EXPERIMENTAL MODELLING AND SIMULATION OF A 150 MW COAL POWER PLANT

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Abstract: This paper presents the reduced mathematical model for the power generation of a steam power plant. The dynamic model for operating conditions of the multivariable plant have been developed by application of parameter estimation methods. In this paper the mesaurement results and models describing dynamic behaviour of a 150 MW coal power plant are presented.

Keywords: Power plant, model reference, identification, modelling and simulation.

Introduction:

Identification of power plant dynamics can involve the use of physical (mec-hanistic) models or empirical (input- output) models. Both approaches have been used for identification of power plants. The choice of which approach to use may be determined by the intended application and by the extent of a prior knowledge about plant dynamics. A plant identification program generally may be divided into four phases, planning, testing, analysis and interpretation. The relative effort needed for each of these phases is different for physical model identification and for emprical model identification.

Planning for identification of physical models may include formulation of the model. The physical model is usually used to help assess the identifiability of parameters of interest. This is very important for tests that are used to determine safety-related or performance – related parameters. The model is also used to assist in designing the test (usually selecting the frequency range of interest). Thus, for identification of physical models, the plannig phase can be the most time consuming part of an identification program. In emprical model identification, test planning usually involves only designing the test, and prior experience or intuition are often used for this.

Testing may involve monitoring normal operating records or using specially designed input perturba-tions. Operating records are available with no disruption of normal power production, but it is often difficult to establish cause and effect relations because of multiple simultaneous inputs and low signal levels. Specially designed inputs may consist of a single, large perturbation or low-level periodic perturbation. The single large perturbation reveals nonlinear effects but involves a major disruption of power generation, and an inability to perform repeated tests usually prohibits averaging to obtain statistically meaningful data. Low –level periodic perturbations give only the linear response, but there is insignificant interference with normal operation and high-confidence results can be obtained

The investigated power plant consist of a block-combination of a steam and turbine-generator system which provides fast operation for the case of frequent starting up and shutting down phases as well as for large and sudden load changes. Such a plant represents from the control engineering point of view a time-variant and nonlinear multivariable process or multi-input/ multi- output (MIMO) system with strong interactions and hence is very difficult to control.

The dynamic behaviour of power plants heavily depends on inner and outer disturbances, setpoint point. This is especially the case for large coal fired power plants. The main input variables of a fossile power plant are the follow rates of fuel, feed water, injection water and air, while the main output variables are represented by the electrical power, steam entalpy after evaporator which in turn is a function of temparature and pressure of steam. In many cases it seems advantageous to consider not the total plant model, but to reduce it to a number of significant input and output variables for a special partial problem.

Whereas physical models based on a dynamic analysis using physical laws can hardly be evaluated for complex modern power plants, experimental system identification methods provide always possibilities for obtaining a mathematical model by evaluation of the input and output measurements. A 150 MW coal power plant was made experimental measurement and evaluated dynamical model by experimental system identification. All of them will be described in this paper.

Modelling of Power Plant

The investigated plant represents generator / steam turbine unit providing 159.8 MW electrical power due to a coal fired sulzer type boiler with live steam at 135 bar and 535 °C. Pulverized coal is fed 24 burners which are arranged 6 layers. İt is neccesay that air for the combustion is supplied by two ventilators.

The power plant consists of boiler, steam turbine and generator. The boiler can be modeled by a strongly coupled multivariable system. This makes it very interesting from a control engineering point of view. In the boiler, the chemical energy is converted to the thermal energy (steam). The dynamic behaviour of a boiler is heavily dependent on many different operating conditions, as e.g. ,

- the quality and thus calorific value of the fuel are changing, which results in changes in the enthalpy and pressure of the live steam as well as that of the generator power.
- the efficiency of the fuel feeder decreases in time.
- drying of heating surfaces, burners, feeders etc. cause changes in the system dynamic.
- changes in reference variables and load changes represent changes in the operating point.
- changes in the outlet temperature of the gas turbine in a combinational power station block which are due to climatic changes may strongly influence the boiler dynamics;

The dynamic and static properties of the system must be well known to design an efficient controller. On the other hand, to handle such a complexs system with several inputs and outputs is complicated. Therefore the most important input and output variables will be used for model building as shown figure 1. For the investigated power plant two input and two output variables are sufficient for describing the desired process behaviour.

As shown in fig. 1 the fuel feed and feedwater flow are chosen as input variables. The output variables are electrical power and enthalpy.

The choice of these variables may be justified as follows: The power plant operators in natural balanced pressure mode. By this operation the heat storage of the boiler cannot be used because the speed of changing power depends only on the steam generator. This means, the steam generation influences immediately the generated electrical power, which is important for the user.

The enthalpy of the steam at the outlet of the evaporator seems to be the best measure for steam quality, due to its fast reaction to heating disturbances further it is not affected by injection water.

After deciding the input and output variables, measurements were made in the power plant. Due to lack of physical properties the dynamic behaviour cannot be determined by theoretical calculations. Measurements were made such that the affect of each input on the electrical power and enthalpy was determined. When a step change is made for one input, the other is kept constant.

