MODEL OF THE DECISION-MAKING SYSTEM FOR ASSESSMENT OF THE STATE OF TECHNICAL OBJECTS

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The most wear-out is production equipment with rotary motion (turbines, generators, motors, gearboxes, pumps, compressors, fans, etc.). It is possible to reduce the cost of its operation by introducing modern maintenance systems, which are based on the use of technologies for monitoring, assessing the condition, diagnosing, predicting the development of defects, which, in terms of their organization and functioning, are intelligent systems. The state of the observed technical objects is determined by the parameters and characteristics. The aim of the work is to develop a model of the basic element of the decision-making system and consideration of options for its practical application. The proposed model of the basic element of the decision-making system allows you to create various structures designed to assess the state of complex technical and natural objects. An example of the implementation of a decision-making system for assessing the state of a multi-support power unit is presented, as a combination of basic solver modules.

Keywords: condition, vibration, parameter, characteristic, model, system, solution.

1. Introduction

In production processes, the costs allocated to ensure the operability of production equipment make up a significant part of the operating costs. It is believed that the equipment with rotational movement is the most worn out (turbines, generators, engines, gearboxes, pumps, compressors, fans, etc.). It is possible to reduce the cost of its operation by introducing modern maintenance systems, which are based on the use of technologies for monitoring, assessing the state, diagnosing, predicting the development of defects, which, from the point of view of their organization and functioning, are intelligent systems [1].

The state of production equipment can be characterized by many parameters of the main and secondary processes that develop during its operation. For control, it is advisable to choose those that reflect the functional state of objects quite well and do not require too much expenditure for their measurement. In this regard, for mechanisms with rotational motion, these are the vibration parameters [1,2]. Based on the analysis of the vibrational state of a group of the same type of mechanisms during their operation in different modes, in different technical conditions and for a long time, diagnostic signs can be substantiated and formulated to localize the places and causes of increased vibration. This creates the conditions for building automated intelligent systems for assessing the technical condition and diagnostics, which greatly facilitate the work of engineering and technical personnel. [3].

2. Model of the basic element of the decision-making system

The state of the observed technical or natural object is described by parameters and characteristics.

A parameter is a value whose values serve to distinguish the elements of a certain set from each other; a value that is constant within the limits of a given phenomenon or task, but in the transition to another phenomenon or task, which has the ability to change its value. Sometimes parameters are also called quantities that change very slowly compared to other quantities (variables). A parameter is a property (indicator) of an object or system that can be measured. The result of measuring a system parameter is a number or quantity, and the system itself can be viewed as a set of parameters that need to be measured in order to model or evaluate its behavior. Examples of vibration parameters are: the root mean square value (RMS) of vibration acceleration (vibration velocity), the range of vibrations, the amplitude of vibrations at a certain frequency, calculated by processing the vibration signal generated by primary transducers (sensors) mounted on the bearing support of the mechanism.

A characteristic is a set of distinctive properties of someone or something. A characteristic in technology is a graphical or tabular expression of the dependence of one parameter on another. As well as a function that expresses or describes this dependence. For example, a characteristic of an object is the amplitude spectrum of the vibration signal excited on the housing of the bearing support or the segment of the temporal implementation of the vibration signal.

In order to evaluate the state of the observed object, some kind of decision-making or decision support system is required. The following model of the basic decisive element of the decision-making system for assessing the state of the observed object or developing recommendations for the impact on this object is proposed.

The base element inputs are:

x_i − parameter value i, $i = 1..N$.

$\omega_j\left(y_{j,1},.....,y_{j,k}\right)$ – characteristic j at discrete values of the argument y_j, $j = 1..M$.

$\omega_j\left(y_j\left(t\right)\right)$ – characteristic j with a continuous value of the argument y_j, $j = 1..M$.

