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ABSTRACT

of the dissertation for a degree of Doctor of Philosophy

DEVELOPMENT OF A CONTROL SYSTEM TAKİNG İNTO ACCOUNT THE FACTOR OF THE DECİSİON-MAKER

Specialty **:** 3338.01- Systematic analysis, control and processing of information (Control and decision making)

Field of science: Technics

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GENERAL CHARACTERISTICS OF THE WORK

Relevance of the topic and development degree . Decision-making is one of the modern research areas in which interests have increased significantly recently. The basis of this problem is the importance of the role that decision-making plays in everyday human activities. In reality, the decision-making process is associated with a mental (mental) and practical situation when it is necessary to act in constantly changing conditions when there is no complete information about the problem.

There is a need to use information from related scientific fields to develop the conceptual, theoretical basis of practical decision-making procedures (DM). Further development of decision-making theory involves and even requires the development of a number of new approaches and research, including theoretical and practical problems.

In the process of making management decisions, the factor of the decision-maker plays an important role. Although sufficient attention has been paid to the study of the decision-making ability(DMA) of the decision-maker, the study of its psychological and physiological determinants, and the determination of the decision-making ability of the decision-maker, their application in the management of many specific production areas has not been widely applied. The production of liquid oxygen, argon, and nitrogen of the technical gas plant (TQP) of the Sumgayit Technology Park (STP) was selected as the research and application area of the decision-making ability of the State Administration of Agriculture.

The production of liquid oxygen, argon, and nitrogen itself is of interest as a research object. Although a modern management system has been implemented in that production, many issues have not been resolved.

It is important to consider the management of that area and decision-making of operative personnel as a research object in the form of a whole system.

The purpose of the study. The aim of the dissertation work called development of the management system taking into account the factor of DMP - the creation of methods and tools that allow determining the decision-making ability of the DM, the research of TQP as a management object for the production of oxygen, argon, nitrogen, and the solution of the following issues for the creation of a management system :

- determination of the psychological and physiological characteristics of the DM;
- Determination of weight coefficients of psychological and physiological characteristics affecting decision-making;
- Determination of terms and appropriate coefficients of all factors affecting decision-making with the help of experts;
- Development of decision-making capacity determination algorithms;
- Studying the production area as a management object;
- Acquisition of mathematical models of the technological process;
- Establishing and solving the problem of process optimization;
- Development of the expansion turbine start-up and regulation system;
- of the developed method and algorithms.

The research object is the oxygen, argon, nitrogen production of the Technical Gas plant of the Sumgayit Technology Park and its operational personnel.

Research methods. The Decision-making theory, automatic control theory, operations research methods, fuzzy identification and optimization methods, MATLAB and other research tools were widely used to solve the problems posed in the thesis work.

The main provisions defended :

1. Determination of the psychological and physiological determinants of DM;
2. Designation and application of the DM to the management system of the DMA;
3. Studying, identification, and optimization of TQP as a management facility for oxygen, argon, and nitrogen production;
4. Development of startup and regulation algorithms of the expansion turbine;
5. Development of simulation tools for experimental study of control system.

Scientific innovations of research. The scientific innovations of the dissertation consist of the following:

- On the basis of expert opinion, the indicators characterizing the DMP were determined, and the effect of each of them on the Decision-making was investigated.
- A method, algorithm, and program were developed to determine the decision-making ability of the DM.
- Oxygen, argon, nitrogen production of Sumgayit Technology Park (STP) Technical Gases plant was studied as a management object, its characteristic features were determined;
- Fuzzy mathematical models of the rectification cable under conditions of uncertainty were obtained, based on those models, the issue of fuzzy optimization of the rectification cable was set and solved;
- In the production of liquid oxygen, argon and nitrogen at the technical gases plant, a fully automatic start-up and regulation system of the expansion turbine was developed;
- Algorithms and programs for the software implementation of transfer functions were developed for the simulation study of the automatic regulation system in the environment of Step 7 and WinCC flexible tandem.

Theoretical and practical significance of research. The production of oxygen, argon, and nitrogen of the TQP of STP was studied, mathematical models were obtained and the issue of optimization was worked out. The psychological and physiological factors of DM, the weight coefficients of those factors were determined, and the DMA of DM was determined based on the weight coefficients.

Production start-up algorithms have been studied and it has been determined that one of the important stages, the start-up of the expansion turbine, uses tedious manual labor. For this purpose, keeping the existing management method as a reserve, a system was created that fully automatically implements the turbine start-up and adjusts it in the working mode as well.

The scientific results obtained in the thesis work were tested in the production of oxygen, argon, and nitrogen of TQP. The received theoretical and practical results can be used in the management of similar processes.

Dissertation work approbation. The main results of the work were presented at the XIX scientific conference of doctoral students and young researchers (Baku, April 7-8, 2015); Mathematics application issues and new information technologies at the III Republican Scientific Conference (Sumgait, December 15-16, 2016); SSU, Sustainable development of the economy. Problems, perspectives. International scientific conference April 27-28, 2016); XX Republican scientific conference of doctoral students and young researchers (Baku-2016); XXI Republican scientific conference of doctoral students and young researchers. (BSU October 24-25, 2017); International scientific and technical conference dedicated to the Day of Chemistry and the 40th anniversary of the Department of Chemical and Technological Processes of the branch of the Ufa State Oil Technical University (Ufa, Salavat, May 26, 2017); SSU, current issues of applied physics and energy. International Scientific Conference (Sumgait, May 24-25, 2018); Azerbaijan University of Architecture and Construction. International scientific-practical conference " Possibilities and perspectives of application of information technologies and systems in construction " . (Baku, July 5, 2018); International conference on "Information systems and technologies achievements and perspectives". (Baku, November 15-16, 2018); " Information systems and technologies: achievements and perspectives " international scientific conference (Sumgait, July 09-10, 2020); "Issues of application of mathematics and new information technologies" republican scientific conference (Sumgait, December 09-10, 2021) ; " Information systems and technologies: achievements and perspectives " III international scientific conference (Sumgait, 08-09 December 2022) ; reported and discussed.

The name of the institution where the dissertation work was performed. Dissertation work was performed at the Department of Process Automation of Sumgayit State University.

The structure and scope of the dissertation.

The dissertation consists of an introduction, five chapters, conclusions, a list of used literature and appendices. The dissertation has a total of 167,567 characters, introduction 17,417 characters, chapter I – 54,626 characters, chapter II 21,532 characters, chapter III 29,852 characters, chapter IV 21,053 characters, chapter V 19,521 characters, conclusion consists of 3,718 characters, as well as 53 pictures and 12 tables.

CONTENTS OF THE WORK

In the introduction , the actuality of the dissertation topic is - justified , the purpose of the research is explained, the main issues that need to be solved are defined, the main terms defended are indicated, and the scientific innovations and practical significance of the obtained results are indicated.

In the first chapter , modern scientific works and practical works in the field of decision-making methods, the study of management decision-making, the development of optimal management systems and employment were examined, the gaps in this field were identified by analysis, and the purpose and issues of the dissertation were determined.

In the second chapter, the essence of decision-making is explained and the physiological and psychological factors affecting decision-making in the relevant field - mood, responsibility, self-confidence, determination, professionalism, fatigue-sleeplessness, relationship with management are determined based on expert opinion[1].

Let's assume that $B=\{b_1, b_2,...,b_l\}$ is a set of factors that express the psychological and physiological state of a person, $A=\{a_1, a_2...,a_n\} \subset B$ is the decision-making function of the DM working in the field under consideration there are many factors that influence it.

There are various methods of determining the weight coefficients of factors, including ranking, pairwise comparison. Due to its simplicity and ease, pairwise comparison method is mostly used. The essence of the method is to compare all the factors with each other and determine whether one is superior (or weaker) than the other and draw up a pairwise comparison matrix (Table 1).

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[1] Alakbarli, F.H, Askarova, S.F, Hajiyeva, E.M, Characteristic features affecting decision-making. //- SSU: Scientific news, Sumgayit:-2016, volume 16, #4, -p. 61-64.

