006; Golovanov *et al.*, 2007; Georgescu *et al.*, 2008; Neagu *et al.*, 2012).

In this paper were analyzed only aspects concerning the increase or appearance of additional active power losses in LV distribution systems which are normally operated in distorting states for the most part of the year.

2. A Mathematical Model for Computing Active Power Losses in LV Distribution Systems Operated in Distorted Steady State

The notion of “harmonic wave” was first introduced by J.B.J. Fourier. Actually, it has its origins in the study of acoustic waves, where it denotes a vibration occurring in a chord, which accompanies the fundamental vibration, having the same nature, but a frequency which is a multiple integer of the fundamental vibration. Similarly, voltage and current harmonics are defined in electrical engineering as any electrical signal which has the frequency equal to an integer multiple of the fundamental wave generated at 50 or 60 Hz (Chicco *et al.*, 2011; Eremia *et al.*, 2006; Georgescu *et al.*, 2008; Hanzelka *et al.*, 2004).

In the literature (Eremia *et al.*, 2006; Georgescu *et al.*, 2008), for studying the steady distorting states, the harmonic analysis is used, which, mainly consists of the computation of phases and magnitudes of the fundamental wave and of the components which are integer multiples of the fundamental wavelength that propagate in an electrical network.

If a periodic function denoted with $\alpha(t)$ can be represented over a period as a piecewise smooth function, then it can be decomposed in a trigonometric series of the following type:

$$\alpha(t) = A_0 + \sum_{n=1}^{\infty} B_{hm}\sin(h\omega t) + \sum_{k=1}^{\infty} C_{hm}\cos(h\omega t). \tag{1}$$

In which for $h = 1$ the equation of the fundamental wave is obtained, and for $h = 2, 3, 4, \ldots$ the corresponding order harmonics result. A_0, is a constant.

Since a trigonometric series is completely determined only when the A_0, B_{hm} and C_{hm}, coefficients are known, it follows that for determining these coefficients a harmonic analysis is used, namely:

$$A_0 = \frac{1}{T}\int_0^T \alpha(t)\,\mathrm{d}t;\quad B_{hm} = \frac{2}{T}\int_0^T \alpha(t)\sin(h\omega t)\,\mathrm{d}t;\quad C_{hm} = \frac{2}{T}\int_0^T \alpha(t)\cos(h\omega t)\,\mathrm{d}t. \tag{2}$$

It should be noted that, for some particular cases, it is more convenient to attach to a distorted signal a trigonometric series using the following notations:

$$\begin{aligned} \underline{\alpha}(t) &= \frac{1}{T}\int_{h=-\infty}^{+\infty} \alpha(\tau)\,\mathrm{e}^{\mathrm{j}h\omega(t-\tau)}\,\mathrm{d}\tau, \\ \underline{\varphi}(\mathrm{j}h\omega) &= \frac{1}{T}\int_0^T \alpha(\tau)\,\mathrm{e}^{-\mathrm{j}h\omega\tau}\,\mathrm{d}\tau = \varphi(h\omega)\,\mathrm{e}^{\mathrm{j}\varphi(h\omega)}, \end{aligned} \tag{3}$$

where the complex function $\underline{\varphi}(\mathrm{j}h\omega)$ is called spectral amplitude, described by its magnitude $\varphi(h\omega)$ and argument $\phi(h\omega)$. For this type of approach, the $\underline{\varphi}(\mathrm{j}h\omega)$ function can be written as:

$$\underline{\phi}(\mathrm{j}h\omega) = \frac{1}{2}\left(C_{hm} - \mathrm{j}B_{hm}\right) = \frac{1}{2}A_{hm} = \frac{1}{2}A_{hm}\mathrm{e}^{\mathrm{j}\upsilon_{ah}}, \tag{4}$$

where A_{hm} is the magnitude (complex number), and $\upsilon_{ah} = \varphi(h\omega)$ is its argument (also a complex number).

