Spectral Analysis of the Signal Applied to the Electromechanical Actuators in the Thermal Power Plant Component

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Abstract: *The purpose of the scientific research in this paper is the spectral analysis of the signal applied to the electromechanical actuators from the thermal power plants component through experimental measurements to determine the level of noise and vibrations in operation. Experimental measurements were performed with the signal analyser system, on the Brüel & Kjaer platform for noise and vibration analysis PULSE Diagnostics Toolbox Type 9727, with the PULSE Type 3560-B measurement system and with the Bundle Type 7910 package the basic measurement software is the fast Fourier transform (FFT) analysis and a constant percentage bandwidth filter (CPB) analysis to determine the maximum frequencies, magnitudes in terms of spectral density. The measurements were performed on the solenoid valve produced by SIT Group, model Sigma 845 which includes in its composition the electromechanical actuators EV1 – EV2 which are the object of the study in this scientific paper. The electronic transducers produced by ENDEVCO model TEDS and ISOTRON 752A12 which are piezoelectric accelerometers with integrated electronics, which have electronic data of the IEEE P1451.4 transducer, measure the mechanical oscillation, the dynamic acceleration of a physical device as a voltage, obtaining the amplitude-frequency spectra are at different values of the alternating supply voltage.*

Keywords: *actuator, analysis, electromechanical, signal, transducer, vibration.*

1 INTRODUCTION

In accordance with Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 on energy efficiency, given the climate and energy policy framework for 2030, the energy saving obligation established by Directive 2012/27 / EU should be extended beyond 2020. Measures to increase energy efficiency have a positive impact on air quality, as more energy-efficient buildings help reduce the demand for heating fuels. Therefore, energy efficiency measures contribute to improving indoor and outdoor air quality and support the cost-effective achievement of the Union's air quality policy objectives, as set out in particular by Directive (EU) 2016/2284 of the European Union. European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/ EC and repealing Directive 2001/81/ EC (OJL 344, 17.12.2016). [7]

The spectral analysis of the signal applied to the gas solenoid valve, which is a subassembly of the thermal power plant, aims on the one hand to reduce vibrations and noise produced in operation, as well as a reduction in electricity at start-up, which will contribute over time to a better energy efficiency.

At the same time by analysing the signal which is a single-phase alternating voltage, an optimized motion control can be obtained on the EV1 and EV2 electromechanical actuators in the gas solenoid valve, by reducing the forces acting on the actuator rod, which implicitly leads to a smooth operation and a lower consumption of electricity and methane gas (CH4). The reduction of forces is achieved by the variation in time of the electric voltage, which leads to a variation of the intensity of the electric current in the winding of the actuator coil. By varying the voltage and electric current, the magnetic field that generates the driving forces in the solenoid valve changes. [3]

1.1 The notion of signal

Signals are physical quantities that send messages. The signal is an electrical oscillation, obtained either from a generator specially built for this purpose, or in any section of an electronic apparatus or system. An electronic device consists of a chain of successive subassemblies at which the terminals (input and output gate) are highlighted. The block diagram of a subassembly in an apparatus is shown in Figure 1.

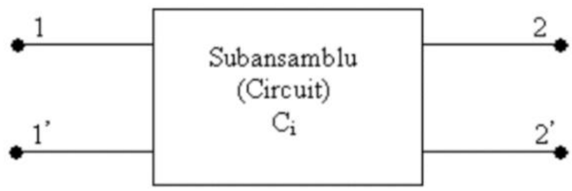

Fig. 1 Subassembly of an electronic system, equipment, or apparatus

In most cases, the circuits can be considered as quadrupoles (portals) that have four specialized access terminals: two terminals represent the entrance gate (1, respectively 1'), and other two exit gate (2, respectively 2'). The oscillation applied to the input terminals is usually called the signal and the one at the output is the response of the circuit C_i to the signal applied. Obviously, the response of the circuit C_i can be a signal (input) for the diversion C_i +1 located downstream of C_i. Similarly, the input signal of circuit C_i may be the response of circuit C_i -1 upstream of C_i.

Since it concerns the past or future evolution of a signal, it must be assumed that these are time functions t. From the point of view of the possibility to characterize by time functions the evolution of a signal, they can be classified into two groups:

- **group I** of deterministic signals, can be expressed by analytical time functions x (t) with a finite number of parameters;
- **group II** random signals, can be expressed by analytical time functions with a finite number of parameters, but by random functions.

