The Pollution with Harmonics in Public Electric Energy Repartition and Distribution Systems

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Abstract—**Public repartition and distribution systems are responsible for supplying electrical power to home and third-party receivers and consumers located in a habitable area. The appearance of the distortion state in such distribution systems is inevitable under present technological conditions. In the paper are determined, based on records from 2000, 2005 and 2009 the parameters specific of the distortion state related to voltage and current, their evolving trend over a 5-year interval and 9-year interval, as well as their deviations from the norms imposed by our country's regulations. There are also presented the main steps and the technical means there can be taken for reducing the disruptive effects of harmonic pollution.**

Index Terms—**harmonics, distortion state, temporary evolution**

I. INTRODUCTION

In the last decades, the process of introducing power electronics in almost all the industrial branches, allowed the obtaining oh high quality products, with low energetic consumptions and superior efficiency in transformation process of energy. But, this process of intensive using of power electronics, of introducing performance technology and machinery, by using with precedence of some non-linear equipments, had intensified the pollution process of electric networks which are included in repartition and distribution systems, with superior harmonics, determined by the appearance of this distortion state. In this terms, their activity leads to an accentuate distortion of the voltage and current curves, having disturbance effects on electric installations which operates in sinusoidal state.

We have to mention that the dispatch between installed power in non-linear sources of consumers end those from power plants assembly is increasing. Thus, based on the effectuated analysis in electric networks from energetic systems of our country, this dispatch presents the next evolution – 30,2% in 1976; 36,6% in 1980; 59,88% in 1990, the process keeping also in present. In the future, we expect an increase in the number and in the power of distorting elements, as well as a great variety of collecting points of distorting consumers in electric networks. For example, the high annual increase rate of distorting consumers supplied at low voltage, is high, at approximately 0.5 % [1], [4], [5], [7], [10].

By public electrical power supply system we understand the totality of: power distribution lines for a nominal voltage of 110 kV; 110 kV connection stations; 110 kV/medium voltage and medium voltage/medium voltage transforming stations; low and medium voltage power distribution lines; medium voltage/low voltage transforming stations. This systems supply energy to home and third-party receivers and consumers (i.e. commercial, social-cultural consumers, public services, small industrial and industrial-like consumers), located in a rural or urban habitable area.

As for low, medium and 110 kV three-phase electric networks composing the distribution systems, since a symmetrical load of the three phases cannot be provided for a long interval, the real functioning state of these devices usually is an unbalanced non-sinusoidal periodical permanent one.

The appearance of the non-sinusoidal (distortion) state in public electrical power supply systems is inevitable under present technological conditions, because any element of a non-linear or parametrical circuit represents a harmonic source. The response signal of such an element, excited by a sinusoidal signal, is a non-sinusoidal periodical signal.

The issue of the contribution of each distorting element to the circulation of harmonic currents is a current one in the studies in this domain, and attempts have been made to set more specific rules, responding to the complexity of the matter. Setting rules too severe can thus lead to unjustified economic costs, required for consumer adaptation. Besides, an ethical problem appears concerning the responsibilities of customers and suppliers of energy.

In this context, according to PE 143/94, we have specific values allowed for the parameters of the distortion state of our country's distribution systems. In accordance with this regulation, we have considered as parameters characterizing the distortion state of the voltage wave the distortion coefficient (δ_U - THD_u) and the harmonic level (γ_u), both for even and uneven harmonics. By comparing these values to those of other international regulations, we can see that there is no differentiation between various electrical devices for general use, connected to a 400/380 V voltage, as well as that there are no values indicated for the maximum currents in Amps of the various categories of receivers [2], [6], [14], [15].

II. THE ORIGINS OF HARMONIC DISTORTIONS. HARMONICS SOURCES

In the electrical power supply systems, the distortion state or the harmonic distortion derives from the distortion of the voltage and current wave, so that the spectral analysis brings out multiple frequencies of the fundamental one. Voltages are not perfectly sinusoidal in a supply system, since certain electrical devices, absorbing non-sinusoidal currents, spread them by distorting, at the same time, the voltage wave. These distortions are spread through the electrical network.

