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POWER QUALITY ASPECTS CONCERNING ELIGIBLE CONSUMERS

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INTRODUCTION

This paper looks at Power Quality issues from Transmission and Distribution Operators point of view. Customers of the services provided by these operators are producers, suppliers, final consumers (suppliers’ customers) and can also be extended to commercial relationships between Distribution and Transmission Operators.

Usually, Transmission and Distribution Operators do not have competitors like any other liberalized energy market participants. Despite this fact, increasing transmission and distribution efficiency is a permanent goal in all countries. Lack of competition in this field of activity determines the need for a regulation system in order to diminish costs and improve the service quality. First part of this paper contains an enumeration of actual standards, technical and commercial regulations issued by ANRE regarding power quality with respect for the network operators and customer’s positions.

Eligible consumers appeared with the implementation of the liberalized wholesale energy market. According to development strategies, the market share for eligible consumers will increase over the next years. The authors try to evaluate the power quality parameters using field measurements in case of some representative eligible consumers and in case of transmission and distribution boundaries.

Currently, a great variety of equipments dedicated to power quality analysis are available. Those equipments are differentiated by technical characteristics, memory storage, communication capabilities, software tools and interface with monitored installations (panel mounted or portable devices). This paper intention is to set the guidelines for correct choice of power quality monitoring device according to the needs of specific applications. Use of data provided by different devices in order to obtain a synthetic view is another important issue.

Conclusions are also proposals for future power quality analysis.

LEGISLATIVE FRAME

Romanian Transmission Operator is Transelectrica. Metering Branch OMEPA main task is to accurate measure the energy flow between participants in wholesale market of electricity. To achieve this goal is necessary to process a large amount of information from different sources as shown in figure 1.

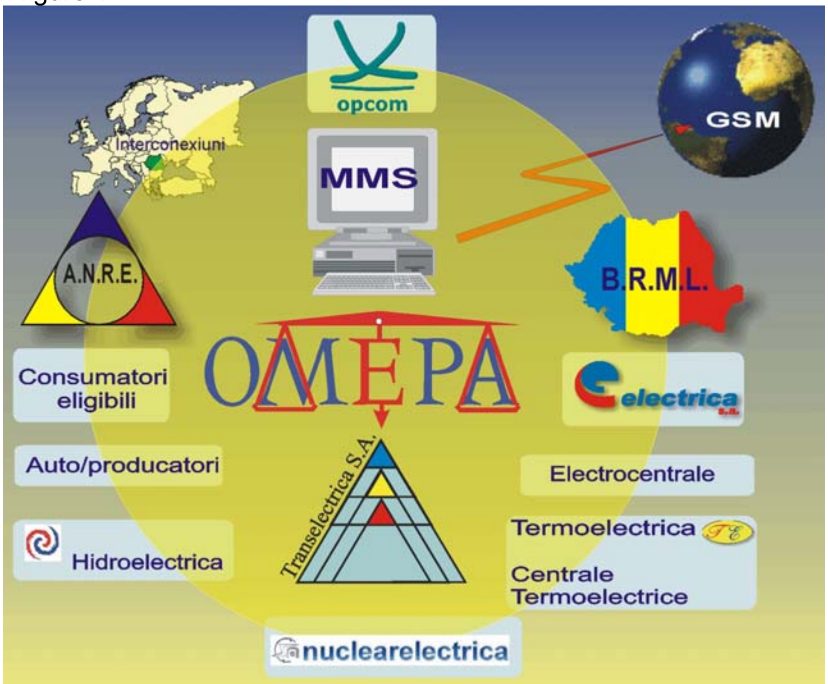


Figure 1

It is important that the regulation gives the network operators economic incentives to obtain an appropriate quality level. Therefore economic incentive regulation cannot disregard the quality of services offered to connected customers.

Quality can be considered from both the customer and network operator's point of view both as specific feature of the product (electricity) and as a measure of the service provided by the Utilities. The rules and regulations that govern the electricity power sector must take into account a broad range of quality criteria.

It is generally known that electricity is an interaction between the following players: Generators, Transmission System Operators, Transmission Network owners, Distribution Network owners, Suppliers and Customers.

