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MULTI-MODE REGULATION OF THE DRYING PROCESS OF INDUSTRIAL GAS

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Abstract. *Currently, much attention is paid to the issue of energy efficiency of gas processing enterprises. The continuous growth of world prices for energy resources requires constant improvement of the management system, providing the most optimal conditions for the flow of technological processes. A conceptual model of the heat-mass transfer process occurring in the absorber as an object of research has been developed, which characterizes the relationship of the variables involved in the drying process of natural gas, control, measurable and immeasurable, as well as controlled parameters have been selected, which are used to develop and study a mathematical model of the controlled drying process of natural gas in the absorber. The developed mathematical models make it possible to predict the behavior and control of a technological unit under various modes of its operation. A system of multi-mode control of the natural gas drying process is proposed, which ensures the maintenance of the specified parameters of the drained gas in wide changes in technological parameters such as pressure, temperature and flow.*

Key words: *gas drying, absorber, automation, mathematical model, energy efficiency, regulation, multi-mode.*

Annotatsiya: *Ayni paytda gazni qayta ishlash korxonalarining energiya samaradorligi masalasiga katta etibor qaratilmoqda. Energiya resurslariga jahon narxlarining uzluksiz o‘sib borishi texnologik jarayonlar oqimi uchun eng maqbul sharoitlarni taminlovchi boshqaruv tizimini doimiy ravishda takomillashtirishni talab qiladi. Tadqiqot obyekti sifatida absorberda sodir bo‘ladigan issiqlik massasini uzatish jarayonining kontseptual modeli ishlab chiqilgan bo‘lib, u tabiiy gazni quritish jarayonida ishtirok etuvchi o‘zgaruvchilar, nazorat, o‘lchash va o‘lchash mumkin bo‘lmagan, shuningdek boshqariladigan parametrlar bilan bog‘liqligini tavsiflaydi. Rivojlangan matematik modellar texnologik birlikning turli xil ish rejimlarida ishlashi va boshqaruvini bashorat qilish imkonini beradi. Tabiiy gazni quritish jarayonini ko‘p rejimli boshqarish tizimi taklif qilinmoqda, bu bosim, harorat va oqim kabi texnologik parametrlarning keng o‘zgarishida drenajlangan gazning belgilangan parametrlarini saqlashni ta'minlaydi.*

Tayanch so‘zlar: *gazni quritish, absorber, avtomatlashtirish, matematik model, energiya samaradorligi, tartibga solish, ko‘p rejimli.*

Аннотация: *В настоящее время вопросу энергоэффективности газоперерабатывающих предприятий уделяется большое внимание. Непрерывный рост мировых цен на энергоресурсы требует постоянного совершенствования системы управления, обеспечивающей наиболее оптимальные условия протекания технологических процессов. Разработана концептуальная модель процесса тепломассопереноса, происходящего в абсорбере, как объекта исследования, которая характеризует взаимосвязь переменных, участвующих в процессе осушки природного газа, контрольных, измеримых и неизмеримых, а также выбраны контролируемые параметры, которые используются для разработки и изучите математическую модель управляемого процесса осушки природного газа в абсорбере. Разработанные математические модели позволяют прогнозировать поведение технологического агрегата и управлять им при различных режимах его работы. Предложена система многорежимного управления процессом осушки природного газа, обеспечивающая поддержание заданных параметров осушаемого газа при широких изменениях технологических параметров, таких как давление, температура и расход.*

Ключевые слова: *осушка газа, абсорбер, автоматизация, математическая модель, энергоэффективность, регулирование, многорежимность.*

Introduction

At present, the development and implementation of process automation systems for gas processing facilities is becoming particularly relevant due to the high energy intensity. The greatest energy consumption occurs in absorption columns,

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where natural gas is dried, which is the most important technological process. Natural gas extracted from underground is saturated with wet droplets and heavy impurities, which can cause undesirable situations when preparing gas for consumption, which significantly affect the quality of industrial gas.

These factors determine the high quality requirements for the preparation of natural gas for industrial use. The continuous nature of gas processing production, as well as the variability of dynamic properties and external influences, requires constant optimization of the operating modes of technological equipment during the operation of the entire automation complex, which determines the creation of new or improvement of existing automatic control systems based on modern control methods with the involvement of information technology achievements [1].

