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Dynamic Simulation Study of IGCC Power Plant: Impact of Coal Flow Change

Rasesh Kotdawala*, Thirugnanam C* and Nagaraj Kumar T V S*

Coal usage is becoming more widespread in India because coal reserves are much greater than oil and gas reserves combined together and the cost of coal is also very attractive. For reducing the carbon emissions when coal is utilised for power generation, Integrated Gasification Combined Cycle (IGCC) technology can be used, which uses a gasifier to turn solid or somewhat pulverised coal into gaseous form which is called as synthesis gas (syngas). IGCC has the potential to generate power with better efficiency or efficiency on par with the existing technologies. It is very important to understand operational and design aspects of the IGCC technology via dynamic simulation studies. The paper discusses the transient behavior of the commercial scale IGCC plant through dynamic simulation studies. The major components of IGGC plants-gasifier, Heat Recovery Boiler (HRB), syngas clean up system, gas turbine, HRSG and regenerative steam cycle were modeled in Modular Modelling System (MMS). The objective is to study the effect of coal flow to the gasifier on the transient behaviour of the plant parameters.

Keywords: *IGCC, HRB, HGCS, GT, HRSG, ST, MMS and Gasifier.*

1.0 INTRODUCTION

Due to stringent environment regulations for reduction of carbon content in the emissions, power generation technology which offers not only less CO_2 emissions but also either better efficiency or efficiency on par with the existing technologies is desirable. An integrated gasification combined cycle (IGCC) is a technology that turns coal into synthetic gas (syngas). It then removes impurities from the syngas before it is combusted and attempts to turn any pollutants into reusable by products. This results in lower emissions of sulphur dioxide, particulates and mercury. Excess heat from primary combustion is then passed to a steam cycle, similarly to a combined cycle gas turbine [1–3]. This then also results in improved efficiency compared to conventional power plant with pulverized coal. IGCC has been found promising technology having net efficiency up to 60%. Several efforts have been made to understand IGCC plant under various operating conditions via steady state as well as dynamic simulations [4–7]. In this study a plant model was developed using MMS simulation software tool for coal based Integrated Gasification Combined Cycle (IGCC) considering the major equipment viz. Gasifier, Heat Recovery Boiler (HRB), Hot Gas Cleanup System (HGCS), Gas Turbine (GT), Heat Recovery Steam Generator (HRSG), Steam Turbine (ST). It is felt necessary to observe the plant behaviour in dynamic situations to enable to understand how the parameters are getting controlled with prescribed design. If controllers are not able to control process parameters then new control logic need to be evolved. So a dynamic simulation study was conducted to study the plant behaviour when a disturbance like coal flow into the gasifier is changed.

The results so obtained are presented in the paper.

*Power Plant Dynamics and Simulators Group, BHEL Corp R&D, Hyderabad, Andhra Pradesh, India. E-mail: rkotdawala@bhelrnd.co.in.

2.0 SYSTEM CONSIDERED FOR MODEL

The schematic of the system considered for modelling is shown in Figure 1. The integrated IGCC model was configured with the components like Gasifier, HRB consisting of Economiser and Evaporator, HGCS consisting of Barrier Filter, Gas to Gas Heat Exchanger, Gas to Water Heat Exchanger, Absorber, Gas Turbine, HRSG consisting of High Pressure (HP) cycle and Low Pressure (LP) cycle. The HP cycle consists of Feed control valve, Economiser, Evaporator, Superheaters, Attemperator, vent and drain system. The LP cycle consists of Feed control valve, Economiser, Evaporator, Superheaters, Attemperator, vent and drain system. The necessary control system for level control in the evaporator and steam temperature control for superheater outlet steam was also considered for modeling with Actuators and Controllers, Steam Turbine, HP, LP Bypass System. For the Gasifier, the inputs such as Coal, Air and steam were represented with boundary module. For the HRB and HRSG, the feed water was represented as boundary with its flow, pressure and temperature as corresponding inputs. The required control devices such as control valves along with the controllers and actuators were represented with the available design data.

