# ELECTRICITY SECTOR EVOLUTION AND POWER QUALITY REGULATION - THE PORTUGUESE EXPERIENCE

| Amanda FALCÃO | Hélder MILHEIRAS | Jorge ESTEVES | Maria José CLARA |
|---|---|---|---|
| ERSE – Portugal | ERSE – Portugal | ERSE – Portugal | ERSE – Portugal |
| afalcao@erse.pt | hmilheiras@erse.pt | jesteves@erse.pt | mjclara@erse.pt |

## *ABSTRACT*

*The concept of quality in the electricity sector has changed over the years in response to the evolution of equipments and technologies available and meeting the clients' needs. Power quality (continuity of supply, voltage and current waveform quality) and commercial quality define today not only the product but also the service associated to the electrical energy supply.*

*In this context, it is necessary to find out technical, legal and economical procedures and rules. Electricity sector evolution in Europe reinforced the need for regulation. In Portugal, ERSE, the energy regulatory authority, is one of the entities involved in power quality promotion.*

*This paper covers the multiple issues of power quality. Taking as an example the power quality regulation in Portugal, the regulatory approaches that have been taken in power quality are described and its application results are analysed, pointing out the identified difficulties, the adopted solutions and the issues needing short- term solutions.*

## INTRODUCTION

The concept of quality in the electricity sector has changed over the years.

In the beginning the focus was to ensure that everyone got electricity at their consumption's location. The first concern about power quality was related to continuity of service. Responsibility was endorsed only to transmission and distribution operators. Physically, the system had a linear structure with power flowing from generators to the clients (linear loads), in one direction, through the transmission and distribution grids. Electricity sector was organized under vertically integrated utilities that were treated as monopolies.

Nowadays, the structure is much more complex. New technological solutions bring out different needs and power quality is now established, not only from the operator network point of view but also from the client, and different grid user's expectations. Loads became non linear, not only for industrial but also for domestic clients. Some equipment connected to the grid is also less tolerant to voltage quality disturbances and can be simultaneously a source of disturbances to the grid. Also new social concerns, as environmental and energy efficiency, must now be considered and electrical energy is nowadays considered as an essential public good. Distributed and small scale generation created the possibility of bi-directional power flows and the status of the different players is no longer unique, for example, an installation connected to the grid can be a costumer and a generator at the same time. The new industrial productive processes appeal for a higher power quality level not only for short-time interruptions, that can be as hurtful as longer ones, but also waveform variations affect the productive processes. Cost of the non-quality on the electricity supplied to the clients affects the industry competitiveness and it can create distortions between companies from different locations.

With the power quality being no longer only a question of continuity of supply but also of maintaining the voltage and the current waveforms quality, it is verified that clients have different needs accordingly to the use they give to the electrical energy resulting, from this viewpoint, in different clients' classes. It is necessary not just to supply power to the equipments but also to ensure that this power supply complies with specified voltage waveform characteristics.

Evolution from a vertical integrated system into a liberalized model came along with the recognition that power generation and power supply are potentially competitive activities (allowing the existence of several independent players), while transmission and distribution activities are maintained as natural monopolies that use intensive capital technologies (not allowing investment indivisibility and involving long construction periods). It becomes necessary to define power quality indices and minimum level values in order to settle the minimum-guaranteed power quality offered by the grid. Indices and minimum-guaranteed levels must be consistent with all users' needs and with their expectations in terms of power quality. Technically it is still necessary to developed theoretical approaches to lead with a non-sinusoidal waveform supply and determine disturbances sources location. However, the share of responsibilities and the investments needs justify a stronger and a new legal and economical approach. Information and its processing acquire more importance, and transparency in the procedures is essential. Audits on the processes become an indispensable requisite.

Impact of the product electricity in ours' day-live, the diversity of its use and the increasing of the number players brings electricity to a new dimension - it must be considered also as a service. Commercial quality, the relationship between operators and suppliers with their clients, complete the definition of quality of service in the electricity sector.

In addition to the equipments required to operate clients' installations and grid, it is also required procedures and equipments to control and to assess power quality. All this imposed the need for regulation of the natural monopoly activities of the electricity sector, transmission and distribution activities being developed by regulated companies (usually one Transmission System Operator, TSO, and one or more Distribution System Operators, DSO, per country), and the creation of independent energy regulators at national level. Organized markets have also been introduced in the electricity sector.

Concerns about power quality in Portugal have grown up in importance and several measures have been adopted since year 2000. Quality of service regulation has been developed, quality levels have been defined and data about the situation began to be collected. DGGE (General-Directorate for Energy and Geology) published the Quality of Service Code. Network operators reinforced their investments for power quality improvements that were accepted by ERSE, the Portuguese energy regulator, to be considered as a part of the regulated asset base. ERSE established in the Tariff Code an incentive scheme to continuity of power supply improvement.

