SELF-ACCESS STUDYING ENVIRONMENT FOR CONTROL ENGINEERING EDUCATION

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Abstract: A new system has been developed for the self-access studying of the power plant operation. The system consists of a simulator, plant operation system, instructor application and student application. The instructor application includes tools for the management of students and courses, execution of example task by simulator, definition of the feedback criteria and preparation of the malfunction pointing. With the student application the user can execute exercises, get immediate feedback from his performance and see the total status of his progress. The system can be used without a supervising person, specific room and according to the users own schedule. With the system the control education is effectively based on the learning-by-doing method in the real circumstances. In this paper the structure and function of the system and a practical example is presented.

Keywords: computer simulation, control education, education, educational aids, simulators, training.

1. INTRODUCTION

The power plant is an example of multi-parameter relationships. It is a very complex system whose behavior is described by intricate relationships between its parameters. Unlike direct and inverse monotonic relationships, where knowledge of the change in one parameter gives the change in the other, additional information is necessary in reasoning about non-monotonic relationships. This information is typically plant-specific and it is cumulatively collected during plant construction and lifetime and mainly stored in the plant control and automation system beside the tacit knowledge of operators. Because of the advanced control and automation systems the operation of the plant is nowadays mainly observing of the monitoring systems and so the understanding of the real physical process may be very thin.

In the incidents and changing modes it is important to have deep knowledge about the behavior of the process and the function of the control system. The traditional education of control and automation systems for the operators is based on the system descriptions, textbooks and laboratory exercises, which are supervised by the full time instructor. In the cases, where the education background of the operator students is compendious, the motivation to that kind of studying is often poor and the results are unsatisfactory. The simulator training has been the effective way to improve the skill of the operation personnel alongside with theoretical lessons. Because of the high training expenses, the use of the full-scale simulators is not very common in the education of the conventional power plant personnel. Initial costs, employment of instructors and reservation of classroom are the main reasons for the restricted use of simulators. The training arrangements are also quite laborious including collecting the trainee group, scheduling the training, measuring of individual results and maintenance of simulator.

The purpose of this work has been to develop a new system for the self-training of power plant personnel. This system is called Training Manager. With this system the student can practice the operation of the plant and study the function of subprocesses, e.g. control and automation. The drawbacks of the traditional simulator training has been avoided by introducing the following features to the new system:

1. System runs on a single PC, the equipment costs are very low.
2. Instructor is not needed; system gives instant feedback automatically.
3. Classroom is unnecessary, the study may happen anywhere using the portable PC.
4. There is no need to collect a trainee group; single person can use the system according his own schedule.

5. Measure of individual learning results is impartial; system generates the results automatically using the same criteria for all students.

In the Training Manager system the learning is based on learning-by-doing method, which is an effective tool, when the high theoretical knowledge is not the goal of education. The best equipment for the learning-by-doing method is the simulator and real or almost real operation system of the plant, which are essential parts of the system.

In this paper the structure and functions of a new system for the self-access training of power plant personnel is described. The presented practical example shows how the system is used for the control education of the power plant.

2. SYSTEM DESCRIPTION

2.1 Studying environment

The system consists of a training simulator, plant operation system, instructor application and student application. Figure 1 shows the general structure and basic flow of the information. The education data and results are stored in xml-files. Via these files the two separate application are connected to the common database. Xml-files include the following data:

- information of the system users: names, roles and achievements of students
- the list of quantities, which are available in the system for the monitoring during the task
- information about the configuration of the simulator
- available malfunctions or events
- descriptions of the separate training tasks
- evaluation criteria of the tasks.

In addition to the mentioned xml-files three ascii-files are created during the exercise. The first includes the list of registered courses, the second includes the values of the quantities during the reference performance and the third includes the values of quantities during the student performance.

2.2 Instructor application

The instructor application provides tools for administration of system and to maintain, create and modify exercises. The main functions are:

Administration of the study books. The instructor can add, view and modify study books. Study books include information about the skill level of the students, which are registered in the system. The executed courses and gathered scores are presented.

