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Expert System for ABC Tuning of Once-Through Boiler

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Abstract:

A newly developed Expert System (ES) for the tuning of thermal power plant control equipment is described.

The system is furnished with the rules for controller tuning which were obtained by analysis and arranging the data and knowledge from the experts or tuning records.

Based on these rules, automatic tuning or setting of the control parameters is performed in real-time base.

The performance of the test equipment, a combi nation of ES and a boiler simulator , was examined in the automatic tuning test for steam pressure, steam temperature, and load controllers of a constant-pressure once-through boiler model.

It was confirmed from the test results that the system is quite promising for future application to actual plants, since the tuning results obtained by the proposed system were similar to those by tuning experts.

1. Introduction

A lot of improvement has been realized in the control equipment of thermal power plants.

Recently development of the equipment utilizing the know-hows of skillful plant engineers and tuning engineers has been one of the attractive subjects in this field.

To meet this requirement the authors carried out fundamental studies on the development of the equipment for automatic tuning which introduces AI technique and improves the control performance of the plant by providing proper tuning guidance of the control parameters.

Usually, the tuning of power plant control systems has been performed by experts with abundant experties.

Since the work requires a lot of skill, and the tuning results differ depending on the individuals, it is desirable to unify and refine the tuning work.

2. Configuration and function of the system

As shown in Fig.1, the newly developed system consists of an AI computer (Symbolics 3650), a distributed digital control system (DCS), an engineering work station (EWS) for manipulating DCS, and a computer for data display.

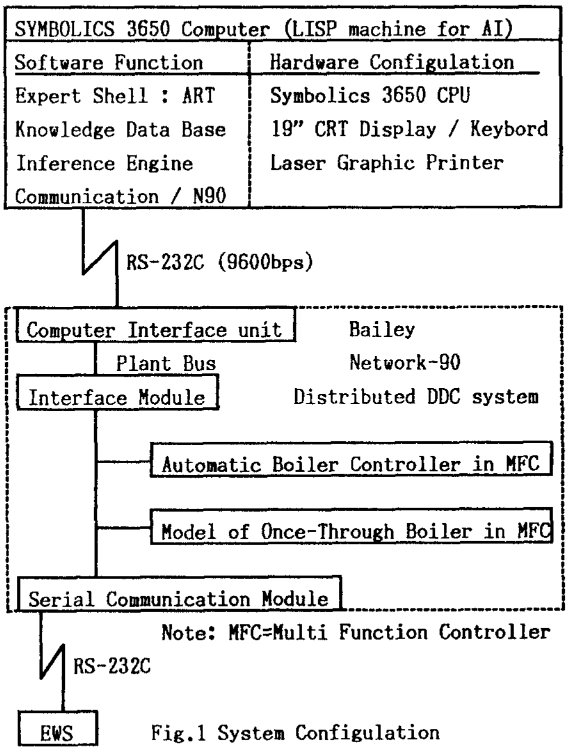


Fig.1 System Configulation

It carries out simulation studies by using a boiler and controller modeles set up within the DCS.

The AI computer examines the behavior of the boiler and, if necessary, improves control performance by revising control parameters.

The development of the Expert System was carried out by means of ART, a building tool of Expert System, and LISP language.

Considering future transfer of the progrum, we used production rules rather than the sophisticated built-in functions of ART, since the production rules are commonly used means for knowledge description.

3. Collection and Arrangement of Knowledge

The test equipment was developed aiming at the tuning of the turbine-boiler coordinated control for the constant-pressure one-through boiler.

Usually the experts perform the tuning to get better control performance by observing the overall plant dynamics.

It is commonly said that a specialist called Knowledge Engineer (KE) is required for the collection and arrangement of knowledge.

However,since the controller tuning technique belongs to quite a specialized field, we did not rely on the KE in our Expert System building.

Instead,the know-hows which had been acquired by experts themselves during their long-term experiences were analysed and arranged.

These knowledge were stored in the data base after having been analyzed and classified until they were suitable to be dealt with by the computer.

The item covered are as follows:

(1) Power plants in routine operation the methods and procedures of controller tuning
 - by interviewing tuning specialists.

(2) Knowledge on the adjustment of fuel correction signal which is used to lessen the influence of load changes on the main steam temperature
 - collected from the analysis of experts' tuning records.

(3) Knowledge to judge the "good or bad" of control performance, or to find what part of the control system should be re-adjusted when the control performance gets wrse
 - collected from the analysis of tuning records.

(4) Knowledge to maitain desirable dynamic balance of the water, fuel and plant load in the transient state
 - collected by the asnalysis of the technical materrials of Bailey Controls Company.

