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# DEVELOPMENT OF HARDWARE AND SOFTWARE SUPPORT OF COMPUTER-INTEGRATED TECHNOLOGY OF COMPLEX OF SECONDARY CONDENSATION OF AMMONIA PRODUCTION

The object of research is the technological complex of secondary condensation (TCSC) and the control system of a typical ammonia synthesis unit of the AM-1360 series.

The analysis of the conditions of its functioning and hardware and technological design was carried out. The coordinates of the control vector are determined. The features of the proposed functional diagram and the necessary algorithmic software for the computer-integrated control technology of the TCSC with a correction subsystem for decision-making under uncertainty are established. The implementation of the proposed solutions is complicated by the use of the information and control complex TDC-300 (USA) with closed-type software installed on the existing ammonia synthesis units. The need for such a control complex to implement a decision-making subsystem under conditions of uncertainty is shown to supplement the existing control system with hardware and software of an «open» type.

A computer-integrated TCSC technology based on a three-level hierarchical structure has been created. The implementation of the zero and first levels of such a structure form single software and hardware complex consisting of a programmable logic controller and an automated operator's workplace based on an industrial computer with installed software. A software implementation of decision-making on the correction of the coordinates of the control vector by additional hardware and software based on the VIPA logic controller and the Zenon SCADA system was made. A scheme of network information flows has been implemented, which illustrates the functioning of the decision-making correction subsystem in the general structure of the TCSC computer-integrated control technology.

Implementation of the developed system allows, under the existing uncertainties, to reduce the secondary condensation temperature by an average of 3 °C, which ensures an annual reduction in natural gas consumption by 1 million nm<sup>3</sup>. The proposed approach to the possibility of combining «open» and «closed» type hardware and software can be applied in other industries.

**Keywords:** ammonia production, secondary condensation, energy efficiency, computer-integrated technology, hardware and software.

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## 1. Introduction

Recently, due to the possibility of utilizing the low-grade heat of material flows, absorption (ARU) and steam-jet (SRU) refrigeration units have found wide application in various energy-technological systems in the production of the chemical industry, in particular, in the secondary condensation process complex (TCSC) of ammonia synthesis units [1, 2]. This complex ensures the final extraction of production ammonia from the circulating gas (CG) due to its sequential cooling in a condensation column (CC), high temperature (HTE)

and two low temperature (LTE) evaporators connected in accordance with the SRU and two ARUs [1].

Taking into account the large-capacity ammonia synthesis units and the use of air coolers at the previous stage of primary condensation, changes in environmental parameters (temperature and air humidity) cause not only parametric uncertainty in the operation of the facility, but also lead to significant economic losses. The latter is associated with a significant deviation of the CG cooling temperature from the regulatory norm – 5 °C, the range of which is from –5 °C to 6 °C. An increase in this temperature even

by 1 °C in the operating synthesis units of the AM-1360 series (Ukraine) causes a decrease in production energy costs due to an increase in the annual consumption of natural gas by 307.3 thousand nm<sup>3</sup> [1].

Excessive metal consumption of technological equipment, due to large displacement of ammonia synthesis units, contributes to a significant inertia of heat exchange processes in TCSC. The latter circumstance further complicates the process of controlling the stabilization of the TCSC temperature regime at the regulatory level. The above puts forward high requirements for the quality and reliability of the TCSC control system, the development of which is an urgent problem in the overall process of improving the energy efficiency of existing ammonia plants.

According to literature sources [3–5], the task of creating a high-quality control system under conditions of uncertainty and excessive inertia of objects is most effectively solved using computer-integrated technologies. The functional diagram and algorithmic software of the computer-integrated control technology in relation to the TCSC are described in previous works [6].