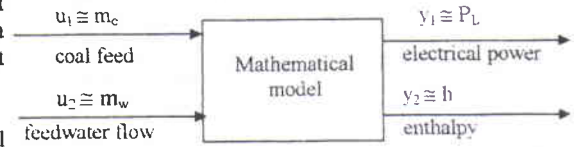
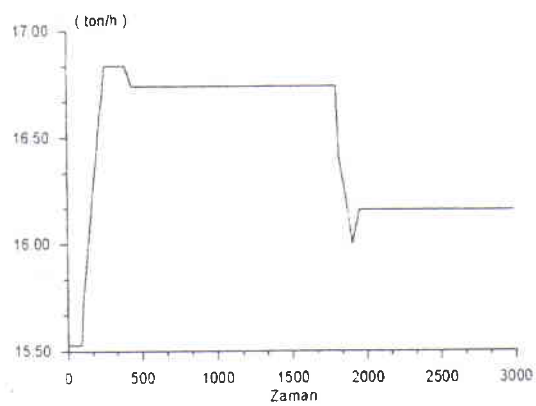


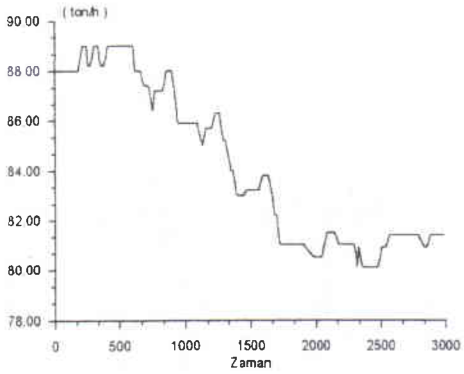
Figure 1. Mathematical model of power plant

Measurements of Power Plant

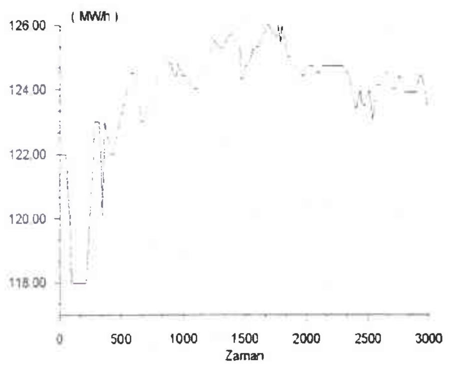
After deciding the input and output variables, mesaurements were made in the power plant. Due to lack of physical properties the dynamic behaviour cannot be determined by theoritical calculations. Measuruments were made such that the effect of each input on the electrical power and enthalpy was determined. All mesaurements are given in fig 2.



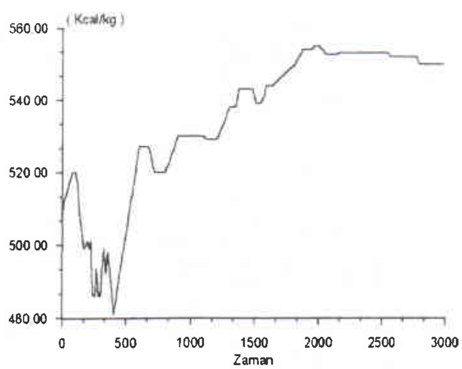
(a)



(b)



(c)



(d)

Figure 2. Measurements of :

(a) Coal feed
(b) Feedwater
(c) Electrical power
(d) Enthapy

The idetification of the MIMO system fig 1. had been performed by apply the IMIMO program package (in the CADACS) to obtained measurements. The identification program is based on a direct estimation of the parameters of discrete-time linear time-invariant MIMO system. The corresponding model output is described by a left- hand polynomial quotient

$$y_M(z) = A^{-1}(z).B(z).u(z) \qquad (1)$$

from equation 1 follows the linear system of equation

$$y_i(N) = M_i\,(N).p_i + \varepsilon_i(N) \qquad (2)$$

Where $y_i(N)$ is the signal vector of N sampled measurement values. M_i (N) is a NxN matrix of measurement data. p_i is the estimated parameter vector and $\varepsilon_i(N)$ is an error vector. which has to be minimized using the least square method.

As the result of this parameter estimation the parameters of the corresponding four impulse transfer function G_{ij} (fig 3) beetwen the input signals u_1 and u_2 and the output signal y_1 and y_2 have been obtained operating condition. These transfer function represent the mathematical model.

