

## QUALITY OF ELECTRICITY SUPPLY IN URUGUAY: VOLTAGE QUALITY OVERALL REGULATION AND ITS CONTROL EXPERIENCE

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### ABSTRACT

*Since 2006, a control scheme for the Quality of Service of the electric energy distribution was established in Uruguay. The Uruguayan Energy Services Regulator (URSEA), set parameters and goals for all the three Quality of Service aspects: Continuity of Supply, Voltage Quality and Commercial Service Quality.*

*The Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE) is a state-owned enterprise responsible for the Distribution of electricity in all the Uruguayan territory.*

*This paper summarizes UTE's experience in the control of the Voltage Quality aspect after six years of the establishment of this control scheme.*

### INTRODUCTION

Along this work, a resume of the normative and the historical modifications in the Voltage Quality control is presented, as well as a description of the procedure used and the main results that were obtained.

Moreover, it is presented a brief description of the measuring equipment used in the control campaign and the CAPTE system (a software tool completely developed by UTE, used for the validation, data processing and management of the control measurements, as well as for the data communication with the Regulator).

Finally, some conclusions on the obtained results during this past six years are exposed, and the challenges for the future, where the objective is to control and analyze a greater amount of parameters related to Power Quality, are presented.

### OVERALL REGULATION AND HISTORY

The Electricity Sector Industry Regulation law was approved in 1997, pointing out the need of an external and independent regulation of the electricity supply companies. This law proposes the equality between state-owned and private companies that will be incorporated to the Electricity Sector Industry.

After the approbation of this law, the electricity sector industry is regulated in all of its stages (Generation, Transmission, Distribution, Commercialization and Customers) by a regulatory agency that depends on the executive branch of the government.

That agency is linked to the Energy Ministry, and it is named Unidad Reguladora de Servicios de Energía y Agua (URSEA).

In 2003, URSEA approved the Electricity Distribution Quality of Service Code that started ruling in Uruguay since January 1<sup>st</sup>, 2006, establishing the control parameters and the corresponding quality goals.

Electricity Distribution Quality of Service Code is divided on:

- a) Continuity of supply (number of interruptions and interruption duration)
- b) Voltage quality (waveform disturbances and voltage magnitude deviations)
- c) Commercial service quality (connection, customer care, technical service, metering and billing)

Each of these topics contains a variety of indicators used to measure the Distributor's performance.

If the established goals are not met, the Distributor will pay an economic compensation to the affected customers.

Following, the historical stages related to Voltage quality control approved up to date are listed:

1997 – Law N°16.832 Electricity Sector Industry Regulation is approved

2002 – The codes for the regulatory framework are established: 276/002 General Code for the National electric system Regulation; 277/002 Distribution Code; 278/002 Transmission Code and 360/002 Wholesale Market Code.

2003 – URSEA Resolution 29/003 containing the text of the Electric energy Distribution Quality of Service (QoS Code) to be applied from January, 2005.

2005 – URSEA Resolution 05/005 postponed the entrance of the QoS Code until January, 2006.

2006 – QoS Code starts ruling since January 1<sup>st</sup>, 2006, controlling the Voltage Quality since July 1<sup>st</sup>, 2006. Initially, the voltage level in MV/LV distribution transformers is controlled.

2009 – URSEA Resolution 61/009 modifies the acceptable voltage levels to a tighter scheme. During this stage, the amount of measurements to be done directly in consumers is progressively increased. It is also established that the Distributor has to start measuring voltage disturbances (Total Harmonic Distortion – THD) in a massive way.

In the future, the QoS Code [2] establishes the continuity of the voltage level measurements in customers and in MV/LV transformers, adding some special disturbances measurements to be done in particular points of the

Distribution network.

The defined disturbances for doing this control are listed below:

- Unbalance (voltage and current)
- Total harmonic distortion (THD) and individual harmonics (voltage and current)
- Flicker (Pst, Plt)

The QoS Code establishes a first step with diagnosis measurement campaigns in order to locate sources of disturbances and determinate the reference values to be used in the future.

The second step includes voltage and current disturbance measurement campaigns and a penalization scheme that applies to both Customers and the Distributor.

