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DETECTION AND ANALISYS OF TRANSIENTS IN ELECTRICAL NETWORKS BASED ON A MULTIRESOLUTION SCHEME

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Abstract: – The use of the wavelet theory and multiresolution analysis allows to design algorithms to localize transients in electrical networks. Perturbations caused by capacitors switching are the source of the studied waveform. These signals were provided by the voltage measurements on capacitor buses to correct the power factor. Multiresolution analysis allows to identify the transient parameters that have influence on the perturbation characteristics. Other events like dips, sags, swells and impulsive transients can be located by means of the same tool.

Key Words: – Transients – Capacitor Banks – Capacitors Switching – Wavelets –Multiresolution Analysis – Power Quality.

1 Introduction

The capacitor banks used to correct the power factor reduce the reactive power increasing the power transmission capacity. In this paper oscillatory transients caused by capacitors switching are analyzed, specially the short time and high frequency transients in voltage measurements on capacitors buses. The frequency range is 400 - 2000 Hz; the value depends on the ratio between the fault power and the bank capacitor power. On the other hand, this frequency corresponds to the serial resonance frequency that involves the bank capacity and the system inductance at the connection bus.

The overshoot on voltage bus varies from 1.3 to 1.8 times [2]. When a high frequency overvoltage transient appear, failures on electronic devices, such as PLCs, control systems, measurements devices, etc, might happen. Ground potential rises during the transient period and causes a misoperation of the protection system, even poses a safety hazard to personnel working nearby if grounding is inadequate [2]. The problem increases its complexity when other capacitors are connected; in this case the overvoltage can rises up to 4 times, and higher frequencies can be reached. The reason why this behavior is more prejudicial is that at the moment a capacitor is connected its voltage is zero; consequently, the network voltage tends to be zero behaving as if it were a short circuit. Then the energized capacitors will discharge on the new one, being the impedance among them the only limitation of energy.

The disturbances introduced in a network due to capacitors switching have well defined characteristics [2]:

- The capacitor voltage as well as the electric field cannot vary in a discontinuous way. The voltage network will be forced to zero or to the capacitor residual voltage, behaving as if it were a short circuit.

- Immediately after the depression, the system voltage recovers itself overshooting the nominal voltage, with a value that is similar to the depression.

- The transient frequency theoretically is the same to the natural system frequency.

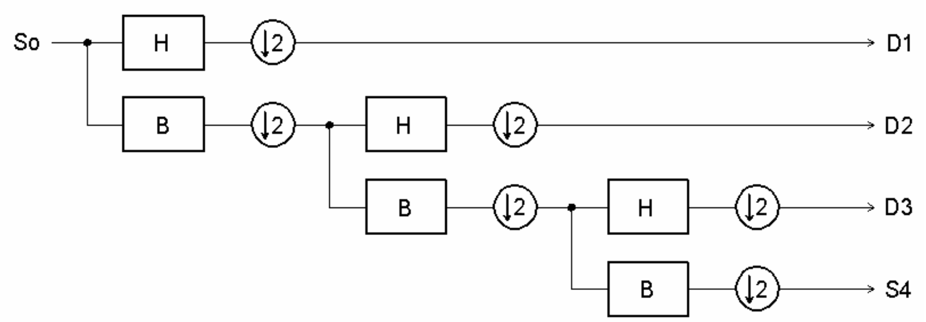

Fig 4. Digital Filter Bank with Decimation

Consequently, the more the bank capacitor power, the less the frequency of oscillation. And the more fault power, the more the introduced transient frequency.

- The transient duration is equal to the ratio between the inductance and the resistance of the system.

As examples, perturbations on voltage at different magnitudes can be seen in Figs 1 and 2.

This paper is organized as follows:
In section 2, the electrical circuit is presented. On this circuit the voltage measurements are taken on capacitor bus. In section 3, the introduction to multiresolution analysis is shown. In section 4, the results obtained in different cases are presented. Finally in section 5, the conclusions are given.

