Characterization of Telecommunication and IT Devices as Nonlinear Loads

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Abstract— **Power supply of telecommunication and IT devices are considered from the point of view of their power quality parameters. Quality indicators are defined intended to study the nonlinear nature of this kind of loads. These are based at the most advanced modern research in the field of nonlinear loads to the grid. A measurement setup is described being powerful, versatile but inexpensive and enabling both verification of compliance with existing standard and categorization within a series production. The measurement and data processing system was here implemented for characterization of power supplies and battery chargers of personal communication and IT devices which in fact are considered small loads. The goal of this choice was to expose the properties of this kind of loads and to give a picture of how "green" they are. A set of measurements was performed and measured data analyzed to show that no matter how small, this kind of loads are a burden to the quality of the power delivered to the customers and even to the functionality of the electrical grid as such.**

Index Terms— **power quality, power factor, nonlinear loads**

I. INTRODUCTION

In our recent studies [1, 2] we were considering the interaction between two domains being of crucial importance for the development of modern world: electrical power systems and ICT systems. While the first are striving to reduce the carbon footprint by changing the very source of energy to be converted into electricity, and to rise efficiency by using more and more sophisticated means in electricity production, distribution and control. On the other hand, the ICT systems are being transformed from a marginal to one of the most important loads to the electrical grid. In that interaction between these two systems, as we stated in [1], much effort is devoted to efficiency, dependability, and availability of power supply, while the understanding of the term "quality" undergoes a serious change in recent decades.

Namely, modern society critically depends on a secure supply of high-quality electrical energy [3] but the views about what quality in this respect means is gradually changing due to the new ubiquitous loads emerging in the last decades. For example, businesses as large as billions of dollars are emerging based on loads being not conceivable in the not so far past [4]. The loads we are speaking about, even in the cases when special care was devoted to their design, behave as nonlinear ones. This means they impregnate harmonics into the current waveform distributed by the greed which is designed to operate at a single frequency. So, if there is high volume of harmonics and phase distortions, no matter the: efficiency, dependability, availability, stability etc. the quality is jeopardized.

These issues were discussed in a study [5], claiming that nowadays we are witnessing changes in the demand and energy use. In fact the new demand determines 'new' load characteristics and trends while changes in the nature of the aggregate utility load happen. All of that is mostly due to the electronic plug-ins that became ubiquitous. Among them we may list a large group of loads but, instead, we will look at them as AC-to-DC converters used both as power supplies and as battery chargers. In the application cases we have in mind here, they are used in personal ICT equipment. A common property of these loads is that they consume small power, usually less than 100 W, hence the name "small loads". Nowadays it is probably not adequate to say that these are ubiquitous. In fact they are more of that since their numbers exceeded the human population by large margin and are growing much faster. These numbers give importance to these loads no matter how small a single item is in comparison to others used mainly for heating water, classical lighting or powering machines.

The question is how green they are and how shall we define the greenness of such devices. How do they influence the quality of the power delivered to the customers? To get quantitative answers one has to have both: means to measure and theory to process the measurement results so that practical indicators to be produced based on which aggregate statistical calculations and comparisons may be done.

In our previous research we were first developing a tool for efficient measurements that will allow for proper and complete characterization of the new emerging loads [2]. Namely we found that the tools for characterization of modern loads available on the market, most frequently, lack at least one of the following properties: low price, ability of implementation of complex data processing algorithms (versatility), ability to store and statistically analyze the measured data, and ability to communicate with its environment no matter how distant it is. All these were achieved by the system reported in [2, 6] and the measurement results demonstrated here were obtained by these tools.

Next, we implemented these tools for characterization of small loads. The results obtained, as reported in [7] and [8] for example, were, in some cases, surprisingly different from what expected. That stands for the power components which

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are not the active power and for the abundance of harmonics. In [9] we demonstrated that based on the main's current, by proper data processing, despite the complex signal transformation between the mains and the components of a computer via the power supply chain, one may deduce the activities within the computer. Even more, one may recognize a software running within the computer. Such an information is distributed via the grid.

