Міністерство освіти і науки України
Державний вищий навчальний заклад
"Національний гірничий університет"

Електротехнічний
(факультет)

Кафедра Електропривода
(повна назва)

ПОЯСНЮВАЛЬНА ЗАПИСКА

дипломної роботи
магістра
(назва освітньо-кваліфікаційного рівня)

галузь знань 14 Електрична інженерія
(шифр і назва галузі знань)
спеціальність 141 Електроенергетика, електротехніка та електромеханіка
(код і назва спеціальності)
(освітня програма «Електромеханічні системи автоматизації та електропривод»)
освітній рівень магістр
(назва освітнього рівня)
Кваліфікація 2151.2 (Int) Інженер-електромеханік
(код і назва кваліфікації)
на тему: Водневий накопичувач для електрогенеруючих пристроїв

Виконавець:
Студент 6 курсу, групи 141м-16-4
____________ Бондаренко Д.А.
(підпис) (прізвище та ініціали)

Керівники	**Прізвище, ініціали**	**Оцінка**	**Підпис**
проекту	Азюковський О.О.		
розділів:			
Аналітична частина	Азюковський О.О.		
Основна частина	Азюковський О.О.		

Рецензент			

Нормоконтроль	Казачковський М.М.		

Дніпро
2018

Міністерство освіти і науки України
Державний вищий навчальний заклад
"Національний гірничий університет"

ЗАТВЕРДЖЕНО:

завідувач кафедри
Електроприводу
(повна назва)

______________ Казачковський М.М.

(підпис) (прізвище, ініціали)

«_____»______________2018 року

ЗАВДАННЯ
на виконання кваліфікаційної роботи магістра
спеціальності 141 Електроенергетика, електротехніка та електромеханіка
(код і назва спеціальності)

(освітня програма «Електромеханічні системи автоматизації та електропривод»)

студенту 141м-16-4 Бондаренко Д.А.
(група) (прізвище та ініціали)

Тема дипломної роботи : Водневий накопичувач для електрогенеруючих пристроїв

1 ПІДСТАВИ ДЛЯ ПРОВЕДЕННЯ РОБОТИ

Наказ ректора ДВНЗ "НГУ" від ________________№_____

2 МЕТА ТА ВИХІДНІ ДАНІ ДЛЯ ПРОВЕДЕННЯ РОБІТ

Об’єкт досліджень водневий накопичувач

Предмет досліджень водневий накопичувач та система регулювання процесу електролізу

Мета НДР дослідження параметрів що впливають на процес електролізу в водневому накопичувачі, побудова структурної схеми об’єкту керування та розробка автоматичної системи керування процесом електроліза з подальшим виявленням критеріїв якості роботи системи.

Вихідні дані для проведення роботи параметри хімічних, фізичних та термодинамічних процесів електролізу. Виробничі схеми та параметри існуючих комірок електролізера

3 ОЧІКУВАНІ НАУКОВІ РЕЗУЛЬТАТИ

Наукова новизна полягає у дослідженні та побудові ефективної моделі водневого накопичувача з автоматичної системою регулювання процесу електролізу
Практична цінність полягає у дослідженні системи сучасними методами та отриманні критеріїв якості її роботи.

4 ВИМОГИ ДО РЕЗУЛЬТАТІВ ВИКОНАННЯ РОБОТИ
Результати повинні бути достовірними та обґрунтованими

5 ЕТАПИ ВИКОНАННЯ РОБІТ

Найменування етапів робіт	**Строки виконання робіт (початок-кінець**
Огляд технології отримання водню методом електролізу	01.09.2017 – 17.09.2017
Розробка технічних рішень щодо систем водневого накопичувача	17.09.2017 – 18.10.2017

6 ДОДАТКОВІ ВИМОГИ

Відповідність оформлення ДСТУ 3008-95. Документація. Звіти у сфері науки і техніки. Структура і правила оформлення

Завдання видав _______________ Азюковський О.О.
(підпис) (прізвище, ініціали)
Завдання прийняв до виконання _______________ Бондаренко Д.А.
(підпис) (прізвище, ініціали)

Дата видачі завдання: ___________________

Термін подання дипломної роботи до ЕК ___________

Реферат

Пояснювальна записка: 53с., 20 рис., 8 джерел.

Об’єкт дослідження – водородний накопичувач.

В розділі «ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНОГО ПРОЦЕСУ ОТРИМАННЯ ВОДНЮ ЯК ОБ’ЄКТУ КЕРУВАННЯ» виконаний комплекс досліджень процесів що відбуваються під час роботи об’єкту, а саме: фізичні та хімічні властивості; термодинамічні процеси розпаду води під час електролізу; отримана кількість необхідної води та електроенергії для роботи; досліджений вплив використовуваних матеріалів; описана схема виробництва; досліджене технічне обладнання; приведені параметри нормального технологічного режиму.

В розділі «ВИБІР ТА ОБГРУНТУВАННЯ ПАРАМЕТРІВ КОНТРОЛЮ ТА КЕРУВАННЯ» : виконаний вибір та обґрунтування параметрів контролю температури, тиску, витрат, густини; Обрані та обґрунтовані параметри каналів впливу на температуру та рівень електроліту в електролізері, рівень рідини в зрівняльних баках, температуру рідини в накопичувальному нагрівачі.

В розділі «ОПИС РОБОТИ АВТОМАТИЧНОЇ СИСТЕМИ РЕГУЛЮВАННЯ» були описані принципи роботи систем регулювання електроліту в електролізері, рівня рідини в зрівнювальних баках, рівня електроліту в накопичувальному нагрівачі, описана система автоматичного перемикання між технологічними режимами.

В розділі «РОЗРАХУНОК АСР РІВНЯ ЕЛЕКТРОЛІТУ В ЕЛЕКТРОЛІЗЕРІ ТА ВИЗНАЧЕННЯ ЯКОСТІ ЇЇ РОБОТИ» розроблена структурна схема АСР та розраховані датчик зворотного зв’язку, електронного підсилювача, виконавчого механізму та об’єкту керування. Отримані критерії якості роботи та виконаний синтез цієї системи керування. У підсумку змодельована система та виявлені показники якості її роботи.

В розділі «РОЗРОБКА УНІВЕРСАЛЬНОЇ СИСТЕМИ РЕГУЛЮВАННЯ ТЕМПЕРАТУРИ ПО КАНАЛУ «ТЕМПЕРАТУРА ЕЛЕКТРОЛІТУ-СТРУМ НА КОМІРЦІ ЕЛЕКТРОЛІЗЕРА» розроблена структурна схема системи, обрані керуючий мікроконтролер та семісторний регулятор потужності.

В розділі «ОПИС СХЕМИ АВТОМАТИЗАЦІЇ ПРОЦЕСУ ОТРИМАННЯ ВОДНЮ ЕЛЕКТРОЛІТИЧНИМ МЕТОДОМ» описана розроблена схема, обрані та обґрунтовані моделі датчиків.

ВОДНЕВИЙ НАКОПИЧУВАЧ, АВТОМАТИЧНА СИСТЕМА РЕГУЛЮВАННЯ ПРОЦЕСУ ЕЛЕКТРОЛІЗУ.

Abstract

Explanatory note: 53 p., 20 fig., 8 references.

The object of investigation – hydrogen storage system.

In the chapter "INVESTIGATION OF THE TECHNOLOGICAL PROCESS OF OBTAINING HYDROGEN AS A CONTROL OBJECT" complex investigations process which carried out during the work of the object, namely: physical and chemical properties; thermodynamic processes of decomposition of water during electrolysis; received quantity of necessary water and electricity for work; investigated influence of materials used; the scheme of production is described; technical equipment is investigated; the parameters of the normal technological mode are given.

In the chapter "SELECTION AND JUSTIFICATION OF CONTROL AND MANAGEMENT PARAMETERS": the choice and justification of parameters of temperature, pressure, flow, density control; Selected and substantiated parameters of the channels of influence on temperature and level of electrolyte in the electrolyzer, level of liquid in equalizing tanks, temperature of liquid in the accumulator heater.

In the chapter "DESCRIPTION OF AUTOMATIC CONTROL SYSTEM(ACS) OPERATION" the principles of operation of the electrolyte regulation systems in the electrolyzer, the level of liquid in the equalizer tanks, the level of the electrolyte in the accumulator heater were described, and the system of automatic switching between the technological regimes was described.

In the chapter "CALCULATION OF ASC OF ELECTROLYTE LEVEL IS ELECTROLYSER AND DETERMINATION OF QUALITY OF ITS WORK ", an ASC structural scheme was developed and a feedback sensor, an electronic amplifier, an actuator and an object of control were calculated. The criteria of work quality are obtained and the synthesis of this control system is carried out. As a result, the system is simulated and the quality indicators of its work are revealed.

In the chapter "DEVELOPMENT OF THE UNIVERSAL TEMPERATURE REGULATION SYSTEM ON THE CHANNEL "ELECTROLYTE TEMPERATURE – CURRENT ON THE ELECTROLYSER CELL", a structural diagram of the system was developed, a controlling microcontroller and a semistoric power regulator were selected.

In the chapter "DESCRIPTION OF THE AUTOMATION DIAGRAM OF THE TP OF HYDROGEN PRODUCTION BY ELECTROLYTIC METHOD" the developed scheme, the selected and substantiated models of sensors are described.

WATER HEATER, ACS OF THE ELECTRICAL PROCESS.

Реферат

Пояснительная записка: 53с., 20 рис., 8 источников.

Объект исследования - водородный накопитель.

В разделе «ИССЛЕДОВАНИЕ ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА ПОЛУЧЕНИЯ ВОДОРОДА КАК ОБЪЕКТА УПРАВЛЕНИЯ» выполнено комплексное исследование происходящих во время работы объекта процессов, а именно: физические и химические свойства; термодинамические процессы распада воды при электролизе; рассчитано количество необходимой воды и электроэнергии для электролиза; исследовано влияние используемых материалов; описана схема производства; исследовано техническое оборудование; приведены параметры нормального технологического режима.

В разделе «ВЫБОР И ОБОСНОВАНИЕ ПАРАМЕТРОВ КОНТРОЛЯ И УПРАВЛЕНИЯ»: выполнен выбор и обоснование параметров контроля температуры, давления, расхода, плотности; выбраны и обоснованы параметры каналов влияния на температуру и уровень электролита в электролизере, уровень жидкости в уравнительных баках, температуру жидкости в накопительном нагревателе.

