SIMULATION AIDED PROCESS AUTOMATION TESTING

**Jarno Rinta-Valkama*, Martti Välisuo*,
Tommi Karhela**, Pasi Laakso**, Matti Paljakka****

**Fortum Power and Heat Oy, FIN-01019 Fortum, Finland,
Tel. +358-10-4534747, Fax. +358-9-5632225,
e-mail: Jarno.Rinta-Valkama@fortum.com
** VTT Automation, Technical Research Centre of Finland, P.O.Box 1301, FIN-02044
VTT, Finland*

Abstract: In this paper, simulation aided automation testing is discussed. The architecture for a testing environment is presented and analysed. The simulation aided working method is studied from the point of view of the design and testing engineers. The emphasis in the analyses will be in how the method can be applied in the normal workflow of an automation delivery. A case study is presented and the benefits and drawbacks are analysed. *Copyright ©2000 IFAC*

Keywords: Process simulators, Dynamic models, Process control, Validation

INTRODUCTION

Traditionally, the factory acceptance test of a control system concentrates on the process interface and operator displays. It has been difficult or even impossible to test the more complicated functions. Thus a lot of testing has had to be done at site, which is expensive due to labour costs and possible loss of plant operation time.

A potential remedy has been seen in dynamic process simulation, and simulation has been successfully used in process and control concept design, control application testing and operator training. So far, the functionality of the control system has been included in the model either using the automation component libraries of the simulation tool, or a vendor-specific link to the real control system implementation. Either way, the costs of using simulation have been high either due to the manpower needed to do the non-reusable control system configuration on the simulator tool, or due to the costs of real control system hardware and the vendor-specific, often tailor-made software bridge between the simulator and the DCS.

The recent development of automation domain information technology has opened new opportunities. Especially the shifting of the DCS's towards PC based systems and the development of specifications for open connectivity have made it possible to expand the use of simulation-aided methods during an automation delivery. The development of simulation tools and the increase of computing power have contributed to the more extensive use of dynamic process simulation.

1. PRINCIPLES OF SIMULATION AIDED WORK PRACTICES

1.1 Benefits of Simulation

Linking the control system to a dynamic simulation model of the process makes it easy to test even complicated control functions and to tune parameters. This way, a great deal of the work traditionally done at site can be done during the factory acceptance test. This improves the quality of the DCS delivered to the plant, cuts down the time used for commissioning of the control system, and enables an earlier start up of the plant's normal operation.

A dynamic simulation model linked to the DCS can also be used for integrated process and control engineering, for training the operators with the simulator prior to the start up, and for operator support throughout the lifecycle of the plant.

In integrated process and control engineering, the process and automation are designed simultaneously by engineers of the different domains and various options are tested even during the meetings between the engineers and the customer. This way the verification of the control application can be started already in the design and implementation phase. Furthermore, the process dynamics and controllability are taken into account earlier than in the traditional workflow.

1.2 Architecture of Test Environment

A link between the control system and a process simulator can be established in an ordinary PC environment using the vendor-independent OPC (OLE for Process Control) data access specification, developed by the OPC foundation [Karhela,OPC]. Therefore, OPC compatibility is the most important feature in both the DCS and the simulation tool.

To achieve efficient simulation aided testing the simulator and distributed control system has to work in a close co-operation. The new use cases set new requirements to the DCS. The save and load features are needed for efficient handling of large models, and the capability to adjust the execution speed is the more useful the more slowly the process behaves. Freeze and resume options are also practical.

A primary requirement for the process simulation tool used is the capability to provide a realistic picture of the dynamic behaviour of the entire plant at real time. This is best achieved by using mechanistic models and complementing them where necessary with empirical correlations, e.g. with regard to energy transfer and transportation properties.

1.3 Workflow Description

The phases of an automation delivery can be divided into design, implementation, installation and comissioning. In this division implementation phase includes also FAT (Factory Acceptance Test) and comissioning includes SAT (Site Acceptance Test). As outlined earlier dynamic simulation can be applied in all of these phases as described in figure 1.

The design phase is commonly seen to have the greatest effect on the quality of the automation delivery, and dynamic simulation can assist in many decisions made in this phase.

By using an appropriate dynamic simulation tool, different choices can be compared and the plans can be tested before freezing the functional specifications of the automation. The possibility to compare different choices may also encourage applying new control schemes. Simulation can also be used in discussing the operating practices and in reviewing documents with the customer. This way more profound understanding is formed on both sides about the process and the automation.

