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Behavior Computational Tool for Detection and Diagnosis Oscillations in a Control Systems

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Abstract — Control systems receive input signals to execute a process, resulting in an output. Based on this sequence, the computational tool has the function of detecting and diagnosing anomalies in the system. The oscillation diagnosis of the system is based on the analysis of the oscillations generated by any disturbance, whether internal or external. The most appropriate form of detection is through non-invasive methods, therefore, there are some specialized in system improvements such as; detection of peaks in the power spectrum (FFT), the method based on time domain criteria and the absolute error integral (IAE) and the method based on the autocovariance function (ACF). The computational tool aims to detect oscillations of closed-loop control systems, through the 'IAE', 'ACF' and 'FFT' method.

Keywords: Control System, Oscillating Disturbances, Integral Absolute Error, Fast Fourier Transform, Autocovariance Function.

1. Introduction

There are certain anomalies in the industry, which usually generate wear and tear in production and energy consumption [1]. This is called disturbances that can be both internal and external, these anomalies that are generated by the control system can be detected and diagnosed by certain methods called as, detection of peaks in the power spectrum, can also be done with the method based on the time domain criteria as the integral of absolute error (IAE), and with the method based on the function of autocovariance [2], among others. Disturbances are usually represented oscillating [3]; due to this they are represented as a very drastic form of degradation of a control system. For this, a computational tool was created in a graphical user interface of MATLAB®, called GUI, which allows us to detect and diagnoses in closed loop control systems, through the IAE, ACF and FFT methods. Experimental and theoretical tests were simulated through Simulink, MATLAB® interface each of the methods, to verify and validate the device [4].

2. Tools and Methods

2.1 Mathematic Models

Three methods were integrated through the MATLAB® application and its GUI graphical interface, in which they were implemented and developed. The first method named IAE is intended to calculate IAE between zero junctions of the control error.

$$IAE = \int_{ti-1}^{ti} |e(t)|\, dt \quad (1)$$

Assume that the control error is a pure sine wave with amplitude A and frequency, and that this signal should be detected as a sequence of load disturbances. This means that the integral of each half-period of the oscillation must be greater than IAElim [5].

Then you get the following upper limit of IAElim:

$$IAElim \leq \int_0^{\pi/\omega} |Asin(\omega\tau)| dt = \frac{2A}{\omega} \qquad (2)$$

For the second method named ACF uses the ACF zero crossing patterns with which you can diagnose the presence of oscillations more clearly than at zero crossings of the time trend.

$$R_{acf} = \frac{a}{b} \qquad (3)$$

For this one you must identify and locate the minimum and maximum peaks respectively, as seen in **Figure 1**.

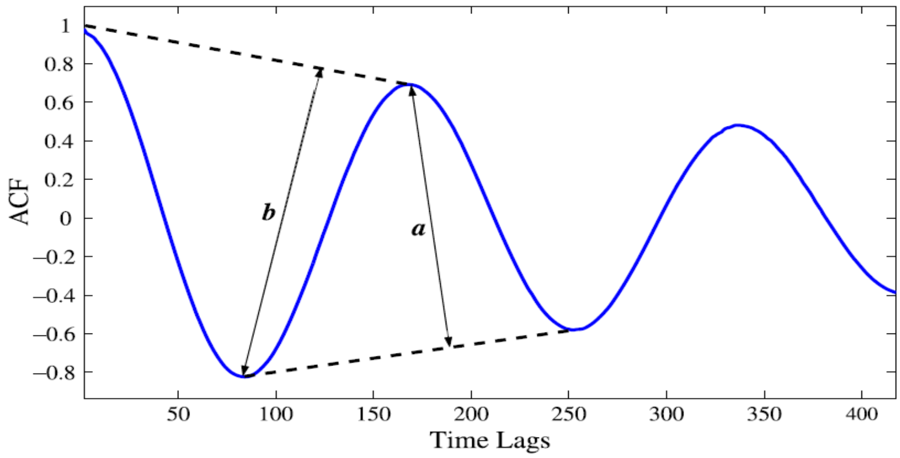

Figure 1. Determine with in the method based on the auto covariance function (M. Jelali) [5].