В разделе «ОПИСАНИЕ РАБОТЫ АВТОМАТИЧЕСКОЙ СИСТЕМЫ РЕГУЛИРОВАНИЯ» были описаны принципы работы систем регулирования электролита в электролизере, уровня жидкости в уравнительных баках, уровня электролита в накопительном нагревателе, описана система автоматического переключения между технологическими режимами.

В разделе «РАСЧЕТ АСР УРОВАНЯ ЭЛЕКТРОЛИТА В ЭЛЕКТРОЛИЗЕРЕ И ОПРЕДЕЛЕНИЯ КАЧЕСТВА ЕЕ РАБОТЫ» разработана структурная схема АСР и рассчитаны: датчик обратной связи; электронный усилитель; передаточная функция исполнительного механизма и объекта регулирования. Получены критерии качества работы и выполнен синтез этой системы управления. В итоге смоделирована система и выявленные показатели качества ее работы.

В разделе «РАЗРАБОТКА УНИВЕРСАЛЬНОЙ СИСТЕМЫ РЕГУЛИРОВАНИЯ ТЕМПЕРАТУРЫ ПО КАНАЛУ «ТЕМПЕРАТУРА ЭЛЕКТРОЛИТА-ТОК НА ЯЧЕЙКЕ ЭЛЕКТРОЛИЗЕРА» разработана структурная схема системы, выбраны управляющий микроконтроллер и семисторный регулятор мощности.

В разделе «ОПИСАНИЕ СХЕМЫ АВТОМАТИЗАЦИИ ПРОЦЕССА ПОЛУЧЕНИЯ ВОДОРОДА ЭЛЕКТРОЛИТИЧЕСКИМ МЕТОДОМ» описана разработанная схема, выбраны и обоснованы модели датчиков и другого оборудования.

ВОДОРОДНЫЙ НАКОПИТЕЛЬ, АВТОМАТИЧЕСКАЯ СИСТЕМА РЕГУЛИРОВАНИЯ ПРОЦЕСА ЕЛЕКТРОЛИЗА

Content

INTRODUCTION

Hydrogen as a technical product is widely used in many sectors of the economy - in the technological processes of oil refining, ammonia, methanol production, in the metallurgical industry, in many branches of science and technology. Recently, hydrogen is considered as a universal coolant and as a battery of energy.

Hydrogen can be used very efficiently as a secondary energy carrier, because its heat of combustion (in terms of mass) is three times higher than that of hydrocarbon fuels.

It should also be taken into account that hydrogen is an environmentally friendly type of fuel. For the economy of highly developed countries, this parameter is one of the most important.

The only drawback of this energy carrier is relative high cost, compared with hydrocarbon raw materials. But the development of production technologies, including automation, may allow solving this problem in the near future.

1. INVESTIGATION OF THE TECHNOLOGICAL PROCESS OF OBTAINING HYDROGEN AS A CONTROL OBJECT

1.1 Physical and chemical basis of a hydrogen production

Two immersed electrodes in a container, which contains aqueous solution of electrolytes and supplied by DC voltage, provided that voltage is greater than voltage of decomposition of water, can produce the closed electrical circuit and oxygen will be released at the anode, and hydrogen at the cathode, in volume ratio of ½. This leads following reactions to take place:

$2H2O+2e- \rightarrow H2+2OH-$ (cathodic reaction)

$2OH- \rightarrow 1/2O2+H2O+2e-$ (anodic reaction)

$H2O \rightarrow H2+1/2O2$ (overall reaction)

The specific electrical conductivity of purified water is insignificant: at 18 ° C it is (2-6) • 10-6 ohm-m-1. Therefore, aqueous solutions of strong acids or alkalis are subjected to electrolysis. Other electrolytes are usually not used, because they themselves decompose during electrolysis and produce undesirable by-products. In view of the significant corrosion problems that arise in the electrolysis of acids, almost all electrolyzers now use aqueous solutions of potassium hydroxide and sodium with a concentration of 350-400 g / l.

KOH solutions have advantages over NaOH due to the greater conductivity of K + against the Na + ion. The equilibrium composition of the vapor above the aqueous solution of KOH is lower, which means that the final products of the electrolysis of H2 and O2 contain less water vapor. Concentration of KOH corresponds to the optimal values of current densities. Small admixtures of KOH are not an obstacle to its use.

The aforementioned cathodic and anodic reactions are staged, and their mechanism depends on the material of the electrode, the composition of the solution, and also the magnitude of the overvoltage, temperature, and other factors.

One of the possible mechanisms of cathodic hydrogen evolution from alkaline solutions is as follows. In the first stage, water molecules are discharged to form hydrogen atoms adsorbed on the electrode:

$$H_2O + e^- \rightarrow H_{ads} + OH^-$$

Then comes the reaction of the so-called electrochemical desorption (Heyrovsky reaction):

$$H_{ads} + H_2O + e^- \leftrightarrow H_2 + OH^-$$

In sum, these two processes produce a cathodic reaction, as a result hydrogen releasing. At the anode, the probable first stage is the discharge of hydroxide ions with the formation of OH radicals:

$$2OH^- \leftrightarrow 2OH + 2e^-$$

Then there is a chain of processes:

$$2OH + 2O^- \rightarrow 2H_2O + 2e^-$$

$$2O^- \rightarrow 2O + 2e^-$$

$$2O \rightarrow O_2$$

Other schemes of the summation process are suggested, for example, involving the metal of the electrode. The most common electrolyte in modern industrial electrolysers is 25-30% KOH.

Acid electrolytes give a good yield on H2, but they lead to serious problems in the selection of materials that resist corrosion in sulfuric acid. Electrodes are currently manufactured mostly from carbon steel; the anodes are coated with nickel, and the cathodes are activated by applying either a sulfur-containing nickel or a metal of the platinum group to their surface.

The alkali contained in the solution, as can be seen from the above equations, does not participate in the discharge, but serves only for ion transport. Its consumption (2-3 g per 1 m3 of hydrogen under normal conditions) is due to entrainment with the products of electrolysis. In the electrolyte additionally add K2Cr2O7 (2-3 g / dm3); this makes it possible to reduce the corrosion of the steel parts of the cell.

The total process of water decomposition by electrolysis is a process opposite to the process of hydrogen burning. Therefore, the theoretical value of energy, which is required per unit amount of hydrogen produced, is equal to the heat of combustion of hydrogen. Each molecule is formed by attaching two electrons to two hydrogen ions, so that there is a direct relationship between the current passing and the rate of hydrogen production.

1.1.1 Thermodynamics of the process of decomposition of water in the process of electrolysis

The amount of electricity transferred per mole of material is F*n*, where *n* is the number of electrons participating in the electrode reaction, F is the Faraday number (96 487 Cl / mol). If this amount of electricity is transferred at a potential difference E_r, then the work done is equal to *n*FE_r. To change the free energy of Gibbs:

$$\Delta G = -nFE_r$$

Substituting the known value ΔG298 = 237190 kJ / mol for water formation, we obtain for standard conditions (pressure 0.1 MPa and temperature 25 ° C):

$$E_r = 1.23\ V$$

The general thermodynamics of the process can be summarized as follows. For the isobaric-isothermal process:

$$\Delta G = T\Delta S = \Delta H - \Delta G$$

Otherwise, the cell will be cooled. The thermal efficiency of electrolysis is defined as the ratio of the cell voltage corresponding to the neutral process (1.4V at 25° C and 0.1MPa), to the actual acting voltage. This corresponds to the ratio of the higher heat of combustion of the hydrogen produced to the amount of electricity supplied.

The thermal efficiency of electrolysis is defined as the ratio of the cell voltage corresponding to the thermoneutral process (1.4 V at 25 ° C and 0.1 MPa), to the actual acting voltage. This corresponds to the ratio of the higher heat of combustion of the hydrogen produced to the amount of electric energy supplied.

1.1.2 Electricity and water consumption during electrolysis.

The power consumption is determined by the product of the quantity of

electricity spent by the voltage applied to the buses of the cell:

$$W_b=Eq$$

where W_b is electricity consumption, W * h; E is the voltage, V; q is quantity of electricity, C;

To obtain 1 m^3 H_2 and 0.5 m^3 of O_2 under normal conditions with a theoretical decomposition of water of 1.23 V, the electric power consumption is

$$W_T = 1.23\,\frac{2*26.68}{0.0224} = 2.95 \text{ kWh},$$

where 26.8 is the Faraday number, expressed in ampere hours per mole; 2 is the Faraday number spent on the allocation of 1 mole of H2; 0.0224 is the volume of 1 mole of hydrogen under normal conditions.

At a thermoneutral voltage of 1.48 V, 3.54 kWh per 1 m3 of hydrogen is consumed. The actual electricity consumption on modern electrolyzers is 4.0-4.5 up to 5.5 kWh per 1 m^3H_2. To obtain 1 m3H2 and 0.5 m3O2 under normal conditions, it is necessary to spend, in theory, 805 g of water. Practically the water consumption is 820-850 g.

1.1.3 Influence of electrode material, diaphragms and catalysts on the process of water electrolysis

In order to increase the real efficiency of the electrolysis process, accelerate the electrochemical reaction, the applied potential can be lowered for a given current using (2) electrodes carrying catalytically active metals or subjected to a treatment increasing their porosity. The main purpose of such processing of electrodes, the structure of their surface is to increase the real surface of the electrode without increasing the overall cell size.

It should be emphasized that the structure of the surfaces of the electrodes depends not only on the composition of the catalytic additives, but also on the methods of their preparation and application to the surface, as well as on the methods of preliminary treatment and activation of the surface of the electrodes. Only if these methods, strict observance of the conditions for the preparation of electrodes and application of additives we can be expect significant acceleration of the electrode reactions, which ultimately leads to a decrease in the potential for decomposition of water.

To separate the gaseous products obtained during the electrolysis process, the electrolyte and the gas space of the cell are separated by a gas-tight diaphragm into the anode and cathode spaces. This simple device provides one of the most important advantages of electrolysis. The diaphragms are permeable to H + and OH- ions and to a small extent affect the internal resistance of the cell. Corrosion and temperature resistance, small pore size are requirements for materials for manufacturing diaphragms (membranes). Modern diaphragms are made from asbestos, but they are also performed on the basis of plastics.

1.2 Description of the production scheme

The electric current is supplied to the extreme monopolar electrodes. From the main parts of the cell we nickel followings / 2 /: a) frames with stuck tubes, gas and nutrient channels; b) the main electrodes from the anode side; c) remote electrodes on both sides; d) an anode end plate (from the side of the remote electrode).