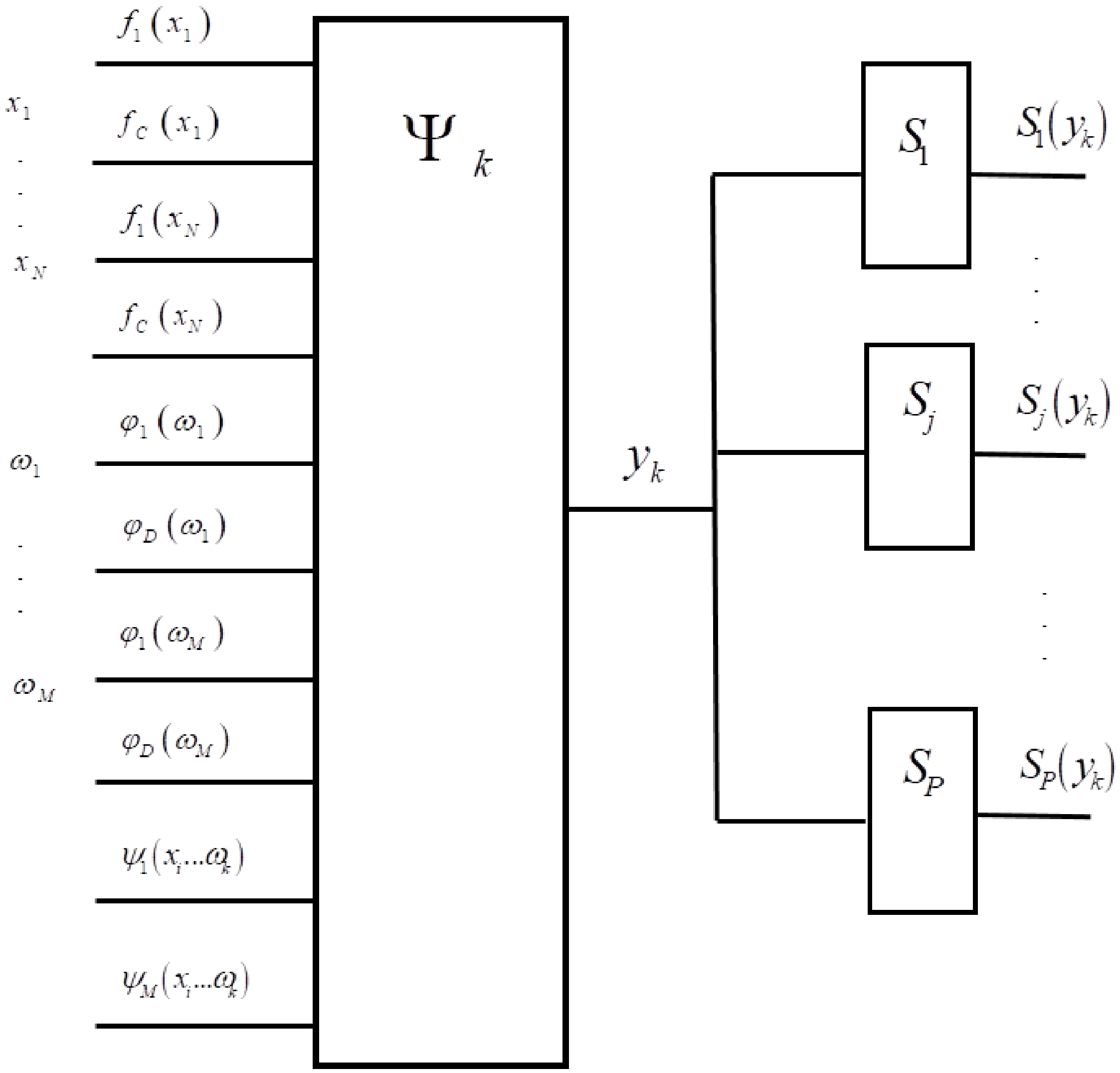

Figure 1: Model of the basic element of the decision support system for assessing the state of the observed object

In relation to the input initial parameters and characteristics, the functions of primary processing are applied:

$f_l(x_i)$, where $l = 1..B$; and $\varphi_m(\omega_j)$, where $m = 1..C$.

Moreover, different functions f_l can be applied in relation to the same parameter x_i, and different functions φ_m, to the same value of the characteristic ω_j. There may also be complex multi-parameter-multi-characteristic functions:

$\psi_n(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p)$, where $n = 1..D$; $i, j, k \in 1..N$; $l, m, p \in 1..M$.

Relative to feature set: $f_l\left(x_i\right)$, $\varphi_m\left(\omega_j\right)$, $\psi_n\left(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p\right)$ generalizing functions are applied:

$$y_k=\Psi_k\left\lfloor f_l(x_i),l=1..B;\varphi_m(\omega_j),m=1..C;\psi_n(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p),n=1..D\right\rfloor;$$

$k=1..L$.

And already in y_k relation to apply various decision functions

$S_\eta\left(y_k\right),\ \eta=1..P$.