3.0 SIMULATION RESULTS

When plant is in operation at full load where all the major equipment Gasifier, Heat Recovery Boiler (HRB), Hot Gas Cleanup System (HGCS), Gas Turbine (GT), Heat Recovery

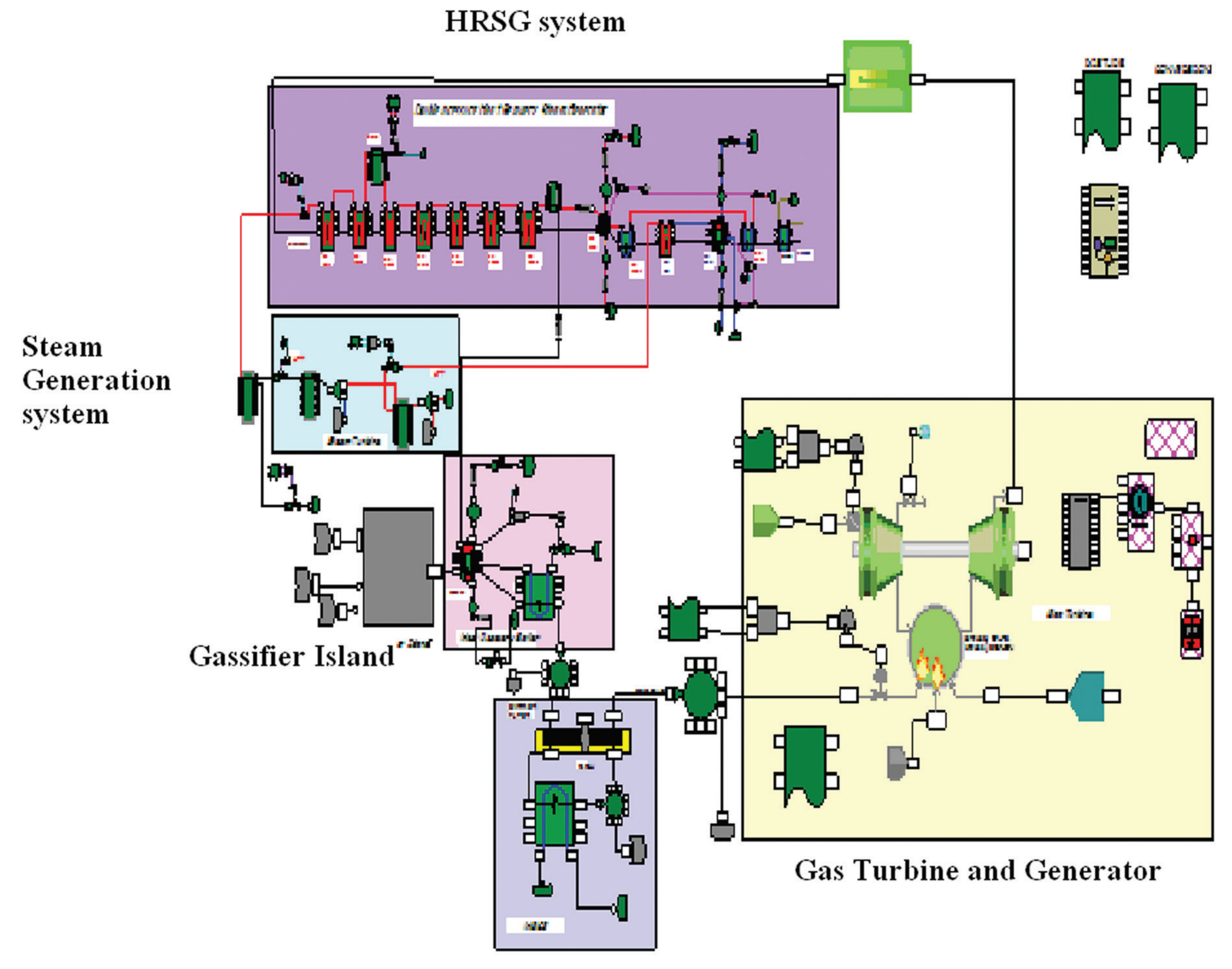

FIG. 1 SCHEMATICS OF IGCC PLANT.