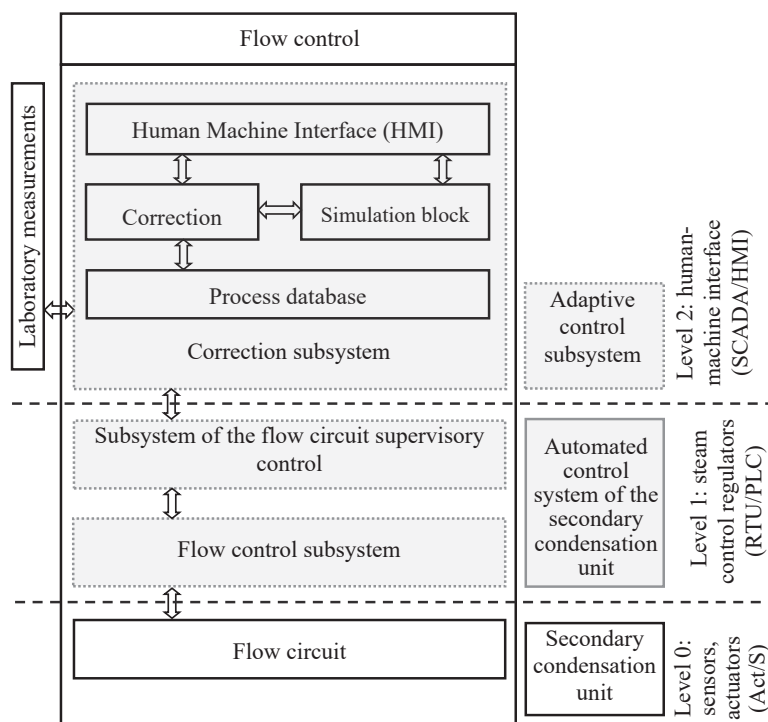
At the same time, the functional diagram is characterized by an identifier with a mathematical model, an optimal control computer and regulators for the refrigerant flow at the inlet to the HTE ( $M_{HT}^{RF}$ ), the monoethanolamine solution ( $M_{MEA}$ ) to the ARU and reflux steam generator at the outlet of two LTEs ( $M_P$ ). The flow controllers are implemented in the control correction subsystem, the set value for which can also be changed in the supervisory mode. Algorithmic software predicts the mode of operation, which makes it possible for the TCSC operator to prepare, under existing uncertainties, to make decisions on stabilizing the temperature regime.

However, the implementation of these developments is complicated by the use of the information and control complex TDC-3000 (USA) with the installed software of a closed type, which cannot be significantly upgraded, at operating ammonia synthesis units [7]. Therefore, the implementation of the proposed structure with algorithmically created software regarding the functioning of the decision-making subsystem under conditions of uncertainty requires the completion of the existing control system with available hardware and software of the «open» type, which is of particular relevance, both in the general process of improving the efficiency of control technology and economy production.

So, *the object of research* is the TCSC and its control system of a typical unit for the synthesis of ammonia of the AM-1360 series. *The aim of this research* is to create hardware and software of an «open» type TCSC computer-integrated control technology, adapted to the information system of the control complex TDC-3000 of large-capacity ammonia synthesis units of the AM-1360 series.

## 2. Research methodology

The technical implementation of the computer-integrated technology TCSC is based on a three-level hierarchical structure, the general scheme of which is shown in Fig. 1.



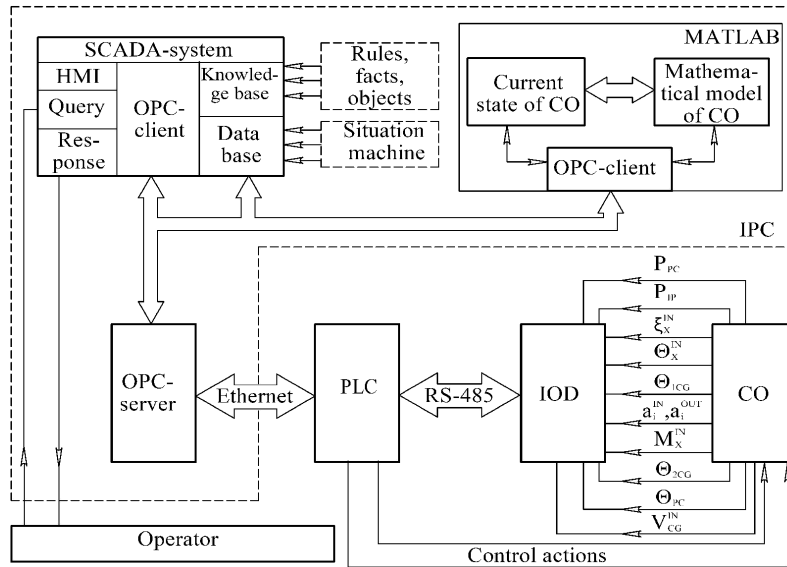
**Fig. 1.** General structure of the flow control system