The result of the function $S_\eta\left(y_k\right)$ determines one of the possible states of the analyzed object, the type of the object itself, and the decision to be made. In figure 1, this model is presented in a graphical form.

In the simplest case, the parameters of the proposed decision-making model will have the following form:

$f_l\left(x_i\right)=a_l x_i$, where $l=1..B$; $\varphi_m\left(\omega_j\right)=b_m\omega_j$, where $m=1..C$; a_l, b_m − real numbers.

$$\psi_n\left(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p\right)=c_n\left(\sum_{i=1}^{N}r_i x_i+\sum_{j=1}^{N}s_j\omega_j\right),$$

where $n=1..D$; $i,j,k\in 1..N$; $l,m,p\in 1..M$; r_i, s_j − real numbers.

$$y_k=\sum_{l=1}^{B}u_{l,k}f_l(x_i)+\sum_{m=1}^{C}v_{m,k}\varphi_m(\omega_j)+\sum_{n=1}^{D}w_{n,k}\psi_n\left(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p\right),$$

where $k=1..L$; $u_{l,k}$, $v_{m,k}$, $w_{n,k}$ − real numbers.

$S_\eta\left(y_k\right)=\rho_\eta y_k$, $\eta=1..P$.

3. Making a decision on the protective shutdown of the turbine unit based on vibration parameters

The most important task of modern vibration control and diagnostic systems is to prevent accidental damage to the protected object in the event of a sudden malfunction or mechanical damage in its components or in the event of a significant deviation of any technological parameters from the nominal ones. However, the fact of the occurrence of a situation requiring the shutdown of a technical object in many cases has an ambiguous mapping into vibration parameters. The standardized protection criteria [4] reflect the most general relationships obtained on the basis of long-term operating experience and research of mechanisms with rotational motion, and by no means always fully satisfy the operating and management personnel.

Vibration control and protection systems built on the basis of computer technology make it possible to implement various and complex protection algorithms focused on specific types of defects and emergencies. This, in turn, makes it possible to avoid unreasonable ("false alarm") trips of the protective shutdown and prevent "missing a defect" [5,6]. Implemented and tested on a number of turbine units is an algorithm for protective shutdown by vibration, which takes into account several factors.

1. Factor of the low-frequency component of the vibration.

Under the low-frequency vibration (LFV) is understood the mean square value of the vibration velocity (RMS) in the frequency zone equal to half the reverse. A protective shutdown signal is generated if the following situation occurs for any bearing support of the turbine unit: RMS of the LFV vibration velocity, measured for the vertical direction and for the transverse-horizontal direction of any bearing support, exceeds v *mm/s* for 4-6 seconds and, at the same time, at least for one of these directions, it exceeds $3v$ *mm/s* during the same time. The level is determined by the type and operating frequencies of the mechanism.

2. The factor of the reverse component of vibration.

The reverse component of vibration is understood as the RMS of the vibration velocity of the spectral component with a frequency equal to the frequency of rotation of the shaft (rotor) of the unit.

2.1. The value of the RMS of the turnover component.

For each bearing support and each of the directions of vibration measurement, the RMS value of the vibration velocity of the reverse component is set, corresponding to the emergency level, which is selected taking into account the design, functional and operational features of the controlled mechanism. A protective shutdown signal is generated if, at four or more control points, the RMS of the vibration velocity of the circulating component exceeded the emergency level specified for the corresponding point.

2.2. Increment vector of the turnover component.

For each bearing support and each of the vibration measurement directions, the value of the turnaround component increment vector corresponding to the emergency level is set. A protective shutdown signal is generated if at four or more measurement points the turnover component increment vector has exceeded the emergency level specified for the corresponding measurement point.

3. The factor of the high-frequency component of the vibration.

The high-frequency component of vibration (HFV) is understood as the RMS of the vibration velocity in the frequency band, the lower limit of which is equal to the double reverse frequency, and the upper limit is the upper limit of the frequency range in which the vibration control of the observed mechanism is performed. A protective shutdown signal is generated if, for any two directions of vibration measurement for any bearing support, high-frequency vibration exceeded the alarm level set for this object for 3-6 seconds.

The signal for the protective shutdown of the controlled mechanism is generated if it is generated according to one of the specified criteria, or according to several criteria simultaneously [5,7-8].