Here we will for the first time summarize the theoretical background of all computations necessary to be performed for complete characterization of a small load. Then, we will demonstrate our new results in the implementation of the theory and the measurement tools on a set of AC-to-DC converters used as power supplies or battery chargers of telecommunication and IT devices.

The paper will be organized as follows. First a short description of the measurement experiment will be given. To preserve conciseness, for this purpose, we will mainly refer to our previous work. The definitions used in modern characterization of the main's current, voltage, and power which are implemented by our system will be listed in the third section so enabling the main attention to be devoted to the set of measured results and their analysis, which will be given next.

II. MEASUREMENT OF SMALL LOADS

To establish a comprehensive picture about the properties of a given load one need to perform complete analysis of the current and voltage waveforms at its terminals. In that way the basic and the higher harmonics of both the current and the voltage may be found. More frequently, however, indicators related to the power are sought in order to quantitatively characterize the load. Namely, a linear resistive load will have voltage and current in-phase and will consume only real power. Any other load will deviate from this characterization and one wants to know the extent of deviation expressed by as much indicators as necessary to get a complete picture. In the Appendix A, definitions of most important indicators are given based on the literature. All these were implemented in our measuring system which will be shortly described in the next.

The solution, as described in full details in [8,10], is based on a real time system for nonlinear load analysis. The system is based on virtual instrumentation paradigm, keeping main advantage of legacy instruments – determinism in measurement. The hardware part of the system is implemented using field programming gate array (PXI chassis equipped with PXI-7813R FPGA card with Virtex II FPGA) in control of data acquisition [11]. The software subsystem is implemented in two stages, executing on real-time operating system (PharLap RTOS) and general purpose operating system (GPOS). Described system enables calculation of a number of parameters in real-time that characterize nonlinear loads, which is impossible using classical instruments. The measured quantities are calculated from the current and voltage waveforms according to IEEE 1459-2000 [12] and IEEE 1459-2010 standards [13].

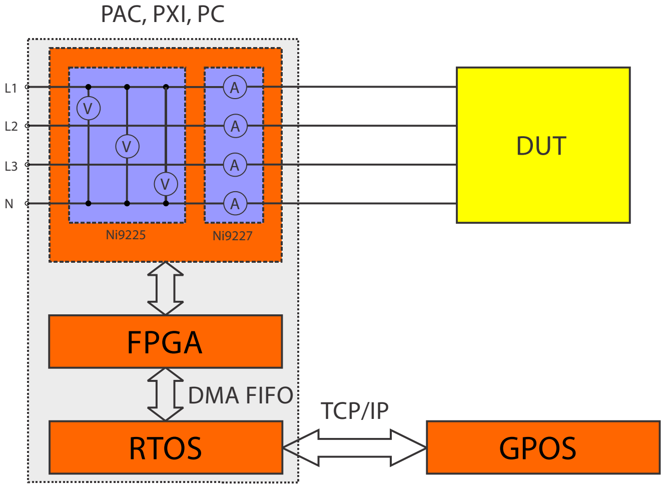

Fig. 1. System architecture

The system consists of three subsystems: acquisition subsystem, real time application for parameter calculations and virtual instrument for additional analysis and data manipulation. Acquisition subsystem consists of NI 9225 [14] and NI 9227 [15] c-series acquisition modules for A/D conversion connected to PXI-7813R FPGA card [2]. A/D resolution is 24-bit, with 50 kSa/s sampling rate and dynamic range ±300 V for voltages and ±5 A for currents.