Steam Generator (HRSG), Steam Turbine (ST) are interconnected. Steady state simulation and Dynamic simulation with an upset condition was carried out. A disturbance condition of reduction of coal flow into the gasifier was invoked when model was running at full load and then behaviors of different plant parameters were observed and they were plotted. The parameters in the plot are percentage based values. The 100 % is assigned to steady state value. Plots 2.1–2.6 shows variation of different parameters during the transient state. In Figure 2.1 we can observe that of coal flow was decreased to 90% from the rated (steady state) condition. On this disturbance gasifier outlet gas flow has changed only after 320 sec of invoking the disturbance and settled at lower value from the rated condition. This phenomenon can be observed in Figure 2.2. Figure 2.3 shows the changes in syngas composition after the disturbance has been introduced. The change of parameters in Heat recovery boiler, gas turbine and steam turbine sidecan be observed in Figures 2.4–2.6 respectively. On invoking the disturbance of coal change into the gasifier, syngas flow rate decreases and hence gas turbine power output decreases. This can be due to flow rate decreases and hence gas turbine power output decreases. This can be observed in Figure 2.5. The steam pressure at the HRB outlet decreases as shown in Figure 2.4. Figure 2.6 indicates that total steam turbine power (combined HP and LP).

4.0 CONCLUSION

The coal flow was reduced by 10% from the rated steady state values and the transient behavior of