In the public electrical power supply systems, the distortion state is produced by the distorting elements generating or amplifying harmonic voltages and currents.

Such distorting elements can be divided into the following categories:

- *Elements which, supplied with rigorously sinusoidal voltages or currents, produce distorting phenomena*, such as arc furnaces, welding devices, rectifiers and, more generally, any highly non-linear circuit element.
- *Elements which do not generate distorting phenomena, but which, being supplied with distorting currents, amplify this distortion.* This category includes electrical lines when their own inductances and capacitances form oscillating circuits, whose frequency may coincide with the one of the harmonic currents produced by elements generating distorting phenomena.

In addition, distortion state sources can also be classified as follows:

- *Harmonic voltage sources*, represented by sources producing non-sinusoidal electromotive voltages. For such sources, voltage and current waves are alternately symmetrical and, consequently, only contain uneven harmonics. Even harmonics are mainly generated by harmonic current sources. The mutual dependency between current and voltage harmonics is strongly influenced both by the reactances and the configuration of the electrical network, and by the resonance phenomena that may appear under certain circumstances.
- *Harmonic current sources*, represented by distorting elements which, in a sinusoidal voltage state, usually introduce superior harmonics into the current absorbed from the electrical distribution network. As for the values of the harmonic voltages generated in the source connection point, these are proportional to the intensities of the generated harmonic currents, as well as to the values of the equivalent impedances of the electrical network.

As stated above, the sources responsible for the distortion state can exist both at the energy suppliers' and in the consumers' electrical networks.

At present, the main sources of low power harmonics in public electrical power supply systems are represented by strip lighting, also called fluorescent, TV-sets, computers, printers, faxes, copying machines and, more and more often, the whole range of domestic electrical appliances. All these receivers have input supply systems for electrical devices with switch-mode-power-supply commuting sources. The major problems of these receivers are mostly related to the variety of connection points in the electrical power supply systems, with implications in current flow.

The main effects of supply systems functioning in a distortion state are the following: increase in active power losses; appearance of over voltages in electrical network nodes and in appliance terminals; over currents; malfunctionning of measuring devices, protection and automation devices, meters, measuring transformers, other fittings in the supply systems, remote-controlled devices; increase of noise produced by electrical machines and other appliances; telephone distortions, etc. [1], [3], [4], [8], [9], [11].

III. ANALYSIS OF THE DISTORTION STATE IN ELECTRIC ENERGY DISTRIBUTION SYSTEMS

In order to examine the distortion state, certain records have been provided with Alpha Power Plus-meters for parameters specific of the distortion state. These records have been made in several conversion stations supplied from the 20 kV distribution network of the county of Iasi, on the low voltage bar level (0.4 kV). To bring out the evolution of the harmonic level in time, the records have been made in working days of 2000, 2005 and 2009, respectively, out of 20 conversion stations in urban distribution. The conversion stations where the records have been made supply various types of consumers: domestic consumers, street lighting, small, large and very large plazas, hotels, restaurants. In this respect, for each conversion station, on the 0.4 kV bar level, measurements have been made, at 15-minute intervals, in working days, for the content of voltage and current harmonics up to harmonic 15th, the actual voltage and current values, the total distortion coefficients for current and voltage for the three phases. Fig. 1 presents an example of the records made with the Alpha-meter for two distinct phases, at the same moment of the day. Accordingly with the measurements effectuated with the Alpha-meter in the distribution network there have been determined the phase shift between the vectors attached to voltage and current, for each phase, according to Fig. 2. Generally, the phase difference between the two vectors, are different on those three phases, to every recorded harmonics, but practically and in accordance with the records given by the Alpha-meter, it can be considered that the phase difference between the two vectors, on fundamental, are approximately equal on those three phases.

