Cairo University

HRSG Drum Level Control in Combined Cycle Power Plant Using Fractional Order PI

BY

Eng. Yahia Mounir Mahmoud Hamdy Mostafa

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

IN

ELECTRICAL POWER AND MACHINES ENGINEERING

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List of Abbreviations

CCPP	Drum volume (m^3)
HRSG	Drum down comer volume (m^3)
NWL	Drum riser volume (m^3)
GT	Steam bubbles volume under water level (m^3)
RDLI	Water total volume (m^3)
DP	Average volume fraction
CPH	Steam Density
HP	High Pressure
LP	Low Pressure
PID	Proportional Integral Derivative Controller
IC	Integral Controller
DC	Derivative Controller
PSO	Particle Swarm Optimization

List of Symbols

A_d	Drum area (m^2)
A_{dc}	Down comer area (m^2)
Alpha(α_r)	Steam quality at the riser (%)
Beta (β)	Empirical coefficient
C_p	Metal specific heat capacity (Pascal.m^3/kg.K)
h_c	Condensation Enthalpy
h_f	Feedwater Enthalpy
h_s	Steam Enthalpy
h_w	Water Enthalpy
K	Friction coefficient in down comer
L	Drum Level
M_d	Drum mass (kg)
M_r	Riser mass (kg)
M_t	Total metal mass (kg)
P	Pressure (Pascal)
Q	Amount of heat flow rate added to the system
q_{dc}	Total mass flow rate into the risers
q_f	Feedwater flow rate (kg/s)
q_s	Steam flow rate (kg/s)
T_d	Residence time of steam in drum(s)
T_f	Feedwater Temperature
V_{0sd}	Steam bubbles volume in the hypothetical situation
V_d	Drum volume (m^3)
V_{dc}	Drum down comer volume (m^3)
V_r	Drum riser volume (m^3)

V_{sd}	Steam bubbles volume under water level (m^3)
V_t	$V_d + V_r + V_{dc}$; Total drum volume (m^3)
V_{wt}	Water total volume (m^3)
$\alpha\bar{v}$	Average volume fraction
ϱ_s	Steam Density
ϱ_w	Water Density

ABSTRACT

An important issue in the combined cycle power plant operation is the control of drum water level in the boiler. Under steady operating conditions, the drum level is usually stable. However, for power plants that are frequently changing load or subject to sudden disturbances, in such circumstances poor control can result in costly plant trip or even serious damage by boiling the drum or carrying water over into the steam turbine.

Accordingly, in the Thesis, the combined cycle power plant main components are introduced as well as the main control loops for the Heat Recovery Steam Generator (HRSG). The HRSG drum level control is studied. A MATLAB model is developed to simulate the heat flow rate for four gas turbines feeding four HRSG drums, and four HRSG drums steam flow feeding two steam turbines control valves through common steam header, as shown in Figure (4-1) and Figure (6-1). The steam turbine control valves are operated using Sliding Mode pressure control.

The drum level controller is a three Element drum level control with cascaded and feed-forward control. In the thesis the disturbance is represented as one gas turbine trip, and the drum level of the other three HRSGS is controlled using conventional PI controller. Then Fractional Order PI Controller is introduced to the closed loop drum level control.

It was proven that the fractional order controller utilized to achieve drum water level control of HRSG, gives better results: less settling time, undershoot and overshoot, under different disturbances compared with conventional PI controller.

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Summary

An important issue on the combined cycle power plant control is the control of drum water level in the boiler. Under steady operating conditions, the drum level control is usually stable. However, for power plants that are frequently changing load or subject to sudden disturbances, In such circumstances poor control can result in costly plant trip or even serious damage by boiling the drum or carrying water over into the steam turbine. Accordingly, In the Thesis, the combined cycled power plant main components are introduced as well as the main control loops for the Heat Recovery Steam Generator (HRSG). The Thesis will study the HRSG drum level control. The MATLAB model will simulate the heat flow rate for four gas turbines feeding four HRSGs drum and four HRSGs drum steam flow feeding two steam turbines control valves through common steam header. The steam turbine control valves are operated using Sliding Mode pressure control. The drum level controller is a three Element drum level control with cascaded and feedforward control; the thesis will illustrate the disturbance of one gas turbine trip in the drum level of the other three HRSGS using classical PI controller. Then fractional order PI Controller is introduced to the closed loop drum level control. It is proven that the fractional order controller utilized to achieve drum water level control of HRSG, achieves better results with less settling time, undershoot and overshoot under different disturbances compared with classical controller.