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ROME: A FIRST EXAMPLE OF PERCEIVED POWER QUALITY OF ELECTRICAL ENERGY

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ABSTRACT
A first comparison between data comes from an investigation on the Perceived Power Quality (PPQ) parameters effected on customers of Rome (Italy) and data measured of Power Quality (PQ) normed parameters in the same zone is presented. The results show how the intuitions and the experiences of the customers are verified. The PQ parameters have been measured by means a self made instrument developed ad hoc for this purpose.

KEY WORDS
Perceived Power Quality

1. Introduction

The absence of biological detectors able to do to quantify to man the electrical entities, with respect for instance mechanical ones, made mysterious the "electrical world". This biological limitations made the approach, commonly used by normal consumers with respect electrical energy, not only not scientific but neither easily intuitive as for examples with mechanicals entities.
This made the consumers blind to the electrical energy's problematic, to deter them from the idea of comprehension of this entity and relying it completely to professionals in the field. The typical attitude wants that the primary necessity to have energy is satisfied, if this happen "probably there aren't problems"; if "unluckily" there isn't energy this is turn on a varied, soon funny, spectrum of emotions that everyone has experienced during a black out. Emotions anyway conditioned from the reassuring idea that the energy will come back. Nothing is then sure if there are some bad functioning in the electrical systems or apparatus used, only the strong suspicious that the cause is due to the electric company supplier of energy.
This superficial approach is present both in the domestic consumers and in the little and medium enterprise (LME), surely more sensible than the firsts to the electrics problematic, but not economic strong to dialogue with the giant society energy supplier [1,2,3,4].
On the base of epochal changes in the entire electrical division (production, distribution and selling), and being convinced that an effort in the comprehension of the entity electrical energy can save money, the sensibility of the final consumer is changing, evolving and refining in the perspective to understand better this good of vital importance for our society. To understand better the electrical energy without a solid scientific base means to try to interpret the good judge it on the base of own convictions and own expectations that are anyway referable somehow to rigorous scientific parameters.
An interpretation of a series of definitions linked each others and furnished by ISO 9001 has conducted us to a definition for the quality of Electrical Energy that put at the same level of importance the producers, the distributors and the customers and strictly joined to the satisfaction of the expectations of the customers.
The new take of awareness from the consumer that the electrical energy can be considered a good as others, and thus subject to normal commercial rules, made that assumes more relevance in the connections with the electrical industry.
To try to understand what the consumer wants from the electrical energy and how him interprets this entity, it has been object of a research started four years ago at the Roma Tre University, and actually operative too, destined to the definition of Perceived Power Quality for the LME customers.
We tried to find a common language between two worlds completely different how the "Academia" and the LME.
With the helps of electrical operators, used by LME either for the project of electrical plants both for the maintenance and so practice of LME electrical problems, we developed an heuristic procedure that took us to think a Questionnaire conceived as a "linguistic bridge" between the legal lexicon, typical of the academia, and the vocabulary of the LME customers for the electrical problems.
The Questionnaire is been thought and refined to face the practice problem to converse with much categories of the technology of commerce different each others finding a solution in an interpretative filter called: "Pertaining to the Technology of Commerce Filter".
The procedure, developed under the supervision of University, has permitted to determine the language to use in the Perceived Power Quality field and shows which is the interpretative key that the world of LMEs gives of the electrical parameters defined by the normative.
The questions present in the Questionnaire reflect this idea and shows how the perception of electrical

parameters are not congruent with the Rule EN 50160 and therefore the most of questions are about on failures. The parameters defined by the Questionnaire and indicate as Perceived Power Quality Parameters, are six and their meaning cover, sometime fully, sometime partially, the sense of the thirteen normed parameters present in the EN 50160 that define the well known Power Quality Parameters[4].

To put at the same level the subjects of the electric world means to identify and to accept the owns responsibility in the electric problems. For example in a so articulate net as electric one, it is not correct to think that the problem in a sub section of the net have produced only by the electric supplier. It is more probable that someone in another sub section close with the first are producing some disturbs that can filter into the first section.

The questions are: who is guilty for this situation? And then, how can we establish the damage for the other users?

