ELSAMPROJEKT A/S
POWER STATION ENGINEERING

REPORT

Control Strategy for Improving the Load Following Abillity of Power Plants.

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Table of Contents.

1. Introduction.

This report sumarizes the work carried out with respect to the implementation of simulation model of a utility boiler. For further information about the simulator please refer to the report: Control Strategy for Improving the Load Following Abillity of Power Plants. Development of a Simulator for a 250MW Coal-fired Benson Boiler" (For the present in danish only).

The project is implemented as an industrial research project with ELSAMPROJEKT A/S as the industrial partner and Aalborg University, Institute for Electronic Systems, Department of Process Control, as the institute of education.

The persons involved in the project are:

Industrial Researcher:	Jan H. Mortensen, ELSAMPROJEKT A/S
Tutor from industrial partner:	Tommy Mølbak, ELSAMPROJEKT A/S
Tutor from the institute of education:	Tom S. Pedersen

Furthermore, a reference group has been formed for the project, comprising: Hjalmar Hasselbalch, I/S Nordjyllandsværket; Palle Andersen and Per P. Madsen, Aalborg University.

The project is subsidised by ELSAM's R&D Committee, the Danish Agency for development of Trade and Industry, and ELSAMPROJEKT A/S.

2. Project Description.

The problems presented in the project are based on the development of energy politics which has resulted in an increase in the number of decentralized heat and power plants and wind turbines, which again has caused the controllable share of the production to decrease steadily. At the same time this imposes increasingly heavy demands on the controllability of the individual power plant units when the reliability of the supply is to be ensured.

The limit of a unit's controllability can often be traced back to the controllability of the boiler, as this is characterized by exhibiting the slowest dynamics of the main process. Furthermore, the boiler process is characterized by being markedly multivariable (one input affects several outputs) and non-linear (especially concerning load dependency).

On this basis this project aims at improving the controllability of a boiler by applying advanced control methods. These methods are to improve handling of a boiler's multivariable and non-linear characteristics.

For this purpose it has been determined to set up a dynamic simulation model of an existing power plant boiler (Skærbækværket unit 2, SVS2). The advantage of this is that it will be possible to carry out realistic trials in a safe environment and at the same time carry out tests that cannot be performed in real life. More specifically, the simulator is to be applied for the following:

1. Process analyses.
2. Data acquisition tests for mathematical modelling.
3. Optimisation of data acquisition tests.
4. Test of controller.

3. Simulation Model of the Boiler at Skærbækværket, Unit 2.

As a tool for the development of the simulator of the SVS2 boiler, MMS-ACSL was chosen as it - compared to other tools - is estimated to limit the development process time and at the same time live up to the requirements for model quality. Secondly the fact that MMS was already being used by ELSAMPROJEKT A/S weighed in its favour.

With a view to the subsequent use of the simulator, it is imperative that it reflects the dynamics of the boiler process as well as the existing control system correctly.

The most important elements of the boiler process included in the model are as follows:

- Evaporator, HP and IP superheaters, attemperators, feedwater pumps, coal mills, approximation of HP preheaters, HP, IP and LP turbine.

The following parts of the control system have been included:

- Feedwater control, stoking control, superheater control, output power control.

The control system of the simulator has been set up as a copy of the existing control system - in terms of structure as well as control components and parameters[1].

In the following emphasis will be placed on the validation of the developed simulator. Four different types of evaluation have been made of which the first is a validation of the stationary properties of the simulator and the other three are validation of the dynamic properties of the simulator.

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[1] However, the actual superheater control has been approximated through a gain scheduled cascade control with PID controllers relative to the adaptive controllers existing at the time.

1. Static validation.
2. Open loop responses
3. Closed loop responses
4. Validation by comparing with collected data.

3.1 Static Validation.

The simulator is parametrized in one operating point (100% load). As the simulator is to reflect the process dynamics from 50% load to 100% load, it has been investigated whether the simulator - from a stationary point of view - is moving towards the correct state. For this validation the simulator's load profiles for water/steam temperatures, amounts of water/steam and flue gas temperatures are compared with load profiles given from design data.

Based on the comparisons performed it may be concluded that the simulator exhibits the same characteristics as the stated design data meaning that in the case of load changes the simulator will move towards the correct state.

3.2 Open Loop Responses.

For validation of the quality of the simulation of a boiler process, simulations have been made in an open loop with all control loops in manual which makes it possible to separate validation of the simulated process from the simulated control system.

In the open loop validation the individual process inputs are evaluated as follows: fuel setpoints, feedwater setpoints, position of attemperator valves and turbine control valve.

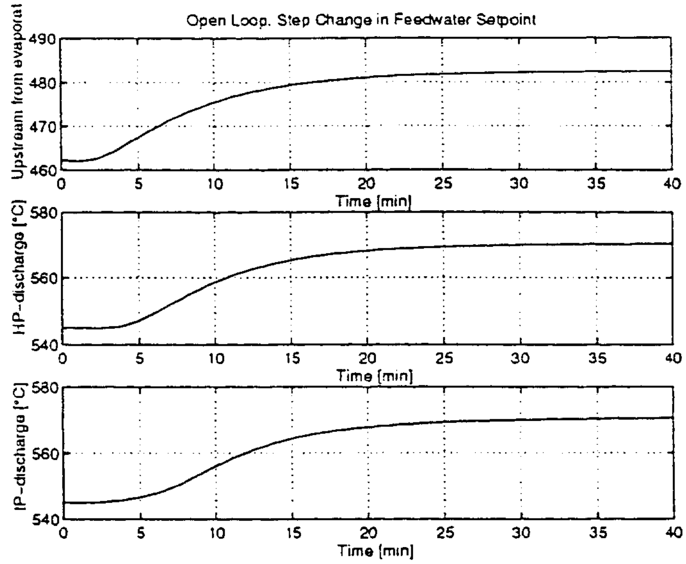

Figure 1. *Stepwise change in feedwater setpoint. Steam temperatures:*
A: Downstream from 1st attemperator.
B: HP-discharge.
C: IP-discharge.