## VOLTAGE QUALITY CONTROL

Voltage level was the first parameter that was controlled. Since then, voltage level is controlled through measurements campaigns. Measurements are carried out in sampled points of the distribution network given by the Regulator.

From July, 2006 to June 2009, the sampling consisted on a monthly record of the voltage level in 1% of MV/LV transformers in urban networks and 0,2% of MV/LV transformers in rural networks.

These measured points were randomly selected by the Regulator. Moreover, the Regulator monthly selects an amount of up to 50 extra network points.

From July 2009 to June 2010, the sampling introduced a random selection of measurements to be made in customers, maintaining the number of control measurements made by the Distributor.

The sampling consisted on a monthly record of the voltage level in 0,75% of MV/LV transformers in urban networks, 0,15% of MV/LV transformers in rural networks and one out of each 30.000 of the Distributor's customers.

The points above mentioned were randomly selected.

Once again, during this period, the Distributor monthly made up to 50 extra measurements in points selected by the Regulator.

In July 2010 a new modification in the way the sample is chosen was introduced; the amount of measurements in customers was duplicated reducing the measurements in transformers in a way so as for the total amount of measurements not to be modified.

Since then, the samples consist on a monthly record of the voltage level in 0,5% of MV/LV transformers in urban networks, 0,1% of MV/LV transformers in rural networks and one out of each 15.000 of the Distributor's customers. The points above mentioned are randomly selected.

Moreover, the Distributor continues making up to 50 extra measurements per month in points selected by the Regulator.

The actual sample results in about 1000-1300 measurements to be carried out per semester (control period established by the Regulator).

The Regulator made a Procedure Manual for the voltage level measurement campaign [1], where the measurements

requirements for the acquisition and data processing are established.

According to this manual, each voltage level measurement must fulfill the following requirements:

- Minimum time of measurement: 1 week
- Averaging period: 15 minutes intervals
- Calculations are made considering only the valid records (this validation marking is automatically made by the measuring monitor)
- The amount of valid records within a measurement must be the equivalent to 5 days
- The percentage of time in which the voltage recordings are outside the established limits is calculated dividing the number of valid records outside the limits by the total number of valid records in all the measurement. If this percentage is higher than 3%, the affected customers must be compensated with a payment made by the Distributor

The payment for the consumers consists in an economic compensation that is made deducting the amount to be paid from the next consumer's billing done after the compensation is approved by the Regulator.

Monthly, the Distributor sends the Regulator the calendar with the installation of the voltage recorders. The Distributor processes all the recorded data, and sends the required information to the Regulator (measurement files, processing results and economic compensations for the customers).

The following Table 1 shows the results achieved in the execution of the measurement campaigns since the beginning of the Voltage Quality control according to the QoS Code.

Table 1 – Accomplishment in the execution of the measurement campaigns (as % of the total sample)

Semester	Sample size	Accomplishment
2006 S2	600	86%
2007 S1	954	96%
2007 S2	960	80%
2008 S1	966	93%
2008 S2	970	92%
2009 S1	978	100%
2009 S2	996	86%
2010 S1	1008	90%
2010 S2	1014	79%
2011 S1	1026	92%
2011 S2	1119	95%
2012 S1	1062	94%

Source: Gestión de Redes – DIS (UTE)

The accomplishment in the execution of the measurement campaigns has an historical average level of 90%. It must be pointed out that the diminutions in the accomplishments are associated to periods in which the measurements sampling scheme was modified (progressive increase of the measurements in customers, than in practice, presented more difficulties to perform in comparison with the measurements in MV/LV transformers).

Table 2 shows the percentage of processed measurements

that produced compensations for the customers due to the fact that more than 3% of its records were outside the voltage level limits established in the QoS Code.

In these cases, UTE must pay the compensation to all the affected customers making deductions in their future billings.

The compensation must be paid monthly considering the number of months that the customers were affected until the moment when UTE solves the problem and carries out a new measurement that is also sent to the Regulator.

Once detected a problem (according to the results of a measurement), the Distributor must solve this problem and inform the Regulator within 120 days while economic compensations to the customers are paid.