In the last method named FFT, the amplitude of the highest peak that is presented outside the low frequency zone is selected and is compared to the total energy found in the frequency area, i.e. the determination of the band command

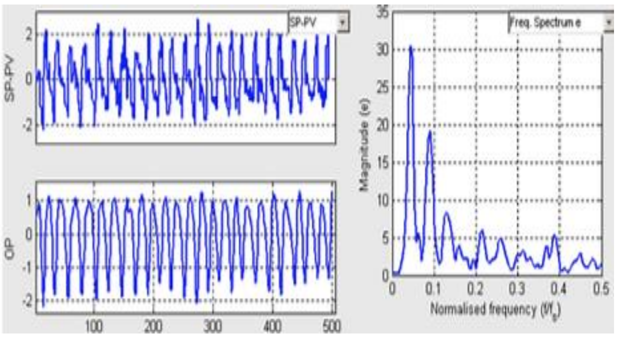

Figure 2. Oscillation detection in a nonlinear control system (M. Jelali) [5].

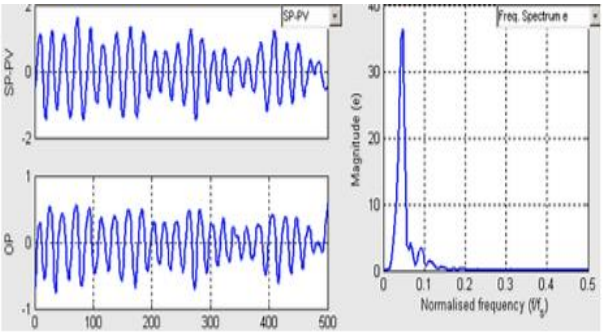

Figure 3. Oscillation detection in a disruptive control system (M. Jelali) [5].

In Figure 2 and Figure 3 it is shown the oscillation detection of an industrial process which in Figure 2 presents the sinusoidal characteristics of oscillations thus demonstrated an indication of nonlinearity in the control system instead in the Figure 3 presents a different spectral peak which can be classified as a disturbance [5].

2.2 Boundary Conditions

The computational tool developed in the GUI, is characterized by integrating the three methods mentioned above, as seen in Figure 4 showing treated values, system behavior graphs, OP and PV.

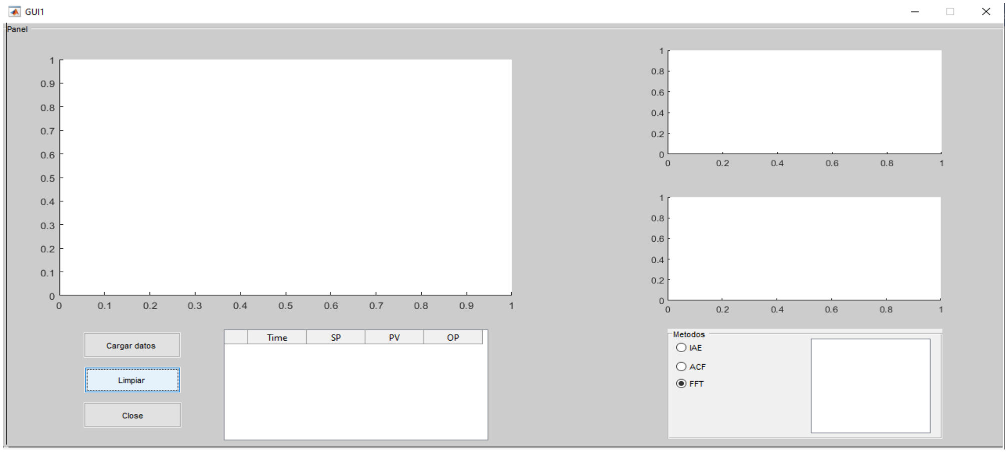

Figure 4. GUI interface® [6].

