POWER QUALITY SURVEY IN PROGRESS ON THE MV ENEL NETWORK: ANALYSIS OF GATHERED DATA

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ABSTRACT

In this paper an analysis of the data made available by the power quality instruments (PQI) installed in MV bus-bars of 360 HV/MV substations and 89 MV/LV customers’ substations of Enel Distribuzione (Enel) network is carried out.

The following topics are dealt with:
- the indicative values of some power quality parameters on MV networks (flicker, harmonics, voltage unbalance), and their correlation with short circuit power in the MV busbars;
- the possible correlation between voltage dips and network characteristics or trip protections.

All data considered for the analysis are related to one year (09/04/2007 – 06/04/2008) of the national power quality survey, started at the end of 2005 and promoted by the Italian Regulator, with the help of CESI Ricerca that has developed the “QUEEN” acquisition system and PQ database.

This analysis has been also carried out to evaluate if the statistical number of voltage dips has significantly changed, compared with the data coming from the first period (10/04/2006 – 08/04/2007).

INTRODUCTION

All the electric disturbances, which could worse the power quality, are mainly due to:
- electric failures on the feeders and on the substations of the DNO;
- electric failures on the customers’ network;
- transformers, capacitors and motors starting currents;
- non linear loads or rapidly changing loads.

Based upon these considerations, it’s important to evaluate both the statistic annual value of main PQ parameters and their way of spreading along the network.

At this aim, Enel, within the PQ survey promoted by the Italian Electricity and Gas Regulator (AEEG) and carried out by CESI Ricerca, has installed 360 PQI in the MV busbars of its HV/MV substations [1]. Some of them (14) are installed in industrial areas, together with other 89 instruments along feeders so forming 14 “clusters” [2].

Taking into account the wrong detection of some “not real” voltage dips during ground faults, in MV networks with insulated neutral, because of the voltage transformers’ core saturation, voltage dips with durations under 100 ms are not considered in the current analysis.

It’s worth noting that also MV networks with neutral point connected to earth by resonant impedance may be affected by the above-said “not real” voltage dips since, temporarily, they can be operated with insulated neutral.

In order to overcome the problem, Enel has developed an automatic system that gives information about the time periods concerning the MV neutral “dynamic status”.

The new tool, called “HV dashboard”, will be useful to classify the number of voltage dips respect to the real MV neutral point operation (“insulated” or “earthed through impedance”). The following figure show, as an example, the HV dashboard.

![Figure 1 – “HV Dashboard” layout](image)

VOLTAGE DIPS

Voltage dips have been analysed taking care of the following MV network characteristics: MV neutral earthing, prevailing MV feeder typology (overhead/buried cable) and short circuit power. Being the HV dashboard available only at the end of august 2008, it was not possible to use it to classify data gathered from April 2007 to April 2008, with respect to the “dynamic” changing of the MV neutral from “insulated” (NI) to “compensated” (NC). Therefore, comparison between NI and NC networks behaviour cannot be done carefully.

**Voltage dips detected on MV bus-bar and coming from HV network**

Voltage dips coming from HV network have been identified by means of the “contemporary” fault detection of distance relays installed in the HV power lines, supplying the HV/MV substation.

The analysis enhanced the following aspects:
- voltage dips coming from HV network have a typical duration between 20 and 200 ms (see Figure 2), the major part of them lasts less than 150 ms. This is due to operation of distance relays on their first zone;
- there are some voltage dips lasting about 350 ms due to
distance relays trips on their second zone;
- there is a short number of voltage dips longer than 500 ms which should need a deep analysis in order to understand their causes (e.g. different propagation on the network of voltage dips due to “electrically far” faults).

Voltage dips coming from HV network detected from 09/04/2007 to 06/04/2008, referred to as “second period”, are about 5% of those coming from MV network, thus confirming essentially the trend of the “first period” [1], i.e. from 10/04/2006 to 08/04/2007 (see figure 3).

Voltage dips coming from MV network

Figure 4 shows all the voltage dips, originated at MV level, and detected by PQI installed in bus-bars supplying MV networks operated with “compensated” neutral (NC) and “insulated” neutral (NI).

The following data don’t take into account the events whose duration is under 100 ms, (potentially affected by uncertainty), even if they are around 40-60% of the total amount.

The trend is almost the same in both the periods and neutral operation conditions, but it’s important to underline the huge range of voltage dips that can occur to the single PQI. In fact, independently by the network characteristics and the duration of the observation period, the number of voltage dips detected by the single PQI can change substantially. At this aim, figure 5 shows how the voltage dips variation from year to year (from 1st to 2nd period) can rise and be distributed, for all the PQI.

In order to complete the general picture given for the comparison of voltage dips coming from MV network, in the two period, here are the average data for PQI (see table 1).

