

## HYDROTREATING UNIT SIMULATOR: REASONS FOR DESIGN AND DEVELOPMENT TECHNOLOGY

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*It is spoken about necessity of training simulator development. The example of training simulator creation for hydrotreatment unit on JSC "Salavatnefteorgsintez" is shown.*

*Keywords: training simulator, hydrotreatment unit, reasons of accidents, human factor, modeling, simulation program, furnace, practical skills, startup, shutdown.*

The enterprises of oil and gas branch are multiple structural complexes composed of separate technological units combined by a common operative process. The main feature of production processes for such facilities is the conditions of high explosion and fire risks.

In 2007 in Russia the number of organizations exploiting hazard production entities of petrochemical and oil refining industry, oil products entities equaled 5856.

In 2007 twenty two accidents occurred at the production entities of petrochemical and oil refining industry, for 1 accident more than in 2006. The amount of damage equaled about 191 million RUR.

Table 1

Accidents distribution on industry branches

	2007	2006
Oil refining facilities	9	10
Petrochemical facilities	4	4
Oil products entities	9	7
Total:	22	21

Table 2

Accidents distribution at the entities of petrochemical and oil refining industry on types

Accident types	Accident quantities			
	2006		2007	
		%		%
Explosion	10	48	5	23
Fire	10	48	14	64
Hazardous substances emissions (distractions)	1	4	3	13
Bcero:	21	100	22	100

Among the accidents occurred in 2007 it is domination of the accidents connected with fires the share of which in comparison with 2006 has increased from 48 to 64 %. At the same time the share of accidents accompanied with explosions has decreased by 16 % and the share of accidents connected with hazardous substances emissions and technical devices destroy has increased from 4 to 13 % [1].

Among possible reasons assisting the accidents origin and development in general it is possible to distinguish the following four main groups:

- the failure of equipment, pipelines, instrumentation and control systems;
- the deviation from regulated production processes (conditions);
- the events associated with human factor;
- the external exposure of natural and anthropogenic character.

The main reasons of accident occurrence are the failures of equipment, pipelines, control and measurement instruments (40 % of accidents). The second important reason of accident occurrence is a human factor. Because of the mistakes of operating, maintenance and repair personnel about 30 % of accidents occur. The violation of the operation process, the norms of equipment preparation for startup, break and repair can cause serious equipment faults. The circumstances of possible emergency situations connected with energy supply ceasing can be considerably reduced under strict measures observance by personnel provided by the appropriate requirements.

Possible wrong actions of personnel can cause a serious accident. In this case the availability of highly qualified personnel, the services responsible for safe facility operation, high requirements to personnel knowledge of instructions on unit exploitation, safety engineering and training have a very important point.

Highly unit automation of petrochemical and oil refining industry doesn't exclude the maintenance personnel activity and in case of necessity the interference into operation process control.

For practical knowledge acquisition of safe operation, accidents prevention and elimination of their consequences at the engineering units with the blocks of I and II explosibility categories all workers and engineering workers directly involved into the operation process and equipment exploitation at these units pass through training course with the usage of modern technologies of training and skills practicing (simulators, educational-training polygon and so on). For this purpose the indicated organizations

should have computer simulators providing maximum real dynamic process models and real control means (functional keyboards, graphic screen forms and so on). The training and skills practice using computer simulators must provide the study of operation process and control system, startup, planned and emergency breakdown in typical and specific off-nominal and emergency situations.

The programs for skills practice of startup, normal functioning, planned and emergency operation breakdown are developed on the basis of operation standards and other engineering norms [2].

Technological process simulator is a computer program modeling the process operation and its subsystems and reproducing the interface of existing automatic control system of technological process. Trainer-simulator is used for the training of operational personal and provides:

1. study a process flow sheet;
2. study the purpose and characteristics of used operational equipment;
3. gain practical skills on unit control at:
  - startup;
  - shutdown;
  - normal process;
  - emergency and off normal situations;
4. check knowledge and make the attestation of operational personnel.

To solve this problem a computer simulator is being developed at the hydrotreatment unit of JSC «Salavatnefteorgsintez».

There are several ways of computer simulators development such as the software integration of two classes: the package for mathematical (VisSim, MATLAB and others) or technological (Hysys, PRO II and others) process modeling and SCADA or the usage of control systems including the attachment applying for process modeling.

The purpose of computer modeling for chemical-operational process is to solve the tasks of mathematical model construction, identification and optimization of chemical production that is to solve the specified set of tasks for process flow sheet of general process. For computer modeling of chemical-engineering processes it is necessary to possess a powerful tool – simulation programs package.

The well known packages of simulation programs include the following software systems – ASPEN, HYSYS, PRO-II и ChemCad [3]. Aspen Plus is a revolutionary combination of modeling strategies on the basis of equation and consecutive model method in one software product. Users can try the advantages of every modeling mean for results calculation with a very high speed [4].

