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On a Noise Reduced Configurated Smart System

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Introduction

The noise reduced configurated smart systems (NRCSS) are designed using methods and technical tools, which remove (decrease) the factors, introducing parametric modulations in the static and/or dynamic characteristics of the object in the configuration process of the object controlled with the control element (CE). Intelligent executive devices (IED) and noise reduced and anti-cavitational CE are applied in NRCSS. The purpose of the technical configuration of NRCSS is maximal decrease of the disturbances (the acoustic noise in CE) and stabilization of the parameters of choking in CE. The purpose and the criteria for synthesis of the control algorithm are subordinated to the existing technological requirements for control system quality.

The purpose of the paper is the development of a method for noise reduced configuration of NRCSS, solving the problems of: analysis of IED features, determination of an analytical method for IED configuration with CE, estimation of the results from the application of the configuration method in NRCSS.

Solution. The features of IED are shown in the functional diagram (actigrams) of the action and intelligent driving (Fig. 1). Unlike classical driving (Fig. 2), it is a possible result of the consequence of decision making, information processing – estimation-observation, multidimensional measuring and communication. The IED are characterised by:

1. Locally based intellect in the control system of the IED, implemented with the help of:

– proprioceptive and extraceptive initial transducers [1, 8] in the structural and technical organization of IED (Fig. 3).

– built in by IED manufacturer data basis for the normal and extremal operational parameters and modes (Fig. 4), providing possibility for self-test control of IED status.

2. Locally based in IED regulating functions [3, 5].

3. Significant efficiency due to the reduced hydrodynamic losses in choking and decrease of the parameter and structural disturbances in the object controlled when applying anti-noise and anti-cavitational CE.

The actigram of IED (Fig. 1) is organised similarly to the neural system in human body. The latter divides the influences of the physical values on the body into two categories – internal (proprioceptive) and external (extraceptive). The neural system has got the respective receptors.

The receptors for internal sensitivity of the status are proprioceptive. They are sensitive neural fibres directed towards the bone marrow reaching the brain with the help of golls and burdachs. The sensitivity about the status of the body bones, muscles and connecting tissues is the internal sensitivity of the body.

The extraceptive receptors are sensors of the neuro-epithal, peripheral neural system for outer sensitivity of the body. They are located in the skin, the membranes and the covering layers of the body organs. Their role is to sense the modifications of the environment and to stimulate the extraceptive sensitivity, connected with a feeling about the status of the human organs and all the modifications on the surface cover of important organs (heart, lungs, liver, stomach, etc. and of the muscle and bone system). This is temperature sensitivity, pressure and pain sensitivity.