Using these notations, $\underline{\alpha}(t)$ can be rewritten as:

$$\underline{\alpha}(t) = \frac{1}{T}\sum_{h\to-\infty}^{+\infty}\int_0^T \alpha(\tau)\mathrm{e}^{\mathrm{j}h\omega(t-\tau)}\mathrm{d}\,\tau = \sum_{h\to-\infty}^{+\infty}\underline{\phi}(\mathrm{j}h\omega)\mathrm{e}^{\mathrm{j}h\omega t} = \frac{1}{2}\sum_{h\to-\infty}^{+\infty}A_{hm}\mathrm{e}^{\mathrm{j}h\omega t}, \tag{5}$$

It follows that in steady distorted states, the voltages and currents can be written as:

$$u(t) = U_0 + \sum_{h=1}^{+\infty}U_{hm}\sin\left(h\omega t + \gamma_{uh}\right);\quad i(t) = I_0 + \sum_{h=1}^{+\infty}I_{hm}\sin\left(h\omega t + \gamma_{ih}\right), \tag{6}$$

In a three-phase electrical network with balanced load, operating in a sinusoidal state, the active power losses occurring in active can be computed with the following equation:

$$\Delta P_{\sin} = 3r_f I_1^2 \tag{7}$$

where r_f is the phase electrical resistance, and I_1 is the phase current flow.

If a LV three-phase distribution network is operated with balanced loads, but supplies nonlinear consumers, the steady operating state of that network will inevitably be distorted.

In the following paragraphs, for these situations, a number of cases or scenarios will be analyzed, which are considered to be the closest to the real operating conditions found in Romanian LV networks. For these scenarios, several simplifying assumptions were adopted, by not considering the skin effect and the variation of the electrical resistance of the phase and neutral wires when the frequency changes. Given the amplitude and range of the harmonic waves encountered most frequently in distribution networks, it is considered that using these simplifying assumptions and approximations in the mathematical model used for evaluating active power losses will result in acceptable errors in the final results.

Case I – the scenario when the current flowing through the phase wires contains the fundamental wavelength (I_1) and a third order harmonic (I_{3h}). It should be noted that the third order harmonics can also be found on the neutral wire (Chicco *et al.*, 2011; Neagu *et al.*, 2016).

The power losses that occur in the electrical network in this case can be computed using the following equation:

$$\Delta P_{\text{defor}} = 3r_f\left(I_1^2 + I_{3h}^2\right) + r_n\left(3I_{3h}\right)^2 \tag{8}$$

or with

$$\Delta P_{\text{defor}} = 3r_f\left[I_1^2 + (1+3\varphi)I_{3h}^2\right] \tag{9}$$

where: I_1 is the RMS current on the fundamental wavelength; I_{3h} – the RMS value of the current for the third order harmonic; r_n – the neutral wire electrical resistance; $\phi = r_n / r_f$ is the ratio between neutral and active phase resistance.

If (7) and (9) are compared, it can be seen that the relative increase of the losses in distorted state can be evaluated with an equation written as:

$$\varepsilon_{\Delta P} = \frac{\Delta P_{\text{defor}} - \Delta P_1}{\Delta P_1}\cdot 100[\%] \quad \text{or} \quad \varepsilon_{\Delta P} = (1+3\varphi)\gamma_{3h}^2\cdot 100[\%] \tag{10}$$

where: $\gamma_{3h} = I_{3h}/I_1$ is the weight of the third order harmonic in the fundamental wave.

Case II – the scenario when the current flowing through the phase wires contains the fundamental wavelength (I_1), a third order harmonic (I_{3h}) and another harmonic, which is not a three order ($I_{\neq 3h}$) and which is absent in the neutral wire. The relative increase of the losses in distorted state can be evaluated with the following equation:

$$\Delta P_{\text{defor}} = 3\left(I_1^2 + I_{3h}^2 + I_{\neq 3h}^2\right)r_f + \left(3I_{3h}\right)^2 r_n \tag{11}$$

or with

$$\Delta P_{\text{defor}} = 3\left[I_1^2 + I_{\neq 3h}^2 + (1+3\varphi)I_{3h}^2\right]r_f \tag{12}$$

In this case, the relative increase of the losses in distorted state can be evaluated with:

$$\varepsilon_{\Delta P} = \left(1 + 3\cdot\phi + \beta^2\right)\cdot\gamma_{3h}^2\cdot 100\ [\%] \tag{13}$$

where $\beta = I_{\neq 3h} / I_{3h}$ is the ratio between the harmonic which is not three order ($I_{\neq 3h}$) and the three order harmonic (I_{3h}).

