

OPERATOR TRAINING SIMULATOR OF COAL-FIRED POWER AND HEATING UNITS

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Abstract:

This paper continue the description of the first computerized Operator Training Simulator (OTS) of coal-fired Power and Heating Plant for operator's training, which is in standard utilization in Czech Republic – see [1]. The process model is developed on the base of mathematical-physical analysis ("first principles" method) of the separate technological subsystems of two drum steam boilers working into one section of the common steam collector and two steam turbines. The process model describes the standard and abnormal operation regimes in the range of 0 % - 100 % of Maximum Continues Rate, with implementation of individual disturbances by the instructor.

In this paper are described some modifications and enlargements of OTS implemented during last year. That is, e.g. realization of start-up and shut down processes. There are realized not only standard shut down but also sliding shut down of separate unit, which requested realistic way of modelling of steam turbine – not so called IEEE model.

In the next time the whole energy cycle of power unit will be modelled, i.e. including electric generator. For this purpose we suggest using of generator from SIMULINK Toolbox SimPowerSystems.

Keywords: modeling, simulation, training simulator, thermal power plants, operation staff.

1. INTRODUCTION

This OTS is based on modules library called "EnergySIM" developed in the packages MATLAB-SIMULINK. This library could be used for modelling of all types of power plants (Conventional Power Plants, Combined Cycle Power Plants, etc.) based on following modules: Drum Boilers, Steam Turbines, Superheaters, Reheaters, Once-Through Boilers, Fluidized Bed Boilers, Gas Turbines.

The "distributed control system" is also emulated in MATLAB-SIMULINK. The Human Machine Interface (HMI) is realized in package InTouch and the real desks and panels MOZAIC are connected through the PCI slots and I/O cards. The communication between MATLAB-SIMULINK and InTouch is based on standard DDE protocol. This Operator Training Simulator belongs to "replica - partially stimulation types".

The noise effects were also implemented into the range of realistic replica of OTS, e.g. noise effect of safety steam valves opening .

2. SIMULATOR CONFIGURATION

The details of the simulator layout can be seen in Fig. 1. The process and the control system are modeled in MATLAB-SIMULINK. The InTouch mimics and the operator control panels (MOZAIC) are used as such in real plant. Three PCs are used, two for two operators, who are in training on the simulator and the third PC is used for the instructor who produces some disturbances and who monitors the performance of the operator. MATLAB-SIMULINK models and all the InTouch mimics are placed on instructor PC and are coupled together via DDE protocol. DDE is one of several mechanisms of inter process communication supported by OS Windows, which was explained last year [1].

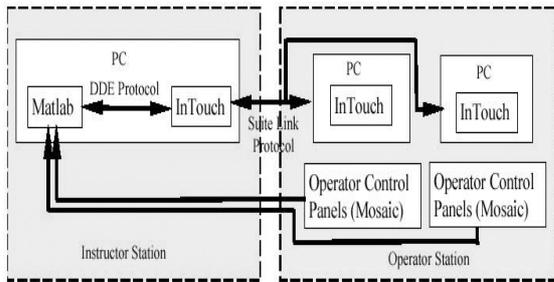


Fig. 1 Layout of Instructor and Operator Stations of Training Simulator

The data communication via DDE is possible only between MATLAB-SIMULINK and InTouch. The model has been created in SIMULINK so it was necessary to program special S-functions in order to establish DDE communication between MATLAB-SIMULINK model and InTouch mimics. Also operator control panels (MOSAIC) are connected to the instructor PC where the connection with MATLAB-SIMULINK model is carried out.

The operator training simulator is under full control of the operator by means of InTouch mimics and operator control panels (MOSAIC).

3. MODELING OF SUBSYSTEMS

The base information for creating structure of an OTS represents a process diagrams. It was demonstrated on an example of a feeding water subsystem last year [1]. This part is depicted in Fig. 2, which represents so called Process Instrumentation Diagram (P&ID). Other subsystems modelled by the same way are following:

Above mentioned way of Technology Object Oriented Modeling describes each part of the model as an object with certain behaviour; therefore the own-built library called “EnergySIM” was partially developed up to this time.

