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TECHNOLOGICAL PROCESS CONTROL OF OIL GAS ABSORPTION

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Abstract. The main purpose of the paper is to study the optimization of the technological process of oil gas absorption. For this purpose, a complete analysis of the technological process was made with the identification of automation tasks: ensuring a stable temperature of absorbent in the circuit; ensuring a stable temperature of the cooling circuit; filtration of absorbent; ensuring a stable gas pressure in the system; free flow of absorbent between the tanks; accounting of purified gas. The process of selecting equipment for development of a three-level automated control system for oil gas absorption was investigated. The system has 35 discrete signals and 17 analog signals. The measuring devices that should be responsible for collecting and transmitting process information to the logic controller model were selected, the actuators that directly interact with the gas absorption process were selected. Based on the selected sensors, the type of sensor signal, its name and the required number for the possible realization of the automated system were specified. The industrial logic controller, which meets all the requirements of the technological process, was selected. The article provides a rationale for the choice made.

Keywords: oil gas absorption, resource processing, technological process, automated control system, SCADA system

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УПРАВЛЕНИЕ ТЕХНОЛОГИЧЕСКИМ ПРОЦЕССОМ МАСЛЯНОЙ АБСОРБЦИИ ГАЗА

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Аннотация. Основная цель данной статьи заключается в исследовании оптимизации технологического процесса масляной абсорбции газа. Для этого был произведен полный анализ технологического процесса с выявлением задач автоматизации: обеспечение стабильной температуры абсорбента в контуре; обеспечение стабильной температуры холодильного контура; фильтрация абсорбента; обеспечение стабильного давления газа в системе; свободное протекание абсорбента между баками; учет очищенного газа. Был исследован процесс выбора оборудования для реализации трехуровневой автоматизированной системы управления масляной абсорбции газа. Система насчитывает 35 дискретных сигналов и 17 аналоговых. Выбраны измерительные устройства, которые должны отвечать за сбор и передачу информации о процессе к моделируемому логическому контроллеру, выбраны исполнительные устройства, которые непосредственно взаимодействуют на процесс абсорбции газа. Исходя из выбранных датчиков, указан тип сигнала датчика, его наименования и необходимое количество для возможной реализации автоматизированной системы. Выбран промышленный логический контроллер, который отвечает всем требованиям технологического процесса. В статье приведено обоснование проведенного выбора.

Ключевые слова: масляная абсорбция газа, переработка ресурсов, технологический процесс, автоматизированная система управления, SCADA-система

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Introduction

Oil absorption of gas is one of the most common and used methods of extracting natural gasoline, as it is the most cost-effective and less resource-intensive [1, 2]. The technological process takes place in hard-to-reach areas, in other words, directly in the gas or gasoline field, which increases the risks to human life.

Based on the above, there is a need to introduce an automated process control system (APCS), which increases the quality of purified gas and gasoline, while constantly maintaining the quality of gas, optimizes the operation of the technological process, maintaining the specified values of the parameters of the plants, and provides an opportunity to reduce risks to human life.

Process control systems are divided into automated and automatic. An automated control system implies human participation in the direct control of the technological process, for example, an operator or a dispatcher [3]. An automatic control system consists of a control object and a control device that operate independently [4, 5].

An automated control system is categorized into several levels of automation, where humans occupy the top level. Each automated control system has its own requirements for speed, safety and labor protection. The main task of an automated system is to collect and process information that helps to optimize the control of the technological process.

The subject of the study is the methods and ways of controlling the technological process of oil gas absorption.

The purpose of the study is the approaches to the automation of the technological process of oil gas absorption. Achieving this goal is ensured by solving a number of problems:

- to conduct a complete analysis of the technological process with the identification of automation tasks;
- to analyze the technical characteristics of equipment for the implementation of automated control system for oil gas absorption;
- to model software and hardware for the process of creating a human-machine interface [6, 7].

Analysis of the technological process

Gas absorption is a method for drying and purifying gas from heavy hydrocarbons using liquid absorbent. The temperature at which the process takes place and the purity of the liquid reagent play an important role in absorption [8].