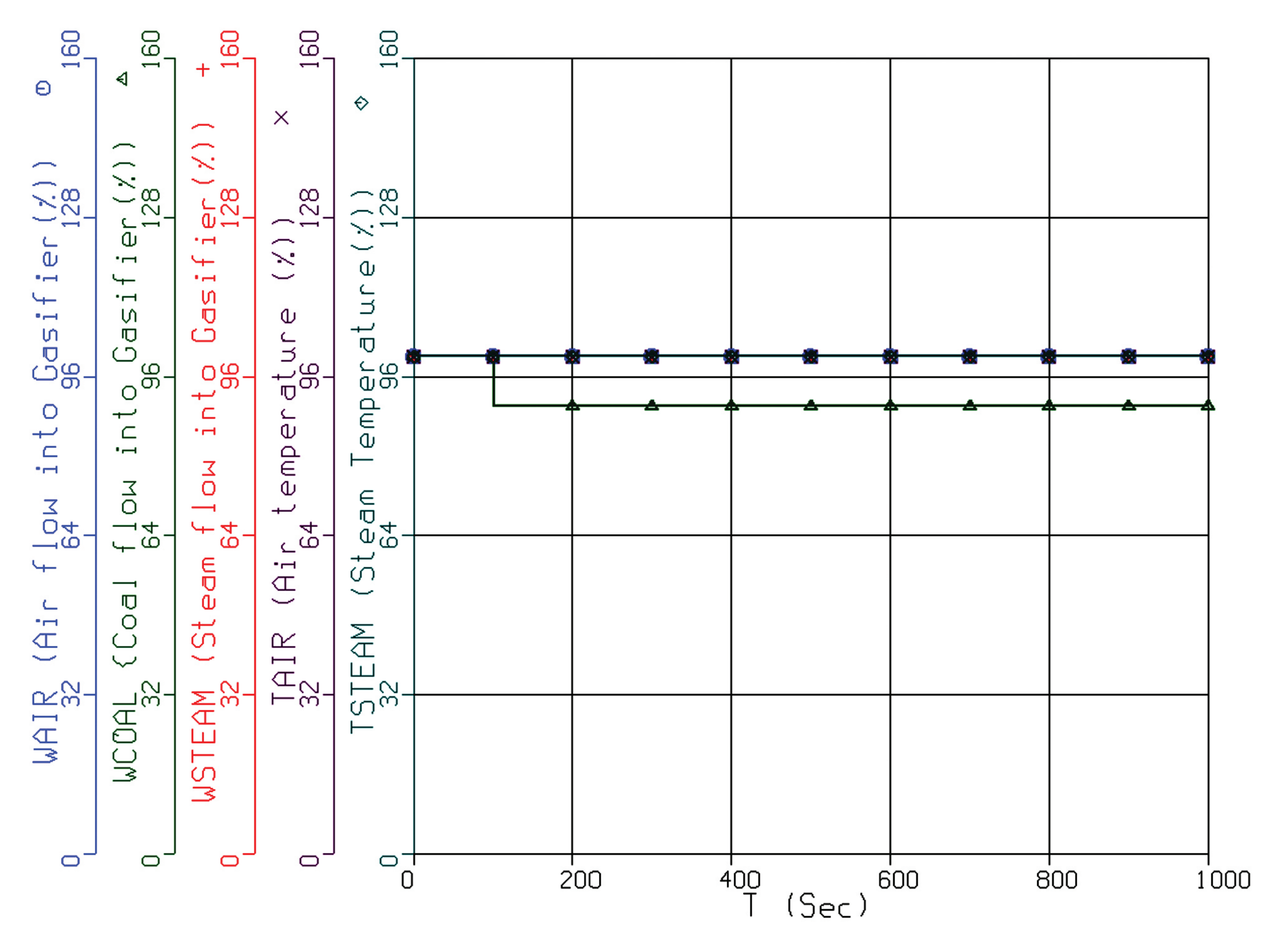

FIG. 2.1 GASIFIER INLET PARAMETERS.

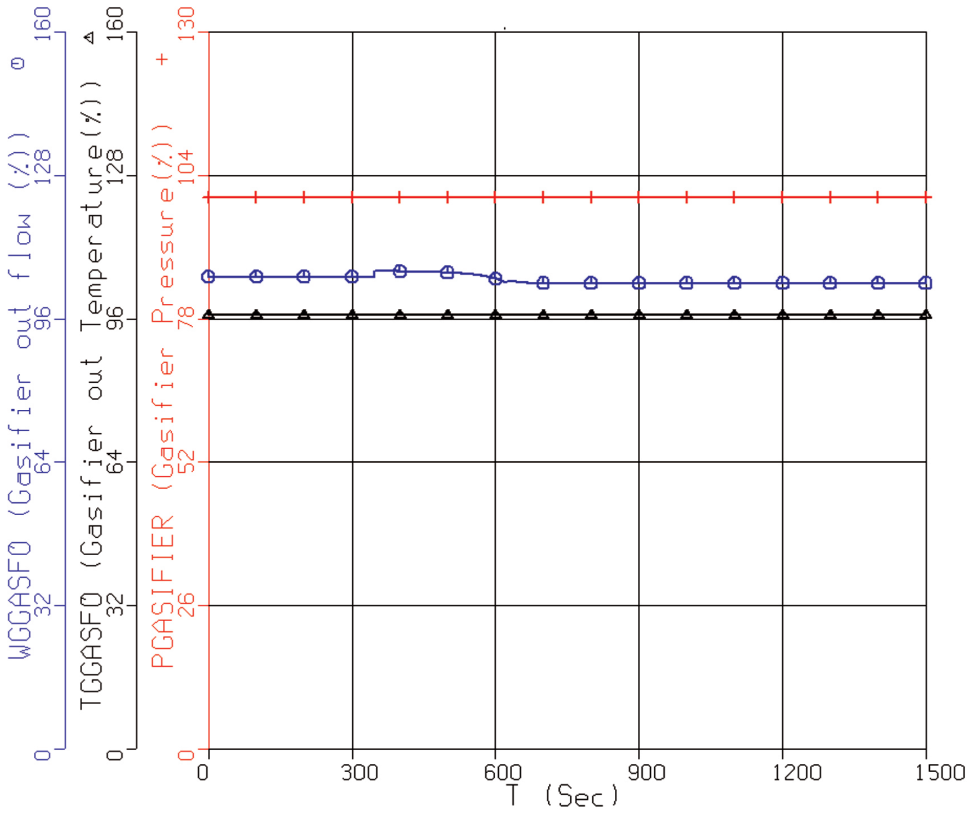

FIG. 2.2 GASIFIER OUTLET PARAMETERS.

