DEVELOPMENT AND IMPLEMENTATION OF A METHODOLOGY FOR THE STUDY OF VOLTAGE DIPS IN BOGOTA D.C.

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ABSTRACT

This paper presents a methodology developed by the authors for the study of quality power, in particular voltage dips in industrial and commercial users. The methodology consists of several steps and is applied to Mosquera Substation in Bogotá D.C. From the application of the methodology gives a method of extracting information of power quality meters, it applies a methodology to classify the different industrial and commercial users, then it applies the Bollen methodology to obtain the amount, duration, magnitude and types of voltage dips, then it uses an alternative methodology based on wavelet transformed and it compares the results of both methods. Finally, it develops contour curves and it evaluates some immunity cases from customer equipment in the substation under study.

INTRODUCTION

Currently, the distribution systems consist of a large number of interconnections, attend a large number of industrial, commercial and residential customers and are immersed in markets that offer a particular regulation and state intervention, depending on the country and the region they are. In Colombia the electricity sector suffered a major transformation from the Laws 142 and 143 of 1994, resulting in a change of economic model to the electricity sector, focusing primarily on the quality and coverage.

Bogota D.C. is the most important city in Colombia, with a rapid growth of its PIB nearly 6% (2009) and with approximately 7.000.000 inhabitants in 2009, making it a large, industrial, commercial and business center. Codensa E.S.P. is the network operator of the city and one of the main problems are voltage dips in industrial and commercial sectors.

This paper presents a methodology developed by the authors and applied to the Mosquera Substation (one of the substations that make up the electrical system of the city). To develop the methodology takes into account the extraction of information from network analyzers installed in the feeder circuits in 34.5 kV, the application of the Bollen methodology, [1], [6], the Wavelet transform [2] and the use of contour curves presented at the CIGRE paper 412 [3]. All this is done to present subsequently the results, analysis and relevant discussions about them.

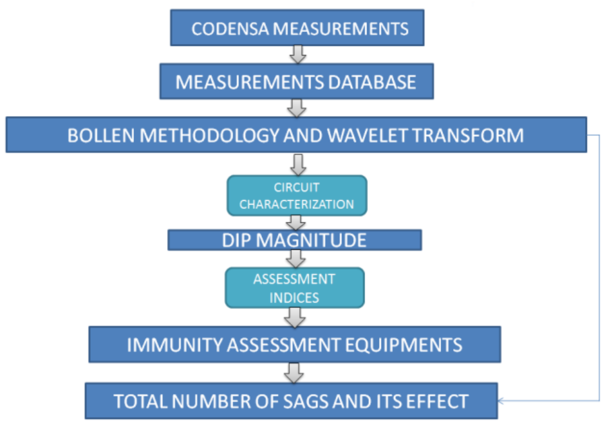
METHODOLOGY

A methodology was developed to characterize and quantify voltage dips from Codensa E.S.P. In this article we present the application of the methodology to the Mosquera substation.

The methodology uses a software application that is based on the methodology proposed by Bollen to characterize voltage dips, the Wavelet transform, the development of contour curves and the analysis of the immunity of electronic equipment.

Figure 1 shows the flow chart for application of the methodology:

Figure 1 Flow chart of the methodology developed and implemented



The methodology is discriminated as follows:
1. Extracting information from measurements of Codensa E.S.P.
2. Formation of measurements database
3. Characterization of medium-voltage circuits
4. Application of the Bollen methodology
5. Application of Wavelet transform
6. Development of immunity curves

The development of this methodology allows characterizing and quantifying the voltage dips from the Codensa substations measurements on network by network analyzers Class A. Initially, the information is decrypted and sent to Matlab for processing. Then apply the Bollen methodology and Wavelet transform, determining the amount of voltage dips, residual voltage, voltage dip type, among other results. At the end and through an immunity algorithm, defines the boundary curves related to the amount found dips.