Absorption is divided into two processes: physical and chemical. The first one is characterized by achieving equilibrium between interacting gas and liquid flows due to diffusion (transfer) of substance from one phase to another. It can also be noted that physical absorption is a reversible process, therefore absorption-desorption plants are used to reduce the cost of absorbents. The desorber is used to regenerate the liquid reactant, whereby the absorbed component is released. While sorption requires high pressure and low temperature, the reverse process (desorption) requires high temperature and low pressure [9].

The absorber is selected according to the following criteria: absorption capacity; dependence of absorption capacity on changes in thermobarometric characteristics; selectivity to the selected substance; cost; possibility of regeneration [10, 11].

The process of oil gas absorption is presented in the form of a process flow diagram (Fig. 1).

After compression, the oil gas from the second and third stages of separation passes the cooler No. 2 and is transported through a pipeline to the absorber. In the process of gas rising up the absorber, the absorbent absorbs heavy hydrocarbons, which flows down the plates from the upper part of the column. The stripped gas first passes through the mist eliminator, where the absorbent carried away by the gas will be captured, then it enters the dehydration unit, and then it is sent to the main gas pipeline or to the consumer [12].

The “fat” absorbent, saturated with heavy hydrocarbon vapors, is discharged through the level regulator (not shown in Fig. 1) from the lower part of the absorber and enters the weathering unit. Since the pressure in this unit is somewhat lower than in absorber, most of the methane and ethane dissolved in the absorbent is released from the “fat” absorbent [13].

From the weathering unit, the “fat” absorbent is first sent to heat exchanger No. 8, where it is preheated with “lean” absorbent coming from the lower part of desorption column, and then to furnace. In the furnace, the “fat” absorbent is heated to a temperature of about 250°C, after which it enters the middle part of desorber, where intensive release of hydrocarbons from the saturated absorbent occurs due to high temperature and significant decrease in pressure reduction. To intensify the desorption process, gas is fed to the lower part of the desorber from the weathering unit, which is preheated in the heat exchanger No. 5 due to the heat of the hot absorbent coming from the lower part of the desorber. Heavy hydrocarbon vapors from the upper part of the desorber together with the weathering gases, are sent to the cooler No. 12, where they are condensed. The condensate together with the weathering gas enters the separator, from where part of the condensate is taken by the pump No. 16 and sent for irrigation to the desorber. The other part enters the tank with unstable condensate. The hot absorbent from the lower part of the desorber, as already mentioned above, passes sequentially through the heat exchangers No. 5 and 8, then enters the cooler No. 7, where its temperature decreases to approximately 38°C.

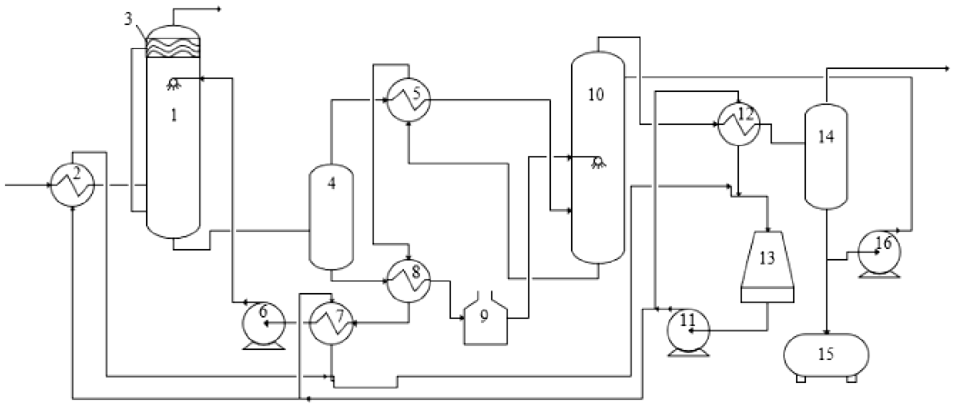

Fig. 1. Process flow diagram of oil gas absorption (compiled by the authors):
1 – absorber; *2*, *7*, *12* – cooler; *3* – mist eliminator; *4* – weathering unit; *5*, *8* – heat exchanger; *9* – furnace; *10* – desorber; *11*, *16* – pump; *13* – cooling tower; *14* – separator; *15* – tank with unstable condensate

The cooled absorbent is fed to the suction by the unit No. 6, which pumps it into the upper part of absorber for irrigation, and the cycle of movement of the "lean" absorbent is repeated. Cooling of the hot absorbent in cooler No. 7 and condensation in coolers No. 12 of heavy hydrocarbon vapors released from the "fat" absorbent in desorber is carried out in this plant as a result of closed circulation of water cooled in the cooling tower and pumped by the pump No. 11.