Case III – the scenario when the current flowing through the phase wires contains the fundamental wavelength (I_1), a third order harmonic (I_{3h}), and two other harmonics $3h+1$ and $3h+2$, which are not three order harmonics, namely harmonics I_{3h+1} and I_{3h+2}. These two harmonics are not present in the neutral wire. With a reasoning similar to the first two cases, the relative increase of the losses in distorted state can be computed with the following equation:

$$\Delta P_{\text{defor}} = 3\left(I_1^2 + I_{3h}^2 + I_{3h+1}^2 + I_{3h+2}^2\right)r_f + \left(3I_{3h}\right)^2 r_n \tag{14}$$

or with

$$\Delta P_{\text{defor}} = 3\left[I_1^2 + I_{3h+1}^2 + I_{3h+2}^2 + (1+3\varphi)I_{3h}^2\right]r_f \tag{15}$$

the relative increase of the losses in distorted state can be evaluated with an equation written as:

$$\varepsilon_{\Delta P} = \left(1+3\varphi+\beta_1^2+\beta_2^2\right)\gamma_{3h}^2 \cdot 100[\%] \tag{16}$$

where $\beta_1 = I_{3h+1}/I_{3h}$ and $\beta_2 = I_{3h+2}/I_{3h}$ are the ratios between the harmonics which are not three order (I_{3h+1} and I_{3h+2}) and the three order harmonic (I_{3h}).

The operation of Romanian electricity distribution networks in steady distorted states was pointed out and analyzed in the literature (Chicco *et al.*, 2011; Chindriş *et al.*, 2005; Georgescu *et al.*, 2008; Neagu *et al.*, 2016), emphasizing on the decrease of the quality of supply for the consumers, the increase of power losses both in active an neutral wires ($\Delta P_{\text{supl}} = \Delta P_{\text{defor}} - \Delta P_{\text{sin}}$), and the significant increase of neutral wire currents in these networks.

3. Application Program for Computing Active Power Losses in LV Networks Operating in Distorted State

For automated computing of active power losses which occur in LV distribution networks operating in distorted states, the REDEF (Rețele Electrice în regim DEFormant) software was written, which allows for a complex analysis of operating scenarios which can appear in these electrical networks. The core mathematical model used for this application was described in the previous paragraph. The REDEF software was developed in the C# programming environment, with several subroutines controlled through a simple and flexible user interface, which is very easy to use in practice.

The accelerated technological evolution seen in the last decades in electronic devices, offline and online monitoring tools and computing power, faster communications tools and acquisition of more data, enabled the development and use of smart metering devices, which allowed monitoring, storing and transmission of state variables (voltages and currents) measured in LV distribution systems, which describe electrically the distorted operating states.

The input data required by the REDEF software are: the general parameters of the analyzed electrical network (type, topology, wire material, active and neutral wire length and cross section), measured electrical values or readings taken directly from the system (RMS current and voltage values on the three phases and the neutral wire, amplitudes for harmonics up to the 50th order measured in % from the fundamental wavelength for current and voltage)

After running the program, several results are displayed for active power (energy) losses in the network, as follows:

- ✓ Active power loss in sinusoidal steady state, in absolute values.
- ✓ Active power loss in distorted steady state, in absolute values, for each of the three cases described in this paper, with different combinations for harmonics of different orders measured in the system.

- ✓ The additional active power loses occurring in distorted operating states, in per unit values, with different combinations for harmonics of different orders measured in the system.

4. Case Study

Public LV urban distribution networks undergo a continuous and gradual upgrading process. They supply a low number of small industrial consumers and an increasingly larger number of residential consumers. Both consumer types, industrial and residential, use sophisticated electrical equipment which, among other inconveniences, generate distorting states and induce voltage and current harmonics in all operating states thorough all the year.

