HARMONICS DISTURBANCES SURVEY IN DISTRIBUTION NETWORKS

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ABSTRACT

This paper concentrates in the harmonics disturbances survey in Edenor distribution utility. The disturbances survey (harmonics and flicker) is mandatory to the utility due to the control (Continuity and Power Quality) by a governmental institution (called ENRE). The results of the harmonic disturbances survey are presented, related to a phenomenon with no direct and clear explanation to the date (at least in the internal studies of the utility). The main issue is that the economically fined recordings, (over the fixed reference levels of harmonic voltages) presented a very high concentration on the 15th and 21st harmonic (mainly 15th). There are no problems (or negligible) in other harmonic orders with the exception of recordings in individual industrial customers or substations MV/LV with a remarkable industrial or commercial load. A preliminary relationship is established linked to the type of presumed load, and the period from late afternoon and midnight.

INTRODUCTION

Edenor distribution utility is an Argentinean company with about 2 700 000 customers, a network of 1 370 kms HV, 9 300 kms MV and 25 000 kms LV, with nearly 75 substations (HV/HV and HV/MV) and about 15 000 MV/LV transformers) that serves an area (Buenos Aires city and surroundings) with a broad spectrum of customers and installation types, from high density underground networks to rural areas with extended aerial MV feeders. The standard voltage levels are 220 kV, 132 kV, 33 kV, 13.2 kV in HV and MV and 0.400/0.240 kV in the LV level.

As stated in the Abstract the survey is mandatory and the regulatory issues have been detailed on CIRED 2009 – Session 2 – Paper 0762 – "Disturbances (harmonics and flicker) in distribution networks" (Reference [1]).

To give a start point, the regulated Harmonics Reference Levels for each Harmonic order are reproduced here (Table 1). The level of the harmonics voltages (individual and THD) cannot be over the reference levels detailed for more than a 5 % of the total measurement time length. The length of a valid file, must be at least of seven days, or (with an integration period of ten minutes) a minimum of 1 008 valid registers. Usually the survey aims to have files of eight or nine days length to cover any problem in the initialization of the recording or eventual interruptions contained in the file.

Harmonic order (n)	Harmonic Reference Level (% of fundamental)
Odds not multiples of 3	
5	6.0
7	5.0
11	3.5
13	3.0
17	2.0
19	1.5
23	1.5
25	1.5
> 25	0.2 + 0.5*25/n
Odds multiples of 3	
3	5.0
9	1.5
15	0.3
21	0.2
> 21	0.2
Evens	
2	2.0
4	1.0
6	0.5
8	0.5
10	0.5
12	0.2
> 12	0.2
Total Harmonic Distortion (THD): 8 %	

Table 1: Reference Levels for Harmonics (MV & LV)

For HV level, the admitted percentages are lower and the THD is of 3 %.

The harmonic disturbance recorder must accomplish the standard IEC 61000-4-7, according with the requirements of the Governmental Regulatory Agency.

There are three recorder types in use for harmonics control: LEM TOPAS 1000 (only one in campaign today after ten years of hard work), Dranetz BMI 440S and Fluke 435 (both since 2007).

All the data presented here comes from recorders installed in MV/LV substations, on the LV side. (Transformer wired type is delta MV / star LV with neutral directly to ground).

DATA FOR SURVEY ANALYSIS

From April 1997 to September 2010 a total of 2 024 recorders with valid recordings where installed in one week cycles (in substations MV/LV and customers) in the Edenor distribution network, as can be seen in Table 2.

Valid Harmonic Recordings	Quantity	%
Total	2 024	100.0
Without a fine	1 919	94.8
With a fine (More than 5 % of intervals off the Standard Reference Level)	105	5.2

Table 2: Abstract of harmonic campaign

To study the issue of the presence of 15^{th} and 21^{st} order harmonic, the sample to be presented was reduced to the records from 2007 to September 2010, and as stated in the introduction only to the recorders installed en substations MV/LV.

Only the fined files with presence of 15^{th} and/or 21^{st} order harmonics out of the Standard Reference Level (0.3% for 15^{th} and 0.2 % for 21^{st}) where selected.

The resulting sample is composed of 46 recordings, and an abstract of their characteristics (network type, phases with distortion, harmonic orders, etc) are resumed in the Table 3.