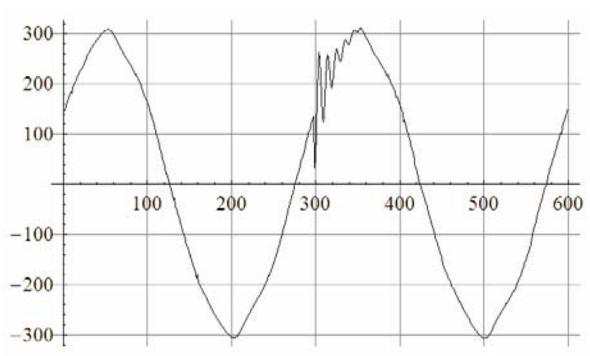

Fig. 1 - Capacitor switched at 140 V

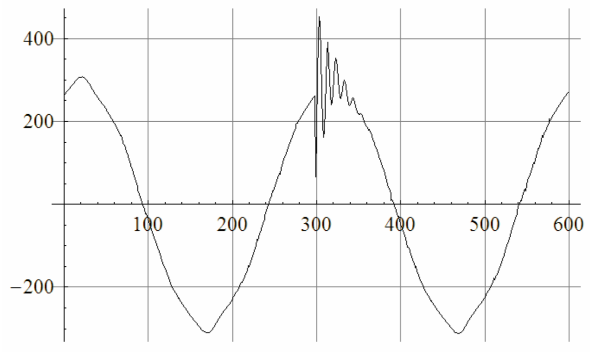

Fig. 2 - Capacitor switched at 250 V

2 Experimental Scheme

In figure 3 the electrical circuit on which the measurement were taken is shown. The recorded signal is the voltage on capacitor bus. The perturbation appear when this one is connected to correct the power factor.

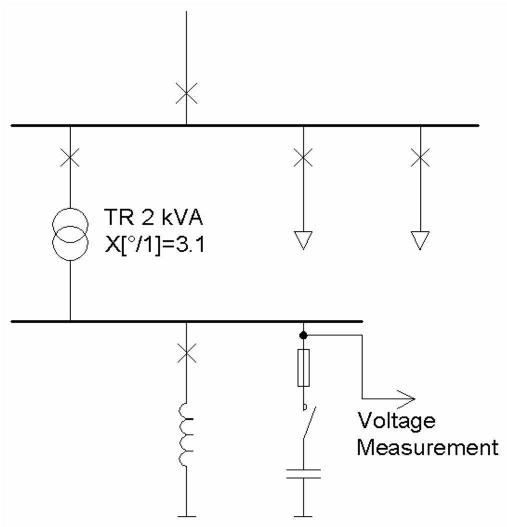

Fig. 3

3 Theoretical Basis

The theoretical basis on which the algorithms for detecting the transients introduced in the electrical network depicted in figure 3, is based on wavelet theory ([3], [4]). The fundamental advantage this tool offers is the detection in time and frequency of transient events. This theory, as well as the Windowed Fourier Transform, has been used in power quality problems ([5], [6]). The advantage of the use of Wavelet Transform is the refined precision to identify transient frequencies of short duration in time as well as brisk jump of the signal. The approach to the subject presented in this work is based on a Multiresolution analysis [8], which proposes a fast transform scheme by means of digital filters with decimation (Fig. 4). The analysis consists of the decomposition of the signal in frequency bands in dyadic steps which allows to localize events in time in different levels or frequency bands. In the case consider in this paper the transients looked for correspond to the high frequency levels. The central frequencies and the bandwidth of each level of the multiresolution is linked with the sampling frequency and the basic wavelet used for the analysis [7].