In order to analyze the quality of supply in public LV distribution networks and to point out their distorting operation states, a significant number of measurements and other recordings has been taken from real networks, in different locations and on several LV branches. For on-site measurements, the CA8334 (Chauvin Arnoux), analyzer was used. This device allows a full and complex analysis of the electricity supply, according to the SR EN 50160 and IEC 6100–4–30 standards. This analyzer can measure the following instantaneous electrical quantities: frequency (in Hz), line-to-line U_{rms} and line-to-ground V_{rms} RMS voltages, [V], active phase and neutral wire currents A_{rms}, [A], the phase active power P_{L1}, P_{L2}, P_{L3}, the three-phase active power P_{tot}, [W] and the similar quantities for reactive power, [Var] and apparent power, [VA], the power factor (PF) and tangent (tan) on each phase ant the three-phase values, the imbalance coefficients for voltage and current V_{unb} and A_{unb}, the RMS fundamental Vh01, [V] and harmonic voltages up to the 50th order (in percent of the fundamental wave amplitude), and similarly for the current fundamental wave (Vh01, [A]) and harmonics (Vh02…Vh50 in percent of the fundamental wave amplitude), the total harmonic distortion on each phase for line-to-line voltages U_{thd} and line-to-ground voltages V_{thd}, and the same for currents A_{thd}.

In this regard, for emphasizing the approach proposed in the paper and the capabilities of the REDEF software, a real LV distribution network connected to a MV/LV transformer was used. Its one-line diagram is given in Fig. 1, together with its relevant physical and electrical parameters (cable type, cross section and lengths). This LV distribution network has 6 feeders operated in a radial configuration and supplies multiple stories residential buildings, a food store, an office building and a mobile communication antenna. The placement of the analyzers is shown on the diagram, namely after the transformer LV side (1) and at the beginning of each feeder (2,…,7).

After analyzing the data obtained in an extensive measurement campaign with instantaneous and interval values, taken directly from LV networks belonging to E.ON Romania Distribuție with the aforementioned analyzers, and from the data presented in this paper, it is certain that that the operating states of these public distribution networks are unbalanced and distorting on all LV feeders tested during the measurement campaign.

As an example, in Fig. 2 is shown the evolution of the three order current harmonics at the LV side of the transformer (analyzer 1 from the one-line diagram), and in Figs. 3,…,5 is presented the fifth, seventh and eleventh order harmonics in the same location.

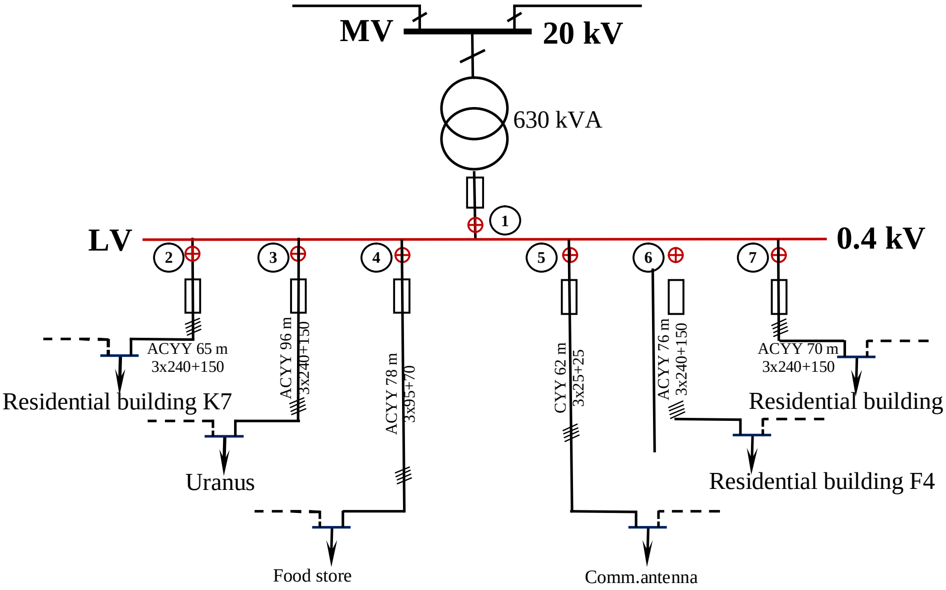

Fig. 1 – The one-line diagram of the MV/LV substation and LV distribution network.