Network Type	Phases	Harmonic order	
		15^{th}	15^{th} & 21^{st}
Aerial	M	16	3
	B	9	4
	T	2	3
Underground	M	7	0
	B	2	0
	T	0	0

Table 3: Abstract of harmonic campaign

M stands for Monophasic (the harmonic appears only in one phase), B for Biphasic, and T for Triphasic. The 21^{st} harmonics in all cases appears with the 15^{th} too, but the main component in the 46 cases is the 15^{th} order. The phenomenon seems to be mainly of Monophasic or Biphasic type.

The Table 4 opens the sample under study by season, and includes also the transformer kVA. It's seems to be a well distributed sample with recordings in each season of the year and a broad range of transformers power. All transformers operate under their nominal power.

Season	Type	kVA	Phase	Order
Fall	A	250	M	15th
Fall	A	500	M	15th
Fall	A	500	M	15th
Fall	A	800	M	15th
Fall	U	1000	M	15th
Fall	A	315	M	15th & 21st
Fall	A	315	B	15th
Fall	A	63	B	15th
Fall	A	200	B	15th
Fall	A	160	B	15th & 21st
Fall	A	315	T	15th
Fall	A	500	T	15th & 21st
Spring	A	500	M	15th
Spring	A	500	M	15th
Spring	U	1000	M	15th
Spring	U	800	M	15th
Spring	U	1000	M	15th
Spring	A	800	M	15th
Spring	A	800	M	15th
Spring	U	800	M	15th
Spring	A	63	B	15th
Spring	A	500	B	15th
Spring	A	100	B	15th & 21st
Spring	A	160	B	15th & 21st
Spring	A	500	T	15th & 21st
Summer	A	315	M	15th
Summer	A	315	M	15th
Summer	A	500	M	15th
Summer	A	500	M	15th & 21st
Summer	A	500	M	15th & 21st
Summer	A	500	B	15th & 21st
Summer	A	100	T	15th
Summer	A	160	T	15th & 21st
Winter	A	160	M	15th
Winter	A	160	M	15th
Winter	A	315	M	15th
Winter	A	315	M	15th
Winter	U	500	M	15th
Winter	U	800	M	15th
Winter	A	500	M	15th
Winter	A	160	B	15th
Winter	A	160	B	15th
Winter	U	800	B	15th
Winter	U	1000	B	15th
Winter	A	315	B	15th
Winter	A	1000	B	15th

Table 4: Aperture by Season and Power

DATA ANALYSIS FORMATS

All the files from recorders of different brand where converted to a common format, and processed with this approach to facilitate the graphic analysis:

Each 24 hours period (144 records) from each file were separated in workable and holiday days.

Usually there are incomplete record's quantity at the beginning and end of file (the first and last days). These records where trimmed to have only complete days of 144 records each to facilitate comparisons.

Some correlation seems to exist between the unbalanced load, the peak and the presence of harmonics, so the fundamental load in each phase where represented together with harmonic component (15^{th} and 21^{st}) in the same timeline base (24 hours clock (ISO 8601) is used).

DATA ANALYSIS EXAMPLES

Residential load

This substation MV/LV (with 371 customers associated) was selected, because the analysis of the customer's billing doesn't detect any commercial or industrial energy. The load profile doesn't change sharply in any workable or holiday's days of the week under study (summer).

Monophasic Harmonic - Workable Day

The Figure 1 represented the load in each phase and the harmonics (15^{th}) for 24 hours (Phase 2 is off limits). There is a correspondence between the phase load and the harmonic distortion off limits. The load profile is clearly a residential one, because the remarkable peak in night time and the growing load from 07:00 Hs. (Wednesday).

