POWER QUALITY ANALYSIS OF MV NETWORKS SUPPLYING INDUSTRIAL AREAS IN ITALY

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ABSTRACT

Within the Italian power quality survey [1], Enel Distribuzione (here after ENEL) arranged a complete monitoring of some MV networks, the so-called "clusters", by the installation of a large number of equipment both in the MV bus-bars and in the critical points of the relevant feeders.
The present paper is focused to examine the first results of the power quality survey applied to three of such clusters, situated in the core of some industrial areas, carefully observed taking care of the claims on voltage quality raised by Confindustria, the Italian Industrial Association.

INTRODUCTION

The economic development is giving more and more importance to the industrial activities and services and consequently to the electric supply voltage quality.
The improvement of the supply voltage quality requires an integral approach to the problem.
To such aim the power system must be considered like an unique system that involves not only the subjects in charge for the production, transmission and distribution of the electric power, but also the customers responsible for the right choice of their equipment and for the correct planning, installation, management and maintenance of the same devices and of their own systems.
The power quality survey of the MV networks, promoted by the Italian Electrical Energy Regulator, foresaw the installation of power quality instruments (PQI) on 400 MV bus-bars of HV/MV substations and on 200 MV bus-bars of MV/LV customer supply installations.
Since only less than 0.1 % of the MV customers (67 over about 100.000) applied for the installation of the PQI, ENEL decided to use the vacant positions in order to control in a complete way the supply voltage quality of some MV networks.
So, ENEL identified 14 clusters, for a total number of 105 PQI, concentrated in three areas of the country, with the presence of particularly sensitive industrial users to the problems of power quality. In each cluster the PQI have been installed either on the MV bus-bars of the HV/MV substation, or along the MV power lines.
Main objective is not only to measure the most important parameters of the power quality (supply voltage variations, rapid changes, interruptions, unbalance and harmonic distortion), but also to find the causes and the way of propagation of some particular types of disturbance (voltage dips) along the networks and to test the reliability of the monitoring system.
All the equipments are, in fact, synchronized by a GPS signal and connected by a GSM modem to a control center for the data transfer and management.
Before starting to analyze the main results, it's important to say that data about voltage dips with durations within 80 ms will not be given in this paper, because, up to now, they are not considered completely reliable [2].
In fact, the PQI set in MV networks with neutral point insulated wrongly detected some fictitious voltage dips during ground faults, not due to real events because of the voltage transformers' core saturation. This phenomenon can be detected also in MV networks with neutral point connected to earth by resonant impedance in the temporary periods when they are operated with insulated neutral.
The analysis of the results reported in this paper cannot be used as a guideline to evaluate the technical countermeasures to undertake, but it is framed like an effort to characterize in completed way the network and to give the first feedback for the improvement of the monitoring system.

CLUSTERS DESCRIPTION

As above mentioned, the analysis is focused on the data coming from three MV clusters.
The first, with 7 PQI, is located in the north of Italy in a 20 kV overhead network with medium extension, including about 100 MV/LV substations; the MV neutral point is connected to earth by resonant impedance.
The second cluster (10 PQI) is in the centre of Italy in a 20 kV overhead network with great extension, comprehending 180 MV/LV substations; the MV neutral point has been operated insulated during the first half of the survey and connected to earth by resonant impedance during the second half.
The third cluster (7 PQI) is in the south of Italy in a 20 kV network with insulated MV neutral point. This cluster belongs to a cable network pointed out by Confindustria because of the frequent claims made by the customers there connected.

METHOD AND DATA

In this paragraph is described the method used to analyze the power quality parameters recorded by the PQI of the clusters.
The method used is the following:
1. downloading of row data stored in the internal memory

of each PQI of the cluster, using the internet connection to the QUEEN website[1];
2. aggregating row data of the same instrument, related to different time periods;
3. exporting data in Excel files;
4. joining of data of all the PQI belonging to the same cluster in a graphic synthesis or in a table and comparison of every parameter with the limits and prescriptions given by European Standard EN 50160 *"Voltage characteristics of electricity supplied by public distribution systems"*.

MAIN RESULTS

Voltage variations

The voltage variations detected by the PQI of all the three clusters during the monitoring survey are largely within the limits foreseen by the standard EN 50160.
Each PQI gives the maximum (blu), medium (green) and minimum (red) voltage profile, as shown in figure 1, relevant to a PQI in the HV/MV substation of the second cluster.

