Research Article

Design Of Standard Regulators For Multi-Link Control Objects

Siddikov Isamiddin Xakimovich[1], Khujanazarov Ulugbek Olimovich[2]*, Izmaylova Renata Nikolayevna[1], Yunusova Sayyora Tashkenboevna[1], Alimova Gulchexra Raximjonovna[1]

[1]Department of Information Processing and Control Systems, Tashkent State Technical University, Tashkent, Uzbekistan
[2]Department of Automation and management of industrial and technological processes, Tashkent Institute of Textile and Light Industry, Tashkent, Uzbekistan
*Corresponding author: uxujanazarov@mail.ru

Siddikov Isamiddin Xakimovich (isamiddin54@gmail.com),
Khujanazarov Ulugbek Olimjonovich (uxujanazarov@gmail.com),
Izmaylova Renata Nikolayevna (verona781r@gmail.com),
Yunusova Sayyora Tashkenboevna (yunusova_sayyora@mail.com),
Alimova Gulchexra Raximjonovna (alimova250479@mail.com)

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 16 April 2021

Absract : The article is devoted to the study of the possibility of using a combined method of tuning typical regulators to control multivariate multilink dynamic objects with several controlled and controlling parameters. The designed combined regulator, built on the basis of the joint use of two methods of setting the parameters of the regulator, based on ensuring the autonomy of control channels, and taking into account the effects of cross channels in static, has the properties of structural stability and rudeness to errors of the model of the control object. Invention proposes automated method of finding optimal parameters of regulators for multivariate multilink objects with lag property and high inertia. The disclosed method enables real-time operational control of multidimensional dynamic objects. The developed combined method of tuning multidimensional standard regulators makes it possible to calculate the parameters of regulators, taking into account the limitations of control influences and a number of engineering requirements for transients.

Keywords: Multiply connected control object, Typical regulator, Software package, Simulation, Delay.

INTRODUCTION. One of the primary tasks of modern technologies is to maintain the main indicators of technological processes (TP) at the optimal level. The solution to this problem is due to some difficulties caused by various disturbing factors, which lead to a significant increase in energy consumption, underperformance and product quality [1 - 5].

One of the ways to solve the set task of indicators is to create a system for automatic and automated control of the intensity of material and energy flows, as well as the mode parameters of TP, which allow ensuring the stability of quality indicators. For example, for drying raw cotton, it is important to maintain an optimal temperature profile along the length of the drum, affecting the flow rates of cotton, fuel supplied to the air furnace, as well as the rotation speed of the drum [2, 11, 16].

The difficulty of solving this problem lies in the fact that each control effect in different degrees and with different dynamics affects all stabilized TP variables. The article proposes a fairly simple implementation and at the same time a universal automatic method of solving the problem of stabilization of multidimensional TP using standard regulators [2, 6, 8, 15].

In typical circuits of controlled TP including a control object, under the influence of both a number of control signals and a number of uncontrolled disturbances output, each control input influences each controlled output to be stabilized at a predetermined level, i.e. autonomous control of communication channels is provided.

Due to the complexity of the mathematical description of the dynamics of multi-link control and the difficulties in developing methods for forming controlled inputs, they are most often limited to the development of unrelated single-circuit automatic systems for stabilizing input control actions.

An important promising task, which will be discussed in the future, is to move from automatic control of individual TP fragments to automatic control of the TP as a whole, including the generation of tasks by the control system with an autonomous control loop. These tasks should be changed in such a way that the TP output indicators are as close as possible to the economically optimal mode values [4].

The works [1, 5, 12, 15] stated that modern control methods are poorly adapted to solve practical problems, due to a number of features as control objects, which include information and transport lag phenomena, significant measuring noises, the presence of strict restrictions on the field of change of various variables, non-standard control quality criteria. In such cases, so-called "advanced" control methods have recently been widely used to solve TP control problems (Advanced Process Control - APC) [5, 6], which include in the control algorithm real-time and accelerated dynamic models of the controlled process.

