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A methodology for intelligent monitoring the vibrations of an asynchronous motor

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A methodology for intelligent monitoring the vibrations of an asynchronous motor

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Abstract. This paper presents an intelligent methodology for diagnosing incipient defects of rotating machines and is focused on monitoring the vibrations of an asynchronous motor. Monitoring of industrial plant operation parameters requires the acquisition of many electrical and non-electric parameters, parameters that can be monitored with powerful software. The technical state of operation of an industrial machine can be judged based on the symptoms it exhibits during operation, in our case the vibrations. Vibration analysis that occurs during engine operation may indicate electrical defects, such as broken rotor blades, unbalanced stator circuits, eccentric rotors and stators, loose power connections. There are mechanical defects and electrical faults in the vibration spectrum. A web application has been created to facilitate the interpretation of the linear spectrum resulting from the vibration monitoring of an asynchronous motor and to be accessible to any user. There was developed an application with Microsoft Silverlight, a software platform that allows us to display advanced multimedia content from a web browser. The spectrum reproduced by the application is simple, precisely to be accessible to everyone and to know very easily whether the machine is working correctly or not.

1. Introduction

Intelligent digital devices are mounted separately on each measuring point (cell) and besides the function of measuring several values of electrical quantities (currents, voltages, reactive powers, frequency, power factor), they also have the role of transmitting these values via a serial port directly to the computer.Classical transducers for unified signal output have been replaced by digital devices, which, besides the function of the transducer, also perform other functions, such as data processing to be transmitted directly to the computer. Compared to centralized systems, the distributed systems equipped with Intelligent Electronic Devices (IED) have some advantages:

- saving of wires, clamps, labour payment etc.;
- the abandonment of classical electrical transducers with unified signal output
- higher net reliability (failure of an IED affects information only for a point of measurement, while failure of a terminal unit of data leads to a loss of much more information);
- ease of designing and configuring the system.

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2. The research paper purpose

Through this project we wanted to highlight the following aspect, namely, the importance of a monitoring system.

2.1. The vibratory systems

Monitoring of industrial installations parameters requires the acquisition of many electrical and non-electric parameters, parameters that can be monitored with powerful software. Modelling vibrational phenomena involves defining the structure and parameters of bodies in vibration, functions that describe excitation and levels of dynamic response. Vibrations are oscillations of elastic systems, ie movements of mechanical systems due to an elastic resilient force.

A vibratory system has both kinetic energies, stored in the moving mass, and potential energy, stored in the elastic element as deformation energy. During vibrations, there is a cyclical transformation of potential energy into kinetic energy and vice versa. Vibratory systems are subject to damping due to loss of energy through dissipation or radiation.

2.2. Characteristic vibration sizes

A simple vibratory movement can be expressed with the equation (1) by a harmonic movement of the type [1]:

$$x(t) = A\cos(\omega t + \varphi) \tag{1}$$

where: x - is linear or angular elongation,
A - maximum elongation,
ω -vibration pulse,
φ – Initial phase.

The vibrations are alternate movements performed by the mechanical system relative to the reference state, being caused by disturbing forces (called excitations) whose magnitudes, directions, or application points vary over time. Vibration and noise spectrum analysis, produced in machines and equipment, is a way to control, diagnose, and monitor the dynamic behaviour of the entire system.

2.3. The proposed fault monitoring methodology

The fault monitoring methodology - represents the monitoring of electronic equipment’s compliance with the requirements of the technical applicable standards throughout their lifecycle. The stages of proposed fault methodology for intelligent monitoring of asynchronous motor vibrations are as follows:

- Mount the VSA001 oscillating sensor on the asynchronous motor.
- Realization of the experimental assembly.
- Making connections to the VSE100 electronic diagnostic device.
- Setting and collecting parameters from the asynchronous motor.
- Transferring data to a computing unit.
- Open the Microsoft Silverlight application.
- Display advanced multimedia content in a web browser.
- Monitoring and analysis of wave and vibrational phenomena accompanying asynchronous electric motor operation.
- Analysis and diagnosis of the technical condition of the asynchronous electric motor.

Stage 1: Mounting the VSA001 [2] oscillating sensor on the asynchronous motor (figure 1)

The recording of the vibration spectra from the asynchronous electric motor was done using the VSE100 [3] electronic diagnostic device produced by IFM Electronic, which, via the VSA001 oscillating sensor, measures and records vibration spectra automatically or with operator intervention.