Codensa E.S.P. Measurements Database

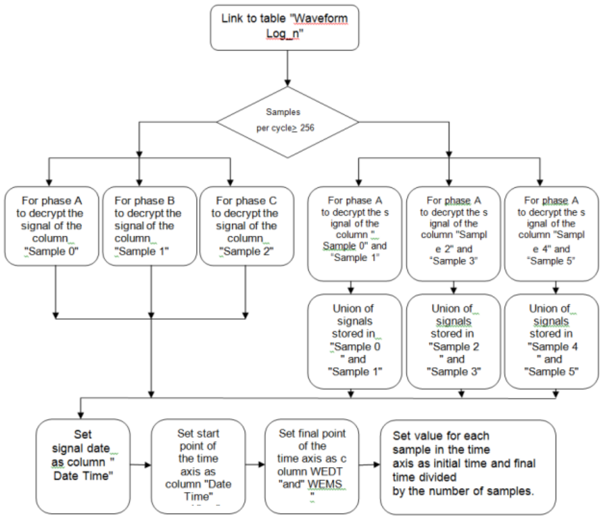
Initially it is determined that the equipment uses as measuring the voltage U_{DIN}, through interpretation of the standard IEC 61000-4-30, and an extensive review of the Nexus equipment operation 1252, it develops the necessary methodology to extract the information stored in the fields of the database.

The network analyzer Nexus 1252 allows a wide variety of making and recording of information which is based on its previous settings before the connection [4].

Nexus database 1252: according to the preset configuration for the measurement by the Nexus 1252, it creates a database that stores the primary information for monitoring voltage dips and other events that occur in the equipment connection point.

Figure 2 shows the system information storage and the decrypting of the same for later processing through the developed algorithms.

Figure 2 Decryption process information database Nexus 1252.



Circuit Characterization

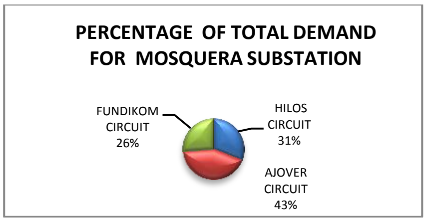
Once identified each one of the industrial and commercial users that are associated with the substation under study is necessary to develop a characterization of circuits, according to industrial processes that are handled by different companies [5]. The sectors selected for study are: food industry, plastics industry, brewing industry, paper industry, ceramics industry, petrochemical industry, textile industry, wood industry, metallurgical industry, cardboard industry, steel industry, commercial enterprises and other.

The Mosquera substation has 3 circuits in 34.5 kV. In these circuits there are 19 industrial type customers. Table 1 shows each one of the circuits with their respective monthly energy demand, while Figure 3 illustrates the percentage of each stage in the total demand of the substation.

Table 1 Circuits in 34.5 kV associated with Mosquera substation.

Circuit	Energy Demand MW/h
Hilos	5078,1
Ajover	7076,4
Fundikom	4319,8
Total demand	16474,3

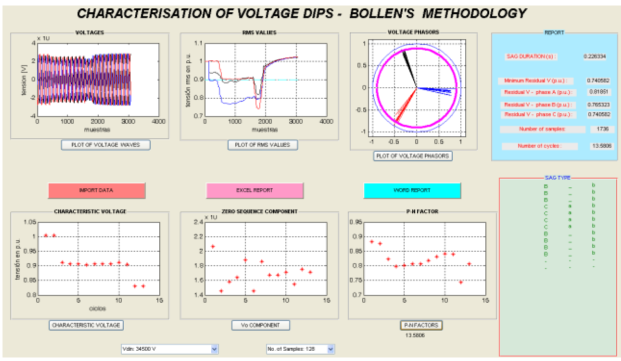
Figure 3 Discrimination of the total demand percentage of the Mosquera substation.



Bollen Methodology

In order to implement in an interactive methodology proposed by Bollen, [1] [6], it develops an interactive application and in a graphical environment in MATLAB, as shown in Figure 4, to find the basic parameters of voltage dips: magnitude and duration, and additional parameters described in the methodology.

Fig. 4 Main display of the application developed in matlab.



The application determines the phasors of the voltages (through the technique of Fast Fourier Transform, FFT) and found effective values of the voltages (with the technique of calculating r.m.s. value of a sample moving window), determining the beginning and ends of the voltage dip (from the comparison of the effective current values with a threshold value of 0.9 p.u.).

