

POWER QUALITY MONITORING

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Abstract

In this forever changing world, the Energy market rises new concerns about the level of Power Quality present in the Power System. The on-going deregulation process involves more legal and contractual interfaces between the Market Players, and also more sources of Power Quality disruption, brought by the actors of the Energy market. In this new situation, the Electricity becomes a good, that partners or retailers are trading at different levels, thus requiring a proper quantification of the good exchanged. This is not only a kwh matter, but this is becoming a concern of "how good" is the power that my supplier is providing to me.

Some Power Quality Standards are already existing, and are giving some minimum parameters to be kept within acceptable limits for the different parties involved in the Power Trading. The Asset Management approach, is requiring a more accurate Power Quality Monitoring, in order to improve the Network Planning, and consequently to optimise the investments, by avoiding the "over-quality". The point is then to evaluate "How far" (or "How close") is the Power Quality, versus the standard to be reached at interconnection level.

In the Industries, the use of more and more automation, makes the industrial processes , very vulnerable to Power Quality disruptions, which may result on

considerable losses. The Industries have then to evaluate whether it is more cost effective, to settle premium power contracts with their utilities, or to make their processes less sensitive to failures in the power delivery. The Energy cost optimisation, leads to try to regroup loads in order to better negotiate the Energy rates, and also to avoid penalties for bad power factor, or excessive electrical pollution rejected to the network. Thus more specific Power Quality monitoring is required to reach these goals.

From the here-above concerns, we can see that data has to be made accessible to technical people, but also to financial non-technical deciders. That is why advanced expert analysis software are needed, in order to generate automatically Power Quality Reports, that shall transform the tremendous amount of data collected, into real Information, useful to both network expert, and contractual authorities.

This paper is exploring how the Power Quality Monitoring solutions, have to fit in the deregulated context, and how different type of Power Quality Meters, linked to advanced Power Quality analysis software, can fulfil the new concerns of the Energy Market players.

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INTRODUCTION

In the last decades, the power systems have been monitored in order to be able to determine the exact type of fault, to find the proper ways to clear the faults, and to check the reactions of the protective devices. This was rather done for reporting purposes, that is extracting the exact picture of the fault, to include these data in reports for the uses of deciders, administrators, or authorities. Another goal for this monitoring system, was engineering oriented, that is improving the theoretical models of the electrical networks, thus studying the appropriateness, between the “calculated behaviour of the network” in regards of the “actual behaviour of the network”.

The time constant of the analysis was of different types, from half a day or a day, to analyse the faults and to check that all the parameters were as expected, up to several months of theoretical expertise, to draw advanced conclusions about the influence of the design of the power system, on the consequences of the faults.

The use of these monitored data, was used as well in litigation context, where the responsibility between several actors in the electrical networks was to be looked into for cost assignment in particularly severe consequences of faults on the electrical network. In some cases, a very accurate analysis of the fault was required to know the exact values of the electrical parameters just before the faults, to see whether such piece of equipment were right to have failed or not.

We can see that according the here-above description, these monitored data were obtained for internal use of the electrical companies and their internal actors, rather than for an external use.

With the POWER QUALITY concerns, the goals are different. If the use of the data for internal Engineering purposes are still valid, a new approach is to evaluate the “level of quality” of the electrical supply, giving information, on which legal contractual agreements can

be based upon, and giving data which can be issued to the public. This is particularly true with the deregulation occurring on the markets, where legal interfaces have to be defined between, more than one actors of the Energy market. The appearance of “retailers company”, which buy the electricity from one company, to resell it to other companies, make now critical, the way of monitoring the electrical parameters of the networks. This involves that two monitoring equipment placed at the same location should give the same results for the same events, requiring to measure in the same way the same parameters. These measures have to follow standards for the type of parameters such as the European EN 50160, or the IEEE 1159 standards and measurement guide for the way to measure these parameters.

After having required some monitoring devices specifically designed upon specifications of utilities, the trend of the market is to choose “from the shelves” equipment which then have got to be compliant with the Power Quality standards.

THE PHILOSOPHY OF POWER QUALITY IMPROVEMENT

A first approach is to try to improve at any cost the level of Power Quality, independently of the context producer-consumer at the delivery points. The level of quality can be significantly improved by using FACTS and DVR technologies, but their costs have to be put in balance with how much it would cost to improve the immunity of the equipment installed near critical processes, and to limit the pollution of the loads installed by the customer. This involves a co-survey of the problem by both the utilities and the critical customers. The point is to study the gap existing between the power quality, and the immunity of equipment to power quality disorders. A predictable conclusion coming along with the power quality levels of the supply is that equipment immunity should be drastically improved. A strange consequence of the evolution of the technology is that, hard-wired relay logic gave way to solid state circuitry, and to greater computational capacity. These most recent systems are generally more sensitive to power quality disruption, and have greater consequences on the whole process because controlling most of the process parameters by the same piece of equipment.