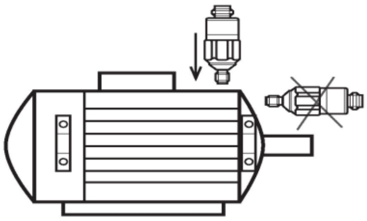

Figure 1. Mounting the VSA001 oscillating sensor on the asynchronous motor.

Stage 2: Realization of the experimental assembly (figure 2).

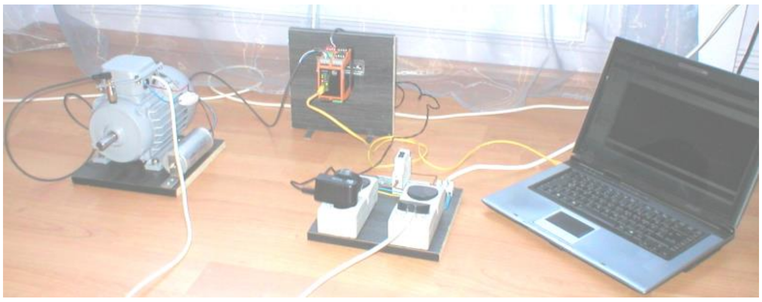

Figure 2. The experimental assembly.

The electrical scheme of experimental assembly [2] is shown in figure 3.

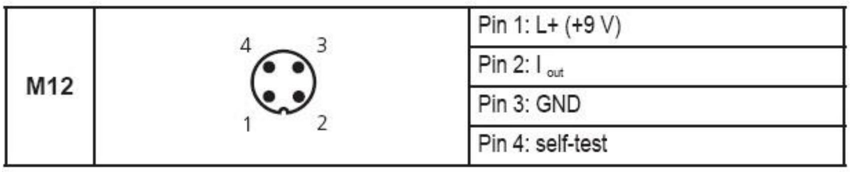

Figure 3. The electrical scheme of experimental assembly.

Stage 3: Making connections to the VSE100 [2] electronic diagnostic device (figure 4).

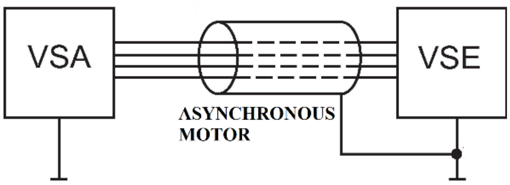

Figure 4. The connections between VSE100, VSA001 and asynchronous motor for electronic diagnostic.

Stage 4: Setting and collecting parameters from the asynchronous motor

Parameters recorded from the engine to be measured are: speed (FFT), acceleration (FFT and time variation), filter acceleration, always with signal demodulation, the size obtained being called in the literature "envelope" and having the mathematical significance of the FFT acceleration function inflator. There are numerous causes of Asynchronous Electric Motor stator damage such as manufacturing faults, maintenance mistakes and insulation deficiencies. Any defect that occurs in the stator produces a uneven field around the rotor inducing variable stresses, speed disruption and electrical vibrations.

Stage 5: Transferring data to a computing unit

The *Efector Octavis* application starts to connect the VSE100 to your PC [4]. To connect to the device (VSE), the IP address and port are required. The connection being made, the parameter setting begins, this operation being an essential one for the VSE device configuration. To set the parameters (figure 5), call the guide function that comes to your attention, setting the parameters to become an easy operation. If you want to edit the previously set parameters, you can use the Preferences option. Finally, writing the parameters to the VSE device memory (write to VSE) occurs.