The oil gas absorption plant performs purification and production in two stages, where the first stage is the purification of gas directly from the extraction site, and the second stage involves obtaining gas from the absorbent. The process itself has two circuits, where the main control parameter is temperature. The system controls several parameters, namely: the filling level of the tanks; the pressure in the pipes before and after the tanks; the pressure drop across the filters; the temperature of the absorbent in the tanks [14]. The process is controlled directly by gate valves, starters, and a furnace that heats the absorbent.

For ease of monitoring the process and reducing the risk of an emergency, it is necessary to develop an automatic workstation (AWS) for the operator, who makes adjustments to the process, prevents accidents and monitors technological parameters of the process.

When analyzing the process, seven main tasks of automation of oil gas absorption were identified:

1. Ensuring a stable temperature of the absorbent in the circuit.
2. Ensuring a stable temperature of the cooling circuit.
3. Filtration of the absorbent.
4. Ensuring a stable gas pressure in the system.
5. Free flow of absorbent between tanks.
6. Accounting of the purified gas.

The system has several types of signals: discrete input (DI), discrete output (DO), analog input (AI), analog output (AO). Discrete inputs are signals from limit sensors, differential pressure sensors. Analog input signals are temperature, liquid level, and system pressure sensors. Discrete outputs in the system control the starters and gate valves of the technological process. Analog outputs are required to control the temperature and position of the valve for opening/closing the gas supply to the plant for purification.

From the entire process description, the total number of signals in the system was determined to be 52, including 17 DI, 18 DO, 15 AI, 2 AO.

Justification of the selection of technical automation equipment

In order to correctly select the technical automation equipment, let us consider the architecture of automated process control system (Fig. 2).

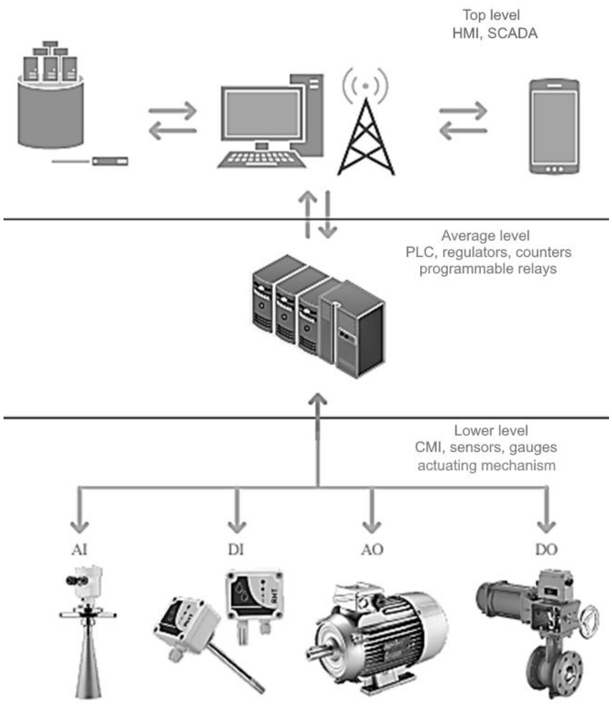

Fig. 2. Architecture of automated process control system (compiled by the authors)

The upper level (SCADA level) of the automated process control system is the level where a person can influence the system [15–17]. This level also implies the presence of a real-time database management system, where the operator's screen displays current information about the system and the interface of interacting with the process (buttons for opening/closing the gate valves, setting the temperature, engine speed etc.) [18–20]. At the moment, such a system can imply remote control at a distance of tens of kilometers [21, 22].