At the first question it is possible to answer that obviously the superficial attitude of the consumers with respect the electric good make them unaware that the Quality of Electrical Energy can depend on the modality used by consumers to get energy from the net.

A model that describe the interaction between the customer and the net was presented in reference [4]. It clarifies that generic consumer needs that some parameters are particularly care to do his job while he could not interested to others aspects introducing "disturbs" on the net that can create troubles to others consumers.

The second is a technical question which is possible to answer establishing the direction of the fluxes of the quality of the energy in the categories individuated both by customers and by Rule EN 50160 crossing them appropriately.

The different demands in terms of quality of energy are functions of the particular commercial category under exam and each one expresses the own exigencies with own culture; these must be compared with well prepared producers and distributors.

Basing on this model it is possible to think a new type of electric customer-producer agreement that may safeguard the consumer rights to have an energy with high quality suitable for own specific job exigency but characterizing the rise in costs in the furniture in dependence on how the consumer dirty the energy.

In Italy, the Electrical Energy and Gas Authority is responsible to define the framework of this comparison and declared that the Quality can be introduced in customer-producer agreement, with arranged parameters observed, at least, for one year. Obviously the observation of every parameter can be obtained only by measurements.

The observance of agreed quality parameters must be, also, obtained by measurements and if it is not satisfied, the possible commercial causes can be settled by Commercial Court.

To measure the electrical parameters, it has been developed a new instrument, able to control continuously voltages and currents for the four phases of electrical net and able to help us in the manage of the data. The instruments, or probes, are installed in the Rome territory in zones that represent the four cardinal points[4].

2. An application to Rome customers – the global results

For logistic and belonging reasons, the Rome territory has given the natural geographic context where to start our research. It has been a certain number of EO acting in this area and with their helps have been identified four thousands possible consumers members of LMEs which the Questionnaire have been supplied. The answers have been critically analyzed by the light of our idea to try a connection between the world of LMEs and the Academy one. To obtain this we have grouped the consumers, and so their answers, around the four physical probes, as indicated in last phrase of the introduction, distributed on the territory, because the our ultimate goal will be the comparison between ruled parameters fluxes and the Perceived Power Quality ones in the same territory.

The data treatment implied the use of non optimal statistical parameters.

Now we have to remind the six P.P.Q. parameters defined by the questionnaire, that characterize the categories of problems that the consumers understand and that represent them vocabulary in the electric field.

A certain number of questions has been associated then to each parameter depending on the particular parameter under exam. The subsequent list shows the six parameters in bold and, for each one, the question associated:

a) Interruptions and phase losing

1) Failure on machines tools;
2) Failure on control machine;
3) Breaking of one-phase electricity meter;
4) Breaking of three-phase electricity meter;
5) Flop of storage batteries;
6) Flop of power factor correction.

b) Voltage Variations

1) Anomalous replacement of lamps;
2) Anomalous replacement of motors or transformers;
3) Breaking of electric motor caused by no intervention of protection systems;
4) Substitution of differential switches;
5) Incorrect activation of antitheft device or burglar alarm.

c) Electrical Disturbances

1) Breaking of television or radio tuning systems;
2) Incorrect transmission data for CAD-CAM programs;
3) Anomalous behavior of cash registers or computers.

d) Harmonics

1) Abnormal consumption of electric machines;
2) Impossibility to correct the power factor completely;
3) Anomalous earth or neutral conductor current for three-phase balanced symmetric loads;
4) Superheat of power factor correction capacitors;
5) Superheat of drive shaft.

e) Transients

1) Superheat or stopping of electric motors ;
2) Superheat or stopping of refrigerant compressor electric motors;
3) Failures of conditioning plants.

f) Currents dispersions

1) Phenomenon associable to currents dispersions;
2) No well-timed intervention of differential switch associable to currents dispersions;
3) Phenomenon of corrosion associable to currents dispersions;
4) Presence of voltage on earth conductor.

