CONTRIBUTION TO MODELS OF SUPERVISORY CONTROL, DATA ACQUISITION AND HUMAN MACHINE INTERFACE

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SUMMARY

This article is dealing with systems called SCADA/HMI - Supervisory Control and Data Acquisition/Human Machine Interface, known as visualization systems as well. It contributes to a discussion about models of complex ICS - information and control systems and within their framework mainly about logical and physical models of SCADA/HMI systems. The emphasis is placed on their software and communication parts with the aim to integrate and distribute their functions in ICS. It demonstrates their use on one of the applications within the framework of a model workshop for a complex ICS and selected control systems– a heat system and portal crane. Physical software architecture is built on the basis of DDE - Dynamic Data Exchange and ODBC - Open Database Connectivity communication technologies. User interface with ActiveX controls and ASP - Active Server Pages is available to clients of Internet network, and this enables remote supervisory control with process visualization.

Keywords: *Information and Control System - ICS, Supervisory Control, Data Acquisition, Human Machine Interface - SCADA/HMI, logical and physical model, Dynamic Data Exchange – DDE, ActiveX control, Active Server Pages - ASP, remote visualization*

1. INTRODUCTION

Development of **ICS - information and control systems** is still very dynamic. New theoretical knowledge, software, hardware and communication technologies bring the challenge of improving existing and designing new models of complex ICS. The main goal of this article is to contribute to a discussion about their possible logical and physical variants. The main focus is put on the integration and distribution of **SCADA/HMI - Supervisory Control, Data Acquisition, Human Machine Interface** type of systems in the framework of complex ICS, which is presented at the end of the article at one of the applications – as a physical model. Implementation into an environment uses selected accessible communication protocols, database systems and remote visualization based on Internet. It is obvious, that architectures of SCADA/HMI systems are not observed only from the point of view of a scientific or pedagogical approach, but more often for the practical application reason.

2. HIERARCHY OF LOGICAL MODEL OF ICS

2.1 Logical model of ICS

At the present time, a large number of **logical models** of complex ICS exists. Their form depends very much on the level of abstraction, goals for application, scientific-research community or commercial use [5, 7]. One of the variants (Fig. 1) mainly follows SCADA/HMI systems position in the framework of ICS hierarchy. This ICS includes hierarchically higher MES systems - Manufacturing Execution System and MRP/ERP - Manufacturing Resource Planning / Enterprise Resource Planning. It emphasizes as well, that user's human-machine interface can be not only at the level of supervisory control, but they can appear at higher levels of ICS [6, 9].

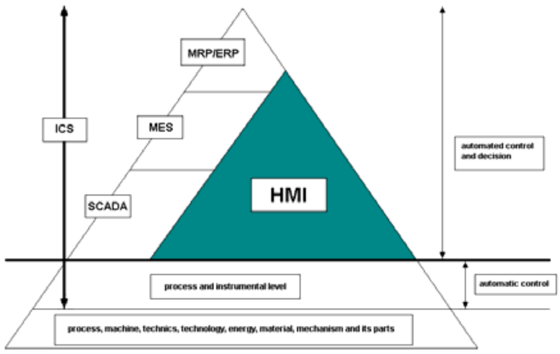

Fig. 1 Logical model of ICS

2.2 Physical model

Physical model implements logical model into concrete implementation environment, at the present time, usually as a certain computer system, which includes hardware, software and communication subsystems.

3. SCADA/HMI SYSTEMS

First articles which use SCADA/HMI term [1, 3] provide us with system overview of their functions. SCADA/HMI technology is being best applied on processes, which are located at a long distance or area, and which are suitable for supervisory control [2, 4, 7, 10]. Present **SCADA/HMI systems** are however characteristic with communication with associated systems at a vertical and horizontal level in the framework of ICS. To its original goal of data acquisition from technological processes is added their storing in databases of various types. Typical, is also data processing, for example knowledge acquired from the processing and exchange of different information with associated systems. At the present time, SCADA/HMI systems are known as **visualization systems**, because it is concluded from their typical powerful, graphical, human-machine interface [9]. They stand as user support for control and decision making.