Outgoing (2,3) from electrolyzers 1 gases (hydrogen and oxygen jointly with the electrolyte vapor), the separation columns 2, 3 are first of all sent, where the electrolyte and gas are tentatively separated. To cool the electrolyte, the separation columns are equipped with coil coolers. The cooled electrolyte from the separation columns by gravity goes back to the cell.

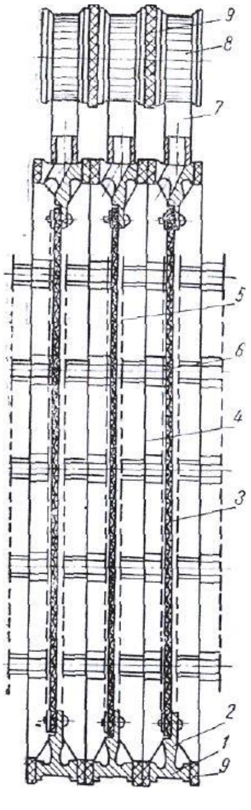


Figure 1 - Cells of electrolyzer EF-12 in assembled form

From the dividing columns, gases enter the washers, where bubbling occurs through the layers of liquid, and are freed from the electrolyte residues. The washers are also equipped with coil coolers, which serve to cool the gas.

Distilled water is used as the washing liquid for gases, which, after trapping the electrolyte, can be used in the process. The washers are connected to the pressure regulators (equalizing tanks), serving to equalize the pressure in both gas spaces of the cell. A special technological regime for filling the system (equalizing tanks and washers) with distilled water is provided. To do this, power is supplied to the electrolysers (test run) and some of the hydrogen enters the equalizing tanks. At the same time, the tanks are filled with distilled water, before it is blocked by a signal from the radar level gauge. Hydrogen is released into the atmosphere through the expander. In this process, it is necessary to ensure that the pressure in the regulators of hydrogen and oxygen is approximately equal. After filling the tanks the valve is closed after the expander, and the system switches to the normal process mode. In the normal technological mode, the pressure fluctuations are small and eliminated by maintaining the level of distilled water in the equalizing tanks in the range of 0.5 to 0.7 meters. Hydrogen at the same time in small quantities is released into the atmosphere. In case of malfunctions, overfilling (emptying) of equalizing tanks, a manual discharge of liquid from them into the water tank. After this, it is necessary to fill the system again with water and equalize the pressure in the washer-regulators.

After passing the washers, the gases are taken out: hydrogen, with the content of the volume fraction of oxygen not more than 1%, in the purification section for drying and purification from the admixture of oxygen, and oxygen, with a content of hydrogen with the content of the volume of no more than 2% - for drying.

There is also a special mode for purging the equipment with nitrogen, which is usually used at starting-up, as well as for malfunctions. Typically, this mode is used when the purity of hydrogen falls at the output or when the permissible values of the pressure in the cell and in the washers are exceeded. Nitrogen purge is also used in the pneumatic tests of the system. In such a case, it is necessary to turn off the power supply to the cell, remove the distillate from the equalizing tanks and washers, and purge the equipment with nitrogen.

Hydrogen is released into the atmosphere through the flame filter. For the purging of the ED apparatus with nitrogen, the ramp, to which nitrogen cylinders are attached.

1.3 Description of the main process equipment

Electrolyzer is designed for the electrochemical decomposition of water into hydrogen and oxygen. The electrolyzer is a horizontal prefabricated filter-press apparatus operating at a pressure of up to 10 atm. It consists of two monopolar electrodes located on insulated end plates, and 25-50 (depending on the type of electrolyzer) of bipolar electrodes compressed between the end plates and separated from each other by sealing and insulating spacers and diaphragm frames.

Bipolar electrodes when passing through a direct current electrolyzer release hydrogen on one side (cathode) and oxygen on the other (anode).

The gases released on the electrodes are separated by an asbestos diaphragm attached to the diaphragm frames. The electrolyzer has three collectors: the upper collectors are designed to drain gases and electrolyte, the lower one is used to return to the cells of the cooling electrolyte. All elements of the cell are connected in a common package and are tightened by four tightening bolts.

Belt springs are fitted at the ends of the bolts to compensate the temperature elongations of the apparatus. The technical data of the electrolyser used in this diagram are given in Table 1.

Table 1 - Technical characteristics of the electrolyzer of the type ED-4M

Parameter	
Quantity of cells, pcs.	30
Current, A:	
nominal	165
maximum	330
Voltage in the cell, V	220-230
Voltage at one cell of the cell, V	5.0-5.4
Current density, A / m^2	1250-2500
Operating pressure, MPa	1.0
Operating temperature of the electrolyte, ° C	85
Purity of gases,%:	
Hydrogen	99
Oxygen	98
Productivity, m^3 / h:	
Hydrogen	2-4
Oxygen	1-2
cell capacity, m^3	0.16
overall dimensions, mm	
length	1700
width	610
high	830
electrolyzer weight, kg	1289

Separating columns are designed for separating gases from electrolyte and cooling. Separating columns are equipped with coils.

The pressure regulators (washers) are designed to maintain the equality of the pressures of hydrogen and oxygen in the ED apparatus, regardless of the pressure at which each gas is used. Pressure regulators are equipped with floats and control valves. Floats can move vertically, closing and opening valves to release gases. Pressure regulators are also designed for washing hydrogen and oxygen from alkaline mist and for cooling gases. Provided with safety valves for the discharge of gas into the atmosphere when the permissible pressure values are exceeded.

Equalizing tanks serve for storage of distilled water and are also connected to pressure regulators and together provide relative pressure equality in both gas spaces.

The hydraulic seal is a device designed to release oxygen (hydrogen) into the atmosphere and to prevent air from entering the ED system.

Flame filter is a device filled with gravel, installed on the pipelines of the release of hydrogen into the atmosphere. The flame filter is designed to prevent "flashing" of the flame into the ED system during the ignition of hydrogen at the outlet.

Storage heater serves to preheat the electrolyte coming from the preparation system. A thermal relay is provided, which allows maintaining a constant temperature of the liquid. Uniform heating is provided by natural recirculation. Characteristics of the heater used in Table 2.

Table 2 - Characteristics of the VM 100 type heater D400-2-BC

Heater Type	Accumulative
Tank capacity, l	200
Heating element power, W	6000
Type of heating element	Dry tan
Operating temperature of liquid, ^{0}C	80
Operating pressure, atm	7
Method of temperature control	Thermal relays

1.4 Parameters of normal technological mode

Table 3 shows the values of the optimal process parameters set experimentally. Also note the place of measurement of each parameter and the need for monitoring / registration / regulation. If these parameters are observed, the system works stably, the yield of the product meets the specified standards, and the corrosive effect on the equipment is minimal. The parameters of normal technical mode is shown in appendix A.

2 SELECTION AND JUSTIFICATION OF CONTROL AND MANAGEMENT PARAMETERS

2.1 Selection and justification of control parameters

To achieve the best quality of products, to ensure efficiency and safety of production, the following main technological parameters should be monitored:

- cell voltage in the cell
- electrolyte level in the cell
- pressure and temperature in the cell
- hydrogen concentration at the output from the system
- oxygen concentration at the output from the system

2.1.1 Temperature monitoring

During the electrolysis of the electrolyte solution, it heats up. In this case, temperature control is necessary primarily to prevent the boiling of the electrolyte during operation, as well as to prevent the destruction of equipment under the influence of corrosion. In addition, the temperature of the electrolyte that comes from the preparation system should be monitored. It should have a temperature close to the operative temperature of the electrolyte in the cell. Otherwise – either the efficiency of the process will drop, or there will be a risk of boiling the electrolyte and exceeding the permissible pressure values. To measure the temperature of the electrolyte in this process, a thermoelectric method can be used that allows information to be transmitted over a sufficiently large distance.

2.1.2 Pressure monitoring

The control of the pressure in the electrolyzer, in this technological process is necessary, because the efficiency of the electrolysis process depends much on the pressure under which it takes place. In addition, pressure control allows to reveal at the early stages system malfunction, such as depressurization, clogging, etc. In this case, the most preferred is the strain-resistive method (5), since sensitive element is a membrane with strain gauges connected to the bridge circuit. Under the pressure of the ambient being measured, the membrane flexes, the strain gages change their resistance, which leads to imbalance of the Wheatstone bridge. The imbalance depends linearly on the degree of deformation of the resistors and, consequently, on the applied pressure. In this case, you can also transmit the signal to the required distance, and the necessary accuracy is provided, in spite of hysteresis phenomena.

2.1.3 Flow control

Flow control is required in this process to determine the amount of products obtained. Because we are dealing with gases, then the method of variable pressure drop is used.

2.1.4 Density control

Density control in this case is used to determine the density of electrolyte, as the main indicator of its quality. The density can be judged, for example, on the concentration of H + ions in the solution. In this process, it is advisable to use a vibratory densimeter, since it is neutral to the electrical properties of the medium, is operable at high and low temperatures (from minus 70 to 200 ° C) and high static pressures (up to 20MPa).

2.2 Selection and justification of control parameters and exposure pathway

2.2.1 Controlling the temperature and electrolyte level in the cell

In order to maintain the optimum operating mode of the cell, it is necessary to somehow control the temperature of the electrolyte, since it is the most accurate indicator demonstrating the quality of the device operation. The temperature of the electrolyte can be used to judge the amount of hydrogen formed on the cathode, and so on.

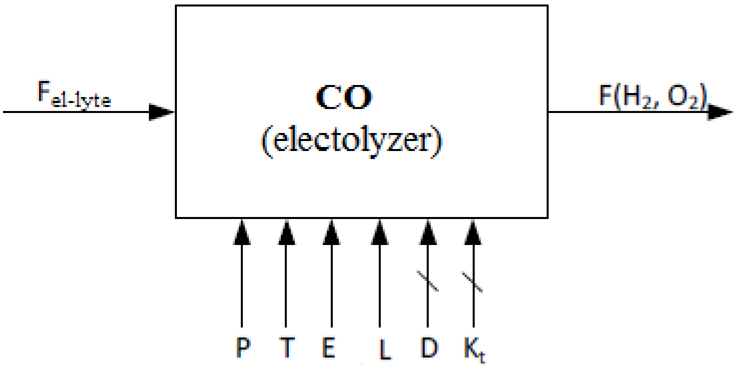


Figure 2 - Analysis of the electrolyzer as a control object.

The crossed out arrows indicate the parameters, the influence on which is extremely difficult or impossible

Figure 2: P is pressure in the device, T is temperature, E is suppling cell voltage, L-level of electrolyte, D-density of electrolyte, K_t - the coefficient of thermal conductivity of the shell materials.

