POWER QUALITY MONITORING IN BELGIAN DISTRIBUTION NETWORKS

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INTRODUCTION

Netmanagement, as a major partner of most Belgian distribution networks operators, is consequently active in nearly 80% of the power distribution networks in Belgium.
For management of Power Quality Monitoring, Netmanagement refers to Laborelec.
The present paper is experience-based and gives a survey of progress, the regulatory framework, the goals, the system configuration, data acquisition and processing, etc.

EVOLUTION IN A NUTSHELL

Being stimulated by the activities of the DISDIP group operating within the UNIPEDE (presently Eurelectric) framework, Electrabel[1] decides in the early 90-ies to start a permanent measurement campaign in the Belgian electrical power network. Both the goals (only voltage dips, voltage swells and interruptions) and the volume (about twenty devices monitoring about 60 three-phase measurement points, essentially on the power transmission network) of the campaign are rather restricted. It is nevertheless the first structuralized campaign in Belgium and it can be considered as the initiator of a strongly progressing Power Quality Monitoring.
The devices, the so-called "MEDs" (purchased from the Swiss company PANENSA), are read-out manually on a three-monthly basis. The first practical results are obtained for the year 1995. This measurement campaign is then extended with measurement sites in the distribution network.

Power Quality however exceeds the sole voltage dips and short interruptions. As to cope with the increasing risk of compliance problems, the activity in EMC standardization areas is very intense; the EN50160 standard for instance was issued in 1994. This results also in an increasing demand for registration of a wider range of quality indicators; a new generation of PQ Monitoring devices is born.
In 1998 Netmanagement decides they will invest in 'quality management', adopting therefore a more-steps project foreseeing the installation of a PQ monitor at MV busbars in almost each HV/MV injection substation, starting with the most critical substations. In the past 6 years a steadily increasing number of such devices have been installed over the whole country and today 75% of the substations are equipped with a permanent measurement system that provides useful information for operating purposes of the power distribution network.
For this new step ahead, Netmanagement installs Qwave-devices, which have been developed by ACT'L with the help of Laborelec's experience and knowledge and is nowadays proposed by LEM Instruments.
It is clear that the managing system progresses together with the requirements resulting from such policy.

The last years Belgian regulators have also worked out a well-defined framework for the processing of complaints dealing with PQ that are communicated to the distribution network operator (DNO). For the measurement campaigns initiated this way Netmangement also uses a Qwave (although with slightly different configurations and peripherals) that is integrated in the same management system. These campaigns are essentially shorter term ones. In 2004 nearly 1500 measurements of this kind were performed.

REGULATORY FRAMEWORK

In Belgium the legal competence for electrical power distribution is devoted to the Regions (Brussels, Flemish and Walloon Regions). In each region there is a separate regulatory authority that has fixed independently a time-schedule for liberalization of the energy market. Consequently this time-schedule is not completely parallel in the different Regions. As a mere fact, the regulatory framework can be different or not developed at the same level. In one region (Flemish region) the market is already 100% liberalized, which involves regulation is most developed in this region.

As far as Power Quality is concerned, the distribution network operator is engaged, in accordance with the tasks and obligations specified in the technical regulation, to make available all reasonable means he is entitled to provide as to ensure that the voltage supplied at a connection point meets the requirements of the NBN EN 50160 standard.
Moreover, the regulator describes on one hand the procedure to be implemented when processing complaints dealing with the quality of the supplied voltage and, on the other hand, the synthesized reporting of the DNO to the regulator.

1 By the time Electrabel still was an integrated company, active in electrical power generation, transmission, supply and sales.

There are no legal requirements for the installation of permanent PQ measurements. In the mentioned procedure for processing of complaints, temporary PQ measurements are indeed required.

BRIEF DESCRIPTION OF THE MEASUREMENT DEVICES

Within the framework of structuralized PQ measurement campaigns, Netmanagement uses two different devices, i.e. MED and QWave.

Med

This device belongs to the first generation of devices and focuses more specifically on the registration of voltage dips, swells and interruptions. A single device can monitor 2 three-phase measurement points, with a possible extension up to 4 measurement points.
Principle of the measurement: the device measures every 10 ms the effective value of the voltage and compares it with the detection thresholds (with programmable hysteresis) that is set freely by the user.
If the measured RMS voltage exceeds the triggering threshold, as well for a voltage dip, an interruption or a swell, the device records the extreme voltage magnitude and the exceeding duration of the triggering threshold. As the device does not provide information about the evolution of the voltage during the event, interpretation possibilities are limited. The result is transposed into a list of occurred phenomena or a survey of these in a table, as described below.