The existing control systems for the technological process of gas drying in the gas processing industry do not allow for a tangible effect, which requires the development of a gas drying process control system taking into account the physical characteristics of the controlled process.

Currently, when developing control systems for the drying process of industrial gases, the main attention is paid to static and dynamic models of individual technological equipment [2].

It is known that static process models determine the main material flows during the normal operation of the units, and dynamic models are formed on the basis of linearization of dependencies with minor deviations from the stationary states of technological parameters provided for by technological regulations and they are used only for the development of local control circuits. On the other hand, various disturbing factors affect the technological process of drying natural gas, such as changes in the technological regime, moisture content and gas pressure, and others that are uncertain and probabilistic. These and other factors make it necessary to develop adequate dynamic models of the natural gas drying process, taking into account the multiphase nature of interacting material flows, the distribution of parameters and the nonlinear relationship of physical quantities, which are the mathematical basis for designing a control system for multi-mode objects. In this direction, a number of fundamental studies have been carried out to improve the technology of natural gas processing [3,4].

The scientific work of many scientists is devoted to the issues of modeling and control of dynamic objects [5,6], where the main attention is paid to the management of technological processes that have a quasi-established character and insufficient attention is paid to the action of disturbing influences (changes in the technological regime, moisture content and gas pressure, etc.), leading to significant deviations of the process from the stationary regime, which causes the creation of highly efficient control systems, taking into account uncertainty, changes in external influences and internal properties of controlled parameters.

Solution method

An important stage in the construction of a process control system is the analysis of physical processes occurring at the facility in order to determine the relationship of variables to identify regulated and regulatory parameters, on the basis of which a conceptual model of controlled processes is being developed. At the same time, the conceptual model, which is an abstract model of the process, reflects the basic physical laws of the process of absorption drying of natural gas, establishes causal relationships to the method of regulated and regulatory parameters, as well as external disturbing influences.

The main disturbing effects of the natural gas drying process include changes in the operating mode of the technological unit- absorber, the speed of the phases moving through the interaction zones, reservoir pressure and temperature, gas composition and concentration, and others.

When natural gas is dried, heat and mass transfer processes occur in the absorber, which are represented by a nonlinear system of partial differential equations [7]. The dynamic model of the natural gas drying process characterizes the dependence of the change in the drying rate of gas on its flow rate, temperature and pressure and is represented as:

$$v_{\Gamma}\left(\overline{Q}_{\Gamma}, \theta_{\Gamma}, \mathrm{p}_{\Gamma.\mathrm{p}}\right) = \frac{V_m \overline{Q}_{\Gamma}(\theta_0 + \theta_{\Gamma}) p_0}{0{,}785 \theta_0 p_{\Gamma.\mathrm{p}} D^2}, \quad (1)$$

Where $\overline{Q}_{\Gamma}$ is the gas consumption; θ_{Γ}- the operating temperature of the gas; $p_{\Gamma.\mathrm{p}}$- the operating pressure of the gas; – $V_m = 22.4$ – the volume of a mole of ideal gas under normal conditions; $\theta_0=273$ – normal temperature; p_0 – normal pressure; D – the diameter of the column.

With this in mind, using the relations [8,9], we obtain a continuously discrete model of a controlled process in the following form:

$$
\begin{aligned}
&dC_{ц.г\ i+1}/dt = -\big((v_г/h) + R_г(v_г)\big)C_{ц.г\ i+1} + R_г(v_г)E_pC_{ц.а\ n-i} + (v_г/h)C_{ц.г\ i}\ ;\\
&dC_{ц.а\ i+1}/dt = -\Big((f\,(u)/h) + R_aE_p\Big)C_{ц.а\ i+1} + R_aC_{ц.г\ n-i} + \big((f\,(u)/h)\big)C_{ц.а\ i}\ ;\\
&dC_{ц.п\ i+1}/dt = -\big((v_п/h) - R_п\big)C_{ц.п\ i+1} + (v_г/h)C_{ц.п\ i} - R_пEC'_{ц.а\ n-i}\ ;\\
&dC'_{ц.а\ n-i}/dt = -\big((v_a/h) - R'_a(v_a)E\big)C'_{ц.а\ i+1} + (v_a/h)C'_{ц.а\ i} - R'_a(v_a)C'_{ц.а\ n-i}\ ,
\end{aligned}
\qquad (2)
$$