In the literature it is often suggested to regulate the temperature of the electrolyte by the channel: the supply voltage of the cell - the temperature of electrolyte (pressure in the cell). However, due to the very large inertia this method is not effective.

In this case, you can solve the problem as follows: make the system of continuous supply of electrolyte to the electrolyzer from the preparation system, which will be preheated to a temperature close to the operative temperature. During electrolysis a continuous recirculation of the electrolyte solution takes place between the cell and the separating column, in the process the part of electrolyte is consumed. Nevertheless, it is necessary to maintain the level of electrolyte in the cell approximately at 1.5 m, because in this case the system works stably, and the yield of the product is quite large. Then by signal from the level gauge you can form a control action, with the amount of electrolyte supplied to the electrolyzer from the preparation system. The level fluctuations in the process will be sufficiently small and permissible. Thus, it is possible not only to stabilize the electrolyte level in the cell, but also its temperature.

2.2.2 Controlling the level of the liquid in the surge drum

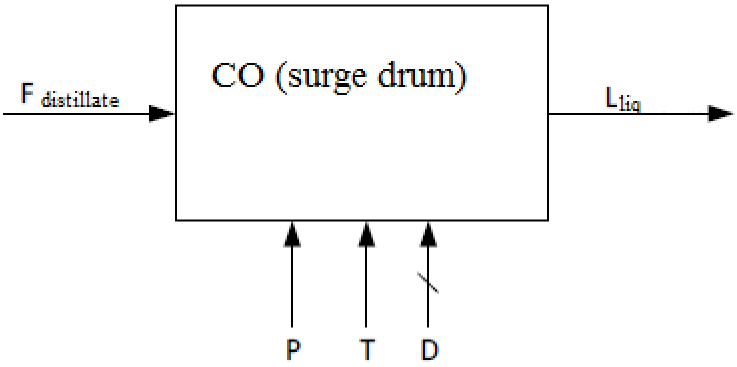


Figure 3 - Analysis of the equalization tank as a control object.

The crossed out arrows indicate the parameters, the influence on which is extremely difficult or impossible.

In Figure 3: P is for pressure in the tank, T is liquid temperature, D is density of the liquid.

During the system starting-up and operation, it is necessary to align and maintain at approximately the same level the pressure in both gas spaces of the cell. To do this, surge drum are used where during the system starting-up to fill distilled water up to the certain level. During the operation of the device, pressure fluctuations may occur that are eliminated by changing the level of liquid in the surge tanks. In this case also radar level gauges are used, the signal from which is used for formation of control actions. In this case, you can regulate the amount of distilled water that enters the surge tanks. The system also provides for manual discharge of liquid from regulating tanks in the water tank.

By other channels control is not possible, since the tanks participate in the pressure equalizating system. Consequently, it is highly undesirable to exposure to the temperature or pressure in them. In addition, fluid flow control is the most convenient and simple way to maintain a given level in them.

2.2.3 Concentration of hydrogen and oxygen under various technological modes

In the case of normal process conditions, the hydrogen concentration at the outlet of the system (pipeline after the condenser) is approximately 99%. The electrolytic method of obtaining hydrogen implies a very high purity of the product, so if the concentration of hydrogen has fallen by more than 2-3%, then this indicates a serious malfunction in the system, leaks, foreign substances, etc. Then it is necessary to purge the system with nitrogen and to release the gas through the flame filter. The situation with oxygen is similar. There is also a special mode of filling the surge tanks when the hydrogen contained in them is released into the atmosphere through the expander.

2.2.4 Control of the temperature of the liquid in the storage heater

The storage heater receives electrolyte from the preparation system. During the operation of electrolysers, it is being consumed, but it is necessary to maintain its level within acceptable limits. The pump creates in the pipeline a pressure sufficient for the electrolyte to enter the cells when the valves are opened. At the outlet at the top of the heater, the temperature of the electrolyte must be constantly equal to 800^0C (close to the working temperature of the electrolyte in the cell).

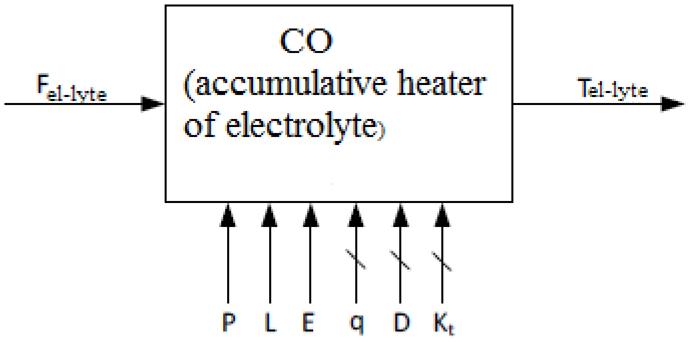


Figure 4 - Analysis of the storage electrolyte heater as object of control.

The crossed-out arrows show the parameters which are extremely difficult or impossible to exposure.

In this case, the amount of liquid (used in the process of electrolysis), which left the heater should be approximately correspond to the amount of fluid that will come from the preparation system in the heater. This can be achieved by maintaining a certain level in the storage heater, adjusting the supply cold electrolyte from the preparation system. Design and power of the heater allows him to heat up the incoming electrolyte, which then enter the upper part of the heater due to the difference in densities. If regulation of the electrolyte level in electrolyzer does not take place (valves are closed), then in the heater a constant temperature will be automatically maintained of the electrolyte contained in it, switching on/off the heating element with the help of a thermorelay.

3. Description of automatic control system (ACS) operation

3.1. ACS of the electrolyte level in the cell

As the electrolyte is consumed during the process, its level will decrease. We need to maintain its value, approximately equal to 1.5 m. Oscillations within 10-20 cm are permissible. For this, a radar level gauge at the signal of which the regulator creates a control signal. This signal is simultaneously applied to the control valve Upon the incoming command, the valve is opened, ensuring that the heated electrolyte is supplied to the cell. This maintains the required level of liquid in the cell.

3.2. ACS of liquid level in leveling tanks

Leveling tanks serve to equalize the pressure in the gas spaces of the system. It has been experimentally established that a stable operating mode is provided at a level value in the equalizing tanks, if it is approximately 0.5 m. Oscillations within 10-15 cm are also permissible. A source of distilled water is supplied to the equalizing tanks. The level in the tanks is measured by radar level gauges. On the signal from the level gauges, a control action is generated and applied to the valves pos. 20в, 21в, which open/close the supply of distilled water in the tanks. The system also provides for manual discharge of fluid from the pressure equalization system, for this purpose valves with remote control are used.

3.3. ACS of liquid level in leveling tanks

On the signal from the radar transmitter, the control actions pos. 15b, which controls the valve 15b. Due to this, the electrolyte supply to the container is regulated, as a consequence - its level. In addition, this storage heater is equipped with a thermostat that maintains the set temperature of the electrolyte and prevents its overheating. If the pump pos. 17 does not work, the storage level of the liquid in the storage heater remains constant, therefore, the valve 15c will be shut off and no electrolyte will be supplied at this time. In this case, the thermostat installed in the upper part of the heater will switch on / off the heating element (TET), thereby maintaining a constant temperature.

4. Calculation of ASC of electrolyte level in electrolyser and determination of quality of its work

4.1. Drawing up the structural diagram of ACS

We use the classical control system with feedback. To ensure the operation of such a system, it is necessary to:

- measure an adjustable parameter
- compare it with a given value
- determine the magnitude of the error and its sign
- calculate the control effect by the selected control algorithm
- Provide a control action through the actuator to the control object.

The following elements are necessary for the system under development:

- level sensor;
- regulator with a sensor, a comparison element and a control algorithm;
- Preliminary amplifier;
- power amplifier to ensure coordination with the actuator;

4.1.1. Calculation of feedback sensor

Transfer function of the sensor is calculated by the formula:

$$W_s(p) = \frac{k}{(Tp+1)}$$

The transfer coefficient of SAPPHIRE-22M-DI is determined by the static characteristic:

$$k = \frac{\Delta I}{\Delta P} = \frac{5 \cdot 10^{-3}}{0.6} = 8.3 \cdot 10^{-3}\ \frac{\text{A}}{kg/cm^2}$$

ΔI- maximum output current signal,

ΔP-maximum preasure.

The time constant will be determined as the time constant of the membrane by the formula:

$$T_m = \frac{f}{c}$$

Where: $f = 101 \cdot 10^{-8}$ – The coefficient of viscous friction

$$c = \frac{2 \cdot E \cdot h^3 \cdot (1+\alpha)(3+\alpha)}{3 \cdot (1 - \frac{\mu^2}{\alpha^2}) \cdot R^4 \cdot \left[1 - ((\frac{\alpha+1}{\alpha-1}) \cdot \rho)^4\right]}$$

c- membrane stiffness

$R = 30mm$ – operating radius of a membrane

$h = 0.35mm$ – width of membrane

$E = 2.1 \cdot 10^{-11} Pa$- modulus of elasticity of material

$\rho = 0.2mm$ – relative radius of a rigid center

$\alpha = 3.64$

After

$$c = \frac{2 \cdot 2.1 \cdot 10^{-11} \cdot 0.35^3 \cdot (1+3.64)(3+3.64)}{3 \cdot (1 - \frac{0.3^2}{3.64^2}) \cdot 30^4 \cdot \left[1 - ((\frac{3.64+1}{3.64-1}) \cdot 0.2)^4\right]} = 2.3 \cdot 10^5 \, \frac{N}{M}$$

Then, we obtain:

$$T_m = \frac{f}{c} = \frac{101 \cdot 10^{-8}}{2.3 \cdot 10^5} = 4.3 \cdot 10^{-12} \; s$$

Transfer function of a sensor:

$$W_s(p) = \frac{k}{(Tp+1)} = \frac{8.3 \cdot 10^{-3}}{(4.3 \cdot 10^{-12}\,p+1)}$$

4.1.2. Calculation of electronic amplifier

The amplifier is selected from the Cridom line of industrial power amplifiers and is described by a 1-order differential equation:

$$T_2 \frac{dU_2}{dt} + U_2 = k_2 U_1$$

Where:

U_2- output voltage of amplifier,(V)

U_1- input voltage of amplifier,(V)

k- amplifier gain.

