SURVEYING SUPPLY RELIABILITY AND VOLTAGE QUALITY AT ITALIAN CUSTOMERS

Riccardo CHIUME**, Giuseppe ESPOSITO**, Stefano MALGAROTTI* (malgarotti@cesi.it), Alberto PRUDENZI^ (prudenzi@ing.univaq.it), Stefano QUAIA^^ (quaias@deei.units.it), Giuseppe SIMIOLI*, Dario ZANINELLI** (dario.zaninelli@polimi.it)
*CESI S.p.A. – Milano - ** Politechnic of Milano - ^ University of L’Aquila - ^^ University of Trieste

INTRODUCTION

While outages and voltage quality problems are today main concerns and highly affect electric customers, nevertheless reports on effects of Power Quality (PQ) events are not yet well documented and there are still few estimates of PQ-related costs to the national industrial segment economy. For this reason a survey activity focused on assessing PQ in the industrial customers’ segment of end-use was promoted within a wide Italian research project (called “Ricerca di Sistema” and supported by the Italian Ministry of Productive Activities with the aim to get benefits for the customers of the Italian Power System; it is worthy of note that the activities connected to this project are considered of public interest and are therefore financed from a specific item in the electric bill of not eligible customers). This survey is mainly aimed at identifying power quality levels at demand-side throughout the Country and collecting information about PQ costs, according to the industrial customers’ point of view. The survey method was based on a questionnaire, providing the approach of asking customers about their reliability experiences and perceptions. In the questionnaire, both the main topics of PQ were clearly addressed: voltage continuity (or supply reliability), related to power supply outages, and voltage quality, related to low frequency disturbances (or voltage deviations from an ideal waveform) reaching equipment through the electricity supply. The paper presents, comments and discusses the main survey results, with special emphasis to the PQ related costs.

QUESTIONNAIRE AND SURVEY SAMPLE

The survey is based on a questionnaire prepared for a nationwide sample of industrial customers and concerns several areas of Italy. In some areas of Italy the survey has been supported by the local Manufacturers’ Associations, which encouraged customers to participate in the initiative or directly collected the filled-out questionnaires. The questionnaire addresses to the following main items:
- Customer data (sector of activity and type of production, weekly productive cycle, power demand, energy consumption, supply voltage level and type of connection to the distribution system, and so on)
- Supply outages: number per year, duration, effects and related costs
- Other disturbances: type, number per year, effects and related costs. Voltage dips are especially highlighted here
- Installed equipment for supply PQ-problems mitigation

- Customer satisfaction for its electricity service
- Effects and cost of the 28 September 2003 blackout.

The questionnaire diffusion and collection has been divided according to three different large areas of the Italian territory: North-East (treated by the University of Trieste), North-West (treated by the Politechnic of Milano), Central-South (treated by the University of L’Aquila).

The survey activity performed during the 2004 allowed collecting information relevant to a considerably large sample of 512 industrial customers located all over the Country. The sample includes the activities reported in Figure 1.

Figure 1. Industrial activities connected to the survey sample

On the electrical point of view, the sample was in the main part (85%) constituted by MV users, supported by cable lines (64%) and with a “multi-hour tariff” economic charge (62%). In particular Figure 2 shows the rated power of the customer sample.

Figure 2. Rated power of the investigated users
RESULTS OF THE SURVEY

In the present section the main results of the survey are reported, highlighting the power quality aspect. Figure 3 reports the annual number of supply interruptions, while Figure 4 shows the voltage disturbances detected by the users per year.

The figures above mentioned show that in the North Regions the interruptions number is mainly concentrated in the field between 1 and 5, while in the Middle-South there are several users (47%) that complaint up to 20 interruptions per year. It is worthy of note that these data do not match the standards proposed by Italian Authority of Energy and Gas (AEEG), that establishes for the 2006, in MV with rated power >500 kW, a maximum number of interruptions per year equal to 3 or 5, depending on the user’s density in the territory.

Concerning the other disturbances, a certain difference is found again between North and Central-South Italy, where in particular 14% of the users complains between 31 and 50 events per year and 5.7% complains between 50 and 100 events per year.

While economical evaluation of the disturbances are reported and discussed in the following section, it is interesting to report the analysis performed on the customer willingness to pay for improving the quality of the electric energy supply. Figure 5 shows the summary of the answers related to this subject. The diagrams are reported in percentage of the annual cost of the electric energy that the industry has to pay as electric energy bill. In the North Regions about 20% of the users are available to pay up to 3% of the annual electric energy bill for improving the Power Quality, while this number increase to 34% in the Central-South survey. This is on the line of the other results of the survey that show a reduced reliability of the supply system in the Central-South area of the Country with respect to the North one.

PQ COSTS

The PQ costs here considered include only those costs, caused by outages and supply voltage disturbances, that are above and beyond the normal production costs. They are the value of lost production plus all the disturbance-related costs (for wasted materials, imperfect product, damaged equipment, extra maintenance). Note that labour costs during production downtime that are not beyond the normal costs have not to be added (a common mistake is to include them in the PQ costs). For accurate assessment, savings on raw materials and electricity and fuel (if any) not consumed, and labour savings (if any) during production downtime, should be subtracted. Finally, the eventual recovery of lost production should be properly considered.

206 out of 512 industrial users (about 40% of the whole sample) provided estimate of their annual costs caused by PQ problems. These costs are shown in Figure 6.
Of course large customers experience costs orders of magnitude higher than those of smaller users. The collected cost figures range from zero to some millions of Euro, while the contractual power of customers ranges from 20 kW to 160 MW. Therefore, to allow comparison among plants of different size, it is recommendable to consider properly normalized costs, for instance dividing costs by the plant contractual power, or consumed energy, or employees number, and so on. Figure 7 shows the specific annual costs due to PQ, normalized using the contractual power.