On the other hand, the well-known model PI- and PID-laws of control are widely used in world practice [3, 14, 17]. In this regard, we will form control algorithms based on typical regulators.

In the presence of strong cross-connections of the control object, typical regulators cannot ensure the stability of the closed system. Since each control loop can create additional disturbances for the remaining loops.

In this case, more complex methods for calculating typical regulators are usually used. At the same time, in calculation procedures, the model of the object with some "equivalent" dynamic model is replaced, taking into account the influence of other loops [3]. The main disadvantage of these methods is the lack of guarantee to ensure the stability of a multidimensional closed system and the need to select values of a number of coefficients.

And when using a centralized control system structure based on standard regulators, it becomes necessary to adjust a large number of parameters of typical control laws.

For example, for an object with *M*-control inputs and *N*-stabilized outputs, when using PI-regulators, it is necessary to configure $2M \times N$.

Solution method. Let the transfer matrix of the object $H(p)$ contain elements $h_{ij}(p)$, each of which is a serial connection of a stable fractional-rational transfer function $\tilde{h}_{ij}(p)$ with a delay link $e^{-p\tau_{ij}}$. The task of adjusting typical regulators is to develop methods for calculating the matrices *A* and *B*, which determine the parameters of the transfer matrix of a multidimensional PI-regulator with a transfer function $W(p) = A + B/p$.

The essence of the method for an object with a square transfer matrix ($M = N$) is the joint use of typical regulators with a decentralized and centralized structure (Fig. 1). Then the law of administration is defined as follows:

$$W(p) = rW^{(1)}(p) + (1-\rho)W^{(2)}(p),$$

where $W^{(1)}(p)$ and $W^{(2)}(p)$ - are the transfer matrices of auxiliary standard regulators, and ρ - is the weight factor to be selected, at the same time $\rho \in [0,1]$.

The diagonal transfer matrix $W^{(1)}(p)$ corresponds to a multidimensional standard regulator designed to stabilize the object $H(p)$ within a decentralized structure.

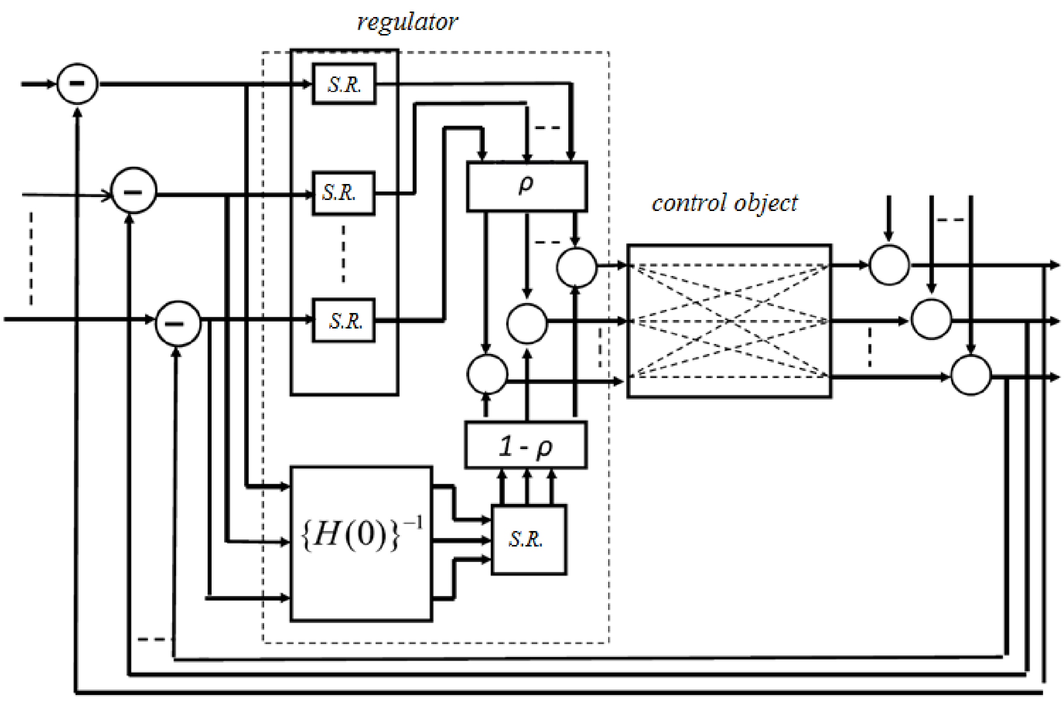

Fig. 1. - System with combined multidimensional standard regulator (S.R.)