Then the transfer function of the power amplifier has the form of an aperiodic link of the 1st order:

$$W_{amp1} \frac{U_2(p)}{U_1(p)} = \frac{k}{(Tp+1)}$$

The gain of the amplifier is chosen from the condition that the output signal of the regulator 0-5B is matched with the voltage of the subsequent amplifier equal to 24V.

$$k = \frac{24}{4} = 4.8$$

In the passport to the amplifying element of type D4825 the time of the transient process t_{tr} = 0.004 s is indicated. For a link of the first order, the following relation relates the time of the transient process to the time constant:

$$t_{tr}(3 \div 4)T \approx 4T$$

According to this formula, the time constant of the amplifying element is equal to:

$$T = \frac{t_{tr}}{4} = \frac{0.004}{4} = 0.001\ \ (s) = 0.000167\ (min)$$

Then the final transfer function of the amplifying element has the form:

$$W_{amp1} = \frac{k}{(Tp + 1)} = \frac{4.8}{0.000167p + 1} = 4.8$$

4.1.3. Calculation of the executive amplifier

This element amplifies the 24V signal into the 220V signal to control the actuator.

The transfer function of this element:

$$W_{amp2}(p) = k$$

$$W_{amp2}(p) = \frac{220}{24} = 9.2$$

4.1.4. Calculation of the actuator

The actuator is an electric one-turn mechanism, which includes three links. Define the transfer functions of these links.

MOTOR

According to the passport data, a motor of the type DAU-25 is used.

- Engine power (N_m) - 25W,
- Power supply voltage (U_s) - 220B,
- The number of poles (n) is 12,
- The moment of loading on a shaft (M_l) – 40 Nm.

The transfer function of the motor is calculated by the formula (there is feedback on the rotation angle):

$$W_m(p) = \frac{k}{p(Tp+1)}$$

$$T = 3.3\frac{N_m}{n \cdot U_s} = 3.3\frac{25}{12 \cdot 220} = 0.031\ (s)$$

$$k = 0.14\frac{N_m \cdot n}{M_l} = 0.14\frac{25 \cdot 12}{40} = 1.05$$

Then, the final transfer function:

$$W_m(p) = \frac{k}{p(Tp+1)} = \frac{1.05}{p(0.031p+1)}$$

REDUCER

The transfer function of the reducer is the reciprocal of its gear ratio (i). Lets obtain it:

$$W_{red}(p) = \frac{1}{i} = k$$

According to the passport data gear ratio of reducer = 416.7. Then:

$$W_{red}(p) = \frac{1}{416.7} = 2.4 \cdot 10^{-3}$$

VALVE

Valve transfer function is calculated by the formula:

$$W_v(p) = k$$

The transmission coefficient K is found from the static characteristic:

$$k = \frac{\Delta L}{\Delta \omega} = \frac{0.5}{0.25} = 2\frac{m}{rad}$$

$$W_v(p) = 2$$

Thus, the transfer function of the actuator will look like this:

$$W_{act}(p) = W_m(p) \cdot W_{red}(p) \cdot W_v(p)$$

After substitution of values:

$$W_{act}(p) = \frac{1.05 \cdot 2 \cdot 2.4 \cdot 10^{-3}}{p(0.031p + 1)} = \frac{5.04 \cdot 10^{-3}}{p(0.031p + 1)}$$

4.1.5. The object of regulation

During the simulation of the control object (capacitance of electrolyzer) the following assumptions were adopted:

-the flowrate of the electrolyte is uniform across the entire interface liquid / gas;

- the density of the electrolyte remains constant throughout simulation time.

In this case, the regulatory object is a stable link of a first order, and its transfer function is found by the formula:

$$W_{OR}(p) = \frac{k}{(Tp+1)}$$

The transmission ratio will be:

$$k = \frac{1}{k_f} = 2$$

The time constant of the control object is found from the formula:

$$T = \frac{T_\varepsilon}{k_f}$$

$T_\varepsilon = \frac{A \cdot L_0}{F_0} = \frac{12.5 \cdot 0.1}{0.041} = 30.45\ (s)$ - acceleration time of OR

$A = \pi \cdot R^2 = 3.14 \cdot 2^2 = 12.5\ (m^2)$ - horizontal section area OR

$L_0 F_0$ - the values of the corresponding quantities at the equilibrium state of OR

$$k_f = \frac{1}{2}$$

$$T = \frac{30.45}{(\frac{1}{2})} = 61\ (s)$$

We obtain the transfer function:

$$W_{OR}(p) = \frac{k}{(Tp+1)} = \frac{2}{(61p+1)}$$

Finally, it is possible to compose a functional scheme for automatic level control in the cell pot, which includes the transfer functions of the elements (Figure 5):

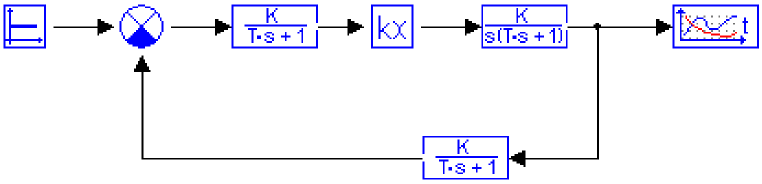


Figure 5 - Functional diagram of level control in the cell

4.2.Analysis of the system, the formulation of its quality criteria

At this stage of the work, it is necessary to model the level electrolyte in an electrolyzer and to clarify the main parameters of the system.

We construct the Nyquist travel time for the open system (Figure 6).

It can be established from Fig. 6 that the AFCX covers the point (-1; j0), consequently, the closed system is unstable.

The main criterion for the operation of the system is its stability, which is not provided. In addition, the requirements of the technology are superimposed the following restrictions:

1. $T \leq 10$ s - regulation time

2. $0 \leq y\_max \leq 1.2$ (20%) – overshoot

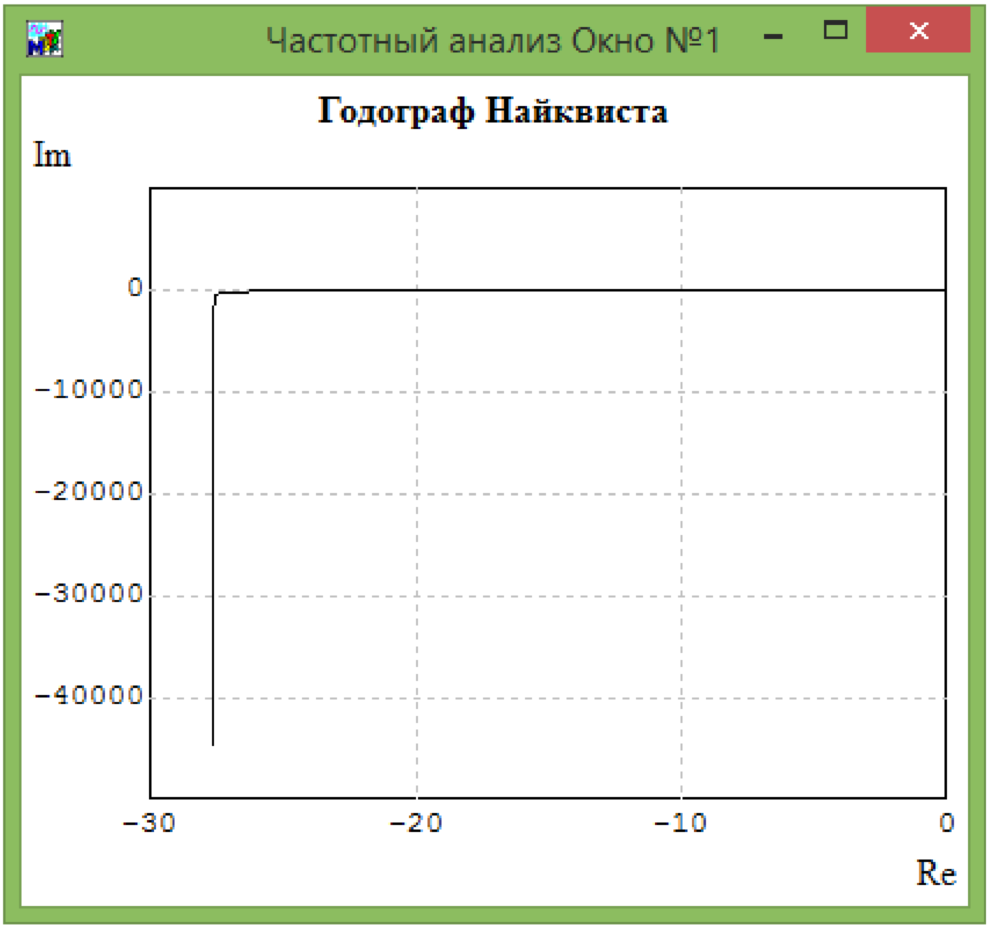


Figure 6 - Nyquist Hodograph for an open system

In this case, it is necessary to use a regulator that will achieve the specified parameters of the quality of the transient process.

4.3.Synthesis of the management system

A regulator of the OWEN TRM148 type was chosen, differing in comparative cheapness and versatility. Thanks to the built-in program "Configurator TRM148" it is possible to separately model the system in specialized program environments, and then set the calculated coefficients.

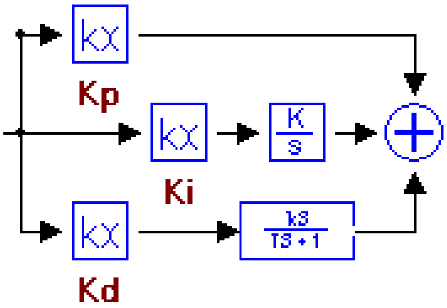


Figure 7.1 - PID connection diagram

Set the PID controller using the function blocks of the software package MVTU 3.7, then connect it to the closed functional circuit ACS of the electrolyte level as shown in Figure 7.2:

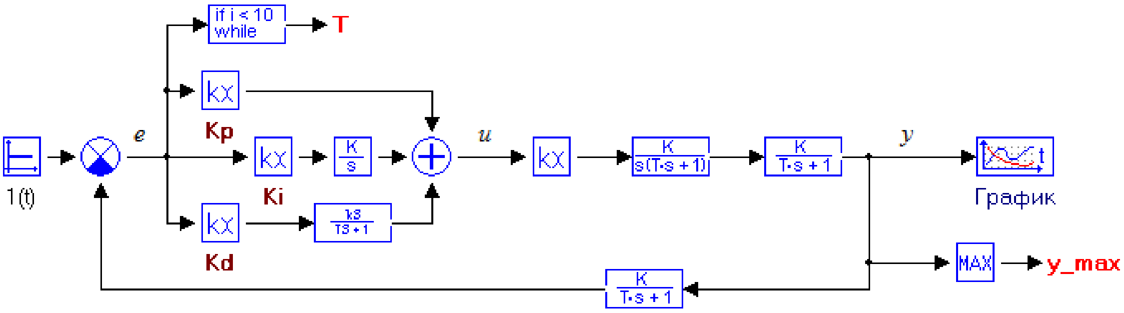


Figure 7.2 - PID connection diagram

The transfer function of the PID controller is:

$$K(p) = K_p + \frac{k}{p} + \frac{K_p p}{(1 + 0.01p)}$$

The following quality criteria are formed in the scheme:

- T - transient time (tp);

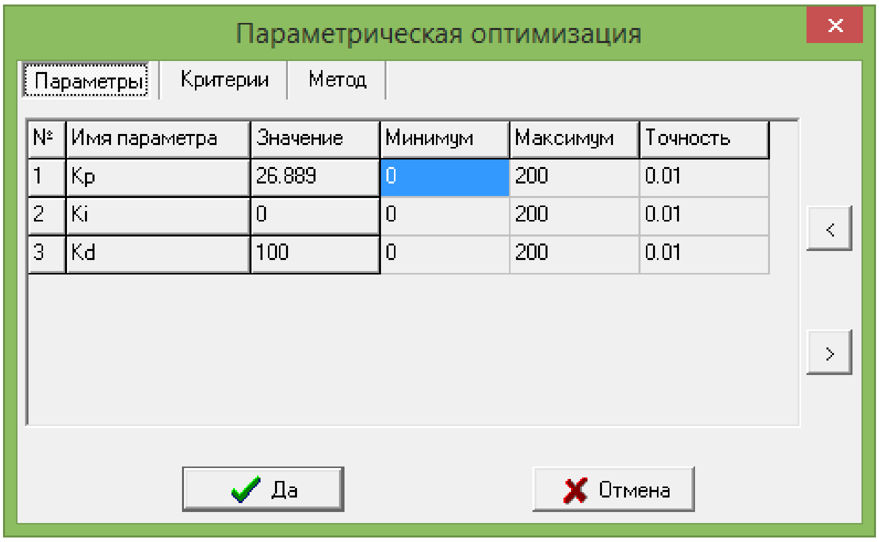
- y_max - the maximum value of the output variable;

The criterion of T is formed in the block Programming language, the program of which has the form:

```
input e;
if abs(e)>0.05 then T=time;
   output T;
```

Here, a corridor is set up, in which an adjustable value for some time T. If the control error is e≤ ± 5% (from the level in the cell's capacity), then the quality criterion is considered to be fulfilled.

Now it is necessary to solve the problem of optimizing the PID parameters by the generated criteria. The settings window in Figure 8:



№	Имя параметра	Значение	Минимум	Максимум	Точность
1	Kp	26.889	0	200	0.01
2	Ki	0	0	200	0.01
3	Kd	100	0	200	0.01

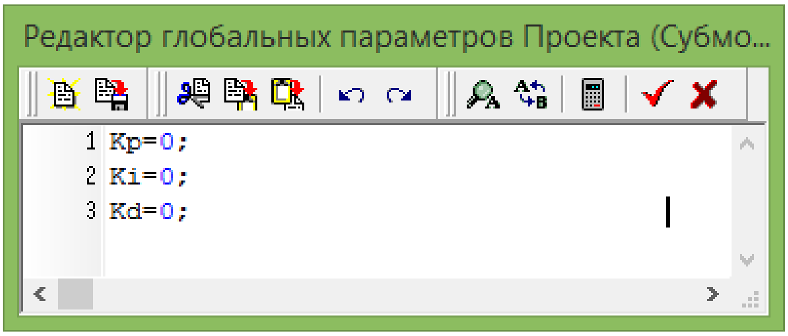
Figure 8 - Parameters of optimization of regulator settings

In the "Parameters" dialog box, the range for changing the coefficient settings is set, as well as the accuracy with which the selection is made. In the "Criteria" window -

the required quality indicators of the transient process. It follows from Figure 8 that the integral coefficient Ki is zero, i.e. we are dealing with PD-regulator.

4.4.Modeling the system and determining the quality indicators of its work

We will calculate the regulator coefficients according to the specified quality indicators, setting the model's global parameters to zero (Figure 9)

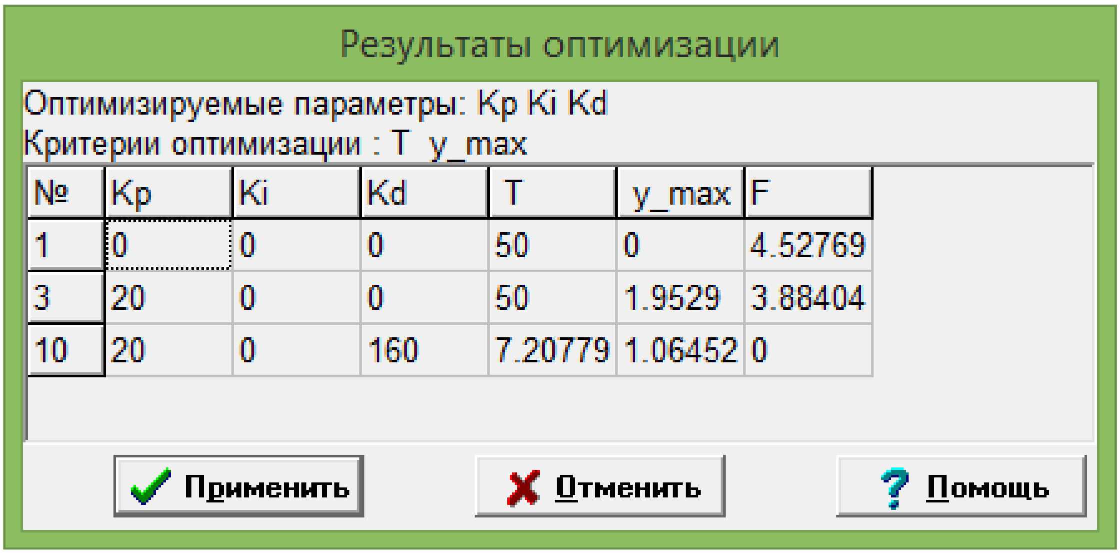


Редактор глобальных параметров Проекта (Субмо...

```
Kp=0;
Ki=0;
Kd=0;
```

Figure 9 - The global parameters editor of the model.

The program calculates the regulator parameters and displays the results in the "Optimization Results" window (Figure 10)



Результаты оптимизации

Оптимизируемые параметры: Kp Ki Kd
Критерии оптимизации : T y_max

№	Kp	Ki	Kd	T	y_max	F
1	0	0	0	50	0	4.52769
3	20	0	0	50	1.9529	3.88404
10	20	0	160	7.20779	1.06452	0

Figure 10 - Results of optimization

With the adjustment factors Kp = 20 and Kd = 160, the control time T = 7.20779c, and the maximum value of the output value y_max = 1.06452, i.e. overshoot does not exceed 20%.

Let us construct the transient response of a closed, corrected ACS (Figure 11):

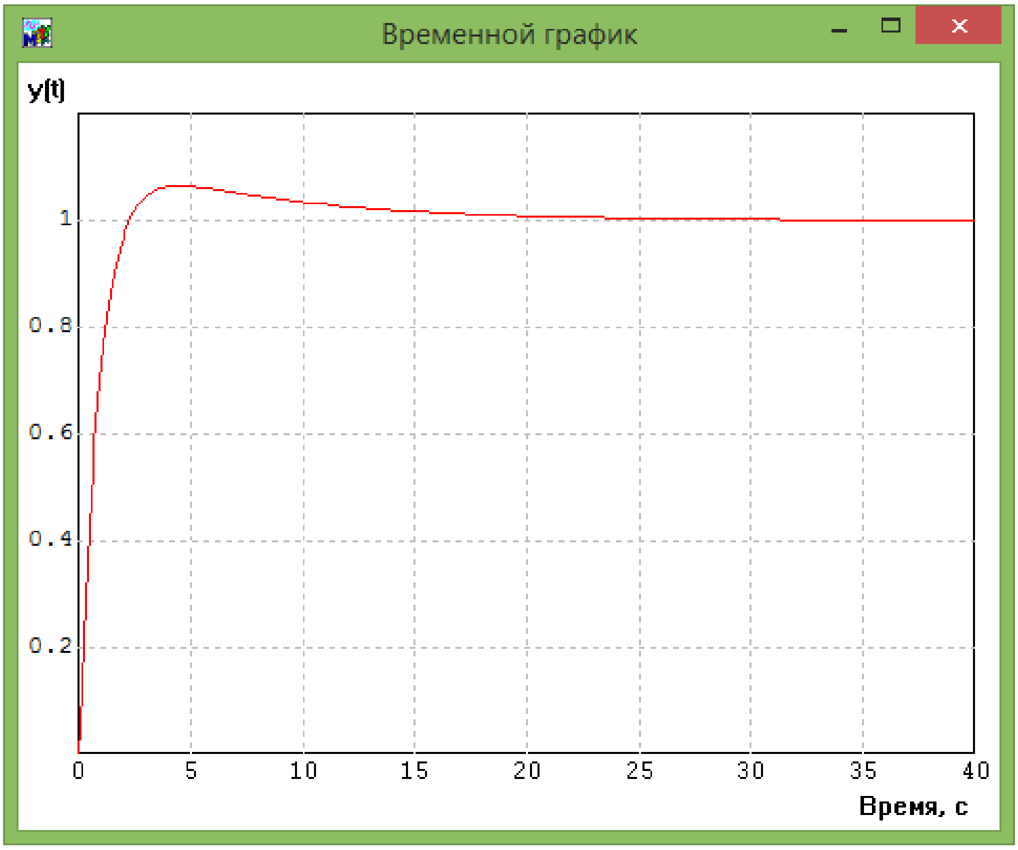


Figure 11 - Transient response of the system with a PID controller.

According to figure 11, it can be judged that a given quality of regulation is ensured.

5. DEVELOPMENT OF THE UNIVERSAL TEMPERATURE REGULATION SYSTEM ON THE CHANNEL "ELECTROLYTE TEMPERATURE – CURRENT ON THE ELECTROLYSER CELL

Structurally, the device is made in the form of three blocks: sensors, located directly on the monitored object; microcontroller, indicator and controller, which constitute the main microcircuit; as well as the power section, powered by an alternating current network.

The optoelectronic technology is used as a link between the microcontroller and the controller and which is promising in recent times.

5.1.Block diagram of the system

The structural diagram (Figure 12) is the basis for the development of concept of the device.

