POWER QUALITY AND DISTURBANCE RECORDING

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The disturbance recording systems are designed to meet the needs of the electrical companies and industries involved in the monitoring of electrical networks. The electrical parameters are stored upon triggering conditions, allowing the analysis of the faults (type of the fault, nature of the fault, values before during and after the faults) and of the behaviour of the protections (comparison to the theoretical reclosing cycles. These devices are usually based upon the calculations of RMS values of the electrical parameters, with some additional calculated parameters (symmetrical components, Powers, Power factors).

The growing interest in Power Quality concerns, leads to rise up the technical characteristics of the disturbance recording systems, in order to be able to take into account wide spectrum disturbances phenomena, and to be able to compare the quality of the power to bi-dimensional criteria (RMS – Time), with pre-defined integration time and observation period. These more complex Power Quality monitoring parameters are linked to existing standards, mostly connected to contractual and legal agreements between the power suppliers and the power consumers.

The Power Quality factors being set mostly to yearly statistics of the occurrence of phenomena, database treatments are necessary in the analysing tools of such systems.

Besides, the algorithms of integration involve natural or quadratic averaging, synchronised calculation windows. This results in a different technical approach in the product proposed on the market with wider spectrum measurement stages, and advanced signal processing capability.

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 points to be considered, is that in a critical industrial plants, 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 remarks, 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.

SOME DEFINITIONS

General term: **Power Quality** problem is any variation in electric power service resulting in miss-operation or failure of end-use equipment

More explicitly, the term of Power Quality means **Voltage Quality**.

Power **system reliability**: adequacy (ability to supply the demand) and security (ability to withstand sudden disturbances)

Supply reliability: means in fact the availability and is concerned with long interruptions. It is characterised with several indices of the interruption frequency and duration

Supply quality = supply reliability + voltage quality

Service quality: reliability of supply to a customer, quality of power offered to a customer, provision of information to a customer.

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:

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

$$P_{10}l = \left(P_{6} + P_{8} + P_{10} + P_{13} + P_{17}\right)/5$$

$$P_{3}l = \left(P_{2,2} + P_{3} + P_{4}\right)/3$$

$$P_{1}l = \left(P_{0,7} + P_{1} + P_{1,5}\right)/3$$

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

giving the PST factor:

$$Pst = \sqrt{0{,}0314 P_{0,1l} + 0{,}0525 P_{1l} + 0{,}0657 P_{3l} + 0{,}280 P_{10l} + 0{,}08 P_{50l}}\,.$$

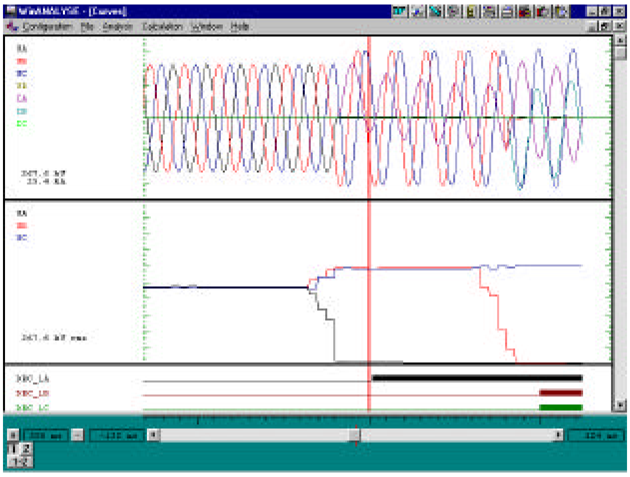
The standard is stating a limits only for PLT parameter: within a week the values Plt.95% or Plt.99%.

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).

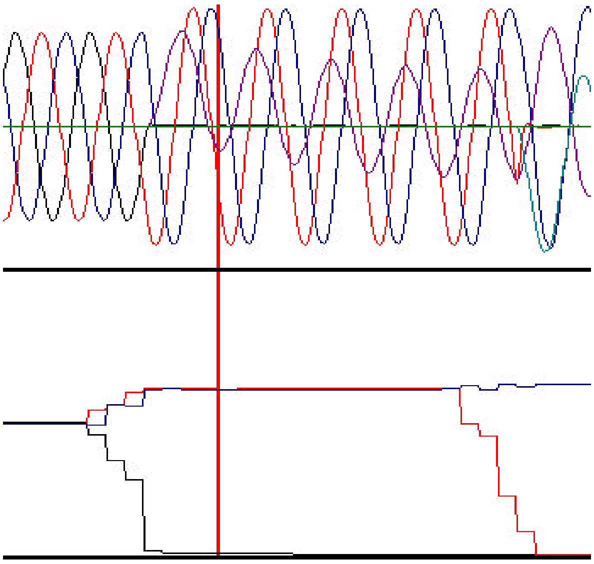
A second example about the difference between the planning levels and the voltage characteristics could be the 100 % value of the voltage instead of the 95% value given in the voltage characteristics.

EXAMPLE OF PQ PARAMETERS GIVEN BY DISTURBANCE RECORDING SYSTEM

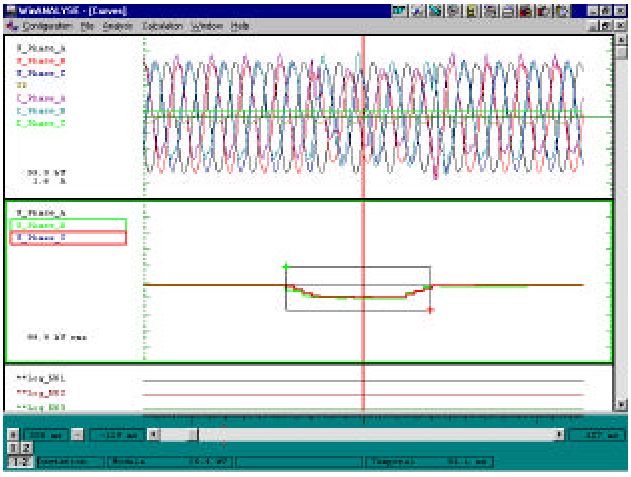
You will find in here below the example of the voltage dip evaluation by a Disturbance Recording system composed with a Disturbance Recorder MiCOM M840 and the associated analysis software Win DR Manager.



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 127 ms.



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 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.