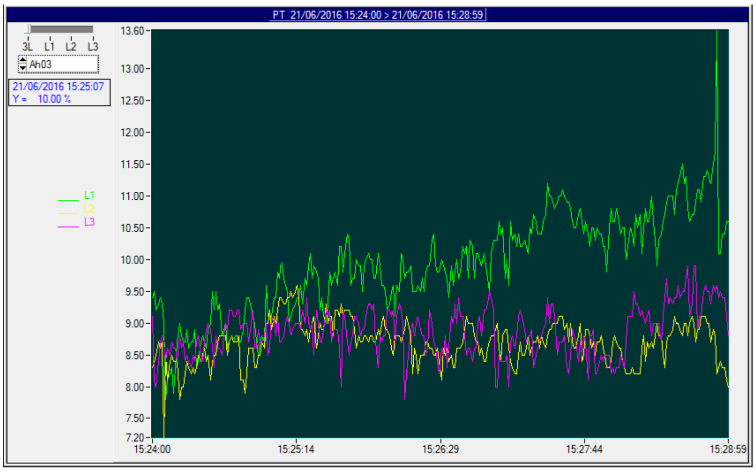

Fig. 2 – The third order harmonic at the LV side of the transformer.

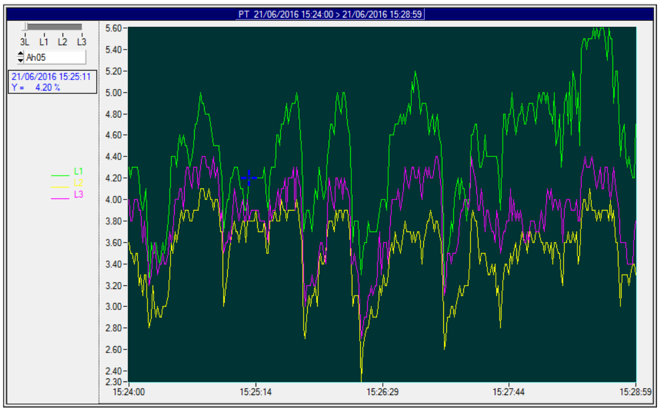

Fig. 3 – The fifth order harmonic at the LV side of the transformer.

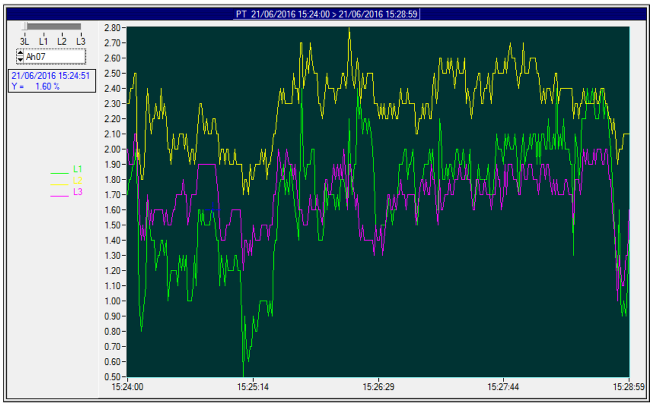

Fig. 4 – The seventh order harmonic at the LV side of the transformer.

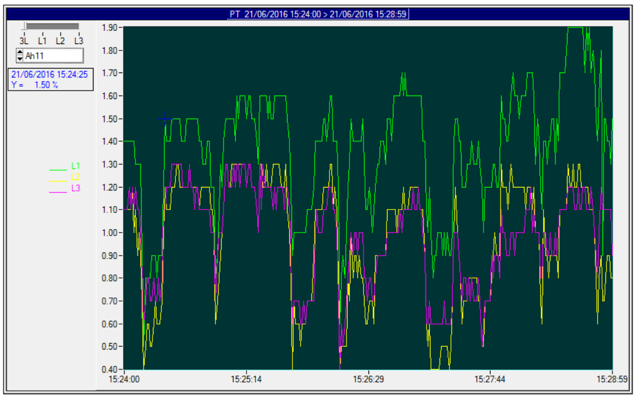

Fig. 5 – The eleventh order harmonic at the LV side of the transformer.

The data gathered during the measurement campaign carried out for evaluating the supply quality in LV distribution networks operating in unbalanced or distorting state has shown that the most significant voltage and current harmonics, measured in % out of the fundamental wave magnitude, are the odd order harmonics of third, fifth, seventh and eleventh order, and the even order harmonics of second and fourth order for current, and only odd order, third, fifth and seventh order, for voltage.

For the LV network used in the case study, by using the instantaneous state quantities measured with the analyzers placed in different points of the network as input data for the REDEF software, the additional power losses in the transformer windings and on the main six LV feeders were computed.