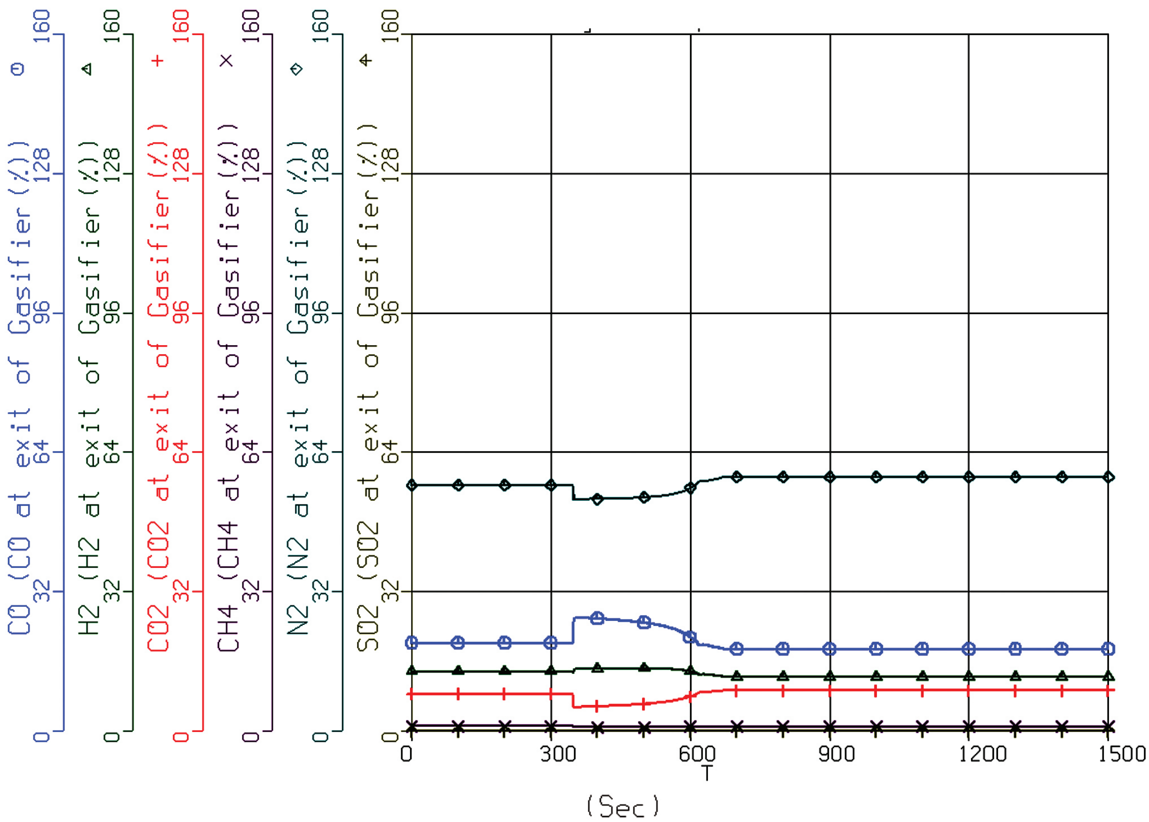

FIG. 2.3 SYNGAS COMPOSITION AT GASIFIER OUTLET.