The data is entered in the format (.xlsx), with the following parameters: Time: First column, SP: Second column, PV: Third column and OP: Fourth column.

2.3 Design

In **Figure 5** you can see the GUI design for oscillation detection, by this way you can see the SP, PV, and OP behavior. You can even observe the application of the IAE method, where we indicate the amplitude, frequency, IAE value and IAElim value which will be compared to the IAE. On the other hand, the interface has an automatic response when it comes to displaying the results of each of the methods, as can be seen in **Figure 5**, this facilitates the interpretation of the user. In addition, the computational tool allows modification both to load data and to delete it. Finally, you have the option to expand or decrease the graph for further study.

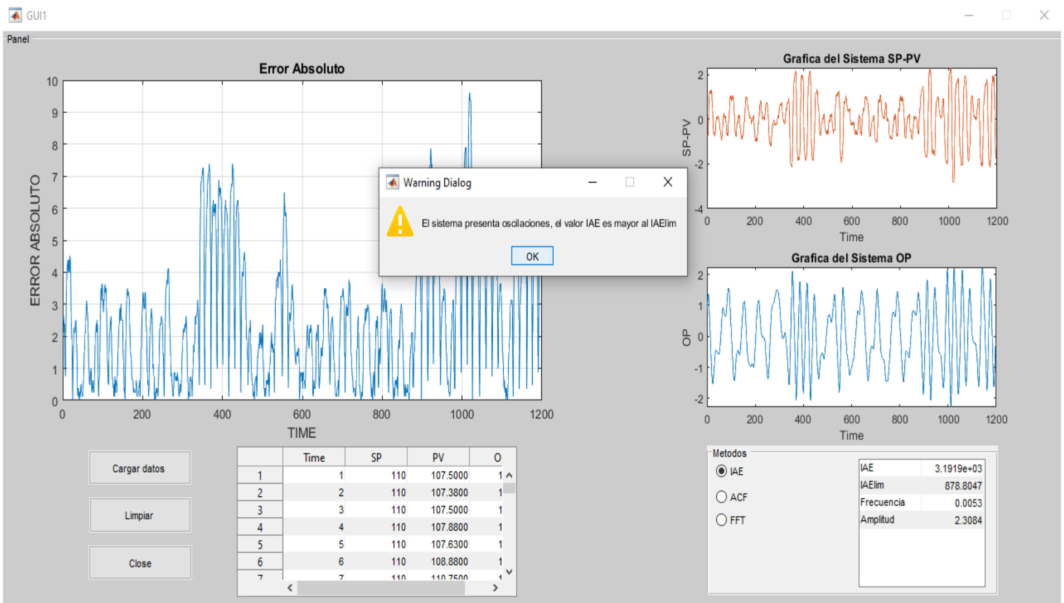

Figure 5. Final design for oscillation detection [6].

In addition, the peak detection method in the power spectrum can be observed in Figure 6. In Figure 7 the method applied is the ACF with respect to the minimum and maximum peaks selected by the user, determining whether the system has oscillations. En Figura 7 se puede observar un bloque en la parte central baja donde se muestra los picos seleccionado por el usuario.