To ensure that electricity market runs properly rules are required to exert control on the activities of these players. One of these issues is power quality. Failed generators, faulty networks or polluting customers can destabilize an efficient market.

In order to establish a legislative frame for energy quality in electricity power sector, Romanian Electricity and Heat Regulatory Authority (ANRE) introduced a number of stipulations in a series of key technical and commercial secondary legislation documents. Bellow are listed the main regulations issued by ANRE who contains rules regarding quality aspects of delivered energy (to final users or other customers)

1. *Electricity Transmission Grid - Technical Code* include a distinct chapter regarding "Quality technical parameters of the Transmission and System Services". Here are established:

- the nominal frequency in the National Electricity System;
- the normed operation frequency range in normal conditions and exceptional conditions;
- the nominal values of the voltage in Romanian Electricity Transmission Network
- the values of the voltage considered normal in any point of the electrical network
- the variations of voltage under perturbed operation conditions
- the quality of voltage and current waves
- safety in operation and performance indicators (interruption mean time, severity indicator, "one minute" indicator, mean number of interruptions followed by repairs, mean number of interruptions followed by maneuvers).

2. *Electricity Distribution Grid - Technical Code* contain a detailed set of quality indices, concerning both the product (electricity) and the service, included in Chapter 4 "Performance Standard for Electricity Distribution Service":

- interruption of electricity supply (interruption frequency, supply unavailability, interruption duration)
  - Accidental Interruptions

- Scheduled Interruptions
- Quality of electricity
  - Frequency accepted variation range
  - Voltage variation range
  - The quality of voltage curves (shape and non-symmetry)

In contrast with technical regulation, commercial contracts between various utilities covering production, through transmission and distribution, to suppliers and the end customer reflect not only the quality requirements but the financial incentives/penalties, related to target performance. As a consequence, utilities will need to consider the commercial implications of meeting their customers needs, including the management of risk associated with default on contractual quality terms.

It is also important to say that the Electricity Distribution Grid - Technical Code and all regulated contracts for supply of energy at regulated tariffs include references to EN 50160 – Voltage characteristics of electricity supply by distribution systems standard, adopted in Romania as SR EN 50160.This European standard lead to the strict obligation to implement the requirements as a national standard.

MONITORING THE QUALITY INDICES

The quality indices defined by SR EN 50160 are the basis for monitoring voltage quality resulting from the activities of the Network operator. In 1995, Eurelectric (Union of the Electricity Industry) issued a very useful document titled “Measurement guide for voltage characteristic – Electricity product characteristics and electromagnetic compatibility” Ref: 23002Ren9531, who provide a practical approach for measuring and evaluating characteristics of supply voltage as specified by the European standard EN 50160.

The document analyzes the problem of voltage quality with a view of the different situations witch can occur in practice:

- Permanent verification of supply characteristics, depending on contractual obligations;
- Temporary surveying motivated by distributor’s requirements to check the performance of the supply system or by user’s complaints;
- Surveys to check the performance of a supply system for general purpose investigations.

Considering commercial contracts requirements and the right of any customer to ask for financial compensations, in accordance with article 43 “Consumer’s rights” from Romanian Electrical Energy Law nr. 318/2003, the problem of measuring and evaluating of supply voltage must be taken into account by both the network operator and the final consumer, especially the permanent verification.

The evolution of energy sector from vertical Companies with a large character of monopoly towards deregulation and introducing of the competition in the production and distribution area.

The international juncture and the UE directives, connected from the settles which are in the energy sector.

For a good operation of the system it must evidence the neutrality of the Operator. From this results the necessity of regulations and procedures to define without any possibility of diverse interpretation, all the obligations and rights of all parts of wholesale electricity market.

The boundary for Transelectrica’s Subsidiary, figure 3, contains all the partners, all exchange points between subsidiary and other entities grouped according to substations site and voltage levels. Exchange metering points are very important to determine the relations between the participants, the quantity of electric energy received from or delivered to other participants in the wholesale electricity market.

The eligible consumers are the part of the wholesale electricity market. In this moment about 54 consumers are licensed as eligible and they represent about 15-20% from the entire market.

Contractual relationships between entities involved in an actual exchange metering point have an important commercial nature. Power Quality indicators can be used for penalties calculation. Several studies were carried to determine the magnitude of this problem in two locations involving ST Pitesti and ST Sibiu (Figure 2).