Another point to be considered, is that in a critical industrial plant, less than 10 % of the supply is used for very vulnerable equipment. So looking into this matter only from the supply point of view is equivalent in spending consequent effort and money, for as well the 90 % of non sensitive loads. As a remark, let us point at the fact that most of the domestic equipment can survive dips of 40 % , Industrial drive equipment can only withstand a little 10 % variation of the voltages, as more severe variations may cause very harmful consequence on the controlled processes.

POWER QUALITY IS ALSO A SERVICE TO THE CUSTOMER

Utilities have to know the perception of their customers about the quality of the power supply. Taking into account the customer expectations on Power Quality, at the design stage of such section of the power system, leads to a higher appropriateness between the expected and the delivered products. The final step of this principle would be to actually design and manage the power system with the customer care concern. The utilities should be able to issue relevant data about the quality of delivery, to their customers as it is found as important to be reported the quality disruption, as the bad quality itself. New dimensions have to be added in the evaluation of Power Quality given to the customers, as they may be more concerned about cost of undelivered energy, the cost of lost loads, the cost of clean up of contaminated plants, the cost of scrapped materials, the cost of restoring production, the cost of recovering lost production. Potential losses are to be added such as: cost of replacing damaged equipment, cost of lost sales.

We can see that the reality of the customer is an index composed with several dimensions, as the Power Quality standards are only giving the values of the electrical parameters.

The quality of the service is composed with 3 components:

- the reliability/availability of the power supply : the reliability being defined as the number of outages in a period of time, as the availability is the number of failures , the duration of each failure and the total interruption time per year.
- the quality of the voltage : can be described in term of magnitude, frequency, waveform and symmetry of the three phase voltage. PQ disturbances which affects one or more of the above characteristics such as: slow variations, voltage fluctuations causing flicker, voltage dips, temporary over-voltages, transient over-voltages, short and long voltages interruptions, harmonics, inter-harmonics, and unbalance.

- the relational aspects between the utility and the customer: mainly provision of information to a customer.

We have to bear in mind that the customer is not conscious, that he is buying such an amount of power at a particular moment based upon its price at this moment. This is completely different from any other supply of goods. The customer is aware only once a year, likely during the year account, of his consumption level. Any action helping the customer to monitor more often the amount of power he is buying at which cost, is a part of the improvement of the quality of service.

STANDARD VOLTAGE CHARACTERISTICS/VS EMC CHARACTERISTICS

The EMC is the ability of an equipment to function satisfactorily in its' electromagnetic environment, without introducing intolerable electromagnetic disturbances to anything in that environment. As a concept EMC is involving disturbances penetrating in an appliance through its input/output leads, superimposed to the electricity feeding, radiated interference in addition to conducted ones.

In other words EMC is the fact to ensure the compatibility between immunity levels of sensitive loads, and emission levels of disturbing loads.

In the common language, EMC is used to speak about the high frequency disturbances, penetrating through earthing, input/output signals or radiation.

Power Quality is used for low frequency disturbances, penetrating through the electric power feeding.

Compatibility levels: reference values used for co-ordination of emission and immunity of equipment making up or being supplied by a network in order to ensure EMC throughout the whole system. These levels are considered to correspond to a 95 % probability that the limits values are not exceeded.

Voltage characteristics: European standard EN 50160 lists the main characteristics of the voltage at the customer supply points in low and medium voltage public networks under normal conditions. For the parameters described in the standard, some are virtually guaranteed limits at all points of the network. These limits are close to compatibility levels (or higher). These parameters are based upon statistics, with integration period, and observation period. For example, for harmonic voltages, the measurement period is 1 week, and 95 % of the RMS

values integrated on 10 minutes, should not exceed the limits.

Planning levels: these levels are the internal power quality objectives of the utilities. They are used for planning when evaluating the impact of all consumer loads combined, on the network. They are chosen as equal or less than the compatibility levels. These values are only indicatives, because varying upon the structure of the network, and the circumstances. The evaluations of the real levels to be compared to the planning levels are based on a statistic which may be different that the one described in the standards, aiming to define more accurately the disturbing capacity of the phenomena on the network. These indicators are much more severe and then we can say that the planning levels are stricter, than the voltage characteristics.