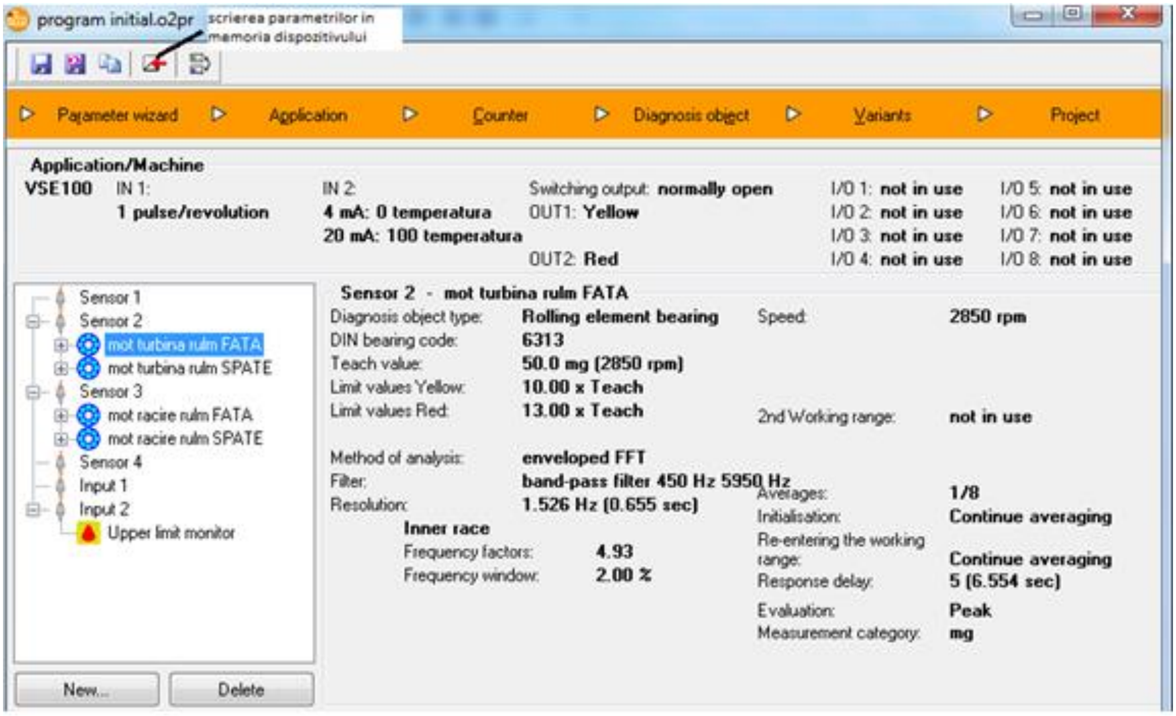

Figure 5. Setting the parameters.

Stage 6: Open the Microsoft Silverlight application

A web application has been created to facilitate the interpretation of the linear spectrum resulting from the vibration monitoring of an asynchronous motor and to be accessible to any user. The application was developed with Microsoft Silverlight, a software platform that allows you to display advanced multimedia content from a web browser based on the Microsoft .NET Framework. Silverlight allows designers and developers to easily use existing tools to bring Rich Internet Applications (RIAs) to the Web. For this, designers have Microsoft Expression Studio and Visual Studio developers. Silverlight can include Extensible Application Markup Language (XAML) content dynamically generated by the server, and can also access content from databases, enabling complex applications.

Stage 7: Display the advanced multimedia content in a web browser [4]