The main assets of „EnergySIM“ are the following:

- It is a modular system, a model is obtained by assembling instances of general-purpose models taken from libraries.
- The system is open, a user is free to expand the default libraries with its own models.
- The library “EnergySIM” includes the models and modules of many typical components to be found in thermoelectric power plants. Some examples: Gas and Steam Turbine Units, Two Phase Units (HRSG, boiler-evaporator, condenser, deaerator tank), Single Phase Units (economiser, superheater), special Drum and Once-through Evaporator Units, Water Storage, Media Flow Resistance Unit, Heat Flow Resistance Unit, Burner Units, Combustion Chamber Units, etc.

Each module is formulated from basic three conservation physical laws (first principles) and it needs few parameters. However the description of all modules is out of scope of this paper, and therefore only one module is shortly described. It is the ECO (economizer) module as a part of Feeding Water Subsystem.

It is based on heat exchanger principal – see Fig. 3. The more detailed description of I/O specification and parametrization is available in commercial documents and customer manuals. The parameters of

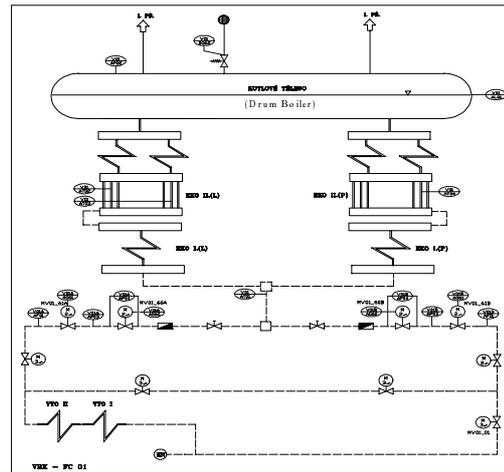


Fig. 2 Feeding Water Scheme of the Coal Fired Thermal Power Plant

ECO modules is also shown in Fig. 5, where V is volume, m is mass, A_i is cross sectional area, α_i and α_o are input and output coefficients of heat transfer, C_p is specific heat. There are also seen the following parameters: h_o is enthalpy, T_m is mean temperature of wall, T is temperature of wall surface.

For example ECO, which is a heat exchanger as shown in Fig. 3, is a sub-model. In chamber 1, water enters and leave as steam passing through a flow resistance, while in chamber 2 hot flow gases enters and leave with heat loss through a flow resistance. Theses two chambers are connected through a heat resistance.

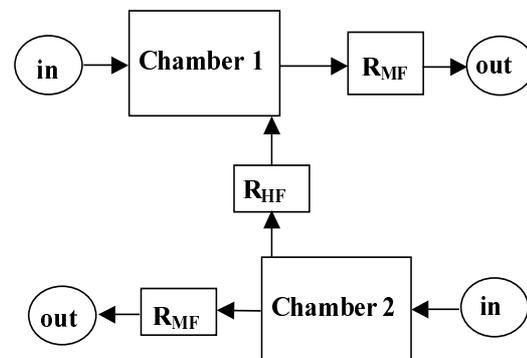


Fig. 3 Heat exchanger layout

where:

- V - chest storage volume
- ρ_0 - outlet steam density from the chest
- h_0 - outlet steam specific enthalpy (from the steam chest)
- h_i - inlet steam specific enthalpy
- w_i - inlet steam flow
- w_{ohp} - outlet steam flow
- r_{hp} - ratio of nozzle pressure drop
- m - exponent of polytropic curve for superheated steam
- n - exponent of polytropic curve for wet steam (outlet steam of control stage of turbine)

The scheme of complex SIMULINK turbine model is shown in Figs. 5, 6 and 7.