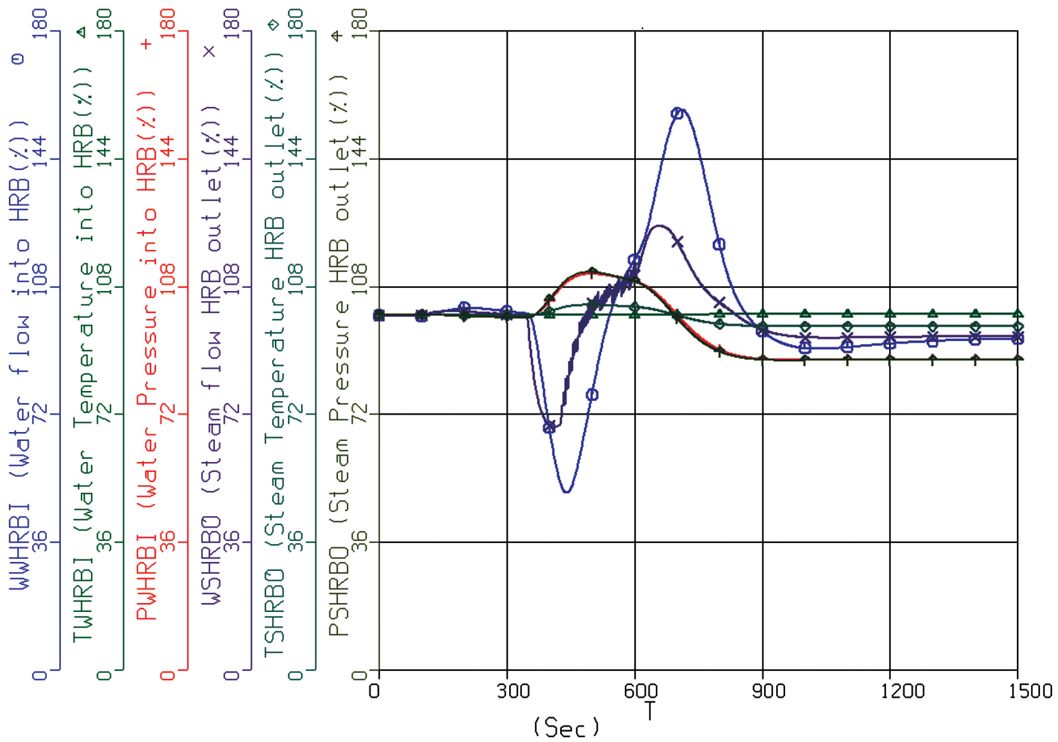

FIG. 2.4 HRB PARAMETERS.

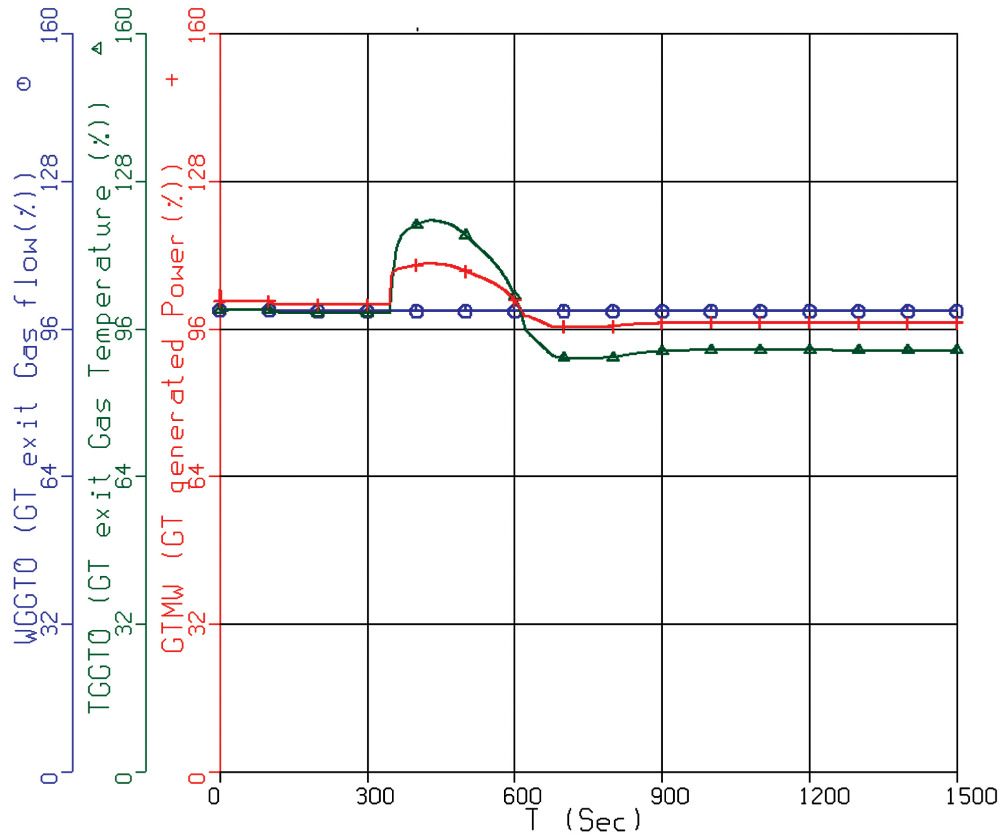

FIG. 2.5 GAS TURBINE PARAMETERS.

