NOISE TECHNOLOGIES OF IDENTIFICATION OF CHANGE OF COMPLEX OBJECTS FROM NORMAL TO FAILURE STATE

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Numerous failures with catastrophic consequences of such technical objects as thermal and atomic power stations, large capacity petrochemical complexes, deep-water stationary sea platforms and hydraulic engineering constructions, main oil and gas pipelines, failures of airliners, mistakes of forecasting earthquakes in seismic stations, mistakes in systems of diagnosing diseases, etc., were connected by scientists with unreliability of the element base of technical devices. Now, when the reliability of both single technical base elements and all system as a whole has repeatedly increased, the probability of the occurrence of failures through the fault of information systems has decreased slightly. The carried researches [1, 2] have shown that one of the principal causes of making inadequate decisions to the arising situation by information systems is connected with changing characteristics of signals $g(i\Delta t) = x(i\Delta t) + \varepsilon(i\Delta t)$ received on outputs of appropriate sensors [1].

This occurs from the moment of appearing the defect which is caused by fatigue, fret, corrosion, etc., up to the moment of obtaining by it the obviously expressed form. It is established that during the operation of technical objects characteristics of useful signals $X(i\Delta t)$ and noises $\varepsilon(i\Delta t)$ received on outputs of appropriate sensors continuously vary, and frequently the noise becomes a carrier of valuable information [1, 2]. When defects get obviously expressed form, required estimations are gradually stabilized. But in this case the violation of the normal distribution law and the absence of the correlation between the useful signal and the noise proceeds. Unfortunately, in traditional technologies the mentioned above specificity of physical processes of formation of real signals is not taken into account sufficiently. That is way besides the information of the useful signal $X(i\Delta t)$ it is expedient to extract the information which the noise $\varepsilon(i\Delta t)$ carries.

From foregoing it is obvious that for reliable and correct indication of the beginning of this process it is necessary to create new effective technologies of the analysis of noisy signals $g(i\Delta t)$ for the case when estimations of their characteristics vary in time, and the noise $\varepsilon(i\Delta t)$ is the carrier of valuable information.

Let us consider the opportunity of creating one of the variants of such technologies.

Assume that during the time T_0 prior to the beginning of the process of the origin of the defect classical conditions take place, the following equalities hold true:

$$D_{\varepsilon T_0} \approx 0\,,\; r_{X\varepsilon T_0} \approx 0\,,\; W_{T_0}\left[g(i\Delta t)\right] = \frac{1}{\sqrt{2\pi D(g)}} e^{-\frac{(g-m_g)^2}{2D(g)}}\,, \tag{1}$$

in the periods of time T_1, T_2, T_3 which are the moments of the first, second, third stage of the process of the origin of the defect, as well as at the periods of time T_4, T_5 when the defect gets the obviously expressed form the following relations take place:

$$\begin{cases} D_{\varepsilon T_1} \neq D_{\varepsilon T_0}; & W_{T_1}[g(i\Delta t)] \neq W_{T_0}[g(i\Delta t)]; & r_{X\varepsilon T_1} \neq r_{X\varepsilon T_0}; \quad r_{X\varepsilon T_1} > 0 \\ D_{\varepsilon T_2} \neq D_{\varepsilon T_1}; & W_{T_2}[g(i\Delta t)] \neq W_{T_1}[g(i\Delta t)]; & r_{X\varepsilon T_2} \neq r_{X\varepsilon T_1} \\ D_{\varepsilon T_3} \neq D_{\varepsilon T_2}; & W_{T_3}[g(i\Delta t)] \neq W_{T_2}[g(i\Delta t)]; & r_{X\varepsilon T_3} \neq r_{X\varepsilon T_2} \\ D_{\varepsilon T_4} \neq D_{\varepsilon T_3}; & W_{T_4}[g(i\Delta t)] \neq W_{T_3}[g(i\Delta t)]; & r_{X\varepsilon T_4} \neq r_{X\varepsilon T_3} \\ D_{\varepsilon T_5} \approx D_{\varepsilon T_4}; & W_{T_5}[g(i\Delta t)] \approx W_{T_4}[g(i\Delta t)]; & r_{X\varepsilon T_5} \approx r_{X\varepsilon T_4} \end{cases}, \quad (2)$$