where $i=0, ..., n-1$; E_p, E – phase equilibrium coefficients; $f(u)$ – control action; h – sampling step; $C_{ц.п}$ – concentration; $C_{ц.г}$ – concentration of the target component; $v_г$ – gas velocity; $R_г$– physico-technological coefficient of gas; R_a– physico–technological absorber.

The developed mathematical model of the absorption process makes it possible to predict changes in the operating parameters taking into account the physico-chemical properties of the reagents, as well as the condition of the equipment on the basis of which it is possible to determine the optimal parameters of the regulated parameters, which significantly reduce energy consumption for the gas drying process.

Based on the analysis of the mathematical model of the process that characterizes the static mode of operation of the equipment, the operating parameters of the unit are determined. The main thing is to maintain high stability of the temperature of the gas stream, as well as the absorption process by maintaining the maximum possible temperature difference at the inlet and outlet of the absorption column.

The control object under study is characterized by various production situations caused by changes in the technological modes of the units, external influences (flow rate, temperature and pressure of gas) and internal factors. The change in internal disturbing effects is associated with a change in the design features of the installation during the operation of the system. To maintain the required values in a wide range of changes in external influences, it is advisable to use methods of multi-mode control of dynamic objects.

When using the principle of multi-mode regulation for the management of technological objects, the law of regulation is selected from a set of regime regulators, taking into account the technological regulations and production situations for a given time.

The choice of a particular law of regulation occurs on the basis of formulated information features, according to the current state of the aggregate and external factors. A multimode controller consists of a set of (linear, discrete and nonlinear) control laws that generate the desired control signal in accordance with the current dynamic production situation and the technological mode of operation of the unit. To analyze dynamic situations, an analyzer of production situations has been added to the multimode controller, designed to select the necessary local controller that ensures the desired behavior of the process.

The input of the multimode controller is fed:

- information about unmeasurable data obtained from laboratory analysis or from a database corresponding to technological regulations;
- information about measured values obtained from sensors installed on aggregates;
- information on the qualitative assessment of the products obtained, i.e. the concentration and humidity of natural gas obtained from underground and drained gas.

Based on this information, the dynamic situation analyzer processes this data, recognizes the image of production situations and makes decisions about the current state of the dynamic production situation. This solution will serve as the basis for connecting the required local controller, which is configured for this production situation.

It should be noted that the actual operating technological facilities have been confirmed for various impacts having a probabilistic and random nature.

This circumstance determines the use of fuzzy regulators to control the technological process of drying natural gas.

On the other hand, when using fuzzy controllers, some difficulties arise related to the choice of the membership function for the formation of terms of a linguistic variable, since the informativeness of the response surface of the membership function directly depends on the number of terms. The greater the number of terms, the higher the quality of information processing by the fuzzy controller. However, this circumstance leads to an increase in the number of terms, which, accordingly, leads to an increase in the volume of the rule base.

It is known that the volume of the fuzzy controller rule base depends on the number of input, output variables and the number of terms. As the number of terms and input variables increases, the number of rules increases

It follows from this that the use of one fuzzy controller in the control of the natural gas drying process does not ensure optimal operation of the absorber, because each mode of operation of the object is characterized by a wide range of changes in the regulated parameters and external conditions. In addition, the fuzzy controller is limited by a rigid range of input effects. If a multimode fuzzy controller consists of three fuzzy controllers, each of them contains five terms, then the total number of the rule base is seventy-five rules, and when using one fuzzy controller, the number of rules will be equal to two hundred and twenty-five [10-13].

In this regard, in order to reduce the number of rules in the work, a hybrid application of the principle of multimode regulation with the method of fuzzy regulation with a changing structure is proposed. A distinctive feature of a multimode fuzzy controller with a variable structure is that the control signal generated by the controller has a high sensitivity to changes in input signals during the operation of the control object.