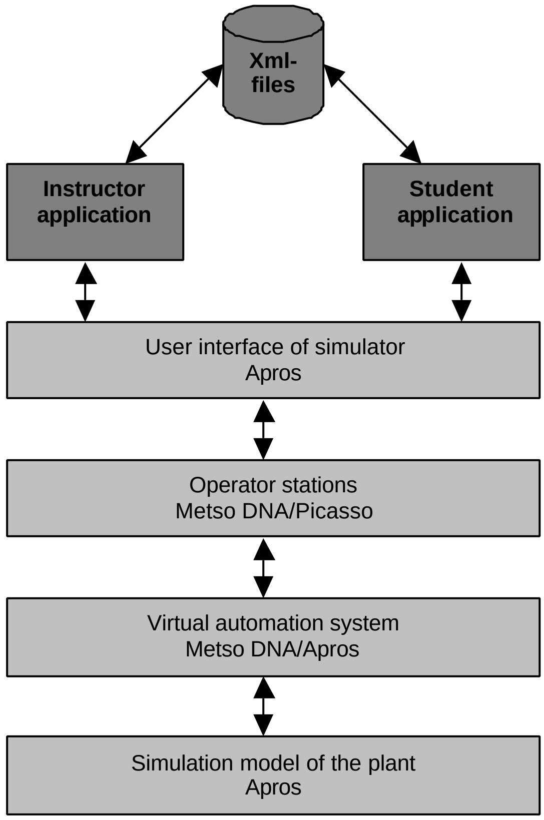

Fig. 1. Principal structure of the Training Manager studying environment.

Creating new course. By this function a new course is added to the system. The name, location and description of the course can be given. The course may contain several exercises.

Creating new exercise. A new exercise is prepared by choosing the initial condition of the plant, trend variables and malfunction. The comprehensive set of initial conditions of plant is available for the user. All exercises shall begin from these states, if necessary it is possible to add new states to the system.

The trend variables are either analog or binary quantities, whose values are inspected during the evaluation on the exercise. Binary trend variable can be e.g. state indication of automation sequence, controller, valve, pump and motor.

A malfunction may be included into the exercise to enable the creation of the more complicated tasks. The malfunctions are prepared and included in advance to the system. From the malfunction list the instructor may choose the proper incident and set the time, when the malfunction activates in the process.

Execution of the reference exercise. The evaluation of the student's skill is based on the comparison be-