Here λ_{ij} - is a numerical quantity indicating the superiority (weakness) of ***a_i*** factor in the *i*- th row over ***a_j*** factor in *j* -th column . Its quantity is determined differently in different sources . λ_{ij} For example:

1. If the factor ***a_i*** exceeds the factor ***a_j*** , then $\lambda_{ij} = 1$ and $\lambda_{ji} = 1 - \lambda_{ij} = 0$ is taken;
2. If the factor ***a_i*** exceeds the factor ***a_j*** , then $\lambda_{ij} = a \left(a \in R, R = [0,1] \right)$ and $\lambda_{ji} = 1 - \lambda_{ij} = 1 - a$ is taken.

Table 1.

Pairwise comparison matrix

Factors	***a 1***	***a 2***	…	***a n***	$\sigma_i = \sum_{j=1}^{n} \lambda ij$	$\alpha_i = \frac{\sigma_i}{\sigma}$
a 1	λ_{11}	λ_{12}		λ_{1n}	$\sigma_1 = \sum_{j=1}^{n} \lambda_1 j$	$\alpha_1 = \frac{\sigma_1}{\sigma}$
a 2	λ_{21}	λ_{22}		λ_{2n}	$\sigma_2 = \sum_{j=1}^{n} \lambda_2 j$	$\alpha_2 = \frac{\sigma_2}{\sigma}$
: :	: :	: :	: :	: :	: :	: :
a n	λ_{n1}	λ_{n2}		λ_{nn}	$\sigma_n = \sum_{j=1}^{n} \lambda nj$	$\alpha_n = \frac{\sigma_n}{\sigma}$
					$\sigma = \sum_{i=1}^{n} \sigma_i$	

allows not only to express the complete superiority (weakness) of one factor over another, but also to evaluate the partial superiority (weakness) of one factor over another, but also to evaluate the comparative voice of the same strong factors in pairs. In this case $\lambda_{ij} = \lambda_{ji} = 0.5$ it is taken. Another point is that $\lambda_{ii} = 1$ while it is taken in some sources, that place of the matrix is kept empty in others.

Studies show that λ_{ii} although the value of the quantity affects the value of the weight coefficients of the factors, it does not affect the decision-making result.

Based on the pairwise comparison matrix of the factors, their weight coefficients are also determined in different ways[2]. In the dissertation work, it is defined as follows: the sum of the numbers on the rows of the comparison matrix

$$\sigma_i = \sum_{j=1}^{n} \lambda ij \tag{1}$$

the expression, then

$$\sigma = \sum_{i=1}^{n} \sigma_i \tag{2}$$

the sum of the numbers in the column with the formula and

$$\alpha_i = \frac{\sigma_i}{\sigma} \tag{3}$$

weight coefficients are determined by the expression

The following algorithm is proposed to determine the decision-making ability of the DM according to the weighting coefficients of the factors:

- For each of the selected factors, a tuple of terms used by DMP is defined:

$$a_i = (t_i^1, t_i^2, \ldots, t_i^k) \qquad (4).$$

The number of terms of linguistic variables characterizing technical systems is usually odd (for example, 3, 5, 7, etc.) and symmetrical. A tuple of coefficients corresponding to the tuple of terms of each factor is compiled. Components of a procession Takes values in [-1 ,1]. For example: (t_1, t_2, t_3) the coefficients corresponding to the

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[2] Alekbarli FH, Askarova SF Method of determination of decision-making ability.// SSU. "Information systems and technologies: achievements and perspectives" International scientific conference. Sumgait: November 15-16, 2018. pp. 84-89.

tuple of ternary symmetric terms $\beta = (-1,0,1)$ are quintuple $(t_1, t_2, t_3, t_4, t_5)$ terms a tuple of coefficients corresponding $\beta = (-1,-0.5,0,0.5,1)$ to the tuple and so on. will be. The components of the tuple of coefficients corresponding to the tuple of non-symmetric terms take values depending on the direction and the number of terms . For example, the tuple of terms $\beta = (-1,-0.75,-0.5,-0.25,1)$ (4) will be like the tuple of operations.

$$p = \sum_{i=1}^{n} \alpha_i \beta_i^j \qquad (5)$$

- The ability indicator of DMP is calculated by expression (5). - α_i the weight coefficient of factor β_i^j ***a i*** that affects decision-making , - is the coefficient corresponding to the term related to the DMP of that factor.

If it is $p > 0$, it is determined that the DM has the decision-making capacity, and if it does not, it is determined that it does not have the decision-making capacity. $p \leq 0$

Pairwise comparison coefficients (Table 2), their terms and corresponding coefficients (Table 3) of all factors influencing decision-making were determined with the help of experts. A program named QQŞQQV was designed in JAVA HTML programming language to determine the DMA of the DM[3]. Factors affecting decision-making and linguistic terms corresponding to each factor appear on the screen (pictures 1, 2).

Among the factors in Figure 1, Professionalism was evaluated as "good", tired "partially", determination "completely determined", health "Healthy", relationship with management "normal", mood

[3] Askarova, SF, Alakbarli, FH Determining the decision-making ability of the decision-maker./Azerbaijan Technical University: Journal of scientific works, - - Baku: 2019.- #1, -p.210-216

"normal", Family-household concerns "partial" and as a result "Decided to be left" was received.

Among the factors in Figure 2, professionalism was evaluated as "none", fatigue as "partial", determination as "completely determined", relationship with management as "very good", health as "healthy", morale as "good", Family and household concerns as "none" and as a result, "Not allowed to make a decision" was received

Table 2

Pairwise comparison matrix of the considered example

Psychological and physiological factors.	Professionalism	Tiredness	Determination	Relationship with management	Health	Mood	Family-household concerns	σ_i	α_i
Professionalism	-	1	1	1	1	1	1	6	0.28
Tiredness	0	-	0.4	0.2	0.7	0.3	0.8	2.2	0.1
Determination	0	0.6	-	0.3	0.5	0.6	0.5	2.5	0.12
Relationship with management	0	0.8	0.7	-	0.85	0.7	0.3	3.35	0.16
Health	0	0.3	0.5	0.15	-	0.5	0.7	2.15	0.1
Mood	0	0.7	0.4	0.3	0.5	-	0.6	2.5	0.12
Family-household concerns	0	0.2	0.5	0.65	0.3	0.4	-	2.05	0.09
σ								20.75	

Table 3.

Table of factors, terms and coefficients

Psychological and physiological situations	Terms and coefficients				
	-1	-0.5	0	0.5	1
Professionalism	there is no	down	medium	good	high
Tiredness	very tired	tired	Partially	-	happy
Determination	indecisive	-	medium	-	resolute
Relationship with management	Very bad	bad	normal	good	Very Good
Health	unhealthy	-	-	-	healthy
Mood	Very bad	bad	normal	good	Very Good
Family-household concerns	there is	partially	-	-	there is no

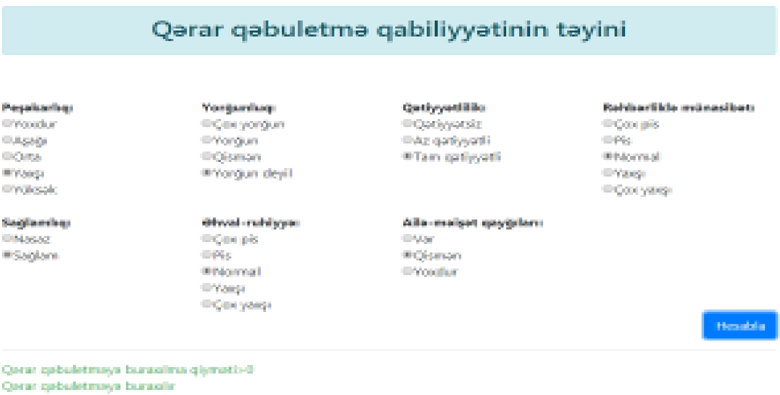

Figure 1. The psychological and physiological conditions that the DM takes to be allowed to make decisions.