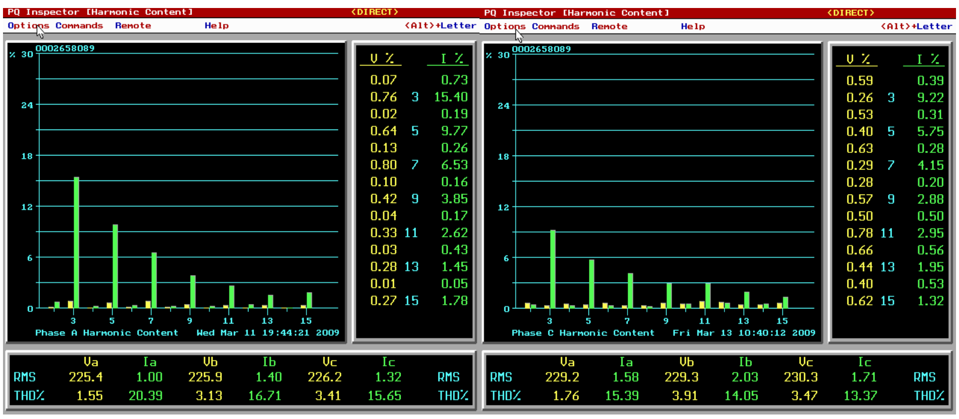

Fig. 1 Record of the Alpha-meter for two distinct phases, at the same moment of the day

1) The level of voltage and current harmonics is estimated with coefficients γ_u and γ_i, calculated for each single phase and defined accordingly:

$$\gamma_u = \frac{U_k}{U_1} \cdot 100 \ [\%], \qquad \gamma_i = \frac{I_k}{I_1} \cdot 100 \ [\%] \qquad (1)$$

where: U_k, I_k – k- harmonic order for voltage and current, respectively; U_1, I_1 – 1st harmonic (the fundamental one).

The Total Harmonic Distortion coefficient (THD) in voltage and current is calculated for each phase and defined by relations such as:

$$THD_u = \frac{\sqrt{\sum_{k=2}^{\infty} U_k^2}}{U_1} \cdot 100 \ [\%], \quad THD_i = \frac{\sqrt{\sum_{k=2}^{\infty} I_k^2}}{I_1} \cdot 100 \ [\%] \qquad (2)$$

For the provided measurements, the maximum level of the recorded harmonics being 15, the superscript in relations (2) takes this value.

The Root Mean Square (RMS) in voltage and current for non-sinusoidal values is defined and calculated with the formulae:

$$U = \sqrt{\sum_{k=0}^{\infty} U_k^2} \ \text{[V]}, \qquad I = \sqrt{\sum_{k=0}^{\infty} I_k^2} \ \text{[A]}. \qquad (3)$$

In the analyzed situations, the d.c. component (the harmonic of order 0) being null, the inferior sum index is 1, and the superior one, 15.

Since relations (3) are known through measurements, as well as the voltage and current harmonic levels γ_{umk} and γ_{imk} (*m* – phase index, *m=a, b, c; k* – harmonic order) and the actual values U_m, I_m, the U_{1m} and I_{1m} fundamental amplitude can be calculated with the formulae:

$$U_{1m} = \frac{100 U_m}{\sqrt{100^2 + \sum_{k=2}^{15} \gamma_{umk}^2}} \ \text{[V]}, \qquad I_{1m} = \frac{100 I_m}{\sqrt{100^2 + \sum_{k=2}^{15} \gamma_{imk}^2}} \ \text{[A]}. \quad (4)$$

The actual values of each harmonic for voltage and current are calculated with the following relations:

$$U_{km} = \gamma_{ukm} \cdot U_{1m} \ \text{[V]}, \ I_{km} = \gamma_{ikm} \cdot I_{1m} \ \text{[A]}, \quad m = a, b, c; \quad k = 2, 3, \ldots 15 \qquad (5)$$