According to Fig. 1 block of the human-machine interface (HMI) of the second level is formed by three modules. The module for entering new data of laboratory analyzes allows modifying tables with data for new components in a convenient form for the operator. The model setup module is designed to manually enter the necessary design data for the evaporators, condenser column and heat exchanger and start the process of checking the full adequacy of the models. Graphical screens provide a more detailed analysis of all information about the secondary condensation process and are intended only for the subsystem operator. At the same time, the HMI unit must ensure the adjustment of the correction subsystem and the analysis of its operation, as well as the creation and maintenance of the process database, that is, the collection, processing, storage and management of process data. The division of correction and modeling blocks in the structure of the correction subsystem is carried out taking into account their final implementation, which is due to the use of model software in the form of user libraries.

## 3. Research results and discussion

The implementation of the first level of the control system of this complex depends on the technical implementation of the zero level and the tasks that are assigned to the HMI level. Therefore, as a rule, these two levels should be considered as a single software and hardware complex, including a controller (PLC) and an automated workplace (AWP) of an operator-technologist based on an industrial computer (IPC) with developed special software.

Thus, the established general structure of the control system made it possible to determine and develop a functional diagram of the computer-integrated technology of the TCSC of the first level, shown in Fig. 2.



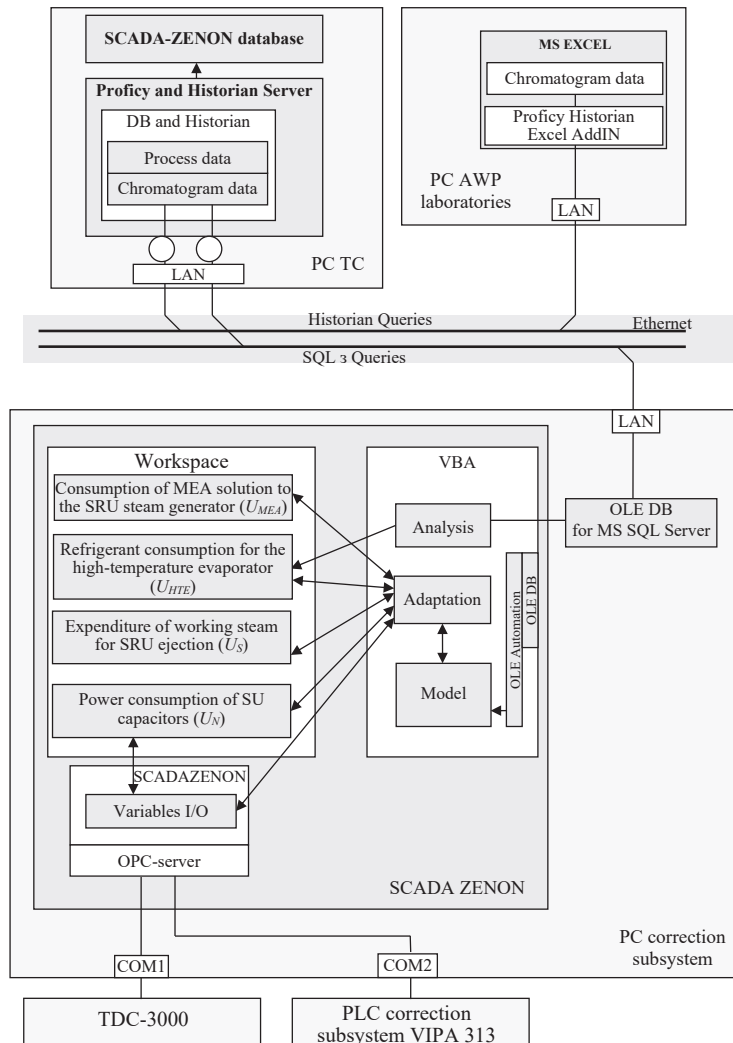
**Fig. 2.** Functional diagram of the computer-integrated technology of the secondary condensation complex:  $P_{PC}, P_{AS}$  – pressure, respectively, of primary condensation and boiling agent in the annular space of the LTE;  $\xi_c^{IN}$  – weight concentration of the refrigerant at the LTE inlet;  $\theta_{c}^{IN}, \theta_{c}^{OUT}$  – temperature, respectively, of the refrigerant at the inlet and outlet of the LTE;  $\theta_{c}^{IN}, \theta_{c}^{OUT}$  – temperature, respectively, of the refrigerant at the inlet and outlet of the LTE and primary condensation;  $a_i^{IN}, a_i^{OUT}$  – volumetric concentrations of CG components at the inlet and outlet of the TCSC;  $M_c^{IN}$  – mass flow rate of the refrigerant at the LTE inlet;  $V_c^{IN}$  – volume flow rate of CG at the TCSC inlet; CO – control object; IOD – input output devices