STANDARD VOLTAGE CHARACTERISTICS

The parameters of the voltage characteristics are the following:

- frequency,
- magnitude,
- rapid changes,
- dips (or sags),
- short and long interruption,
- temporary or transient over-voltages,
- unbalance,
- harmonics,
- inter-harmonics,
- mains signalling,
- DC components.

The measurements algorithms are specific for all the parameters described in the standards.

In the context of deregulated markets, some data are to be published yearly such as:

- Interruptions/year (per consumer)
- Supply unavailability: minutes/year (per consumer)
- Interruption duration: average duration of consumer interruption

The limits and the measurement methods (Integration periods and Observation periods) described in the standard EN 50160 are listed in Appendix A.

Example of a planning level vs Voltage characteristics

As an example, the flicker parameters is calculated as follows:

The treatment is composed with the here-below formulas:

$$P_{50}l = (P_{30} + P_{50} + P_{80})/3$$

$$P_{10}l = (P_6 + P_8 + P_{10} + P_{13} + P_{17})/5$$

$$P_3l = (P_{2,2} + P_3 + P_4)/3$$

$$P_1l = (P_{0,7} + P_1 + P_{1,5})/3$$

$$P_{0,1}l = P_{0,1}$$

giving the PST factor:

$$Pst = \sqrt{0,031P_{0,1} + 0,052P_1 + 0,065P_3 + 0,280P_{10} + 0,08P_{50}}$$

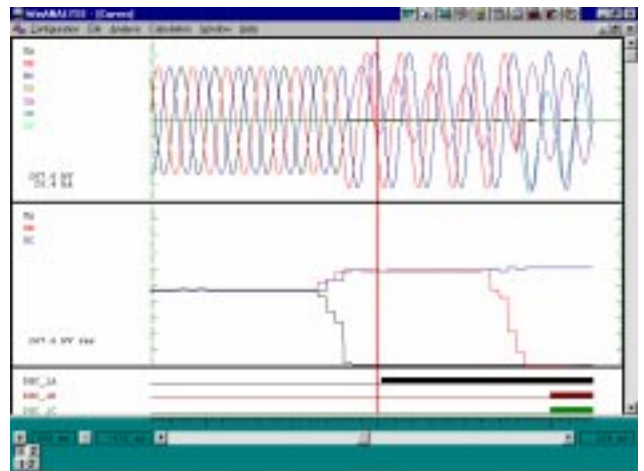
The standard is stating a limits only for PLT parameter: within a week the values Plt.95% or Plt.99%.

The planning levels could be defined as Plt.max per day, Pst.3 max (3rd value of the highest value of Pst) or Pst.2max (2nd value of the highest value of Pst).

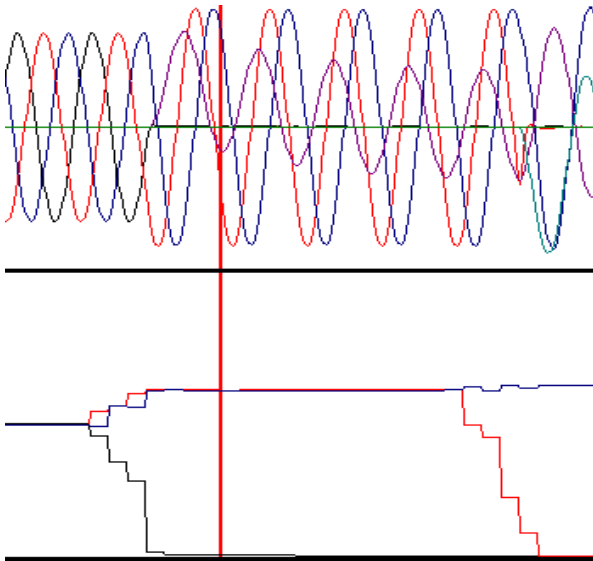
A second example about the difference between the planning levels and the voltage characteristics could be the 100 % value of the voltage instead of the 95% value given in the voltage characteristics.