where $W_{T_0}[g(i\Delta t)]$, $W_{T_1}[g(i\Delta t)]$, $W_{T_2}[g(i\Delta t)]$, $W_{T_3}[g(i\Delta t)]$, $W_{T_4}[g(i\Delta t)]$, $W_{T_5}[g(i\Delta t)]$ are the laws of distribution of the signal $g(i\Delta t)$; $D_{\varepsilon T_0}, D_{\varepsilon T_1}$, $D_{\varepsilon T_2}$, $D_{\varepsilon T_3}$, $D_{\varepsilon T_4}, D_{\varepsilon T_5}$ are the estimations of the variance of the noise $\varepsilon(i\Delta t)$; $r_{X\varepsilon T_0}$, $r_{X\varepsilon T_1}$, $r_{X\varepsilon T_2}$, $r_{X\varepsilon T_3}$, $r_{X\varepsilon T_4}$, $r_{X\varepsilon T_5}$ are the estimations of the coefficient of the correlation between the useful signal $X(i\Delta t)$ and the noise $\varepsilon(i\Delta t)$ at the periods of time T_0, T_1, T_2, T_3, T_4, T_5; $D(g)$ is a variance of the signal $g(i\Delta t)$; m_g is a mathematical expectation of the signal $g(i\Delta t)$.

It is obvious, that in this case at the moment of the occurrence of the process of the origin of the defect the signals $g(i\Delta t)$ from a time interval T_0 pass to the time intervals T_1, T_2 or T_3, and the latent period of changing the technical condition of an object begins. In this case the known classical conditions are not met, i.e., equalities (2) take place, and because of it in applying traditional technologies of the statistical analysis of noisy random signals, required estimations are determined with some error. For this reason the control system does not manage to find out an initial stage of the process of the origin of the defect [1, 2]. Hence, it is necessary to create technologies, allowing one to seize the moment of transition of a signal $g(i\Delta t)$ from the time interval T_0 to all time intervals T_1, T_2, T_3, T_4, T_5.

It is known that in the above-mentioned objects in some cases the origin of the defect promotes latent transition of an object from a normal condition to emergency one. Therefore, in systems it is expedient to solve problems of monitoring and indication of the beginning of the origin of the defect simultaneously with problems of identification of their technical condition. For this purpose, first of all, it is necessary to form appropriate correlation matrices because solving numerous important problems of identification of statics as well as dynamics is reduced to the numerical solution of matrix correlation equations of this type:

$$\vec{R}_{\overset{\circ}{X}\overset{\circ}{X}}(0) \cdot \vec{B} = \vec{R}_{\overset{\circ}{X}\overset{\circ}{Y}}(0), \quad (3)$$

$$\vec{R}_{\overset{\circ}{X}\overset{\circ}{Y}}(\mu) = \vec{R}_{\overset{\circ}{X}\overset{\circ}{X}}(\mu)\, \vec{W}(\mu), \ \mu = 0, \quad \Delta t, \quad 2\Delta t, \quad \ldots, \quad (N-1)\Delta t, \quad (4)$$

where $\vec{B}$ is a vector-column of coefficients of the statics equation; $\vec{W}(\mu)$ is a vector-column of pulse transitive functions [1, 2, 7, 8].

However for real complex objects even solving matrix equations like (3), (4) is a laborious enough problem and in solving problems of monitoring, control, diagnostics, applying such approach in many cases turns out to be unjustified. Therefore for solving problems of indications, as well as identification of the beginning of transition of these objects from a normal condition to emergency, it is expedient to use matrices by means of which it is easy to receive the full picture reflecting their technical condition. Consider one of the possible variants of such solution of this problem.

For a case when the object has n inputs and m outputs it is clear that for each input signal $g_1(i\Delta t), g_2(i\Delta t), \ldots, g_n(i\Delta t)$ and output signal $\eta_1(i\Delta t), \eta_2(i\Delta t), \ldots, \eta_m(i\Delta t)$ it is necessary to find appropriate correlation indicators, and then, using them, to form matrix indicators as follows:

$$W\left[r^R_{\overset{\circ}{g}\overset{\circ}{g}}(\mu')\right]=\begin{Vmatrix} r^R_{\overset{\circ}{g}_1\overset{\circ}{g}_1}(\mu') & r^R_{\overset{\circ}{\eta}_1\overset{\circ}{\eta}_1}(\mu') & r^R_{\overset{\circ}{g}_1\eta_1}(\mu') & r^R_{\overset{\circ}{g}_1\eta_2}(\mu') & \dots & r^R_{\overset{\circ}{g}_1\eta_k}(\mu') \\ r^R_{\overset{\circ}{g}_2\overset{\circ}{g}_2}(\mu') & r^R_{\overset{\circ}{\eta}_2\overset{\circ}{\eta}_2}(\mu') & r^R_{\overset{\circ}{g}_2\eta_1}(\mu') & r^R_{\overset{\circ}{g}_2\eta_2}(\mu') & \dots & r^R_{\overset{\circ}{g}_2\eta_2}(\mu') \\ r^R_{\overset{\circ}{g}_3\overset{\circ}{g}_3}(\mu') & r^R_{\overset{\circ}{\eta}_3\overset{\circ}{\eta}_3}(\mu') & r^R_{\overset{\circ}{g}_3\eta_1}(\mu') & r^R_{\overset{\circ}{g}_3\eta_2}(\mu') & \dots & r^R_{\overset{\circ}{g}_3\eta_k}(\mu') \\ \dots & \dots & \dots & \dots & \dots & \dots \\ r^R_{\overset{\circ}{g}_k\overset{\circ}{g}_k}(\mu') & r^R_{\overset{\circ}{\eta}_k\overset{\circ}{\eta}_k}(\mu') & r^R_{\overset{\circ}{g}_k\eta_1}(\mu') & r^R_{\overset{\circ}{g}_k\eta_2}(\mu') & \dots & r^R_{\overset{\circ}{g}_k\eta_k}(\mu') \end{Vmatrix}, \tag{5}$$