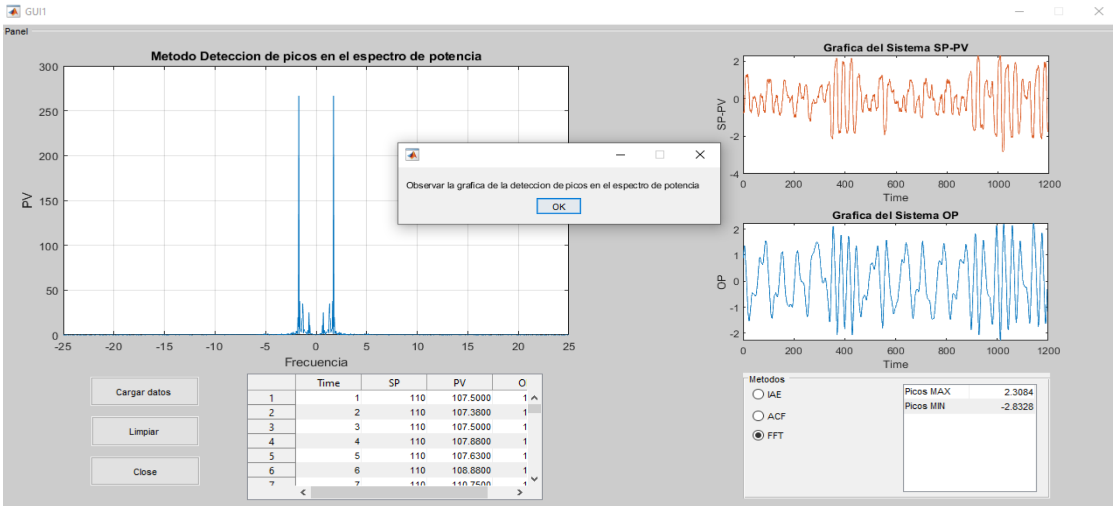

Figure 6. Method of detecting peaks in the power spectrum [6].

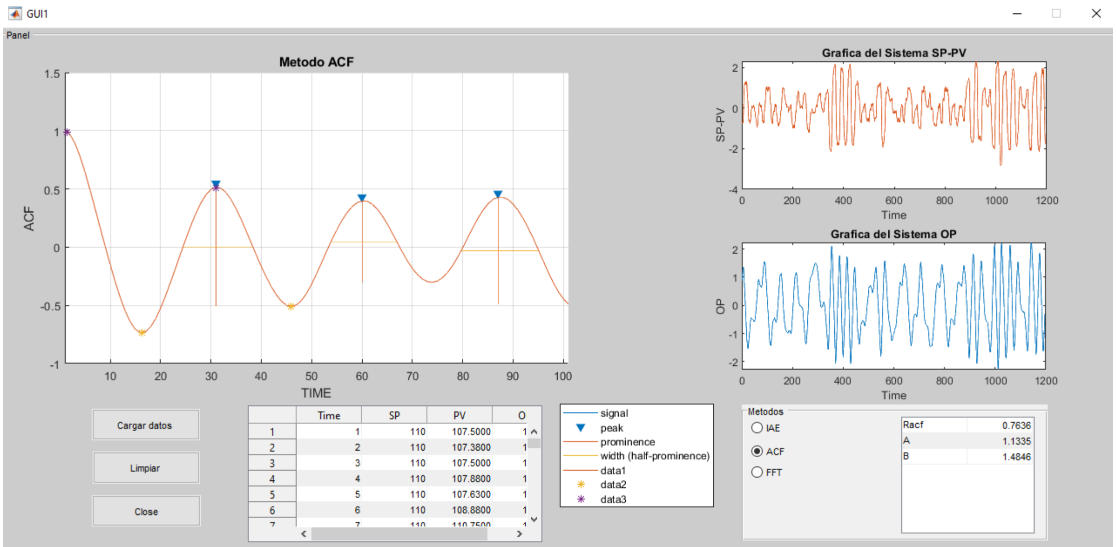

Figure 7. ACF Method [6].

3. Results and Discussion

The integral absolute error method (IAE) developed in the GUI® is one of the most accurate methods, as it calculates the IAE between the zero junctions of the control error, thus analyzing the load of the disturbance. Where the control error is a pure sine wave with amplitude ‘A’ and frequency, and that this signal must be detected as a sequence of load disturbances, which is displayed in the method information panel shown in Figure 7. This means that the integral of each half-period of the oscillation must be greater than IAElim, so that the system presents oscillations, otherwise it can be said that the system does not have oscillations that alter processes [7]. Considering the description of the system it is sought to check the behavior of the process to determine if it has oscillations. As can be seen in Figure 8 based on the IAE method and the IAElim comparison is made establishing that the process has oscillations because the IAE over passes to the IAElim [8].