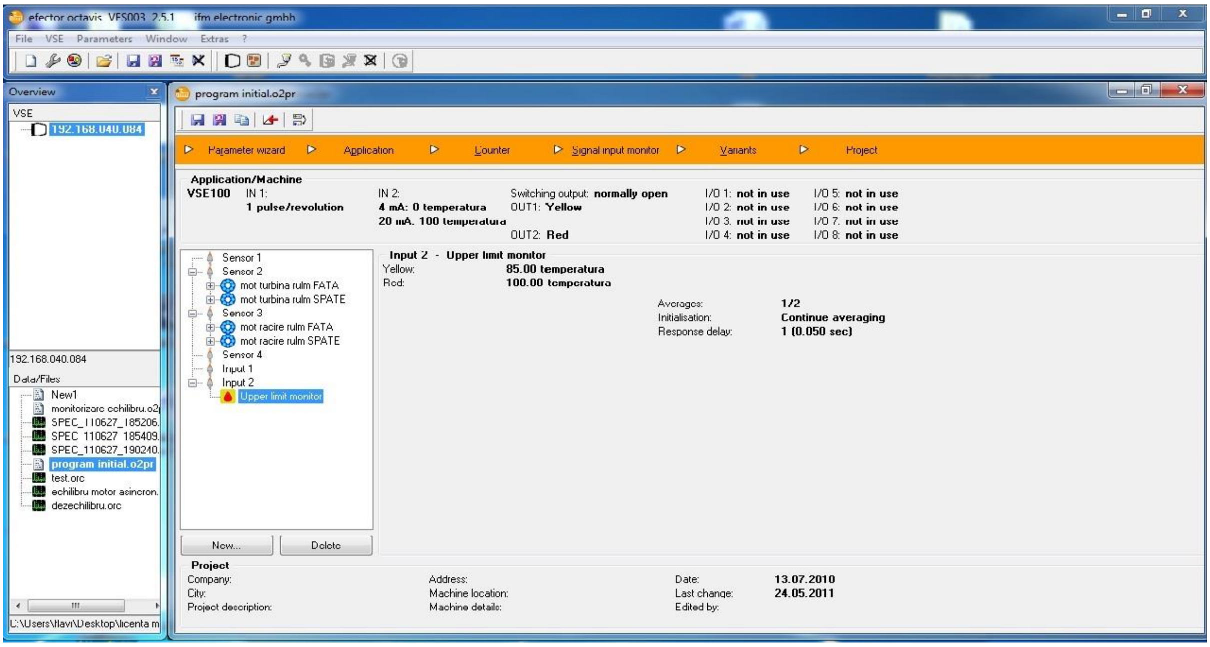

Figure 6. User Interface.

After entering the program, the first image in the user interface (figure 6) is divided into 3 segments: main menu (up), program settings and standard function window. The Overview *Window* (left) is divided into: *Hardware* that tells us whether the address of the VSE is active and *File* that tells us which files have been opened and used. The *Files* can be of the type: parameters, measurements or archives. Parameter setting (center): In this window we can set parameters using a parameter (Parameter Wizard). The main window contains the main menu and the toolbars. We can access various data and functions (parameter set, monitoring, history, settings) in a new window by double clicking on the corresponding input of the VSE device displayed. Monitor device connections can be grouped together, and data and files can be grouped into a container.

Stage 8: Monitoring and analysis of wave and vibrational phenomena accompanying asynchronous electric motor operation Vibration monitoring under steady conditions (figure 7)

Following the analysis of the operation of the asynchronous electric motor in steady state it is observed that it uses a current of 2.2 A. The values appearing in the linear spectrum can be exported to a *.*csv* file. The exported values were taken into the *.*csv* file and inserted into the MATLAB *MathWorks* program to perform linear filtering of the VSE100 device. For filtering, the *fft* function was used, and the result is as follows (figure 8): Vibration monitoring under unbalanced conditions (figure 9).

As a result of the analysis of the asynchronous engine operation under unbalanced conditions, it is observed that it uses a current of 2.1 A. In addition, it can be seen, by analysing the two linear spectra, an increase in the values in the range 1500-2500 Hz. If under constant conditions or under normal operating conditions the maximum value does not exceed 50 mg in the 1500-2500 Hz range, under imbalance conditions it is noted that the maximum value obtained in the same range is 200 mg. This indicates the malfunction of the asynchronous electric motor.

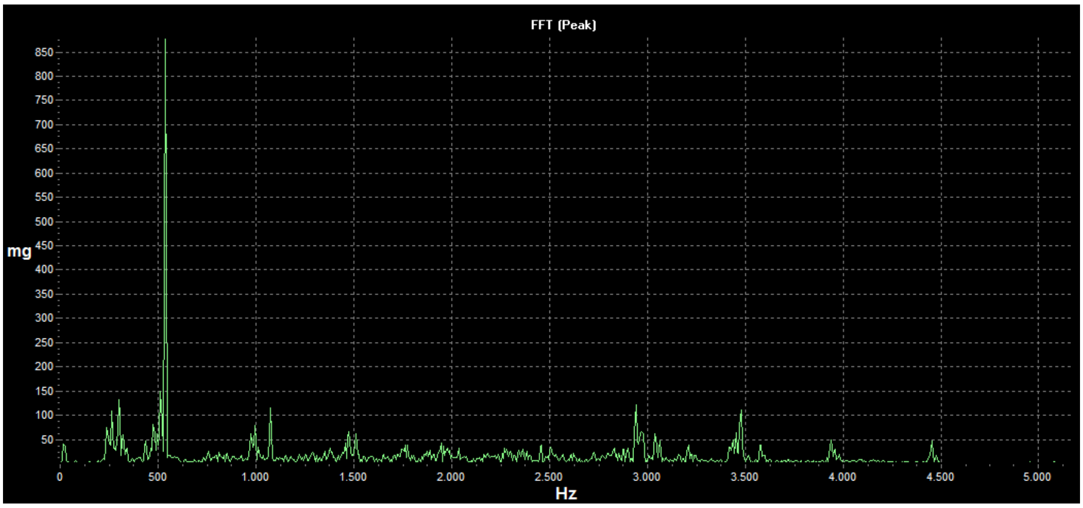

Figure 7. Linear spectrum under steady conditions.