3.1 Logical model of SCADA/HMI

Functions (goals, services) of SCADA/HMI systems create fundamentals for their logical models with a selected abstraction level. Also, three areas are in the names of these systems, which are suitable for corresponding with logical models definition and physical models based on them. The logical model is defined mainly as the following subsystems and their functions:

- **HMI - Human Machine Interface (MMI – Man Machine Interface)**
  - enables access into a system with different access levels of rights,
  - makes easy user orientation in control process with visualization (animation, display) according to a real structure and state of the process,
  - intermediates mutual interaction with a control system with the aim to supervise control by graphical control panels,
  - intermediates mutual interaction with other associated systems,
  - visualizes different types of information about control process and control system, for example alarms, trends, statistical diagrams, system events, help texts,
  - enables the allocation of sound signals,
- **SC - Supervisory (Operator) Control**
  - remote control, for example for input of new required state of technological elements, for actions into the control process in the case of usual operation and emergency unpredictable events, set points for emergency limits, control of controllers, setting up parameters of controlled circuits, control of sequential processes,
  - working out messages coming from process and processing control stations, it means signals for originated alarms (critical values), their acknowledgment, filtering by priorities,
  - various possibilities of working out real time and historical process data,
  - computing statistical information for monitoring and control of process quality,
  - diagnostics of equipment according to a periodic plan or special requirements,
  - other modules supporting control and decision making,
- **DA - Data Acquisition**
  - data acquisition from process and processing control systems and storing information and knowledge into database of various types (technological real time and historical values, alarms, critical values, reports about user activities and system events),
  - their interchange with associated systems.

3.2 Physical model of SCADA/HMI

Visualization systems are systems containing **hardware, software and communication** sub-systems, which support users throughout a user interface (operator, supervisor, manager, and chief executive) in their controlling and managing activities. These systems implement a logical model in a certain physical environment.

4. MODELED ICS WORKSHOP

4.1 Logical model of ICS

At the Department of Cybernetics and Artificial Intelligence - KKUI FEI TU in Košice in the laboratory, a unique model of ICS has been built, which is also known in the Department's community as DCR – distributed control system. It serves as a scientific-research, educational, and demonstration workshop. A logic model is basically identical with the model shown in Fig.1, the level of MRP/ERP is labeled as an information level. The level of MES is often being integrated due to its simple technological processes into neighboring levels.

4.2 Physical model of IRS

Model workshop is physically distributed into more labs, for example: L513, L535, L536, L540. The **controlled systems** are:

- different simulated systems (built with *Matlab* tools, analog MEDA 50 computer, *MS Visual C++*, *MS Visual Basic*, etc.),
- physical models of technological systems (stove, heat system, intersection, overhead crane).

One of the possible **physical models of ICS** is shown in Fig. 2. It is possible to built in other tools within the sense of pyramid logical structure:

- **Technological (Process) level of control**

- ***hardware*** - sensors and actuators, programming logical controllers, one-chip and industrial computers,
- ***software*** – programming tools PLC (function diagrams, relay diagrams), operating systems (*Windows, QNX, Linux*), simulation models (*Matlab, MS Visual C++, MS Visual Basic*),
- ***communication*** **–** industrial technological networks (ASI, DeviceNet, Profibus, DH485, DH+, Remote I/O, Ethernet) and protocols TCP/IP, IPX, NetBios,

• **Visualization level (SCADA/HMI level)**

- ***hardware*** – mostly PC, visualization panels (PanelView),
- ***software*** - operating systems (*Windows 95/NT/2000, Linux, QNX),* programming languages and systems (*MS Visual C++, MS Visual Basic, C++, Matlab), ActiveX* components, SCADA/HMI professional systems (*InTouch, RSView),* individual process database (*IndustrialSQL),* application www servers (*MIIS, Factory Web Server, Voyager),*
- ***communication*** **–** data acquisition from technological networks with DDE protocols – Dynamic Data Exchange and OPC – OLE for Process Control, link to information level and internet with TCP/IP protocol,

• **Information level**

- ***hardware*** – PC and powerful workstations and servers – PC (Pentium III), IBM (RISC), DEC Alpha,
- ***software*** – operation systems (*Windows 2000 Advanced Server, UNIX, VMS),* database (*Oracle, InSQL),* www servers,
- ***communication*** – local, intranet and internet networks based on TCP/IP and ODBC – *Open Database Connectivity* and OLE DB – *OLE for Database*.