The value of the U_d (voltage) and I_d (current) residual distortion can be determined, for the analyzed situations, specific on each phase, with the formulae:

$$U_d = \sqrt{\sum_{k=2}^{15} U_k^2} \ \text{[V]}, \quad I_d = \sqrt{\sum_{k=2}^{15} I_k^2} \ \text{[A]} \qquad (6)$$

TABLE I. PARAMETERS OF THE DISTORTION STATE PERTAINING TO VOLTAGE IN 2000

	PT11			**PT63**			**PT68**			**PT413**		
Phase	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
U (V)	225.40	225.60	225.40	232.00	231.30	231.00	214.20	212.80	213.30	223.60	223.50	224.10
$U_1(V)$	225.37	225.55	225.35	231.98	231.24	230.98	214.16	212.71	213.18	223.58	223.42	224.03
U_2	0.59	1.35	1.35	0.12	0.67	0.16	0.66	1.49	1.53	0.47	0.60	1.66
U_3	1.62	0.95	0.95	0.46	2.71	0.95	0.88	1.53	2.13	1.27	2.44	0.56
U_4	0.14	0.99	0.99	0.05	0.97	0.05	0.58	1.08	0.98	0.29	0.92	1.01
U_5	2.95	1.44	1.44	2.55	1.32	0.90	3.75	4.15	5.46	1.45	2.59	1.88
U_6	0.14	0.83	0.83	0.28	0.81	1.48	0.21	0.79	0.72	0.29	0.71	1.14
U_7	1.89	2.28	2.28	1.16	2.31	1.15	1.20	0.51	1.71	0.31	1.14	1.55
U_8	0.18	0.56	0.56	0.21	0.60	0.42	0.24	1.19	0.98	0.13	1.27	1.08
U_9	0.14	0.90	0.90	0.37	1.64	0.55	0.49	1.04	0.98	0.76	1.74	1.55
U_{10}	0.14	1.31	1.31	0.07	1.11	0.46	0.15	1.55	0.68	0.02	1.25	1.08
U_{11}	0.36	1.01	1.01	0.63	1.80	0.76	0.79	0.91	1.36	2.01	2.17	2.69
U_{12}	0.02	1.01	1.01	0.05	0.97	0.42	0.06	0.91	1.53	0.07	1.16	1.16
U_{13}	0.45	1.51	1.51	0.19	1.18	0.67	0.90	1.77	1.30	0.80	1.85	2.08
U_{14}	0.20	0.95	0.95	0.07	1.57	0.49	0.06	1.23	1.11	0.13	1.34	1.08
U_{15}	0.09	1.58	1.58	0.37	0.76	0.39	0.17	1.74	1.00	0.42	1.14	1.43
THD_U	1.78	3.34	3.5	1.35	2.8	2.89	1.97	4.63	3.8	1.78	3.64	4.04
$U_d(V)$	3.97	4.72	4.71	2.99	5.42	2.75	4.34	6.17	7.18	3.12	5.87	5.67