(5) Knowledge to revise control parameters, such as controller gains, etc, to meet the change in plant dynamics due to seasoning effect and regular inspection of auxiliary machines
 - collected from tuning records.

4. Fundamental Action of the Equipment

In the test equipment, the computer substitutes the tuning process of the skilled experts.

In other words, the computer judges control performance on the basis of the quantitized signal to time relation and makes on-line adjustment of the control parameters, if necessary.

The test equipment is composed to deal with all the processes necessary for controler tuning, such as data collection, performance judgement, and parameter setting, in the same manner as the skilled engineer.

For instance, for the plant under load changes the expert system carries out supervise and observation of the plant behavior.

When the load change is over,the system analys is the plant behavior by comparing it with past pe rformance data, and makes decision on the tuning.

Leaening function is also added which reflects past results on the tuning.

5. Optimal Tuning of Boiler Input Rate (BIR) Signal for Main Steam Temperature Control

** refer Fig.2 **

(1) Boiler Input Rate (BIR)

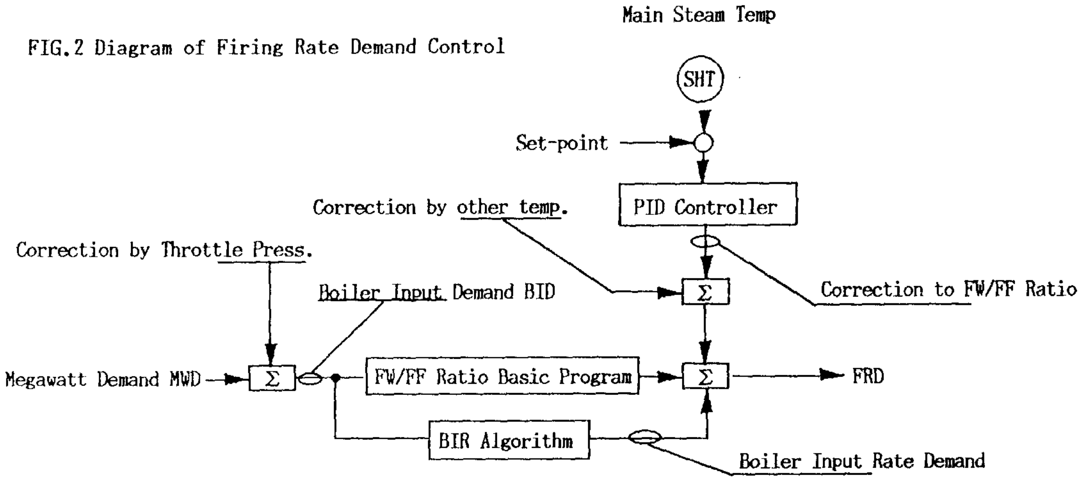
Basic configuration of the fuel-feedwater-ratio controller for main steam temperature control is composed from three elements:

fundamental program for fuel-feedwater ratio,
PID-feedback control and
boiler input rate (BIR) signal.

The boiler input rate signal is called BIR (boiler input rate) or over/under-firing.

The BIR signal is a predictive correction signal for a main steam temperatrure change at load

FIG.2 Diagram of Firing Rate Demand Control



change.

It acts as a feedforward signal to compensate for the shortage or abundance of boiler internal energy caused by load changes.

(2) Optimal Tuning

Fig. 3 shows the record of the BIR tuning procedure adjusted by a skilled engineer (expert).

The expert system described in this paper works to obtain the optimal values for the rate and the amount of the BIR signal.

When the deviation of the main steam temperature at load change is grater than +3℃ or less than -3℃ due to the plant dynamics change, the optimal values for the rateand the amount of the BIR signal are calculatedfrom the data for the integlal value of the mainsteam temperature deviation and the main steampressure deviation and also from automatically adjusted with the optimal values.

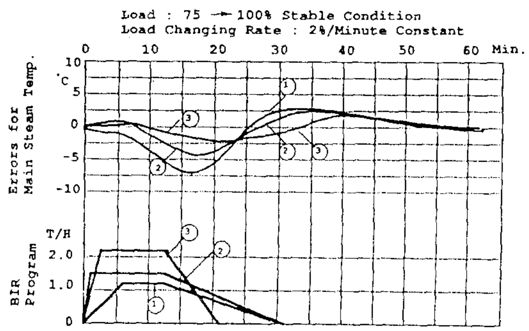


Fig.4 Main steam temp vs. BIR

(3) Automatic Tuning Tests

Fig.4 shows the tuning results at the load change from 375MW to 500MW.