The modeling of chemical-engineering objects is possible with the using of computer calculations carried out in different program languages namely in the language Basic [5].

Due to the signing of strategic agreement on partnership between JSC «Salavatnefteorgsintez» and Yokogawa Electric Corporation the devices of this company for the realization of the simulator are considered to be optimal. Besides in this case the full equivalence of operation mnemonic diagrams and simulator interface is achieved.

For the development of simulator the ability of Centum CS300 Yokogawa system is used to operate in the mode of Test Function which makes possible to operate without hardware of FCS. The hardware and software System View is used for engineering. The usage of this system makes possible to create visually rather complex models and besides there is the possibility to use finished models. For visualization SCADA system Centum CS3000 is applied which also has some ready elements of graphical interface. The creation of blocks and connections between them is carried out in the Control Drawing Builder. Among a vast variety of functional blocks for the realization of assigned task it is possible to distinguish:

- the blocks of arithmetical calculations (summation, multiplication, dividing);
- the blocks of analogue calculations (extraction of square root, integration, first order lag, lead/lag, lag time calculation);
- the general purpose computing block;
- the blocks of information viewing;
- the block of constant control;
- the block of functional sequential circuit.

As many production facilities the hydrotreatment unit of diesel fraction is a complex system consisting of interconnected subsystems.

Reactors, columns, furnaces, heat exchangers, pumps and so on belong to the main unit devices. These devices are interconnected between each other and the

variation of mode parameters of one of them results in the change of other ones which effect on the process. The models of separate units can be built with the application of different ways and methods (analytical, experimental-statistic, indistinct, combined) depending on the kind of accessible information.

Deterministic (casual, structural, sign, theoretical) models show the deterministic (casual) essence of phenomena interrelation when it is possible to explain the reason theoretically because of which the system changes occurred, explain the essence of phenomena interrelation taking place in a modeling system and described by the equations of statics and dynamics of chemical, physical-chemical, hydrodynamic, heat processes of chemical technology.

Stochastic (empirical, statistic) models indicate the possible (stochastic) character of phenomena when the non-right process parameters are calculated but the probability of their calculation in a certain limits. This fact can be explained in the following way: at first by the mistakes of practical parameters measurement and secondly by the impossibility to take into account in a mathematical model all factors (parameters) effecting on the process and its final results (at this it is necessary to take into account that all factors influencing on the process can be unknown to the model designer or he will neglect some unimportant factors) [5].

Because of the devices complexity the difficulties concerning the study of processes and impossibility of obtaining reliable data the building of deterministic models for main aggregates (reactors, columns, furnaces) is actually impossible. For heat exchangers it is reasonable to work out deterministic models [6]. The example of unit object is a furnace. The furnace is shown as a model represented on Figure 1. The stream temperature at furnace outlet depends on feed flow, its initial temperature and the volume of burnt fuel.

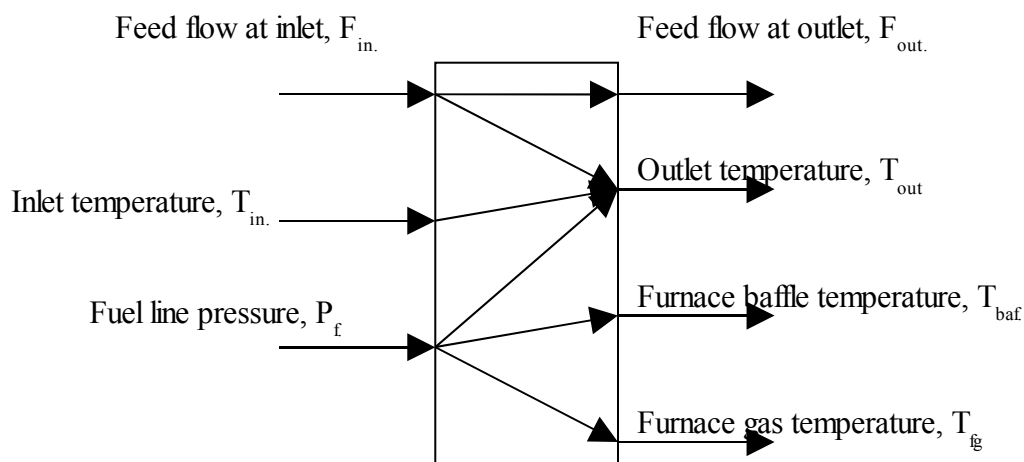


Figure 1. Structural drawing of furnace model

$$T_{out} = T_{in} + \frac{P_F \cdot k_1}{F_{in}},$$

where  $k_1$  – correction index taking feed heat capacity and specific heat of fuel combustion.