TABLE II. PARAMETERS OF THE DISTORTION STATE PERTAINING TO VOLTAGE IN 2005

	PT11			**PT63**			**PT68**			**PT413**		
Phase	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
U (V)	229.8	229.5	230.1	233.9	233.1	232.0	225.3	224.2	224.4	227.7	227.9	227.4
$U_1(V)$	225,37	225,54	225,32	231,95	231,25	230,94	214,16	212,72	213,24	223,55	223,44	224,03
U_2	0,69	0,77	1,31	0,65	0,81	0,35	0,81	2,04	1,41	0,83	0,78	1,48
U_3	1,60	1,65	1,76	0,99	0,99	1,08	1,11	0,40	0,23	1,36	2,36	1,25
U_4	0,20	0,95	1,22	0,16	1,25	1,06	0,25	0,06	0,95	0,15	0,91	1,03
U_5	1,35	1,33	2,99	4,10	2,22	3,48	2,33	3,80	2,87	1,16	2,05	1,16
U_6	0,11	0,68	0,70	0,09	1,45	0,90	0,25	0,72	0,63	0,17	0,80	1,34
U_7	2,52	2,89	2,68	1,76	0,43	0,90	1,99	2,42	0,91	3,59	0,96	2,75
U_8	0,18	1,49	0,58	0,11	0,60	1,08	0,04	0,38	0,57	0,08	0,58	1,45
U_9	0,65	1,06	1,44	0,69	1,68	0,43	0,66	1,40	0,78	0,80	1,20	0,60
U_{10}	0,13	1,06	1,10	0,11	1,36	1,15	0,08	0,65	1,02	0,17	1,38	1,09
U_{11}	0,81	0,56	1,91	0,12	0,90	0,90	1,02	1,48	2,11	1,00	1,98	1,85
U_{12}	0,02	0,90	1,49	0,07	1,52	1,33	0,06	0,25	1,30	0,02	0,93	0,89
U_{13}	0,67	1,28	1,19	0,18	0,92	0,76	1,28	1,42	0,68	0,64	1,40	1,07
U_{14}	0,20	1,56	0,97	0,16	1,52	1,15	0,19	0,46	1,42	0,17	1,54	0,67
U_{15}	0,32	1,47	0,99	0,62	0,92	1,27	0,21	0,63	1,49	0,31	1,00	1,72
THD_U	1.71	3.44	2.83	2.13	2.97	3.85	1.99	2.60	3.27	1.93	3.90	2.52
$U_d(V)$	3,61	5,15	5,98	4,73	4,76	5,00	3,83	5,72	5,03	4,37	5,17	5,30

TABLE III. PARAMETERS OF THE DISTORTION STATE PERTAINING TO VOLTAGE IN 2009

	PT11			PT63			PT68			PT413		
Phase	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
U (V)	226.2	227.2	227.3	233.7	233.1	239.2	221.8	223.6	224.5	229.8	230.6	230.6
$U_1(V)$	226,17	227,15	227,25	233,3	231,3	239,1	221,3	223,3	224,1	229,7	230,5	230,5
U_2	0,15	0,81	1,34	0,86	0,81	0,16	0,77	0,61	0,53	0,87	0,62	0,76
U_3	1,72	2,067	0,591	1,22	0,99	0,98	1,92	2,25	3,22	2,59	2,51	3,08
U_4	0,04	1,022	1,204	0,25	1,25	0,04	0,19	0,17	0,40	1,01	0,94	1,04
U_5	1,44	1,908	0,909	1,11	2,22	0,93	3,78	3,75	5,57	1,79	2,67	1,52
U_6	0,29	0,840	1,431	0,18	1,45	1,53	0,24	0,42	0,47	0,64	0,73	1,38
U_7	1,81	0,567	0,659	2,43	0,43	1,19	3,27	2,99	3,34	1,97	1,17	4,40
U_8	0,23	0,613	0,636	0,09	0,60	0,43	0,11	0,82	0,49	0,62	1,31	0,66
U_9	0,95	1,635	1,29	0,61	1,68	0,57	0,75	1,54	2,04	0,25	1,79	0,76
U_{10}	0,09	1,362	1,136	0,18	1,36	0,47	0,08	1,72	0,69	1,07	1,29	1,15
U_{11}	0,75	1,091	1,772	0,44	0,90	0,78	0,62	0,42	0,81	1,21	2,23	1,71
U_{12}	0,07	1,022	1,499	0.65	1,52	0,43	0,06	0,92	0,78	1,44	1,19	0,94
U_{13}	0,63	0,908	0,99	2,22	0,92	0,69	0,82	1,49	2,73	0,85	1,91	1,04
U_{14}	0,03	0,931	0,909	0,21	1,52	0,51	0,08	1,16	2,11	0,66	1,38	0,81
U_{15}	0,61	1,431	1,408	0,25	0,92	0,40	0,28	1,31	1,32	1,99	1,17	0,89
THD_U	1.76	3.91	3.46	1.85	2.97	3.29	3.26	2.83	4.05	2.05	4.16	3.06
$U_d(V)$	3,27	4,64	4,41	2.99	4,61	4.13	5,58	6,41	7,55	5,14	6,05	6,59