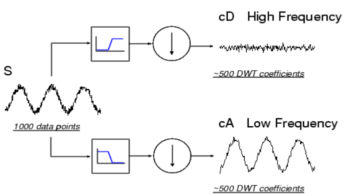
The developed application has the following characteristics:

1. Ability to import raw data files with extension .xls (Excel) or .Mat (Matlab), select the sampling rate information that is imported and select the line voltage among four available (208; 11400, 34500 or 57500 V).
2. Presentation, in graphic form, of the processing results (phase voltages wave, effective value of the voltages, temporal evolution of the phasors) and the parameters of the characterization given by Bollen (determining the type of dip, characteristic voltage, PN factor, zero sequence components). The display results also allows observing the basic characterization parameters (magnitude and duration of the dip) and providing the option of producing reports in Word or Excel for the voltage dips analyzed in detail.

Discrete Wavelet Transform Algorithm TWD

The underlying algorithm of TWD [2], consists in the decomposition and reconstruction of the signal using wavelet function. The decomposition form consists of two filters FIR with responses to the impulse low pass and high pass, respectively, followed by decimation by two. Therefore, if at the input there are signal samples, at the output will have approach coefficients cA (from the response of high pass filter), as illustrated in Figure 5.

Figure 5 Operating diagram of the algorithm



This set of filters is determined by the "Wavelet Mother Function" selected for processing.

Immunity Evaluation of Electronic Equipment

To evaluate the immunity of electric and electronic equipment and know the amount of voltage dips presented in a node under study it uses the elaboration of cumulative tables of voltage dips, it develops of contour curves and it elaborates 3D graphics, which summarize the number of events in the node. The above information allows determining the equipment that will be affected by the presence of voltage dips depending on magnitude and duration. This method is validated by the committee C4.110 CIGRE Working Group and it is used by different authors in studies and researches in power quality.

RESULTS

Methodology

Table 2 presents a summary of voltage dips for 2009 year, obtained by Bollen methodology and the software developed.

It obtained the total number of voltage dips, the type of voltage dip, the voltage dips with duration less than one cycle, and voltage dips that are not identified according to the types proposed by Bollen methodology. A summary of results are presented in Table 3.

Table 2 General characteristics of dips identified in Mosquera substation.

DESCRIPTION	No.
Total substation dips in 2009	39
Dips with duration less than 1 cycle (16,666 ms)	4
Dips with one type present in its temporal evolution	30
Dips with several types present in its temporal evolution	5
Dips where the methodology did not identify the type of dip	3

The discrimination by type is seen in Table 3. It shows that most voltage dips presented correspond to types B and C. There were no dips type A, D, F and G.

Table 4 shows, simultaneously, the magnitudes and durations mean, minimum and maximum of 30 voltage dips characterized with the developed computational tool.

The observations made on the distributions of durations and magnitudes allow visualizing a large asymmetry of the data, so that measurements of central tendency, such as standard deviation and variance are not representative in this case. The average value indicated constitutes a simple reference.

Table 3 Type, amount and percentage of 30 voltage dips of one type presented at the Mosquera substation.

TYPE	No.	(%)
A	0	0
Ba	6	20.00
Bb	5	16.67
Bc	12	40.00
Cab	2	6.67
Cbc	3	10.00
Cac	1	3.33
Dab	0	0.00
Dbc	0	0.00
Dca	0	0.00
Eab	0	0.00
Ebc	1	3.33
Eca	0	0.00
Fab	0	0.00
Fbc	0	0.00
Fca	0	0.00
Gab	0	0.00
Gbc	0	0.00
Gca	0	0.00

Table 4 Basic statistics for the entire dips presented in Mosquera substation.

DURATION (Time)	s
Average	0.07
Min	0.01
Max	0.33
MAGNITUDE	p.u.
Average	0.73
Min	0.13
Max	0.90

From the found results for Mosquera substation are:
1. There are voltage dips that do not enter in any of the types identified in the Bollen methodology.
2. It's possible to present voltage dips in which a temporal evolution it shows some types (A, B, C, etc)
3. The majority of voltage dips correspond to the type which is designated as B.
4. It's possible to present dips with durations less than one cycle (16.66 ms).

Results by TWD

One of the most important steps to detect and identify voltage dips using TWD [2], is classify them. Taking into account this classification of events and using the decomposition scheme it obtains the detail Wavelet coefficients which allow, with the reconstruction scheme of these coefficients, finding the details of the signal (Figure 5).

Applying again the decomposition scheme to the approach signal can find new details in another range of frequencies lower than the frequencies of the details already calculated. In this way you can analyze different levels of detail (or frequency ranges) of the signal.