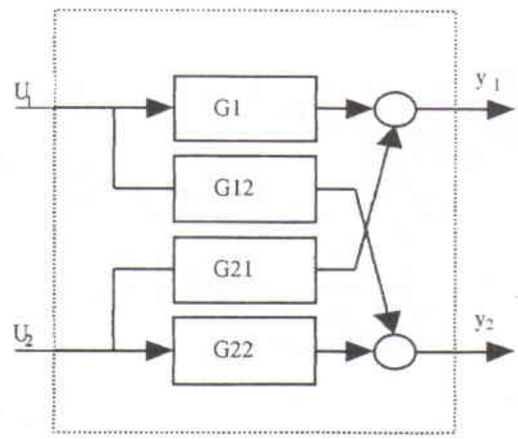


Figure 3. Transfer function of a coal power plant

In order to give a better view of the simulated four partial model is given in fig 4. All the partial models step response are given

Step responce of the dynamic model

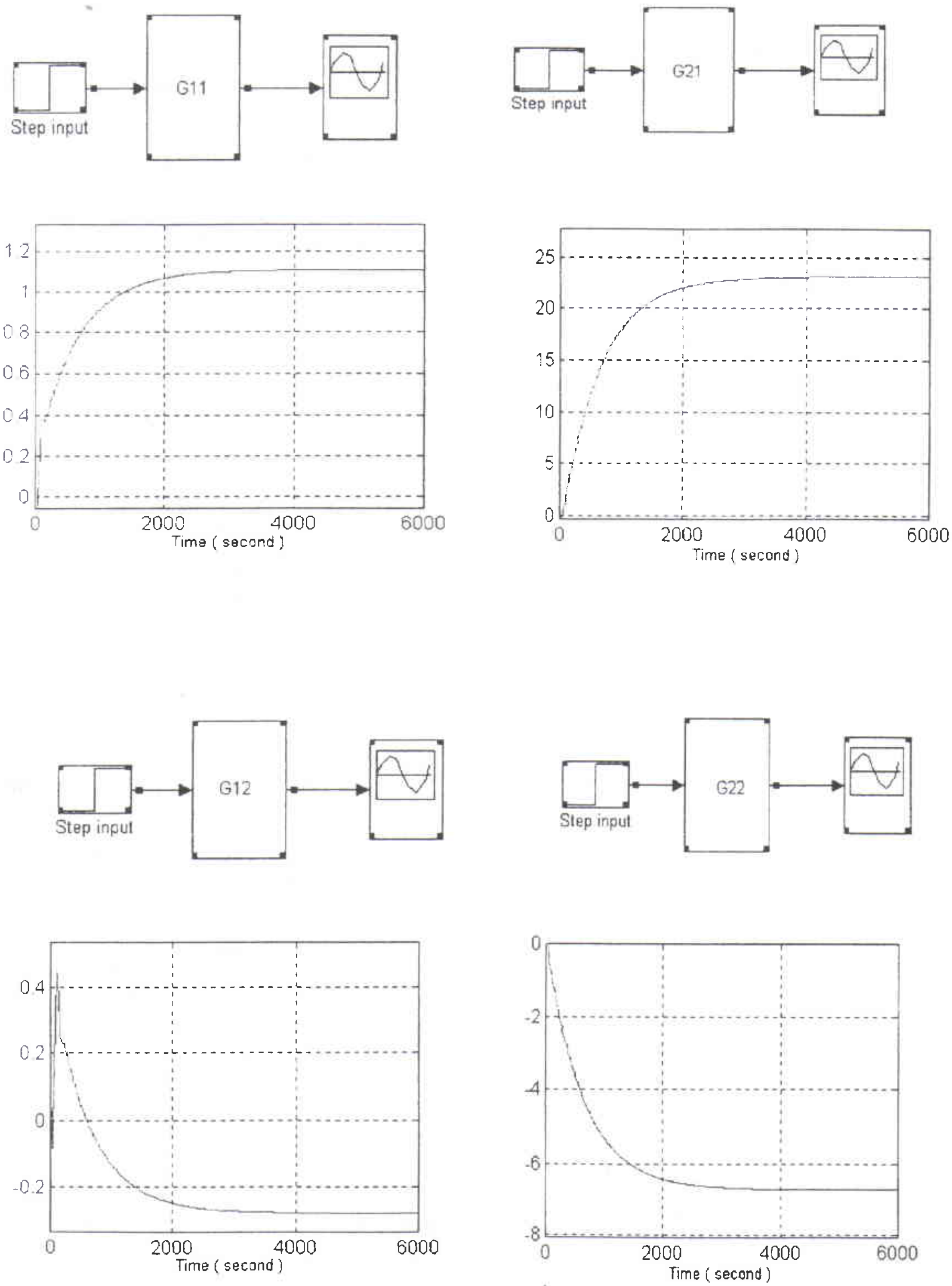


Figure 4. All the partial models step responce

Conclusion

In a modern 150 MW power plant, measurements were made to build a mathematical model which is intended to be used for advenced control algorithms, such as, fuzzy, neuro- fuuzy, adaptive –neuro – fuzzy... control. The measured variables had been recorded and applying paremeter estimation methods, a linear multi input, multi output model for the multivariable plant had been developed which fits with the measurement very weel. This model relates coal and feed water flow rate as input variables with the electrical power and enthalpy as output variables. From the simulation results it can be seen that the dynamic behaivour of the boiler is very strongly dependent on the operating point and conditions. This proves conclusively that for boiler control, modern control concepts (fuzzy, neuro , neuro-fuzzy) are necessary.

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