For each question we have asked how many times the particular event, associated to the question, is happened, subdividing the answers in five interval: a) never, b) 1-5 times, c) 5-10 times, d) 10-20 times, e) >20 times.
We have ascertained that to the fifth interval there are never answer so we have omitted the this interval from the next graphs.
For these parameters we have defined the "signature" of all the territory in the sense of frequency of answers for each question, in each field defined by customers.
We have to watch next graphs that show the signatures for each parameter reminding that the questions have been formulated in terms of failures, pointing out principally the breaking of machine or systems particularly dear to the customers for their jobs or that anyway point out problems to the production or to normal execution of their activity.
The answers for each category, point out both from kind of failure and times of happened, are normalized dividing them for the total number of answers for kind of failure.
In the graphics is also presents the answer "Never" that is not useful for the representation of the failures, but is an index that help us to understand better the situation.
The first graphic shows the global signature for the macro question on the field of "Interruption and/or absence of one or more phases" for all the answers in civic territory.

Signature – Interruptions and/or absence of one or more phases

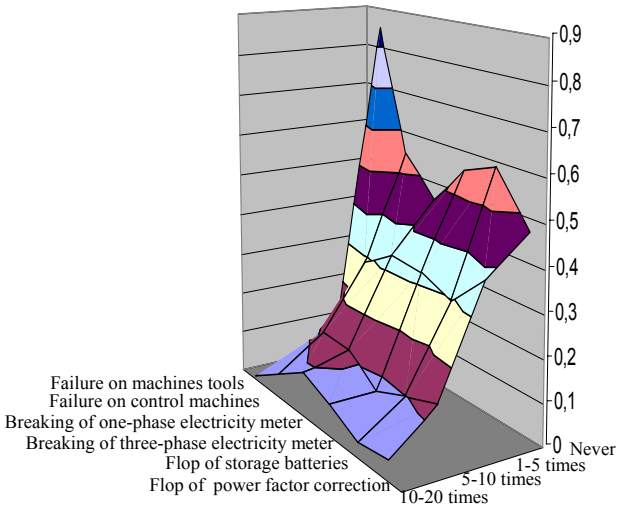

Fig. 1. Signature on the field of "Interruption and/or absence of one or more phases"

As it was possible to wait, the peak of faults is centered around the failures on machines tools, problems that are happened with quite often.
Next graphic shows the global signature for the macro question on the field of "Voltage Variations" for all the answers in civic territory.
In this field the answers are more homogeneous than the first field because, although the breaking of electric motor, caused by no intervention of protection systems, is the answer most voted because is caused of great problems and so particularly felt, it's easy to understand that the anomalous replacement of lamps or the incorrect activation of antitheft alarm are phenomenon immediately comprehensible by the customers and so easily reported.

Signature – Voltage Variations

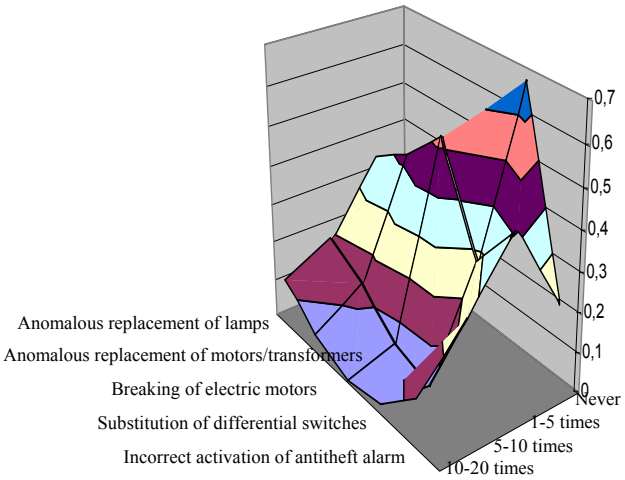

Fig. 2. Signature on the field of "Voltage Variations"

The graphic in figure 3 shows the local signature for "Electrical Disturbances". For the same reasons presented before, also this field shows how the answers are homogeneous with a peak for the incorrect transmission

data for PCs because the worker in this area are anyway technicians even if membership of other category than electrical one.