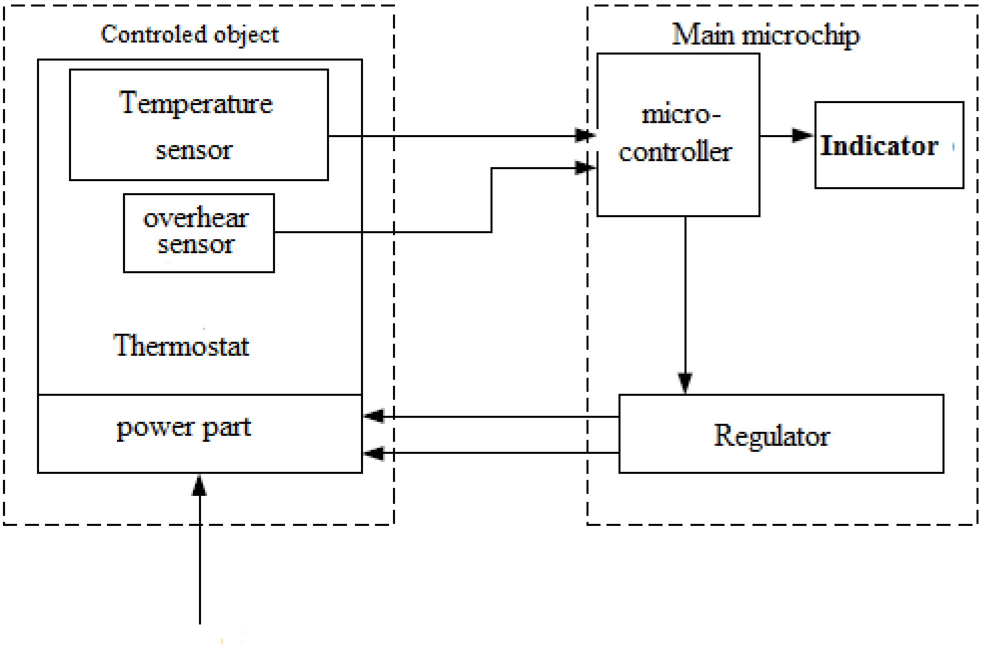


Figure 12 - Block diagram of the temperature control system

With the help of sensors built into the monitored object the microcontroller obtains the necessary information about its temperature state and can analyze, according to the program stored in FLASH memory. Visualization of the device is possible due to the indicator connected to the microcontroller. The microcontroller controls the phase power regulator. The regulator is connected to the power part of the device, which is powered by an alternating current network with a voltage of 220 V. It carries out the work of the final load.

5.2.Selection of the microcontroller

The microcontroller PIC16C62 from Microchip was selected (Figure 13):

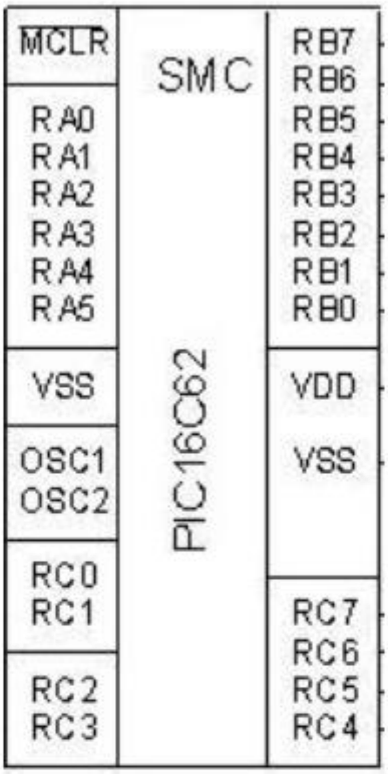


Figure 13 – Microchip PIC16C62

Features of the PIC16C6X microcontroller core:

1. High-performance RISC-processor;
2. Only 35 simple instructions for learning;
3. All instructions are executed in one step, except for the instructions for the transition, performed in two steps;

4. Operating speed: clock speed up to 20 MHz, minimum clock duration 200 ns;
5. Interrupt mechanism;
6. Eight-level hardware stack;
7. Direct, indirect and relative addressing modes for data and instructions;
8. Power-on reset (POR);
9. Power-on Timer (PWRT) and Generator Start Timer (OST);
10. Reset by drop in supply voltage;
11. Watchdog Timer (WDT) with its own built-in RC-generator to increase reliability of operation;
12. Programmable code protection;
13. Power saving mode (SLEEP);
14. Selectable clock modes;
15. Cost-effective, high-speed CMOS EEPROM technology;
16. Fully static architecture;
17. Wide range of operating supply voltages: from 2.5 V. to 6.0 V;
18. Commercial, industrial and extended temperature ranges;
19. Low power consumption:
20. <2 mA at 5.0 V. 4.0 MHz;
21. 15 μA (typical value) at 3 V, 32 kHz;
22. <1.0 μA (typical value) in STANDBY mode.

The microcontroller is programmed using an in-circuit emulator-debugger, based on the use of PIC16C6X series crystals. Such a programmer allows using the in-circuit debugging capability implemented in the PIC16C6x series chips, running under the Integrated Development Environment (IDE). The debugger provides startup, step-by-step debugging, installation / removal of the program breakpoint, and so on.

The principle of programming the microcontroller is as follows: the COM port of the computer is connected to the chip of the programmer, where the PIC is located. In the process of programming a debuggable PIC in its Programmemory, a small subroutine of the ICD Debugger is appended to the debugged program, which receives control when the Microcontroller is Started or Reset.

This subroutine communicates with the computer and allows you to execute commands such as:

1. Run one step of the program being debugged (Step);
2. Run the debugged program in real time;
3. Halt;
4. Reset the microcontroller;
5. Transfer the contents of control registers or memory registers to the computer;
6. Change the contents of the control register or memory register.

To measure the resistance, a Capture-module of the microcontroller is used, capable of storing the value of a 16-bit counter at the time of an external signal. This allows the hardware to implement the measurement by the integration method.

Measuring the resistance of thermistors consists of the following steps:

To measure the resistance, a Capture-module of the microcontroller is used, capable of storing the value of a 16-bit counter at the time of an external signal. This allows the hardware to implement the measurement by the integration method.

Measuring the resistance of thermistors consists of the following steps:

1. Discharge the capacitor C1 through the resistor R2 by applying a logic zero to the output RC2 DD1.

2. Conversion of RC0, RC1 to high-impedance state, supply of logical unit to RA5. RC2 is programmed as the input of the Capture module, the internal counter is started.
3. The voltage on the capacitor increases smoothly, and when its level exceeds the limit of approximately 3 V, the Capture module is activated, the contents of the counter are stored.
4. Repeat steps 1..3, but the logical unit is fed to RC0 (charge through the temperature sensor).
5. Repeat steps 1..3, but the logical unit is fed to RC1 (charge through the overheating sensor).

5.3. Triac Power Controller

The 1182PM1 chip is a new solution to the power adjustment problem.

Features:

1. The maximum load power is not more than 150 W;
2. Sequential switching with load;
3. Low-voltage and low-power external controls.

When using one 118МП1 chip in the device, the permissible power is limited to 150 W. It is necessary to consider the possibility of increasing the permissible load power. To do this, you must connect two or more chips in parallel, as shown in Figure 14.

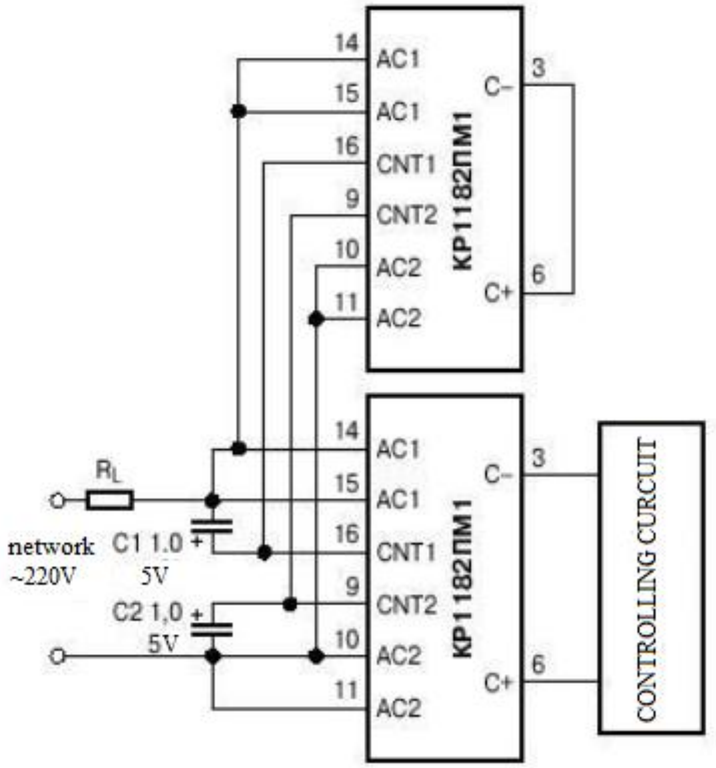


Figure 14 - Diagram of connection of microcircuits for increasing the adjustable power

The permissible power increases in proportion to the number of microcircuits. The number of controls remains the same. The control elements are connected to one of the microcircuits, the other chips are connected to each other by the outputs of the power thyristors 14, 15 (AC1) and 10, 11 (AC2), the control inputs C- (pin 3) and C + (pin 6) of each microcircuit are shorted, excepting main.

Of course, the resulting performance gain is not the most effective. A more effective method of increasing the adjustable power is the option (figure 15.), in which the chip will control the triac VS1 (MTT2-63-7), and already it will load EL1 up to seven kilowatts.

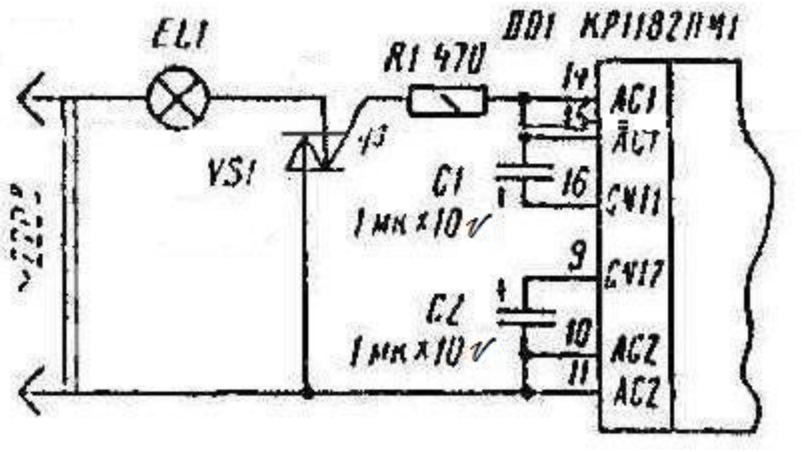


Figure 15 - Using a triac to control the current on the cell of the cell

The connection between the microcontroller and the power controller is carried out with the help of a transistor optocoupler AOD128A, which performs the function of a logical key.