The quality of service performance of TSO and DSO is published every year in their quality of service report and in the quality of service report published by ERSE (www.erse.pt).

## QUALITY OF SERVICE AND REGULATION - THE PORTUGUESE EXPERIENCE

### Quality of service incentive

In theory, an optimal power quality value could be defined by taking into consideration the evolution of the investment costs (increasing with the quality level value) together with the inconveniencies cost to consumers (decreasing with the quality level value).

However, this calculation in a real scenario is not an easy task. To define the inconveniences cost to consumers is necessary to define quality, i.e., to find an indicator for quality. However, quality of service is a multi-dimensional issue (continuity of supply, voltage waveform, current waveform and commercial quality), and for each dimension exists a huge number of indicators to evaluate. Furthermore, the expectation on quality of service depends on the clients' class and its willingness to pay for an improvement in quality level. In what concerns the relation between cost investment and the evolution of the quality offered to costumers, its definition is not also an easy task. Besides, it is not simple to split from the actual investment amount the strictly part dispensed for quality improvement (investments are usually developed not only for quality improvement but related to the consumption evolution, to equipment replacement due to aging, to network losses reduction and to network congestions resolution).

In our days, regulators have to contribute for this searching for an optimal quality of service.

ERSE established in the Tariff Code an incentive scheme for the improvement of continuity of power supply in Portugal. This financial scheme works *ex-post* and affects the allowed revenues for the DSO activity of electricity distribution in MV, resulting in a penalty or in a reward depending on the results of the grid continuity of supply performance. The continuity indicator considered is the Energy Not Supplied (ENS).

Related to a reference value of ENS ($ENS_{REF}$), the incentive scheme, Fig.1, is symmetric for penalty and reward. A dead-band with a $\pm\Delta V$ value is applied. Also, incentive and reward values are limited to the values of $RQS_{max}$ and $RQS_{min}$.

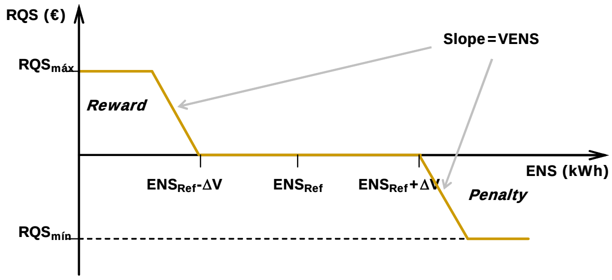


Fig. 1: Portuguese incentive scheme for continuity of supply improvement.

Table 1 presents the parameters of the incentive scheme for continuity of supply improvement on the period 2003-2008. ES is the supplied energy.

| | |
|---|---|
| $ENS_{REF}$ (2003-2005) | 0,0004 x ES |
| $ENS_{REF}$ (2006) | 0,00019 x ES |
| $ENS_{REF}$ (2007) | 0,000175 x ES |
| $ENS_{REF}$ (2008) | 0,000161 x ES |
| $\Delta V$ | 0,12x $ENS_{REF}$ |
| VEND | 1,5 €/kWh |
| $\vert RQSmáx\vert = \vert RQSmin\vert$ | 5 000 000 € |

Table 1: Incentive scheme parameters

This incentive scheme is of particular importance because a price cap regulation formulae is applied to the distribution activity in Portugal. It is known that price cap regulation does not promote investment. In order to counteract this effect, this scheme appears as an incentive to specific investments and to the implementation of measures allowing a better performance on continuity of power supply by the DSO.

**First results attained**

An expressive reduction on the number of interruptions and minutes lost per client was attained in Portugal since 2001 till 2005. The same positive evolution is expressed when analysing the evolution of the ENS and equivalent interruption time related to installed capacity (TIEPI).

Fig. 2, show the evolution of TIEPI since 2001 till 2005. Also evolutions of dead-band limits and of the reference value (translated in TIEPI values) are presented. Applied for the first time in 2003, we can verify that the continuity of supply performance fell in the dead-band giving to the DSO a null reward for this year. However, performance results from 2004 and 2005 have clearly improved and the maximum incentive was given to the DSO. On the other hand, 2001 and 2002 results show that, if the incentive was in force during those years, the DSO would have been obliged to pay penalties related to these years' performance arriving to the maximum penalty value in 2001.

For the period (2007-2008), ERSE reviewed the parameters of this incentive scheme imposing more restricted value to $ENS_{REF}$. The aim is to obtain a continuity of supply performance in 2008 closer from the other European countries and values from Spain were used as reference.