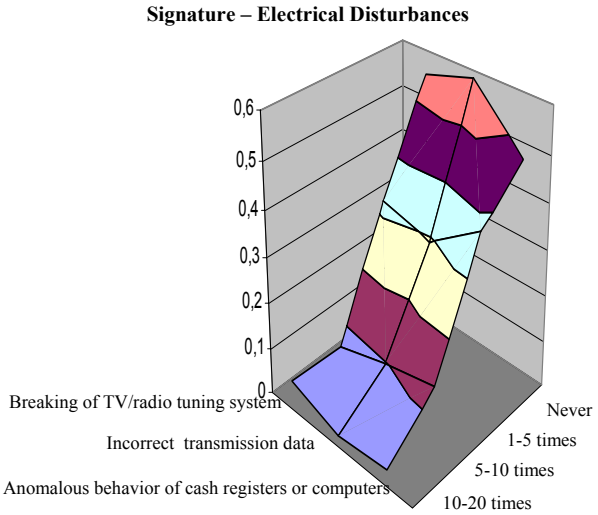

Fig. 3. Signature on the field of "Electrical Disturbances"

The graphic in figure 4 shows the local signature for the generic field "Harmonics".
Here it is possible to note how at the question on the no possibility to correct the power factor we have a reduction of negative answers: this because for this question the customers have been helped by their EO, that have given an answer extremely precise knowing well the problem.

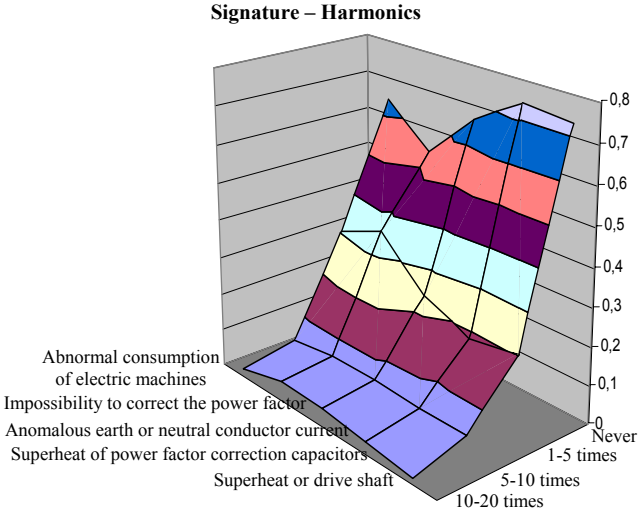

Fig. 4. Signature on the field of "Harmonics"

Next graph shows the local signature for the generic field "Transients". Also in this case the easily comprehension of the questions brings a homogenization of the answers.

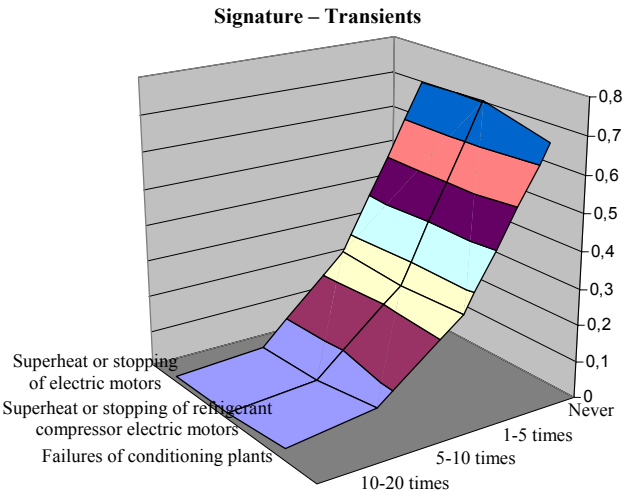

Fig. 5. Signature on the field of "Transients"

The graph in figure 6 shows the local signature for the generic field "Current Dispersions". Here, the difficulty to understand deeply the term current dispersion creates some incomprehension in the correct definition of the phenomenon associated, so the answers more significant are expressed in terms of corrosion.
The answers have been grouped on the base of the distance between the customers and each probe. Each customer "belongs" to the nearest probe that became the "barycentre" for the customer. For each field and for each probe it will be possible to draw "partial signature" that would show the behavior of the parameters around each probe but for expository clarity are left out. Anyway, soon these graphics show that the local signatures is different from global ones because the local behavior can be different from a global interaction.