The transfer matrix $W^{(2)}(p)$ is designed to stabilize an auxiliary object $H^{(2)}(p)$ having the same matrix of static amplification coefficients $H(0)$ as the original object, but a single dynamics over all control channels. Calculation of parameters of multidimensional centralized standard regulator $W^{(2)}(p)$ for object $H^{(2)}(p)$ by method of dynamic compensation results in the following ratios:

$$H^{(2)}(p) = [H(0)]^{-1}(a^{(2)} + b^{(2)} / p,$$

where "free" scalar parameters $a^{(2)}$, $b^{(2)}$.

The methodology discussed is based on a combination of two methods for tuning multidimensional typical regulators. The first method simplifies the configuration by eliminating cross-links, and the second - takes into account cross-links in static, simplifying the structure of the dynamic part of the multidimensional standard regulator.

The combined regulator thus designed has structural stability and robustness properties, that is, it is always possible to find values of its adjustable parameters, in which the closed control system will be stable and low-sensitivity to the errors of the model of the control object.

Example solution. Let the control object, there is a transfer matrix:

$$H(p) = \begin{bmatrix} \dfrac{0{,}126e^{-6p}}{60p+1} & \dfrac{-0{,}101e^{-12p}}{(48p+1)(45p+1)} \\ \dfrac{0{,}094e^{-8p}}{38p+1} & \dfrac{-12e^{-8p}}{35p+1} \end{bmatrix}.$$

Single step disturbances of different signs are applied to the outputs of the object. At that transient processes by control and output variables occur (Fig. 2).