Probabilistic assessments can determine their evolution possibilities.

An example of a deterministic electrical signal may be the single-phase alternating current voltage. It is known or can be determined at any time the totality of the parameters that characterize the signal (amplitude, frequency, phase), due to the fact that this signal can be described by a simple mathematical expression.

Signal analysis establishes the possibilities to represent signals by discrete or continuous sums of elementary functions (exponential, sinusoidal, unit stage). This mathematical representation is useful for the following purposes: determining the frequency range (frequency band) and determining the response of linear circuits to a given signal.

An x (t) signal is periodic if the time function that describes it satisfies the relation:

$$x(t) = x(t \pm kT) \qquad (1.1.)$$

where: $k \varepsilon N$

T - represents the signal period (the minimum time interval after which the signal x (t) is repeated identically).

If the signal is even, we have:

$$\int_{-t_0}^{t_0} x(t)dt = 2\int_{0}^{t_0} x(t)dt \qquad (1.2)$$

If the signal is odd, then:

$$\int_{-t_0}^{t_0} x(t)dt = 0 \qquad (1.3)$$

The spectral analysis of signals often involves the calculation of integrals of the form (1.2) or (1.3), so the classification of signals into even or odd (if possible) brings a substantial simplification of the calculations. [6]

2. RESEARCH METHODOLOGY

2.1. Data acquisition

The spectral analysis of the signal will be performed on the experimental study stand, which was performed for the verification, testing and adjustment of the dynamic parameters of the electromechanical actuators from the gas solenoid valve component, presented in figure 2 where:

A - support base plate with the dimensions: 70x35x1.8 mm of yellow melamine chipboard;
B - vertical support plate with the dimensions: 70x42x1.8 mm of yellow melamine chipboard;
C - single-phase alternating voltage variable module in softstart variant.;
D - switch with LED signaling the presence of voltage;
E - automatic for SATRONIC DKG 972 gas burners;
F - adjustable 10 stage gas pressure regulator;
G - standard manometer, radial attack, range 0-10 bar;
H - combustion chamber, burner and boiler nozzle boiler;
I - central heating ignition electrode;
J - SIT 845 SIGMA gas valve with spark transformer module attached;
K - central heating ionization electrode;
L - standard manometer, radial attack, range 0-2.5 bar D150 G1/2;
M - electronic alternating current voltmeter, mounted in a support box 115x115x60 mm. [4]

Fig.2 Experimental stand for checking, testing, and adjusting the dynamic parameters of electromechanical actuators

The data acquisition was performed with a multi-analyser, multi-channel vibration system PULSE™ 9727, Bruel & Kjaer which is a mobile equipment for vibration determination.

In figure 3, shows the Machine Diagnostics Toolbox Type 9727, which includes the PULSE 3560-B multi-channel data acquisition unit and a Dell ™ notebook packed in a carrying case, rugged, weather-resistant connection, and a Bundle Type software package 7910 dedicated.

Fig.3 PULSE ™ Machine Diagnostics Toolbox - Type 9727

The built-in PULSE unit is a versatile unit for data acquisition and pre-processing, analysis for noise and vibration.

PULSE™ Machine Diagnostics Toolbox - Type 9727 is a compact, portable case that contains all the hardware needed for field testing and analysis, including:

• PULSE data acquisition unit type 3560-B;
• Notebook PC;
• Batteries for both computer and PULSE front end;
• Network adapters;
• RS-232 cable;
• Inputs and sockets, tacho, and BNC.

The 5-channel front end is a compact data acquisition system for industrial and everyday use, running on battery or direct current. It is installed at the bottom of the case with the notebook attached to a separate board on top. [11]

The diagnostic toolbox provides a complete suite of tools needed to perform diagnostics on any type of machine or structure. The system used allows multichannel fast Fourier transform (FFT) and constant percentage bandwidth (CPB) spectrum analysis to diagnose vibrations.

Spectral analysis of signals is widely used for information encoded in the form of sinusoids that form a signal. The shape of the time domain of the wave is not so important, in these signals the key information is in the frequency, amplitude and phase of the component sinusoids. (CPB) is one of the most reliable, stable, and economical method for detecting the widest possible range of defects in machines at an early stage of development. It has good reproducibility with optimal resolution and is therefore a "standard" in the early detection of defects in state monitoring applications.