Furnace baffle temperature and furnace gas temperature can be shown as:

$$T_{baf} = k_2 \cdot P_F$$

$$T_{fg} = k_3 \cdot P_F,$$

where  $k_2$  and  $k_3$  – correction indices.

The first stage of model development is the information collection on object, type model definition, coefficients for static model and then it is necessary to select transfer functions for every inlet-outlet pair for dynamic model building.

The model of startup and shutdown on the basis of initial data can be shown in Petri nets represented on Figure 2 and then the algorithms are realized in the function scheme sequence blocks of system Centum CS3000. The example of such scheme is shown on Figure 3.

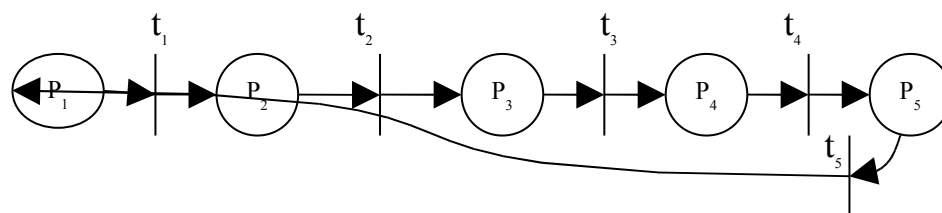


Figure 2. Petri net of shutdown model

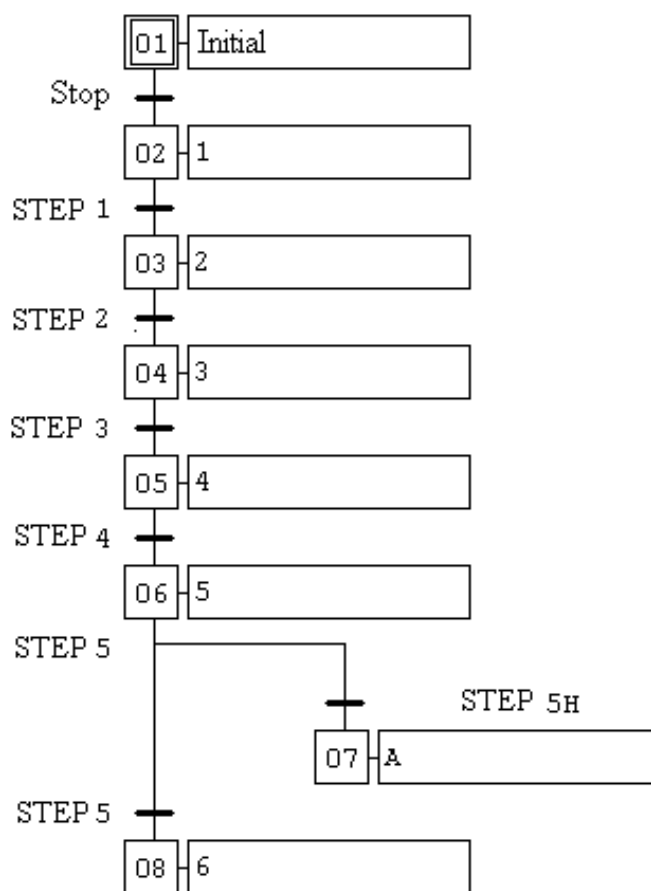


Figure 3. The example of functional sequence scheme of shutdown program

The simulator performances of this type are rather wide. Besides main functions of operator process training in a normal mode, during startup and shutdown, there is the possibility of algorithms adding of possible emergencies during simulator exploiting and also the possibility of parameters alteration of unit objects at process change. The photos of real unit objects are added to graphic drawings system.

The designers of such training-simulators are:

- «Sistemotekhnics» company;
- «Resikon» firm;
- GK «Stins Coman»;
- CC "Severodonetskii ORGHIM" and others.

Some well known designs are represented below:

- automated training system of operating personal for emergency situation elimination JSC "Rosneft - TNPZ" Tuapse city;

- program operator-engineer training simulator for Yablunovskii oil refining plant (Ukraine) designed by “ChemDesing, Inc” (Houston, Texas, USA);
- program trainer-simulator for operator-engineer of oil-pumping station JSC «Severnii magistralniye nefteprovody» (Uhta, Russia), AK «Transneft»;
- program operator training simulator of atmospheric – vacuum oil refining technology (ELOU AVT), OOO «LINOS», Ukraine;
- automated simulator for emergency situation elimination at the technological unit of DK-5 Block No. 9 (ATLAS-VSK.DK5).

The result of simulator usage is not only the increase of labor culture but the increase of management quality, in time alarm signals and consequently the increase of safety operation and in some cases the possibility to avoid emergencies.

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