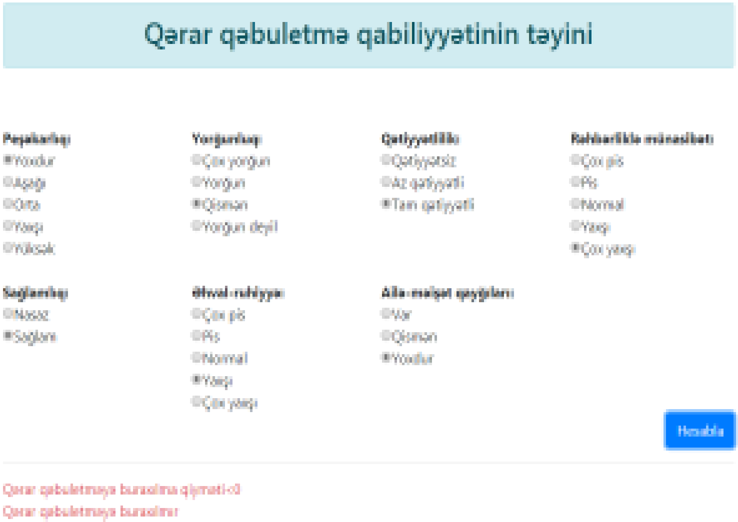

Figure 2. The psychological and physiological state of the DM to prevent it from making decisions

In the third chapter, the issue of optimization of TQP oxygen, argon, nitrogen production is solved. For this purpose, primarily technological a brief explanation of the process is considered: the air taken from the atmosphere through the compressor is first passed through the filter and cleaned of air impurities, cooled in the cooling unit, and then the air compressed in the air cleaning unit is cleaned of moisture and other impurities. Compressed air passes through the main heat exchanger at low pressure and is supplied to the braking compressor. As a result of the rectification of the compressed air in the separator (T60.1/2), the liquid product is split into oxygen, nitrogen and argon.

Liquid oxygen and nitrogen are taken from the main rectification cylinder T60.1/2 and injected into suitable vacuum-insulated liquid gas tanks D71 and D72. The products stored in these tanks are vaporized in high-pressure atmospheric vaporizers by

means of high-pressure liquid gas pumps and transferred to cylinder filling systems .
Raw argon is taken from the middle and lower parts of the T.60.2 tank in order to purify it until the required quality is obtained, in order to remove oxygen.
T60.3 argon calo nu na na . In this column, argon and oxygen are separated by rectification, raw argon gas is taken from the top of the column, and oxygen-rich liquid is collected at the bottom of the column and returned back to the main rectification column.
Thus, oxygen, nitrogen and argon, which are production products, are separated from each other, each of them is filled into cylinders as a ready product for sale after auxiliary operations and sent to the warehouse. (Figure 3).

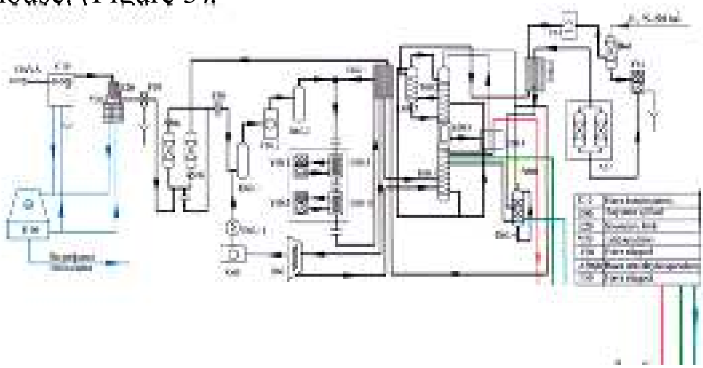

Figure 3. Scheme of the technological process

As can be seen from the explanation of the process, the separation of the target products - *oxygen, argon, nitrogen* - takes place in the rectification column. The progress of the rectification process depends on the working mode of the kalon[4]. The operating mode of the boiler is determined by the level of the product of

[4] Askarova SF Obtaining the model of nitrogen, argon and oxygen production.// XXI Republican scientific conference of doctoral students and young researchers, - volume 1. BSU, Baku, October 24-25, 2017, pp. 28-29.

temperature and pressure inside it. The goal is to get high-quality oxygen, argon, and nitrogen. In order for these products to be of good quality, a better - optimal working mode should be maintained within the regulation. Thus, depending on the degree of purity of the filter, the mode of operation of the rectification column should be set in such a way that the required quality of the received products is ensured.

As a result of the study of the process, the input and output variables characterizing it were determined.

Login settings:

X_1 - Temperature supplied to the inlet of the rectification coil (T-61) - (-200 ÷-180(^{0}C)) ;
X_2 - level in Kalon (T-61) - (23 ÷30(mbar));
X_3 - pressure in the tank (T-61) - (2.5 ÷6(bar));
X_4 - level in Alaryk calon (E-69) - (70 ÷120(mbar));
X_5 - air filter pressure (depending on the degree of cleanliness) (-0.07 ÷-0.01) (bar));

Output parameters:

Y_1 - output of argon (18 ÷23 (Nm ^{3}/h));
Y_2 - degree of purity of argon ((99.95 ÷99.99%));
Y_3 - Nitrogen extraction (500 ÷550 (Nm ^{3}/hour));
Y_4 -Nitrogen purity (99.95 ÷99.99(%));
Y_5 - Oxygen extraction (450 ÷550 (Nm ^{3}/hour));
Y_6 - Oxygen purity (99.95 ÷99.99(%));

Then the mathematical model of the process is obtained. Taking into account the uncertainty in process management, the mathematical model is assumed to be obtained as ***If-Then*** production models ***(Mamdani model).*** For this purpose, using a technologist-engineer as an expert, according to his opinion, it was considered appropriate to express all input and output parameters with 3 linguistic values: low (***a***), normal (***n***), high (***y***). With the participation of that expert, he compiled a fuzzy model consisting of 243 productions:

1. IF
" The temperature of the rectification coil ***is low*** " and
" The level in the rectification tank ***is low*** " and
“The level in intermediate kaolin E-69 is ***low*** " and
" The pressure in rectification cylinder is l***ow "*** and

"Filter cleanliness indicator is **low** *"*
THEN
" argon output **low** ", " argon purity **low** ",
"Oxygen output ***is below the norm*** ",
"Oxygen purity is **low** " , " Nitrogen output **is low** ",
"Nitrogen purity level **is low** " ;

As an example, the relation function obtained from the accepted thermal and intermediate values of the inlet temperature is given in figure 4:

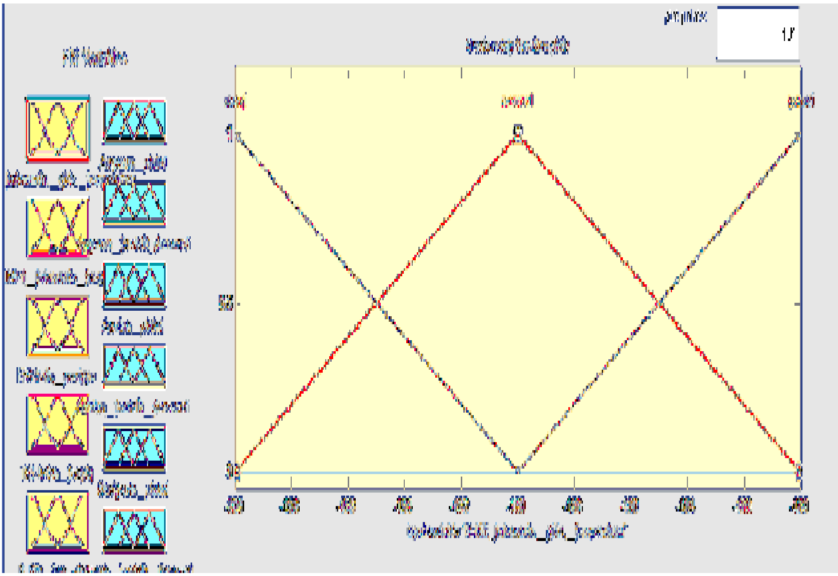

Figure. 4. Correlation function of inlet temperature.