The CPB has a frequency resolution that allows the automatic detection of all these defects in both high and low frequency ranges. Spectrum simplicity (CPB) makes it ideal for rapid diagnosis.

Analysis (FFT) is based on the concept that real-world signals can be broken down into sinusoidal sums, each with its own amplitude, frequency, and phase.

The most used procedure for the transition from the time domain to the frequency domain is the Fast Fourier Transform (FFT), being a high precision spectral analysis technique. [10]

The data were purchased through two channels, from two translators positioned on the EV1 and EV2 actuators from the SIT Sigma 845 solenoid valve component.

The translators used for the experimental measurements were:

- **ISOTRON** piezoelectric accelerometer, IEPE TEDS ENDEVCO, model 752A12, sensitivity of 98.37mV/ g at 100 Hz or 10.03 m / m / s2 at 100 Hz and transverse sensitivity of 1.5%;
- **I-TEDS** piezoelectric accelerometer, ENDEVCO, model 752A12, sensitivity of 107.6 mV / g at 100Hz or 10.98 mV/ m / s2 at 100 Hz and transverse sensitivity of 1%.

The positioning of the transducers on the gas solenoid valve can be seen on the experimental stand in figure 4, and in figure 5 you can see the SIT Sigma 845 solenoid valve in section.

Fig.4 Positioning scheme of the transducers

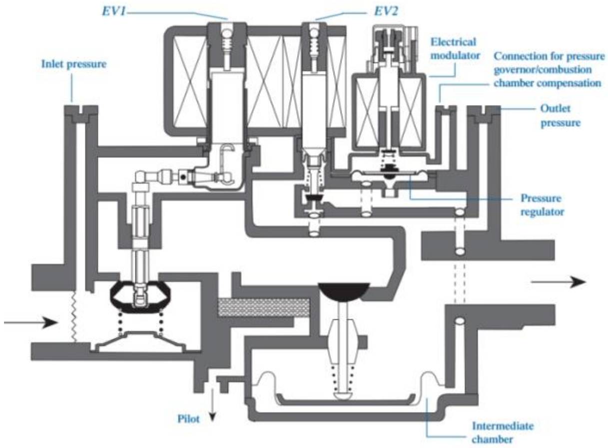

Fig.5 Section in SIT Sigma 845 solenoid valve [12]

2.2 The experimental process

Analysis of the frequency spectrum of the signals obtained using PULSE ™ Machine Diagnostics Toolbox - Type 9727, "Pulse" vibration measurement system, type 3560-B, Brüel & Kjaer sound and vibration, by means of ISOTRON - TEDS acceleration sensors.

The acceleration sensor, the operating principle can be seen in figure 6.

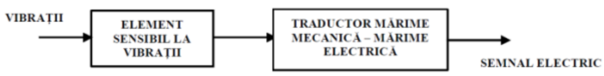

Fig.6 Principle of operation of the acceleration sensor [9]

By means of the alternating voltage (VTA) module, presented in the scientific papers [2] and [5], on the experimental stand the VTA module marked with (**C**), the sequential supply with electric voltage of the gas solenoid valve can be ensured (60, 65 , 70, 75, 80, 85, 90 and 100%), as a percentage of the input voltage of 230 V approx.

The values of the calculated resistive voltage divider were presented in the scientific paper [1] and the voltages were obtained (138 V, 149.5 V, 161 V, 172.5 V, 184 V, 195.5 V, 207 V, 230 V), for these values of the alternating voltage s- performed the measurements to obtain the acquisition data via PULSE™ Machine Diagnostics Toolbox - Type 9727.

In figure 7, shows the data processing diagram.

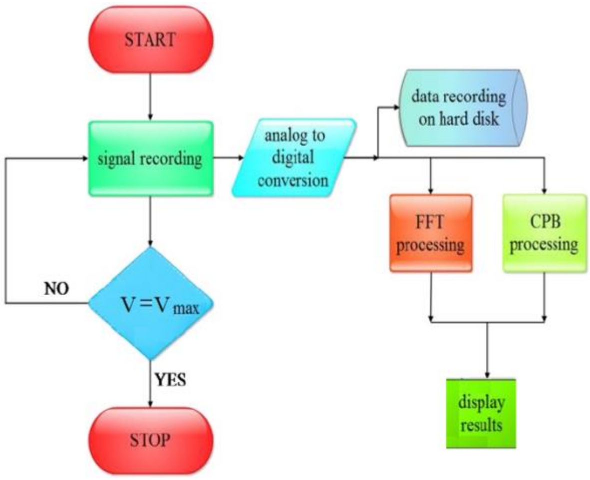

Fig.7 Data processing diagram [8]

