Graphic tools for analysing the influence of noise and aperiodic components in the performance of digital filters: A case study

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1. Introduction

An accurate phasor estimation is an important task for a correct operation of control and protection devices. The presence of aperiodic components in electrical signals is a major problem for the correct performance of digital filters. In addition, their stability is heavily conditioned by the distortion resulting from the noise inherent to signal processing.

Consequently, a complete study of the behaviour of any filtering algorithm (in the presence of noise and aperiodic components) must be carried out before its implementation. Usually, numerical performance indices are used to measure the accuracy of a proposed method. In order to ease the analysis and comparison of different digital filters, a new set of graphic tools is presented in this paper.

Key words

Digital filter, protection relaying, phasor estimation, signal processing, harmonic analysis.

2. Numerical indices

In the last years, the use of digital technologies in protection relays is increasing. Because of this, an ever growing number of filtering algorithms based on different methodologies is being developed.

A rigorous testing process must be carried out for the selected algorithm in order to cope with the practical requirements of the protection functions.

The accuracy of these algorithms is usually measured by the means of numerical indices related to the different characteristics featured by the proposed methods.

Chi-Shan Yu [1] proposes the use of two indices to evaluate the filtering performance, Percentage root-mean-square error (PRMSE) and Percentage peak error (PPE). Other performance indices are considered by G. Benmouyal [2]: PI_0, PI_1 and PI_2; T.S. Sidhu *et al.* [3]: MPD; and J. Pan *et al.* [4]: EI_{com} and EI_{sat}. These indices are used to evaluate different aspects of the proposed methods.These numerical indices provide useful information in order to compare the accuracy in the output of argument and module separately.

In this paper four graphics tools are proposed for integrating both outputs in a single criterion. These tools will help to a better understanding of the geometric characteristics in the filtering process. In addition, a new numerical index is defined in order to compare the accuracy in the output of argument and module together.

3. Graphic tools

The four following graphic tools have been integrated in the G-CAT (Graphic – Convergence Analysis Tool) application. This application has been developed in MATLAB (MathWorks) and Mathematica (Wolfram Research) environments.

DCM (*Dynamic Convergence Movie*): it is an animation movie made from the respective outputs for argument and phase provided by a digital filter. Phasor oscillations lead to a quick and intuitive way to appreciate and compare the influence of aperiodic components and noise in the convergence process for different algorithms.

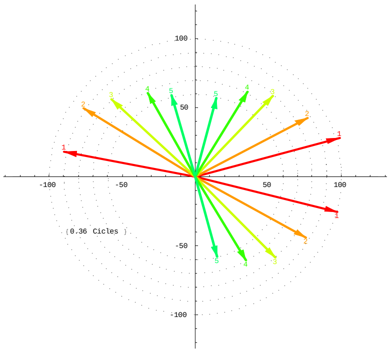

Fig. 1. Dynamic Convergence Movie (DCM)

USD (*Uncertainty Surface Diagram*): it is the static representation of the information given by the corresponding DCM. This graphic is made from the successive positions of the estimated phasor during the convergence process.

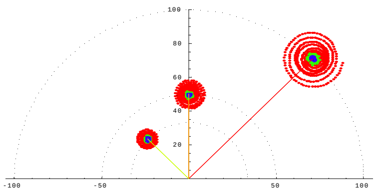

Fig. 2. Uncertainty Surface Diagram (USD)

USDOT (*Uncertainty Surface Diagram-Origin Translation*): it is the USD translated to the axes origin of the plot for a specific harmonic. A sector diagram is included for compensating the loss of the phase oscillations information as a result from the translation.

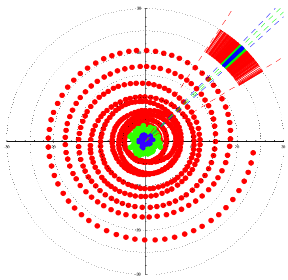

Fig. 3. Uncertainty Surface Diagram-Origin Translation (USDOT)

USEC (*Uncertainty Surface Equivalent Circle*): it is the reunification in a single drawing of the phase and argument oscillations shown in the corresponding USDOT. The area of the circle is an estimation of the surface described in the DCM by the oscillating phasor. The radius gives a numerical index of the global oscillation problem when joining the separate oscillations in the phase and arguments obtained by the digital filter.

The four graphic tools are intended to work in a complementary manner with the numerical indices, in order to ease the analysis and comparison of different filtering algorithms. (Figures 1 to 4 illustrate the application of the proposed tools to three digital filters and different harmonics.)

The full paper includes a case study in which two new methods (CharmDF and s-CharmDF) [5] proposed by the authors are compared with DFT based filtering algorithms.

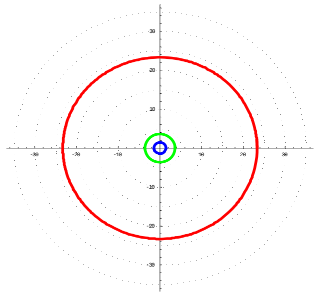

Fig. 4. Uncertainty Surface Equivalent Circle (USEC)

4. Conclusions

In this paper four graphic tools and a new numerical index have been defined in order to ease the analysis and comparison of different digital filters. These tools may be used in a great variety of ways for a deeper understanding of the convergence process. For example, in differential transformer protections different sets of harmonics can be analysed simultaneously to evaluate the performance of the protections functions.

Acknowledgement

The research work presented in this paper is a part of UPV Research Project UE05/A16, sponsored by the Basque Country University (UPV/EHU) and GE Multilin.

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