PRETRAŽIVANJE / SEARCH
ŠTAMPANJE / PRINT
IZLAZ / EXIT

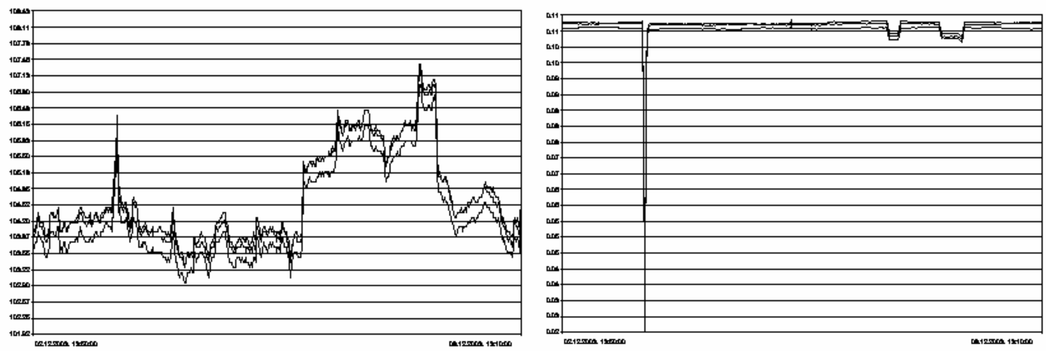
In the first case a portable PQ Analyzer was installed in the exchange metering point between Pitesti Subsidiary and eligible customer ALRO Slatina. Second field test used a fixed PQ Analyzer installed at Sibiu Subsidiary between Transmision and Distribution operators on an 110kV overhead line.

FIELD EXPERIENCE

Principal target of both studies mentioned before was Harmonic analysis in respective metering points. Those measurements, results and conclusions are the presence of harmonics in the power system put higher demands on both power system components and on the measurement equipment. In power system measurements the problems caused by harmonics have been incorporated in increased uncertainty figures, or worse, have just been ignored. However, the increasing levels of harmonics and the economic value of an optimized power system as well as the possibility of a larger stability margin makes a more thorough study of the influence of harmonics on measurements well worthwhile.
Much of the problems associated with power quality are due to asymmetrical voltage or high levels of harmonics. Many different all-round instruments such as voltmeters, oscilloscopes and wattmeter's are used in these situations. Specialized instruments, such as power analyzers, combine the functions of all these instruments and are increasingly being used to determine the power quality. The measured quantities are mainly voltage, current and power spectra, but active and reactive power and total harmonic distortion, THD, can also be of interest in a problem-solving situation. Flicker meters that evaluate the stability of the voltage in the short time perspective are also increasingly being used, and are sometimes incorporated in instrumentation. Total Harmonic Distortion, or distortion factor (THD), is often used to quantify the level of harmonics. For practical reasons the number of harmonics is limited when THD is calculated; this limit is most often in the range n=30 to n=50. To separate voltage THD and current THD the abbreviations THD_U and THD_I are sometimes used.

