Chapter 3
Genetic-Algorithm-Based Performance Optimization for Non-Linear MIMO System

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ABSTRACT

Environmental regulations demand efficient and eco-friendly ways of power generation. Coal continues to play a vital role in power generation because of its availability in abundance. Power generation using coal leads to local pollution problems. Hence this conflicting situation demands a new technology - Integrated Gasification Combined Cycle (IGCC). Gasifier is one of the subsystems in IGCC. It is a multivariable system with four inputs and four outputs with higher degree of cross coupling between the input and output variables. ALSTOM – a multinational and Original Equipment Manufacturer (OEM) - developed a detailed nonlinear mathematical model, validated made this model available to the academic community and demanded different control strategies which will satisfy certain stringent performance criteria during specified disturbances. These demands of ALSTOM are well known as "ALSTOM Benchmark Challenges". The chapter is addressed to solve Alstom Benchmark Challenges using Proportional-Integral-Derivative-Filter (PIDF) controllers optimised by Genetic Algorithm.

INTRODUCTION

Electrical energy plays an important role in determining the quality of life in today's modern world. Coal, as a fuel, has been quite popular in power generation because of its availability in abundance. Unfortunately, it loses its ground due to the pollutants being produced and the stringent environmental regulations. The present day situation demands clean, climate-friendly and affordable energy. Although much efforts have been put on generating power through renewable sources such as solar energy, wind, geothermal, hydrogen and other green technologies, the contribution of energy from these sources continue to be minimal percentage compared to total requirement. At this juncture, the scientists have evolved new methods of combustion which will reduce or remove the unwanted pollutants from conventional

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thermal power generation with the central idea of using cheap and plentiful coal. As one of the solutions to this problem, Integrated Gasification Combined Cycle (IGCC) is emerging as an attractive means of power generation due to very high efficiency (10% more than conventional power generation) coupled with significantly lower pollutants.

In the case of IGCC technology, the solid coal is converted into a gaseous fuel (Gasification process) and burnt in the gas turbine of the most popular combined cycle power generation scheme. In spite of IGCC being high efficient and clean source of power, the developmental efforts are sporadic and operating plants are a little in number because of its high capital cost. The notable IGCC plants are given in Table 1. It is worthwhile to mention a few significant advantages associated with IGCC technology. They are as follows:

- Environmentally acceptable and much lower atmospheric pollutants.
- Lower water consumption required for cooling purposes (an important consideration in areas of limited water resources).
- Less coal is used per megawatt - an hour of output (due to higher efficiency).

Schemes of IGCC

Two typical schemes of IGCC are shown in Figure 1 and Figure 2.

In Figure 1, Gasifier coupled with Conventional Combined Cycle Power plant while in Figure 2, the bedmass from the gas turbine are sent to Circulating Fluidized Bed Combustor (CFBC) for heat extraction.It is to be noted that the Gasifier serves as a fuel source for the gas turbine. Coal, steam, and air react with the gasifier and fuel gas (also known as syngas) is produced. This syngas becomes the fuel for the gas turbine and the pressure and temperature of syngas are to be maintained at specified values at the inlet of the gas turbine. Also, the pressure and temperature are to be controlled with minimal overshoot and undershoot during disturbances like load changes and changes in the calorific value of

Table 1. Notable IGCC plants across the world

S. No.	Name of the Plant	Country	Year of Commencement	Year of Delivering Power	Power Capacity (MW)
1	Wabash River Coal gasification plant	United States	1993	1995	262
2	Tampa Electric	United States	1996	2001	250
3	William Alexander	Beggenum, Netherlands	1994	1998	253
4	ELCOGAS	Puertollano, Spain	1998	1998	330
5	DUKE energy Edwardsport	Indiana	2008	2013	618
6	NOKOSO	Japan	2001	2007	250
7	Tianjin	China	2012	2012	250