Intelligent Simulators for Management Industrial Personnel of High-Tech Industries

T. B. Chistyakova[1], I. V. Novozhilova[2], A. M. Araztaganova[3]
Chair of Computer Design and Control
Saint-Petersburg State Institute of Technology
St. Petersburg, Russia
[1]chistb@mail.ru, [2]novozhilova@bk.ru, [3]alinaami@mail.ru

Gunter Reinig
Chair of Control Engineering and System Theory
Ruhr-Universitat Bochum
Bochum, Germany
Gunter.Reinig@ruhr-uni-bochum.de

***Abstract*— The article describes the questions of developing intelligent computer simulators that allow studying modern industrial equipment, training in the control of technological processes on the basis of imitation mathematical models using 2D and 3D interfaces, as well as virtual reality (Immersive Training). The advantages of using intelligent computer simulators in training managerial production personnel are to acquire experience and skills of behavior in emergency situations, a thorough understanding of cause-effect relationships in the facility, quick response to problems, reduce psychological overload, increase confidence and self-management. Increasing the professional level of the managerial production personnel of enterprises allows improving the quality of products, reducing spoilage and improving the environmental characteristics of industrial production of high-tech industries.**

Keywords*— distributed control systems; intelligent technologies; simulation modeling; practice-oriented training; simulators

I. Introduction

Intensive development of production technologies dictates the need for high-quality and timely training of management production personnel of industrial enterprises to master new special professional competencies in the field of design, processing information and managing complex objects of high-tech industries [1].

Statistical data from J&H Marsh & McLennan, Inc. и Gulf Publishing Holdings, LLC (Hydrocarbon Processing) companies [2] shows that manufacturing enterprises loose up to 20 billion dollars or 5% of annual production volume because of unplanned equipment idle time and low quality of production. According to the results of ARC Advisory Group's research [3] for the global industry, about 80 percent of losses can be prevented, as 40 percent of them are operator errors. The loses, caused by management production personnel's mistakes, lead to a decrease of product quality, unplanned equipment idle time, environmental damage and other losses comparable in scale with losses from production accidents [4].

The most promising direction for mastering the competence results of training and elimination of qualification deficiencies of managerial production personnel is development of intelligent computer simulators.

The simulators must enable studying of modern industrial equipment, training to control technological processes, based on simulation mathematical models (MM) with 2D and 3D interfaces, as well as virtual reality (Immersive Training) using audio tools to support training.

The advantages of using intelligent computer simulators in training management and production personnel are to acquire experience and skills of behavior in emergency situations, a deeper understanding of the cause-effect relations of the object, a quick reaction to problems, to reduce psychological overload, increase confidence and self-reliance while solving control problems [5].

II. Technologies for Computer-Aided Synthesis of Distributed Control Systems and Intelligent Simulators

The solution of the these tasks for the implementation of this direction made possible to develop a unified methodology and technologies for computer-aided synthesis of distributed control systems and intelligent computer training simulators for management production personnel of high-tech industries using modern information and network technologies [6, 7]. Basic architecture types of training systems are represented in Fig. 1.

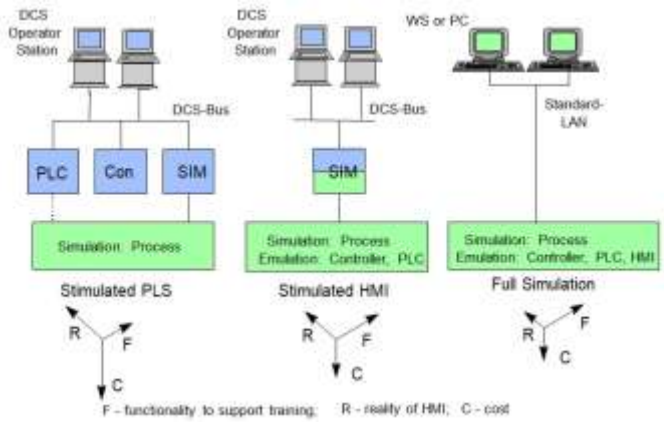

Fig. 1. Architecture of training systems

On the Fig. 1 the following notation is used: DCS – Distributed Control System; PLC – Programmable Logic

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Controller; LAN – Local Area Network; HMI – Human-Machine Interface.