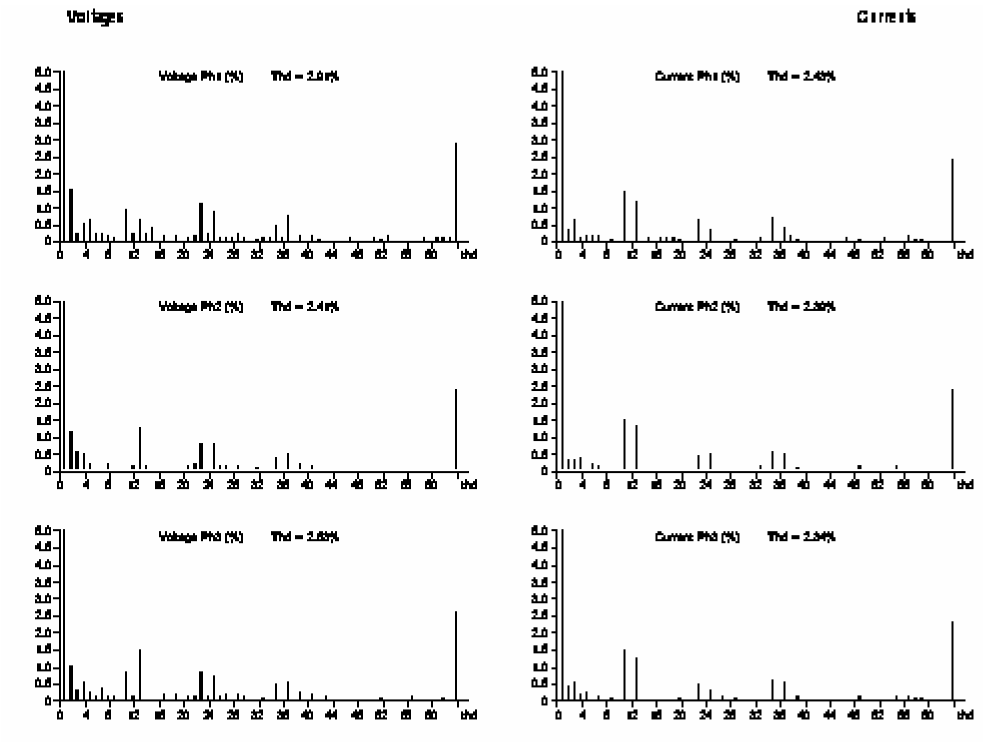
Results for case study 1.

Figure 2 presents the evolution of average voltages and currents over the test period and figure 5 presents a snapshot of harmonics spectrum for voltages and currents.
ALRO Slatina for the secondary voltage THDu: 2,4% phaseR, 2,9% phases and 2,67% phaseT. The most important harmonics are 13, 23, 25, 35 and 37 as shown in figure 4.



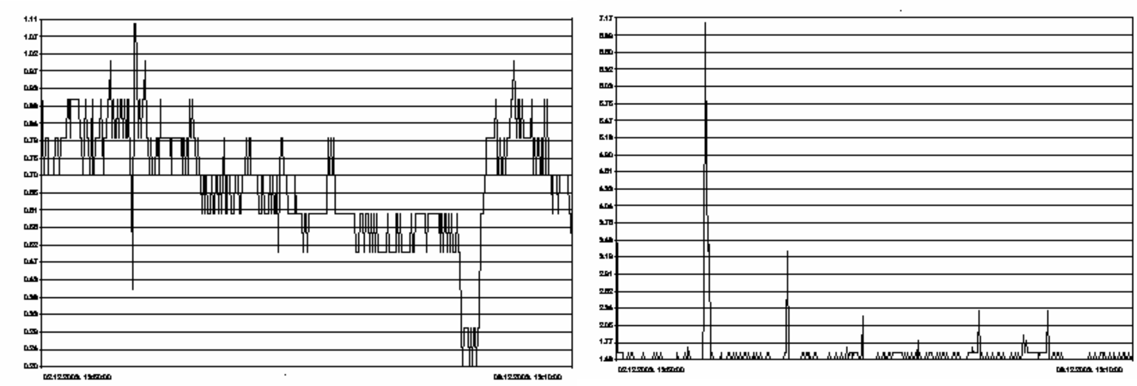
a) b)

Figure 2. Voltage a) and current (b) evolution during test period



a) b)

Figure 3. Voltage a) and current (b) harmonics snapshot



a) b)