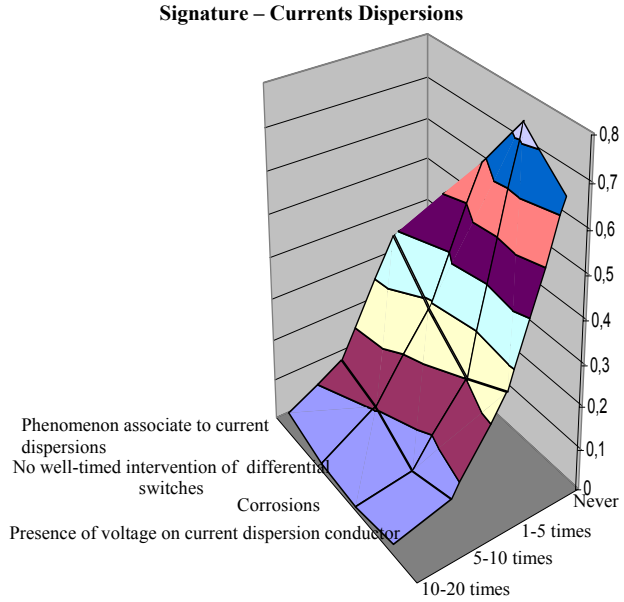

Fig. 6. Signature on the field of "Currents dispersions"

From previous considerations, it is possible to define and to determine the "gradient" for the analyzed parameter.

This gradient can be considered an index that allow us to synthesize the information of flux for this parameter.
The gradient between two probes is defined as the absolute value of the difference between each answer for each probe and the same of another probe, along their line of conjunction, divided for their distance.
Obviously previously this definition it is necessary characterize the six directions between the four probes determining the kilometric distance, and to organize data of the questionnaire dividing the sum of the answers for each interval of occurrences with respect to the total sum of the answers for the question under exam. Normalizing these results by means of non optimal statistical valuators, we obtain the next tables for each field[4][5].
The first table shows the Gradient along the probes directions for the field of "Interruption and/or absence of one or more phases".

Table 1. Absolute values of Gradients along the probes directions for the field of "Interruption and/or absence of one or more phases".

	SOUTH	WEST	NORTH	EAST
SOUTH	0	0.169	0.238	0.138
WEST	0.169	0	0.456	0.247
NORTH	0.238	0.456	0	0.260
EAST	0.138	0.247	0.260	0

It is interesting to see how the gradients are developed on the map of Rome. To obtain this, first of all it is necessary to find the absolute maximum of the gradient in the table: in this case the gradient between north and west probes. After this it is necessary to search the highest value in the table not present in the rows where it is present the previous gradient: in our case the value among south and east probes. Repeating the procedure another time we obtain the direction for the gradients. Anyway the number of iterations depend by the number of the probes[5].
The second table shows the Gradient along the probes directions for the field of "Voltage Variations".

Table 2. Absolute values of Gradients along the probes directions for the field of "Voltage Variations".

	SOUTH	WEST	NORTH	EAST
SOUTH	0	0.401	0.065	0.239
WEST	0.401	0	0.193	0.044
NORTH	0.065	0.193	0	0.195
EAST	0.239	0.044	0.195	0

The next table shows the Gradient along the probes directions for the field of "Electrical Disturbances".

Table 3. Absolute values of Gradients along the probes directions for the field of "Electrical Disturbances".

	SOUTH	WEST	NORTH	EAST
SOUTH	0	0.066	0.020	0.018
WEST	0.066	0	0.018	0.062
NORTH	0.020	0.018	0	0.062
EAST	0.018	0.062	0.062	0

The table 4 shows the Gradient along the probes directions for the field of "Harmonics".

Table 4. Absolute values of Gradients along the probes directions for the field of "Harmonics".

	SOUTH	WEST	NORTH	EAST
SOUTH	0	0.309	0.458	0.346
WEST	0.309	0	0.427	0.122
NORTH	0.458	0.427	0	0.394
EAST	0.346	0.122	0.394	0

The table 5 shows the Gradient along the probes directions for the field of "Transients".

Table 5. Absolute values of Gradients along the probes directions for the field of "Transients".

	SOUTH	WEST	NORTH	EAST
SOUTH	0	0.085	0.640	0.161
WEST	0.085	0	0.843	0.097
NORTH	0.640	0.843	0	0.979
EAST	0.161	0.097	0.979	0

The table 6 shows the Gradient along the probes directions for the field of "Currents Dispersions".