[%] / [sec]	0.010 to <0.020	0.020 to <0.100	0.100 to <0.250	0.250 to <0.500	0.500 to <1.000	1.000 to <3.000	3.000 to <20	20 to <60	60 to <180
-10 to <-20	0	23	13	9	6	3	2	4	0
-20 to <-30	0	0	1	1	0	0	0	0	0
-30 to <-40	0	0	0	0	0	0	0	0	0
-40 to <-50	0	0	0	0	0	0	0	0	0
-50 to <-60	0	0	1	0	0	0	0	0	0
-60 to <-70	0	0	0	0	0	0	0	0	0
-70 to <-80	0	0	0	0	0	0	0	0	0
-80 to <-90	0	0	1	0	0	0	0	0	0
-90 to <-100	0	0	0	0	0	0	0	1	0
Total =65	0	23	16	10	6	3	2	5	0

Figure 1. Example of a DISDIP table over 1 year for 1 measurement point

QWave

This device offers a wide variety of possibilities that cannot all be described within the framework of the present paper. The features focused on here therefore are only those that are significant within the framework of the PQ Monitoring implemented by Netmanagement.

As 3 voltages and, if necessary, 3 currents can be coupled, we become a large variety of calculated parameters relating with voltage (RMS, Frequency, flicker, THD, (inter-)harmonics, unbalance, Neg, Pos and Zero Sequence, Ripple control, …) current (Neg, Pos and Zero Sequence TDD, (inter-) harmonics) and power output.

Figure 2. Qwave device

These are the data types that are used:

- Recordings: systematic registration of a parameter with a given time interval.
- Events: same principle as for MED, but also implementable for other characteristics. An event is generated when a threshold is exceeded. It is characterized by a timestamp, a duration and a peak value.
- EN50160 counters: they indicate for each concerned parameter to which extent of the measured intervals the limit value is met.
- Incremental recording: when a trigger value is exceeded, a registration of the parameter curve is started (including pre- and post-trigger). "Incremental" deals with the fact that – owing the memory capacity savings – not all values are recorded, but only those differing sufficiently from the previous stored value.

Each type of information is useful, but shows also disadvantages. Some provide very compact information about many parameters; some other provide many details about a well defined one. Some deliver a value under normal operating conditions, while the other provide only information when a triggering threshold is exceeded, etc.
It is therefore not very easy to work out a basic configuration. The compromise to be found should meet as closely as possible the needs and should take into account the technical limitations and financial effects (capacity of the local memory, communication times, storage capacity, post-processing, reporting, ….)

PERMANENT AND TEMPORARY MEASUREMENTS

The PQ measurements performed on the power distribution network can be subdivided into permanent and temporary measurements. They are performed exclusively with a specific goal and also their reporting is adapted consequently.

Permanent measurements -Fixed QWaves

In 1998 Netmanagement decided they would invest in 'quality management'. The project foresees the installation of a PQ monitor at MV busbars in almost each HV/MV injection substation, starting with the most critical substations. Nowadays nearly 75% of the injection points are equipped with monitoring equipment.

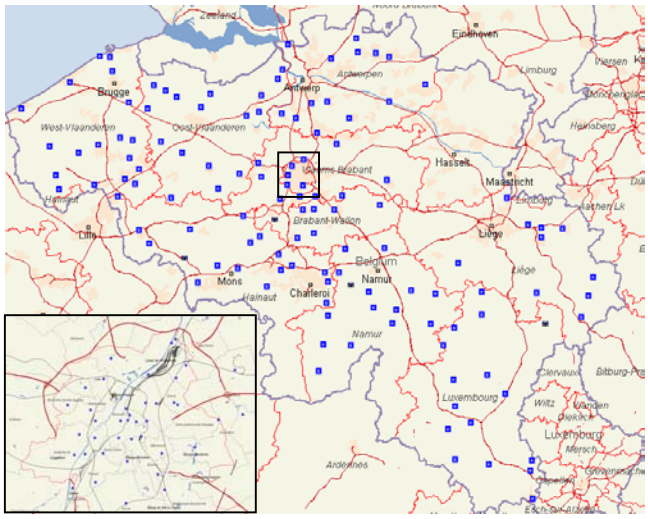

Figure 3. Fixed Qwaves sites

Issuing the EN50160 standard was undoubtedly a catalyst in the creation of this device pool, but Netmanagement's aim always exceeded the verification of the criteria of this standard. The primary goal was indisputably to get a clear image of the voltage quality at all injection points.
The results are essentially used for :

- o The overall monitoring of voltage quality
- o The evaluation with respect to the EN50160 criteria
- o Long term statistics for voltage dips and short-term interruptions
- o Analyzing of long term trends
- o Evaluation of network configuration changes, with possibly a signficant effect on voltage quality. This can occur in combination with semi-permanent measurements.