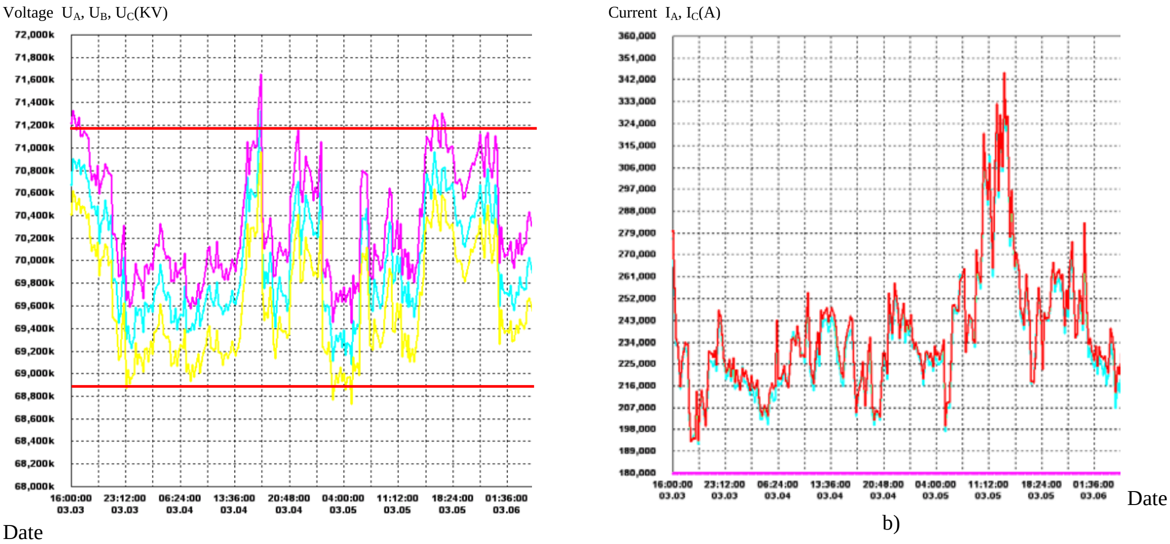
Figure 4. 13'th order voltage harmonic a) and current harmonic b) evolution during test interval

Results for case study 2

Figures 5 to 7 show different types of records during the test period. Red lines mark the set limits for each data point. We can easily see that THD for voltages and currents often exceed the set limits.

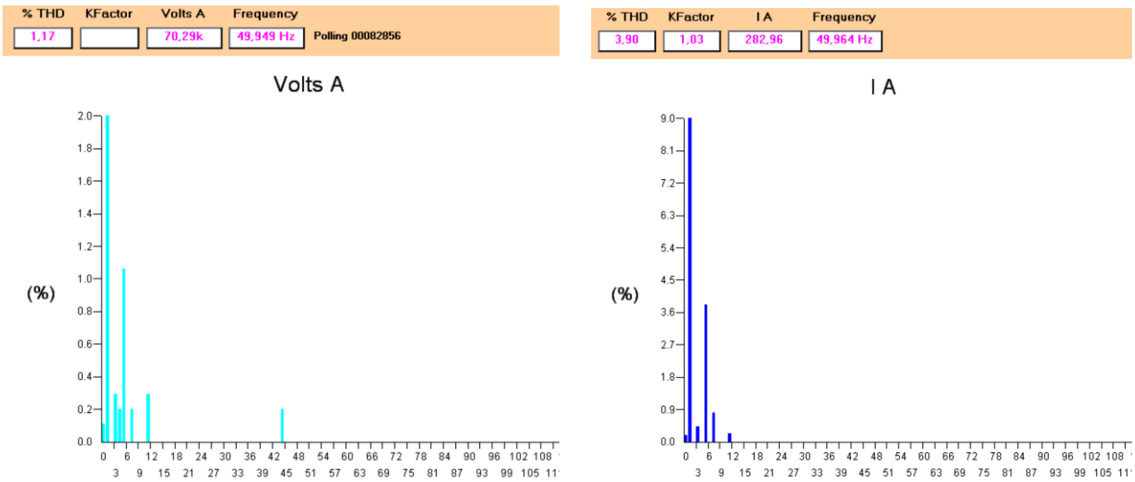
Figures 8 to 10 exemplify an important facility offered by the PQ analyzer. Beside history logs of measured values, two other logs are used to determine the power quality event. When set limits are exceeded for the measured value that event is recorded in the Limits Log (Figure 8). This feature permits to identify without tracing the history log the nature, cause, time stamp and actual value for each PQ event.

For severe perturbations the Power Quality log is available (Figure 9). This feature contains the records taken for great variations of measured values. For some type of events the actual waveform is recorded (Figure 10).