Table 2 – Measurements producing compensations (as % of the measurements carried out)

Semester	% producing compensation
2006 S2	1,2%
2007 S1	0,5%
2007 S2	1,0%
2008 S1	0,2%
2008 S2	0,0%
2009 S1	0,2%
2009 S2	1,6%
2010 S1	1,0%
2010 S2	1,9%
2011 S1	1,0%
2011 S2	1,3%
2012 S1	2,0%

Source: Gestión de Redes – DIS (UTE)

It is observed that for all the controlled semesters, less than 2% of the measurements carried out by UTE produced an economic compensation for the customers due to not compliance with the voltage quality requirements.

The last controlled semesters showed a little increase in the number of measurements that produce compensation. This can be explained by the fact that the number of measurements made in customers (where there is a little more probability for a problem to exist) has been increased during these semesters.

## CAPTE SOFTWARE

The storage and processing of data obtained in the measurement campaigns is made using the CAPTE software, developed by UTE, that has a data base and analysis capability.

CAPTE software daily processes the files corresponding to the measurements carried out which results in a processing of more than 2000 measurements per year.

The requirements established by the Regulator are checked for each measurement and the voltage level data is processed and analyzed.

In order to make the verifications and the corresponding data analysis, CAPTE has interfaces with other corporative systems (SGI – Processing of interruptions, SGC – Commercial management system, EGEO – Geographical identification) and with a web page used for the exchange of

information with the Regulator. Moreover, CAPTE software has an e-mail service that automatically sends warning messages to the unit responsible for each measurement.

CAPTE has analysis as well as management and control of the measurement campaign tools. Among its analysis tools, the system has graphic tools that allow the users to visualize the recorded voltage levels and the results (percentage of recordings inside and outside the acceptable voltage level range, voltage level distribution classified in ranges and the values of the economic compensations to be paid to customers). Daily reports on the recently processed measurements are also available in this system.

The management of the measurement campaign is also supported by the CAPTE system where users can find reports on the processed measurements during a selected period and lists with the measurements left to do.

To send the monthly information to the Regulator, the software has a series of tools that allow the creation of reports and data tables containing information of the execution and results of the measurement campaign during the selected month. This reports and data tables are also used as a basis for the internal reports of the company.

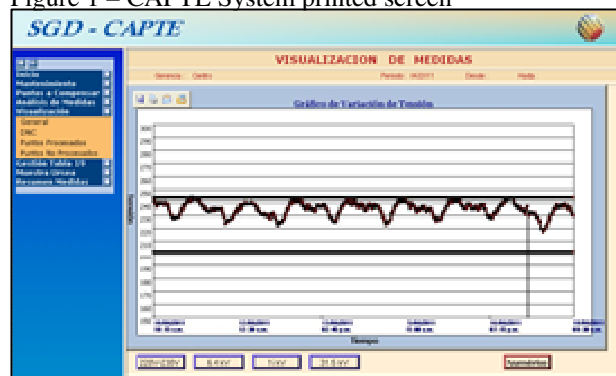
Since its beginnings, CAPTE has been updated in order to fulfill the regulation requirements and the needs of the users. It started as a system used just for the storage of the voltage level measurements. Then, the capability for verifying, processing and analyzing the stored data was developed. Nowadays, it also stores all the voltage Total Harmonic Distortion (THD) measurements. On a short horizon, it is expected that the software has the capability to analyze these THD measurements too.

In the future, the QoS Code establishes the analysis and storage of measurements of other disturbances such as individual harmonics (measured in voltage and current), unbalance (measured in voltage and current) and flicker.

The software should increase its capabilities in order to adapt itself to the established in the QoS Code and also to satisfy the needs of the users, including more sophisticated analysis tools that could be used as support in internal studies and reports made in UTE.

As an illustration, Figure 1 shows a printed screen of the CAPTE system.

Figure 1 – CAPTE System printed screen



Source: CAPTE system (UTE)

## MEASURING MONITORS

UTE owns 400 portable network monitors distributed all over the country, used for carrying out the measurement campaign defined in the QoS Code.