3. RESULTS OF THE EXPERIMENT

Four measurements were performed for the voltage values stated above, resulting in 32 graphs for analysing the frequency spectra. Due to the multitude of data and graphs obtained, the spectra obtained at the percentage values will be presented in figures 8-11:

- 65% with a voltage value of 149.5V;
- 75% with a voltage value of 172.5V;
- 85% with a voltage value of 195.5V;
- 100% with a voltage value of 230V.

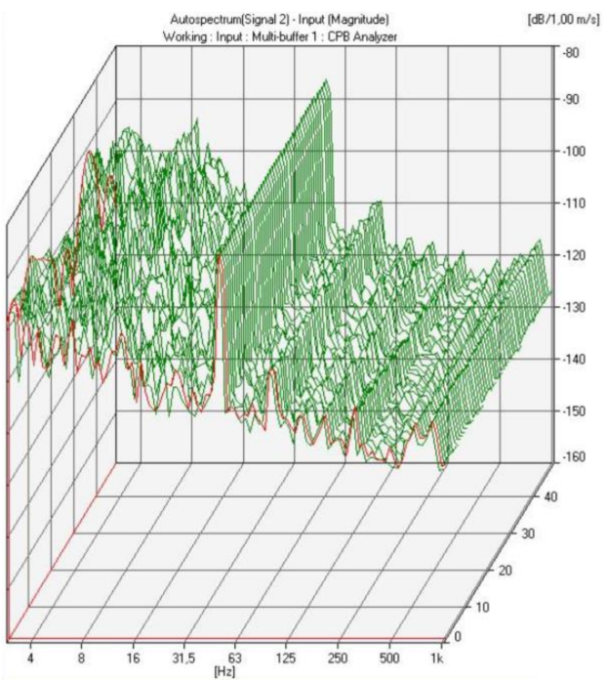

Fig.8 CPB-129 dB analysis at 230V (100%)

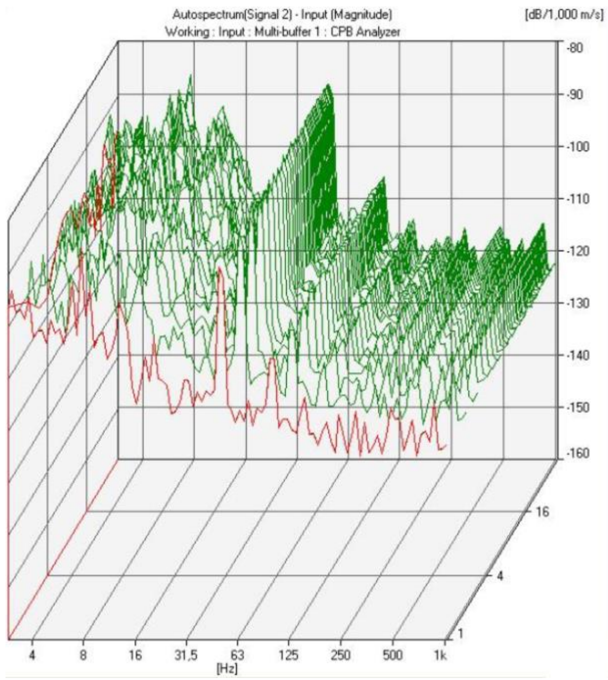

Fig.9 CPB-127.6 dB analysis value at 195.5V (85%)