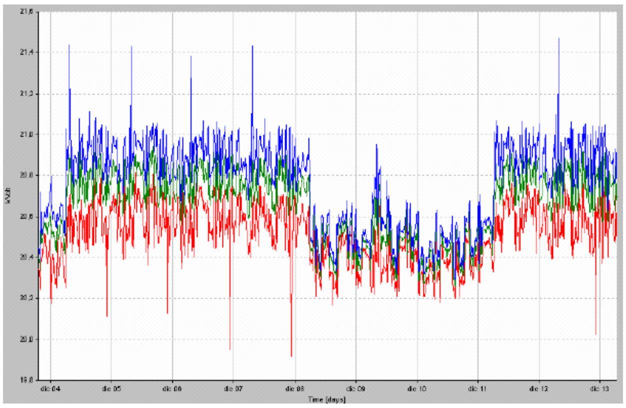

Figure 1 –Voltage variation measured in HV/MV substation of Cluster 2 (period 04-09/12/2006).

Rapid voltage changes

The detection of these events was not always synchronous for all the PQI in the cluster, so some changes were detected only by some instruments and not by the rest of them.
Moreover it could happen that rapid voltage changes, characterized by a high voltage decrease are not detected like rapid changes, but are detected as voltage dips. So, up to now, no significant data are available to be commented.

Harmonic distortion

The total harmonic distortion of the supply voltage doesn't represent a problem for any cluster; in fact the THD measured in every instrument was always less than 4 %.

Voltage unbalance

During the monitoring survey this parameter is largely within the limits imposed by standard EN 50160, for each cluster.
All the equipments along the feeders measured a value less than 0,5 %, similar to that detected in HV/MV substation, so no further comment is given.

Flicker

The long term flicker severity is under the limit of standard EN50160, for all the PQI in the clusters described above.
Some trouble could happen in the analysis of the flicker's measure, depending on the presence of high peaks in particular time period when a voltage dip or a voltage interruption occurs (see detail in figure 2).

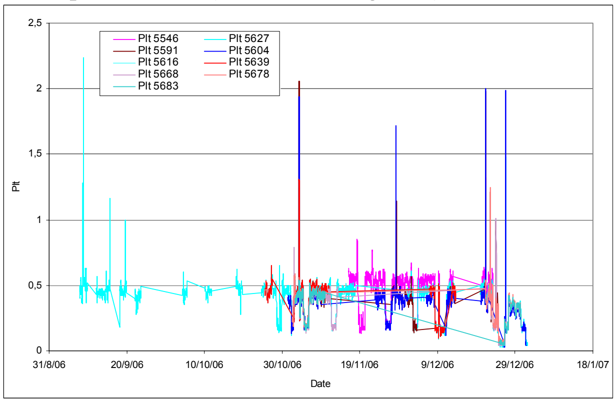

Figure 2 - Flicker profile of Cluster 2 (period 31/08/2006-31/12/2006)

These peaks are not due to real voltage fluctuations, but to the wrong influence of the voltage dips and supply interruptions in the flicker calculation made by the instrument.
In these situations PQI introduced a mistake in the profile, so a right analysis needs an improvement of the PQI flicker algorithm in order to take correctly into account voltage dips and interruptions.

Voltage dips

Here below the main results for each cluster, comparing them with the characteristics of the network and of the MV neutral point status will be described.

First Cluster analysis

In this clause are summarized the main data of the first cluster recorded by the PQI during a time period of around 4 months between the 6^{th} of June and the 17^{th} of October 2006. During this period the instruments in HV/MV substation detected 35 voltage dips, but it's very interesting to observe how these events are spread along the feeders (see figures 3 and 4).

[1] QUEEN is the website where the measures of the PQI are available.

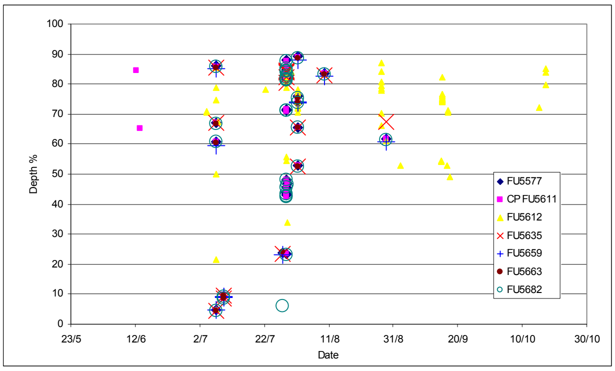

Figure 3 - First cluster's spreading of voltage dips in terms of depth (detail in the period 06/06/2006-17/10/2006)

The depth and duration of the voltage dips measured by the instruments of the cluster is almost the same for all the events, so it is possible to say that the events detected by the equipment in HV/MV substation are representative of those detected along the feeders. The most of voltage dips has duration around 150 ms, probably due to the circuit breaker's operation in HV/MV substation (see figure n. 4). Only one instrument (yellow symbol) shows different results (probably caused by the higher number of faults in the feeder) and needs more investigation.