The middle level of the automated process control system includes the functions of measurement, control, protection, blocking, regulation [23, 24]. Here are the algorithms for the operation of the technological process and communication with the upper level, to which all the information collected from sensors is sent. The middle level implies the presence of industrial logic controller, which performs all functions.

At the very bottom of the hierarchy are the actuators that directly affect the technological process (switching on/off electric engines, as well as regulating the position of gate valves, process temperature etc.), and all kinds of sensors that collect data on the process (water temperature, pressure in pipes, engine speed etc.) [25].

The main factor for selecting a differential pressure sensor is the maximum possible differential pressure [26, 27]. A comparative analysis showed the advantage of the IFM PK5522 sensor, since its price can compete with other differential pressure sensors ROSMA RPD-D and Huba Control 652.

Based on the maximum measured temperature plus a 10% reserve, we will select a sensor for the desorber and the furnace, where the maximum temperature reaches 250°C. It should be understood that for both the furnace and the desorber, the measured medium will be the absorbent that flows in the system. Comparison of high-temperature temperature sensors OWEN DTS035M-100P.0,5.400.MG.I and TURCK TTMS-206A-CF-LIUPN-H1140-L150 showed the first of them to be the leader in the price segment.

The choice of temperature sensor for an absorber and cooling tower was between Balluff BFT 6050-DX001-R02A0A-S4, TURCK TP-103A-G1/8-H1141-L013 and OWEN DTPK084-00.250/3K. Despite the more protected versions of Balluff and TURCK, the OVEN sensor is more profitable. When measuring the temperature of a cooling tower, there is no need for precise temperature measurement, therefore the error fades into the background compared to the price of the sensor.

The gas creates the pressure at the absorber inlet, therefore it is worth using a pressure sensor for natural gas, which can withstand up to 2 MPa, to obtain and record pressure values during overloads. For comparison, the following sensors were selected: OWEN PD100-DI2,5-111-0,5, ADZ-SML-10.0 0/20 BAR, ROSMA RPD-I 0...2.5 MPa 4...20 mA. There is no significant difference in technical characteristics of the sensors, therefore we will focus on the economic component, where ROSMA stands out. The sensor is universal for both gases and liquids, and it can be used for absorbent pressure in pipes.

The studied automated process control system includes two types of level sensors: high-temperature and conventional. The first one is used for the desorber, because the temperature in it is maintained at 250°C, and can even go beyond the limits, in other words, the maximum temperature that the sensor must maintain should not be lower than 300°C. The process takes place under pressure, where the maximum pressure value reaches 2 MPa. In addition to the level gauge, it is also possible to use a level switch, but at least three of them will be needed to know the lower limit, working limit and upper limit of the permissible values of the absorbent level in the desorber. For comparison, three sensors were selected: RIZUR-2030, SIRUR-03B and VEGASWING 66. The first one is the most economical and most functional.

To measure the level in the absorber, weathering and unstable condensate tanks, conventional float sensors are suitable, which must only meet the temperature conditions that do not exceed 70°C, and contact with chemically aggressive liquids (RIZUR-NMT-G sensor is suitable for this).

The flowmeter in the technological process is not subject to certain temperature limitations only because the gas at the absorber inlet and separator outlet has a temperature of 20 ± 10°C and its pressure is limited by the outlet of 1.5 MPa. In this case, we select the flow transducer EMIS-VIKHR 200 (EV-200).

Based on the information about the selected sensors, Table 1 with their number and type of signal was created.

Table 1

Summary table of control and measuring instruments (compiled by the authors)

	Product Name	AI	DI	Quantity
1	IFM PK5522		+	2
2	OWEN DTS035M-100P.0,5.400.MG.I	+		2
3	OWEN DTPK084-00.250/3K	+		2
4	ROSMA RPD-I 0...2,5 MPa 4...20 mA	+		4
5	RIZUR-2030	+		1
6	RIZUR-NMT-G	+		3
7	EV-200	+		2

The system uses 16 electric drives with 3-phase power supply of 380 V, a power of 90 W and a discrete input for their control (GZ-OF 200/7M) as actuators (Table 2).