To implement this system for making a decision on a protective shutdown, the characteristic is used as input data:

$TI(x_0,...,x_{N-1}),\ j=1..M$ − temporal implementation of vibration signal.

M − the number of control points for the observed turbine unit. For each bearing support, vibration control is carried out at three points-directions: vertical, transverse-horizontal, axial.

τ − discrete time that determines the frequency of receiving the initial vibration signals.

Function $f_{1,j,\Delta}\left[A_{CCV,j};\ \tau_{\Delta}\right],\ j=1..M;\Delta=1,2,......$ designed to calculate the RMS of the turnover component.

Function $f_{2,j,\Delta}\left[A_{CCV,j};\Phi_{CCF,j};\ \tau_{\Delta-1};\tau_{\Delta}\right]$, $j=1..M;\Delta=1,2,......$ is designed to calculate the increment vector of the turnover component.

Function $\varphi_{1,j,\Delta}\left[TI\left(x_0,...,x_{N-1}\right),\tau_{\Delta}\right],\ j=1..M\ ;\ \Delta=1,2.....$ is designed to calculate the RMS of the reverse component of vibration $A_{CCV,j}$ (circulating component of vibration).

Function $\varphi_{2,j,\Delta}\left[TI\left(x_0,...,x_{N-1}\right),\tau_{\Delta}\right],\ j=1..M\ ;\ \Delta=1,2.....$ is designed to calculate the phase of the reverse component of vibration $\Phi_{CCV,j}$.

Function $\varphi_{3,j,\Delta}\left[TI\left(x_0,...,x_{N-1}\right),\tau_{\Delta}\right],\ j=1..M\ ;\ \Delta=1,2.....$ designed to calculate the RMS LFV.

Function $\varphi_{4,j,\Delta}\left[TI\left(x_0,...,x_{N-1}\right),\tau_{\Delta}\right],\ j=1..M\ ;\ \Delta=1,2.....$ is designed to calculate RMS HCV.

Function $f_{1,j,\Delta}\left(A_{CCV,j},\Phi_{CCV,j},\tau_{\Delta-1},\tau_{\Delta}\right),\ j=1..M\ ;\ \Delta=1,2.....$ is designed to calculate the increment vector of the turnover component.

Generalizing functions of the first level have the form:

$$y_{1,\Delta}=\Psi_{1,1,\Delta}\left\lfloor\varphi_{3,j,\Delta}(\ );\tau_{\Delta};\ j=1..M;\Delta=1,2.....\right\rfloor;$$

$$y_{2,\Delta}=\Psi_{1,2,\Delta}\left\lfloor\varphi_{2,j,\Delta}(\ );\tau_{\Delta};\ j=1..M;\Delta=1,2.....\right\rfloor;$$

$$y_{3,\Delta}=\Psi_{1,3,\Delta}\left\lfloor f_{1,j,\Delta}(\ );\tau_{\Delta};\ j=1..M;\Delta=1,2.....\right\rfloor;$$

$$y_{4,\Delta}=\Psi_{1,4,\Delta}\left\lfloor\varphi_{4,j,\Delta}(\ );\tau_{\Delta};\ j=1..M;\Delta=1,2.....\right\rfloor;$$

The result of each of the generalizing functions of the first level $\Psi_{1,k,\Delta}(\ )$, $k=1..4$ is , which $y_{k,\Delta}$ takes two values: zero or one. $y_{k,\Delta}$ are input parameters $x_{k,\Delta}$ for the generalizing function of the second level:

$$z_{\Delta}=\Psi_{2,\Delta}\left(x_{1,\Delta}=y_{1,\Delta},x_{2,\Delta}=y_{2,\Delta},x_{3,\Delta}=y_{3,\Delta},x_{4,\Delta}=y_{4,\Delta}\right).$$

The result of the generalizing function of the second level z_{Δ}. The value $z_{\Delta}=1$ corresponds to the decision on the operation of the protective shutdown. Value $z_{\Delta}=0$ corresponds to the normal mode of operation of the controlled object.

4. Conclusion

The proposed model of the basic element of the decision-making system allows you to configure various structures designed to assess the state of complex technical and natural objects. An example of the implementation of a decision-making system for assessing the state of a multi-support power unit is presented, as a combination of basic decision modules, which is software implemented and put into commercial operation [5,6]. The considered approach can be used in modeling various systems, including living organisms, the control device of which is a multilevel, multilayer, volumetric neural network, the typical element of which has the form of the proposed basic element.

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