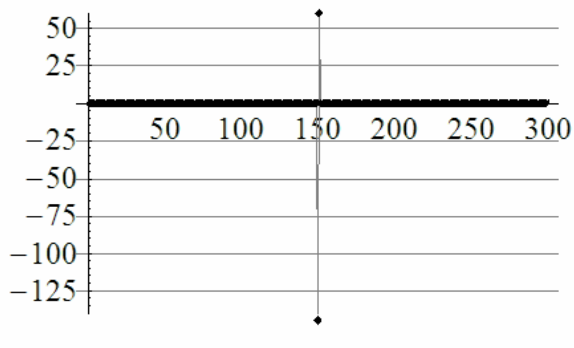

Fig. 5.1 - Level 1 - Central Frequency, 3450 Hz

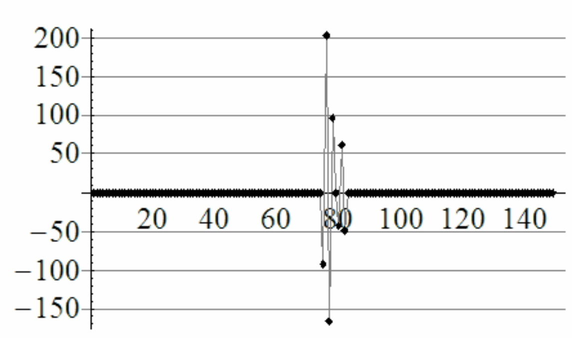

Fig. 5.2 - Level 2 - Central Frequency, 1725 Hz

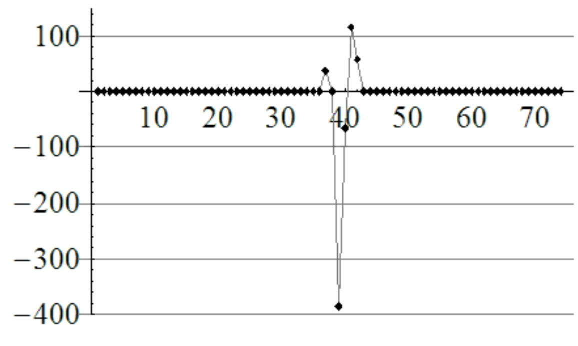

Fig. 5.3 - Level 3 - Central Frequency, 862 Hz

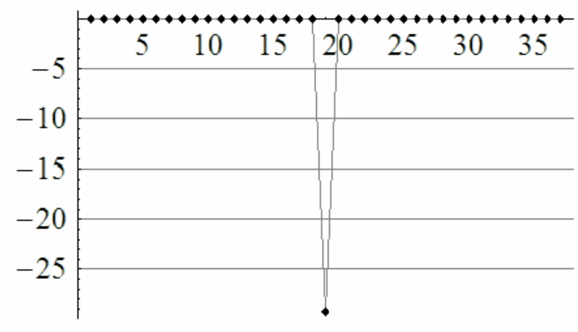

Fig. 5.4 - Level 4 - Central Frequency, 431 Hz

The algorithm developed for the time localization and characterization of the disturbances studied are based on the Daubechies-4 wavelet [3]. Its can be performed in real time.

The sampling frequency used for the signal acquisition was of 15 kHz. The levels 1, 2, 3 and 4 (higher frequencies) were considered due to the fact they show the events looked for, because the central frequency of each level bandwidth is close to the one of the perturbation [7].

4 Results

Some of the results obtained are shown in Figures 5.1 - 5.4. They depict the first four levels of the multiresolution analysis.

The localization of the perturbation is obtained from the energy in those levels. Due to the fact that the Daubechies wavelet is orthogonal [3], the energy is obtained through the squares of the wavelet coefficients of each level. The transient total energy as a function of time is shown in Figure 6; it was obtained adding, in each time, the energy in each of the four levels.

From this energy localized in time, a pre-detection of the transient is performed (Fig. 7). The pre-detection focuses basically on its beginning but does not precise exactly its end. The reason for that are two: on one hand, the exponential decay character of the transient, and, on the other hand, the noise suppression by thresholds defined adequately eliminates wavelet coefficients of low intensity.

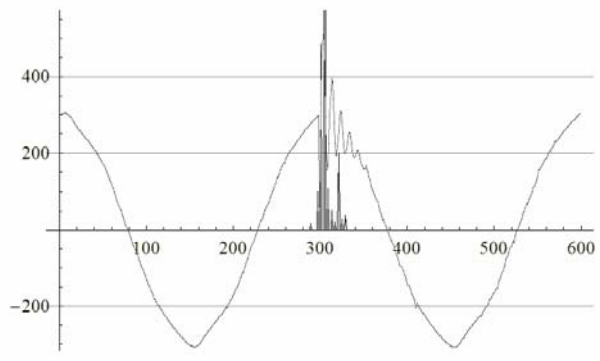

Fig. 6 - Time Energy Spectrum corresponding to levels 1 to 4

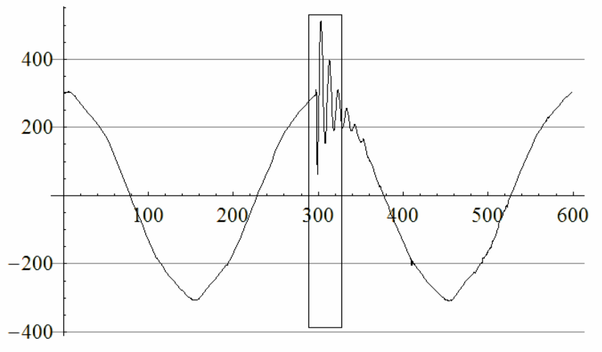

Fig. 7 - Pre-detection, based on the spectrum shown in Fig 6 spectrum

The pre-detection is improved by an algorithm based on the temporal localization of the transient frequency oscillation. To get that, the perturbation is extracted by means of the reconstruction of the signal from the four first levels of the Multiresolution, limited to the time interval obtained from the pre-detection (Fig. 8).