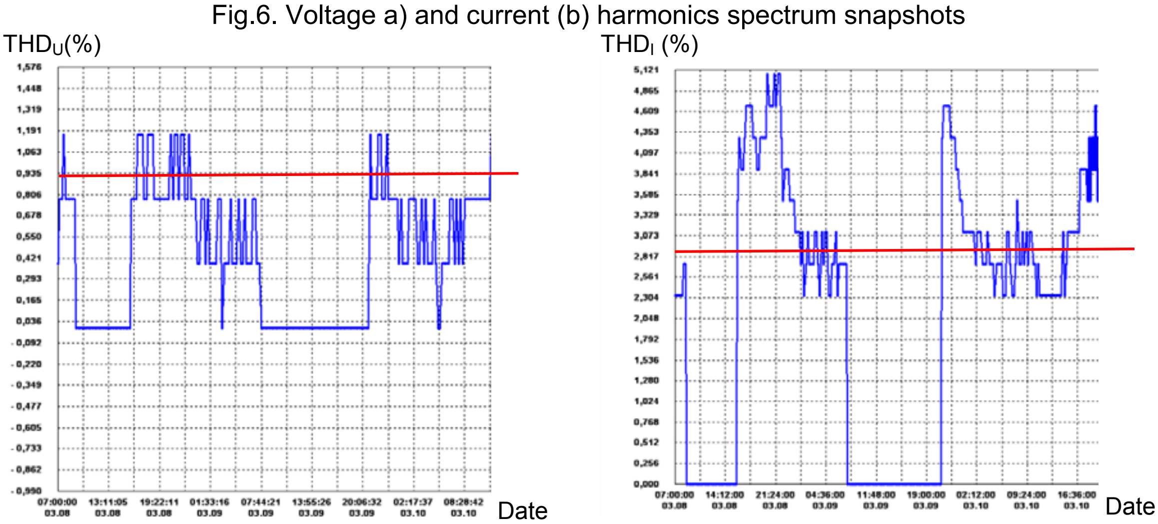
a) b)

Fig.5. Voltage a) and curent (b) evolution during test period



a) b)

Fig.6. Voltage a) and current (b) harmonics spectrum snapshots



a) b)

Fig.7. Voltage a) and current (b) THD evolution during test period

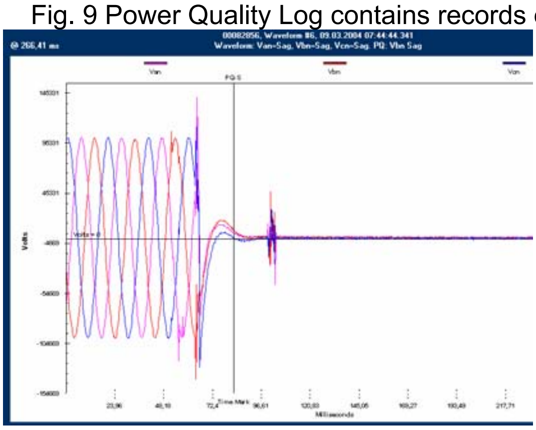
Start Date/Time	End Date/Time	Duration (S)	Device	Set Index	Limit ID	State	Data	Value	Set Point
11.03.2004 11:06:15.090	11.03.2004 11:06:15.130	0,04	00082856	2	Limit 1	Above	0.1s Vbn	71.938,48	Above 71098,1 or 102,5%
11.03.2004 11:06:15.090	11.03.2004 11:06:15.130	0,04	00082856	1	Limit 1	Above	0.1s Van	74.986,21	Above 71098,1 or 102,5%
11.03.2004 11:06:13.180	11.03.2004 11:06:13.220	0,04	00082856	3	Limit 1	Above	0.1s Vcn	71.128,69	Above 71098,1 or 102,5%
11.03.2004 11:06:02.990	11.03.2004 11:06:03.040	0,05	00082856	1	Limit 1	Above	0.1s Van	71.879,60	Above 71098,1 or 102,5%
11.03.2004 11:06:02.950		0	00082856	4	Limit 2	Below	0.1s Ia	4,33	Below 60 or 10%
11.03.2004 11:06:02.950		0	00082856	6	Limit 2	Below	0.1s Ic	2,88	Below 60 or 10%
	11.03.2004 11:05:59.080	0	00082856	6	Limit 2	Normal	0.1s Ic	419,30	Below 60 or 10%
	11.03.2004 11:05:59.080	0	00082856	4	Limit 2	Normal	0.1s Ia	415,35	Below 60 or 10%
11.03.2004 11:05:58.160	11.03.2004 11:05:58.200	0,04	00082856	1	Limit 1	Above	0.1s Van	72.409,63	Above 71098,1 or 102,5%
11.03.2004 11:05:58.160	11.03.2004 11:05:58.200	0,04	00082856	3	Limit 1	Above	0.1s Vcn	72.144,60	Above 71098,1 or 102,5%
11.03.2004 11:05:58.160	11.03.2004 11:05:58.200	0,04	00082856	2	Limit 1	Above	0.1s Vbn	72.497,98	Above 71098,1 or 102,5%
11.03.2004 11:05:36.970	11.03.2004 11:05:36.990	0,02	00082856	1	Limit 1	Above	0.1s Van	71.217,04	Above 71098,1 or 102,5%
11.03.2004 11:03:08.850	11.03.2004 11:03:08.890	0,04	00082856	1	Limit 1	Above	0.1s Van	71.202,31	Above 71098,1 or 102,5%
11.03.2004 11:03:08.850	11.03.2004 11:03:08.890	0,04	00082856	2	Limit 1	Above	0.1s Vbn	71.172,87	Above 71098,1 or 102,5%
11.03.2004 11:03:08.850	11.03.2004 11:03:08.890	0,04	00082856	3	Limit 1	Above	0.1s Vcn	71.290,66	Above 71098,1 or 102,5%
11.03.2004 11:03:08.850		0	00082856	4	Limit 2	Below	0.1s Ia	3,08	Below 60 or 10%
11.03.2004 11:03:08.850		0	00082856	6	Limit 2	Below	0.1s Ic	3,27	Below 60 or 10%
11.03.2004 11:03:03.050	11.03.2004 11:03:04.150	1,1	00082856	6	Limit 2	Below	0.1s Ic	4,42	Below 60 or 10%
11.03.2004 11:03:03.050	11.03.2004 11:03:04.150	1,1	00082856	4	Limit 2	Below	0.1s Ia	4,04	Below 60 or 10%
11.03.2004 09:59:06.520	11.03.2004 09:59:16.520	10	00082856	12	Limit 2	Above	%THD Ic	4,29	Above 4 or 4%
11.03.2004 09:59:06.520	11.03.2004 09:59:16.520	10	00082856	12	Limit 1	Above	%THD Ic	4,29	Above 4 or 4%

