

Expert analysis of the automation equipment for the integrated oil treatment unit

V S Tynchenko^{1,2}, V V Bukhtoyarov^{1,2}, V V Tynchenko^{1,2}, E A Petrovsky¹,
K A Bashmur¹ and V V Kukartsev^{1,2}

¹ Siberian Federal University, 79, Svobodny pr., Krasnoyarsk, 660041, Russian Federation

² Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russian Federation

E-mail: vadimond@mail.ru

Abstract. The article discusses the problem of control automation for integrated oil treatment unit. The main goals of such automation are presented, the achievement of which allows increasing oil treatment unit productivity, as well as improving working conditions of staff. As a result of the study, an analysis of the features of oil treatment unit automation was carried out. The principles of automation of such an object were considered and an oil treatment unit principal schema was presented. The presented features of the SCADA system involve the use of a number of sensors to measure the current parameters of the oil treatment unit. Using the expert study method, a reasonable choice of specific measuring and control devices was made. Reviewed measuring and control devices are modern equipment of Russian and foreign production, which have a good service life and the necessary measurement accuracy.

1. Introduction

The processes of dehydration, desalination and oil stabilization are carried out at the complex oil treatment facilities (COTF) [1]. The basic scheme of COTF with rectification is shown in Figure 1.

Consider the work of complex oil treatment facilities. Cold crude oil from the tanks pump 1 through the heat exchanger 2 is fed into the sedimentation tank 3. Here, most of the mineralized water settles to the bottom of the apparatus and is diverted for further preparation for injection into the reservoir (III). Next, fresh water (V) is added into the stream to reduce the salt concentration in the remaining mineralized water. In the electric dehydrator 4, the final separation of water from oil is carried out and the dehydrated oil through the heat exchanger 5 enters the stabilization column 6. By pumping oil from the bottom of the column through the furnace 10 by pump 11, its temperature is brought to 240 °C. In this case, light oil fractions evaporate, rise to the top of the column and then enter the condenser-cooler 7. Here the propane-butane and pentane fractions are mainly condensed, forming the so-called broad fraction, and non-condensed components are discharged for use as fuel. A wide fraction is pumped out by pump 9 for fractionation, and partially used for irrigation in column 6. Stable oil from the bottom of the column is pumped by pump 12 to commodity tanks. On this way, hot stable oil gives up part of its heat to crude oil in heat exchangers 1 and 5.

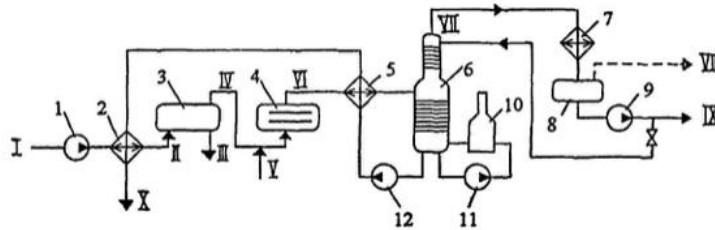


Figure 1. Schematic diagram of the integrated oil treatment installation, where: 1, 9,11,12 - pumps; 2,5 - heat exchangers; 3 - sedimentation tank; 4 - electric dehydrator; 6 - stabilization column; 7 - condenser-cooler; 8 - irrigation capacity; 10 - oven; I - cold crude oil; II - warmed up crude oil; III - drainage water; IV - partially dehydrated oil; V - fresh water; VI - dehydrated and desalted oil; VII - pairs of light hydrocarbons; VIII - non-condensing vapors; IX - broad fraction (condensed vapors); X - stable oil.

Thus, in COTF dehydration, desalination and oil stabilization are carried out. Moreover, for dehydration, heating, sedimentation and electrical exposure are used simultaneously.

The object of the study in this work is a part of the integrated oil treatment unit, consisting of a tank, a pumping station unit and an oil heater. The oil supplied for transportation to the highway must comply with the established parameters and be in a certain temperature range.

The automated COTF system, consisting of measuring devices, controllers and actuators, should provide [2, 3]:

- Automated monitoring and control in real time of the technological process of preliminary preparation and oil and water pumping [4].
- Safety of the technological process of oil and water preliminary preparation [5].
- Automatic and remote correction of the technological process to a safe state in case of emergency situations (fire, failure of technological equipment, etc.) [6].
- Monitoring the level of the product, the temperature of the heater, and their location within the specified regulatory limits and the transfer of COTF to a safe state when the level goes beyond the range [7].
- Control of the technological parameters of oil pumps and oil products [8, 9].
- Control of oil pumps and oil products [10].