Figure 1 above gives an example of how the steam temperatures increase up through the boiler when the feedwater flow is reduced, as insufficient amounts of feedwater are fed into the boiler compared to the stoked fuel. It is can be seen how the response increases with the amount of metal which the steam has to pass, as could be expected.

Similarly, attempts are made to validate all responses on the basis of physical parameters and mutual comparisons.

The conclusion of these trials is that the process part of the simulator qualitatively simulates the boiler process correctly and that the couplings found in a real-life boiler process are also present in the simulator. As regards quantity the responses seem to be realistic; however, they are very difficult to evaluate as it is not possible to perform similar tests in a real boiler.

3.3 Closed Loop Responses.

For validation of the implemented control system, a number of closed loop tests were performed which has provided information about how the boiler control system is adjusted to the dynamics of the boiler. This will reveal if the copy of the real-life boiler control system works satisfactorily in the simulator.

For these tests, changes in set points for the most important control outputs have been made individually for the following outputs: steam pressure, steam temperatures and produced power output.

Figure 2 top shows an example of a step response of the steam pressure before the turbine control valves. Figure 2 bottom shows the control signal.

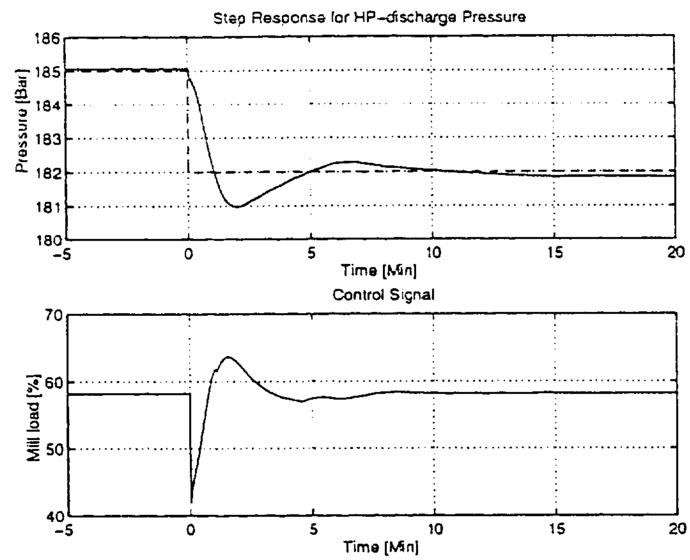

Figure 2. *Step response for steam pressure upstream from superheater 3, at 55% load, and the associated control signal.*

Similar tests have been made for the above-mentioned outputs at 100% load and 50% load.

All closed loop tests were successful in as much as they were evaluated by the operational staff at I/S Skærbækværket to genuinely simulate the responses of the real process. The fact that the model of the model of the boiler control system and the boiler process result in successful closed loop tests indicates that both models are of satisfactory quality.

3.4 Validation by Comparing with Acquired Data.

As a last validation responses from the actual process were compared with simulations. Three different tests were made:

1. Reference steps for steam temperature before attemperator 2.
2. Sequence of injection flow in attemperator 2.
3. Load change.

As an example the resulting response from the HP steam temperature for test 2 is shown in figure 3. As can be seen from the figure, the two responses correspond well with each other.

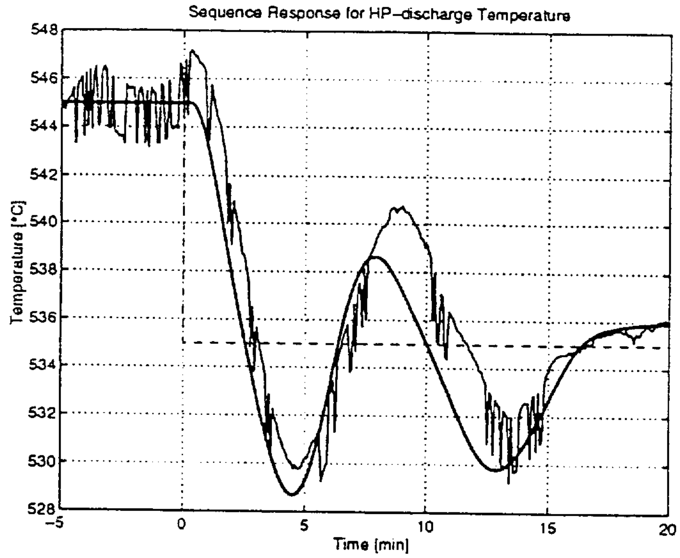

Figure 3. *Sequence response for HP-discharge temperature.*

The results of the three tests are satisfactory which serves to further substantiate the simulator's capacity to satisfactorily reflect the process dynamics.

4. Conclusion.

When summing up the results, it may be concluded that the simulator lives up to the requirement of qualitative presentation of the actual boiler process. It may further be concluded that on the basis of the comparisons made to the actual process, the simulator quantitatively represents the actual boiler process to a wide extent.