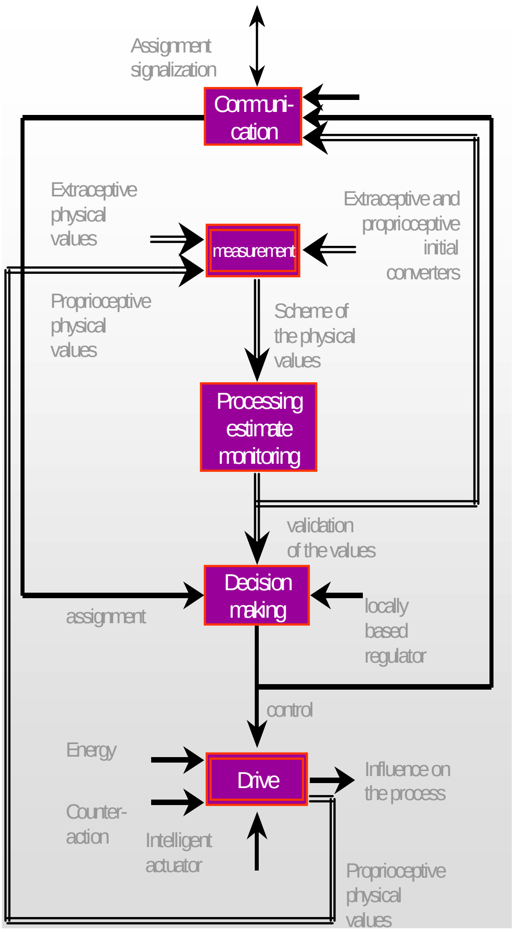


Fig. 1

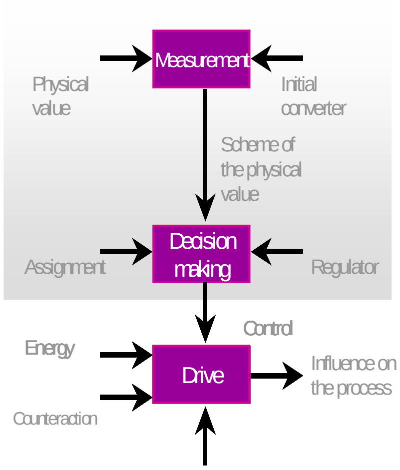


Fig. 2

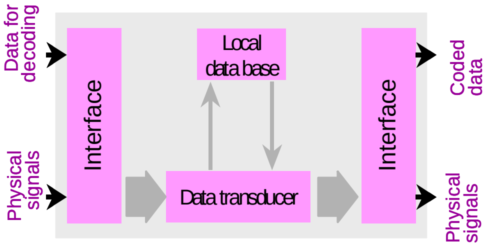


Fig. 3

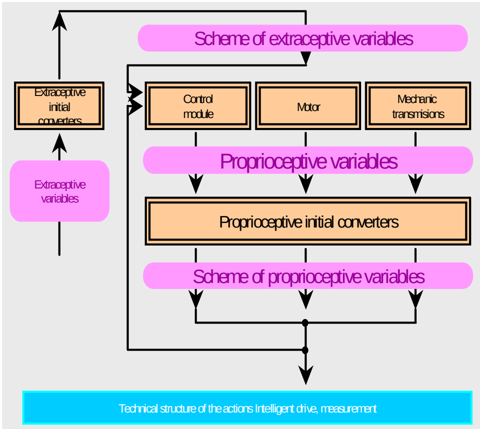


Fig. 4

The design and implementation of NRCSS is connected with the basic phase of general object configuration, illustrated in Fig. 5. The configuration of NRCSS comprises three stages, realizing the selection of the CE in NRCSS:

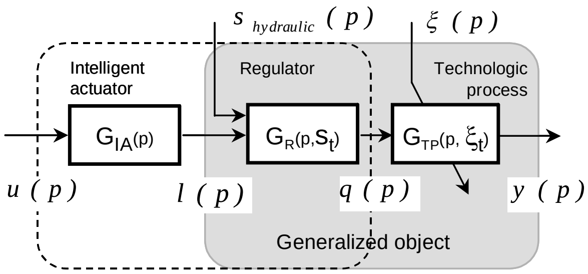


Fig. 5

– selection of the CE type – with a linear (LINCE) or with a proportional (PRCE) capacity d(1);

– dimensioning of the selected CE according to a given approach and determination of the parameters, that classify the CE as a specific technical product.

– anti-noise (or anti-caviational) precising of the CE already dimensioned.

Configuration method. A new method is proposed and an algorithm for NRCSS configuring by CE selection, that:

– is based on the estimation of the areas of linear modes Λ_{GO} in the static characteristics $y(l, s)$ of the generalized object (GO) (Fig. 5) not motivating it by the principle of symmetric-mirror selection of functions;

– uses a transfer coefficient of the object Δy (2), and not an amplifier coefficient;

– sets the selection of the CE with maximum surface $\Lambda_{GO}(l, s)$ of the linear modes area (LMA) and not the constant value of the amplifier coefficient as the purpose of NRCSS configuration;

– uses the exploitation $q(l, s)$, (1) [2, 6, 7] and not the theoretic characteristics of the CE $\delta(l)$;

– introduces the notion differential sensitivity of Δy of the generalized object in NRCSS.

(1) $q=\{l-s[l-\delta^2(l)]\}^{-0.5}$, $q_{lin}=[l-s(l-l^2)]^{-0.5}$, $q_{mp}=[l-s(l-e^{2n(l-1)})]^{-0.5}$;

(2) $\Delta y=(\partial y/\partial l)\Delta l+(\partial y/\partial s)\Delta s=(\partial y/\partial q)(\partial q/\partial l)\Delta l+(\partial y/\partial q)(\partial q/\partial s)\Delta s=$

$$(dy(q)/dq)\Delta q(l, s).$$

(3) $$\delta(\Delta y)=(dy/dq)\left[\left(\partial(\partial q(l,s)/\partial l)+(\partial q(l,s)/\partial s\right)/\partial s)\Delta l+\left[\left(\partial(\partial q(l,s)/\partial l)+(\partial q(l,s)/\partial s\right)/\partial s)\right]\Delta s.$$