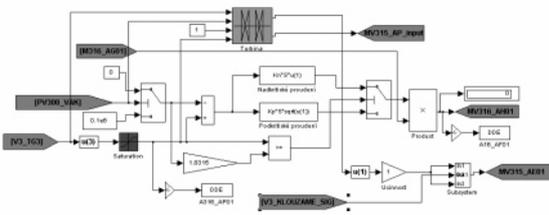


Fig. 5 SIMULINK scheme of turbine model-part I

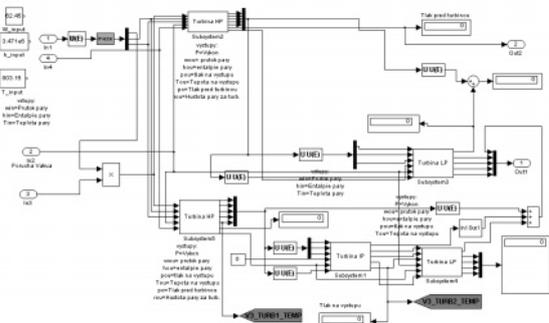


Fig. 6 SIMULINK scheme of turbine model-part II

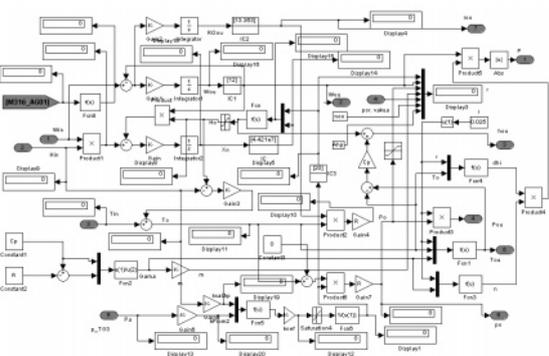


Fig. 7 SIMULINK scheme of turbine model-part III

5. EMULATION OF DCS, REALITY CONDITIONS AND REALIZATION OF HMI

The Distributed Control System (DCS) consists of manual control from operator control panel (MOZAIC), control from InTouch mimics and control from standard industrial PID controllers. For example, the control scheme, where two cascade PID controllers (blocks REG.1, REG.2) and logic control modules (e.g. Blocks 1.2, 1.3, 5.3, from ZAT Manual "Function blocks") for level control in the drum has been modelled (emulated) in MATLAB-SIMULINK. Switching between manual controlling and PID controlling is given either by operator (from InTouch or from MOSAIC) or by a protective mechanism (e.g. Feeding Water Valve could be in PID control mode only when Difference Pressure Valve is also in PID control mode).

All the PID controllers are realized by Z-transformation of the continuous PID controller. Equation for the continuous PID is following $u(t) = r_0 * e(t) + r_0 * T_D * de(t)/dt + r_0 / T_I * \text{INT}\{de(\tau)d\tau\}$, is transformed into $u = q_2 * z^{-2} + q_1 * z^{-1} + q_0$, where $q_2 = r_0 * T_D$, $q_1 = -r_0 * (2 * r_0 * T_D) + (r_0 * 0.5 / T_i)$, $q_0 = r_0 + (r_0 * T_D) + (r_0 * T_D * 0.5 / T_i)$. Sampling period ΔT is included to the equations.

In the scope of reality conditions the noise effects were also connected with MATLAB-SIMULINK model and also with InTouch mimics.

The Human Machine Interface (HMI) is realized in standard SW InTouch and the real desks and panels MOZAIC, which are connected through the PCI slots and I/O cards. The communication between MATLAB-SIMULINK and InTouch is based on standard DDE protocol. For understanding it is necessary to explain the three letter acronym "DDE": DDE - Dynamic Data Exchange is a communication protocol developed by Microsoft to allow applications in the Windows environment to send/receive data and instructions to/from each other. It implements a client-server relationship between two concurrently running applications. The *server* application provides the data and accepts requests from any other application interested in its data. Requesting applications are called *clients*. Some applications such as Wonderware InTouch and Microsoft Excel can simultaneously be both a *client* and a *server*.