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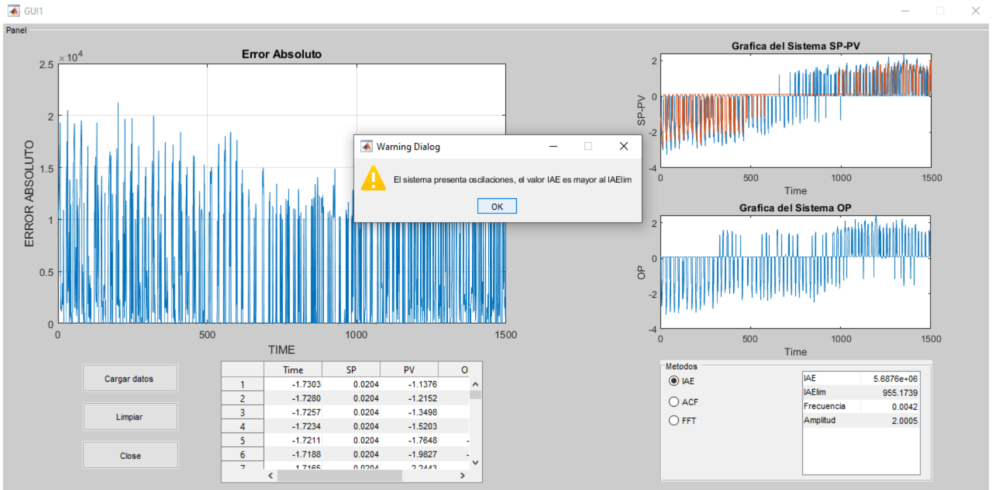

Figure 8. Detection of plant oscillations with the IAE method [6].

During the development of the method based on the auto covariance function (ACF) we realized that it has a great advantage, since the impact of the noise is reduced, the white noise presented by the ACF in theory is zero, by the zero crossing patterns of the ACF, can diagnose the presence of oscillations more clearly, due to this we must be precise in the selection of the maximum and maximum , since by obtaining a good selection of them, it leads a good result in the detection of such disturbances [9]. In Figure 9 where this method was implemented, it was determined that the system has oscillations, because the Racf is greater than the limit range which is 0.5 [10].

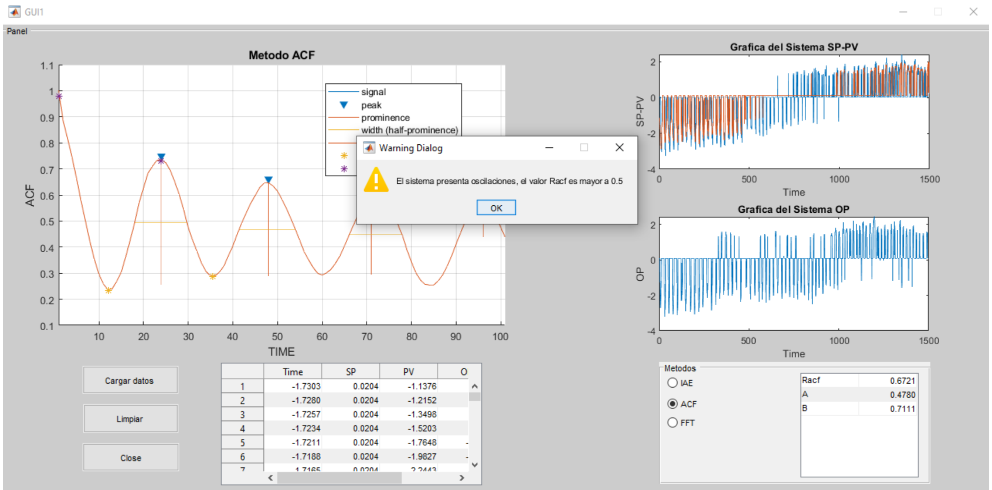

Figure 9. Detection of plant oscillations with the ACF method [6].