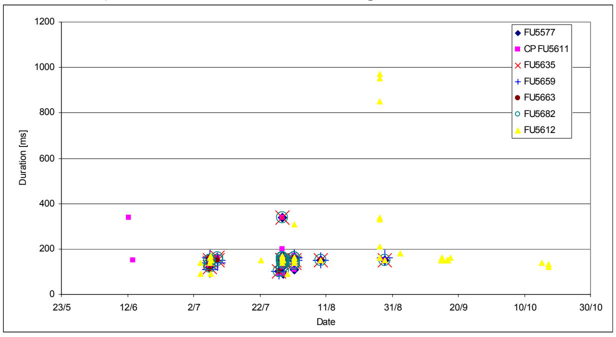

Figure 4 - First cluster's spreading of voltage dips in terms of duration (detail in the period 06/06/2006-17/10/2006)

The slight difference of the voltage dips' number detected by the PQI could be caused by one of the following reasons:

- the different working period of the PQI (the installation were not contemporary for all the PQI);
- the lack of synchronism by some PQI;
- the problems in transmission of row data to the monitoring centre encountered by some PQI (being also switched-off for long time periods).

Second cluster analysis

In this section are reported the main data of the second cluster recorded during the period of about 6 months between 3 July and 31 December 2006. It's worth noting that the network has been operated with the MV neutral point insulated until the 20th of September, whereas it was operated with the MV neutral point connected to earth through resonant impedance for the remaining time.

Figures 5 and 6 show the synthesis of all the voltage dips detected by the PQI during the period from 20 September to 31 December 2006; the voltage dips recorded in the HV/MV substation were 23.

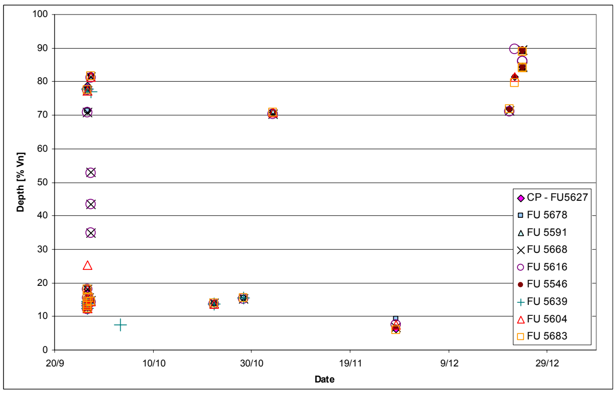

Figure 5 – Second cluster's spreading of voltage dips in terms of depth (detail in the period 20/09/2006-31/12/2006)

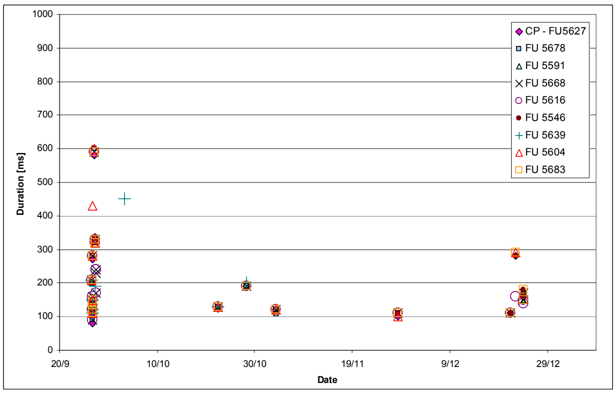

Figure 6 – Second cluster's spreading of voltage dips in terms of duration (detail in the period 20/09/2006-31/12/2006)

Also in this cluster there is a good correlation in terms of depth and duration among the voltage dips detected by all the instruments.

Moreover, it's possible to say that all the voltage dips detected by HV/MV substation are usually detected also by equipment set along the feeders; on the contrary, the disturbances along the feeders are not always recorded by the instrument set in the MV bus-bar. The reason could depend on the reduction of dip's depth, caused by the distance of the fault (the network has a long extension) from HV/MV substation.

Looking at the whole monitoring period, it's possible to see, comparing the results reported in figures 7 and 8, that the number of voltage dips detected is completely different and the gap (about 90 events) mainly involves the PQI in HV/MV substation and not all the others, along the feeders. That confirms the "false" voltage dips detected by the PQI installed in HV/MV substations when the MV neutral point of the network is insulated because of VT saturation. Instead, PQI along the feeders are not affected by saturation because VTs are connected between the phases.