Even though the DDE was originally developed for communication among office applications it doesn't necessarily mean it must be slow. Requests for data can be one of two types: one-time requests or permanent data links. With one-time requests, the client program requests a "snapshot" of the desired data from the server application. An example of a one-time request would be a program (such as Excel) running a report-generating macro. The macro would open a channel to another application, request

specific data, close the channel and use the data to generate the report.

Permanent data links are called "hot links." When a client application sets up a hot link to another application it requests the server application to notify the client whenever a specific item's data value changes. Permanent data links will remain active until either the client or server program terminates the link or the conversation. Permanent data links are a very efficient means of exchanging data because, once the link has been established, no communication occurs until the specified data value changes.

The reasons why the DDE was chosen for communication between Simulink and InTouch at the project OTS of Opatovice Power Plant are as follows:

- 1) The MATLAB-SIMULINK has no support OPC communication.
- 2) The DDE "hot link" type of communication was tested for communication between MATLAB-SIMULINK and InTouch and we didn't encounter any throughput limitation.

On the base of OPC versus DDE comparison the following matter could be said. In spite of the fact that we have had no communication problems using DDE at the Learning and Training Simulator of Power Plant it is obvious, that the Dynamic Data Exchange communication is yet industrially verified while the OPC (OLE for Process Control) is currently widely accepted communication and it becomes a standard.

Components of the Wonderware FactorySuite, including SCADA/HMI InTouch, already support OPC and MathWork's SIMULINK is expected to support this connectivity during next years. When it happens there is no problem to migrate the existing DDE communication to OPC. The migration is easy to do, as it doesn't require any modification of InTouch application itself. Also, new implementations of our project could use the OPC instead of DDE connection, if it will be required and suitable.

6. OBJECT OF OPERATOR TRAINING SIMULATOR

The object of this Operator Training Simulator of one part of Czech Opatovice Power and Heating Plants. This modelled part consists two steam boilers with nominal power 250 t/h, which are working into common steam collector, and two steam turbines are connected. Opatovice Power Plants are equipped with modular DCS ZAT-Plant Suite MP and InTouch Monitoring and Control system. The Human Machine Interface (HMI) is realized in InTouch and one mimics of it is shown in Fig. 8.

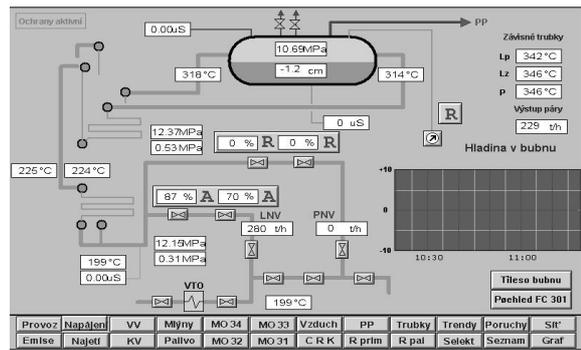


Fig. 8 InTouch mimics of Feeding Water & Steam of the Thermal Power Plant

7. CONCLUSIONS

This OTS was developed, delivered and commissioned for customer, i.e. Czech Opatovice Power and Heating Plants. The parametrization and verification of simulator's features were performed during two months before commitment, every time with participation of minimally one of selected very experienced operators. The condition for commitment of this OTS to customer was the official written confirmation, signed by three the most experienced active operators, that fidelity of OTS is very high and fulfil the customer requirements.

The „teaching experience“ was yet obtained during training courses of operators at real power plants up to this time. In the first stage there were trained all chief operators of boilerhouse for function of Instructor. Then the individual courses for separate shift (which consists of 7 operators) were organized by customer.

The „operating experience“ from the operation of these operator training simulators show that there are no great problems in fidelity of the dynamics features.

Therefore it can be said that the described type of Operator Training Simulators, based on MATLAB-SIMULINK and InTouch packages and if any MOZAIC, are suitable for replica simulators of smaller energy units (e.g. with capacity less and equal of 110 MWe) and acceptable for customers especially in Czech Republic, respectively Central and Eastern Europe and Underdeveloped Countries.

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