The differential sensitivity $\delta(\Delta y)$ (3), of Δy is applied in the analysis of Δy and in the determination of the linear modes area. The set from the values of l and of s, for which $\delta(\Delta y)=0$ define the LMA for operation of the object specified (Fig. 5). The functional analysis of Δy (2) divides $\{l, s\}$ into two subsets–

(4) $$\begin{cases} l\in[0,1];\ s\in[0,1];\ \{l^{l_0}, s^{l_0}\}\in\{l,s\}; \\ \cup\Delta y^{l_0}\left(\{l^{l_0}, s^{l_0}\}\leftrightarrow\Delta y(l^{l_0}, s^{l_0})\neq\text{const}\right). \end{cases}$$

(5) $$\begin{cases} l\in[0,1];\ s\in[0,1];\ \{l^{0}, s^{0}\}\in\{l,s\}; \\ \cup\Delta y^{l_0}\left(\{l^{0}, s^{0}\}\leftrightarrow\Delta y(l^{0}, s^{0})=\text{const}\right); \end{cases}$$

the parameter areas being $\{l^{l_0}, s^{l_0}\}$, (4), and $\{l^0, s^0\}$(5). In $\{l^{l_0}, s^{l_0}\}$ the changes of Δy are significant even for small fluctuations in the parameter values around any basis in $\{l^0, s^0\}$. It defines parametrically the disturbed processes as a result of choking. The second one (the set $\Lambda_{\Delta y}$, $\{l^0, s^0\}\subseteq\Lambda_{\Delta y}$) is LMA of choking with constant value of $\Delta y(l,s)=\text{const}$, independently on the direction of the actions $\{l^0, s^0\}$, i.e., $\forall\ l^0$ and $\forall\ s^0\exists=\Lambda_{\Delta y}(\{l^0, s^0\}\leftrightarrow\Delta y(l^0, s^0)=\text{const})$. The solution of the system of equations {6} determines $\{l^0, s^0\}$– the ALM of choking $\Lambda_{\Delta y}$. The dimension of $\Lambda_{\Delta y}(l,s)$ is expressed by (7).

(6) $$\begin{aligned} &\left(\partial(\Delta y(l,s)\right)/\partial l=0, \\ &\left(\partial(\Delta y(l,s)\right)/\partial s=0. \end{aligned}$$

(7) $$\Lambda_{\Delta y}(l,s)=\iint\limits_{l^0,\,s^0}\Delta y(l,s)dl/ds\,|\,\Delta y=\text{const}$$

The method consists in the selection of such a CE, which guarantees LMA with maximum dimension of the object configurated. The algorithm proposed has the following stages:

1. Determination of the model $y=y(q)$ of the static characteristics of the technological process and its transfer coefficient dy/dq.
2. Formation of the models of the static characteristics $y(l,s)$ and determination of $\Delta y(l,s)$ and $\delta(\Delta y)$ of LMA with the corresponding technological process, configurated with LINCE or PRCE.
3. Formation of a system of inequalities used for the analysis of the object with LINCE or PRCE.
4. Solving the system and determining the LMA $\Lambda_{GO}(l,s)$ of the generalized object with LINCE or PRCE.
5. Evaluation and comparison of the areas $\Lambda_{GO}(l,s)$ of the projections of the areas obtained (LINCE and PRCE).

$$\iint\limits_{l,s}\delta_0[\Delta y(l,s)]_{\text{LINCE}}\,dl/ds>\iint\limits_{l,s}\delta_0[\Delta y(l,s)]_{\text{PRCE}}\,dl/ds$$

$$\iint\limits_{l,s}\delta_0[\Delta y(l,s)]_{\text{LINCE}}\,dl/ds<\iint\limits_{l,s}\delta_0[\Delta y(l,s)]_{\text{PRCE}}\,dl/ds$$

The final selection of the control object (LINCE or PRCE) as the most appropriate is realized taking into consideration::

– the presence of LMA;

– the greatest possible area of LMA of the generalized object.

An example. Fig. 6 illustrates the solution of the inequalities system for the object, the technological process of which is modelled by (8), configurated with LINCE or PRCE. The area in black colour is characteristic. It indicates the set $\{ l^0, s^0 \}$ of the LMA, for which $|\delta_0[\Delta y(l, s)]| \leq 0.005$. The area in white colour indicates the set $\{ l^{l_0}, s^{l_0} \}$.