In addition, associated gas is supplied to the oil heater for heating. According to current legislation, a strict accounting of associated gas consumption is required.

Thus, the urgent task is to choose effective means to control the parameters of the considered technological process in order to improve the quality of the complex oil treatment facilities automated control [11].

2. Choice of controller equipment

When choosing controller equipment, several widely used programmable logic controllers (PLCs) were considered: Emerson Delta V, Siemens SIMATIC S7-400, EMICON DSC-2000. Table 1 shows a comparison of the controller equipment characteristics.

As a result of the expert analysis according to the criteria presented in Table 1, a Siemens SIMATIC S7-400 PLC was selected, equipped with two communication processors (one local, and the second for communication with the upper level).

This controller provides the ability to solve automation problems in the optimal way. The advantages include high platform reliability, the ability to communicate via multiple protocols and interfaces with other systems, and ample expandability.

The appearance of the PLC is shown in Figure 2.

Table 1. Comparison of the controller equipment characteristics.

Characteristics	PLC model		
	Emerson Delta V	EMICON DCS-2000	Siemens SIMATIC S7-400
Programming languages	LD; FBD; ST; SCL; IL.	CONT-Designer; CoDeSys.CFC; GRAPH; HiGraph.	LD; FBD; ST; SCL;
Number of input / output channels	63488 discrete and not more than 3968 analog	1335 discrete and 199 analog	65536 discrete and not more than 4096 analog
Memory and logic data, Mb	48	8	0.5 for code, 3 for data
Communication options	FOUNDATION fieldbus; HART; WirelessHART; Profibus DP; DeviceNet.	RS-485; Modbus RTU; Ethernet	MPI; PROFIBUS; Industrial Ethernet; PROFINet; AS-I; BAC-net; Modbus TCP; Modbus RTU.
Life time, years	8	10	12
Price, rubles	250000	50000	180000
Architecture	modular	modular	modular
Reservation	full support	hardware redundancy	hot standby option



Figure 2. PLC Siemens SIMATIC S7-400.

3. Choice of measuring instruments

During operation of COTF, it is necessary to monitor the oil level in the tanks, the pressure on the suction manifold of the pump, the temperature in the heater, before and after heating the oil, the pressure of gas and nitrogen supplied to the heater. To control the indicated parameters, it is possible to use the following types of sensors: flowmeter, pressure sensor, temperature sensor, level gauge.

When choosing a flow meter, the following options were considered that were widely used in the oil and gas industry: Prowirl 72W vortex flow meter, DRG.M and Annubar Metran-350. A comparison of the selected flowmeter samples is shown in Table 2.

As a result of expert analysis, a Metran-350 flowmeter based on the Annubar averaging pressure tube (APT) was chosen to measure gas and nitrogen flow rates, since it has higher measurement accuracy, high degree of protection, and low price.

Table 2. Comparison of the flowmeters characteristics.

Characteristics	Flowmeter model		
	Prowirl 72W	DRG.M	Metran-350 Annubar
Medium	Liquid, steam, gas	Liquid, gas	Liquid, steam, gas
Measurement principle	Vortex	Vortex	Differential pressure
Output signal, mA	4 ... 20, pulse frequency status signal	4 ... 20	4 ... 20, HART
Intertesting interval, years	4	3	4
The limits of the standard error in the volumetric flow measurement	±1%	±1.5 %	±0.75 %
Degree of protection	IP67	IP57	IP68
Explosion protection	ATEX; FM; CSA; TIIS	IEXdIICT6X	1ExdIICT6(T5) X
Price, rubles	65000	95000	29000

Pressure sensors are used to monitor the pressure on the intake manifold located before the pumps, because when the pressure drops below a predetermined level, gas from the oil will start to be released in the pipeline, which can cause the destruction of the pump units. It is also necessary to measure the pressure of the incoming gas and nitrogen into the heater. And finally, it is necessary to know the pressure of the heated oil at the outlet of the heater.

Three options for widespread gauge pressure sensors were considered: Metran-150CG, KVARTS-2 and Sapphire-22M. The comparison is shown in Table 3.

Table 3. Comparison of the pressure sensors characteristics.