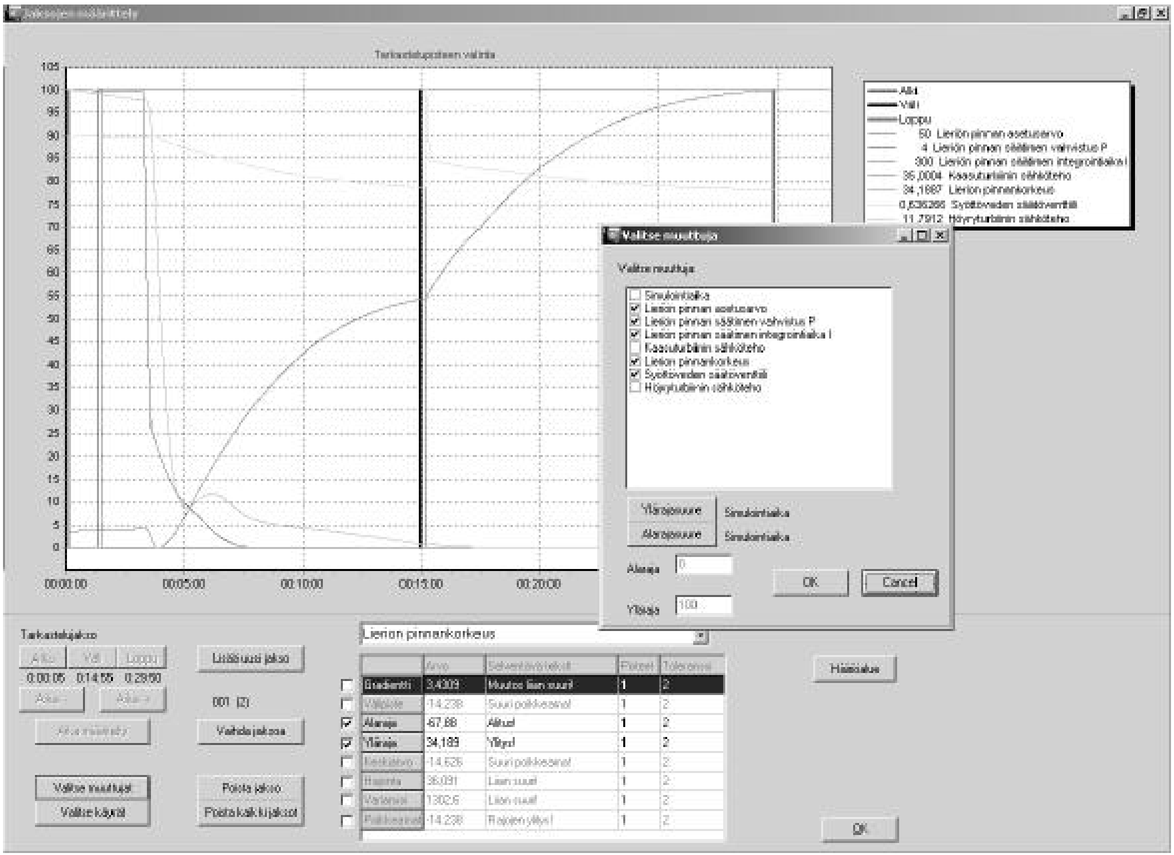

Fig. 2. Finnish version of the exercise definition sheet of the instructor application.

tween the instructor's and student's performance in the certain exercise. Before the definition of the comparison criteria the instructor must perform the reference run by the simulator. In the reference run the given operation task is executed correctly from the instructor's point of view. The simulator is operated via the simulator interface system and the plant via its own operation stations.

Definition of evaluation criteria and scores. The evaluation of the performance of the student is based on the checking of trend variables. In the Figure 2 is shown the interactive window for the definition of the evaluation criteria of the of instructor application. Choose variables –window is opened to pick criticized variables. Curves of the chosen variables are shown on the top left and criteria of the single variable on the table. Defining and navigation of checking periods are done with the buttons on the bottom left.

The system offers eight different criteria for each chosen trend variable. These criteria are the permissible

- deviation from the given value at the defined moment
- maximum value during the checking period
- minimum value during the checking period
- deviation from the reference values during the period
- gradient of the variable during the period
- average value of the variable during the period
- variance of the variable during the period
- standard deviation of the variable during the period.

The instructor chooses the proper criteria and defines the reference values, tolerances and points for those criteria.

Definition of the points in the discovery of malfunction. The discovery of the malfunction in the process is an important ability for the operator. In the instructor's application the user can include the chosen malfunction into some checking period. The instructor prepares the discovery of malfunction according to the following procedure:

1. process diagrams are selected from the drawing gallery

2. location of the malfunction is marked by selecting rectangular areas from the diagrams
3. the points for the correct timing, positioning and type of the malfunction are defined.

2.3 Student application

The student application is a self-access studying environment for the operators of the processes. The student can study the operation of the plant by executing exercises according to his own training program. The exercises are prepared by the instructor's system. The studying session is comprised of choosing, execution and feedback of exercises. Furthermore during the exercise the student can stop the simulation and point the fault in the process or get feedback about his performance.

Choosing of the exercise. After the starting the system the student can browse the list of the available courses and exercises. After the exercise has been chosen, the system offers advice to the student how to execute the task. These instructions include the description of the initial state of the plant, purposes of the exercise and possible operation guides.

Execution of the exercise. The execution of the exercise begins by the automatic starting of the operator and simulator systems. The operator displays of the real plant are available for the required tasks and monitoring. The task may be the change of the load, start-up, shutdown, discovering of the fault, changeover of process components etc…

Pointing of the discovered fault. When the student doubts that there is some fault in the process, he can stop the execution and try to point the location and type of the fault. The activated malfunction system first offers several process diagrams from which the student chooses the right one. In the next step the student points the defective component on the chosen diagram. After the pointing the system asks confirmation and if the selection was correct makes further question about the type of the fault. Finally the system presents the results of the fault discovering. The student gets points from the timing, localization of component and definition of type.