The rule bases of fuzzy controllers of a multimode fuzzy controller were formed on the basis of a fuzzy PID controller. The control actions generated by a multimode fuzzy controller are formed using the error value of the control signal and its derivative. Switching to the necessary control law in a multimode fuzzy controller is implemented based on the analysis of dynamic situations, where a control action is formed and sent to the switchboard to connect the corresponding fuzzy controller.

To reduce the information processing time in the dynamic situation analysis unit and the delay time on the switches, it is necessary to reduce the number of terms of linguistic variables of the database and its BM. This is achieved by switching input variables to a block with the smallest range of changes in the processed input signals.

The input of the control gain receives information about the magnitude of the adjustment error, the setting and device disturbing influences *s(t)* and *f(t)*, as well as information about the adjustable value y, about the intermediate coordinates of the object y_1, y_i, and the actuator μ_1,, μ_k.

At the same time, depending on the change in the magnitude and sign of the input signals, changes in the structure of the control system are carried out, thanks to which the quality of the control process of the technological object is improved.

It follows that, depending on the appropriate algorithm and the available information about the process, the system will have one or another structure. In this approach, the system combines the useful properties of each of the existing set of structures, and allows you to get new properties that are not inherent in any of them. Due to this, the quality of management of the technological object is significantly improved.

To recognize changes in the control error and its derivative, a fuzzy controller is proposed in the work, built on the principle of fuzzy logic inference of the Mamdani type [14,16].

Thus, in order to ensure the required quality of control of the technological parameters of the absorber, control variables are changed using several fuzzy controlletes, each of which ensures optimal control quality in certain operating modes. Taking into account the above, a block diagram of a multimode fuzzy controller with a variable structure has been developed (see Fig.1).

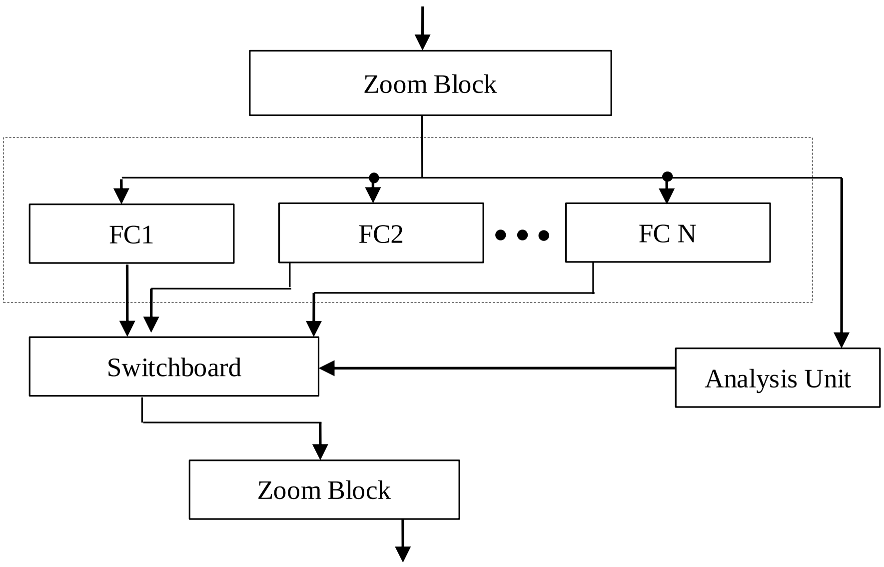

Fig.1. The structure of a multi-mode fuzzy controller with a variable structure

The structure of a multimode fuzzy controller is changed when the magnitude and sign of the signal change. Using this approach allows you to get the process of regulation without hesitation and over-regulation of the transition process.

It should be noted that such systems belong to the class of nonlinear systems, due to the automatic switching of the law due to regulation. In the process of functioning of the system, such systems have certain positive properties, unlike the classical ones, which can significantly improve the quality of management.

Results

Let's consider the possibilities of implementing the proposed expense in the process management task.

In order for a certain regulation law to be fulfilled in each range, it is necessary to divide the temperature range of the absorber into separate sections. Each section will correspond to the necessary regulation regime.

Simulations have shown that the multi-mode fuzzy controller for the control channel satisfies the required control quality.