Table 1 – Average number of voltage dips detected by PQI installed in bus-bars supplying MV networks operated with NI and NC.
**Correlation between voltage dips and type of MV network**

Taking care of the distribution of PQI in the MV busbars (25 PQI have been installed in overhead networks, 72 PQI in buried cable networks and 213 PQI in mixed ones), it’s possible to say that the number of voltage dips in the overhead networks is “only” 2.5 times greater than in cable networks (see figure 6). Considering that the extension of the overhead networks is 5 times higher than the cable ones, a number of voltage dips well greater in overhead networks would be expected.

Possible explanations are the following:
- in cable networks, faults are usually permanent, so the following reclosing operations will cause more voltage dips for the same fault;
- faults in the MV cables can propagate themselves more easily since they have a lower impedance in comparison with the overhead networks one (voltage dips due to faults at the end of cable feeders are seen also in the MV bus-bar).

**Correlation between voltage dips, MV protection system and short circuit power at the MV busbars**

Figure 7 shows the graph comparing voltage dips and the tripping of 51 relay (1st and 2nd threshold) and 67 relay (3rd threshold) used to detect respectively short-circuit faults and cross-country faults in MV networks.

The analysis shows that there is an excellent correlation (almost 90%) between the tripping time of the protections and the characteristics (duration) of voltage dips measured by PQI.

Figure 8 shows, instead, that doesn’t exist a significant correlation between voltage dips and the short circuit power (Scc) at the MV bus-bar.

**Propagation of voltage dips along the feeders**

Here below the main results for the clusters; figure 9 is representative of the general situation and could be taken as an example of the way of spreading of voltage dips along the feeders.

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.

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 (except, of course, for those coming from the VTs core saturation effect); on the contrary, the disturbances along the feeders are not always recorded by the instrument set in the MV bus-bar: the reason should depend on the reduction of dip’s depth, caused by the distance of the fault from HV/MV substation.

**HARMONICS, FLICKER AND VOLTAGE UNBALANCE**

The analysis of total harmonic voltage distortion (THDv), voltage unbalance and flicker(1) is summarized here below:

- a significant correlation between the PQ parameters (THDv, voltage unbalance and Pst) and the short circuit power (Scc) at the MV bus-bar doesn’t exist (see, as an example, the figure 10, relevant to THDv).

![Figure 10 - Correlation between THDv and short circuit power (Scc) in MV busbars](image)

- 95% of PQI registered a THDv lower than 4,1%;
- 85% of PQI registered a Pst lower than 1;
- the overall PQI registered a very low value of voltage unbalance (below 0,8%);

![Figure 11 - Voltage unbalance measured in MV cluster](image)

Furthermore, the other voltage characteristics (THDv, unbalance and Pst), measured in the MV bus-bars, are almost the same of those relevant to the instruments set along the feeders (see, as an example, the figure 11 relevant to the voltage unbalance).

**CONCLUSIONS**

The analysis of the data gathered by PQI installed on the ENEL MV network and made available by QUEEN system of CESI Ricerca has been carried out with the aim:

- to confirm the general overview related to the preliminary statistical picture of the voltage characteristics (see [1] and [2]),
- to study with more detail how they propagate along the network at that voltage level and to find a correlation with the tripping of the protections system used by the DNO or with the network characteristics.

The main results, taking care of consideration carried out in clause 1, are reported here after:

- voltage unbalance and total voltage harmonic distortion are well within limits of EN 50160;
- the flicker parameter Pst is greater than 1 (EN50160 limit) in the 15% of PQI. However it’s worth noting that both Pst and Pst evaluation takes into account the samples relevant to voltage dips [2];
- voltage dips coming from HV network have a typical duration of 50÷150 ms and are about 5% of those coming from MV network;
- voltage dips coming from MV network can change substantially, increasing or decreasing, during one year, even if the network characteristics do not change.
- the number of voltage dips detected in “cable” networks is about 40% of those relevant to “overhead” ones;
- there is an excellent correlation between number of voltage dips and tripping of the MV feeders protection systems;
- short circuit power is not correlated to voltage dips, THDv, flicker parameters and voltage unbalance.

The extension of the power quality survey and the developments of new tools (as HV dashboard developed by Enel) for the equipments will give an important contribute to understand the actual level of power quality, in order to provide more data and information about the causes and the way of spreading of the disturbances. Moreover, this could be used in the future to:

- help the customers to improve their installations, becoming more insensitive from the voltage dips or the other types of disturbance;
- provide a guideline both for the DNO and the customers to draw up a new kind of mutual agreement based on PQ issues (“Quality contracts”);
- make comparison with other European distribution systems.

**REFERENCES**


(1) The flicker analysis has been carried out evaluating only the Pst.