III. DEFINITIONS OF THE QUALITY INDICATORS OF AN ELECTRONIC LOAD

A. Linear loads with sinusoidal stimuli

A sinusoidal voltage source

$$v(t) = \sqrt{2}V_{\mathrm{RMS}}\sin(\omega t) \tag{1}$$

supplying a linear load, will produce a sinusoidal current of

$$i(t) = \sqrt{2}I_{\mathrm{RMS}}\sin(\omega t - \varphi) \tag{2}$$

where VRMS is the RMS value of the voltage, IRMS is the RMS value of the current, ω is the angular frequency, φ is the phase angle and t is the time. The instantaneous power is

$$p(t) = v(t) \cdot i(t) \tag{3}$$

and it can be represented as

$$\begin{aligned} p(t) &= 2V_{\mathrm{RMS}} I_{\mathrm{RMS}} \sin \omega t \cdot \sin(\omega t - \varphi) = \\ &= p_p + p_q. \end{aligned} \tag{4}$$

Using trigonometric transformations we can write:

$$\begin{aligned} p_p &= V_{\mathrm{RMS}} \cdot I_{\mathrm{RMS}} \cdot \cos\varphi \cdot (1 - \cos(2\omega t)) \\ &= P \cdot (1 - \cos(2\omega t)) \end{aligned} \tag{5}$$

and

$$\begin{aligned} p_q &= -V_{\mathrm{RMS}} \cdot I_{\mathrm{RMS}} \cdot \sin\varphi \cdot \sin(2\omega t) = \\ &= -Q \cdot \sin(2\omega t) \end{aligned} \tag{6}$$

where

$$\begin{aligned} P &= V_{\mathrm{RMS}} \cdot I_{\mathrm{RMS}} \cdot \cos\varphi, \\ Q &= V_{\mathrm{RMS}} \cdot I_{\mathrm{RMS}} \cdot \sin\varphi \end{aligned} \tag{7}$$

represent real (P) and reactive (Q) power.

It can be easily shown that the real power presents the average of the instantaneous power over a cycle:

$$P = \frac{1}{T} \int_{\mathrm{t}_0}^{\mathrm{t}_0+\mathrm{T}} v(t) \cdot i(t) \cdot dt \tag{8}$$

where t_0 is arbitrary time (constant) after equilibrium, and T is the period (20ms in European and 1/60s in American system, respectively).

The reactive power Q is the amplitude of the oscillating instantaneous power p_q. The apparent power is the product of the root mean square value of current times the root mean square value of voltage:

$$S = V_{\mathrm{RMS}} \cdot I_{\mathrm{RMS}} \tag{9}$$

or:

$$S = \sqrt{P^2 + Q^2}. \tag{10}$$

Power factor is simply defined as the ratio of real power to apparent power [12, 16]:

$$TPF = {}^{P}\!/\!_{S}. \tag{11}$$

For pure sinusoidal case, using (7), (10) and (11) we can calculate:

$$TPF = \cos\varphi. \tag{12}$$

Nonlinear loads

In the presence of nonlinear loads, the system operates in non-sinusoidal condition and use of legacy parameters such as power factor, defined as cosine of phase difference, does not describe system properly. Traditional power system quantities such as effective value, power (active, reactive, apparent), and power factor need to be numerically calculated from sampled voltage and current sequences by performing DFT, FFT or Goertzel algorithm [16].

The RMS value of some periodic physical entity X (voltage or current) is calculated according to the well-known formula [18]:

$$X_{\mathrm{RMS}} = \sqrt{\frac{1}{\mathrm{T}} \int_{\mathrm{t}_0}^{\mathrm{t}_0+\mathrm{T}} \left(x(t)\right)^2 dt} \tag{13}$$

where x(t) represents time evolution, T is the period and t0 is arbitrary time. For any periodic physical entity $x(t)$, we can give Fourier representation:

$$x(t) = a_0 + \sum_{k=1}^{+\infty} \left(a_k \cdot \cos(k\omega t) + b_k \cdot \sin(k\omega t)\right) \tag{14}$$

or

$$x(t) = c_0 + \sum_{k=1}^{+\infty} c_k \cdot \cos(k\omega t + \psi_k) \tag{15}$$

where $c_0 = a_0$ represents DC component, $c_k = \sqrt{a_k^2 + b_k^2}$ magnitude of k$^{\mathrm{th}}$ harmonic, $\psi_k = \arctan\frac{b_k}{a_k}$ phase of k$^{\mathrm{th}}$ harmonic and $\omega = \frac{2\pi}{\mathrm{T}}$, angular frequency.

