MATHEMATICAL MODELLING AND OPTIMIZATION OF HEAT RATE OF A THERMAL POWER PLANT

by

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CERTIFICATE

This is to certify that the thesis entitled 'MATHEMATICAL MODELLING AND OPTIMIZATION OF HEAT RATE OF A THERMAL POWER PLANT' being submitted by Mr. Vinod Krishna to the Indian Institute of Technology, New Delhi for the award of the degree of Doctor of Philosophy in Mechanical Engineering is a record of the candidate's own bonafide research work.

Mr. Vinod Krishna has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge, has reached the requisite standard.

The results contained in this work have not been submitted, in part or in full to any other University or Institute for the award of any degree.

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ABSTRACT

The work reported in the thesis is concerned with modelling and optimization of heat rate of a thermal power plant. Realistic models for the three prime efficiency functions namely; Turbine Heat Rate, Boiler Efficiency and Plant Heat Rate are developed in terms of controllable operating parameters of the plant. Experimental investigations have been carried out on 60MW and 210MW units for validation of the models developed in the present work. These efficiency functions are then optimized with respect to operating parameters of the power cycle and the boiler using a parametric optimization technique.

The work of present investigation is presented under four major heads viz. a steady state model of heat rate, a transient model for turbine heat rate, experimental investigations and heat rate optimization.

The steady state model for turbine heat rate developed in the present work incorporates real time effect of auxiliary heat inputs and leak-offs to and from the turbine system. Penalty on heat rate due to deterioration in condenser back pressure has been modelled using a linear model which predicts effect of individual condenser performance factors on heat rate and the results of this model are comparable with heat balance model at near MCR conditions of the plant. The steady

state model also incorporates cross effects of boiler excess air on turbine heat rate through two-way coupling. Boiler efficiency and combustion losses have been modelled directly in terms of operating parameters like excess air, particle size and flue gas exit temperature. The effect of these boiler parameters on plant heat rate has been studied using the models for boiler efficiency and turbine heat rate, utilizing a concept of two-way coupling.

The present work also reports on the development of a model of turbine heat rate under load transients. In development of this model a lumped reheater time constant approach has been used for comprehending the transient response of various flows and unit outputs and hence the turbine heat rate. The basic reheater time constant has been determined using an in-situ experiment on a 210MW unit. In the present work a governor test rig was designed,developed and commissioned for determining the governor time constant. The lumped reheater time constant was determined from the knowledge of the governor time constant and the basic time constant of the reheater. The frequence response test of the governor model has further been used for the validation of the results of the transient study.

Experiments have been conducted on 60MW and 210MW boiler and turbine units for validation of various formulations developed in the present investigation:

These include experiments on 210MW and 60MW boilers for validation of statistical model for unburnt carbon loss developed in the present investigation. Turbine heat run tests were also carried out to compare the results of the present study with those obtained from ASME:PTC-6, acceptance test code.

Using the above validated formulations, the turbine heat rate is optimized subject to variations in cycle parameters viz. steam inlet conditions, extraction pressures and temperatures and condenser back pressure. Boiler efficiency is optimized subject to variation in excess air and particle size at various flue gas exit temperatures. Finally an integral objective function of plant heat rate is formulated in terms of operating terminal conditions. The plant heat rate is then optimized subject to variations in above turbine cycle and boiler parameters.

The results of the present study provide a realistic assessment of both the steady state and transient behaviour of turbine heat rate of a thermal power plant. The results of the optimization study further reveal that the extractions before reheater play a significant role in deciding the optimum values of plant heat rate.

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