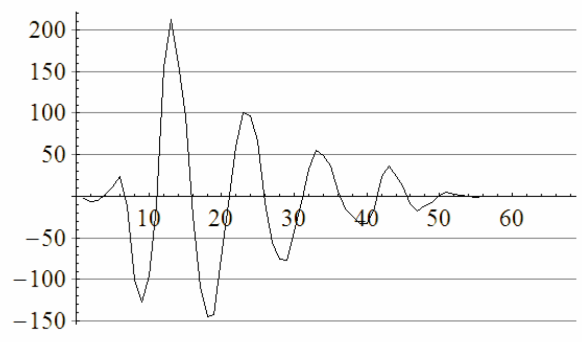

Fig. 8 - Transient reconstructed

The steps followed by the mentioned algorithm are:
(1) Determination of the oscillation frequency of the signal in the time interval the final by the pre-detection.
(2) Reconstruction of the signal in intervals larger than the ones shown by the pre-detection.
(3) The decision of the time of the transient extinction is done by the coincidence in the measurement of the frequency obtained before.
The result of the application of the previously defined algorithm is shown in Figure 9.

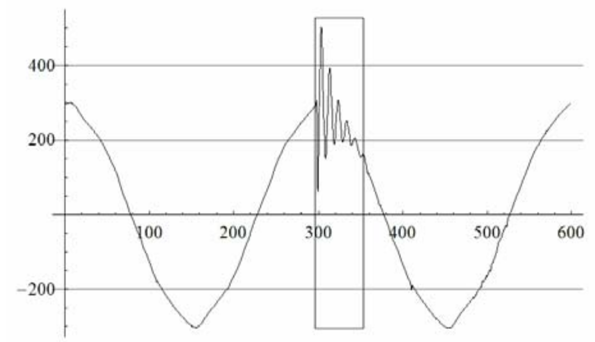

Fig. 9 - Detection of the event.

From this results it can be get an identification and classification of perturbations knowing their parameters, in particular, their exponential decay. Once, the perturbation has been isolated and its time support determined, an exponential curve is adjusted to the relative maxima and minima (Fig. 10).

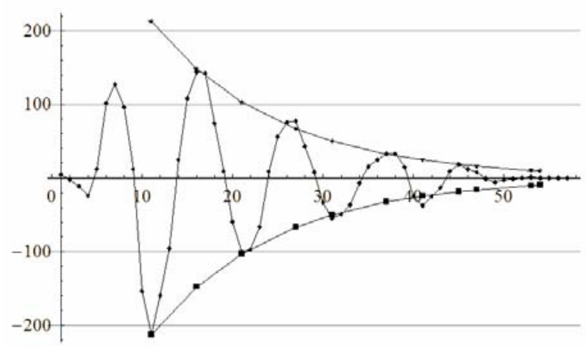

Fig. 10 - Transients with the exponential decay adjusted

The estimation of the exponential decay allows, together with the measured information on the reconstructed signal, to recognize different equipments at the moment in which they are connected to the electrical network.
In Figure 10 can be seen that the adjusted exponential decay do not completely involve all the relative maxima and minima. The objective of the algorithm is to reduce to a minimum the distance between the adjusted curve and each point corresponding on the signal.

5 Conclusion

The proposed algorithm, based on the wavelet theory, allows to localize and characterize transients introduced by a capacitor switching in the electrical system. But not only permits to detect disturbances; also, by means of the pre-detection, the system behaves as a reporter of short duration events, such as dips, swells, sags, impulsive and oscillatory transients, etc.

The experimental and theoretical results thus obtained have been compared between them, showing good correlation. The relative error found between both signals measuring oscillation frequency and exponential decays was one per cent in 64 experiments realized in the laboratory.

Future works will address the problem of parameter identification as, for example, the fault power of point in an electrical network.

Other possible applications could be the indirect measurement of the useful life on capacitor banks by on line monitoring.

As a final remark, it can be mentioned that the algorithm, based on a multiresolution analysis and implemented as a bank of digital filters with decimation (Fig.4), can be used on line.

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