Then, the setting and solution of the process optimization problem is considered. Depending on the demand, different optimization problems can be posed; scalar problem - determination of the best value of only one indicator, vector problem - determination of the best value of several indicators at the same time.

nitrogen or oxygen as a scalar problem and oxygen-nitrogen-argon or oxygen-argon modes as a vector problem is considered[5]. The problem of scalar optimization of the process based on fuzzy models can be expressed as follows.

given $\widetilde{x_5} = \tilde{x}_{50}$values of the degree of contamination of the filter:

$$\widetilde{y_k} = f_k(\tilde{x}_j) \rightarrow max, j = \overline{1,4}, \;\; k \in \{3,5\}$$

functional limitations:

$$\tilde{y}_i \geq \underline{\tilde{y}_j} \qquad i = \overline{1,6}, \;\; i \neq k,$$

position restrictions:

$$\underline{\tilde{x}_j} \leq \tilde{x}_j \leq \overline{\tilde{x}_j}.$$

There are different ways to solve the fuzzy optimization problem. One of them is to move to an equivalent deterministic optimization problem (for example, linear programming).

For this, fuzzy models are replaced by fuzzy models, or rather, fuzzy quantities are defuzzified and brought to deterministic quantities, and deterministic models are obtained based on them . The center of gravity method was used in the thesis work. Defuzzification with this method

$$X_c = \frac{\sum_{i=1}^{k} U_i \mu_A(U_i)}{\sum_{i=1}^{k} \mu_A(U_i)} \qquad (6)$$

is conducted according to the statement.

Here X_c - calculated defuzzification result, U_i – the value of the defuzzified variable at *the i* -th point, $\mu_A(U_i)$- is the value of the membership function at that point. Mathematical models were obtained using the Least Squares method based on statistical data based on the quantities obtained as a result of defuzzification

[5] Askarova SF Determination of the optimal working mode of the rectification column in the production of nitrogen, oxygen argon under uncertain conditions.// Sumgayit State University: Scientific news.-2018 . Volume 18, No. 4 - p. 84-88.

calculated using 10 points using a program built in the Matlab package :

y_1=-12.92-0.176x_1+0.12x_2+0.06x_3-0.0041x_4-10.35x_5

y_2=98.61-0.001x_1+0.027x_2-0.008x_3+0.002x_4-6.73x_5

y_3=379.25-0.54x_2-0.159x_2+4.368x_3+0.204x_4-0.116x_5

y_4=98.89-0.004x_1+0.003x_2+0.006x_3-0.001x_4-8.876x_5

y_5=597.77+0.139x_1-1.719x_2-4.21x_3+0.0472x_4-10.828x_5

y_6=97.02-0.01x_1+0.011x_2+0.012x_3+0.0014x_4-18.92x_5

Setting and solving the optimization problem for the liquid nitrogen regime :

Objective function:

y_3=379.25-0.54x_2-0.159x_2+4.368x_3+0.204x_4-0.116x_5 ⟶ max

Functional limitations:

y_1=-12.92-0.176x_1+0.12x_2+0.06x_3-0.0041x_4-10.35x_5 ≥ 18

y_2=98.61-0.001x_1+0.027x_2-0.008x_3+0.002x_4-6.73x_5 ≥ 99.55

y_4=98.89-0.004x_1+0.003x_2+0.006x_3-0.001x_4-8.876x_5 ≥ 99.55

y_5=597.77+0.139x_1-1.719x_2-4.21x_3+0.0472x_4-10.828x_5 ≥ 450

y_6=97.02-0.01x_1+0.011x_2+0.012x_3+0.0014x_4-18.92x_5 ≥ 99.55

Position restrictions:

$$-200 \leq x_1 \leq -180$$

$$23 \leq x_2 \leq 30$$

$$2.5 \leq x_3 \leq 6$$

$$70 \leq x_4 \leq 120$$

$$x_5 = -0.03$$

The optimal solution for the liquid nitrogen regime [135 , p.1] :

x_{1opt}=-200 ^0C , $x_{2opt} = 23mbar$ $x_{3opt} = 6bar$; $x_4 = 120mbar$;

$y_1 = 20.8\,Nm^3/saat;\quad y_2 = 99.82\%;\ y_3 = 534.3Nm^3/saat;$

$y_4 = 99.94\%;\ y_5 = 511.2Nm^3/saat;\ y_6 = 99.99\%.$

Setting up and solving the optimization problem for the liquid oxygen regime :

Objective function:

y_5=597.77+0.139x_1-1.719x_2-4.21x_3+0.0472x_4-10.828x_5 $\rightarrow$ max

Functional limitations:

y_1=-12.92-0.176x_1+0.12x_2+0.06x_3-0.0041x_4-10.35x_5 ≥ 18

y_2=98.61-0.001x_1+0.027x_2-0.008x_3+0.002x_4-6.73x_5 ≥ 99.55

y_3=379.25-0.54x_2-0.159x_2+4.368x_3+0.204x_4-0.116x_5 ≥ 500

y_4=98.89-0.004x_1+0.003x_2+0.006x_3-0.001x_4-8.876x_5 ≥ 99.55

y_6=97.02-0.01x_1+0.011x_2+0.012x_3+0.0014x_4-18.92x_5 ≥ 99.55

Position restrictions:

$$-200 \leq x_1 \leq -180$$

$$23 \leq x_2 \leq 30$$

$$2.5 \leq x_3 \leq 6$$

$$70 \leq x_4 \leq 120$$

$$x_5 = -0.03$$

The optimal solution for liquid oxygen mode:

x_{1opt}=-180 ^0C , $x_{2opt} = 23mbar$ $x_{3opt} = 2{,}5bar;\ x_4 = 120mbar;$

$y_1 = 17.06\,Nm^3/saat;\quad y_2 = 99.83\%;\ y_3 = 508.2Nm^3/saat;$

$y_4 = 99.84\%;\ y_5 = 528.7Nm^3/saat;\ y_6 = 99.84\%.$

Formulation and solution of vectorial problems

Liquid oxygen-argon-nitrogen mode and liquid oxygen-argon mode, a multi-criteria optimization problem was set with the aim of maximizing the yield of all products. The objective functions and constraint condition for both modes are as follows[6]

Liquid-oxygen-argon mode-

$$\bar{Y}^T = |Y_1; Y_3; Y_5| \to \max$$

Oxygen-argon-nitrogen mode- $\bar{Y}^T = |Y_1; Y_5| \to \max$

.

$$\bar{\psi}_{\min} \le \bar{\psi}(F, X_{opt}) \le \bar{\psi}_{\max}$$

The most common approach to evaluating multivariate alternatives is to use an incremental utility function defined by the following expression:

$$I = \bar{\alpha}\,\bar{Y} \tag{7}$$

Here - α is the vector of weight coefficient

$$\bar{\alpha} = |\alpha_1, \alpha_2, \alpha_3|$$

There are different methods of determining weighting factors. Let's look at two of them.