For the automated process control system, it is optimal to use three starters with a rated voltage 380 V and a rated operating current of 25 A, as well as a discrete signal for control (EKF PML-2160DM 25A 230V Basic).

For the correct operation of the automated system, one thyristor power controller is required, applicable to the heating element capable of heating up to the temperature of 250°C (SIPIN W5-TP4V030-24J).

As a programmable logic controller an industrial logic controller that meets all the requirements of the technological process (industrial modular logic controller REGUL R200) was selected. At the same time, it has a good price-quality ratio in terms of functional and technical capabilities. It was equipped with the following modules: power supply, processor, analog input, discrete input, analog output, discrete output.

Table 2

Summary table of actuators (compiled by the authors)

	Product Name	AO	DI	DO	Quantity
1	GZ-OF-200/7M			+	16
2	GZ-OF-200/7M (limit switches)		+		16
3	EKF Basic PML-2160DM			+	3
4	SIPIN W5-TP4V-030-24J	+			1

Software tools of the automated control system

For the operation of the automated process control system, two interconnected blocks are required, namely: a control program that will be entered into the industrial logic controller; an operator interface that visualizes all the information about the ongoing process in real time and sends control signals to the industrial logic controller [28–30], for example, starting and stopping the process.

The hardware configuration and adjustment of the Regul family industrial logic controller is carried out in the Epsilon LD software, which supports five languages from the IEC 61131-3 standard list, and also has a number of functional capabilities for programming.

Since it is physically impossible to create a control program, it was decided to create a program in a similar free programming environment CoDeSys V2.3. Therefore, the entire created control program is implemented in a free version, which is identical for loading it into Epsilon LD.

According to the description of the technological process and to its settings for physical values, it is necessary to create a program that performs a number of the following functions:

– starting and stopping the oil gas absorption system;
– controlling the absorbent level in the tanks;
– controlling the temperature in the cooling and absorbent circuit;
– controlling the gas pressure at the process inlet as well as the absorbent pressure in the pipes;
– controlling the filter clogging;
– starting and stopping the cooling circuit;
– selecting the “passive” manual operation mode and “active” automated mode.

For this purpose, a flow chart of the technological process of oil gas absorption was developed and algorithms were created on its basis, which keep the technological parameters of the system within the established limits.

All code was created in the Sequential Function Chart (SFC) language, as the most convenient when comparing the program with the flow chart. SFC is convenient in that several states can be active at once on parallel branches, which monitor the process. Moreover, each of the states can be written in a language convenient to the programmer.

To check the program operation, a visualization was created in the internal CoDeSyS software [31] (Fig. 3).

The purpose of modelling an AWS is to provide convenience in analyzing the technological process and making quick decisions.

The main screen contains dashboards with the main process parameters and navigation between the windows. The second-level windows contain control of individual parts of the technological process and more detailed information; it is also possible to change the process settings.

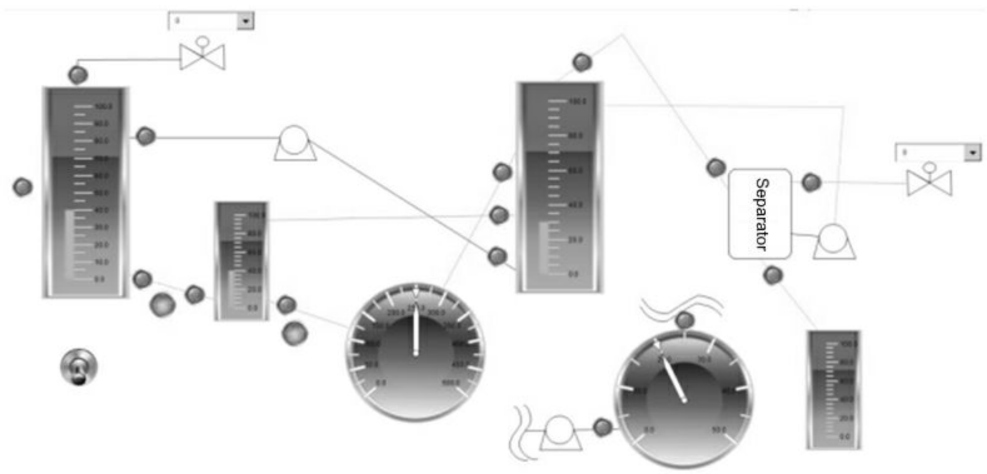

Fig. 3. Visualization of the technological process (compiled by the authors)