TABLE IV. PARAMETERS OF THE DISTORTION STATE PERTAINING TO VOLTAGE – TIME EVOLUTION. LIST OF VALUES DEVIATING FROM REGULATIONS

	Hour: 4 am			Hour: 10 am			Hour: 10 pm		
Phase	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
U (V)	228.9	227.5	230.8	222.8	221.6	223.1	225	224.4	227.2
$U_1(V)$	228.8	227.5	230.8	222.77	221.6	223.1	224.94	224.3	227.2
U_2	**0.801**	**0.751**	0.323	**0.4901**	0.222	0.156	**1.5746**	**1.727**	0.409
U_3	0.984	1.979	0.923	1.0025	1.329	1.606	0.8098	2.512	2.113
U_4	**1.03**	**0.955**	0.138	0.3119	0.066	0.022	**1.0347**	0.942	0.136
U_5	1.899	1.615	1.362	1.4703	1.219	1.829	2.3619	2.624	1.704
U_6	**0.847**	**1.365**	0.254	0.401	**0.554**	0.29	**0.8098**	1.144	0.091
U_7	1.716	1.046	0.854	0.4678	0.82	0.892	0.8773	1.077	1.045
U_8	**1.693**	**0.66**	0.254	0.1782	0.421	0.156	**0.6074**	1.054	0.114
U_9	1.053	0.546	0.485	0.8911	0.222	0.758	1.5071	2.086	0.931
U_{10}	**1.373**	**1.137**	0.138	**2.1163**	**0.465**	0.134	**1.1472**	1.144	**0.091**
U_{11}	1.121	0.682	0.277	0.3787	1.595	0.513	1.9795	1.862	1.045
U_{12}	**1.007**	**0.955**	0.115	0.0446	0.288	0.067	**1.0347**	1.099	**0.068**
U_{13}	1.808	1.024	0.069	0.4901	1.108	0.602	1.1922	1.817	0.954
U_{14}	**1.556**	**1.569**	0.162	0.1337	**0.51**	0.089	**1.5521**	1.346	**0.045**
U_{15}	0.847	1.387	0.254	2.1163	0.377	0.357	0.9898	1.525	0.613
THD_U	1.64	***3.44***	***2.92***	0.94	***2.75***	***3.2***	1.31	***2***	***2.26***
$U_d(V)$	4.948	4.449	2.032	3.7511	2.998	2.866	4.9966	6.199	3.453

TABLE V. PARAMETERS OF THE DISTORTION STATE PERTAINING TO CURRENT – TIME EVOLUTION

	Hour: 4 am			Hour: 10 am			Hour: 10 pm		
Phase	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
I (A)	88	80	56	80	64	60	134	118	82
$I_1(A)$	87.813	79.87	55.94	79.031	62.63	58.69	131.3	116.4	80.67
I_2	0.3688	0.272	0.509	0.3398	0.125	0.417	0.6171	0.908	0.54
I_3	3.3545	2.26	1.421	7.3657	8.925	9.014	18.119	13	10.13
I_4	0.2722	0.543	0.022	0.5453	0.313	0.299	0.1707	0.605	0.686
I_5	3.0032	2.189	1.371	7.666	7.773	6.866	16.268	11.29	8.567
I_6	0.1844	0.28	0.09	0.1818	0.038	0.112	0.3545	0.477	0.331
I_7	1.888	2.053	0.878	4.7418	4.785	4.214	9.4927	7.589	5.518
I_8	0.1405	0.567	0.09	0.4268	0.063	0.194	0.0394	0.547	0.307
I_9	2.1514	1.438	0.962	3.4932	2.768	2.653	5.1074	3.271	2.646
I_{10}	0.0966	0.423	0.078	0.079	0.138	0.018	0.2889	0.663	0.089
I_{11}	1.4665	1.278	0.677	1.8651	0.996	1.273	2.0745	1.385	1.049
I_{12}	0.2459	0.479	0.084	0.5532	0.063	0.158	0.3676	0.594	0.347
I_{13}	1.1767	0.783	0.515	0.8693	0.626	0.563	0.9585	1.804	0.298
I_{14}	0.1756	0.359	0.073	0.1423	0.119	0.147	0.3545	0.687	0.307
I_{15}	0.7201	0.727	0.319	1.1143	0.908	0.651	1.4968	1.292	0.774
THD_I	17.19	16.26	20.07	5.81	4.99	6.34	20.69	22.34	15.58
$I_d(A)$	5.7344	4.501	2.591	12.415	13.15	12.49	26.786	19.36	14.71

