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VIRTUAL INSTRUMENTS FOR IDENTIFICATION AND ANALYSIS OF VOLTAGE DIPS

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ABSTRACT
Power quality is a term often used today for describing any event manifested in voltage, current or frequency variation that can result in malfunction of end-user equipment. During voltage dips the supply voltage drops to a lower value for a short duration, and a lot of modern technologic equipment is very sensitive to this kind of perturbations. A voltage dip means that the required energy is not being delivered to the load and this can have serious consequences depending on the type of load involved. The new Distribution Codes issued all over the world by National Authorities require the survey of power quality in Point of Common Coupling (PCC). In this paper, a Virtual Instrument (VI) for detection and classification of voltage dips is presented. Based on Wavelet Analysis, the proposed VI implements the requirements of IEC 61000-4-30 and proves very good accuracy. The proposed version can evaluate single- or three-phase events.
Keywords: power quality; voltage dips; wavelet transform; virtual instrument

1. INTRODUCTION
Power quality is a term often used today for describing a major aspect of the electrical energy supply and utilization. A power quality problem is any event manifested in voltage, current or frequency variation that can result in malfunction of end-user equipment. Therefore, the power quality is an issue that needs permanent attention.

In power systems, faults, dynamic operations and non-linear loads often cause various types of disturbances such as voltage sags, voltage swells, switching transients, etc. The main power defects are (long and short) interruptions and voltage dips, when the voltage drops to a lower value for a short duration. Naturally, long power interruptions are a problem for all users, but many operations are very sensitive to even very short interruptions or dips. A voltage dip means that the required energy is not being delivered to the load and this can have serious consequences depending on the type of load involved. For suppliers, voltage dips are inherent phenomena associated to operation of any power system, without important economic effects on the supplier's activity.
The new Distribution Codes issued all over the world by National Authorities require the survey of power quality in Point of Common Coupling (PCC). In this paper, a Virtual Instrument (VI) for detection and classification of voltage dips is presented. Based on Wavelet Analysis, the proposed VI implements the requirements of IEC 61000-4-30 [3] and proves very good accuracy. The proposed version can evaluate single- or three-phase perturbations.
Voltage dip is a sudden reduction of the voltage at a particular point of an electricity supply system below a specified dip threshold followed by its recovery after a brief interval. A voltage dip is in most of the regulation a two dimensional electromagnetic disturbance, the level of which is determined by both voltage and time – figure 1 [4].

The mainly source of voltage dips is the electrical short circuit happening on the power system. Short-circuit faults are an unavoidable state of system operation, and can occur between phases, phase and neutral or phase and earth. The switching of large loads, starting of large motors connected to the end of a long supply line, power fluctuations of great magnitude are characteristic of some categories of loads and installations, such as variable load and/or speed drives, arc furnaces, welding equipment, etc. All of them can produce large change in current and intolerable voltage drops.

The economic consequences of such an event can be significant. They include loss of production, cost of restarting the technological process where the time needed for restarting is very long, damage equipment and materials, delayed delivery, reduce customer satisfaction, a decrease in the power delivered to the user, etc.

Voltage dips begin when the voltage falls below the imposed threshold and ends when the voltage reaches again the same level.

2. WAVELET ANALISYS

Wavelet analysis is a technique for carving up functions or data into multiple components corresponding to different frequency bands [5, 6]. From the beginning of 1990s, it began to be employed in science and engineering, and has been known to be particularly useful for analyzing signals that can be described as aperiodic, noisy, intermittent, or transient. If the Fourier transform decomposes the signal in an orthonormal basis containing sine and cosine functions, which are infinitely extending in time, the wavelet transform decomposes the waveform in a basis of signals that are all finite in time and in frequency content. These signals are also orthonormal and thus the decomposition will be unique.

Many scientists have developed specific mother wavelets with special properties that make them suitable for application in different fields; such examples are the Coiflet-, Morlet-, Haar-, or Daubechies – wavelet – figure 2.

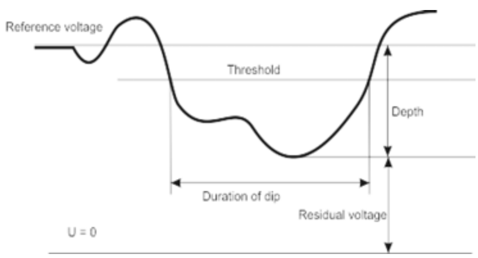

Figure 1. Characteristics of voltage dip

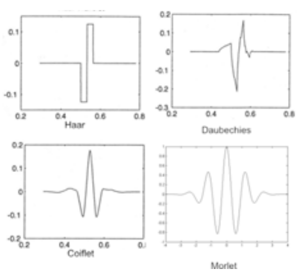

Figure 2. Some mother wavelets

3. VIRTUAL INSTRUMENTS FOR DIP IDENTIFICATION AND ANALISYS

LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications [7]. In contrast to text-based programming languages, where instructions determine program execution, LabVIEW uses dataflow programming, where the flow of data determines execution. In LabVIEW, a user interface can be built by using a set of predefined tools and objects. The user interface is known as the front panel, and the customer may add codes using graphical representations of functions to control the front panel objects. The block diagram contains this code; in some ways, the block diagram resembles a flowchart.

The instrument implements the stipulations of IEC 61000-4-30 and fulfils the requirements for class *A* measurement, as follows:

- the basic measurement U_{rms} of the voltage dip is the r.m.s. voltage refreshed each half-cycle, $U_{rms}(1/2)$;
- the dip threshold is a percentage of the declared input voltage, U_{din};

- the residual voltage is the lowest U_{rms} value measured during the dip;
- the duration of the voltage dip is the time difference between the start time and the end time of the voltage dip;
- the dip threshold and the declared input voltage are both set by the user according to the use.