For computing the distorting state additional losses in the transformer windings, the following equation was used:

$$\Delta P_T = \left(I_{dL1}^2 + I_{dL2}^2 + I_{dL3}^2\right) R_T \tag{17}$$

where: R_T is the transformer resistance, while I_{dL1}, I_{dL2} and I_{dL3} are the instantaneous values of the residual distorting current on the three phases, computed at the LV busbar in the substation, with:

$$I_{dL1} = \sqrt{\sum_{h=2}^{50} I_{hL1}^2}; \quad I_{dL2} = \sqrt{\sum_{h=2}^{50} I_{hL2}^2}; \quad I_{dL3} = \sqrt{\sum_{h=2}^{50} I_{hL3}^2} \tag{18}$$

where: I_{hL1}, I_{hL2} and I_{hL3} are the instantaneous h-th order harmonic currents.

The additional transformer power losses in distorting states, computed using (17), have the value of 0.193 kW, which, according to equation (10) represent an approximatively 10.54% loss increase, compared to the ideal sinusoidal operating state.

It should be noted that the measurements were taken from the LV network on a working day, Tuesday, and the interval was not for peak load, because three of the six feeders supply residential buildings. The transformer loading was only

43.3%, and for summer residential peak load. at hours 21,…,23, the transformer load should be, according to tests, 60,…,68%. So, at peak load, the relative loss increase in distorting state will exceed 10.54%.

As for the additional active power losses that occur in distorting state on the first LV feeder sections, using the instantaneous harmonics measured in placement points (2,…,7) shown in Fig. 1, these were computed, for all the cases described in the paper, using besides the fundamental wave, combinations of the most present harmonics, as measured with the CA 8334 analyzer. In Tables 1,…,3, are given the results computed by the REDEF software regarding the additional active power losses in distorting state and the relative loss increase on all six feeders and for all analyzed cases.

Table 1

Additional Active Power Losses in Distorting State for Case I

Feeder											
2		3		4		5		6		7	
kW	%	kW	%	kW	%	kW	%	kW	%	kW	%
0.13	1.6	0.26	3.28	0.59	7.51	0.05	0.68	0.61	7.82	0.19	2.44

Table 2

Additional Active Power Losses in Distorting State For Case II in the Most Probable 4 Scenarios

Scenario	Feeder											
	2		3		4		5		6		7	
	kW	%	kW	%	kW	%	kW	%	kW	%	kW	%
1 (h_3+h_4)	0.126	1.606	0.257	3.280	0.589	7.511	0.054	0.686	0.613	7.818	0.192	2.444
2 (h_3+h_5)	0.149	1.896	0.263	3.354	0.608	7.749	0.056	0.708	0.629	8.020	0.221	2.820
3 (h_3+h_7)	0.132	1.680	0.262	3.342	0.598	7.621	0.057	0.724	0.624	7.949	0.199	2.536
4 (h_3+h_{11})	0.128	1.627	0.258	3.291	0.591	7.537	0.054	0.687	0.618	7.876	0.192	2.450

Table 3

Additional Active Power Losses In Distorting State for Case III in the Most Probable 10 Scenarios

Scenario	Feeder											
	2		3		4		5		6		7	
	kW	%	kW	%	kW	%	kW	%	kW	%	kW	%
1 (h_2+h_3+h_4)	0.129	1.643	0.258	3.282	0.591	7.528	0.063	0.802	0.614	7.821	0.193	2.460
2 (h_3+h_4+h_5)	0.149	1.898	0.263	3.354	0.608	7.750	0.056	0.711	0.629	8.021	0.221	2.821
3 (h_3+h_7+h_4)	0.132	1.681	0.262	3.342	0.598	7.621	0.057	0.728	0.624	7.949	0.199	2.537
4 (h_3+h_{11}+h_4)	0.128	1.628	0.258	3.291	0.591	7.537	0.054	0.690	0.618	7.876	0.192	2.451
5 (h_3+h_2+h_5)	0.152	1.933	0.263	3.356	0.609	7.766	0.065	0.824	0.630	8.023	0.223	2.836
6 (h_3+h_2+h_7)	0.135	1.717	0.262	3.344	0.599	7.637	0.066	0.841	0.624	7.952	0.200	2.552
7 (h_3+h_2+h_{11})	0.131	1.663	0.258	3.293	0.593	7.553	0.063	0.803	0.618	7.878	0.193	2.466
8 (h_3+h_5+h_7)	0.155	1.971	0.268	3.416	0.617	7.859	0.059	0.750	0.640	8.151	0.229	2.913
9 (h_3+h_5+h_{11})	0.151	1.918	0.264	3.365	0.610	7.775	0.056	0.713	0.634	8.078	0.222	2.827
10 (h_3+h_7+h_{11})	0.134	1.702	0.263	3.353	0.600	7.646	0.057	0.729	0.628	8.007	0.200	2.543