In the first case, the Decision Making Person (DM) determines the relative importance between the two products. A ratio of 8:1 characterizes the overwhelming importance of one product over another; 4:1 is of great importance; 2:1 – is important; 1:1 is of equal importance. Let's write all the interactions between the products using the ratio characterizing the importance of the i-th product compared to the j-th product $y_i : y_j = \alpha_i : \alpha_j$:

Oxygen-argon-nitrogen mode:

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[6] Alekberli, F.A., Optimization of the work of the rectification column of production of liquid oxygen, argon and nitrogen in various modes of functioning./ F.A. Alekberli, S.F. Askerova// Modern science: Actual problems of theory and practice» . Series: Natural and technical sciences. Mockva - 2022 , No. 8 - p. 36-41.

$$y_1^{ar} : y_3^{az} = 2:1;\ y_1^{ar} : y_5^{ok} = 2:1;\ y_3^{az} : y_5^{ok} = 2:1;$$

Liquid oxygen-argon mode:

$$y_1^{ar} : y_5^{ok} = 2:1$$

Based on the relationships written above, comparable significance tables are drawn up for both modes. In Table 4 and Table 5, i is written at the intersection of i -th row and j -th column α, and j is written at the intersection of j -th row and i -th column α. The elements of the last column of the tables are written as the sum of the elements of the corresponding rows.

$$\sigma_i = \sum_{j=1}^{n} \alpha_{ij} \tag{8}$$

Table 4.

Table of comparative significance of products in the oxygen-argon-nitrogen regime

	Y_1 arg.	Y_3 nitr	Y_5 ok	$\sigma = \sum \alpha_i$
Y_1 arg.	1	2	2	5
Y_3 nitr.	1	1	2	4
Y_5 ok	1	1	1	3

Table 5.

Table of comparative significance of products in the oxygen-argon regime

	Y_1 arg.	Y_5 ok	$\sigma = \sum \alpha_i$
Y_1 arg.	1	2	3
Y_5 ok	1	1	2

And Thus,

$$\frac{\alpha_i}{\alpha_j} = \frac{\sigma_i}{\sigma_j} \text{ and } \sum \alpha_i = 1$$

using expressions, the vectors of weighting coefficients for oxygen-argon-nitrogen and liquid oxygen-argon regimes were obtained as follows:

Oxygen-argon-nitrogen mode: $\overline{\alpha} = |0,42; 0,268; 0,312|$

Liquid oxygen-argon mode: $\overline{\alpha} = |0,575; 0,425|$

In the second case, if the technological characteristics of the enterprise do not allow DM to determine the importance of any product. In this case, the weighting factors are determined as follows without the participation of the decision maker. In the releaseable solutions option, optimization is performed for each product, the results are recorded in the form of table 6 and table 7.

Table 6

In oxygen-argon-nitrogen mode of calculated products optimal prices

	Y_1^{ar}	$Y_3^{nitr.}$	Y_5^{ok}
Y_1^{ar}	23	512.5	511.12
$Y_3^{nitr.}$	22.3	550	464
Y_5^{ok}	21.8	515.2	550

Table .7

In oxygen-argon mode of calculated products optimal prices

	Y_1^{ar}	Y_5^{ok}
Y_1^{ar}	23	511.12
Y_5^{ok}	21.8	550

The results of the optimization solution for the i -th product are written on the i -th line. Minimization is then performed again for each product. Using the following expression, all elements of the table are linearly transformed in the range [0,1] .

$$\upsilon_{ij} = \frac{Y_{ij} - Y_{i\min}}{Y_{i\max} - Y\min} \qquad (9)$$

Here υ_{ij} and Y_{ij} are the relative and absolute values, respectively, and Y imin and Y imax are the minimum and maximum values of the ith product as the results of minimization and maximization of the ith product.

Again, $\frac{\alpha_i}{\alpha_j} = \frac{\sigma_i}{\sigma_j}$vectors of weighting coefficients for the oxygen-argon-nitrogen and liquid oxygen- argon regimes according to the expressions and $\sum \alpha_i = 1$

Oxygen-argon-nitrogen mode: $\overline{\alpha} = \left|0{,}258; 0{,}378; 0{,}364\right|$

Liquid oxygen-argon regime : $\overline{\alpha} = \left|0{,}592; 0{,}408\right|$;

designated as

After determining the vector of weight coefficients by one of these methods, the optimization problem is solved.

Liquid oxygen-argon-nitrogen regime :

Objective function:

$$Y_{1,3,5} = 357{,}61 - 0.1989x_1 - 0.6549x_2 + 0.1341x_3 + 0.0837x_4 - 6.66x_5 \rightarrow \max$$

Functional limitations:

$$y_2\text{=}98.61\text{-}0.001x_2 + +0.027x_2\text{-}0.008x_3\text{+}0.002x_4 + \text{-}6.73x_5 \geq 99.55$$

$$y_4\text{=}98.89\text{-}0.004x_1\text{+}0.003x_2\text{+}0.006x_3\text{-}0.001x_4\text{-}8.876x_5 \geq 99.55$$

$$y_6\text{=}97.02\text{-}0.01x_1\text{+}0.011x_2\text{+}0.012x_3\text{+}0.0014x_4\text{-}18.92x_5 \geq 99.55$$

Position restrictions:

$$\text{-}200 \leq x_1 \leq \text{-}180$$

$$23 \leq x_2 \leq 30$$

$$2.5 \leq x_3 \leq 6$$

$$70 \leq x_4 \leq 120$$

$$x_5 = -0.03$$

Optimum solution for oxygen-argon-nitrogen mode

$$x_{1opt} = -200\ {}^0C;\ x_{2opt} = 23mbar;\ x_{3opt} = 6bar;\ x_{4opt} = 120mbar;$$

$y_1 = 20.8 Nm^3/hours; \quad y_2 = 98.58\%; y_3 = 541.6\ Nm^3/hours;$

$y_4 = 99.8\%; y_5 = 590{,}2 Nm^3/hours; \ y_6 = 99.57\%$

Oxygen- argon mode :

Objective function:

$y_{3,5}$=468.4-0.263x_1-0.7955x_2+0.868x_3+0.14x_4-4.4865x_5 $\rightarrow$ max

Functional limitations:

y_1=-12.92-0.176x_1+0.12x_2+0.06x_3-0.0041x_4-10.35x_5 ≥ 18

y_2=98.61-0.001x_2 ++0.027x_2-0.008x_3+0.002x_4 + -6.73x_5 ≥ 99.55

y_4=98.89-0.004x_1+0.003x_2+0.006x_3-0.001x_4-8.876x_5 ≥ 99.55

y_6=97.02-0.01x_1+0.011x_2+0.012x_3+0.0014x_4-18.92x_5 ≥ 99.55

Position restrictions:

$$-200 \leq x_1 \leq -180$$
$$23 \leq x_2 \leq 30$$
$$2.5 \leq x_3 \leq 6$$
$$70 \leq x_4 \leq 120$$
$$x_5 = -0.03$$

Oxygen-argon optimal solution for mode

$x_{1opt} = -200\ ^0C;\ x_{2opt} = 23 mbar;\ x_{3opt} = 6 bar;\ x_{4opt} = 120 mbar;$

$y_1 = 20.8 Nm^3/hours; \quad y_2 = 98.58\%; y_3 = 541.6 Nm^3/hours;$

$y_4 = 99.8\%; y_5 = 590{,}2 Nm^3/hours; \ y_6 = 99.57\%$

In the fourth chapter, the development of the algorithms for starting the production of oxygen, argon, and nitrogen of TQP was considered. Commissioning of production is carried out according to the working instructions issued by its designer[7].

During the study of commissioning regulations, it was determined that the commissioning of production takes more than 30 hours in

[7] Alekberli, F.A. Cleanliness control of the expansion tube shaft rotor./ F.A. Alekberli, I.A. Mustafaev, Dzh.M. Pashaev [etc.]// High-performance computing systems and technologies. - No. 2(9), - 2018. - pp. 138-144.

total. Production start-up is a multi-stage process, one of which is the start-up stage of the expansion turbine.
The start-up of the turbine consists of two parts: in the first part, the automatic regulator increases the rotation frequency of the shaft to 30%; and in the second part, the rotation frequency of the shaft should be regularly increased from 30% to 60%. Also, the transition speed depends on the thermal condition of the production equipment. When the equipment is cold, the transition speed should be 2% per minute, and when it is hot, it should be 1% per 3 minutes [5, p.14]. The transition time is 15 minutes in the cold case, and 90 minutes in the hot case. The current control system is based on a Simatic-type controller, and in that system the second part is performed manually: on the operator panel, 1"a sign like "+ and "-1" The task of the regulator is changed according to the transition speed through virtual buttons. This process is tiring and nerve-wracking.
the above , an automatic regulation system was created in the thesis, keeping the existing control method as a reserve, which fully automatically starts the turbine and provides regulation in the working mode. Figure 6 shows the structural scheme of the automatic regulation system (ARS) that implements the operations shown. In the picture: IO - control object, T - regulator, TFB - task forming block, *g* - task, *e* - regulation error, *u* - regulatory effect, *x* - regulated quantity.
TFB changes the task of the regulator depending on the selected control option. The management options are:
- manual control;
- automatic jump control;
- automatic routine management.