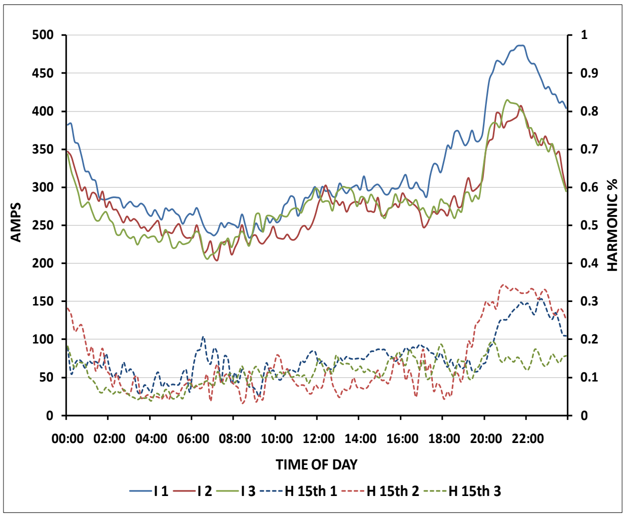

Figure 1

The disturbance off limits appears approximately between 18:00 Hs. and midnight. There are little variations in the correspondence in each day but the trend doesn't changes.

Monophasic Harmonic - Holiday Day

It's the same Substation of Figure 1 but on a Holiday day. The load profile in Figure 2 confirms the classical residential load. The harmonic distortion (15^{th}) is nearly off limits, and the relationship between night time and the higher values of distortion remains.

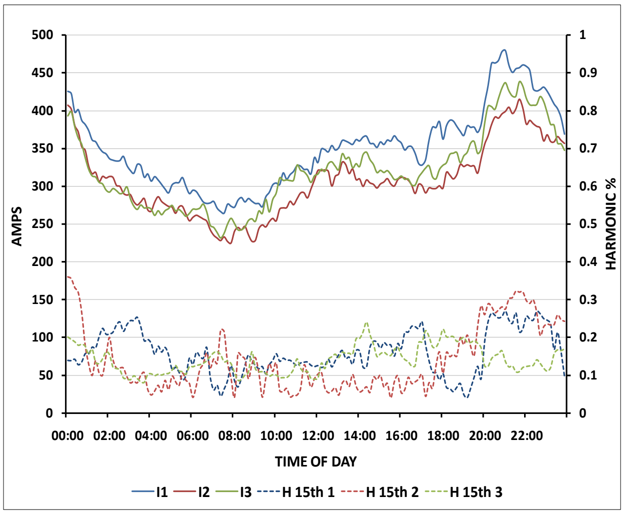

Figure 2

Mixed load

This substation MV/LV was selected, because there are two triphasic customers in LV of industrial type that accounts for the 64 % of the total substation energy. The two first days in Figure 3 are Saturday and Sunday, and the weekly profile is a very clear confirmation of the load's type.

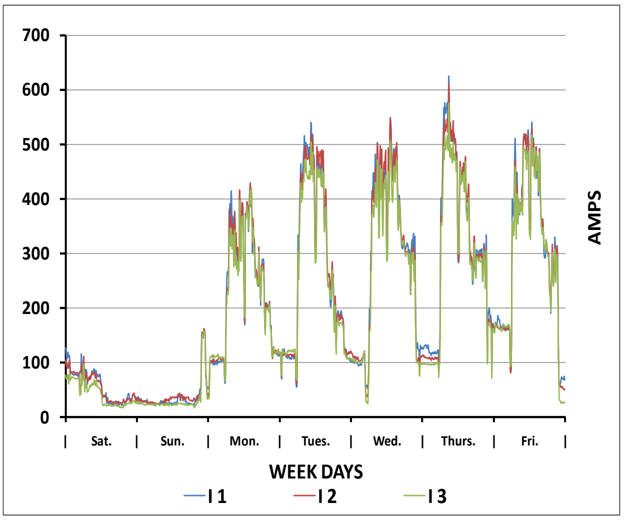

Figure 3

Biphasic Harmonic - Holiday Day

It's very remarkable that the load profiles are modelled by the two industrial customers (both plastic and rubber industries). In a summer Sunday (Figure 4), the profile is very low and nearly flat till 21:00 Hs. where some residential load (lighting probably) appears. There is no presence of harmonic distortion (or negligible).