$$W\left[\lambda^{RT_0T_1}(\mu')\right]=\begin{Vmatrix} \lambda^{RT_0T_1}_{\overset{\circ}{g}_1\overset{\circ}{g}_1}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{\eta}_1\overset{\circ}{\eta}_1}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{g}_1\eta_1}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{g}_1\eta_2}(\mu') & \dots & \lambda^{RT_0T_1}_{\overset{\circ}{g}_1\eta_k}(\mu') \\ \lambda^{RT_0T_1}_{\overset{\circ}{g}_2\overset{\circ}{g}_2}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{\eta}_2\overset{\circ}{\eta}_2}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{g}_2\eta_1}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{g}_2\eta_2}(\mu') & \dots & \lambda^{RT_0T_1}_{\overset{\circ}{g}_2\eta_2}(\mu') \\ \lambda^{RT_0T_1}_{\overset{\circ}{g}_3\overset{\circ}{g}_3}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{\eta}_3\overset{\circ}{\eta}_3}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{g}_3\eta_1}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{g}_3\eta_2}(\mu') & \dots & \lambda^{RT_0T_1}_{\overset{\circ}{g}_3\eta_k}(\mu') \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \lambda^{RT_0T_1}_{\overset{\circ}{g}_k\overset{\circ}{g}_k}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{\eta}_k\overset{\circ}{\eta}_k}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{g}_k\eta_1}(\mu') & \lambda^{RT_0T_1}_{\overset{\circ}{g}_k\eta_2}(\mu') & \dots & \lambda^{RT_0T_1}_{\overset{\circ}{g}_k\eta_k}(\mu') \end{Vmatrix}, \tag{6}$$

where

$$\lambda^{RT_0T_1}_{\overset{\circ}{g}_k\overset{\circ}{g}_m}(\mu=\mu')=r^{RT_0}_{\overset{\circ}{g}_k\overset{\circ}{g}_m}(\mu=\mu')-r^{RT_1}_{\overset{\circ}{g}_k\overset{\circ}{g}_m}(\mu=\mu'),$$

$$\lambda^{RT_0T_1}_{\overset{\circ}{\eta}_k\overset{\circ}{\eta}_k}(\mu=\mu')=r^{RT_0}_{\overset{\circ}{\eta}_k\overset{\circ}{\eta}_k}(\mu=\mu')-r^{RT_1}_{\overset{\circ}{\eta}_k\overset{\circ}{\eta}_k}(\mu=\mu'),\quad \lambda^{RT_0T_1}_{\overset{\circ}{g}_k\overset{\circ}{\eta}}(\mu=\mu')=r^{RT_0}_{\overset{\circ}{g}_k\overset{\circ}{\eta}}(\mu=\mu')-r^{RT_1}_{\overset{\circ}{g}_k\overset{\circ}{\eta}}(\mu=\mu'),$$

$$r^R_{\overset{\circ}{g}_k\overset{\circ}{g}_m}(\mu)=\frac{\frac{1}{N}\sum_{i=1}^{N}\overset{\circ}{g}_k(i\Delta t)\overset{\circ}{g}_m((i+\mu)\Delta t)}{A(g_k)\cdot A(g_m)},\quad r^R_{\overset{\circ}{g}_k\eta}(\mu)=\frac{\frac{1}{N}\sum_{i=1}^{N}\overset{\circ}{g}_k(i\Delta t)\eta((i+\mu)\Delta t)}{A(g_k)\cdot A(\eta)},$$

$$A(g_k)=\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[2\overset{\circ}{g}_k(i\Delta t)\overset{\circ}{g}_k((i+1)\Delta t)-\overset{\circ}{g}_k(i\Delta t)\overset{\circ}{g}_k((i+2)\Delta t)\right]},$$

$$A(g_m)=\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[2\overset{\circ}{g}_m(i\Delta t)\overset{\circ}{g}_m((i+1)\Delta t)-\overset{\circ}{g}_m(i\Delta t)\overset{\circ}{g}_m((i+2)\Delta t)\right]},$$

$$A(\eta)=\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[2\overset{\circ}{\eta}(i\Delta t)\overset{\circ}{\eta}((i+1)\Delta t)-\overset{\circ}{\eta}(i\Delta t)\overset{\circ}{\eta}((i+2)\Delta t)\right]}.$$