Figure 6 Decomposition of a voltage dip (Mosquera 17/08/09) in 5 detail levels "db10".

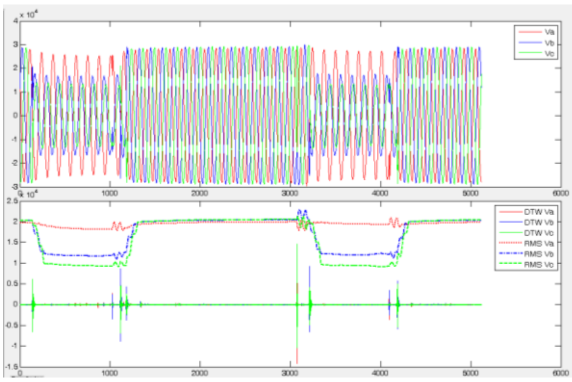


Figure 6 shows the detection of two voltage dips of a circuit in 34.5 kV of Mosquera substation. In the first level of detail, using the Daubechies Wavelet function 10 "db10" [2] can be noted that it is possible to detect the beginning and/or end of different disturbances on the first level of detail. This is because the beginning or end of the disturbance contains mostly high frequencies, which are detected mainly in the detail function of the first level of decomposition.

Immunity Evaluation of electronic equipment

Using an algorithm that takes the information of magnitude and duration of voltage dips table is constructed cumulative voltage dip and curve shape and it develops a 3D bar chart that view the found voltage dips.

Table 5 shows the cumulative table of voltage dips and figure 7 shows the contour curve. Figure 8 shows the 3D histogram, with the number of voltage dips vs. magnitude vs. residual magnitude.

Table 5 Cumulative voltage dips, Mosquera substation.

% V	0.0	0.1	0.2	0.3	>0.4
90	39	5	2	2	0
80	16	5	2	2	0
70	11	4	2	2	0
60	8	3	2	2	0
50	8	3	2	2	0
40	4	0	0	0	0
30	3	0	0	0	0
20	3	0	0	0	0
10	0	0	0	0	0

Figure 7 Contour curve, Mosquera Substation.

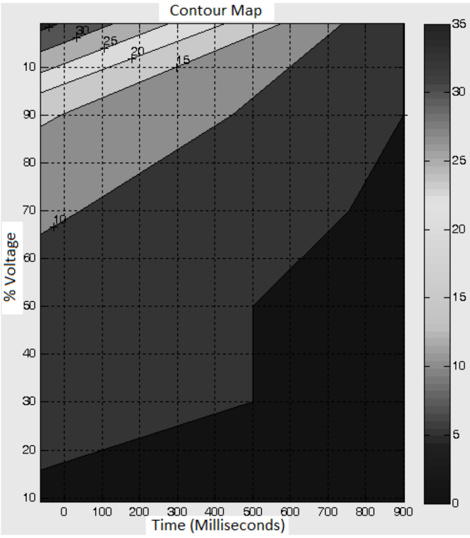
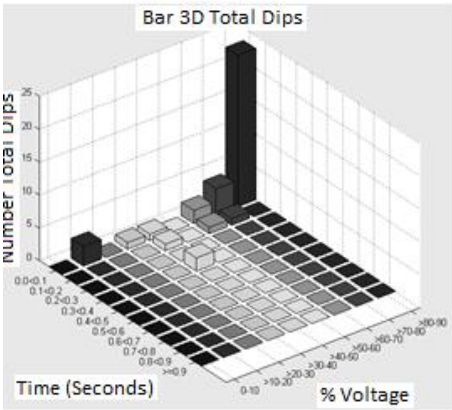


Figure 8 3D bar, cumulative table.



MISCELLANEOUS

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CONCLUSIONS

This paper presents an implemented methodology by the authors to analyze the distributions electrical networks of the network operator Codensa E.S.P.

- It develops tools to decrypt the information stored by the Network Analyzer Nexus 1252.
- It develops computational tools for analysis in an interactive, graph form and produce reports in Word and Excel, based on the Bollen methodology and wavelet transform.
- Finally, using an algorithm developed contour curves of the measurements made by the Network Analyzer Nexus 1252.
- This allows evaluating the operation of the S/E Mosquera, and the other remaining in the distribution electrical system of Bogotá D.C.

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