EXAMPLE OF PQ PARAMETERS GIVEN BY DISTURBANCE RECORDING SYSTEM

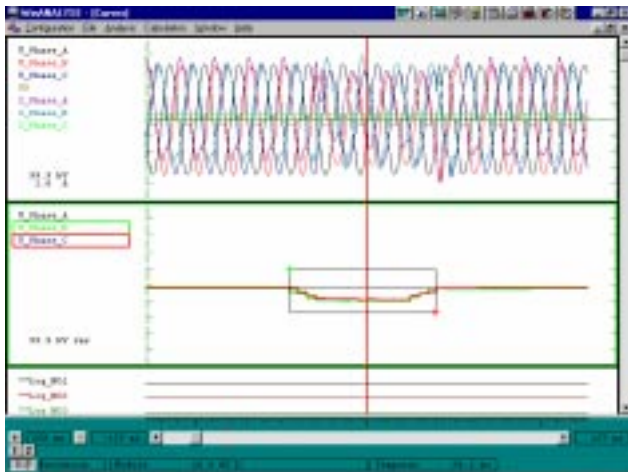
You will find in here below the example of the voltage dip evaluation by a Disturbance Recording system composed with a Disturbance Recorder MICOM M840 and the associated analysis software Win DR Manager.



We can see the evaluation of the voltage dips of an evolving fault starting single-phase fault and finishing with a phase to phase fault.



Another example is given here below, where we can see the voltage dip generated by a bi-phase fault, with duration of 84 ms.

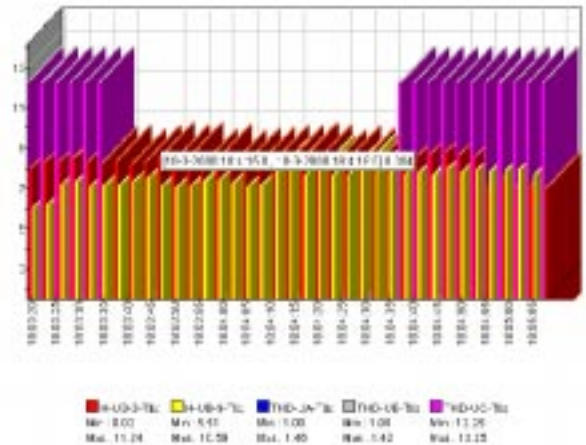


POWER QUALITY REPORTS GIVEN BY POWER QUALITY METERS AND THE ASSOCIATED SOFTWARE

Monitoring Power Quality at district levels, is producing a tremendous amount of data, each Power Quality Meters, bringing approximately 1 Gega byte of data per year. We can see that processing all these data requires a powerful data-base management tools.

Besides, what is interesting for technical or financial deciders is expert information. So the challenge of the Power Quality Monitoring Systems is their ability to transform Power Quality data into Power Quality Information !!

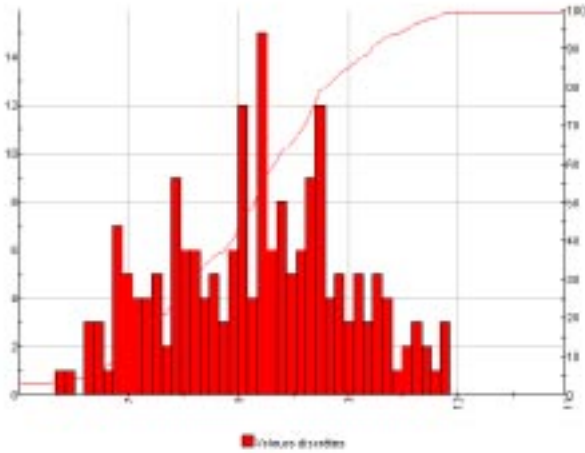
These analysis packages, are usually able to process statistics on gross power quality parameters. Some additional parameters, can be created by filtering on the gross indicators. Namely, in the network planning purposes , it is useful to see how the PQ parameters are converging to the level required by the standards, in



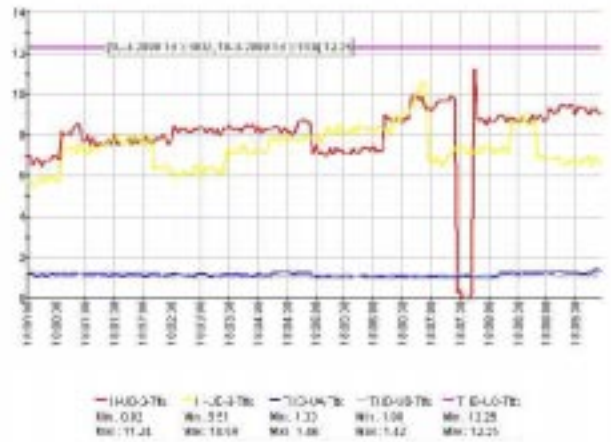
particular locations (common coupling points).