According to Fig. 2 in the MatLab environment, a client-side module (OPC-client) is built-in, which provides free programmatic access to process data [8]. Process parameter controllers and classical controllers in cascade circuits are implemented as a separate control subsystem. The values of the coordinates of the control vectors ( $M_{HT}^{RE}, M_{MEA}, M_P$ ) are formed by the correction subsystem, however, the operator can independently make decisions and change them through the supervisory control level. The latter is important if necessary, especially during the winter period of a complete shutdown of the SRU.

The foregoing makes it possible to create a subsystem for correcting operating modes and integrating it into a single information and control system. The structure of this subsystem includes the following components: a real-time database (RTDB), which is functionally a process database; the algorithmic part, that is, correction and modeling blocks; human-machine interface. In this case, the correction subsystem can be implemented as a separate network node of the system, or integrated into the SCADA node of the TCSC complex, as shown in Fig. 3.

Based on the fact that the subsystem is being developed on the basis of a specific SCADA program (Zenon), the methods for connecting RTDB to data sources (current parameters of the TCSC operation) depend on the technologies used for their implementation [9]. In the case under consideration, the OPC technology and the Open Database Connectivity (ODBC) technology [10] were used.

Implementation of the created hardware and software allows stabilizing the temperature of secondary condensation at a level not higher than  $-5\text{ }^\circ\text{C}$ , regardless of seasonal fluctuations in atmospheric air temperature. This ensures a reduction in the annual consumption of natural gas.



**Fig. 3.** Scheme of network information flows of a fragment of computer-integrated technology of the secondary condensation complex:  $U$  – settings for the flow controller

The developed technology is applicable in any chemical and petrochemical industries with «closed» type control systems. At the same time, integration with systems of this type of control requires the use of additional hardware and software. This is mainly due to the proprietary nature of the exchange protocols within «closed» systems, which necessitates the development of software tools for converting «closed» protocols into «open» ones. Subsequent studies will be aimed at adapting modern software technologies for accessing process data, taking into account the closeness of exchange protocols.

#### 4. Conclusions

The general structure has been chosen and a functional diagram of the computer-integrated technology for controlling the flow circuits of the TCSC, using the VIPA free programming controller and the Zenon SCADA system, has been developed. The use of «open» technologies made it possible to develop hardware and software for a computer-integrated control technology for TCSC. Thanks to this approach, it became possible to integrate it into the existing structure of the TDC-3000 information and control complex and implement it as an operator's workstation of the correction subsystem for final decision making through the supervisory control mode.

Implementation of the developed system makes it possible to increase the energy efficiency of production by reducing the temperature of secondary condensation by an average of 3 °C and, consequently, the consumption of natural gas by 1 million nm<sup>3</sup> per year.

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