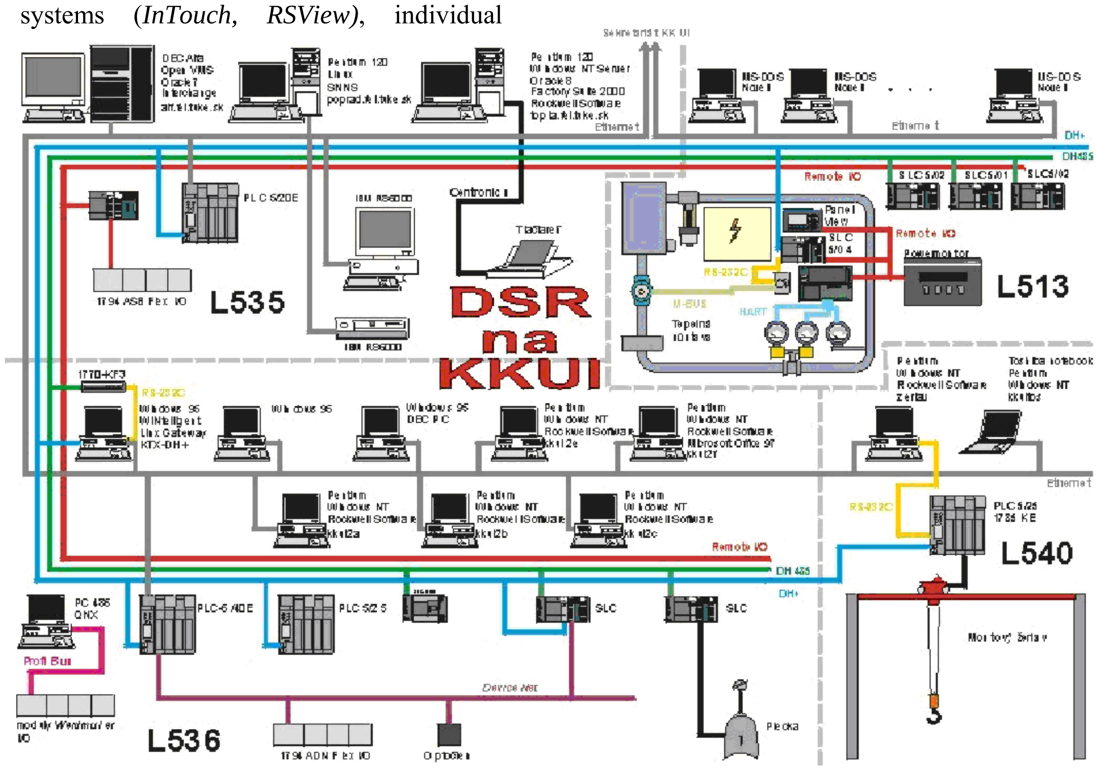

Fig. 2 Physical model of ICS

5. SYSTEM APPLICATION OF SCADA/HMI

In the framework of this physical model several applications of SCADA/HMI type has been implemented and evaluated. One of them was based on distributed visualization (*InTouch* – Wonderware Corp.) with statistical elements (*Matlab*) [11]. A later model of remote visualization has been implemented with ActiveX components [12], or local visualization with emphasis on communication with databases [6]. In this article presented visualization is extending it [12] by using an **internet portal** *(RSPortal* – Rockwell Software Corp.*)* [13] for real technological variables transfer, acquired by DDE into Internet.

