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MULTIVARIABLE WEIGHTED ADAPTIVE CONTROLLER DESIGN AND ITS APPLICATION

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Abstract This paper shows that using the multivariable controller reduces the magnitude of fluctuations of the control signals which result improved control of the steam generator outputs. Comparison of the performance of the multivariable weighted adaptive controller(MWAC) with the performance of the existing PI controller and the self-tuning controller/1/,when the system goes through a transient mode,shows that the outputs stay closer to their set points when they are controlled by the adaptive controller.

1. Introduction

This paper describes the design and application of MWAC to a power plant steam generator. The steam generator. The steam generator represents a nonlinear,time-varying multi input multi output system whose variables generally vary with the operating point. In practice conventional single loop PI controllers are used to control the system.
The performance of the conventional single loop PI controller is limited since they do not account for variations in the system parameters and periodic tuning is necessary. The performance of a self-tuning controller applied to a power plant steam generator was previously reported in /1/. The self-tuning controller restricts the sampling period to be larger than the largest delay between the inputs and outputs of the system, which is 10 seconds for the plant under study. The MWAC does not restrict the sampling period and therefore its application to the same system is considered in this paper.The system is a 500 MW coal fired plant. The system is briefly described in /1/,and a detailed description of the plant and the model is given in /2/. In this paper,the model of the power plant were used to evaluate the performance of the MWAC. Design and application of the MWAC requires the knowledge of the order of the autoregressive moving average (ARMA) model which approximates the behavior of the system at a constant load

level. Using the technique exlained in /1/,this information is obtained in next section of this paper. The interactor matrix of the transfer matrix of the system is also required for the MWAC. The interactor matrix was obtained from the identified ARMA model. In section 2 of this paper the design and application of the controller to the power plant is discussed. The adaptive controller is shown to effectively control the system.The estimator used in the adaptive controller is the recursive least squares estimator with a variable forgetting factor.

2. Problem formulation

The design of the MWAC assumes that the order of the linear model representing the process is known. The power plant,when operating at a constant load can be represented by a linear time invariant ARMA model. The ARMA model which approximates the relationship between the inputs and outputs at a constant load level is of the following form:

$$y(t)+\sum_{i=1}^{N} A_i y(t-i)=\sum_{i=0}^{N} B_{1-i}U(t-1-i) + D + e(t) \qquad (1)$$

where y(t) is the vector of outputs, U(t) is the vector of inputs, D is a constant,steady state output response for a zero input signal,and e(t) is the vector of innovations of the inouts which is independent of the past inputs and outputs. The sampling interval was chosen to be 10 seconds which is smaller than the largest time delay in the system which 20 seconds and between the spperheat steam spray valve actuator and the reheater outlet steam temperature. In this study,controlled outputs y(t),are the superheater outlet steam temperature(SHT),the superheater outlet pressure(SHP) and the reheater outlet steam temperature(RHT). The controller inputs,U(t) chosen are the steam generator master demand signals(MDS),the singal to the burner tilt servo actuator(BTS) and the signal to superheat steam spray valve actuator(SSS). The order,N, of the ARMA model was found to be equal to nine by the identification procedure in explained in /1/. The transfer matrix between the inputs and outputs was obtained from the identified ARMA model. The interactor matrix for this transfer matrix was determined by the procedure explained in /4/. The ARMA model identified in the previous paragraph was used to derive the MWAC for the system. The predictor for $y(t)=\phi(q)y(t)$ has the form given below/4/:

$$y(t)=\phi(q)y(t)=a(q^{-1})y(t)+b(q^{-1})U(t)+k \qquad (2)$$

where $\phi(q)$ is interactor matrix, $a(q^{-1})$, $b(q^{-1})$ are matrix polynomials of N and k is a real constant vector of dimension three. The criterion for calculating the control is the minimization of the performnace index:

$$J(t+d)=[\bar{y}(t)-\bar{y}^*(t)]^T Q[\bar{y}(t)-\bar{y}^*(t)] + U^T(t)RU(t) \qquad (3)$$

where $Q=Q^T$, $R=R^T$ are weighting matrices and $y(t)=\phi(q)y(t)$ is predictor as a known function of $\bar{y}(t+d)$.