Feedback from the exercise. The feedback system can be activated both during and after the execution of the exercise. In Figure 3 is shown the feedback sheet of the Training Manager student application. The intermediate results are presented from all checking periods whose end time is smaller than the actual time of the execution. Execution of student and instructor are presented by the curves. Scores of execution are on the bottom right above navigation buttons. Literary feedback is shown on the bottom left corner.

The feedback system divides the time of performance into several sections. In each section the values of selected trend variables are compared to the reference values. The comparison is done according to the eight possible criteria, which are described in the chapter 2.2. The feedback from each active criterion includes the values of student and reference run, permissible tolerance for the correct performance, the earned points and comment. The user can browse the variables one by one to see all his results. The results are also presented in the graphical format. The reference and student curves of the selected variable are shown with different color from the start to end of the session. In addition to this the permissible limits and the borders of the section are shown on the plot area.

On the feedback form the total points of the section, sum points of all sections and the detailed points of the possible fault discovery are also presented.

2.4 Training Simulator

Training simulators have been developed for along time. Until recently full-scale training simulators has required sophisticated hardware. However during the past decade the improvement in the processor capacity and advances in software technologies have enabled creation of low-cost training systems (Porkholm, *et al*., 1997; Ollikainen, *et al*., 2002). This development has also made Training Manager system possible.

Typical parts of the training simulator are the simulation engine, automation system, operator displays and user interface for the simulator. Simulation engine is used to emulate the behavior of the real process. Automation system controls and "protects" the simulated process. Operator displays are used for interaction between the simulated process and operator. Ideally the functionality of the automation system and operator displays in the simulator are identical or very close to the functionality of the corresponding systems in the real plant. Some kind of simulator interface is used for controlling the training session. Typically it enables e.g. loading of initial states, starting and stopping, changing the speed and triggering malfunctions in the simulator.

3. CONTROL EDUCATION

The operation of the modern steam power station is based on the advanced automation system. The basic task of the automation system is to take care of the correct amount of the steam generation according to the load, to keep the pressure and temperature of steam inside the permissible limits during load