In order to study the distortion state in conversion stations, for each phase, the following characteristic values have been determined, both for voltage and current: the actual non-sinusoidal values, the actual fundamental and all the harmonics (up to harmonic 15), the total distortion coefficients, the residual distortion, the temporal evolution of these values.

The examples offered in this paper are the results related to the parameters specific of the distortion state, for four conversion stations only. Thus, Tables I, II and III present the features of the distortion state pertaining to voltage for the years 2000, 2005 and 2009, respectively, in a working day.

Moreover, Table IV presents the temporal evolution, in various moments of the day, for the parameters specific of the distortion state pertaining to voltage, and Table V shows the same one-day temporal evolution, but for the parameters specific of the distortion state pertaining to current.

As for Table VI, it displays the voltage harmonics and the distortion coefficients calculated in the conversion stations on the low voltage bar level deviating from the values stated in our country's regulation. At the same time, in Table VI, the values deviating from what is stated in the regulation are marked as follows: bold for even harmonics, grey background for uneven harmonics and bold italic for the distortion coefficient.

The analysis of the data presented in Table VI allows noting the existence of a strong distortion state, set for most phases and for most of the recorded harmonics.

TABLE VI. VOLTAGE HARMONICS AND DISSTORTION COEFFICIENTS CALCULATED IN CONVERSION STATIONS. LIST OF VALUES DEVIATING FROM REGULATIONS

	PT11			**PT63**			**PT68**			**PT413**		
Phase	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
U (V)	225.4	225.6	225.4	232.0	231.3	231.0	214.2	212.8	213.3	223.6	223.5	224.1
$U_1(V)$	225.3	225.5	225.3	231.9	231.2	230.9	214.1	212.7	213.1	223.5	223.4	224.0
U_2	**0.26**	**0.6**	**0.6**	0.05	**0.29**	0.07	**0.31**	**0.7**	**0.72**	**0.21**	**0.27**	**0.74**
U_3	0.72	0.42	0.42	0.2	1.17	0.41	0.41	0.72	1	0.57	1.09	0.25
U_4	0.06	**0.44**	**0.44**	0.02	**0.42**	0.02	**0.27**	**0.51**	**0.46**	0.13	**0.41**	**0.45**
U_5	1.31	0.64	0.64	1.1	0.57	0.39	1.75	1.95	2.56	0.65	1.16	0.84
U_6	0.06	**0.37**	**0.37**	0.12	**0.35**	**0.64**	0.1	**0.37**	**0.34**	0.13	**0.32**	**0.51**
U_7	0.84	1.01	1.01	0.5	1	0.5	0.56	0.24	0.8	0.14	0.51	0.69
U_8	0.08	**0.25**	**0.25**	0.09	**0.26**	0.18	0.11	**0.56**	**0.46**	0.06	**0.57**	**0.48**
U_9	0.06	0.4	0.4	0.16	0.71	0.24	0.23	0.49	0.46	0.34	0.78	0.69
U_{10}	0.06	**0.58**	**0.58**	0.03	**0.48**	0.2	0.07	**0.73**	**0.32**	0.01	**0.56**	**0.48**
U_{11}	0.16	0.45	0.45	0.27	0.78	0.33	0.37	0.43	0.64	0.9	0.97	1.2
U_{12}	0.01	**0.45**	**0.45**	0.02	**0.42**	0.18	0.03	**0.43**	**0.72**	0.03	**0.52**	**0.52**
U_{13}	0.2	0.67	0.67	0.08	0.51	0.29	0.42	0.83	0.61	0.36	0.83	0.93
U_{14}	0.09	**0.42**	**0.42**	0.03	**0.68**	**0.21**	0.03	**0.58**	**0.52**	0.06	**0.6**	**0.48**
U_{15}	0.04	0.7	0.7	0.16	0.33	0.17	0.08	0.82	0.47	0.19	0.51	0.64
THD_U	1.78	***3.34***	***3.5***	1.35	***2.8***	***2.89***	1.97	***4.63***	***3.8***	1.78	***3.64***	***4.04***