Distributed control system (DCS) is a complex of technical and software solutions for development of automated process control systems and exhibits a distributed in-put/output system and decentralization of data processing, as well as a deeper integration of code development tools for visualization and management levels.

DCS structure includes three levels. The lowest input/output level contains sensors and actuators. The middle level of the distributed system contains controllers. Controllers are aimed to process obtained data, generate control actions and transfer data to the highest level. The highest level contains database servers and workstations. The workstations pro-vide human-machine interface for the operator and data communication between server and programmable logic controller. In the DCS hierarchy separately stands engineer work-station. Software solutions for development and configuration are installed on the work-station. The solutions are connected to the controllers. Distributed control systems can be developed using programming languages in soft-ware tools such as Matlab, Aspen Dynamics, Hysys, Expert System Shell, Neuro/Fuzzy tools and complex simulation systems, e.g. Honeywell UNISIM, Aspen OTS Framework, Yokogawa OmegaLand [6, 7].

III. Integrated Dynamic Simulation Environment

The modern direction of evolution of distributed control systems is the development of dynamic simulators. Dynamic simulators are a software tool for development of an integrated virtual model of industrial enterprise. Systems of this class allow to carry out design and engineering calculations before or during the construction of an industrial enterprise, perform operations on a virtual model, perform visualization and modeling of technological processes according to conditions of the production. Integrated dynamic simulation environment (Fig. 2) is software which can use simulation function in stationary mode in addition to dynamic simulation function [8].

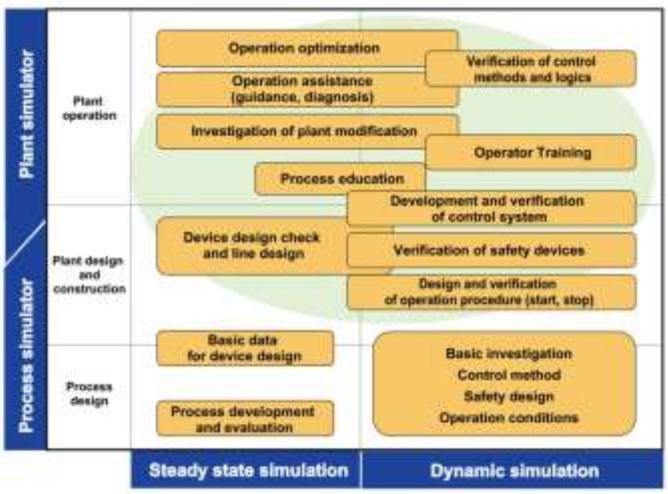

Fig. 2. Use of training systems and computer simulators

Use of dynamic simulation environments and computer simulators exhibits short-term profitability of investments. According to ARC Advisory Group, the world market of computer simulators will grow from $ 459 million to $ 760 million, with a steady growth since the late 1980s.

The cost of a computer simulator for an oil refinery is about $ 300,000. At the same time, the cost of engineering costs is about 75% of the total cost of creating a simulator.

Simulators are highly demanded for the study of technology, technological engineering and engineering of control systems. Effective use of simulators for research of techno-logical processes based on imitation simulation systems and support of control systems, including systems for improved control of technological processes [4].

Modern trends in the development of computer simulators based on the concept of Industrie 4.0 are: the introduction of cyberphysical systems into production, the use of wireless data transmission, the use of virtual and augmented reality (real objects are supplemented with information superimposed on them) [9], use of additive technologies. Fig. 3 shows an example of HMI realization based on Industrie 4.0 [10].

IV. Structure of the Training System

Lifecycle of development of computer training systems includes the following stages:

- analysis of qualification deficiencies of specialists in enterprises of high-tech industries and their transformation into special professional competencies; the competencies allow employees to perform their labor functions as part of a new or substantially renewed type of work activity;
- development of the trajectory and forming of the content of training based on unit technology of vocational training, according to the job descriptions and labor functions of the management and production personnel of enterprises;
- development of methods, algorithms and technologies for the synthesis of training systems, including adaptable imitation modeling subsystems for design and control processes for obtaining high-tech materials of various functional purposes, databases (DB) for raw materials, equipment, technological regulations and parameters, requirements to the quality of materials, a knowledge base of abnormal situations associated with the flows of products;
- approbation of training by development of computer simulators for management production personnel of processes for obtaining high-technology materials for various functional purposes;
- processing the results (protocols) of training management production personnel based on the use of methods of qualitative and quantitative evaluation of the acquired by trainees special professional competencies, necessary for the performance of their labor functions.