Table 6. Absolute values of Gradients along the probes directions for the field of "Currents Dispersions".

	SOUTH	WEST	NORTH	EAST
SOUTH	0	0.282	0.283	0.028
WEST	0.282	0	0.600	0.165
NORTH	0.283	0.600	0	0.565
EAST	0.028	0.165	0.565	0

Considering the versus too (it needs to verify the sign of the difference among the probes) it is possible to draw the route of the gradient on the map of the city. Figure 6 shows the gradients.
The black crosses presents on the map indicate the position of the costumers interviewed on the Rome territory, while the black circles show the position of the probes.
The results of the research on Perceived Power Quality are shown in this figure, obtained by the results of a Questionnaire given to EO operating on the territory.

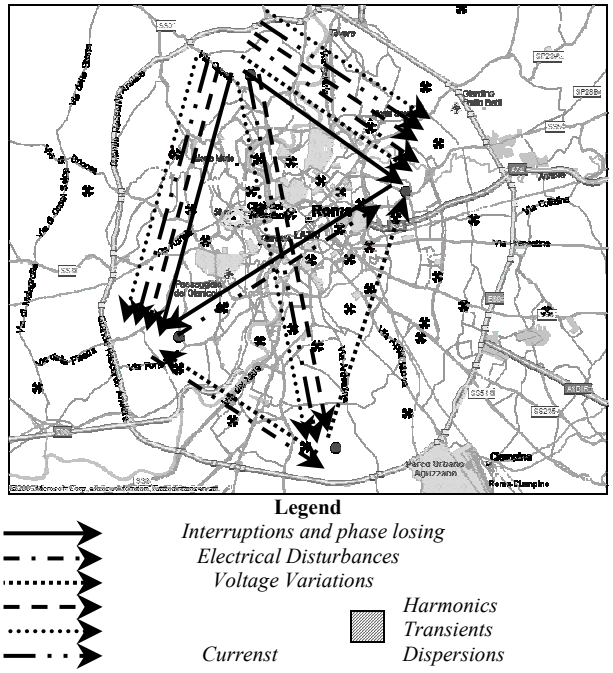

Fig. 6. Flux of Perceived Power Quality for the parameters own defined by customers (the headings of the figure are in Italian).

Watching the previous figure, it is evident the citizens of Rome perceive as very bad the Power Quality indicate by the parameters "interruption and/or absence of one or more phases", "Harmonics", "Transients" and "Currents Dispersions" in the north, a zone poor both of commercial activities and houses in which the supplier would provide to make better the service. The others zones are surely better than the north one, however, analyzing into details the data of the questionnaire the west zone seems to be on the whole the better one.

3. Connection between PPQ parameters and PQ ones

Indicating by numbers the P.Q. entities of the EN 50160

1. Power frequency
2. Magnitude of the supply voltage
3. Supply voltage variations
4. Rapid voltage changes
5. Supply voltage dips
6. Short interruptions of the supply voltage
7. Long interruptions of the supply voltage
8. Temporary power frequency overvoltages between live conductors and earth
9. Transient overvoltages between live conductors and earth
10. Supply voltage unbalance
11. Harmonics voltage
12. Interarhmonics voltage
13. Mains signalling voltage on the supply voltage

and indicating by letters the P.P.Q. parameters defined in the Questionnaire

a. Interruption and phase losing
b. Voltage variation
c. Electrical disturbance
d. Harmonics
e. Transients
f. Current dispersion

it is possible to arrange a table in which are represented two level of heuristic connection as shown in table 7.

Table. 7: Perceived Power Quality parameters heuristic connection with Power Quality entities

	1	2	3	4	5	6	7	8	9	10	11	12	13
a													
b													
c													
d													
e													
f													

Legend

Heavy correlation Light correlation

For some PQ parameters are defined the upper and lower functioning limits by the norms CEI EN 50160, while for the others the normative asks only to measure them[6]. Among these limits the most important are obviously the frequency of the fundamental (50Hz ± 1%), the magnitude of the supply voltage with its changes (230 V ± 10%) and the levels of harmonic voltages variables between 0.5% of the even harmonics and the 6% of the 5th harmonic of the magnitude of the fundamental, anyway, on the whole, the total harmonic distortion shall be less or equal 8% of the magnitude of the fundamental voltage. Interesting the case of interharmonics which levels are under consideration, pending more experiences.