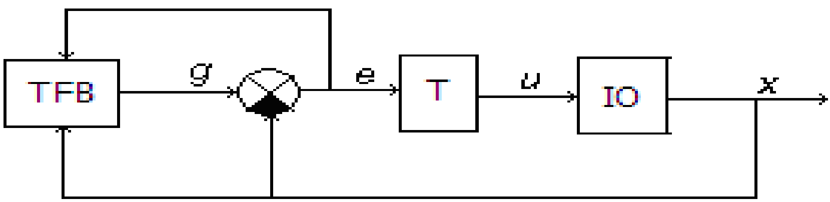

Figure 5. Structural scheme of the alternative management system

Task in manual mode

$$g = \begin{cases} 30, & x \le 30 \\ g+1, & 30 < x < 60 \ \& \ +1 \\ g-1, & 30 < x < 60 \ \& \ -1 \end{cases}$$

as changed.

In automatic control options, the regulator duty is automatically changed from 30% to 60%. Including: changing the task in the leap control option

$$g = \begin{cases} 30, & x \le 30 \\ g+2, & 30 < x < 60 \ \& \ \text{cold} \ \& \ taymer \\ g+1, & 30 < x < 60 \ \& \ \text{hot} \ \& \ taymer \end{cases}$$

as in the case of regular management

$$g = \begin{cases} 30, & x \le 30 \\ 30 + k2 \int dt, & 30 < x < 60 \ \& \ x \ge g \ \& \ cold \\ 30 + k3 \int dt, & 30 < x < 60 \ \& \ x \ge g \ \& \ hot \end{cases}$$

as changed. coefficients *k2* and *k3*

$$60 - 30 = k_2 \int_0^{900} dt$$

$$60 - 30 = k_3 \int_0^{5400} dt$$

from their expressions $k_2 = 0.0333$ and k_3=0.0055

To study the quality of control options, a simulation program was designed in Matlab (Figure 6).

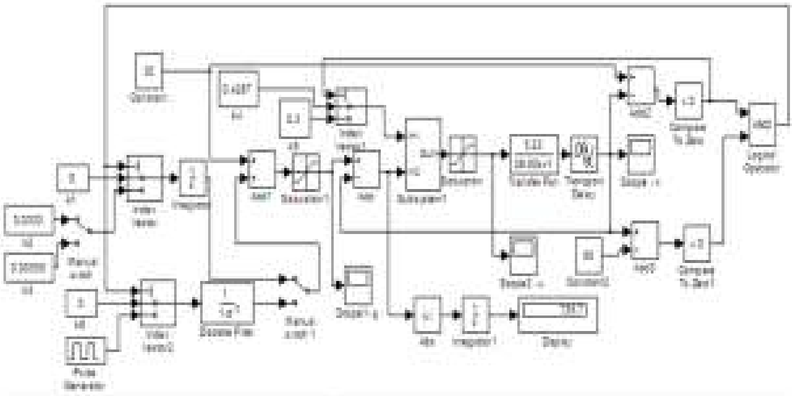

Figure 6. Management simulation software

The object's transfer function

$$W(s) = \frac{5{,}23}{28{,}63s + 1} e^{-12s} \qquad (10)$$

obtained through the automatic identification system, the numerical values of the tuning parameters of the regulator were determined using the "Simulink Response Optimization" function of Matlab ($k_p = 0{,}4287;\ T_i = \frac{1}{0{,}0158} = 63{,}29\ s.$).

Figure 7. and Figure 8. show the time variations of the task (a), control effect (b) and regulated quantity (c) in the start-up mode during the jump and regular control, respectively, in the cold state of the equipment.

Quality of management in different management options

$$J = \int_0^{1200} |e| dt \qquad (11)$$

the numerical value according to the expression was obtained: in breakthrough control $J = 865{,}6$ and regular control $J = 735{,}7$. That is, the quality of regular management increased by 17.6% compared to breakthrough management.

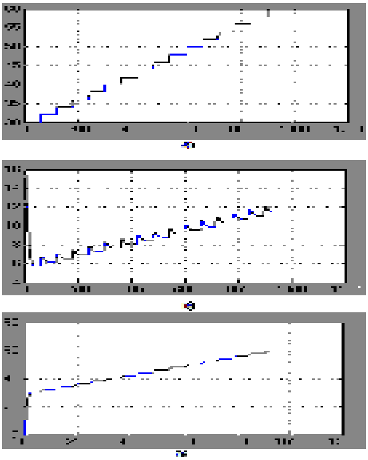

Figure 7.During jump control task (a), managerial influence (b) and (c) time of the regulated quantity change according to

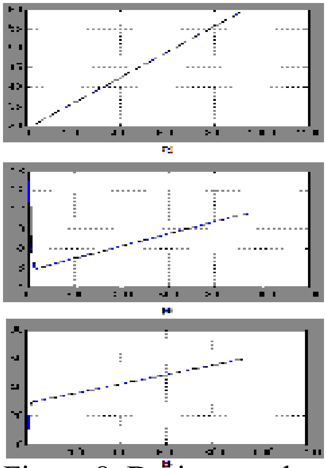

Figure 8. During regular administration task (a), managerial influence (b) and (c) time of the regulated quantity change according to

In the fifth chapter, the interpretation of the programs that allow to study the issues solved in the dissertation through practical implementation and simulation and the study of the relevant issues through them is given[8][9].

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[8]Askarova SF Research of the software and operation of the management system of oxygen, argon and nitrogen production.// Information systems and technologies, achievements and perspectives. Materials of the II international scientific conference - Sumgait: July 9-10 , 2020. - pp. 211-214

[9] Alekberli , F.A., Simulation of the technological process control system and adaptation of its software to industrial conditions./ F.A. Alekberli, S.F. Askerova // Herald of computer and information technologies. -2018, No. 9, p. 39-48.

In the second chapter, in order to check the decision-making ability of the DMP, the psychological and physiological characteristics of the person that affect the Decision-making were investigated, and the weighting coefficients were calculated. Before making this or that important decision, the (DM) program was used to check whether it is capable of making a decision or not, and the results are shown in figure 9 and figure 10.

At the same time, the DM should analyze the optimal results obtained from the computer. An interface was created in addition to the QQŞQQV program, which was compiled in the JAVA HTML programming language, in order to solve the optimization problems of operative personnel under real production conditions. Figure 10 shows the results obtained by DM according to the current situation. That is, if p>0, the results are displayed on the screen, and if the operative personnel are not satisfied with the results, they are given the chance to "change the task values" again.

In Figure 11, the results are again displayed on the screen, but due to the case of P<0, the operational personnel "regulator's task cannot change its values", that is, the cell where task values are entered is not active

At present, automatic regulation systems of continuous technological processes are mainly implemented by means of programmable controllers (PC). One of the PC that is widely used in practice is the Simatic type controller produced by the German company Siemens. Although Simatic Manager and Win CC flexible, a visualization tool included in the STEP7 software package, which is used to configure Simatic-type PC and prepare working programs, fully enable the simulation study of logical control systems, the necessary tools for the study of automatic regulation systems are not provided. In order to implement a transfer function not larger than the second layout in

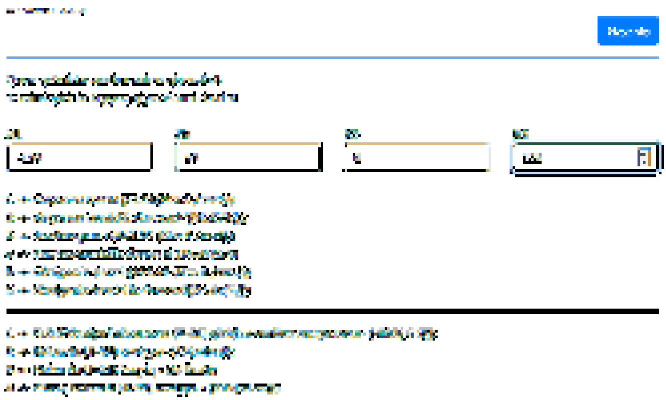


Figure 9. The results of operative personnel in the case of p >0 .