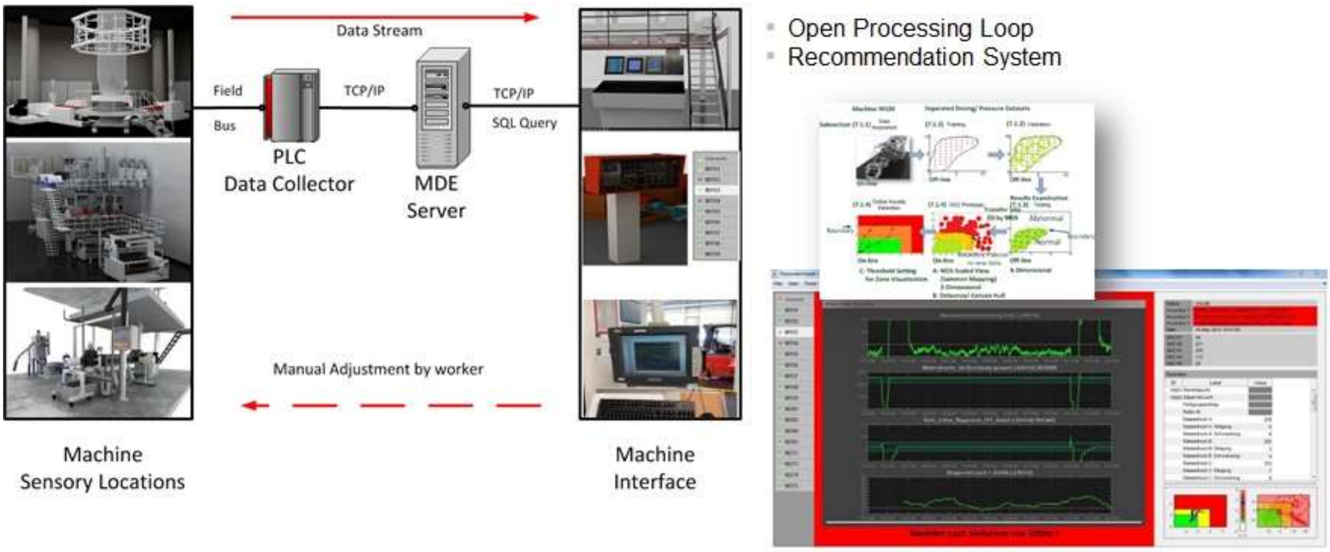

Fig. 3. Example of HMI realization based on Industrie 4.0.

As exploration and simulation object modern production enterprises usually exhibit: different types of production $TP = \{TP_1, \ldots, TP_{tp}\}$ with wide nomenclature $MP = \{MP_1, \ldots, MP_{mp}\}$; variety of technological stages $TS = \{TS_1, \ldots, TS_{ts}\}$, equipment $EQ = \{EQ_1, \ldots, EQ_{eq}\}$; possibility to obtain the same product from different types of raw materials $FS = \{FS_1, \ldots, FS_{fs}\}$ using variety of recipes $RP = \{RP_1, \ldots, RP_{rp}\}$; strong requirements to quality of half-finished products $IP = \{IP_1, \ldots, IP_{ip}\}$ and finished products $QP = \{QP_1, \ldots, QP_{qp}\}$; occurring abnormal situations on different production stages $ST = \{ST_1, \ldots, ST_{st}\}$, caused by violation of production quality indicators (causes of flows $RS = \{RS_1, \ldots, RS_{rs}\}$).

According to the developed methodology of end-to-end design of training systems, a formalized description of the object of study is the basis for computer-aided synthesis using the modern information technologies of the core of computer simulators and training systems.

During development of the functional structure of the training system, units to perform functions of learning and training are created: the instructor's interface; the learner's interface; the unit for performing computational experiments; the unit for the formation of simulation results; infoware and mathware. For the training the instructor has the following options: control of the model; control over the course of training; evaluation of the trainee's actions using the selected model of knowledge control.