5.1 Logical model

Heat system - HS and **portal crane -** PC are controlled systems. The main goal of HS control is to supply the secondary part of a station with the required amount of heat. PC must be controlled to move it into a required location. The process level ensures local control in automatic and manual regimes. From the logical model point of view SCADA/HMI system provides users with the following functions (Fig. 3):

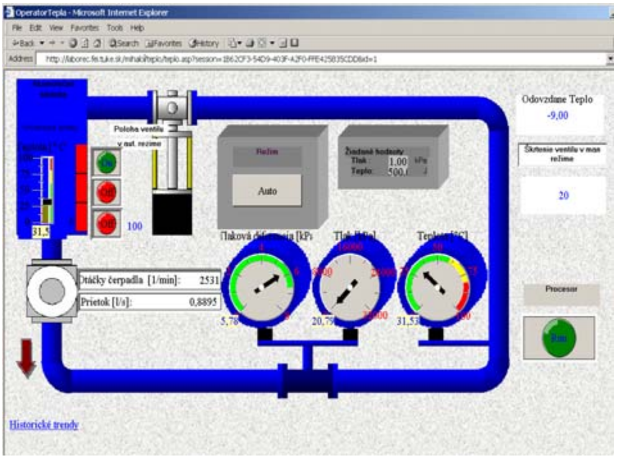

Fig. 3 HMI for heat system

- access into a system with different access levels of rights,
- display of real time values and parameters (for HS it is supplied heat, piping pressure, water temperature in a tank, state of switching on spirals, and for PC it is equipment position in space, readiness to work, speed of movement in different directions),
- indicate regime of control (automatic and manual) and enabling its change,
- input of required values (for TS it is supplied heat, temperature, pressure and for PŽ the required position, calibrating) and setting up actuators,
- acquisition of historical data and their graphical display,
- display of several types of histograms.

5.2 Physical model

Physical model of application is in Fig. 4 and the following means have been used in the sense of a designed logical model:

- **Technological level of control**
  - ***hardware*** - sensors and actuators, programming logic controllers -PLC5 and SLC500,
  - ***software*** – programming PLC,
  - ***communication*** – industrial technological networks (DH485, DH+) and TCP/IP protocols,
- **Visualization level (SCADA/HMI level)**
  - ***hardware*** - powerful servers and clients PC,
  - ***software*** - *MS Windows 2000, MS InterDev, MS Visual Basic Script, Matlab, RSTools - ActiveX* components and *RSPortal* - Rockwell Software Corp, *Industrial SQL* – Wonderware Corp processing database., *MIIS* www server, but only *MS Internet Explorer* at the client's site,
  - ***communication*** – data acquisition from technology by DDE server *RSLinx* - Rockwell Software Corp. and *RSPortal*, link to information level and internet by TCP/IP and ODBC,
- **Information level**
  - ***hardware*** – executive workstations and servers,
  - ***software*** – *Windows 2000 Advanced Server* operation system, *MIIS* www server, *MS SQL* database,
  - ***communication*** – local, intranet and internet networks based on TCP/IP protocol.

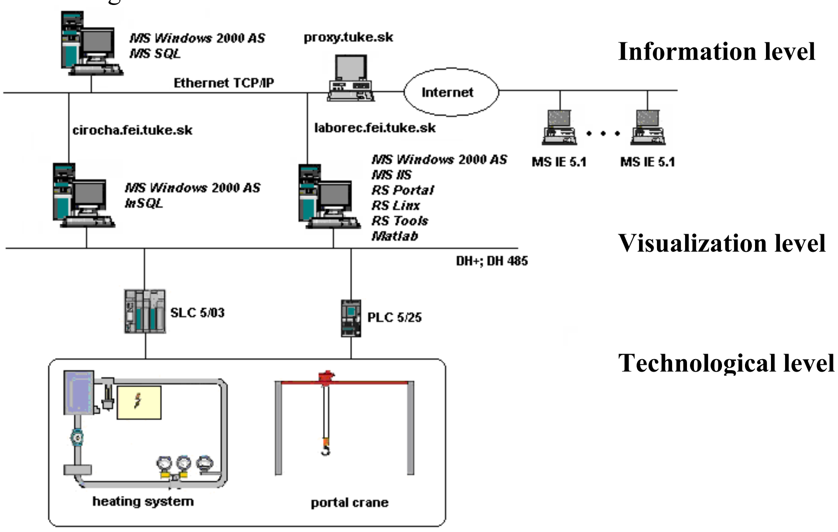

Fig. 4 Physical model of application

5.3 Application evaluation

The goal of this SCADA/HMI application was to define a logical model and implement a physical model in this environment, which is based on development, which has not been tested within the framework of ICS yet. This application is a simple variant of SCADA/HMI system, which is almost entirely implemented by fundamental tools and toolkits. It is not an expensive solution, as it would be by using professional SCADA/HMI development systems, but more demanding on development work. It is mainly suitable for controlling technological processes, which are simple, do not require remote control and are not financially demanding. It is also a very good teaching application, which enables students to get into the fundamentals of implementation, which are otherwise hidden to developers in professional program suites.