(8)
$$y(q) = 0.5a - (a - 3aq)^3, \quad a = 0.5,$$
$$dy/dq = 0.0108(841q^2 - 580q + 100).$$

Analysis of the efficiency of NRCSS in noise emission conditions. The estimation of the effect from the application of NRCSS at apriori indefinity, and the ratio of the indicators of its quality in comparison with the classic system (CLASS), requires analysis of NRCSS operation under conditions of noise emission of CE. The check of its efficiency is connected with the evaluation of the dynamic accuracy and of the hydrodynamic losses ΔE (9) [4] of NRCSS in comparison with CLASS under one and the same conditions.

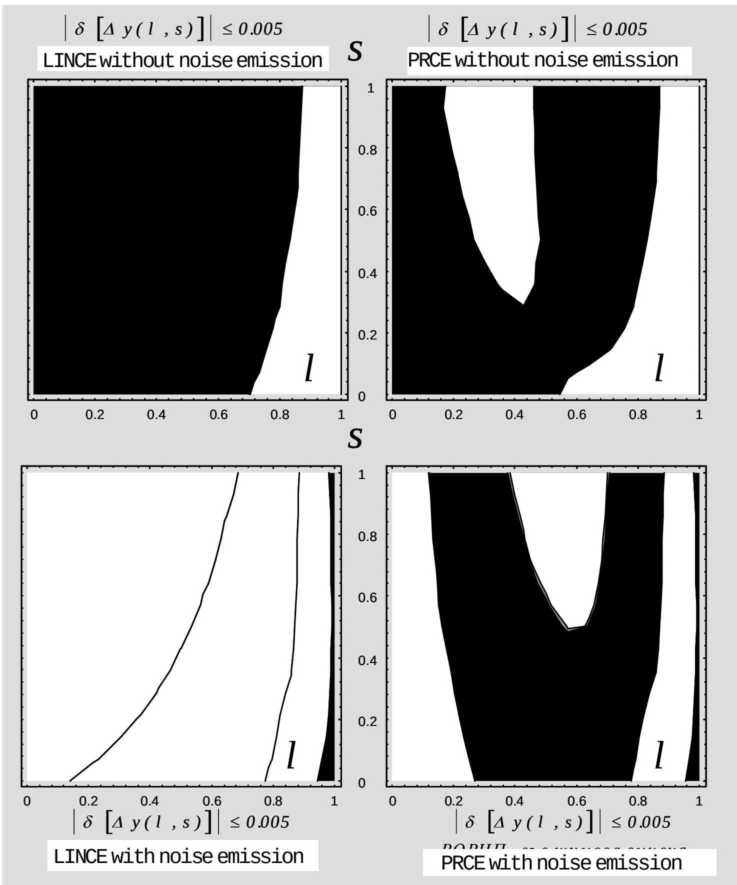


Fig. 6

(9) $\Delta E = \Delta P_{ce} Q_v = cs\,[\,l - s(l - \sigma^{-2})\,]^{-0.5} = csq,\ (c = \Delta P_{ce_{max}} Q_{v_{max}} = \mathrm{const})$.

For this purpose NRCSS and CLASS system are modelled and simulated (Fig. 7), including the disturbance emission in CE [7], introducing:

1. Integral $[\hat{e}(t)]^{\Delta}$ estimate (10) of the multiplicity of the reducing the dynamic error of NRCSS in comparison with the error of CLASS under conditions of disturbance emission in the CE used.

(10) $$[\hat{e}(t)]^{\Delta} = \Big[\, 1 - \Big(\int_0^t |\hat{\varepsilon}^{\mathrm{NRCSS}}_{(t,\,y^0,\,v,\,\xi)}|\,dt \Big/ \int_0^t |\hat{\varepsilon}^{\mathrm{CLASS}}_{(t,\,y^0,\,v,\,\xi)}|\,dt \Big)\Big].$$

2. Integral $[\hat{E}_{\Delta}]$ estimate (11) of the percent decrease of the losses ΔE (9) of NRCSS with respect to the losses of CLASS under the conditions of disturbances emission in the CE used.

(11) $$[\hat{E}_{\Delta}]^{\sim} = \Big(1 - \Big(\int_0^t \hat{E}^{\mathrm{NRCSS}}\,dt \Big/ \int_0^t |\,\hat{E}^{\mathrm{CLASS}}\,dt \Big)\Big) 100\,\%.$$

The simulation analysis uses models of the CE with combined hydraulic loading $s_{\mathrm{hydraulic}}$ (12). They take into account the static q and dynamic V characteristics of the CE without noise emission (16). The models [7] contain the constant binary coefficient c_l, of values 0 or 1.