You can see here-below some examples of Power Quality data processing, synthesised in different views, chosen purposely by the user. For each parameter, it is possible to chose which view will or will not be included into the report.

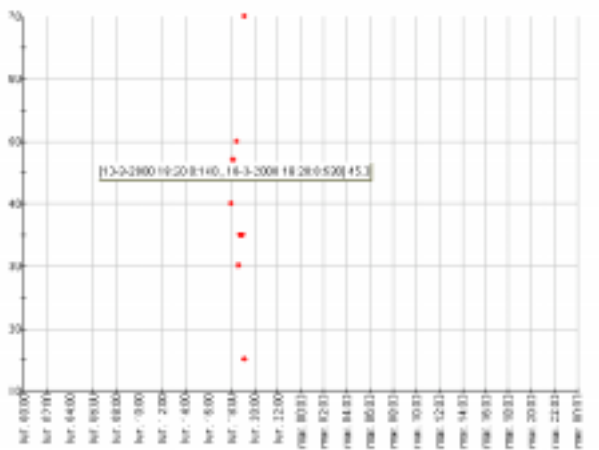
Trend curve of the harmonics, time related.



Density of probability of Power Quality Data.



Trend of multiple Power Quality parameters on the same graph, time related.



Occurrences of Voltage swells - time related.

CONCLUSION

The Power Quality subject contains various aspects in which have to be included the quality of service, as perceived by the customer. We have exposed some definitions and notions, used in Power Quality monitoring, with for instance the planning levels, which are to be monitored as internal Power Quality objectives of the utilities. The parameters defined in the existing standard are bi-dimensional, introducing a notion of time as well as levels. The

Trend curve of the harmonics, time related measurement methods and the algorithms are totally defined in the standard, involving mean values, RMS values, Pk values with a 95 % statistic. The equipment necessary to record these parameters has to be wide spectrum bandwidth and with a great processing capacity, in order to respect the integration time, and the observation period for each parameter.

A pragmatic approach have to be followed in order to do the balance between the economical cost of improving the PQ at the source, and the process of limiting the pollution of the disturbing loads and improve the immunity of the devices critical for the continuity of the industrial processes.

APPENDIX A

The limits and the measurement methods (Integration periods and observation periods) described in the standard EN 50160 are listed here-below :

Parameters	Limits values		Measure and evaluation			
	LV	MV	Mean value	Integr.	Observ	%
Frequency	49.5 to 50.5 Hz 47 to 52 Hz			10s	1 week	95 100
Voltage Variations	230 V +/-10%	Un	RMS value	10 min	1week	95
Rapid change	5% max 10%	4% max 6%	RMS Value	10 ms	1 Day	100%
Flicker	Plt = 1		Algoorythm flicker	2h	1 week	95%

Parameters	Limits values		Measure and evaluation			
	LV	MV		Integr.	Observ	%
Voltage dips	frm 10 to (<1min)	1000 / yr (<85%Un)	RMS value	10mS	1 year	100
Short interruptions (<3min)	10 to (<3min)	100 / year (<1%Un)	Value	10mS	1 year	100
Long interruptions (>3min)	from10 to (>3min)	50 /year (<1%Un)	RMS Value	10mS	1 year	100
Temporary OvervoltagesPH-Earth	<1.5kV	1.7 à 2	RMS Value	10mS	-----	100

Parameters	Limits values		Measure and evaluation			
	LV	MV		Integr.	Observ	%
Transient Overvoltage Phase-Earth	<6kV		depends on operation	PK values	----	100
Unbalance Voltage	2% sometimes	3%	RMS Values	10 min	1 week	95%

Parameters	Limits values		Measure and evaluation		
		LV	MV	Integr.	Observ %
Voltages					
Harm	5	6%	6%	RMS	10 min 1 week 95
	7	5	5		
	11	3.5	3.5		
	13	3.0	3		
	17	2	2		
	19	1,5	1.5		
	23	1,5	1.5		
	25	1,5	1.5		
Parameters	Limits values		Measure and evaluation		
		LV	MV	Integr.	Observ %
Voltages					
Harm	3	5%	5%	RMS	10 min 1 week 95
	9	1.5	1.5		
	15	0.5	0.5		
	21	0.5	0.5		
	2	2	2		
	4	4	1		
	6..24(even)	0.5			
THD		8%			

REFERENCES

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- Power Quality measurement protocol – CEA guide to performing power quality surveys , reference 220 D 711 , Hydro Quebec Varennes, Quebec