The optimal control signal U(t) that minimizes this performance index is given by

$$U(t)=[b_o^T Qb_o+R]^{-1}b_o^T Q[\bar{y}^{*}(t)-a(q^{-1}) \cdot y(t)-(b(q^{-1})-b_o)U(t-1)] \quad (4)$$

The above controller, when the unknown parameters are replaced with their estimates, is called the MWAC. Notice that the MAC[+] can be obtained from (4) by setting Q=0 and R=0. The least square estimator with variable forgetting factor was used the control law given in (4). The performance of the adaptive controller is shown in Fig. 1 for the case where the system is moved from 60% load to 100 % at a rate of 10% per minute and Fig.2 for the case where the system is moved from 1oo% load to 60% load at a rate of 10% per minute. In both cases the ramp starts at T=1o seconds. Weighting matrices, Q and R, were found by trial and error, to be:

Q= diag 10,1,1 and R= 10,10,10 .

Fig.1 and 2 show that, during a transient mode, the outputs of the system deviate less from their set points if the adaptive controller is used. Comparison of the control signals calculated by the MWAC, the self-tuning and the PI controllers shows that during the transient period, MDS calculated by the MWAC is usually of lower magnitude compared with the magnitude of MDS calculated by the self-tuning controller. Notice that during the transient mode and under the MWAC, the superheater outlet steam temperature and the reheater outlet steam temperature stay closer to their set points than the behavior of these outputs under the PI controller. But the SHP does not show much improvement. The reason for this is that the adaptive controller extensively uses the burner tilt control signal(BTS) to control SHT and RHT, see Fig.1 and 2. The manipulation of the control signal BTS does not influence SHP as much as it influences SHT and RHT. The SHP is strongly influenced by the control signal MDS, but the outputs SHT and RHT are also strongly influenced by MDS. Therefore, any more in MDS to bring SHP closer to their set points to derive and therefore to increase The loss calculated by the performance index used to derive the control law. From the above argument, the SHT and RHT as well as the SHP can be closely controlled to their set points by using more MDS and less BTS control signals.

3. Conclusions

In this study, the MWAC was applied to a power plant steam generator to control outputs. The adaptive controller effectively controls the system at constant loads or under transient conditions. The problems with the adaptive controller is the excessive use of the control signal BTS for conteol of SHT and RHT. This results in good control of the outputs, SHT, SHP and RHT. In load ramp conditions, the outputs under the control of the adaptive controller show smaller deviations from their set points when compared with the outputs under the control of the PI controller. The MWAC is shown to

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[+] MAC= multivariable adaptive contr.

rove performance over that of elf-tuning controller applied to the same problem/1/.

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4. References

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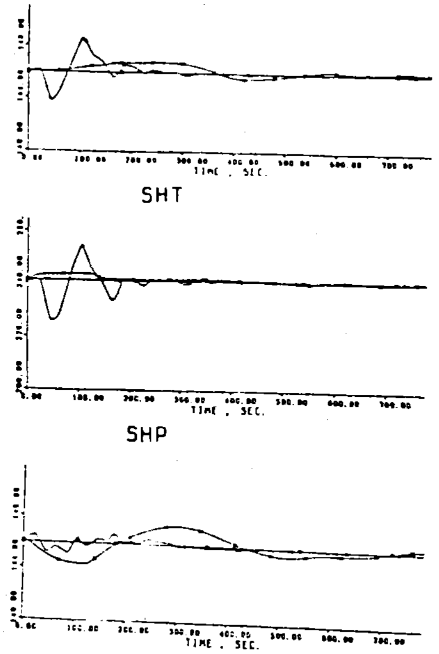

Fig.1 Response of the model and the controllers to a load ramp 100% to 60% load at a rate of 10% 10% per minute. x PI Contr., + Set Point and ▲ MWA Contr.

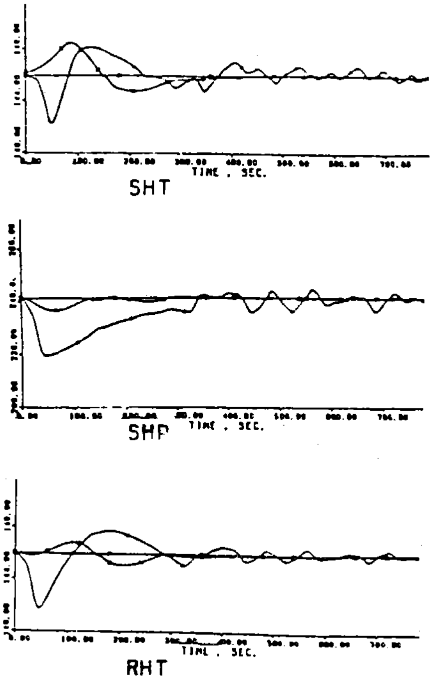

Fig. 2 Response of the model and the controllers to a load ramp from 60% to 100% load at a rate of 10% per minute.