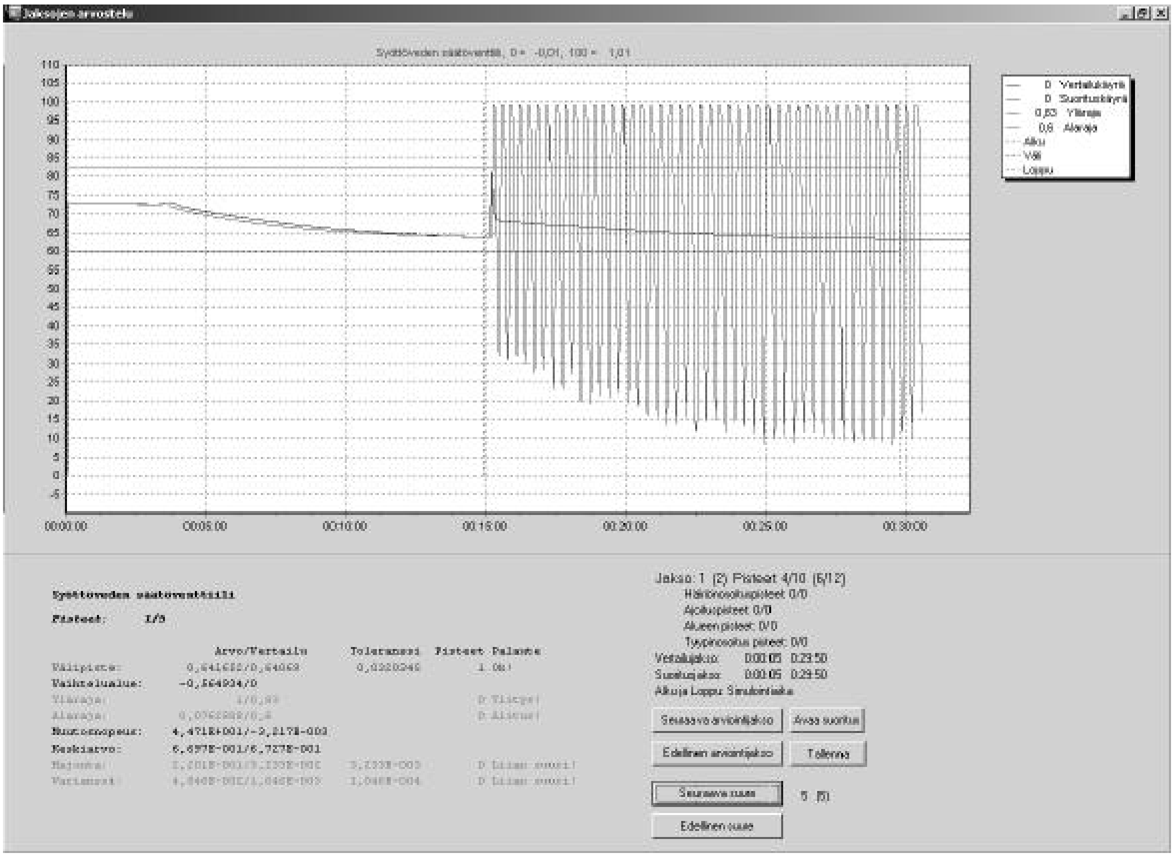

Fig. 3. Finnish version of the feedback sheet of the student application.

changes and to adapt to changing load demands fast. These requirements are implemented by control circuits, which are connected via direct signals or process measurements.

The separate controllers, actuators, sensors and subprocesses compose an integrated unit, whose function is hard to perceive. In the following case it is shown how the previously described Training Manager system can be used for the control education of the combined cycle power plant personnel. The presented exercise is taken from the training course, where the tuning of the drum liquid level controller is rehearsed. Tuning is done with a trial and error method. Student executes the same exercise several times until the transient behaviour of the drum liquid level is good enough. Parameters are tuned in two parts:

1. set point of the heating power of the plant is reduced
2. set point of the drum liquid level is changed.

The main lesson of the exercise is that the control parameters tuned in the first case may not work in the second case. Accidentally it is of course possible to find acceptable parameters already during the execution of the case 1.

Process- and automation model is made with Apros simulation software (Porkholm, *et al*., 1997). Operator's displays are build with Picasso-3 user interface management system (Jokstad and Sundling, 2000).

3.1 *Part 1: Load change of the plant*

Lowering the heating power decreases steam consumption and less feed water is needed in the heat recovery boiler. Liquid level controller takes care of decreasing the feed water flow.

Simulation run is repeated until suitable parameters have been found. Results are shown after every attempt to present the state of tuning compared to reference tuning. Feedback sheet is shown in the Figure 3, where first 15 minutes of the curves are the result of the successful part 1. After this student can continue to part 2.

3.2 *Part 2: Drum level set value change*

In this case the set point of the drum liquid level is increased. Liquid level controller opens feed water valve more for a short period. The valve returns to original position after the level has reached the desired value.

In the figure 3 the curves from 15 minutes to 30 minutes are result of the part 2. It can be seen that the parameters of the controller are valid for the part 1 but not for the part 2. The position of the feed water valve begins to oscillate when previous control parameters are used. In this case student must repeat the exercise and try new control parameters.

4. CONCLUSIONS

A novel system for the education of the dynamical behavior of the power plant was developed. The system can be used in the power plant personnel training and in the control engineering education. Because the system includes entire control system of the plant, it is possible to teach function of the high level control circuits, different modes of controllers, local controllers, automatic sequences and set value formation. The exercises may consists of tuning of controllers, switching control circuits on and off and discovering of the faults in the control system. Regularity, repetition and self-access use are relevant for the education by the developed system. Each student will receive a detailed feedback from system, which offers an opportunity to compensate deficiencies in basic skills.

The study of control systems via the presented system will essentially improve the understanding of the dynamical behavior of the real power plant and clarify the role of the control system as a fundamental part of it.

5. ACKNOWLEDGEMENTS

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