There are possibilities of improving the physical and logical models shown in this article. At the same time there is space for further research and new technology implementation into this application, for example based on OPC and XML – Extended Markup Language.

6. CONCLUSION

The characteristics of SCADA/HMI systems are continuously being improved in every area– data acquisition, supervisory control and users interface. The development is directed more towards open and scalable technologies in the area of technological, programming and communication means. It is expected, that **OPC** and **XML** and thin clients will take over. Software components will be used more, which will require better scientific approaches and techniques, which will support development of these systems. For example, progress in modeling technologies seems to be unavoidable, as well as automatic generating of database items, support of configuration design, implementing other theories for supervisory, situational, intelligent control into real time SCADA/HMI systems.

Although the independent components (hardware and software) are being already developed with a higher degree of intelligence (as agents), it is probable, that ICS will lose its strict hierarchical character and will be directed towards **holonic** systems [6]. Requirements for aims (also for agents) will, however, come from a superior control element (manager).

It is necessary to emphasize that ICS are also considered as **emerging** trends. New events and characteristics of a system as the entire system are being developed from completing subsystems, which worked before as individual entities or parts of a different system, for example. www servers are getting to the PLCs at a technological level, not to mention so-called softPLC, databases in visualization systems being independent now, and smart sensors implemented into the technological part.

For humans, the visual interaction with environment is the most important and provides the most information. A human is creating his/her own intellectual models of world perception with the help of visual perception, which verifies their definition, features and relationships. The role of a human in industrial ICS and SCADA/HMI systems as well is being changed through development and so as mean, which cause these changes and changes in functions of its visual perception. The development is directed towards **optimal competence distribution in control** (control, decision making, management) between a human and a machine (controller, computer), it means towards maximum ability implementation.

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BIOGRAPHIES

Iveta Zolotová graduated (MSc.) at the Department on Technical Cybernetics TU of Košice in 1983. Her Ph.D. thesis (1997) dealt with hierarchical image representations. She defended her habilitation thesis Visualisation as a Aided Tool in Control and Decision Making in 2001. She works at the Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University in Košice as Associate Professor. She teaches Control and Process Visualization, Computer Vision and Object and Component Systems. Her specialization is focused on simulation and modeling of technological processes, their monitoring and control, supervisory control and data acquisition systems, human-machine interfaces and their design, as well as Image Segmentation.

Branislav Mihaľo graduated (MSc.) at the Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University in Košice in 2001. His master thesis deals with ActiveX software components in SCADA/HMI systems and remote visualization. Since 2001 he is a programmer and system administrator in Transpetrol, a.s. His academic research as external postgradual student is specialised on SCADA/HMI and multiagent systems.

Eva Ocelíková defended her Ph.D. thesis, which dealt with multicriterial classification of situations in the complex system, in 1985 at the Slovak Technical University of Bratislava. She works at the Department of Cybernetics and Artificial Intelligence of the Faculty of Electrical Engineering and Informatics at Technical University in Košice as associate professor. Her research work includes problems of decision processes, especially the problems of multicriterial classifications, designing and high dimensionality reduction of feature space of multidimensional data in decision. Her specialization is focused on applications of database systems as well.

Lenka Landryová graduated from the Technical University of Ostrava and started to work at the Department of Control Systems and Instrumentation as an internal postgraduate student on her dissertation thesis, which dealt with expert systems methods and knowledge systems for data acquisition in computer aided control in the area of technical diagnostics of machinery equipment. She works at the Department of Control Systems and Instrumentation of the Mechanical Engineering Faculty at VŠB - Technical University of Ostrava, where she teaches Expert Systems Engineering, the Design of Processing Systems and Control Systems. Her specialization is focused on simulation and modeling of technological processes, their monitoring and control, supervisory control and data acquisition systems, human-machine interfaces and their design, as well as expert systems applications and artificial intelligence techniques in control engineering.