From the figure, the improvement of the control perfprmance for the main steam temperature by the inferred BIR signals is cleary observed.

Although some trial-and-error procedure is observed in the figure, the inferred results finally converge near the optimal values at the fifth trial.

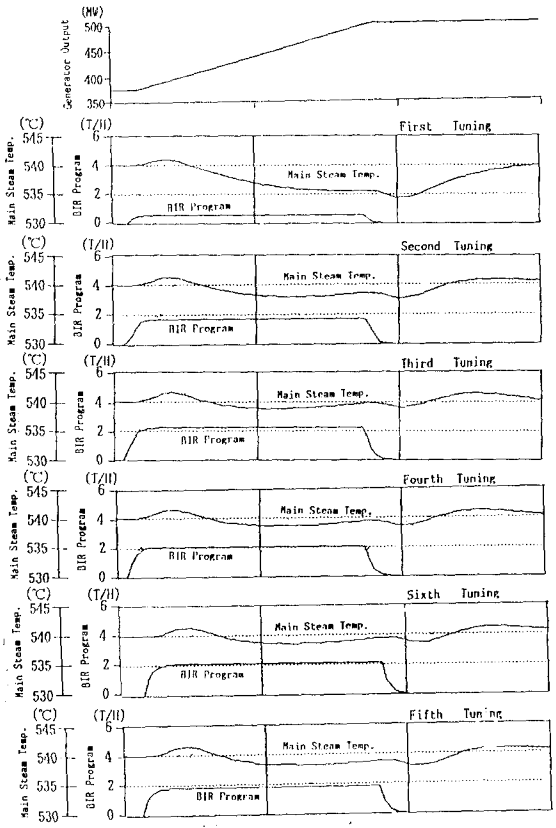


Fig.4 BIR Simulation Test Data

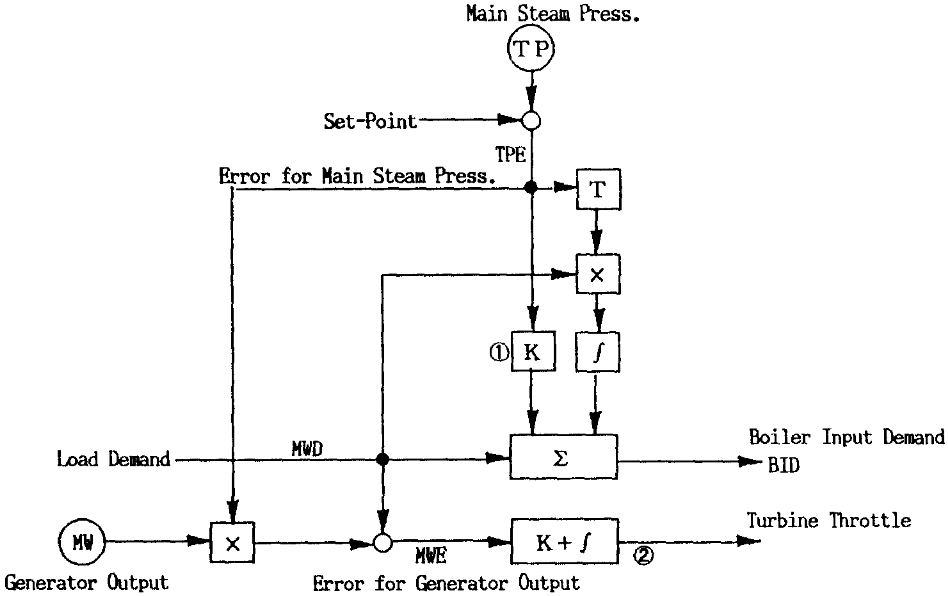


Fig.5 Diagram of Generator Output and Main Steam Press. Control Loop

6. Optimal Tuning of Generator Output and Main Steam Pressure Control Loops

** refer Fig.5 **

(1) Outline of the Control Loope

Fig.5 shows the configration of the controller of generator output and main steam pressure for a once-through boiler.

As shown in the figure, the generateor output controller mainly consists of the P(proportion-al) -I(integral) control elements which provides the feedback signal against load demand.

On the other hand, the maine steam pressure controller is bacically composed of P and I control elements which input main steam pressure deviations and output the BID (Boiler Input Demand)signal.

(2) Procedure for Optimal Tuning

Generator out put error (MWE), the discrepancy between load demand and actual power, and main steam pressure error (TPE), the deviation from the set-point, where investigated from the dynamic response record and the following behaviour for those signals at the constant load were identified.