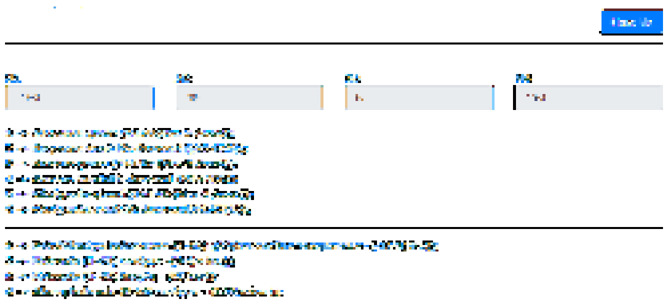


Figure 10. The results of operative personnel in the case of p < 0.

the Simatic Manager -WinCC flexible environment, it is necessary to perform the following tasks:

- creating a block that implements models of dynamic mangas;
- ensure that blocks work on a real-time scale.

Let's use the method of solving differential equations in analog computing machines (ACM) in order to create a block that realizes models of dynamic mangas . The transmission function of dynamic mangas

$$W(s) = \frac{b_1 s + b_o}{a_2 s^2 + a_1 s + a_0} \qquad (12)$$

By choosing the values of the coefficients, it is possible to express the transfer function of any two-design dynamic manga. The differential equation according to expression (12).

$$a_2 y''(t) + a_1 y'(t) + a_0 y(t) = b_1 x'(t) + b_o x(t) \qquad (13)$$

will be in the form and, as is known, to realize the differential equation (9) in ACM, it $y''(t) - \frac{b_1}{a_2} x'(t)$ is solved considering

$$y''(t) - \frac{b_1}{a_2} x'(t) = \frac{b_o}{a_2} x(t) - \frac{a_1}{a_2} y'(t) - \frac{a_0}{a_2} y(t) \qquad (14)$$

The structural scheme that implements the last statement in ACM is as shown in figure 11.

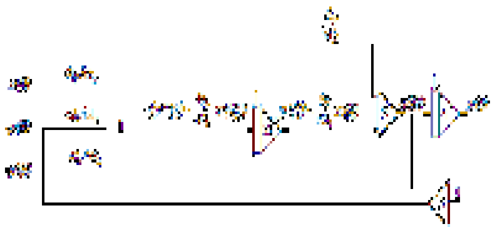


Figure 11. Solution scheme of a two-order differential equation
In the picture: 1 and 3 - adder; 2 and 4 – integrator; 5 – inverter.

Although Simatic Manager's library contains blocks that perform many mathematical functions, there is no dedicated integrator block. The custom built integrator is designed as a Function block (FB1) and Figure 12 shows its **LAD** language program.

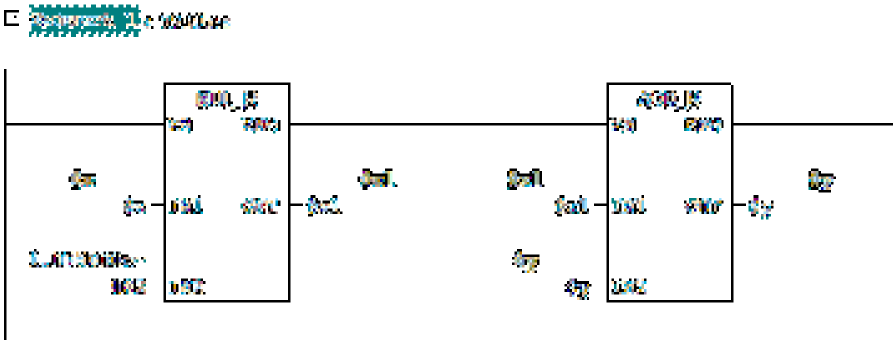


Figure 12. LAD program of the integrating block

Real-time operation of blocks provided through an integrator block. A continuous integrator on a real-time scale

$$y(t) = \int_0^t x(t)dt$$

performs its function. If there is an input signal $x(t) = 1(t)$

$$y(t) = \int_0^t 1(t)dt = t$$

is taken. The integration operation in the controller is through the adder block

$$y(t) = \alpha \sum_0^t x(t) = \alpha \sum_0^t 1(t)$$

is performed according to the statement. α the value of the coefficient should be chosen such that

$\alpha\tau \sum_0^t 1(t) = t$ be provided. τ -is the time spent on one period of the executed program, its price depends on the content of that program. the program in figure α 14 was used to determine the value of the coefficient . When contact M0.0 closes, timer T1 and adder ADD_R start and waiting time (10s

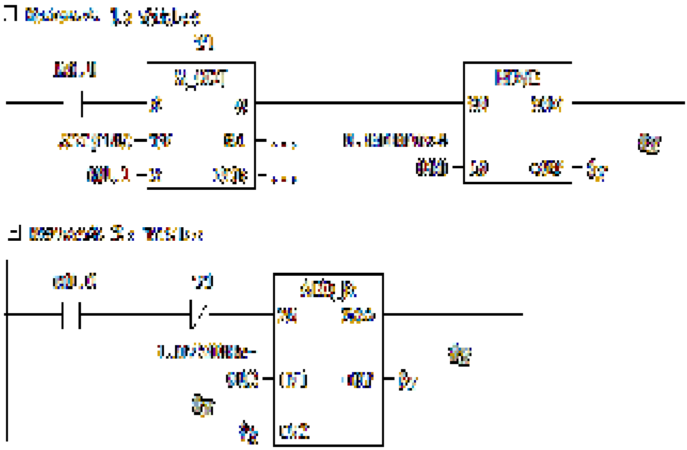
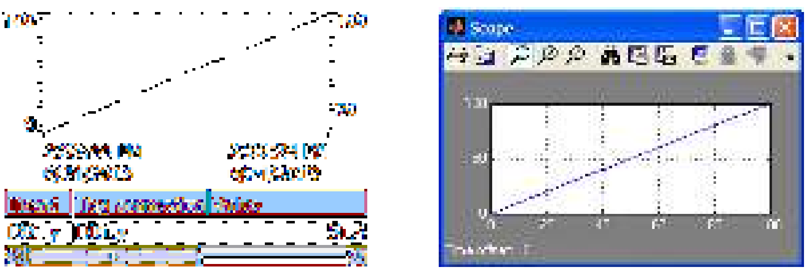


Figure 13. LAD program of real-time coefficient determination

when finished, the normally closed contact T1 of the timer is opened and the summation operation is stopped. The quantity supplied to the input of the adder IN1 is chosen so that the number received at the output of the adder (*#y)* is equal to the waiting time of the timer (10s). It is set according to the specified rule $\alpha = 0.01075$.

100 sec in Fig. 14 for comparison. The results of integrator (a) and Matlab integrator (b) created during



a) b)

Figure 14. Results of generated (a) and Matlab (b) integrators

In Figure 15. show the transition characteristics of various transfer functions by the method created in the dissertation and in Matlab.