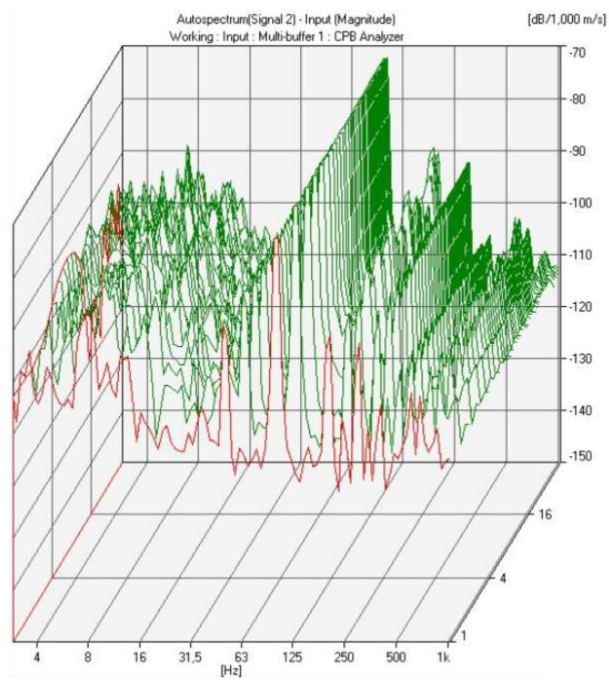

Fig.10 CPB-122.8 dB analysis value of 172.5V (75%)

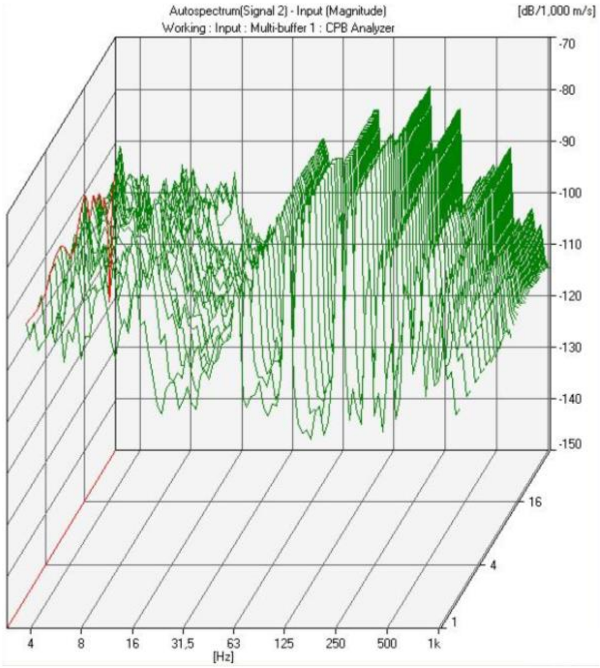

Fig.11 CPB-122.3 dB analysis at 149.5V (65%)

4. CONCLUSIONS

CPB analysis is one of the most stable methods for detecting the widest possible range of defects, with good reproducibility with optimal resolution, being a "standard" in the early detection of defects in state monitoring applications. It has a frequency resolution that allows the automatic detection of all these defects, in the high and low frequency ranges, because the simplicity of the spectrum makes it ideal for rapid diagnosis.

As can be seen in the spectral analysis graphs of the signal presented, figure 8 represents the value 230V of the AC voltage supply of the solenoid valve, where the electromechanical actuators are fully open and show on the CPB - 129dB analysis. In figure 11, at the minimum value of AC power supply 149.5V, CPB analysis - 122.3dB, a decrease of vibrations compared to the maximum value is observed. The EV1 and EV2 actuators have a smoother operation, which will lead to a shock-free operation at start-up.

The analysis of noise and vibration signals with nonlinear models, on which many modern methods of diagnosis and prediction of the operating state of equipment, machines are based, leads to the following conclusions:

- The improvement of vibroacoustic methods for diagnosing the condition of machines depends mainly on the complexity of the signal models used and the corresponding methods of analysis, and only in very rare cases on the volume of diagnostic measurements;
- The application of nonlinear models and the optimization of signal analysis methods significantly increases the volume of information about the oscillation forces that produce noise and vibrations in defective machines and components. These are the properties of the oscillating forces that most fully reflect the particularities of the defects and change significantly during the development of the defect;
- Of all the nonlinear models of noise and vibration signals used in conditioned diagnosis, the most important information is provided by the models of the simplest signals modulated in amplitude, frequency, or shape with low frequency processes.

The volume of diagnostic information extracted from noise and vibration signals, taking into account the degree of their nonlinearity, is usually sufficient to make a diagnosis of the operating condition and a forecast (prediction) for many types of machines, without the need for other types. of measurements. [10]

By supplying sequential AC voltage to the actuators, the force can be controlled, this being generated by the magnetic field passing through the actuator coil.

By controlling the actuating force, the controlled movement of the solenoid rod is achieved, which leads to the reduction of vibrations through the solenoid valve.

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