The Regulator establishes that the monitors must measure the RMS Voltage value according to norm IEC 60050-101 (definition 101-14-16).

The company buys its equipment foreseeing to fulfill the future requirements established in the QoS Code and aiming to give the users a tool that could be used in activities other than the control measurement campaign.

Nowadays, UTE is using monitors manufactured by IMS from Brazil. 3-phase monitors are IMS PowerNET P-600 model and 1-phase monitors are IMS PowerNET P-100 model.

3-phase monitors are voltage and current recorders while 1-phase monitors just record voltage magnitudes.

All the monitors used in measurement campaigns fulfill the requirement of measuring RMS values recording average, maximum and minimum values for each aggregation period. The aggregation period is settable in all monitors.

Odd and even Individual harmonics up to 41° are recorded both in voltage and current according to norm IEC61000-4-7. 3-phase monitors are poly-phase recorders with 3 measuring elements and 4 wires which allow performing delta or wye connections.

The maximum error is 1% for RMS voltage values when measuring under normal network operation conditions (this means a total harmonic distortion lower than 10%).

All monitors have a 0,5% precision for voltage and a 1,5% precision for current measurements.

As a summary, the magnitudes recorded by the used monitors are listed:

- Voltage and current
- THD, odd and even harmonics up to 41° for voltage and current
- Cos phi
- Apparent, Active and Reactive Power
- Direct and Inverse Active Energy
- Direct and Inverse, inductive and capacitive Reactive Energy
- Demand

UTE has signed a contract for the repairing and maintenance of the measuring monitors and there also is a calibration plan carried out in UTE Laboratory. Specific calibration software was bought in order to calibrate these monitors.

During the execution of the measurement campaigns, the increase in measurements to be made in customers brought difficulties (mainly in Montevideo, capital city of Uruguay). These difficulties mainly showed in the negative answer given by customers when asked for permission to install the monitors, equipment steals and vandalism.

As a solution, UTE bought energy meters (the ones used for billing purposes) with voltage record capability. These energy meters are installed in the customers that show difficulties for carrying out the control measurements using portable monitors. In these cases, the energy meter used by UTE for billing purposes is substituted for a voltage

recording capable energy meter.

Moreover, UTE owns FLUKE TR1760 network analyzers that are used for detailed Power Quality studies. These analyzers fulfill the requirements established in IEC 61000-4-30 as full class A equipment and are able to record and analyze all Power Quality parameters.

## CONCLUSIONS

The Voltage Quality control in Uruguay has recently completed its first 6 years.

Up to the moment, control focused almost exclusively in voltage levels in MV/LV transformers and customers in any points of the distribution network. About 10000 measurements were performed resulting that less than 2% of them produced compensations to be paid to customers due to not compliance with the voltage quality requirements established in the QoS Code.

The accomplishment in the execution of the measurement campaigns has an historical average level of 90%. This accomplishment level showed diminutions in semesters where modifications in the measurement points sampling were introduced. Particularly, the increase in the number of measurements in customers brought more difficulties for being carried out, mainly in the capital city. These difficulties were progressively solved achieving better levels of accomplishment in the execution of the measurement campaign.

All the voltage quality control was made with support of the CAPTE software, developed by UTE, that let users validate, process, analyze and manage the measurements as well as the exchange of data with the Regulator.

The measuring monitors used in the measurement campaigns fulfill the requirements established in international norms.

For a next future, UTE faces the challenge to continue the improvement in the accomplishment of the execution of the measurement campaigns establishing a goal of 100% for the next control semesters.

The future development of CAPTE software is being planned in order to add tools that let users to process new Power Quality magnitudes to be considered in further studies: disturbances. This is another challenge for UTE and consists in the development of a system for the analysis of the other Power Quality parameters: total harmonic distortion, individual harmonics, unbalance, flicker, sags and swells.

## REFERENCES

- [1] URSEA, 2007, *Manual de Procedimientos para la realización de campañas de medición de tensión*
- [2] URSEA, 2010, *Versión compilada del Reglamento de Calidad del Servicio de Distribución de Energía Eléctrica – Resolución de la URSEA N°29/2003 con posteriores modificaciones*