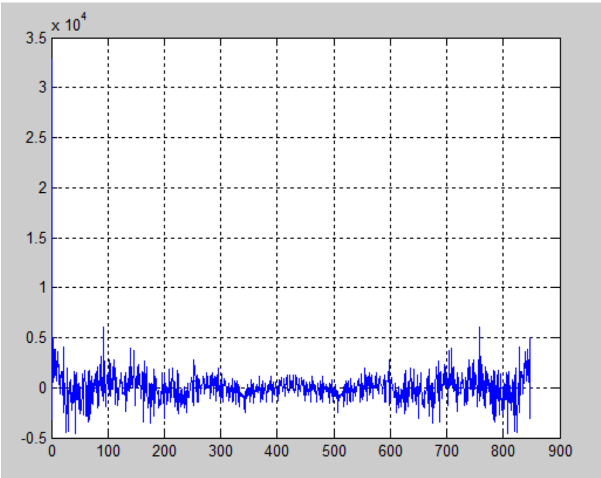

Figure 8. Spectrum filtering with *fft* function.

Figure 9. Linear spectrum under unbalanced conditions.

Stage 9: Analysis and diagnosis of the technical condition of the asynchronous electric motor

Using the toolbar, new groups or connections can be created and the new connection can be selected as active or passive through the sign-in feature. A passive connection contains all relevant information for the connection. If the connection is double-clicked, the "Connect" function can be activated from the drop-down menu or the [Connect] symbol. Similarly, an active connection can be disabled by double-clicking the "Disconnect" function, a function that can be called from the drop-down menu or the [Disconnect] icon. Parameters, monitoring, history, and settings are displayed as minor nodes (figure 10).

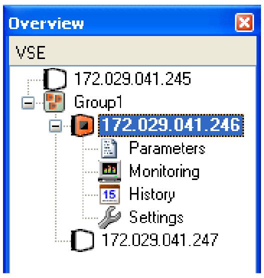

Figure 10. The minor nodes.

With a double click, the minor nodes can be opened in a new window. Each diagnostic device (VSE) can be accessed by three different users at the same time, meaning that multiple users can change the device settings and parameters at the same time.

2.3.1. Connecting the diagnostic device (VSE)

The default setting for a connection uses a static IP address, but it is possible to assign dynamic IP addresses to the electronic diagnostic system (VSE). To connect to the VSE device, the IP address and port of the VSE device need, considering the initial settings. If the network is configured with Dynamic Host Configuration Protocol (DHCP), it is possible to establish a device connection (VSE) using a hostname. The hostname must be previously defined in the network settings. From the menu bar, choose [VSE] and then [Connect ...].

2.3.2. Registering

Recording is required when a password-protected level is accessed if the user and his / her access rights to the device (VSE) have been limited to different levels. If the required level has been selected and a valid password has been entered, then it is possible to save the registration details in encoded form. Once stored, the recording data is used for each connection. Otherwise, the connection is set using the lowest level of access and higher levels must be accessed manually.

2.3.3. Restarting

The electronic device (VSE) can be restarted with the software if the existing connection is lost. Changes to network settings (IP address, hostname, etc.) remain valid. The existing connection is interrupted if changes have been made to the network settings, and a new one is required.

2.2.4. Using reference values

The assessment of the status of the diagnosed object (eg. unbalanced) is based on a signal relative increase to the reference value (Teach). If monitoring takes place on machines built in the same way and on identical measuring positions, then the *Teach* value (reference value) is identical.

The *Teach-In* function can be called from the [VSE] main menu, the [*Teach-In*] option. This function measures the set reference values and stores them in device memory (VSE). The reference and alarm values are preset for each type of diagnosis. These can be manually adjusted if are required by the maintenance process. When the reference setting process is completed, the corresponding diagnostic mode is marked with a green dot. An ongoing process is marked with intermittent red dots.

2.3.5. Monitoring
When selecting the display type in the [Monitor] window, the measured values can be viewed in different evaluation levels: In/Outputs; Spectrum monitoring; Sub-objects; Objects; Damage level. Spectrum monitoring (figure 11).