Multi-mode control based on mathematical model is performed using the control function. In each mode, the signal corresponds to the P- control law, which provides the required gas-absorbent flow ratios. The generated nonlinear characteristic of the controller allows you to obtain the necessary indicator in any permissible mode and does not require switching.

Conclusion

The application of a multimode fuzzy controller is proposed, which includes several fuzzy controllers, each of which is configured for a certain range of changes in external conditions, and dynamic properties for controlling technological objects operating in a wide range of variable changes.

To regulate technological parameters that vary in a wide range, the principle of multi-mode regulation is proposed, based on the selection of the necessary regulation law from a set of regime regulators depending on production situations.

The practical value of the obtained results lies in the absorption drying of natural gas, which makes it possible to explain and predict the behavior of the complex under various external factors that determine the modes of operation of the technological process. A system of multi-mode control of the technological process of natural gas drying is proposed, which ensures the maintenance of the specified parameters of the drained gas in wide changes in technological parameters such as pressure, temperature and flow.

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ADAPTATION ALGORITHM FOR SELF-TUNING OF PARAMETERS OF MODELS OF MULTI-STAGE FLOTATION PROCESSES

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Abstract: *Modern methods for solving problems of planning the execution of batches of tasks in multi-stage systems are characterized by the presence of restrictions on their dimensionality, the impossibility of guaranteed obtaining better results in comparison with fixed packages for different values of the input parameters of the problem. In the article, the author solved the problem of optimizing the composition of job packages running in multi-stage systems using the branch and bound method. Research has been carried out on various ways to form package execution orders tasks in multi-stage systems (heuristic rules for ordering packages tasks in the sequence of their execution on MS devices). A method has been determined ordering packages in the sequence of their execution (heuristic rule), ensuring minimization of the total time for implementing actions with them on devices Based on the obtained rule, a method is formulated for ordering task types, according to which their packages are considered in the method procedure branches and boundaries. A mathematical model of the process of implementing actions with packages on the devices of the system, which provides calculation of its parameters.*

Key words: *analysis, management of multistage processes (MSP), flotation, optimization, automated control system, digital technologies.*

Annotatsiya: *Ko'p bosqichli tizimlarda vazifalar paketlarini bajarishni rejalashtirish muammolarini hal qilishning zamonaviy usullari ularning o'lchamlari bo'yicha cheklovlar mavjudligi, kirish parametrlarining turli qiymatlariga yega bo'lgan sobit paketlarga nisbatan kafolatlangan yaxshi natijalarga yerishishning mumkin yemasligi bilan tavsiflanadi. muammolar. Maqolada muallif ko'p bosqichli tizimlarda bajariladigan vazifalar paketlarining tarkibini filiallar va chegaralar usuli bilan optimallashtirish muammosini hal qildi. Ko'p bosqichli tizimlarda paketlarni bajarish uchun buyurtmalar vazifalarini shakllantirishning turli usullarini o'rganish (paketlarning vazifalarini MS qurilmalarida bajarish ketma-ketligida buyurtma qilishning yevristik qoidalari) amalga oshirildi. Paketlarni ularni bajarish ketma-ketligida buyurtma qilish usuli (yevristik qoida) aniqlanadi, bu ular bilan qurilmalarda harakatlarni amalga oshirish uchun umumiy vaqtni minimallashtiradi. Olingan qoida asosida vazifa turlarini buyurtma qilish usuli shakllantiriladi, unga ko'ra ularning paketlari usul protsedurasining tarmoqlari va chegaralarida hisobga olinadi. Tizim qurilmalarida paketlar bilan harakatlarni amalga oshirish jarayonining matematik modeli, uning parametrlarini hisoblashni ta'minlaydi.*

Kalit so'zlar: *tahlil, ko'p bosqichli jarayonlarni boshqarish (MSP), flotatsiya, optimallashtirish, avtomatlashtirilgan boshqaruv tizimi, raqamli texnologiyalar.*

Аннотация: *Современные методы решения задач планирования выполнения пакетов задач в многоступенчатых системах характеризуются наличием ограничений на их размерность, невозможностью гарантированного получения лучших результатов по*

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