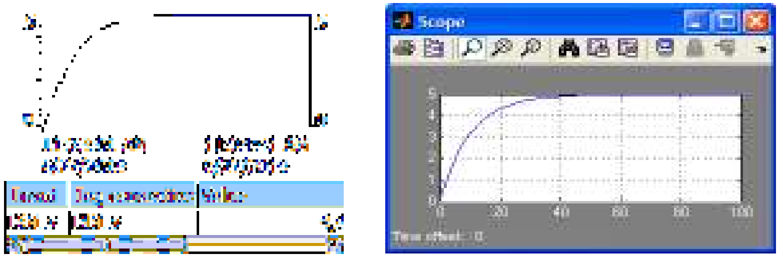


Figure 15. $\frac{5}{10s+1}$ transition processes by transfer function

As can be seen from the presented images, the transition processes established by both tools are practically the same.

Using various software packages (e.g. Matlab) and programming languages, it is possible to study control systems without special difficulties. However, their results cannot be directly applied to real industrial conditions. Therefore, it is more appropriate to study the regulation systems in an environment close to the real industrial conditions where they will be applied. In this case, the operating program of the control system is fully adjusted based on the models of the control object, and then it is adapted to the industrial object.

Industrial regulatory systems operate on a real-time scale. For this, the control program $\div$ is placed in organizational blocks OB30 $\div$ OB38. The period of those blocks works as a cycle with a discretization interval set by the value of the CYCLE parameter of the regulator. If it is appropriate to carry out the simulation study on a real-time scale, then the simulation program is placed in one of those blocks. If the simulation needs to be performed in fast mode, then the program is placed in the organizational block OB1. In this case, the simulation speed is determined by the value of the *mv1 parameter of the integrators.*

The main simulation program of the level and pressure regulation circuits in the T60-1 cylinder of the technical gases plant was developed. Netwok1 and Netwok2 regulate the level and Netwok3 and Netwok4 the pressure in the T60-1 cylinder.

The level of the control object - **memory - level in the regulating valve T60-1 in the oxygen line -** transfer function on the memory channel

$$W(s) = \frac{0.526}{16.38s + 1}, \tag{15}$$

- memory - regulating valve in the discharge line - pressure in T60-1 - transfer function on the memory channel

$$W(s) = \frac{0.068}{72.46s^2 + 21.85s + 1} \tag{16}$$

determined through the given automatic identification system.

In the fourth chapter, the structural and parametric synthesis of the start-up and regulation system of the expansion turbine, its study through the Simulink add-on of Matlab was considered. Here, the program of that system compiled in LAD language and the study of the system in a mode close to real conditions through it are considered.

The visualization tool created for the virtual study of the alternative control system of the turbine is given in figure 16.

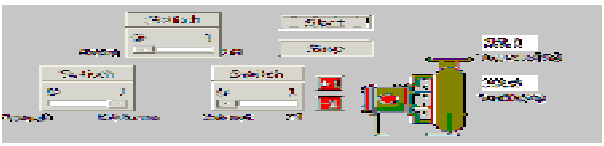


Figure 16. Visualization of the turbine control system

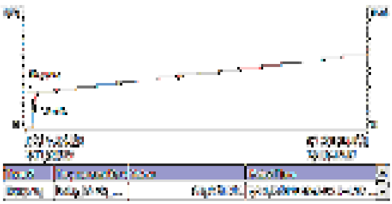
Turbine start-up is carried out with Start, Stop buttons, Switch dials and +1, -1 buttons during manual control. The commissioning of the turbine is carried out in the following sequence when the conditions specified in the technological manual are met:

-the "Hot" or "Cold" state of the equipment is set through the above Switch;

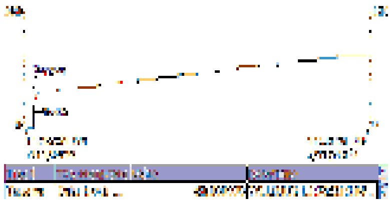
- "Automatic" or "Manual" management option is selected through the Switch on the right;
- "Leap" or "Regular" control is selected through the Switch on the left (in manual control, it does not matter what position this Switch is in);
- The "Start" button is pressed.

In the automatic control options, the turbine starts working without the presence of operative personnel, and in the manual control option, after the +1 and -1 buttons turn red, it is performed with the presence of operative personnel.

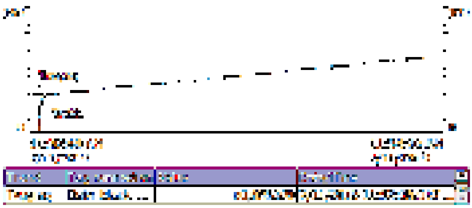
The transition processes of manual control, automatic jump and automatic regular adjustment options of the simulation program in Figure 17 in the cold condition of the mature equipment are shown in Figure 17 using the **Trend View** virtual device. As you can see, the results of manual control (a) and automatic jump (b) options are practically the same. Special care is required to change the task during manual control. And the quality of automatic regular adjustment is significantly higher than that of jump control.



a)



b)



c)

Continuation of Figure 17. Results of different management options

THE RESULT

1. Based on the plan of the dissertation work, the researches of Azerbaijani and foreign scientists were analyzed in the following directions:

-Analysis of decision-making cases;

- Analysis of work related to optimization;
- Analysis of works related to turbine management.

As a result of the analysis of the directions mentioned above, shortcomings were found and the issues of the dissertation work were determined.

2. The essence of decision-making has been clarified, and the influence of the factors affecting decision-making on the decision-maker has been investigated based on expert opinion. The degrees of influence of the selected factors on decision-making (weight coefficients) were determined by the method of pairwise comparison. With the help of experts, the terms and corresponding coefficients of all factors affecting decision-making were determined. Based on the weighting coefficients of the factors, an algorithm and program was developed that determines the decision-making ability of the DM.

3. The technological process of liquid oxygen, argon nitrogen production of TQP of STP was studied and researched according to the factory's manual. The input and output parameters characterizing the technological process are set. An If-Then model of production is constructed with the participation of a fuzzy expert. The technologist-engineer of the plant was used as an expert.

The issues of optimization of liquid liquid oxygen, liquid nitrogen, liquid oxygen-nitrogen-argon and liquid oxygen-argon regimes were considered. For this, fuzzy models were replaced by deterministic models, and the problems were brought to linear programming problems and solved by the simplex method.

4. TQP's liquid oxygen, argon, nitrogen production start-up algorithms were developed based on the working instructions given by the designer.

As a result of the development of the algorithms, the gaps in the commissioning of the process, including the deficiency in the commissioning of the expansion turbine, were revealed. Keeping the control method of the system that fully automatically implements the turbine start-up mode as a backup, an automatic regulation system was created that fully automatically implements the turbine start-up and provides regulation in the working mode as well. In order to study the quality of control options, a simulation program was designed in the Matlab software package.

5. The relevant issues were studied through programs that allow to study the issues solved in the dissertation work through practical implementation and simulation. In real production conditions, a program called QQŞQQV, compiled in the JAVA HTML programming language, was created to solve optimization issues and determine the decision-making ability of operative personnel.

- The software of the automatic regulation system was created with tools that are closer to real industrial conditions and can be easily adapted to the conditions;
- The management system was studied and the issues of adaptation to real conditions were considered.

A program was compiled in LAD language in STEP7 environment. The results of the blocks implementing the transfer functions were compared with the results of the Matlab package and their reliability was proven;

The study of the start-up and regulation system of the expansion turbine in a mode close to real conditions was carried out using a program written in the LAD language. With the help of the simulation program, the results of the options of manual control, automatic jump and automatic regular adjustment of the equipment in cold and hot conditions are graphically presented.

List of published scientific works on the topic of the dissertation work

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Personal activity of the Applicant in cases with co-authors:

[2]-Algorithm and program development.
[4,13,15,17]-Compilation of Simulyaslya program and simulation of the system .
[19]- Development of the structure of the system.
[20]-Acquisition of mathematical models and problem solving
[1,3,5]-Research and selection of factors influencing decision-making.
[14]- Organization of practice, purchase of models.
[6,11]-Development of the program of the decision-making ability determination method.
[16]-Compilation of the Simulyaslya program and development of the system.
[21]-Development of the decision-making ability determination method

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