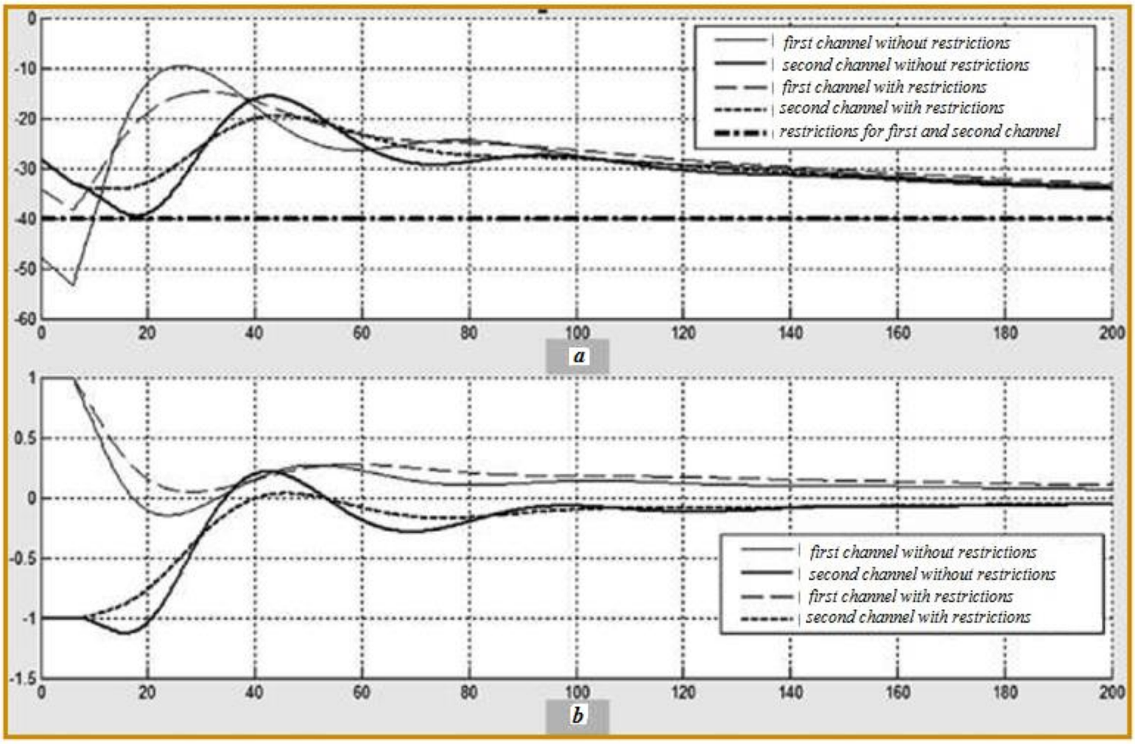

Fig. 2. - Control actions (a) and output variables (b) in a closed system with a PI-regulator, calculated without taking into account (solid lines) and taking into account (dashed lines) control restrictions

Dashed lines correspond to processes in a closed control system with a decentralized structure, where the settings of two PI-regulators are found as a result of minimizing the integral quality criterion (IQC) by a search path without taking into account cross-links (the «autonomous optimal» (AO) method). The settings of the PI regulator are determined by the matrix:

$$A = \begin{bmatrix} 61{,}2 & 0 \\ 0 & -29{,}6 \end{bmatrix}, \qquad B = \begin{bmatrix} 0{,}69 & 0 \\ 0 & -0{,}56 \end{bmatrix}.$$

Continuous lines correspond to the behavior of a centralized system with four PI-regulators calculated using the search procedures of the combined method discussed in the article (the «combined optimal» (CO) method). The settings of the PI-regulator are determined by the matrix:

$$A = \begin{bmatrix} 39{,}6 & -33{,}5 \\ 31 & -41{,}5 \end{bmatrix}, \qquad B = \begin{bmatrix} 0{,}89 & -0{,}75 \\ 0{,}69 & -0{,}93 \end{bmatrix}.$$

Comparison of graphs shows that in the absence of consideration of cross-links, transients are characterized by strong fluctuations and slow convergence. The integration of cross-linkages into a centralized structure reduces fluctuations and accelerates the transition process. If for the autonomous-optimal regulator the control quality indicator IQC = 0.27, then for the combined-optimal regulator IQC = 0.14. Thus, the combined method discussed in the article made it possible to reduce IQC by about half compared to the traditional method of independent configuration of autonomous regulators.

In order to reduce transient oscillation, restrictions on $|u_1(t)| \le 40, \ |u_2(t)| \le 40.$ control are introduced. Taking these restrictions into account, the PI-regulator is also analytically calculated:

$$A = \begin{bmatrix} 28{,}7 & -5{,}4 \\ 5{,}0 & -23{,}2 \end{bmatrix}, \qquad B = \begin{bmatrix} 0{,}55 & -0{,}15 \\ 0{,}14 & -0{,}66 \end{bmatrix}.$$

As can be seen from the graphs (Fig.2), the transients shown by the continuous lines due to the weakening of the regulator settings are less oscillatory. At that, control actions are within specified limits.

Conclusion

Efficiency of TP operation is characterized by a number of process indicators supporting at specified levels in conditions of uncontrolled disturbances. The problem is complicated by the fact that each control effect affects several output variables. The paper proposes a solution to the problem of stabilizing multi-link control objects of arbitrary dimension, which is a set of typical PI-regulators. The developed combined method of tuning multidimensional typical regulators makes it possible to calculate the parameters of regulators, taking into account restrictions on control actions and a number of engineering requirements for transients.