Only at $\mu=\mu'$ the errors $r^{+}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu')$ and $r^{-}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu')$ are compensated between $\overset{\circ}{g}(i\Delta t)$ and $\overset{\circ}{g}((i+\mu')\Delta t)$ because at the time period T_0 the following equality takes place:

$$r^{+}_{\overset{\circ}{g}_k\overset{\circ}{g}_k}(\mu=\mu')\approx r^{-}_{\overset{\circ}{g}_k\overset{\circ}{g}_k}(\mu=\mu'). \tag{7}$$

At the moment of transition $g(i\Delta t)$ from the time interval T_0 to the time interval T_1 the following inequality takes place (instead of equality (7)):

$$r^{+}_{\overset{\circ}{g}_k\overset{\circ}{g}_k}(\mu=\mu')\neq r^{-}_{\overset{\circ}{g}_k\overset{\circ}{g}_k}(\mu=\mu').$$

It is easy to see that these matrices are informative enough. When the condition of an object is normal, all matrix elements will equal to zero. As soon as in any unit the process of the origin of the defect starts, the appropriate element will differ from zero. Then, according to the number of a column and a line of an element of the matrix which differs from zero, it is possible to determine (i.e. identify) a place and character of a failure which leads to transition of the object from normal to an emergency condition.

Clearly, that matrices, which are similar to matrices $W\left[r^{R}(\mu')\right]$, $W\left[\lambda^{RT_0T_1}(\mu')\right]$ one can receive on the basis of auto and cross correlation functions of input $g_1(i\Delta t), g_2(i\Delta t), \ldots, g_n(i\Delta t)$ and output $\eta_1(i\Delta t), \eta_2(i\Delta t), \ldots, \eta_m(i\Delta t)$ signals using the magnitudes $\lambda^{T_0T_1}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu')$, $\lambda^{T_1T_1}_{\overset{\circ}{g}g}(\mu')$, $\lambda^{T_0T_1}_{\overset{\circ}{g}g}(\mu')$, $\lambda^{T_0T_1}_{\overset{\circ}{g}\overset{\circ}{\eta}}(\mu')$, $\lambda^{T_1T_1}_{\overset{\circ}{g}\eta}(\mu')$, $\lambda^{T_0T_1}_{\overset{\circ}{g}\eta}(\mu')$, $\lambda^{T_0T_1}_{gg}(\mu')$, $\lambda^{T_0T_1}_{g\eta}(\mu')$ as indicators. As a result we receive matrix indicators of this type: $W\left[\lambda^{T_0T_1}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu')\right]$, $W\left[\lambda^{T_1T_1}_{\overset{\circ}{g}g}(\mu')\right]$, $W\left[\lambda^{T_0T_1}_{\overset{\circ}{g}g}(\mu')\right]$, $W\left[\lambda^{T_0T_1}_{\overset{\circ}{g}\overset{\circ}{\eta}}(\mu')\right]$, $W\left[\lambda^{T_1T_1}_{\overset{\circ}{g}\eta}(\mu')\right]$, $W\left[\lambda^{T_0T_1}_{\overset{\circ}{g}\eta}(\mu')\right]$, $W\left[\lambda^{T_0T_1}_{gg}(\mu')\right]$, $W\left[\lambda^{T_0T_1}_{g\eta}(\mu')\right]$. According to these matrix indicators one can form the cumulative matrix indicator

$$W\left\{W\left[r^{R}(\mu')\right], W\left[\lambda^{RT_0T_1}(\mu')\right], W\left[\lambda^{T_0T_1}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu')\right], W\left[\lambda^{T_1T_1}_{\overset{\circ}{g}g}(\mu')\right], W\left[\lambda^{T_0T_1}_{\overset{\circ}{g}g}(\mu')\right], \ldots\right\}.$$

Application of such cumulative matrix indicator will allow one to increase a degree of reliability of monitoring indication and identification of transition of an object from a normal condition to emergency one.

Application of the suggested technology of revealing the latent period of the transition of an object from a normal condition to emergency condition in systems of monitoring. control, diagnostics will allow one to reduce quantity of catastrophic failures on sea oil-gas deposits, petrochemical combines, termal and atomic power stations, railway and sea transport, in aviation, etc., which occur because of lateness of diagnostics in modern information systems. Besides, the opportunity appears to decrease considerably the volume of material and human losses which occur from earthquakes in cities located in regions with seismic activity. In this case the population can be beforehand informed about forthcoming earthquake so that the population can leave the buildings and move in safe places.

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