The peak detection in the power spectrum method (FFT), is the simplest of the three chosen, since it is based on the good observation of the waves of the system, when determining the poles of the graph, we can describe the presence of oscillations, if the behavior is symmetrical then NOT presents disturbances, otherwise the system has disturbances. For this method, the person manipulating the tool must have prior knowledge of the method literature [11] In Figure 10 the method of detecting peaks in the power spectrum was applied, this method is determined visually. this way it determines that the system has a different spectral peak due to oscillation, which can be classified as a disturbance. In comparison in Figure 11, it is observed based on the peak detection method that the system is set [12].

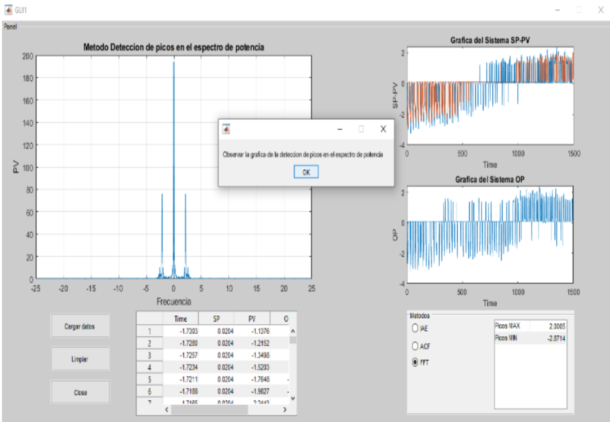

Figure 10. Detection of plant oscillations with the method of detecting peaks in the power spectrum system with disturbance [6].

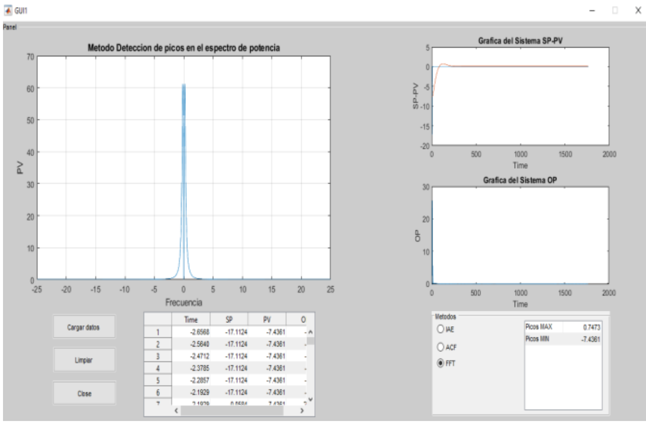

Figure 11. Detection of plant oscillations with the method of detecting peaks in the power spectrum of a stable system [6].

4. Conclusions

The computational tool is versatile, complete, and easy to use. It has as functionality the detection and diagnosis of oscillations in a closed loop control system, which we can conclude from the results of each method. Which are categorized as follows; IAE that corresponds to the integral of the absolute error that allows us to compose it with IAElim giving us as a result the state in which the control system is located, the ACF allows us to determine the points of the highest and lowest peaks that will be purchased with the limit of autocovariance that would be 0.5, as last the FFT method that is based on the peak of the power spectrum. The results obtained with the methods were validated with the Simulink development tool, which is a visual programming environment, which works on the MATLAB programming environment®, thus validating theoretical and practical. Where a stable system was simulated in the environment, then compare and verify that the values obtained in the GUI are accurate and accurate. Otherwise, they were guaranteed not to be invasive so not to alter processes, the tool describes the performance of the controller.

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