In this phase, however, the automation supplier has not necessarily been selected and the application programming has not yet been started, so the automation has to be modelled with the component libraries of the simulation tool instead of using a software solution described in the previous section.

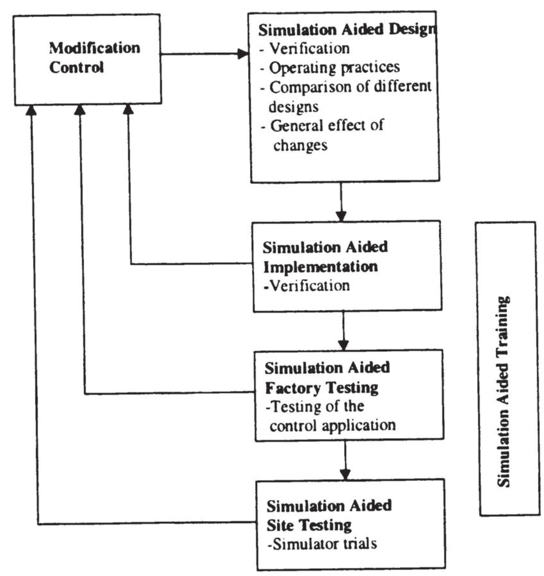

Fig. 1: Simulation aided workflow.

The verification of the automation application can already be started in the application programming phase. Until the latest development, it has been difficult to integrate control engineering tools with process simulation tools. In the environment described in the previous section, the application programmer can verify the implemented control loops against a virtual process. Programmer can see by himself whether the schemes documented in the functional specification work with the simulated process. This way the individual controllers and small subsystems will already be checked in the application programming phase.

Many of the sub phases of the factory testing phase, e.g. general hardware testing and most of the rack testing, have to be still done in a traditional way. With a simulation model, even the widest ranging control schemes and sequences can be tested during factory tests. This saves a lot of time and money in site testing. On the whole, in simulation aided testing, the functionality of the entire system is tested more completely and in more detail than it has earlier been possible.

2. CASE STUDY: ESTONIAN POWER PLANT

2.1 Simulation Model

The Estonian power plant is an oil shale combusting power plant consisting of 8 blocks each with two boilers and one steam turbine. Each block has an electric output of 200 MW. The plant is of Soviet make dating to the 1970's.

Creation of the simulation model was started in March 1999 when the modernisation project was in the functional design phase. Plant was modelled using APROS (Advanced PROcess Simulator) [Juslin]. The model was created in two completely separate parts, turbine and boiler plant, on different computers, in order to divide the labour.

The process data for the model was obtained from the plant personnel as well as from the people involved in the automation design. This data included PI-diagrams and dimensional information on the hardware such as the boilers, preheaters and tubing. Maximum power process values were also obtained as well as some part load data. Additional data was requested several times as the modelling went on.

About the level of details, it was decided that all motors, motor actuators and analog and binary measurements were to be modelled. This was done by September. The two separate parts were then joined and the model worked properly.

2.2 Test Equipment

The testing environment was set up consisting of four 400 MHz PC computers that were networked together through TCP/IP-protocol. See figure 2. The process model ran in one of the computers. The control software (NelesDNA) ran in two computers with the process stations in one and the operating station in another.

The fourth computer had the OPC-servers of the simulator and the automation system in it. A tool called X-connector was also located in this computer. This tool was used to make the connections between the OPC-servers. At the highest there were about 2000 signals conveyed simultaneously though this link.

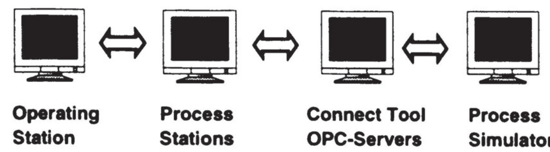

Fig. 2. The Test Bench.

2.3 Testing

The testing was carried out during the spring of 2000. It concentrated mainly on the control loops. The testing procedure was rather similar to the control loop commissioning procedure at site. Each control loop was tuned based on a step response experiment done with the simulator. It was then checked that the loop was stable, followed the set point and had acceptable dynamics. If the loop did not function properly, the fault was located using trend plots and the debugging tool of the automation system. Finally, the problem was fixed and the function block diagram was updated.

Most loops were tested in this fashion. These included steam temperature, steam pressure, drum level, flue gas oxygen, electric power, feedwater tank pressure and mill temperature control loops.

The master controls were tested in a more diverse manner. The master control of the power plant includes the control of the electric power, turbine initial pressure and pressure in the two boilers. The configuration of the master control was not yet decided, when the simulation tests were started. Different variations of the master control were tested by simulation, and compared against each other. In figure 3 some test responses are shown.