Optocouplers (Figure 16.) refer to such optoelectronic devices in which there is a source and receiver of radiation (light emitter and photodetector) with some kind of optical and electrical connection between them, structurally related to each other.

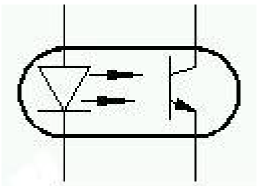


Figure 16 - Transistor optocoupler

By feeding the control signal from the microcontroller to the light emitter (diode) of the optocoupler, the key is activated. Thus, the use of an optocoupler provides galvanic isolation between the regulator and the source of the control electrical signal.

6. DESCRIPTION OF THE AUTOMATION DIAGRAM OF THE TP OF HYDROGEN PRODUCTION BY ELECTROLYTIC METHOD

When developing the scheme for automating hydrogen production, the following tasks shall be solved:

1. To obtain primary information about the state of the technological process and equipment;
2. stabilize technological process parameters;
3. control and registration of technological parameters of process and condition of technological equipment.

The process of hydrogen production begins in the electrolyzer, it is filled with electrolyte in advance and is fed by electrolyte from the storage heater. At this stage, the electrolyte temperature, its density and level, as well as the pressure in the cell are monitored. The process is controlled by the channel level of the electrolyte - the supply of electrolyte from the preparation system. Also, electrolyzers are equipped with thermal relays that do not allow the electrolyte to boil or overheat, shutting off the supply of voltage to the cell when the critical temperature is reached. All instruments in explosion-proof design, control actions (for example, regulation of the electrolyte level and its supply to the cell) / 7 / are formed using technological measuring-regulators such as Metran-961. Thermoelectric converters of the type TXK Metran-252 (Fig. 4) are used as temperature meters with a natural output signal. The secondary device is Metran-901, it is also used to indicate all parameters that do not require regulation.

To measure the pressure, sensors of the Metran-75 type are used, in explosion-proof design and with a unified signa

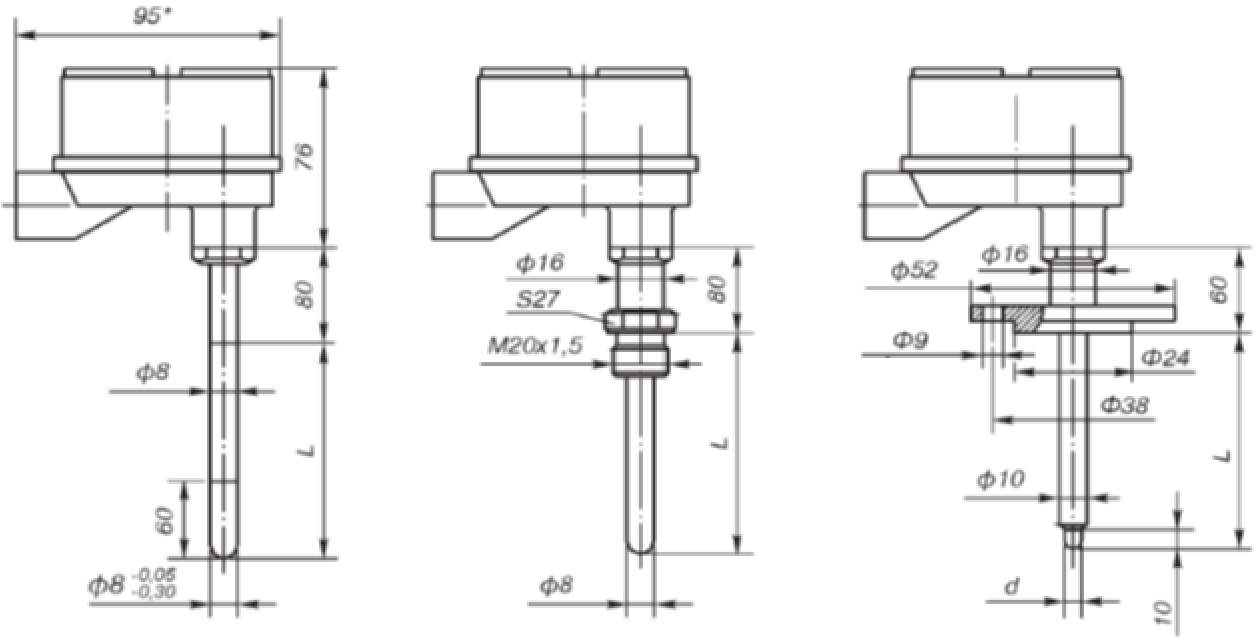


Figure 17- Various versions of the Metran - 252 sensors

To measure and record the flow of gases at the outlet of the system, flowmeters of variable pressure drop type Rosemount 3051SFC, shown in Figure 17, are used.

Figure 18 - Rosemount 3051SFC flowmeter with diaphragm

Rosemount 5300 wave radar level meters are used to measure and regulate the level in electrolyzers, storage heater and equalizing tanks, which work in conjunction with the Metran-961 technological measuring-regulator and a universal Samson 3214 control valve with a built-in current signal converter and an electric drive, shown in Fig. 18.

To control the purity of gases, as well as for the emergency protection system, thermal conductivity sensors of hydrogen are used. These sensors are of low accuracy and react only to the appearance of gas in the pipeline, providing subsequent overlap / opening during the switching between technological modes. In addition, two full-fledged gas analyzers are used - thermal conductivity for hydrogen (GEXMTC) and thermomagnetic for oxygen (GEXMO2) respectively. The sensors provide remote signal transmission to the Metran-961 regulators and a lock / unlock signal to the valves, in the case of a drop in the concentration of the measured substances.

To measure the density of the electrolyte, vibratory density meters of the type VP 804, with a unified output signal.

Figure 7 - Samson-3214 Control Valve

Voltmeters of M42301 direct current type are used to measure the voltage on the electrolytic cell, and the voltmeter of alternating current type E311-1 is used to measure the supply voltage of the storage heater.

7. CONCLUSION

In this master's work, a large-scale study of the technological process was carried out, information was found and processed from specific sources of information, methods of designing automatic control and regulation systems using modern software were applied. In addition, the knowledge accumulated during the study of the master's course of study was structured.

In the course of the graduation project, in accordance with the assigned task, a multifunctional automated control system was created to ensure the safe operation of equipment and the flow of the technological process of hydrogen production.

8. BIBLIOGRAPHY

1. Водород. Свойства, получение, хранение, транспортирование, применение. Справочник /Д. Ю. Гамбург, В. П. Семенов, Н. Ф. Дубовкин, Л. Н. Смирнова; Под ред. Д. Ю. Гамбург, Н. Ф. Дубовкин. – М.: Химия, 1989. – 672 с.
2. Якименко Л. М., Модылевская И. Д., Ткачек З. А. Электролиз воды. – М.: Химия, 1970. – 264 с.
3. Иоффе В. Б. Основы производства водорода. – Л.: ГОСТОПТЕХИЗДАТ, 1960. – 430 с.
4. Серебрянский Ф. З. Электролизеры для производства водорода и кислорода. Химическое и нефтеперерабатывающее машиностроение. – М.: ЦИНТИХИМНЕФТЕМАШ, 1969. – 49 с.
5. Кулаков М. В. Технологические измерения и приборы для химических производств. М.: Машиностроение, 1974. – 464 с.
6. Макаренко В. Г. Схемы автоматизации. Учебное пособие к курсовому и дипломному проектированию. ЮРГТУ (НПИ) – Новочеркасск, 1999. – 48 с.
7. Каталоги компании «МЕТРАН».
8. Фарзане Н. Г., Илясов Л. В., Азим-заде А. Ю. Технологические измерения и приборы. - М.: Высшая школа, 1989. – 465 с.

Apendix A. Technological parameter

	Technological parameter	Value of the controlled value parameter	Place of control	Method of parameter control	Type of control and management			
					Control	Registration	Regulation	Signaling
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	ELECTROLYSER							
1	The temperature of the electrolyte coming from the preparation system	80 ±2^{0}C	pipeline		+	-	-	-
2	The temperature of the electrolyte inside the cell	80±5^{0}C	cell body		+	+	+	-
3	Pressure	10±2 atm	cell body		+	-	-	max 13 atm
4	Density of electrolyte	1230 ± 50kg/m^3	cell body		+	+	-	-
5	Cell voltage	200-230V	cell body		+	-	+	min. 180V max. 260V
6	Electrolyte level	1.5÷0.1m	cell body		+	+	+	min. 1.3 m max. 1.7m
7	The temperature of the electrolyte in the recirculation system (at the entrance to the cell)	65±5^{0}C	at the entrance to the cell)		+	-	-	-

Apendix A. Technological parameter

	HYDROGEN FLUID REGULATOR							
1	Pressure	6±2atm	washer body		+	-	-	min. 3atm max. 8atm
	REGULATOR-WASHER OF OXYGEN							
1	Pressure	6±2atm	washer body		+	-	-	min. 3atm max. 8atm
	SURGE TANKS							
1	Distillate level	$0.5\pm0.1m$	surge tanks		+	+	+	min. 0.3m max. 0.7m
	FLAME FILTER							
1	Hydrogen concentration	0±2%	pipes		+	-	+	max 1%
	HYDRAULIC LOCK							
1	Oxygen concentration	98±0.1%	pipes					min. 95%
2	Oxygen flow rate	1.5±0.2, m3/h	pipes		+	+	-	-
	EXPANDER							
1	Hydrogen concentration	0±2%	pipes		+	-	+	max. 1%
	COOLER BODY							
1	Hydrogen concentration	99±0.1%	pipes		+	-	+	min. 95%
2	Hydrogen flow rate	3±0.2, m^3/h	pipes		+	+	-	-

Apendix A. Technological parameter

	ACCUMULATOR HEATER							
	Temperature of the electrolyte at the inlet to the heater	20±5^{0}C	pipes		+	-	-	-
	Temperature of the electrolyte at the outlet of the heater	80±2^{0}C	pipes		+	-	-	-
	Level of liquid in the heater	1±0.1 m	heater body		+	+	+	-