4. The probe

To obtain the comparison between PPQ parameters and PQ ones, we need to measure all quality parameters foreseen by the Rule. The thirteen normed parameters have been by means of an instrument developed "ad hoc", because, to satisfy such characteristics, when started with the research was not present an instrument on the market able to monitor all the normed parameters.
The probe block scheme is shown in figure 7.
The hardware of the instrument is composed by a personal computer (Pentium IV, 2400 MHz) with inside an eight channels acquisition card with 12 bit resolution and an acquisition frequency of 128 KHz for channel.
The acquisition card is a Measurement Computing Das 8/12. To each channel is connected a sensors. As interface with the entity under measure the instrument use four current sensors and four sensors voltage. The firsts are four Rogowski, that give us the derivative of the current, therefore it is necessary to integrate their output signal before to pass them to the acquisition card.

The integral is obtain by means of a self made amplifier operational integrators. The others sensors are voltage dividers that reduce the high electric network voltages to preserve the input channel of the acquisition card and are mounted on a self made card.
The timing to manage the acquisition and to synchronize all the events is external and in our case is actually furnished directly by the clock of "Telecom", the most important Italian telecommunication society that kindly give us the use of four telecommunication substations. This clock is furnished to Telecom directly by the "Galileo Ferraris" Institute, the Italian National Time Metrological Institute, with an accuracy of 1parts in 10^{-14}.
The instruments is able to endure an eventually black out lasting eight hours thanks a particular self made UPS that use a 12 V truck batteries, feed by a 12 V stabilized supplier, directly connected to the PC.
The instrument has an Ethernet interface to transmit data versus a central server that receives the data from all probes and organize them in such a way as to have constantly the idea of the power quality parameters on the electric network.
The card acquires samples for two seconds and store them in a buffer on which acts the algorithm that permit to evaluate the signal. This is a modification of the well known Curve-Fitting Algorithm [4,7,8].

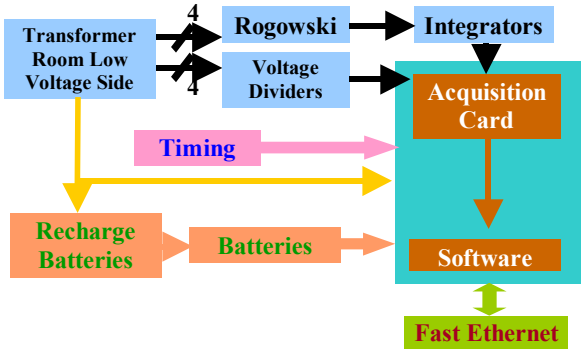

Fig. 7. Probe block scheme.

5. The first results

The probes are inserted in Medium/Low voltage transformer rooms of four telecommunication substations of "Telecom". The management of these probes has presented big problems for two principal reasons: the accessibility and the failures. For safety and insurance problems each time that we wanted to enter inside the substation to intervene on the probes there were problems to find an internal responsible willing to take us to the instrument.
Unluckily the faults on the probes have been a great quantity almost exclusively joined with human internal Telecom resources that, sometime for work exigencies, sometime for ignorance (aware or less deactivation of ADSL line), didn't consent the correct functionality of the probes for long period. In fact the substitution of pieces for PCs soon implied long wait. Obviously whenever that something happened we took adequate countermeasures, anyway multiplying these problems for the four probes there is not been the possibility to have the data originated from probes simultaneously and constantly for long periods. This aspect is important for two reasons the first is that to realize the comparison between PPQ parameters and PQ ones it is necessary to have the data simultaneous of the probes. The second is associated with the request by the Italian Electrical Energy and Gas Authority to have measurements for one year before to think to write a customer-producer agreement that considers the quality as an essential forms of the contract.
Nevertheless we had some useful time window where it is been possible to determine the PQ parameters and so to effect the comparison. The window most long is quite recent, and actually continue yet, but to present the data in useful time we have to stop the acquisition, it is in the period between 05/25/2007 and 06/10/2007. How it is been said the analysis is effected on sample buffer of two second. Whenever the program verifies that one of the parameter exceeds the limits increase the own counter. The parameters that have no limits, as short and long interruptions of the supply voltage, have monitored counting the number of events and their lenght. The thirteenth parameter is always zero because in this zone there aren't mains signalling voltage on the supply voltage.
Another thing to say is that in the period analyzed none events is been cause of interruption of the service, thing happened previously but does not registered in time window considered. In fact still the long interruptions of supply voltage (max 1 minute), was immediately solved with the help of adequate protection and saving devices.
The table 6 reassumes the results for each probe.