The QWave used for this purpose is equipped exclusively with voltage inputs. The voltages monitored by priority are the voltages that reflect in the best possible way the power quality for the network user. Consequently, at MV level measurements are always performed between phases. In areas including many overhead lines, this measurement is sometimes completed with a device that monitors the phase voltages giving information about the functioning of protection systems.

Temporary measurements - Mobile QWaves

Temporary measurements are performed within the framework of the complaint processing procedure that is imposed by the regulator. Netmanagement uses for this purpose easily transferable Qwaves in combination with a mobile phone modem. They are most of the time installed on the LV network.
Here also the aim exceeds an evaluation of the criteria of the involved standard and, consequently, the mobile Qwaves are also equipped with current inlets.
The results are essentially used for :

- o Evaluation of the complaint validity
- o Issuing of advice
- o Elaboration of know-how regarding the possibly disturbing effect of some types of LV loads.

In 2004 nearly 1500 campaigns were performed.

SYSTEM CONFIGURATION

The actual device pool includes:
Permanent measurements (on MV):
16 MEDs
427 Qwaves installed in 218 different injection substations
Temporary measurements:
64 mobile QWaves

This monitoring system includes nearly 500 devices and is one of the largest integrated Power Quality monitoring systems in Europe.
The entire PQ devices pool is managed from a central location. The headquarters is located at Laborelec.
This configuration has been adopted from the initial stage on and in practice it appears to be a good choice for many reasons:

- o The scale magnitude results in operational advantages: a team that is involved full-time in this PQ-monitoring (follow-up, validation, reporting, etc.) can react rapidly when problems occur.
- o Although the system includes all components that are required for an accurate separation of data, the good co-operation between the different regional entities of Netmanagement, discussions and data exchange are stimulated actively and easily achievable.
- o Management of one large database is easier than management of different small ones.

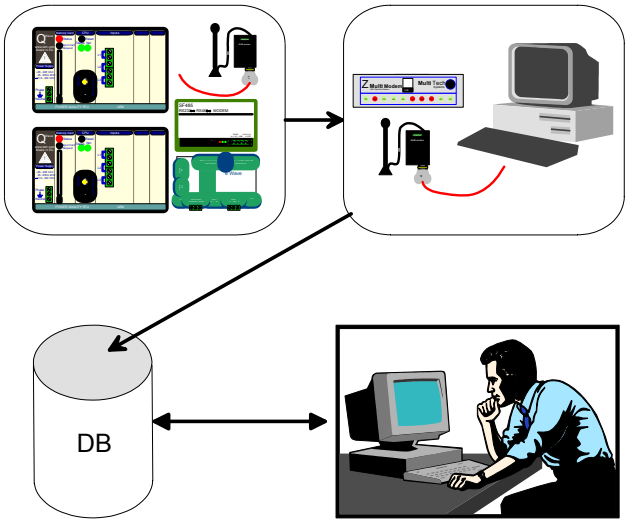

Figure 4. Global system configuration

As soon as the measurement devices are locally installed, communication channels become very important. For permanent measurements a PSTN connection is generally used, for temporary measurements a mobile phone connection. Testing of a GPRS connection as a possible option is in progress.

This communication channel is used for:

- transmission of a measurement configuration to the measurement device
- verification of the electrical connection
- reading-out of measurement data from the memory of the measurement device.

For reading-out of the measurement data an automatic call system is used; it tries several times a day to get communication with the different devices.
When some subsequent attempts fail, an error message is generated; then a manually started attempt is performed and, if necessary, the problem can be investigated more thoroughly.