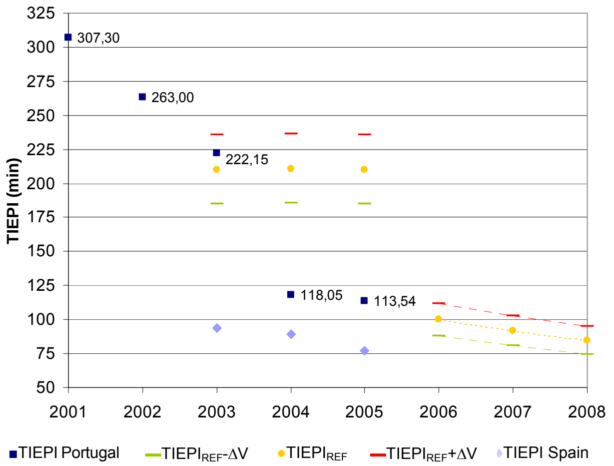


Fig. 2: Evolution of TIEPI from 2001 till 2005 and the new parameters for 2006-2008 of the incentive scheme for continuity of power supply improvement

The improvement reported on the continuity of power supply was possible due to an effective investment effort from the Portuguese TSO and DSO in this field. In spite of this investment effort, a clear reduction of the network access tariffs has also been possible to reach within the same period of time, reflecting efficiency gains on controllable costs at the distribution level.

## Voltage quality monitoring

The Quality of Service Code applied in Portugal mainland and the more recent published ones to be applied at Açores and Madeira Autonomous Regions also consider the need for implementing voltage quality monitoring systems in its transmission and distribution networks.

The transmission and distribution operators are responsible for the network voltage waveform quality. They have the duty to look out for the levels of each characteristic. The limits or values defined to voltage waveform characteristics are the ones established in the NP EN 50 160 (translation of the European Standard EN 50160), for LV and MV. For HV and VHV voltage levels, the limits or values established for each voltage waveform characteristic were the same as the ones established in the following documents:

- Frequency, Flicker severity and Voltage unbalance: NP EN 50 160.
- Harmonic voltage: For even harmonics (HV and VHV) and odd harmonics (VHV) the values are the ones established in the standard IEC 1000-2-6 to compatibility levels to HV and VHV.

In what concerns to voltage dips, and considering the difficulties related to the results recording, is was adopt the standard "IEC 61000-2-8: Electromagnetic compatibility (EMC) - Part 2-8 Environment - Voltage dips and short interruptions on public electric power supply systems with statistical measurement results".

The voltage quality monitoring must be done with the objective of characterising the quality waveform of the grid and identifying zones that require a quality improvement.

The costs associated to the voltage waveform monitoring are supported by each operator.

The client can install equipment to measure its installation voltage quality. If the equipments are installed and sealed after a writing agreement with the distribution operator, its measured values are valid as prove in a claim.

Complains registered in most of the cases are related to voltage dips. However, in some situations the problems are associated with the layout of client installation and the installed equipments protection. Making equipments insensitive to some voltage quality disturbances is another solution allowing efficiently overpassing the problems. This imposes that equipments manufacturers must also be involved in the voltage quality improvement efforts.

The Complementary Instructions to the quality of service codes establish the limits of disturbances that each installation can emit to the network. These limits are defined in accordance with the contracted power. The methodology is established based on the following standards: (1) IEC 61000-3-6 (1996-10) and (2) IEC 61000-3-7.

The definition of the allowed disturbance emissions from the client to the network is a very complex mater and need to be deeply studied and analysed, considering namely the distribution of the disturbances limits in one point for more than one client and the possibility of new clients arrival. Additionally, new equipments and procedures must be adopted to identify the direction of disturbances flow, i.e., the disturbance source and the current waveform. Power quality problems are only possible to be solved by a deep involvement of all the network users.

The voltage quality monitoring systems generate a large amount of information. To characterise the grid and make that information useful, it is necessary to find criterions to select the useful information for each entity (operators, regulator and different grid users types) and indices characterizing the grid in terms of voltage quality and giving orientations to how and where to improve the grid performance. Nowadays, Açores and Madeira Autonomous Regions operators are developing voltage quality indices based on the collected data but selecting the monitoring weeks that effectively characterise the grid performance.

During the appliance of the quality of service code it has been identified some difficulties related to the voltage waveform quality of voltage disposals that in most of the cases become from the appliance of NP EN 50 160 and in other case the inexistence of national or international orientations on how to lead with some issues.