Table. 6: Power Quality parameters measurements

PQ parameters	Probe North	Probe East	Probe South	Probe West
1	12123	7856	7912	7733
2	always	always	always	always
3	312170	230281	111373	178255
4	12010	18071	10624	5679
5	1222	1000	750	899
6	5	3	1	1
7	2	1	0	1
8	0	0	0	0
9	1056	316	324	312
10	52	38	21	29
11	7	10	4	1
12	4	7	3	0
13	0	0	0	0

A first lecture of this table says how some parameters are constantly out the interval foreseen by the norm. In particular the magnitude of the supply voltage is always different with respect the norm. From a specific analysis it is not ever 230V moreover many time the it exceeds the fixed range, but, analyzing the data in detail, it is always lower than the lower limit. This is possible to verify it

also watching harmonics and interharmonics voltage that exceed limits few times in a period quite long and anyway with values not much higher than limits. Moreover the supply voltage dips are quite frequent. The frequency exceeds many times the limits, but analyzing better data, it is always includes in a range not much higher than the established limits (49,4 ÷ 50,5 Hz). We could think that the uncertainty in the calculus of frequency can play a fundamental role to determine exactly the frequency. In fact if the uncertainty would be high, a big part of the events couldn't consider correct, but the uncertainty of modified CFA is about 0.2% so only a very little part of the faults events can be consider receding in the established limits. There are several rapid voltage changes of the supply voltage. This data is very important to understand the idea of Perceived Power Quality, in fact this parameter takes in consideration and is caused either by load changes in the installations or by switching in the system, but being the probes inserted in medium/low telecommunication transformer room, so in environments that work at load almost constant, the cause of so high surmounting of the limits (± 5% of 230V that is nominal fundamental voltage) from this parameter is necessarily due to external causes. A temporary power frequency overvoltage is not present. Normally this event appear during an earth fault in the public distribution system or in a customer's installation and disappears when the fault is cleared. We know that in same case an event like this produced the interruption of the services, but not in these. We registered transient overvoltages between live conductors and earth, but also in this case, always analyzing data, these events has generate a modest overvoltage no able to interrupt the service. Comparing the events with the weather in that day, and in that zone there was a storm. Probably the overvoltages are due to secondary effect of a lightening.
We registered also a modest supply voltage unbalance without consequences.
Another lecture that we can say of the table 6 is that the north probe presents a number of problems bigger than the other ones instead the other seem to have a number of problems similar even if with some light difference mainly for voltage variations, rapid voltage changes and harmonic and interharmonic voltages. Even if the time window is too little to effect statistic considerations, analyzing the data we could realize an ideal overlap between PPQ parameters and PQ ones that could take us to affirm that the personal experiences of the Rome customers, presented by the questionnaire, would seem correct.

6. Conclusion

Thank to the definition of the Perceived Power Quality obtained with the active collaboration of the customers of Rome, in this job we presented a comparison between the Perceived Power Quality Fluxes related with all Parameters defined by costumers and measured data obtained by an self-made instrument developed ad hoc for this purpose.
The comparison shown how measurements carried out seem to confirm the experiences of the customers reported in a investigation effected on them and driven by University.
In the future the increase of the number of probes in the Rome zone will allow us to have information more detailed that will permit to cross better The Quality fluxes with measured data and to apply statistic and stochastic analysis in order to identify the responsible of Electrical Energy Quality falling down meeting the real exigencies of the particular customers joined to the own specific job.

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