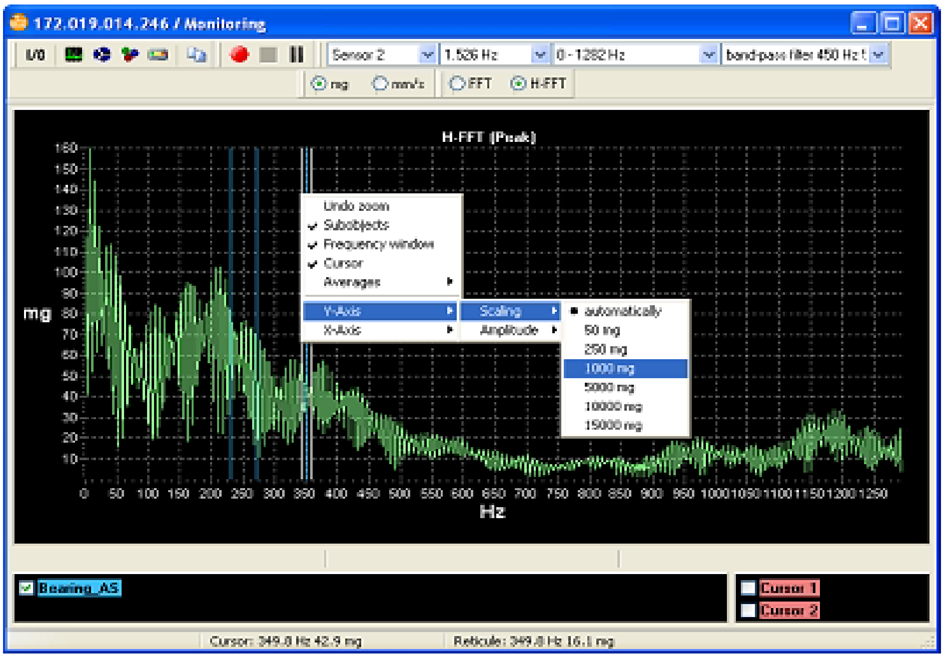

Figure 11. Linear spectrum.

Spectrum monitoring indicates the linear spectrum (FFT) for each sensor. We can change the following settings:

- Resolution: 0.19 ... 24Hz (11.44 ... 1464.84 CMP).
- Frequency band: depends on resolution.
- Filter: We choose the filter we want to use.

Unit of measurement: [mg] and [mm / s]. Analytical method has two modes as following:

- FFT Mode (Linear Spectrum of the Gross Signal
- H-FFT mode (linear spectrum of the demodulated signal) with the possibility to select the filter.

In FFT mode, object tracking is disabled.

3. Conclusions

In a competitive economy, accidental stoppages of production and long repair times are unacceptable, their consequences affecting profit. Unregulated actions of most industrial machinery are made with asynchronous motors with the short-circuit rotor, their maintenance and repair being essential for the safe operations of the plant. To control the condition of the asynchronous engine on its proper functioning, the monitoring system implemented is based on vibration measurement and analysis.

The proposed fault monitoring method identifies both the location and the type of malfunction, acting at the optimum time, the effects being beneficial in reducing maintenance costs.

The asynchronous electric motor is most used in industrial applications because it has the following advantages: low weight and overall dimensions, robust construction and low manufacturing cost

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Types of malfunctions can be determined by asynchronous electric motor vibrations analysis. Vibration analysis that occurs during motor operation may indicate electrical defects, such as broken rotor blades, unbalanced stator circuits, eccentric rotors and stators, loose power connections. There are mechanical defects and electrical faults in the vibration spectrum. The defects in the electrical system are more difficult to detect. In order to distinguish between these defects, an overview of spectrum components and a clear separation of the harmonics caused by the electrical side of the motor is required. The technical state of operation of an electric motor can be judged based on the symptoms it exhibits during operation, in our case the vibrations. The vibration is one of the main criteria for assessing the technical condition of an electric motor. Electric motor preventive monitoring involves periodic measurement of vibrations and comparison of measured values with references or standards. *The proposed fault monitoring methodology* represents a superior quality jump in a modern maintenance system, regardless of the industrial branch because it provides all the necessary information for: early detection of malfunctions; malfunctions location; diagnosis of defects; calculating the safe working time of the motor. All of this is possible to be achieved by frequency vibration analysis (FFT analysis). The use of the *proposed fault monitoring method* for spectral monitoring of the electric motor indicates the linear spectrum (FFT) for each sensor. In fact, no electric motor works without vibration.

4. References

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