A. Stepwise increase of the boiler input demand causes plus MWE and plus TPE.

B. Stepwise increase of the turbine-governer opening results in temporarily plus MWE and minus TPE, and finally minus TPE due to the heat energy balance of the plants. The turbine-governer opening affects MWE and TPE faster than boiler input demand change.

C. Due to the high sensitivity of the turbine-governer control loop at the transfer point of the turbine-throttle valve, the difficulty of the control gain adjustment was found.

Base on such observation and from a lot of calibration records for constant pressure once-through boilers, the follwing approch was used to achieve the optimal tuning of generator output and main steam pressure control loops.

*Minimizing the total value of mean MWE and mean TPE is taken for the optimal tuning of plant output power and main steam pressure at normal load change operation. In the tuning stage, the boiler master gain to compensate the pressure error at the boiler side, shown by ① in the Fig.5, is limited by deviations of feedwater flow and fuel flow, which are the boiler input demand at lower control loops.

*The tuning of the integral action for the turbine-governer controller is carried out reflecting the control behavior at the boiler side.

The quotient of maximum amplitude of MWE divided by maximum amplitude of TPE is used for the index of turbine-governer action.

The integral action of the controller, shown by ② in the Fig.5, is adjusted according to the index value.

(3) Automatic Tuning Test

Automatic tuning test was carried out with looser initial setting and the control performance was evaluated. Seven time load changes were required until the final tuning value was attained.

The comparison of the data at the load change between Fig.6, clearly tells the im-provement of the control performance by the developed expert system.

7. Conclusion

The simulation test carried out with the newly developed auto-tuning equipment revealed that the tuning results are almost the same as those by tuning experts, while the time required for the tuning are small enough.

This result encourages us to proceed further development and implementation of the system in actual plants. It should be emphasized that the examples of AI technique application to the tuning of large control systems seem to be scarce except the ones applied to some small system.

Reference

[1] S.Matsumura, Y.Shirasaka, and M.Suzuki : Expert System for ABC Tuning of Once-Through Boiler
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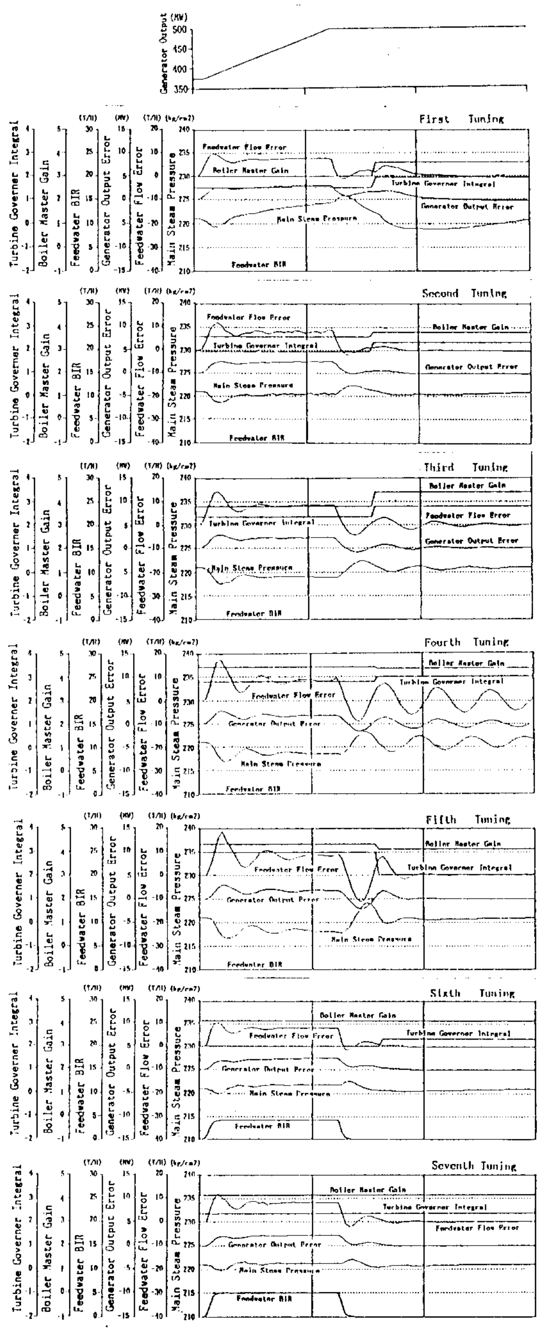

Fig.6 Test Results for Optimal Tuning of Generator and Main Steam Pressure Control Loop