Fourier coefficients a_k, b_k are:

$$a_0 = \frac{1}{\mathrm{T}} \int_{-\mathrm{T}/2}^{+\mathrm{T}/2} x(t)dt, \quad a_k = \frac{2}{\mathrm{T}} \int_{-\mathrm{T}/2}^{+\mathrm{T}/2} x(t) \cdot \cos\left(\frac{2k\pi t}{\mathrm{T}}\right) dt \tag{16}$$

and

$$b_k = \frac{2}{T} \int_{-\mathrm{T}/2}^{+\mathrm{T}/2} x(t) \cdot \sin\left(\frac{2k\pi t}{\mathrm{T}}\right) dt. \tag{17}$$

The RMS value of k$^{\mathrm{th}}$ harmonic is

$$X_{\mathrm{k,\,RMS}} = {}^{c_k}\!/\!_{\sqrt{2}}. \tag{18}$$

We can calculate total RMS value

$$X_{\mathrm{RMS}} = \sqrt{\sum_{k=1}^{M} X_{k,\,\mathrm{RMS}}^2} = \sqrt{X_{1,\,\mathrm{RMS}}^2 + X_{\mathrm{H},\,\mathrm{RMS}}^2} \tag{19}$$

where M is highest order harmonic taken into calculation. Index “1” denotes first or fundamental harmonic, and index “H” denotes contributions of higher harmonics.

Equations (13) – (19) need to be rewritten for voltage and current. Practically, we operate with sampled values and integrals (16) and (17) are transformed into finite sums.

For a single-phase system where k is the harmonic number, φ_k phase difference between voltage and current of k$^{\mathrm{th}}$ harmonic and M is the highest harmonic, the total active power is given by:

$$P = \sum_{k=1}^{M} I_{k,\mathrm{RMS}} \cdot V_{k,\mathrm{RMS}} \cdot \cos\varphi_k = P_1 + P_{\mathrm{H}}. \tag{20}$$

The first addend in the sum (20), denoted with P_1, is fundamental active power. The rest of the sum, denoted with P_{H}, is harmonic active power [17].

There are a number of reactive power definitions for non-sinusoidal conditions in order to characterize nonlinear loads and measure the degree of loads’ non-linearity [18]. As more general term, non-active power N, was introduced. All definitions have some advantages over others. Although tend to be general, there is no generally accepted definition.

The most common definition of reactive power is Budeanu’s definition [19], given by following expression for single phase circuit:

$$Q_{\mathrm{B}} = \sum_{k=1}^{+\infty} I_{k,\mathrm{RMS}} \cdot V_{k,\mathrm{RMS}} \cdot \sin\varphi_k. \tag{21}$$

Budeanu proposed that apparent power is consist of two orthogonal components, active power (20) and non-active power, which is divided into reactive power (21) and distortion power:

$$D = \sqrt{S^2 - P^2 - Q_{\mathrm{B}}^2}. \tag{22}$$

It should be noted that the actual contribution of harmonic frequencies to active and reactive power is small (usually less than 3% of the total active or reactive power). The major contribution of higher harmonic to the power comes as distortion power.

The apparent power, for non-sinusoidal conditions conventionally denoted as U, can be written:

$$U^2 = \underbrace{I^2_{1,\mathrm{RMS}} \cdot V^2_{1,\mathrm{RMS}}}_{S_1^2} + \underbrace{I^2_{1,\mathrm{RMS}} \cdot V^2_{\mathrm{H,RMS}}}_{D_V^2} + \\ + \underbrace{V^2_{1,\mathrm{RMS}} \cdot I^2_{\mathrm{H,RMS}}}_{D_I^2} + \underbrace{V^2_{H,\mathrm{RMS}} \cdot I^2_{\mathrm{H,RMS}}}_{S_\mathrm{H}^2} \tag{23}$$

where S_I represents fundamental apparent power, D_V voltage distortion power, D_I current distortion power and S_H harmonic apparent power. S_1 and S_H are