Fig.8. Limits Log shows record with time stamp when measured values are outside set limits interval (nominal values)

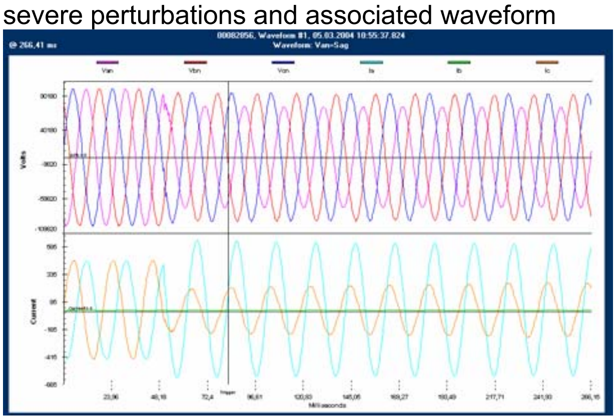
Start Date/Time	End Date/Time	Duration ms	Device	Condition	Channel	Value	% of Full Scale	Waveforms
11.03.2004 11:06:02.907		0	00082856	Sag Start	Ia			☐
11.03.2004 11:06:02.907		0	00082856	Sag Start	Ic			☐
	11.03.2004 11:05:58.217	0	00082856	Normal End	Ic	15,59	2,60	☐
	11.03.2004 11:05:58.197	0	00082856	Normal End	Ia	15,87	2,65	☐
11.03.2004 11:03:08.800		0	00082856	Sag Start	Ia			☐
11.03.2004 11:03:08.800		0	00082856	Sag Start	Ic			☐
11.03.2004 11:03:03.002	11.03.2004 11:03:04.130	1128	00082856	Sag	Ia	15,87	2,65	☐
11.03.2004 11:03:02.982	11.03.2004 11:03:04.130	1148	00082856	Sag	Ic	15,80	2,63	☐
09.03.2004 07:44:44.424	09.03.2004 20:50:50.954	47166530	00082856	Sag	Van	0,00	0,00	☑
09.03.2004 07:44:44.424	09.03.2004 20:50:50.954	47166530	00082856	Sag	Vbn	0,00	0,00	☑
09.03.2004 07:44:44.424	09.03.2004 20:50:50.954	47166530	00082856	Sag	Vcn	0,00	0,00	☑
09.03.2004 07:38:57.082	09.03.2004 21:01:50.720	48173638	00082856	Sag	Ia	15,87	2,65	☐
09.03.2004 07:38:57.082	09.03.2004 21:01:50.720	48173638	00082856	Sag	Ic	7,50	1,25	☐