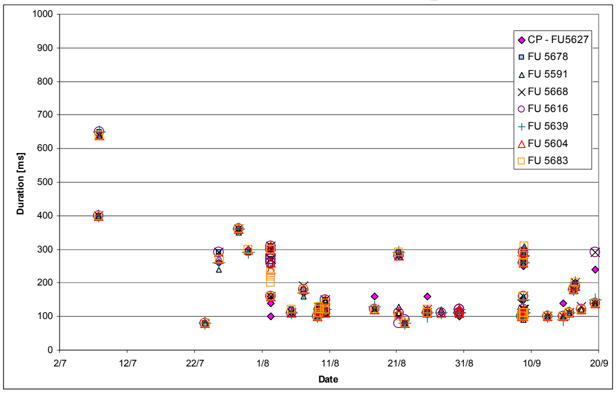

Figure 7 - Second cluster's spreading of voltage dips in terms of duration (excluding events under 80 ms)

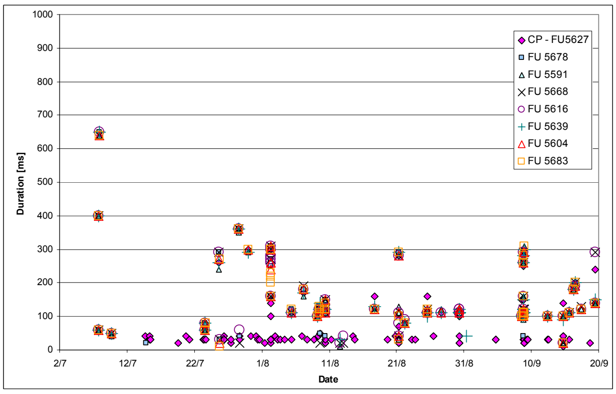

Figure 8 - Second cluster's spreading of voltage dips in terms of duration (including events under 80 ms)

This effect is also supported by the total absence of correlation between depth's values and durations for these "events" (see figures 9 and 10).

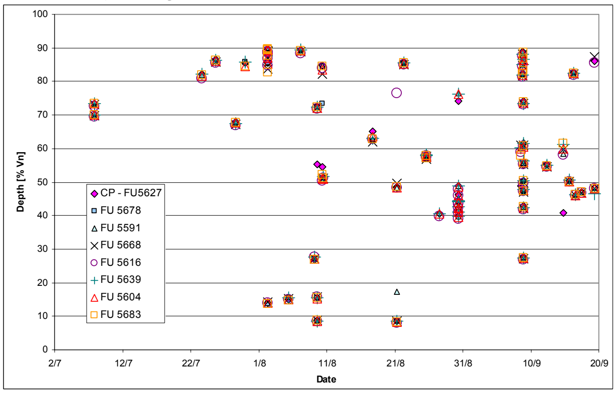

Figure 9 - Second cluster's spreading of voltage dips in terms of depth (excluding events under 80 ms)

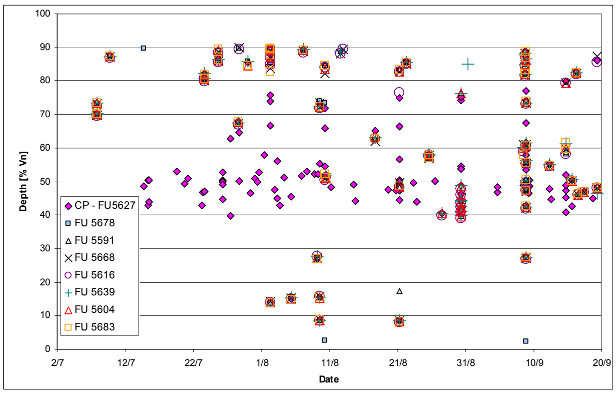

Figure 10 - Second cluster's spreading of voltage dips in terms of depth (including events under 80 ms)

Third cluster analysis

This cluster has been chosen taking into account the claims about supply voltage quality raised in this area by the Confindustria concerning, above all, interruptions.