$$S_1 = \sqrt{P_1^2 + Q_1^2},\ S_\mathrm{H} = \sqrt{P_\mathrm{H}^2 + Q_\mathrm{H}^2 + D_\mathrm{H}^2} \tag{24}$$

where D_H represents harmonic distortion power. The total apparent power, denoted with U, is

$$U = \sqrt{P^2 + Q^2 + D^2}. \tag{25}$$

We can also define non-active power N, defined with equation

$$N = \sqrt{Q^2 + D^2} \tag{26}$$

and phasor power S, defined in the same way apparent power for sinusoidal conditions (10). It is obvious that for sinusoidal conditions, apparent power and phasor power are equal, and (25) reduces to (10).

The total harmonic distortions, THD, are calculated from the following formula [12]:

$$THD_I = \frac{I_{\mathrm{H,\ RMS}}}{I_{1,\ \mathrm{RMS}}} = \frac{1}{I_{1,\ \mathrm{RMS}}}\sqrt{\sum_{j=2}^{M} I^2_{j,\ \mathrm{RMS}}} = \\ = \sqrt{\frac{I^2_{\mathrm{RMS}} - I^2_{1,\ \mathrm{RMS}}}{I^2_{1,\ \mathrm{RMS}}}} \tag{27}$$

and

$$THD_V = \frac{V_{\mathrm{H},\ RMS}}{V_{1,RMS}} = \frac{1}{V_{1,RMS}}\sqrt{\sum_{k=2}^{M} V^2_{k,\ \mathrm{RMS}}} = \\ = \sqrt{\frac{V^2_{\mathrm{RMS}} - V^2_{1,\ \mathrm{RMS}}}{V^2_{1,\ \mathrm{RMS}}}} \tag{28}$$

where I_j, V_k j,k=1, 2, …, M stands for the harmonic of the current or voltage. It can be shown that:

$$D_I = V_{1,\ \mathrm{RMS}} \cdot I_{\mathrm{H,\ RMS}} = S_1 \cdot THD_I \\ D_V = V_{\mathrm{H,\ RMS}} \cdot I_{1,\ \mathrm{RMS}} = S_1 \cdot THD_V \\ S_H = S_1 \cdot THD_I \cdot THD_V. \tag{29}$$

Fundamental power factor or displacement power factor is given by the following formula:

$$PF_1 = \frac{P_1}{S_1} = \cos\varphi_1. \tag{30}$$

Total power factor TPF [12], defined by equation (12), taking into calculation (11) and (23), is

$$TPF = \frac{P}{U} = \frac{P_1 + P_\mathrm{H}}{\sqrt{S_1^2 + D_I^2 + D_V^2 + U_\mathrm{H}^2}} \tag{31}$$

and substituting (29) and (30):

$$TPF = \frac{\left(1 + \frac{P_\mathrm{H}}{P_1}\right)\cos\varphi_1}{\sqrt{1 + THD_I^2 + THD_V^2 + \left(THD_I \cdot THD_V\right)^2}}. \tag{32}$$

Total power factor can be represented as product of distortion power factor DPF and displacement power factor PF1, i.e. $\cos\varphi_1$:

$$TPF = DPF \cdot \cos\varphi_1 \tag{33}$$

Therefore, distortion power factor is [12]

$$DPF = \frac{1 + \frac{P_\mathrm{H}}{P_1}}{\sqrt{1 + THD_I^2 + THD_V^2 + \left(THD_I \cdot THD_V\right)^2}}. \tag{34}$$

In real circuits, $P_H \ll P_1$ and voltage is almost sinusoidal ($THD_V < 5\%$), leading to simpler equation for TPF [12]:

$$TPF = \frac{\cos\varphi_1}{\sqrt{1 + THD_I^2}}. \tag{35}$$

IV. MEASUREMENT RESULTS

As mentioned in the introduction, our goal is here to demonstrate a complete set of measurements and calculations for characterization of small loads. The indicators so obtained may be used for decision making of various kinds such as verification of compliance to some standards or categorization within quality frames. As small loads here we consider power supply devices or battery chargers in case of personal communication and computing devices.