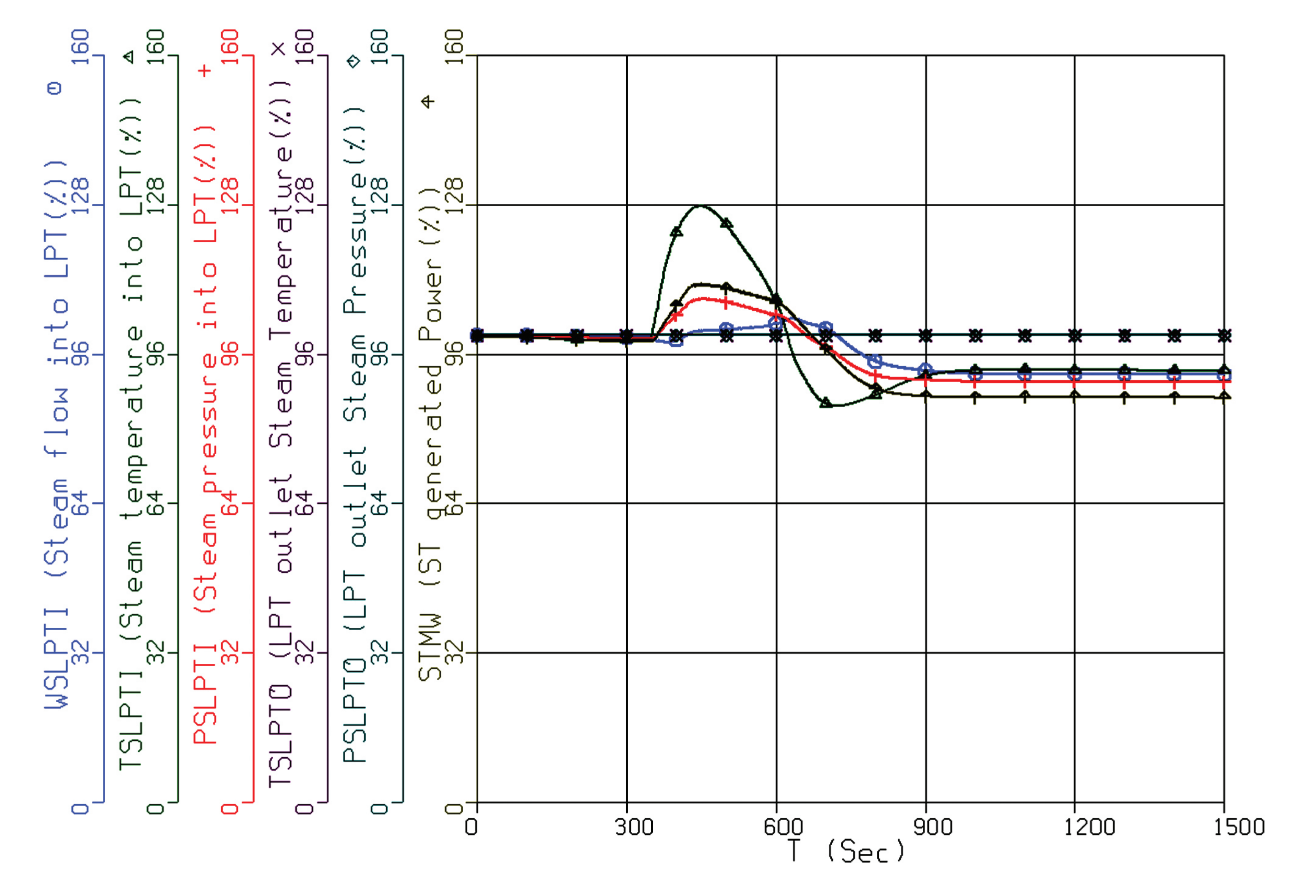

FIG. 2.6 STEAM TURBINE PARAMETERS.

the various plant parameters were observed. The impact on key plant parameters were as follows.

1. The reduction in coal flow by 10% in gasifier results in reduction in the syngas flow generation by 2% from initial steady state values.
2. HRB steam pressure increased by 15% initially and settles at 14% lower than initial steady state values.
3. The gas turbine power output increased by 20% initially and settled at 5% less than the initial steady state value.
4. The power output from steam turbine increases initially by 13% and settled at 9% lower than initial steady state value.

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