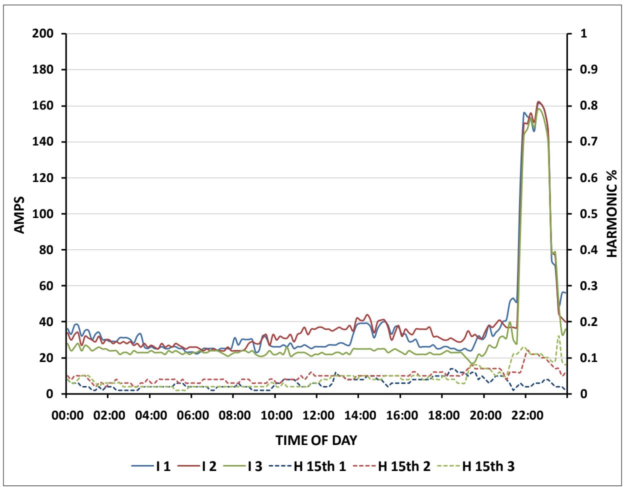

Figure 4

Biphasic Harmonic - Workable Day

The triphasic industrial load results in a balanced load and the main activity models the profile between 07:00 Hs. and 17:00 Hs. (Thursday) as can be seen in Figure 5. The lunch break is easily detected at noon (12:00 Hs). Then, another type of consumption seems to appear between 17:00 Hs. and 22:00 Hs. and downs very sharply at this point. The biphasic disturbance appears only in this period in phase 1 and phase 2.

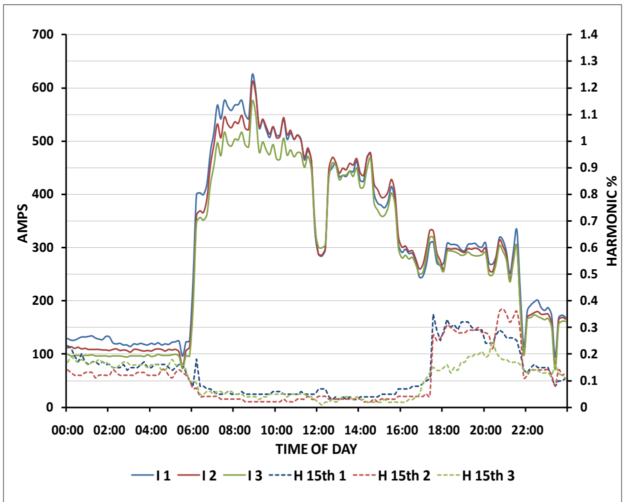

Figure 5

This point has nearly no residential customers (29 and 5 % of the energy). There are other 13 commercial customers. So, is possible that the disturbances linked to late afternoon and early night comes from some residual activity or lighting in the industrial and commercial customers.

CONCLUSIONS

The percentage of monophasic or biphasic disturbance is about 89 %, and only 11 % triphasic. The transformer's sample has unbalanced load (very remarkable), except when a high percentage of energy is linked to triphasic customers.

Practically in all the cases under study, the 15th harmonic disturbance appears from late afternoon to midnight (approximately 18:00 Hs. to 23:00 Hs.). Then, a common characteristic load linked to this timetable must be on the aim to explain the relationship.

In Argentine, in Buenos Aires city and surroundings is very common to dinning about 21:00 Hs. and people usually fall asleep about 23:00 Hs. Many teenagers surf the internet and watch TV to past midnight.

In theory the incandescent lighting is forbidden today and the burn out bulbs must be replaced with compact fluorescent lamps (CFL) as in the U.K. (But regretfully the imported lamps are generally of poor quality). Also, in the last 5 years about 4 million of home air conditioners (heating and cooling) were installed (1 to 10 inhabitants) with high concentration in cities. The use of PC´s and broad band internet are growing very fast too.

The preliminary conclusion is that non incandescent lighting (CFL), electronic devices and low quality air conditioners are in relationship with the presence of 15th harmonic in the distribution networks, due to the load type and simultaneity of usage. The references [2] and [3] deal with the same subject with studies under lab controlled conditions.

In a near future, Edenor is going to install recorders in points with a well known load (as commercial buildings) to establish a more reliable relationship with field conditions.

REFERENCES

[1] Luján Ruiz Díaz, 2009, "Disturbances (harmonics and flicker) in distribution networks", *Cired 2009*, 0762.

[2] M. Ferrari & others, 2010, "Distorsión armónica producida por lámparas de bajo consumo", *Cidel*, 068.

[3] M. Brugnoni and R. Iribarne, 2006, "Estudio de impacto en redes distribución y medio ambiente debido al uso intensivo de lámparas de bajo consumo", *SE-PROCAE 2006*.