The devices that will be measured were chosen at random while measurements were performed for different states of activity of their own load.

The measured results are shown in Table 1. European electrical greed is considered. All tested devices (tablet computer, mobile phone, laptop computer and cordless telephone) contain rechargeable batteries. Working conditions are standby (device turned off and battery not charging), working and charging (device turned on and battery charging) and charging only (device turned off and battery charging). A standalone battery charger is also tested.

Following values are measured and shown in table: voltage RMS (V), current RMS (I), frequency (*f*), cosine of 1st harmonic phase difference (cos φ1), TPF – total power factor (%), distortion power factor (%), THDV – voltage total harmonic distortion (%), THDI – current total harmonic distortion (%), active power (P), Budeanu's reactive power (QB), apparent power (U), Distortion power (D), non-active power (N), phasor power (S), first harmonic active power (P1) and higher harmonic active power (PH).

In the next we will pay some attention to the very results depicted in Table 1. Let's first have a glimpse at the distortions of the current (THDI). As can be seen even in the best cases the THDI is larger than 20%. There is a case, a mobile phone battery charger while charging, where the THDI is 154.51% which means the harmonics exceed by a large margin the fundamental. Note that this is not an isolated case. One may observe several THDIs of similar value. To summarize, THDI is exposing the nonlinear character of all small loads some of which are extremely nonlinear producing harmonics larger than the fundamental one.

TABLE I. MEASURED AND CALCULATED PARAMETERS

No.	Device description	V (V)	I (mA)	f (Hz)
1	Charger 230V 1.7A - 2XAAA NiCd baterry charging. 850mAh	236.06	9.89	50.02
2	Tablet computer turned on. Li-Polimer 8220 mAh battery charging	235.70	80.92	49.98
3	Tablet computer turned off. Li-Polimer 8220 mAh battery charging	236.59	61.65	49.99
4	Tablet computer turned off. charger 230V/2A connected. not charging	236.51	1.70	50.00
5	Mobile phone charger connected. not charging 230V/0.2A	236.62	1.33	49.99
6	Mobile phone turned on. Li-Ion 1230 mAh battery charging	235.65	53.72	49.98
7	Mobile phone turned off. Li-Ion 1230 mAh battery charging	236.09	48.05	50.01
8	Laptop comp. (type 1) turned on. charger 230V. 1.7A connected, not charging	233.49	22.99	50.01
9	Laptop comp. (type 1) turned on. Li-ION 2200mAh battery charging	232.81	231.39	50.00
10	Laptop comp. (type 1) turned off. Li-ION 2200mAh battery charging	233.52	106.52	49.99
11	Laptop comp. (type 2) turned on. Charger 230V 1.5A connected, not charging	233.07	15.71	49.99
12	Laptop computer (type 2) turned on. Li-ION 4400mAh battery charging	232.05	436.60	49.97
13	Cordless telephone base charger 230V/40mA disconected	232.77	21.05	49.97
14	Cordless telephone base. 2XAAA. NiCd. 550mAh baterry not charging	233.68	21.71	50.00
15	Cordless telephone base. 2XAAA. NiCd. 550mAh baterry charging	233.55	25.60	49.99