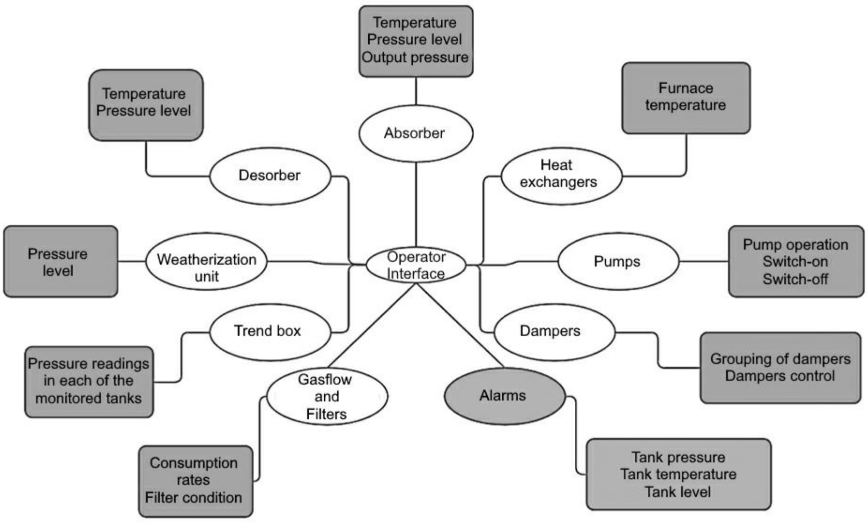

Fig. 4. SCADA screens tree (compiled by authors)

Before we start creating an AWS, let us create a tree of screens in our program, shown in Fig. 4.

Next, an AWS for the operator, who will monitor the process, was developed in SCADA InTouch [32, 33]. All kinds of animations of the program for processing emergencies and operating the system in normal mode were configured. After that, the communication between SCADA system and programmable logic controller program was configured via Matricon Explorer OPC server [34, 35]. Alarms and archiving were configured.

Conclusions

The study examines and describes the design and development process of the automated control system for the technological process of oil gas absorption. The operation of the aforementioned technological process is described and analyzed as an automation object, with 52 signals involved: 18 DI, 19 DO, 14 AI, 1 AO. The technological diagram of the oil gas absorption plant is presented, where the location of sensors and actuators is indicated.

The following sensors and actuators have been selected for the implementation of the automated process control system: differential pressure sensor on the IFM Electronic PK5522 filter (2 pcs.), high-temperature temperature sensor (OWEN DTS035M-100P.0,5.400.MG.I, 2 pcs.), and temperature sensor (OWEN DTPK084-00.250/3K (2 pcs.), pressure sensor ROSMA RPD-I 0...2.5 MPa 4...20 mA (4 pcs.), level transmitter RIZUR-2030 (1 pc.), level transmitter RIZUR-NMT-G (3 pcs.), flowmeter EV-200 (2 pcs.), quarter-turn electric actuator GZ-OF-200/7M (16 pcs.), starter EKF Basic PML-2160DM (3 pcs.), thyristor power regulator SIPIN W5-TP4V030-24J (1 pc.). The REGUL R200 block-module PLC with the required module configuration was selected: R200 CU 00 031 (1 pc.), R200 AI 04 051 (4 pcs.), R200 AO 02 011 (1 pc.), R200 DI 08 011 (3 pcs.), R200 DO 08 011 (2 pcs.), R200 DO 04 021 (1 pc.).

A program for controlling the technological process of oil gas absorption in SFC language in CoDeSys V2.3 software was developed.

An automated operator's workstation in InTouch environment was modelled, thanks to which the operator receives information about the process operation and can perform independent process regulation in the manual mode.

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