The VI can receive data directly from a data acquisition system (DAS) installed in situ or can read previously measured data from an existing file. This software tool analyzes the measured data, detects the existence of voltage dips and evaluates their characteristics; all variable data can be set by the user according to rules imposed by norms.
The VI consists of two parts: the graphic user interface and the intern working program.

The graphic user interface (GUI) represents the part of the VI with which the users come in contact; a simple and easy to understand GUI was built up in order to facilitate the use of this tool. Through it, users can introduce the input data and visualize the obtained results.
The main window - figure 3 - contains the following elements:

1 Signal: is the field where the VI reads the name of the file which contains the measured data; user must choose the file with its specific path. Otherwise, data are received from a DAS;
2 Signal representation: the signals on all three phases are displayed either as a time variation signal – left side, or as an envelope of the signal - right side;
3 Bright marker: its red color indicates the existence of voltage dip(s) in the studied signals;
4 Dips analyze: after the data evaluation, the start moment, duration and residual voltage are indicated for all detected dips and for all single-phase signals;
5 Three-phase dip analyze: information on each phase are aggregated and an evaluation of the perturbation as a three-phase phenomenon is performed and presented;
6 Three-phase dips number: points out the number of dips detected into the analyzed interval.

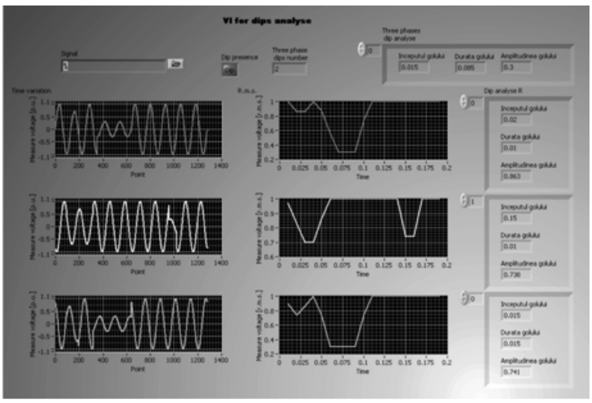

Figure 3. Main window of VI

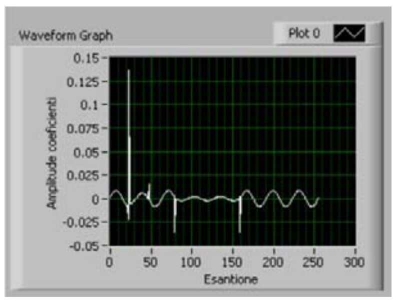

Figure 4. Wavelet transforned signal

The working algorithm of the proposed VI is as follows:

1. the user selects the data file where the measured data were saved or the elected DAS;
2. data are graphically represented as time variation or as $U_{rms}(1/2)$ envelope;
3. data are investigated using the discrete wavelet transform (for each phase) - figure 4;
4. discontinuities existing in the transformed signal allow to detect the presence of voltage dip(s);
5. the start moment, duration and residual voltage of the first dip are calculated;
6. the step (5) is resumed for all detected dips;
7. the evaluation of every voltage dip (start moment, duration and residual voltage) is displayed;
8. information on each phase are aggregated and an evaluation of the perturbation as a three-phase phenomenon is performed and presented.

Figures 5 and 6 depict the VI's blocks, as follows:

- Figure 5 describes the block dedicated to three-phase disturbance analysis;
- Figure 6 highlights connections between the main VI and different sub-instruments existing in its structure.

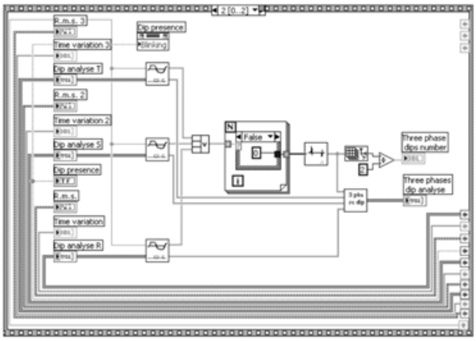

Figure 5. Diagram of three-phase analysis block

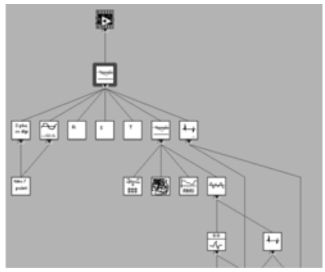

Figure 6. VI hierarchy

The proposed VI was tested for the simulated signal presented in figure 3; the differin g existing voltage dips were detected and their characteristics evaluated with adequate accuracy, proving the correctness of the implemented approach.

4. CONCLUSION

The new Distribution Codes issued all over the world by National Authorities require the survey of power quality in Point of Common Coupling (PCC). Nowadays, voltage dips are known to be among the most costly power quality phenomena in industry as the lost production can be very valuable.

Taking into account the importance of voltage dips for different industrial customers, a Virtual Instrument for detection and classification of these electromagnetic disturbances was presented. Based on Wavelet Analysis, the proposed VI implements the requirements of IEC 61000-4-30 and proves very good accuracy.

The presented VI analyzes three single-phase waveforms corresponding to three line-ground voltages in a power system and can detect the existing dips in signals previously recorded or received from and existing in situ DAS. The VI evaluates all detected dips and calculates the following characteristic parameters: dips start, duration and residual voltage. Afterward information on each phase are aggregated and an evaluation of the perturbation as a three-phase phenomenon is performed and presented

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