The analyzed LV distribution network is operated in a distorting unbalanced state, which leads to distorted currents containing multiple of three order harmonics, and zero sequence components. These currents are arithmetically summed, giving the neutral wire current. The average values of the instantaneous neutral wire currents registered in the measurement interval for the LV feeders shown in Fig. 1 are given in Table 4, together with the consumer type, neutral wire material and cross section and rated current.

Since the measurements recorded and presented in the paper were not taken in a peak load interval for residential consumers (feeders 2, 6 and 7), it is obvious that these rated currents will be higher that the currents measured on the residential feeders and given in Table 4.

Table 4
Average Neutral Wire Currents for the Six LV Feeders

Feeder no.	Consumer type	Wire cross section mm^2	Wire material	Rated current A	Average measured current, [A]
(2)	Residential building	150	Al	275	33.89
(3)	Supermarket	150	Al	275	85.43
(4)	Market	70	Al	175	92.72
(5)	GSM antenna	25	Cu	130	14.85
(6)	Residential building	150	Al	275	28.44
(7)	Residential building	150	Al	275	21.17

5. Conclusion

After an extended measurement campaign with instantaneous and interval recordings, using CA 8334 analyzers installed in different locations on LV distribution systems during a time period of one year, it was confirmed that these network operate in distorting unbalanced states. The most important current and voltage harmonics, measured in percent out of the fundamental wave, were identified, and they are:

a) Odd order harmonics: 3, 5, 7, 11 and even order harmonics 2 and 4, for current;

b) Odd order harmonics, 3, 5 and 7, for voltage.

For the LV distribution system analyzed in the paper, the relative active power loss increase in distorting state was assessed for the MV/LV transformer and on the LV distribution feeders, and it was found to be at 10 up to 18%, in the different cases considered for study, and in a measurement interval with does not match with the peak load times. It clearly results that, for all unbalanced and distorting operating states of LV distribution networks over a year, the relative loss increase will lead to a reduction of delivery efficiency in these networks.

On the other hand, in the same analyzed LV network, the operating state is unbalanced and distorting, which leads to distorted phase currents, containing harmonic currents with multiple of three orders, and also zero sequence components. These currents are arithmetically summed, resulting in neutral wire currents of significant magnitude on the LV feeders. Although the measurements campaign did not coincide with the peak load intervals for the measured consumers, the average values of the measured neutral wire currents were found to be high, with even higher values expected for the peak load intervals, which could approach the rated currents of the respective feeders.

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EVALUAREA PIERDERILOR DE PUTERE ACTIVĂ ÎN SISTEMELE DE DISTRIBUŢIE DE JOASĂ TENSIUNE CARE FUNCŢIONEAZĂ ÎN REGIM PERMANENT DEFORMANT

(Rezumat)

În prezent, reţelele de distributie de joasă tensiune alimentează un număr semnificativ de consumatori rezidenţiali şi un număr mai mic de consumatori industriali, care provoacă o calitate scăzută a energiei. În general, aceşti consumatori sunt neliniari şi nesimetrici pe cele trei faze. În lucrare, în urma analizei măsurătorilor efectuate şi a rezultatelor calculate din urma unei campanii de măsurători în reţelele de joasă tensiune, se confirmă apariţia inevitabilă a regimului deformant şi nesimetric. Cele mai întâlnite armonici de curent şi tensiune sunt determinate ca procent din valoarea fundamentalei. De asemenea, calitatea energiei electrice furnizate în aceste reţele a fost estimată, ţinând seama de pierderile suplimentare de putere activă datorate regimului deformant în liniile electrice şi în transformatoarele de putere, rezultând o încărcare suplimentară a conductorului de neutru al reţelei analizată.