(12) $$s_{\mathrm{hydraulic}} = \frac{\Delta P_{\mathrm{CE}}}{\Delta P_{\mathrm{CE_{max}}}} = \left[\frac{(P_0 - P_1)}{(P_0 - P_1)} + 1 \right]^{-1},\ 0 \le s \le 1.$$

Using the model of the generalized object (one and the same for the two systems being analyzed – Table 1), formed with the respective model of the CE, different technological modes v_i (13) of systems functioning are simulated. Here v(14) is a generalized action, simultaneously driving the systems models, synthesized by a similar local criterion of the quality (LCQ), its variables y^0 (set value), $s_{\mathrm{hydraulic}}$ (loading) and ξ (re-parametrization being generated by independent white noise generators.

(13) $$\begin{aligned} v_1 &= f(v,\ q,\ V\,); \\ v_2 &= f(v,\ q^{\approx},\ V^{\approx}); \\ v_3 &= f(v,\ q^{\sim},\ V^{\sim}); \end{aligned}$$

(14) $$\theta = \{[\,v_i\ s_{\mathrm{hydraulic}}\ \xi\, y^0]^{\mathrm{T}}\},$$

$$0.1 \le s_{\mathrm{hydraulic}} \le 0.9,\quad 10\,\% \le y^0 \le 90\,\%,\ \xi = \bar{l}_a.$$

The results of the simultaneous simulation (Fig. 7) with θ(14) of:

– a model of CLASS and NRCSS for stabilzation of an object with nominal model $G^*(p)$ (15) and parametrically disturbed at the upper bound $G^{\#}(p)$ (16) model, optimally set with $R^*(p)$ (17), Table 1 according to LCQ in normal conditions $v_i = f(v,\ q,\ V)$ without noise emission;

– a model of CLASS and NRCSS for stabilzation of an object with nominal model $G^*(p)$ (15) and parametrically disturbed at the upper bound $G^{\#}(p)$ (16) model, optimally set with $R^*(p)$ (17), Table 1 according to LCQ in conditions of instantaneous $v_2 = f(v,\ q^{\approx},\ V^{\approx})$ and constant noise emission $v_3 = f(v,\ q^{\sim},\ V^{\sim})$ are shown in Figs. 8, 9, 10, 11 for conditions of instantaneous $v_2 = f(v,\ q^{\approx},\ V^{\approx})$ noise emission and Figs. 12, 13, 14, 15 under conditions of constant $v_3 = f(v,\ q^{\sim},\ V^{\sim})$ noise emission.

Fig. 7

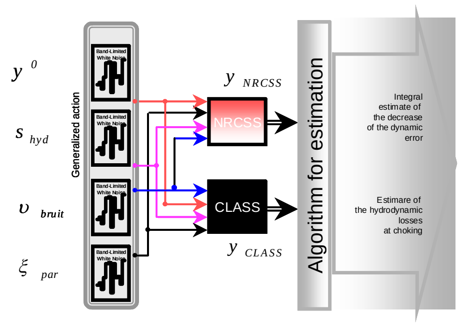
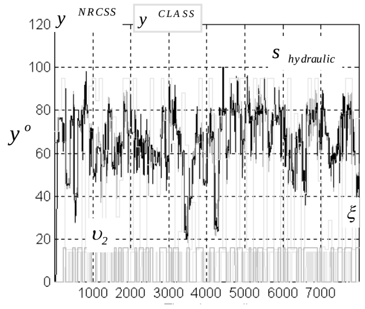


Fig. 8



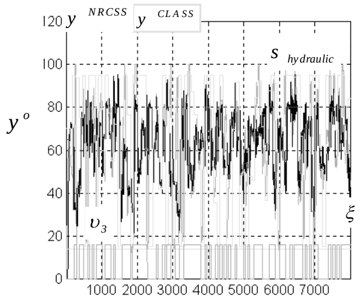
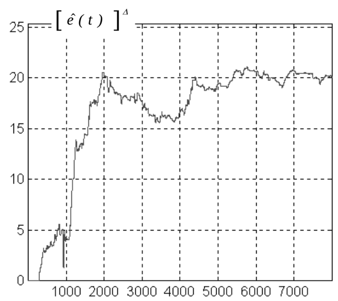