Characteristics	Pressure sensor model		
	Metran-150CG	KVARTS-2	Sapphire-22M
Medium	Liquid, steam, gas	Liquid, steam, gas	Liquid, steam, gas
Output signal, mA	4 ... 20, HART	4 ... 20	4 ... 20
Measuring range, Pa	25 ... 68,000,000	0 ... 100,000,000	80 ... 2,400,000
Adjustment of ranges of measurements	25:1	-	-
Price, rubles	30000	23000	25000
Allowable error	0.075%	0.1%	0.25%
Explosion protection	1ExdIICT6X	ExiaIICT5X	Ex
Protection degree	IP66	IP54	IP65
Life time, years	12	6	12

As a result of expert analysis, pressure sensors Metran-150CG were selected for pressure monitoring. These sensors have a built-in protection against transients that occur in the communication line, which can be caused by lightning discharges or a heavy load caused, for example, by the operation of equipment for conducting electric welding. Metran sensors are resistant to electromagnetic interference, have high spark and explosion safety, high protection against environmental influences, and have a long service life.

When choosing temperature sensors, three options were considered: Rosemount-3144P, Metran-274 and WIKA TR10-C. A comparison of temperature sensors is given in Table 4.

Table 4. Comparison of the temperature sensors characteristics.

Characteristics	Temperature sensor model		
	Rosemount-3144P	Метран-274	WIKA TR10-C
Measured temperature ranges, °C	-200 ... +850	-50 ... +180	-30 ... +150
Medium	Neutral and aggressive environments	Neutral and aggressive environments	Neutral and aggressive environments
Margin of error	0.10%	0.25%	0.1%
Output signal, mA	4 ... 20, HART, Fieldbus	4 ... 20, HART	4 ... 20, HART
Protection degree	IP68	IP65	IP67
Life time, years	10	10	5
Explosion protection	ExdIICT5	ExdIICT6	ExdIICT6
Price, rubles	31500	2300	10000
Power consumption, W	Less than 4.5	Less than 0.5	-

As a result of expert analysis, a temperature sensor Metran-274 was selected to measure the temperature, since it is best suited for solving the task. The advantages of the sensor are: service life, high explosion protection, low price, low energy consumption and the absence of the need for additional standard converters.

In order to avoid emergency situations, the process of filling and emptying the oil tank must be controlled, for which level gauges are used. The following most popular level gauges on the market were considered: Rosemount 5600, Sapphire DU22, PMP-128. A comparison of the level gauges characteristics is given in Table 5.

For an oil tank, sensors with increased accuracy and a HART protocol are required, therefore the Sapphire DU22 level gauge does not meet the requirements. The output signal of the PMP-128 level meter does not meet the requirements of the system. Thus, the Rosemount 5600 is the best suited for level measurement, which also has higher explosion protection.

The Rosemount 5600 Series level gauges are smart meters for non-contact level measurement in tanks of various types and sizes. With high sensitivity, the 5600 Series gauges provide accurate and reliable measurements, even under very difficult process conditions. Level gauges can be used to measure the level of products, including those with low dielectric constant, can operate in a wide range of temperature, pressure and provide high measurement flexibility due to the large selection of various antennas and materials. These level gauges are very simple to manage and maintain during operation, which together reduces the costs of further maintenance.

Table 5. Comparison of the level gauges characteristics.

Characteristics	Level gauge model		
	Rosemount 5600	Sapphire DU22	PMP-128
Operating principle	Radar	Buoy	Reed switch
Measuring range, m	0 ... 50	0.25 ... 10	0.75 ... 25
Medium	petroleum products, acids, solvents	petroleum products	petroleum products
Medium temperature, °C	- 40 ... + 400	- 40 ... + 80	- 50 ... + 60
Mean time before failure, h	100000	100000	100000
Life time, years	12	12	15
Degree of protection	IP67	IP54	IP68
Price, rubles	90000	20000	20000
Basic error, mm	± 5	± 12	± 5
Output signal, mA	4 ... 20, HART, Modbus	4 ... 20	-
Explosion safety	2ExdeiaibIICT6	0ExiaIICT5	ExaidIIBT3

4. Conclusion

As a result of the study, an analysis of the automation features of the integrated oil treatment unit was carried out. The principles of automation of such an object were considered and an oil treatment unit principal schema was presented.

The presented features of the SCADA system involve the use of a number of sensors to measure the current parameters of the oil treatment unit. Using the expert study method, a reasonable choice of specific measuring and control devices was made. Reviewed measuring and control devices are modern equipment of Russian and foreign production, which have a good service life and the necessary measurement accuracy.

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