One can recognize, as expected, a growing trend in Figure 6, and a roughly constant trend in Figure 7, but both figures point out an extremely high data dispersion. The high dispersion is due to several factors, the following having special importance:

- heterogeneity of the sample. One must consider that several industrial sectors are included in the sample, and each individual sector includes different productive processes and workings. In addition, a given perturbation causes to the same user different costs, depending on several variables like phase of the current productive cycle, pieces in production, special workings and so on
- for different reasons, the estimation of PQ costs is really difficult for many customers. Their inability to quantify PQ costs with a certain accuracy clearly emerged during several discussions with plant operators, and can be also deduced by the roughly rounded costs they declared in most cases. With regard to this problem, notice that a reference pattern for computation of PQ costs would provide customers with a tool for a correct costs calculation and, therefore, could be useful especially for the users affected by significant PQ costs. In particular, it can represent a useful guideline for cost-benefit analysis, when decision about the installation of power conditioning devices or backup equipment must be taken [2]
- limits of the surveying method. Questionnaire-based surveys do not allow a real check of the collected information, and unreliable data cannot be individuated with certainty. Reports of similar surveys performed throughout the world often warn against possible overestimation of the cost figures provided by customers. This problem can be mitigated carrying on the survey through personal relationships. This approach should include, for each user, a visit to the plant and a discussion with the plant operators to estimate costs [3]. Of course this approach is very time-consuming, but increases very much the reliability of the information. During the present survey this method has been followed with 65 users (12.7% of the total sample) while an intermediate approach based on discussions via phone calls has been used with other 50 users.

Figure 8 shows the cumulated curve of the specific annual costs, with reference to the already mentioned sample of 206 users that provided cost figures. About 60 (30%) of these users declared a specific cost exceeding 50 €/kW. At the extreme left in the figure there are, in particular, some small users that declared high and roughly rounded costs, resulting in very high, but probably incorrect, specific costs (up to 1000 €/kW, as one can see in Figure 7).

A useful parameter for a global assessment of PQ costs is the global specific annual cost (GSC), defined as follows:

$$GSC = \frac{\sum \text{Annual Costs}}{\sum \text{Contractual Power}}$$  \hspace{1cm} (1)

Then, GSC is the total annual cost divided by the total contractual power of a given sample or group of users. The sample of 206 users provides a GSC around 18 €/kW (with a significant difference between North Italy – 17 €/kW – and Central-South Italy – 30 €/kW). However, it can be reasonably assumed that this sample includes most of the users sensitive to PQ included in the whole sample (512 users). It follows that, if we could calculate the GSC over the whole sample, certainly we would obtain a lower value.

The information got through the questionnaire allow sharing out the costs of outages (voltage continuity) and disturbances (voltage quality). Outages cause a GSC of almost 14 €/kW (this result concerns 196 users, corresponding to 38.3% of the whole sample), while disturbances cause a GSC a little more than 6 €/kW (122 users, 23.8%) that is nearly half of the former value. Even if disturbances include different phenomena, both transient and steady-state, most of the relevant costs can be considered as due to voltage sags (dips), which generally are by far the most perceived and dangerous disturbances for industrial customers.

It is interesting to notice that 52 users out of 206 (25.2%) declared that voltage quality problems cause higher or at least...
equal costs than outages. Again it can be assumed that this percentage, calculated on the whole sample, would be certainly lower (however not less than 10%). It is much easier to get qualitative information about PQ costs. Probably this is due to the already mentioned general difficulty in estimating PQ costs with a certain accuracy, but also to the customers’ widespread reluctance in providing cost figures. Over 80% of the whole sample provided qualitative estimates of costs due to outages and disturbances. Outages cause negligible costs for 21% of these users, low costs for 37%, medium for 24% and high or very high costs for 15% and 3% respectively. Disturbances cause negligible costs for 35%, low costs for 32%, medium for 22% and high or very high costs for 8% and 3%.

Considering both the quantitative and qualitative cost data collected, we can conclude that outages are still the main origin of PQ costs, but at present voltage disturbances cause significant costs to about 25% of the industrial customers. Users were asked to give details of the interruption costs they would experience in the event of an outage lasting some hours (for instance, a permanent fault on the supply line, or a blackout). 152 users provided the relevant costs: the highest costs concern, as expected for a long outage, the value of lost production (55.5% of total interruption costs), followed by costs to restart production (26.1%), costs of wasted materials (9.1%), damage costs to equipment (8%) and other costs (1.3%).

CONCLUSIONS

The paper presents and comments the results of a survey performed in Italy during the 2004 and addressed to industrial customers across Italy, with the aim to assess current problems and attitudes towards power quality in this segment of end-use. The survey results, got from a considerably large sample of 512 customers, point out a certain difference between the North and Middle-South Italy, with a higher average quality of the electrical supply in the North (this result agrees with already known data and is partly due to the physical differences between these two areas of the Country). Voltage continuity (outages and interruptions) is still the most visible problem, but voltage quality (mainly voltage dips) has become a practical problem for a significant percentage of industrial users.

The paper focuses in particular on the costs attributed to PQ problems. In order to compare the PQ costs and to get results applicable to customers of different size, costs have been normalized using the user’s contractual power, while average costs are reported in this paper by means of a parameter properly defined and called global specific annual cost (GSC). The paper provides the GSC calculated for the total annual PQ costs and, separately, for the annual costs due to outages and disturbances.

The survey allows characterising from the PQ point of view different industrial sectors. Some results concerning this item are also reported in this paper.

REFERENCES