**Quality of electricity supply and CEER**

In December 2005, the Council of European Energy

Regulators (CEER) has launched the *"Third Benchmarking Report on Quality of Electricity Supply"* covering the most important features of quality of electricity supply: continuity of supply, commercial quality and voltage quality (www.ceer eu.org). Following this work, during 2006, European energy regulators devoted their attention to power quality issues with the objective to promote the revision of EN 50160 by CENELEC with the participation of CEER and in cooperation with the other stakeholders. On 21 December 2006, ERGEG launched a public consultation on the paper "*Towards Voltage Quality Regulation in Europe, an ERGEG Public Consultation Paper"* (www.ergeg.org). This position paper sets out ERGEG's viewpoints on voltage quality and this consultation process, allowing inputs from all stakeholders, it is an opportunity to refine positions and to reinforce the dialogue between different stakeholders. Recommendations for revising voltage quality standard EN 50160 are envisaged. Following the end of the public consultation period, which ends on 22 February 2007, ERGEG will publish all comments received from stakeholders.

## CONCLUSIONS

ERSE is the energy regulatory authority in Portugal and the promotion of power quality is one of its duties. Efforts developed in Portugal for power quality improvement began to present the first results. An expressive reduction on the number of interruptions and minutes lost per client was attained in Portugal since 2001 till 2005, due to an effective investment effort from grid operators. Nevertheless, a clear reduction of the network access tariffs has also been possible to be reached.

In voltage quality, it were identified some difficulties related in most of the cases to the appliance of the NP EN 50 160 standard and in other cases to the inexistence of national or international orientations to lead with some issues. Voltage dips are the main concern to clients. Indices to select voltage quality information and to create a basis to compare and to characterise the power quality will be applied in the near future.

## ACKNOWLEDGMENT

The authors gratefully acknowledge all other members of ERSE for their contribution on results presented for Portugal. Acknowledgements are also due to the Quality of Supply Task Force from CEER Electricity Working Group and all their members at the different European regulator agencies.

## REFERENCES

[1] A. Falcão, C. Barros, H. Milheiras, J. Esteves, J. Capelo, M. J. Clara, P. Verdelho, 2006, "Some Regulation Perspectives for Power Quality",.*12th ICHQP*.

[2] ERSE, 2006, Relatório da Qualidade de Serviço - 2005, Transporte e Distribuição de Energia Eléctrica em Portugal ,*ERSE* (in Portuguese language).

[3] ERSE, 2006, *Tarifas e Preços para a Energia Eléctrica e Outros Serviços em 2007,ERSE* (in Portuguese language).

[4] Electricity Working Group, the Quality of Supply Task Force - Council of European Energy Regulators, 2005, *Third Benchmarking Report on Quality of Electricity Supply 2005*, Council of European Energy Regulators, Ref: C05-QOS-01-03.

[5] ERGEG, 2006, "*Towards Voltage Quality Regulation in Europe, an ERGEG Public Consultation Paper"*, ERGEG

## BIOGRAPHIES

**Amanda Falcão** was born in Miranda do Douro, Portugal, on September 23, 1975. She received the Dipl. Ing. degree in electrical engineering from the Engineering Faculty of Oporto University, Portugal, in 1998. After an experience at SLE – Electricidade do Sul, in 1999, she joined ERSE, the Portuguese energy regulatory authority, first, within the Consumers and Competitiveness Division and, now, within the Dispatch and Network Division. She made a post-graduation on Electromagnetic Compatibility in 1999 at Universidade Lusíada and an Advanced Studies Program on Economics Regulation and Competition in 2004 at Universidade Católica Portuguesa.

**Hélder Milheiras** was born in Lisbon, Portugal, on July 26, 1973. He received the Dipl. Ing. degree in electrical engineering from Instituto Superior Técnico, Technical University of Lisbon, Portugal in 1997. After his graduation, in 1997, he joined ERSE, the Portuguese energy regulatory authority within the Dispatch and Network Division.

**Jorge Esteves (M'92-SM'02)** was born in Caracas, Venezuela, on October 24, 1958. He received the Dipl. Ing., the M.Sc. and Ph.D. degrees in electrical engineering from Instituto Superior Técnico, Technical University of Lisbon, Portugal in 1983, 1986 and 1992, respectively. Since 1983 till 2004, he reached the position of Assistant Professor with Instituto Superior Técnico, Technical University of Lisbon. Since 1983, he has been a research member of the Centro de Automática of the Technical University of Lisbon. In 2004, he joined Instituto Superior de Engenharia de Lisboa as Coordinator Professor. Also in 2004, he joined ERSE, the Portuguese energy regulatory authority, being responsible for the Dispatch and Network Division.

**Maria José Clara** was born in Portugal on August 11, 1958. She received the Dipl. Ing. degree in electrical engineering from Instituto Superior Técnico, Technical University of Lisbon, Portugal in 1980. She also received the Master in Business Administration degree from the New University of Lisbon in 1989. Since 1983 till 1997 she worked to EDP - Electricidade de Portugal, first in the Long Term Power Planning Division and, after 1992, in the Strategy Planning Division. Since 1997, she joined ERSE, the Portuguese energy regulatory authority, being the actual General-Director.