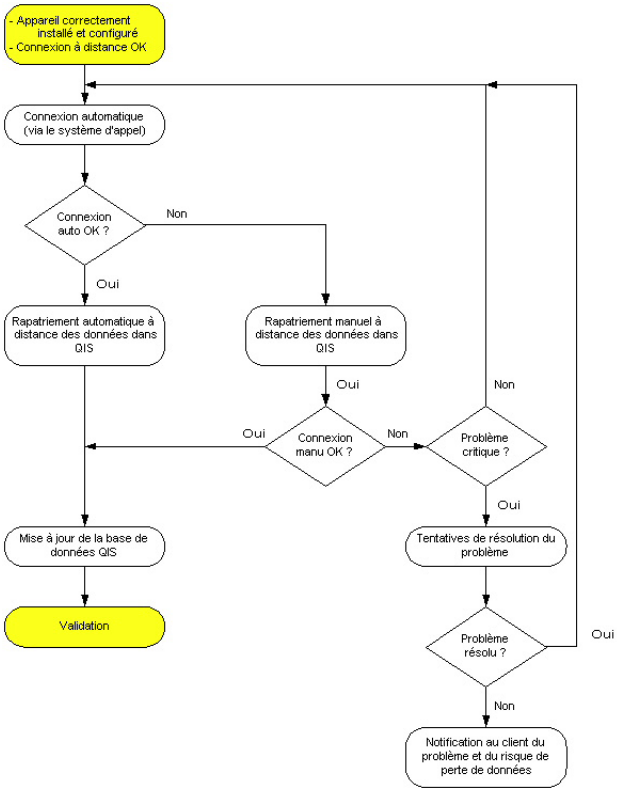

Figure 5. Flow-chart for reading-out purposes

Some figures:

- The database grows every week with 500MB
- 18 PSTN-modems and 8 mobile phone modems ensure the reading-out of the nearly 500 devices
- A daily reading-out requires nearly 8 to 10 min when using a permanent line, 30 to 45 min with a mobile phone modem and 90 minutes with a GPRS connection
- The capacity of the presently operational database amounts to 70Gb. 60Gb have already been archived.

THE CLOSE CO-OPERATION BETWEEN NETMANAGEMENT AND LABORELEC

Any person working in the Power Quality environment is aware of the fact that data collection by itself is not that exaggeratedly complicated, but Netmanagement's final goal is to derive from these bulky data the information that will allow

- a better 'quality' management of the power distribution network
- to provide, in a correct and effective way, information to the different actors (network manager, system user, regulator, …).

That resulted in a close co-operation between Netmanagement and Laborelec.
Within Laborelec there is an important Power Quality department. Referring to their know-how in the concerned field, they are indisputably entitled to ensure the system will meet the changing needs of Netmanagement in the future**.**
Laborelec's mission can be summarized as follows:

- to guarantee that all useful data are stored in the central database
- to foresee the required means enabling the correct and effective implementation of these data by Netmanagement

Laborelec's practical mission includes:

- support for the selection of data to be stored and of the procedures for their post-processing
- the operational tasks (configuration of the devices, read-outs of the devices, data archiving,…)
- validation of measurement data
- post-processing and reporting
- realization (or support to it) of the means required in order to meet in the future the progressing reporting needs.

MEASUREMENT DATA AND THEIR POST-PROCESSING

The different types of measurement data are: events, recordings, incremental recordings and EN50160 counters (see also the paragraph dealing with the measurement devices)
Each type of these measurement data has its specific usefulness with respect to the goals Netmanagement defines for its Power Quality Monitoring.

The events (dips, swells and interruptions) are processed separately, after being documented and validated.

Documentation of the events. Additional information dealing essentially with the origin of the phenomenon is gathered for each event.
The possible correlation with another event recorded by another device is also investigated. For example, an electrical short-circuit in the network is liable to generate events at different places and can also result in the registration of different events at the same place. In such cases all correlated events are documented identically.

Validation of the events. Here it has to be verified whether a registered event has to be considered as a true Power Quality problem whether it results from a programmed network operation (switching, maintenance). Interpretation is, of

course, performed from the point of view of the system user.

Data processing. Reporting of data exceeds the sole representation of registered data. Before drafting a report, data are generally submitted to one or more processing operations : flagging , aggregation, statistical computations, comparison with standardized limits, etc.

Flagging. This item deals with the fact that measurement data that are corrupted by transient phenomena are not taken into account. Both the user guide of the EN50160 standard and the IEC61000-4-30 standard refer to this principle. To our opinion, formulation of the IEC61000-4-30 standard (which is also more recent) meets the aim more exactly. Nevertheless, implementation of the latest definition can result in faulty results prejudicial to the system user when the voltage level approaches the triggering limit for dips (for instance in weak LV networks). That's why a specific flagging procedure taking these elements into account is adopted in our post-processing procedures.