List of literature

1. Yakovis L.M. Multi-level production management (condition, problems, prospects)//Automation in industry. 2009. № 9. p.15-22
2. PID Control for Multivariable Processes // Qing-Guo Wang [et al.] Springer-Verlag. 2008. p.266
3. Yusupbekov N.R., Marakhimov A.R., Igamberdiev H.Z., Umarov S.X. Application of Soft-computing Technologies to the Traffic Control System Design Problems // Procedia Computer Science 102, c. 540-546. DOI: 10.1016/j.procs.2016/09.440.
4. Dozortsev V.M., D.V. Kneller. ARS - advanced process control // Sensors and systems. 2005. № 10. p.56-62
5. Yusupbekov N.R., Marakhimov A.R., Gulyamov Sh.M., Igamberdiev H.Z. APC fuzzy model of estimation of cost of switches at designing and modernization of data- computing network / 4th International Confernce on Application of Information and Communication technologies, AICT2010, 5612015, DOI: 10.1009/ICAICT.2010. 5612015.
6. Yakovis L.M., Sporyagin K.V. Setting up typical regulators for multi-link control objects//Mechatronics. Automation. Management. 2009. №6. p.55-63

7. Siddikov I.X., Umurzakova D.M., Mathematical Modeling of Transient Processes of the Automatic Control System of Water Level in the Steam Generator // Universal Journal of Mechanical Engineering. ISSN: 2332-3361 (Online), Volume 7. No.4. 2019 y., P. 139-146. DOI: 10.13189/ujme.2019.070401.
8. Siddikov I.X., Umurzakova D.M. The Research on the Dynamics of the Three-impulse System of Automatic Control of Water Supply to the Steam Generator When the Load Changes // Journal of Physics: Conference Series. 1706 (2020) 012196. doi:10.1088/1742-6596/1706/1/012196.
9. Khalmatov D.A., Yunusova S.T., Atajonov M.O., Huzanazarov U.O. Formalization of the cotton drying process based on heat and mass transfer equations//IIUM Engineering Journal, Vol. 21, No. 2, 2020. P.256-265. https://doi.org/10.31436/iiumej.v21i2.1456
10. Fokin A.L., Kharazov V.G. Management of a linear object with a lag. Automation and modern technologies. 2002. №5. p.5-10
11. Siddikov I.X., Umurzakova D.M. Fuzzy-logical Control Models of Nonlinear Dynamic Objects // Advances in Science, Technology and Engineering Systems Journal, Vol. 5, No. 4, 419-423 (2020). DOI: 10.25046/aj050449.
12. Khlebnikov M.V. Suppression of limited external disturbances: linear dynamic controller for output//Automation and telemechanics. 2011. №4. Page 3-10.
13. Goodall D.P., Postoyan R. Output feedback stabilization for nonlinear time-delay sestems subject to input constraints // Int. Joornal of Control. 2010.Vol.83, N.4.P. 676-693.
14. I.Kh.Siddikov, D.A.Khalmatov, U.O.Khuzhanazarov, G.R.Alimova. System of Analytical Control and Control of Technological Parameters of Cotton-Cleaning Production // International scientific and technical journal “Chemical technology. Control and management”. 2020, №5-6 (95-96). P.134-139.
15. I.Kh.Siddikov, N.Yu.Mamasodikova, M.A.Khalilov, A.K.Amonov, G.B.Sherboboyeva. Formalization of the task of monitoring the technological safety of industrial facilities in conditions of indistinctness of the initial information // Journal of Physics Conference Series, Volume 1679, Cybernetics and IT.
16. Siddikov I.X., Umurzakova D.M., Bakhrieva H.A., Adaptive system of fuzzy-logical regulation by temperature mode of a drum boiler // IIUM Engineering Journal, Vol. 21, No. 1, 2020. P. 185-192. https://doi.org/10.31436/iiumej.v21i1.1220.
17. X. Siddikov, G. B. Sherboboyeva, M. B. Rustamova. Synthesis of a terminal control system for discrete nonlinear objects with PWM modulation. ASEDU 2020 Journal of Physics: Conference Series 1691 (2020) 012040 IOP Publishing. doi:10.1088/1742-6596/1691/1/012040.