All data were recorded by the instruments during a period of about 6 months between the 2nd of July and the 1st of January 2007;

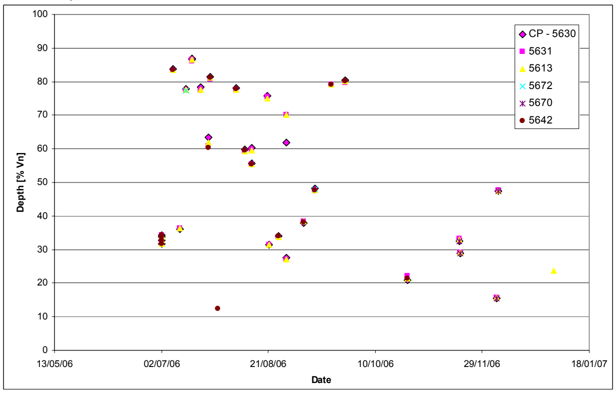

Figure 11 – Third cluster's spreading of voltage dips in terms of depth (detail in the period 02/07/2006 – 01/01/2007)

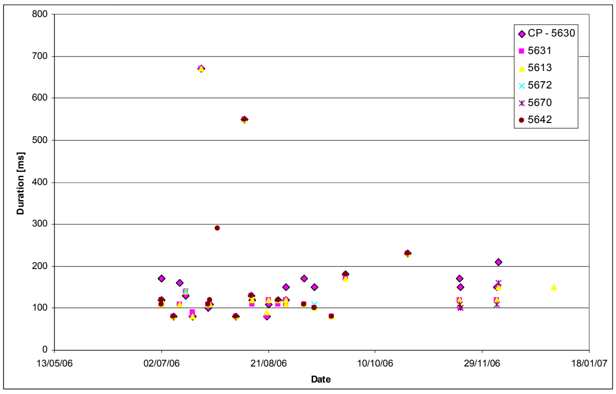

Figure 12 – Third cluster's spreading of voltage dips in terms of duration (detail in the period 02/07/2006 – 01/01/2007)

Also in this case, there is a good correlation between voltage dips detected by the instruments in HV/MV substation and along the feeders (see figures 11 and 12). The number of voltage dips measured in the equipment set on the HV/MV substation is not very high, about 29 (excluding events with duration under 80 ms); so it is possible to say that no particular problem is relevant to this disturbance. As it is also stressed by the claims of the customers, their concerns were about supply interruptions. Actually, in this cluster a large number of interruptions were detected by only one PQI along the feeders, without any correlation with circuit-breaker operation recorded in ENEL SCADA system. So this cluster requires more investigation to establish the real causes of these events.

CONCLUSION

Voltage dips need to be deeply analysed due to the influence they have on sensitive loads of some customers. Therefore in this paper they have received a particular attention, also thanks to the experimental data coming from the results of the monitoring survey, involving, for the first time in Italy, overall MV systems (the clusters).

In comparison with the monitoring survey concerning the HV/MV substations, the clusters help to understand the way of spreading of voltage dips along the network, and the range of depth and duration which could characterize the event.

Until now, data seem to enhance two things:

- the disturbances, in the MV networks taken into account, worth to analyze are voltage dips being the rest of power quality parameters well within the limits of standard EN 50160;
- MV neutral point connected to earth by resonant impedance helps to reduce not only the power lines interruptions, but also the number of voltage dips coming from the evolution of ground faults into short circuits. This supports the results about the effectiveness of resonant impedance respect to MV neutral point insulated or connected to earth by resistive impedance. Actually, in 2001, analyzing 77 MV networks equipped with Petersen coils for a period of about 6 months, a reduction of short circuits higher than 35% was detected (see table 1).

However the data available up to now are not still enough to give a reliable picture of the power quality levels of Italian MV networks.

Moreover some efforts should be made on the monitoring system:

- to avoid missing data and lack of synchronism between PQI. This makes difficult to elaborate the data and to find a mutual relation between causes and effects, concerning more events;
- to improve the instrument's calculation algorithms so that flicker and unbalance are not influenced by voltage dips and interruption.

It is worth to mention that power quality represents a real problem for some customers with very sensitive appliances even if, for the time being, the total absence of requests for "quality contracts" (introduced by Italian Regulator since beginning of 2004) and the very modest adhesion of MV customers to this survey show a modest customer sensitivity to voltage quality issues.

This power quality survey gave the opportunity to Confindustria to launch, within its associated, a campaign of information and training about power supply with particular relevance on desensitization and immunization of industrial plants to voltage quality disturbances. This campaign, activated in the 2005 in a cluster of 500 industries in the area of Naples, is today in Italy a national best practice recommended by Confindustria and ENEL

REFERENCES

[1] Villa, Porrino, Chiumeo, Malgarotti "The PQ monitoring of the MV network promoted by the Italian Regulator. Objectives, organization issues, 2006 statistics", CIRED 2007, paper 0042.

[2 Valtorta, Di Marino et alii "Preliminary results of the power quality survey in progress on the MV ENEL network", CIRED 2007, paper 0654.