No.	TPF (%)	DPF (%)	THDV (%)	THDI (%)	P (W)	QB (VAR)	U (VA)	D (VAR)	N (VAR)	S (VAR)	P1 (W)	PH(W)
1	32.93	70.81	1.70	94.47	0.77	1.77	2.33	1.62	2.20	1.68	0.78	-0.02
2	57.36	58.15	1.73	137.76	10.94	-1.74	19.07	15.53	15.62	11.08	11.08	-0.14
3	55.12	55.54	1.70	146.23	8.04	-0.93	14.59	12.13	12.17	8.09	8.17	-0.12
4	21.43	79.20	1.67	114.80	0.09	0.18	0.40	0.35	0.39	0.20	0.05	0.00
5	12.64	101.35	1.69	59.01	0.04	0.17	0.31	0.26	0.31	0.18	0.02	0.00
6	52.73	53.66	1.71	154.51	6.67	-1.18	12.66	10.69	10.76	6.78	6.73	-0.05
7	51.18	51.98	1.77	161.72	5.81	-0.96	11.34	9.70	9.75	5.88	5.87	-0.06
8	7.00	95.18	1.78	29.07	0.38	1.38	5.37	1.61	5.36	5.12	0.38	-0.01
9	53.67	54.76	2.00	147.11	28.91	-6.10	53.87	45.04	45.45	29.55	29.65	-0.71
10	47.51	50.62	1.92	164.35	11.82	-4.64	24.87	21.39	21.89	12.70	12.18	-0.28
11	12.69	99.22	1.94	40.82	0.46	1.46	3.66	1.42	3.63	3.37	0.43	0.00
12	96.74	97.30	1.83	20.90	98.01	-10.67	101.31	23.32	25.65	98.59	97.86	0.02
13	23.50	90.76	1.80	43.70	1.15	4.33	4.90	1.97	4.76	4.48	1.16	-0.01
14	47.31	92.64	1.78	36.64	2.40	4.09	5.07	1.81	4.47	4.74	2.43	-0.01
15	70.29	92.99	1.82	37.24	4.20	3.66	5.98	2.16	4.25	5.57	4.23	-0.02

The next very important and also interesting set of data is related to the power factor. In early days it was known as $\cos\varphi$ of the load while only linear loads were considered supposedly having reactive component introducing phase shift between the voltage and the current. The total power factor (TPF) encompasses the whole event including the distortions of both the voltage and the current and their mutual phase shift. As can be seen from Table 1, there is only one case where the TPF is approaching unity which is supposed to be its ideal value. In many of the cases the value of TPF is smaller than 50% meaning that the active power is smaller than a half of the total power drawn from the main which, as we could see from the previous paragraph, is mainly due to the distortions. In general, since most of the chargers are considered of small power (look to the column P1 in Table 1), no power factor correction is built in so that significant losses are allowed. That, to repeat once more, would be not a problem if the number of such devices, being attached to the mains all the time, is not in the range of billion(s).

The next column, the distortion power factor (DPF), represents the percentage of power taken by the harmonics. As we can see, except for a small number of cases where the harmonics are approximately on the level of half of the total power, in most cases they are taking as large a power as the fundamental. Note, the harmonics are unwanted not only because of efficiency problems. In fact, in the long term, the presence of harmonics on the grid can cause [20]:

- Increased electrical consumption
- Added wear and tear on motors and other equipment
- Greater maintenance costs
- Upstream and downstream power-quality problems,
- Utility penalties for causing problems on the power grid
- Overheating in transformers, and similar.

Similar conclusion may be drawn in by comparison of the Distortion (D) and the power of the first (fundamental) harmonic (P1). There are only three cases where the second is larger than the former.

To summarize the data from Table 1 one may say that an electronic load to the grid which in fact represents a power supply of a telecommunication or IT device, represents a small but highly nonlinear load. In many cases the TPF of such a load is in favor of everything but not the active power to be delivered to the device.

V. CONCLUSION

The nature of the electrical loads to the grid is changing nowadays due to introduction of electronic apparatus being they home entertainment, home appliances, personal telecommunication or personal IT devices. All these devices behave as nonlinear loads to the grid which is a new state that in general may have damaging effects to the grid as such, to some of its components and, not to forget, to the very electronic loads being connected to it.

Having a right picture on the properties of the load is enabled by two factor: measurement system and signal processing system.

In these proceedings we represent our results in measuring and signal processing intended to characterize small loads. The importance of these results come from the fact that the number of devices of this type connected to the grid globally exceeds billions at any time so producing losses and damage to the quality.

Having all these in mind the importance of the improvement of the performance of these devices comes in fore. That would lead to greener electronics i.e. ICT. We really hope that by offering a quality tool for characterization of these devices and by reporting the results which are exposing their weaknesses one may contribute to better designs or even more restrictive standards in this area.

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