Aggregation. This topic refers to the combining of events that can be coupled. Starting from the 'list of events' (called "basic events") registered on a each phase of a multi-phase system, the following steps are considered:

- Grouping of basic events: some events are considered as making part of the same event, called grouped event, when they overlap in time (events on different phases) or they follow each other within a limited time.
- Selecting the master event(s) in a series of events: when a grouped event follows the previously grouped events by less than typically 60 s, they are part of a same series of events. A series of events will be represented by max two master events (1 dip or 1 swell or 1 dip + 1 swell)

Before or after each step it is possible to activate a filter.

Statistical computations. A wide range of calculations is adopted and adapted to the required utilization of the results (e.g. comparison with − standardized or user defined − limit values, LT statistics, …)

REPORTING

A first reporting level is the comsultation of measurement data. The various concerned services of Netmanagement can use the intranet in order to investigate, display and/or export the data available in the database for further processing purposes.

Different tools are used therefore:

PQ-Lab: This software was developed by Laborelec, with the initial aim: reporting regarding events and their specific documentation, validation and aggregation. Later on the tool has been enlarged, offering a wide range of possibilities.

Q-Browser & Q-Export (LEM products): This software is exclusively implementable by fellow-workers of the Monitoring service.

Depending on the kind of data available in the database a specific reporting will also be outlined.

For permanent measurements under mentioned standard reporting operations are available:

Incident report. When registering an event, a so-called "Incident Report" can be drafted. Such report will bundle as much as possible information about one event, including for instance the incremental recording and the probable origin of the phenomenon.

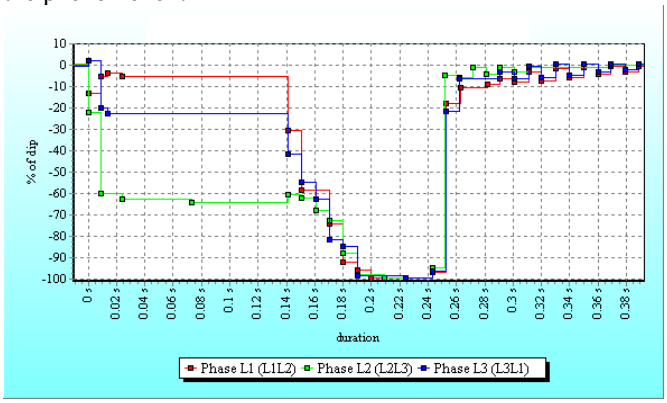

Figure 6. Extract of incident report

NQF-report. For one well-defined measurement spot all dips are taken into consideration over a one year period and weighed in accordance with their depth and duration. The weighed average value is called NQF (or Non-Quality Factor) and is a characteristic value for the measurement spot (cfr. IEC 61000-2-8).

Weekly report. Each week a selection of the most characteristic indicators is calculated and compared with an alarm threshold or a standardized threshold value, according to the EN 50160 standard. The Non-Quality factor calculated over 3 months is also included in this reporting.

CP 95							
Harmonics (% Un)				THD (% Un)	Pst	Plt	Unbalance (%)
H5	H7	H11	H13				
6,00%	5,00%	3,50%	3,00%	8,00%	-	1,00	2,00%
0,66	0,77	0,24	0,13	1,02	0,19	0,18	0,35
1,00	0,34	0,54	0,17	1,22	1,15	0,94	0,36
1,72	0,58	0,18	0,20	1,81	0,25	0,23	0,52
1,37	0,41	0,49	0,19	1,50	0,25	0,21	0,35
0,73	0,61	0,37	0,14	1,03	1,31	1,09	0,43
1,45	0,55	0,26	0,13	1,57	0,24	0,22	0,38
2,86	0,73	0,26	0,13	3,00	0,18	0,15	0,29
3,04	0,75	0,32	0,21	3,22	0,21	0,20	0,33
0,94	0,49	0,43	0,17	1,14	0,34	0,30	0,18
1,00	0,61	0,56	0,27	1,19	0,55	0,48	0,17

Figure 7. Extract of weekly report (orange=alarm, Red= EN50160 non conformity)

Annual report. Each calendar year and for each measurement spot a global synthesis is worked out. In addition, for each region the emerging facts are focused on and the most significant trends are indicated.