The information structure of the trainee interface includes units for operational management of the structure of the learning object using a dynamically controlled process mimic; control and regulation of process parameters; obtaining explanations, advice, recommendations on management. This structure of the trainee interface allows considering the characteristics of the object of study for various modifications, to obtain profound professional knowledge according to the accumulated experience of experts.

For training to design and control of chemical technology processes information models, simulation MMs and knowledge representation models are used [1, 5].

Information models are implemented in the form of a DBs of geometric models and design parameters of production equipment, technological parameters of processes, characteristics of raw materials and target products. By dynamic changing the ranges of the corresponding parameters DBs are set to various structures of the object of study, modes of its functioning, productivity, composition of raw materials and product quality.

Thus, developed training systems are adapted for different modifications of object of study. Therefore, they can be integrated to computer-aided design and control systems for technological enterprises.

Simulation MMs provide active learning during the solution of various training tasks: training for control in emergency situations and while reconfiguration of the production for a new task, raw materials and productivity, studying the methods and tasks of optimal control, studying the cause-effect relationships in the facility, parametric synthesis of the object of study and carrying out verification calculations of the developed objects.

For simulation of the causes of violations the components of the basic model are changed relative to the nominal values. While simulation the event, the basic model continues to function, but the priority of the emergency event switches the trainee's attention to the parameters that determine the emergency situation, usually accompanied by sound and light alarms. For some operational and emergency reasons, a stochastic model has been developed. The model provides determination of the probability of a cause, in case of incompleteness of information.

For studying of expert knowledge, ways to eliminate emergency situations, best practices in the methods of accident-free and effective management and the formation of intellectual advices for the design and control of high-tech production in the training process, models of the representation of non-formalized knowledge about the object of study are integrated into the structure of simulators. To develop computer-aided subsystems of presentation of declarative and procedural knowledge, the tools of object-oriented programming, the shells of expert systems, languages of knowledge representation are used.

The analysis of existing models of knowledge control in different types of training systems made it possible to propose the following methods for determining the level of training of management production personnel: registration of acquired knowledge, assessment of knowledge using a context model, error analysis, method of imposition, generating modeling (computer-aided training is based on the trainee's intentions), mapping the sequence of actions (solution tree, graphs, object state tables).

Manager program is developed to control and organize training process using training systems. The program has following functions: reading settings from a file; setting parameters of object models according to the settings; reading the learning script; display of the state of the learning object on the mimic; recognition and processing of events specified in the training scenario and formed by the trainee and the instructor during the learning process; output of training results in a protocol log file. As a result of the functioning of the manager program, the instructor can learn the training results from the training protocol file, examine the tables and graphs of the state of the learning object from the stored history of the object, correct the training scenario according to the student's knowledge level.

V. CONCLUSION

The developed methods and technologies for design of intelligent computer training systems are used to improve skills and train management production personnel on high-tech technological productionsб such as «Mondi Gronau GmbH», «Maria Soel GmbH – Maria Soel HTF GmbH», «Kloeckner Pentaplast Europe GmbH & Ko.KG», «Virial Ltd.», PAO «Severstal», CJSC «ILIP», PAO «Rigel».

It's important to mention international experience in development of training programs in the field of computer-aided data processing and control of production of nanostructured polymer materials using the example of the international corporation «Kloeckner Pentaplast» [11]. The aim of the program is exploration of new properties of polymer materials, improvement of the technologies for their production and processing, and introduction innovative solutions at international enterprises.

The introduction of intelligent computer simulators in training centers and production showed that the increase in safety and efficiency of high-tech industries was achieved through: improving the characteristics of the control object, improving control systems, improving the professional level of management production personnel.

For modern industrial production, it is actual to improve skills and retrain the management of production personnel to achieve the readiness of specialists to implement their respective professional and labor functions and develop professional competencies that meet the requirements of specific jobs.

Using of simulators based on the concept Industrie 4.0 allows to enhance production quality, reduce flows, improve the environmental characteristics of production by enhancing the professional level of management production personnel and approaching their skills to the requirements of professional standards.

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