IV. STEPS TO BE TAKEN AND TECHNICAL MEANS FOR REDUCING THE DISRUPTIVE EFFECTS OF HARMONIC POLLUTION

The distorting phenomena, inevitable in electrical power supply systems, have negative effects upon power sources, distribution networks, consumers, measurement systems and protection systems with relays.

The disadvantages caused by harmonic distortions can be either instantaneous, or proportional to the duration of distortions, depending on the nature of the appliances supplied from the electrical networks. Most often, instantaneous effects can be related to a certain functioning of electronic devices, such as the appearance of pulsing pairs for magnetic actuators. These effects mainly derive either from an important voltage vacuum, or from the shift in the passing through zero of the voltage wave. As for the effects proportional to the duration of distortions, these are generally related to the heating of rotating electrical devices and capacitors. Such effects also lead to the appearance of extra power losses in the components of the electrical power supply systems.

While designing, the possibility of having a distortion state need to be controlled through the following checkouts [1], [7], [9], [12]:

- Check on the parameters of the non-sinusoidal periodical state by calculating the level of harmonic voltages (γ_u) and of the total distortion coefficient (THD_u), depending on the values of the harmonic currents specified by the producer of the devices or measured in similar systems, as well as on the harmonic impedances (Z_n) of the electrical network supply in the respective area.
- Check on the possible appearance of resonance phenomena when planning to set up a capacitor for compensating the reactive power: check on the possible appearance of resonance, i.e. both harmonic over voltages for the circuit made up of the capacitor and of the electrical network supply, and the overload of the capacitor.

In order to connect a consumer generating harmonic distortions to the electrical network, the most common steps to be taken so as to limit the distortion state are the following [3], [8], [13], [14]:

- ✓ Small distorting power consumers can be connected with no problems to the electrical network.
- ✓ Important distorting power consumers should compensate for the distortion state, usually by setting up harmonic filters. With new systems, these filters are set up when the level of harmonic voltages and of the total distortion coefficient revealed by calculation do not fit the allowed limits set by regulations. For existing systems, setting up filters is necessary when measurements indicate parameters exceeding the non-sinusoidal (distortion) periodical state or when there is a risk of a resonance phenomenon for one of the harmonics produced by this state. When more distorting consumers are connected in a common node to the electrical network and each of them has respected the individual imposed restrictions, while for the whole node the global distortion limit has been exceeded, the electrical energy supplier must take measures in order to diminish the level of these distortions.

V. CONCLUSION

This analysis shows that the public electrical power supply system functions in a distortion state in which the norms prescribed by PE 143/94 are exceeded in almost all respects.

It has been observed that, in the structure of the receivers supplied from the analyzed conversion stations, the main distortion elements in the low voltage distribution networks are fluorescent lighting, color TV-sets, computers, printers, faxes. An increase in the distortion state has been noticed by comparing its specific parameters for the years 2000, 2005 and 2009.

Due to the existence of a great number of small power non-linear elements connected in various points of the low voltage distribution network, the intensity of the manifestation of the distortion state also depends, to a great extent, on the load curve in the respective node or point of the network.

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