Изображенная поверхность вывода, может быть интерпретирована как график функциональной зависимости выходной переменной от входной (рис. 2).

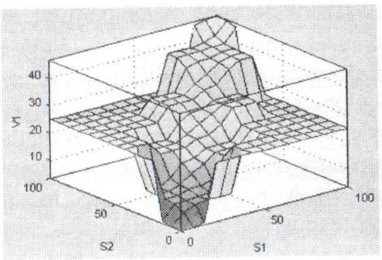

Рис. 1. Вид поверхности нечеткого вывода

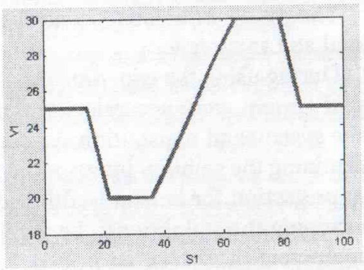

Рис. 2. Тренд функциональной зависимости

Из анализа данного графика видно, что зависимость характеризует некоторый тренд. Установление данной зависимости является решением задачи, известной в классической теории управления как задача синтеза управляющих воздействий.

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SOME CASES OF FINDING DETERMINATION OF AUTOMATIC CONTROL SYSTEM (ACS) AT THE STABILITY BOUNDARY

Automation is one of the main directions of scientific and technical progress and an important means for improving of production efficiency. One of the most important characteristics of control systems is stability, which is directly related to efficiency. Unstable system does not perform control functions (is unusable) and, as a consequence, it is ineffective. Great influence on the stability provides feedback. Unstable control of systems occurs due to improper or very strong action of main feedback. It occurs in the following cases:

- in case of doing feedback positive instead of negative;
- in case of large elements`s inertia of closed loop.

Theory of automotive control has two ways of defining sustainability: experimental and analytical.

During using the experimental method of determining the stability, we must have a valid system, very accurate and sensitive equipment: for forming and fixing effects on the system and registration system behavior after removing effects. This method of determining the stability imposes the following restrictions on process: quite slow process; protection for human health and environment. As a consequence, the method of determining the stability can be applied during readjusting and partial modernization of equipment.

During designing of ACS, when there is a mathematical model, there are used analytical methods for determining stability: finding stability control system on location of roots of characteristic control and a various sustainability criterions.

In determining of stability on roots location of the characteristic control, free movement of system is described by uniform differential equations:

$$a_0\frac{d^n x(t)}{dt^n} + a_1\frac{d^{n-1}x(t)}{dt^{n-1}} + \ldots + a_n x(t) = 0 \quad (1)$$

After transformation of the differential equation we obtain its operational form (characteristic equation):

$$a_0 p^n + a_1 p^{n-1} + \ldots + a_n = 0 \quad (2)$$

Forced component of the output value, depending on the type of external influence, is not affected on the stability of the system.

Solving of equation (1):

$$x(t) = \sum_{k=1}^{n} C_k \exp(p_k t), \quad (3)$$

where C_k – constants which depends on the initial conditions;

p_k – roots of characteristic equation (2).

Imaginary axis is the boundary of stability in the root plane. If at least one root is «right», then the system will be unstable. If there is a pair of absolutely imaginary roots and all other roots are «left», then the system is on the vibrational stability boundary. If there is a zero root, the system is in the aperiodic boundary of stability. If there are two roots, the system is unstable. Consequently, the system in which the characteristic equation can be factorized p2 are unstable [1].

If characteristic equation of the system is higher than the third order (except for the biquadratic equation), it is difficult to find roots, because there are not general formulas of expressing roots of the characteristic equation through equations coefficients. In this case, use different criteria for sustainability: algebraic and frequency.

Algebraic application of Raus and Hurwitz`s criterions and frequency criteria of Mikhailov don`t limited by degree of characteristic equation. It is due to development of computer technology. However, by the criterions of Hurwitz and Mikhailov, it is not possible to determine the amount of the «right» roots of the characteristic equation, unlike Raus.

Raus`s criteria is a quite simple way to determine the stability of ACS of high order by using a quite simple algorithm. However, using this criterion is difficult to determine location of the system on stability boundary: aperiodic and vibrational.

Let`s consider some special cases of finding definitions of automatic control system on stability boundary using Raus and using Hurwitz stability criterion.

1). Hurwitz criterion for the system is on aperiodic stability boundary, if $a_n = 0$. How will the Raus table look like in this case? Consider equations for systems 3 and 4 order.

For a system with a characteristic equation:

$$a_0 p^3 + a_1 p^2 + a_2 p = 0 \quad (4)$$

Raus table is:

a_0	a_2	0
a_1	0	0
a_2	0	0
0	0	0

For a system with a characteristic equation:

$$a_0 p^4 + a_1 p^3 + a_2 p^2 + a_3 p = 0 \quad (5)$$

Form:

a_0	a_2	0
a_1	a_3	0
$a_2 - \frac{a_0}{a_1}a_3$	0	0
a_3	0	0
0	0	0

Comparing the tables for two special cases, we can conclude that a similar results will be at higher degrees of the characteristic equation. Therefore, if in the last row of the Raus table (line number (n + 1)) all coefficients are zero, then the system is on aperiodic boundary of stability [2].

2). To review of finding of ACS on oscillatory stability boundary by Raus, consider the following special case: the characteristic equation of the system is as follow:

$$(K_1 + T_1 p^2)(K_2 + T_2 p)(K_3 + T_3 p) = 0 \qquad (6)$$

Roots of this equation are $p_{1,2} = \pm\sqrt{\frac{K_1}{T_1}}j$, $p_3 = -\frac{K_2}{T_2}$, $p_4 = -\frac{K_3}{T_3}$.

For filling table of Raus, we convert specified characteristic equation and obtain its next form:

$$T_1T_2T_3p^4 + (K_2T_3 + K_3T_2)T_1p^3 + (K_1T_2T_3 + T_1K_2K_3)p^2 + (K_2T_3 + K_3T_2)K_1p + K_1K_2K_3 = 0 \qquad (7)$$

By this expression we can fill the table:

$T_1T_2T_3$	$(K_1T_2T_3 + T_1K_2K_3)$	$K_1K_2K_3$	0
$(K_2T_3 + K_3T_2)T_1$	$(K_2T_3 + K_3T_2)K_1$	0	0
$K_2K_3T_1$	$K_1K_2K_3$	0	0
0	0	0	0
?	?	?	?

During finding of coefficients of 5th line of the table, determining of the line coefficient r_5, we get dividing by zero ($r_5 = \frac{C_{1,3}}{C_{1,4}} = \frac{K_2K_3T_1}{0} = ?$), which can not be done.

From that we can conclude that if in line with the number n (in our case n = 4) are zeros, then the system is on vibrational stability boundary [2].

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