Fig. 12

Fig. 9



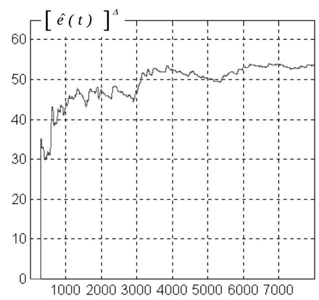
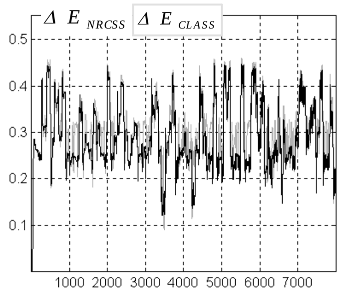


Fig. 13

Fig. 10



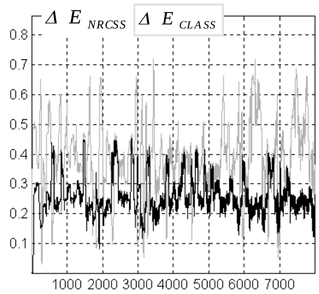
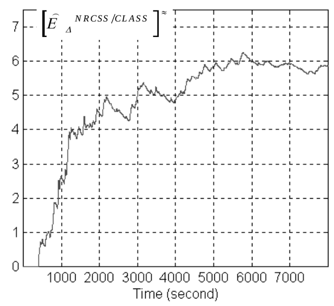


Fig. 14

Fig. 11



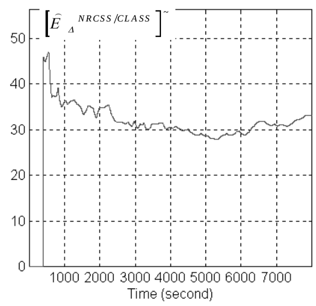


Fig. 15

Table 1

$k_{ob}(l,s)$	1,239	2,960
T_{ob}	10, s	10, s
$\tau_{ob}(l,s)$	2,s	4, s
LCQ	critical-aperiodic process	critical-aperiodic process
$G^{*}(p)$	(15) $\frac{1,239\,e^{-2p}}{10\,p+1}$	
$G^{\square}(p)$		(16) $\frac{2.96\;e^{-4p}}{10\,p+1}$
$R^{*}(p)$	(17) $0,13\frac{(5\,p+1)}{(5\,p)}\frac{(2\,p+1)}{(0,4\,p+1)}$	

Conclusion

The results from the solution of the example and the analysis of NRCSS confirm the appropriate use of the method proposed in NRCSS configuration. Only for the case of acoustic noise emission in CE, under one and the same conditions, the parallel simulation of CLASS and NRCSS demonstrates that:

1. The integral estimate of dynamic error $[\hat{e}(t)]^{\Delta}_{CLASS}$ of CLASS exceeds 20 times the integral estimate of dynamic error $[\hat{e}(t)]^{\Delta}_{NRCSS}$ of NRCSS at instantaneous noise emission and over 55 times at constant noise emission.

2. Under one and the same conditions $[\hat{e}(t)]^{\Delta}_{NRCSS}$ is invariant with respect to the acoustic noise in CE.

3. There are some changes in the character of the exploitation relations, connected with excessive losses. The integral estimate of the hydrodynamic losses $[\hat{E}_{\Delta}]_{CLASS}$ of CLASS at noise emission in CE increases by 6 % in comparison with the losses $[\hat{E}_{\Delta}]_{NRCSS}$ of NRCSS at instantaneous noise emission and by 30 % at constant noise emission.

4. During operation within the range $\{l^{l_0}, s^{l_0}\}$ (4) CLASS does not satisfy the LQC, preset in the synthesis. The noise emission expands these areas on the account of $\{l^{0}, s^{0}\}$.

5. The area $\{l^{l_0}, s^{l_0}\}$ (4) shows the inefficiency of CLASS under conditions of acoustic noise emission in the CE with losses in the control (stabilization) in choking.

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Помехоустойчиво конфигуриванные интеллигентные системы

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(Р е з ю м е)

В проектировании помехоустойчиво конфигуриванных интеллигентных систем (ПКИС) используются методы и технические средства, которые редуцируют факторы, создающие параметрические модуляции в статических и/или динамических характеристиках объекта еще в процессе конфигурации обобщенного объекта управления с регулирующим органом (РО). В ПКИС применяются интеллигентные исполнительные механизмы и помехоустойчивые РО с максимальном редуцированием смущения и со стабилизацией параметров РО, а цель и критерии синтеза алгоритма управления подчиняются конкретным технологическим требованиям к качеству системы управления.