Start Date/Time	End Date/Time	Duration ms	Device	Contiguous	Van RMS	Vbn RMS	Vcn RMS	Vaux RMS	Ia RMS	Ib RMS	Ic RMS	Iaux RM
09.03.2004 20:50:50.871	09.03.2004 20:50:51.137	267	00082856	☐	79.745,24	65.886,38	79.381,36	0,00	15,88	15,84	15,81	0,
09.03.2004 07:44:44.341	09.03.2004 07:44:44.607	267	00082856	☐	35.307,66	38.159,74	41.393,94	0,00	15,87	15,83	15,80	0,

Fig. 9 Power Quality Log contains records of severe perturbations and associated waveform



a)



b)

Fig. 10 Waveform records in case of:
a) Voltage SAG after line disconnection; b) Voltage SAG caused by a distant fault

Main Characteristics	Mobile PQ Analyzer	Fixed PQ Analyzer
Voltage and currents	I,U rms accuracy <1%	Instant, Maximum I,U rms Accuracy < 0.5%
Power measurements	Average P,Q in four quadrants Accuracy <1%	Instant and Average P,Q in four quadrants. Accuracy < 0.5%
Energy	Wh, VARh, VAh in four quadrants	Wh, VARh, VAh in four quadrants with three different integration methods Accuracy <0.05%
Harmonic analyze	Up to 63'th harmonic Interharmonic analyze available	Up to 125'th harmonic real time Up to 255'th harmonic in history log

		Interharmonic analyze available
THDi, THDu	Calculated separately for all analogical inputs	Calculated separately for all analogic inputs
Flicker	available	available
Connection diagram	Selectable	Set in configuration
External sensors and accessories	Voltage sensors and current clamps	No
Human machine Interface	LCD display and touch buttons	LED or LCD display available as option.
Configuration	Local, from PC connected to serial interface	From PC connected to serial interface, Remote configuration and Data logs download via modem connection or LAN network.
Oscilloscope	Local on LCD display or local connected PC No recording of waveforms	ON-Line waveform display available on local/remote connected PC Separate waveform history log (disturbance recording)
Memory	2Mb	4Mb
Recording interval	Selectable range: 1min-24h	Selectable range: 1s-24h
Sampling rate	16; 32; 64 samples/cycle	From 16 to 512 sample/cycle
History log	Record average values for selected channels	Three different history logs with two adjustable sets of limits 1) Trend Log records average values of selected measuring channels for 0.1s and 1s integration interval 2) Limits Log record the time stamp, duration, values and cause of trigger for values outside the set limits 3) Power Quality Log with Waveform recording for severe perturbation.
Remote communication	External modem is required for remote communication	Option for internal modem or LAN connection. Four RS485 serial interfaces for connection to local communication network

Advantages for fix mounting:

- All available functions can be used;
- Integrated communication;
- Extended memory capacity;
- Digital and analogical I/O extensions;
- Equipments with combined functions of meter and power quality analyzer available on the market

LIST OF REFERENCES

1. ANRE – “Electricity Transmission Grid - Technical Code”, available online at: http://www.anre.ro/FisZip/Transmission %20grid%20technical%20code.pdf
2. ANRE – “Electricity Distribution Grid - Technical Code”, available online at: http://www.anre.ro/FisZip/Distribution%20technical%20code.pdf
3. Eurelectric – “23002Ren9531 Measurement guide for voltage characteristics”, available online at: http://unipede.eurelectric.org
4. Eurelectric – “Quality aspects”, available online at: http://unipede.eurelectric.org

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