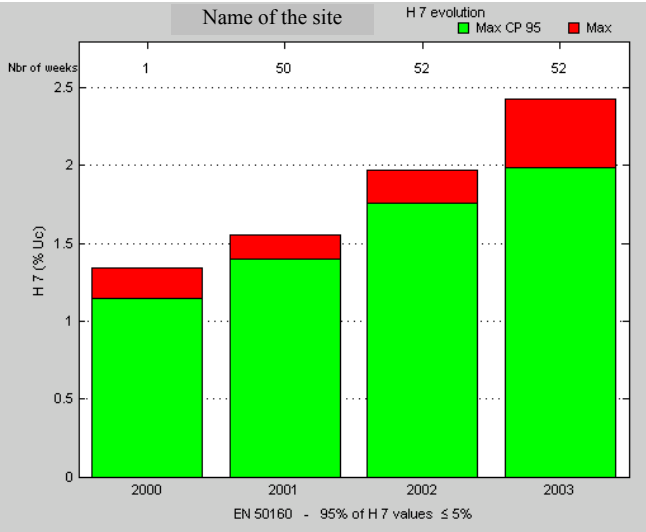

Figure 8. Extract of a yearly report (growing H7 over several years)

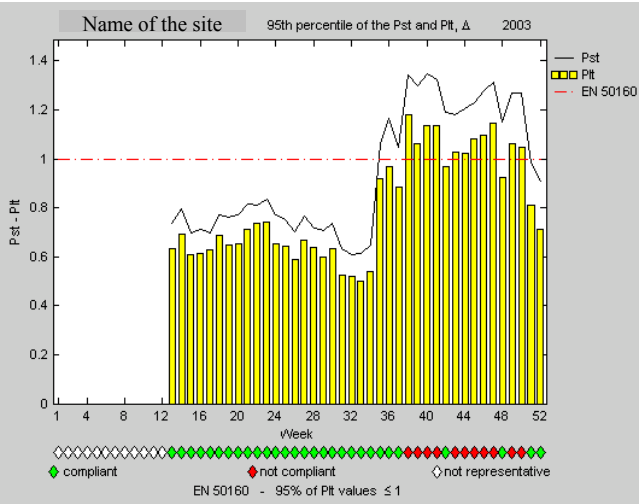

Figure 9. Extract of a yearly report (2003: Flicker compliance problems)

The automatic reporting regarding the temporary measurement campaigns is still rather new and under progress. These measurements being started in the case of complaints, all possible elements liable to clarify a problem or to define a cause relation are emphasized. Furthermore, specific attention is paid to reporting to the regulator.

Data type	Criterion		Measurement			EN50160 LV Compliancy?			VREG LV/MV Compliancy?		
	Compliance condition	Miniumum rate (%)	rate (%)								
									CAT 7		
RMS									3a	4	6
URMS AVG 10'/ UREF	90% ≤ x ≤ 110%	95,00	100,00	98,60	94,94	Yes	Yes	No	na	na	na
URMS AVG 10'/ UREF	85% ≤ x ≤ 110%	100,00	100,00	97,31	97,42	Yes	No	No	Yes	No	No
URMS AVG 10'/ UREF	90% ≤ x ≤ 106%	95,00	100,00	97,66	94,94	na	na	na	Yes	Yes	No

Figure 10. Extract of a temporary campaign (project) (compliancy of EN50160 and regulators criteria)

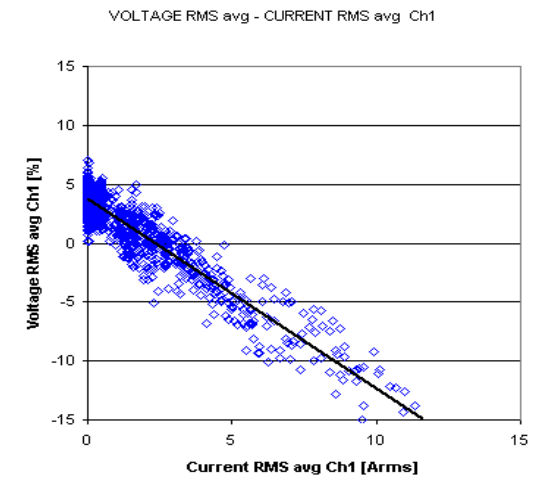

Figure 11. Extract of a temporary campaign (project)

CONCLUSIONS

Over the past years, Netmanagement integrated systematically Power Quality measurements into their operational tasks. Still there are additional possibilities to exploit the gathered data. E.g. predictive maintenance might be one of them, having representative statistical data over time, geographical area and type of network.

REFERENCES

[1] IEC 61000-2-8: Electromagnetic compatibility (EMC) - Part 2-8: Environment - Voltage dips and short interruptions on public electric power supply systems with statistical measurement results (2002-11-22)

[2] EN 50160: Voltage characteristics of electricity supplied by public distribution systems (1999-11-02)