After the operation in steady state and in load changes was checked, it was verified that the control loops worked properly in certain disturbance situations. These included a forced draught fan trip, a fuel mill trip and quick by-passing of the preheaters.

2.4 Notes on the Procedure

The simulation model was unnecessarily detailed as far as the sole control loop testing was considered. There were 800 measurement signals most of which were not necessary for the testing purpose. The same applies to most of the actuators. The reason to this was the uncertainty of the scale of the tests in the beginning of the model building. Of course, these allowed a more realistic viewing of the operator displays as the values were all visible. This also made it possible to show the simulated plant in use to the client.

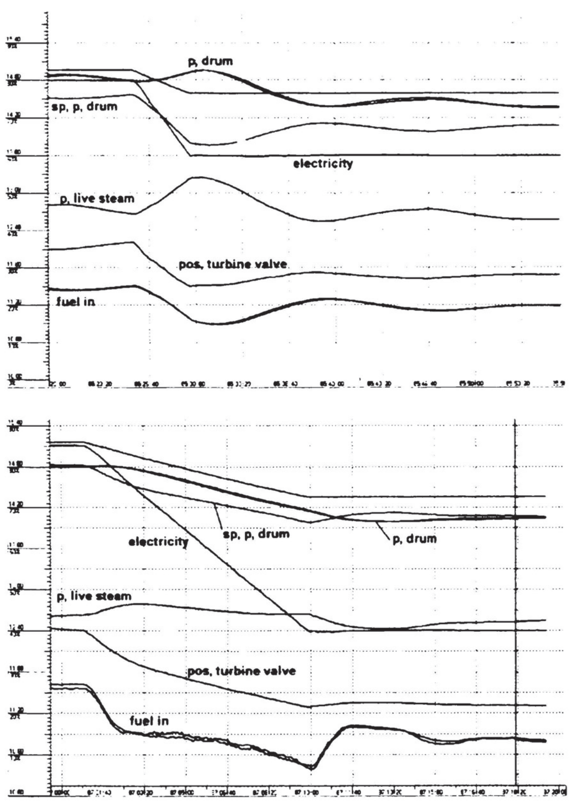

Fig.3. The ramp response as tested with the simulator and the control system. The one above with PI and the one below with PID-control. Note that the pressures fluctuate much less in the PID-case even though the ramp is longer (205 -> 160 MW above vs 200 -> 180 MW below).

The computing power of the 400 MHz Windows NT simulation platform was just enough to carry out the tests. It was the first time the simulator was used on an NT computer in a project of this scale. The price of computing power is constantly lowering so this should not be a problem in the future.

There were some problems with the OPC-server interfaces, as some of the tools were not quite finished when they were first taken in to use, but these were solved in close co-operation with the code producers.

The functioning of the communication itself proved to be more challenging. There was an additional 6-second delay in the feedback loop that could not be decreased. The delay was more than is the case in the real plant so the control loops were tuned somewhat conservative in this context. In addition to this the signal conveying was not synchronised with the control system output. The asynchronous communication caused problems with the motor operated valves, because some control pulses were doubled and some lost. It was possible to get around this problem in the simulator, but in these cases the functionality of the valve position control could not be tested.

CONCLUSION

Dynamic simulation can be used in testing of an automation system in several phases of the delivery and it may improve the quality and lower the costs. With dynamic process simulation tools with easy to use graphical user interfaces and extensive model libraries the process models are nowadays developed more quickly than before. Open connectivity allows for quick and straightforward linking of simulation models and automation systems. The case presented concentrated on the testing of the programmed control applications and proved clear benefits for the method.

REFERENCES

Karhela, Tommi; Laakso, Pasi; Ylijoki, Jukka; Paljakka, Matti; Mätäsniemi, Teemu; Kurki, J.; *Connecting dynamic process simulator with distributed control system using OPC standard* 1999 TAPPI Process Control, Electrical and Information Conference 1-9. Atlanta, GA, 1 - 4 March 1999. TAPPI Press, Atlanta, (1999), 329 - 337

Juslin, Kaj; Silvennoinen, Eero; Kurki, Jorma; Porkholm, Kari. *APROS: An Advanced Process Simulator for Computer Aided Design and Analysis.* 12th IMACS World Congress on Scientific Computation, Paris, France, July 18-22, 1988.

OPC Foundation. (1997), *OPC Standard 1.0a*, http://www.opcfoundation.org