GA Based FGP to Solve BLP Model of EEPGD Problem

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INTRODUCTION

The demand of electric power has increased in alarming rate in recent years owing to rapid growth of human development index across the countries in modern world. It is to be mentioned here that the main supply source of electric energy is thermal power plant, where fossil-fuel used as main power generation resource, discharges emissions to earth's environment. The thermal power generation problems are actually optimization problems with multiplicity of objectives and various system constraints in the environment of generation of power. The two most important objectives associated with the problem are minimization of power generation cost and environmental emission.

The general mathematical programming (MP) model for optimal power generation decision was introduced by Dommel, & Tinney (1968). The deep study made in the field in the past century was surveyed by (Momoh, El-Hawary, & Adapa, 1999). The constructive optimization model for minimization of thermal power plant emissions was first studied by Gent, & Lament (1971).

Here, it is to be noted that the objectives of such a problem are incommensurable in nature and often conflict each other in optimizing them in actual practice. As such, a balanced decision could not be achieved there concerning simultaneous optimization of objectives. To overcome the difficulty, Goal Programming (GP) (Lin, 1980) approach as a robust and flexible tool for multiobjecive decision analysis was employed to economic-environmental power generation and dispatch (EEPGD) problem (Nanda, Kothari, & Lingamurthy, 1988) to obtain goal-oriented solution in a crisp environment.

However, in most of the practical decision situations, it is to be observed that decision parameters of problems with multiplicity of objectives are inexact in nature owing to inherent impressions in parameter themselves as well as imprecise in nature of human judgments of setting parameter values. To cope with the situation, Fuzzy programming (FP) approach (Zimmermann, 1987) based on Fuzzy Set Theory (Zadeh, 1965) to EEPGD problems have been discussed (Wang, & Singh, 2007) in the past. Further, to overcome the computational difficulty with nonlinear and competitive in nature of objectives, genetic algorithms (GAs) (Deb, 2002) based on natural selection and natural genetics have also been employed to EEPGD problems (Abido, 2003; Gong, Zhang, & Qi, 2010). But, deep study in this area is at an early stage.

Now, it is to be observed that the objectives of minimizing power generation cost and environmental emission highly conflict each other owing to current accelerating demand rate of electricity as well as increasing social pressure for controlling pollutions. As an essence, optimization of objectives in a hierarchical structure on the basis of needs of decision maker (DM) can be considered. As such, bilevel programming (BLP) (Pal, & Moitra, 2003) in hierarchical decision system might be an effective one for solving EEPGD problems. Although, the problem of balancing thermal power supply and market demand have

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been studied (Bertsimas, Litvinov, Sun, Zhao, & Zheng, 2013; Zhang, Zhang, Gao, & Lu, 2011; Pal, & Kumar, 2013) in the recent past, BLP approach to EEPGD problem by employing GA based Fuzzy Goal Programming (FGP) method (Pal, Moitra, & Maulik, 2003) is yet to appear in the literature.

In this chapter, the GA base FGP approach studied by Pal, & Chakraborti (2013) to solve quadratic BLP problem (QBLPP) is extended to solve the proposed problem. A case example of IEEE 6-Generator 30-Bus System is considered to illustrate the potential use of the approach.

BACKGROUND

The study on MP approaches for modeling thermal power plant problems was first surveyed by Happs (1977). Then, various optimization models were studied (Saadat, 1999) for controlling power plant operational system. During 1990s, emission control problem within power plant operational system were seriously considered and different strategic optimization models were developed by the active researchers (Hobbs, 1993; Srinivasan, & Tettamanzi, 1997) with due consideration of 1990's Clean Air Amendment (Congressional Amendment to the Constitution, H.R. 3030/S. 1490, 1990). The BLP problem (BLPP) formulations for optimizing two-objective thermal power generation problems have been discussed (Amjady, Keynia, & Zareipour, 2010; Almeida, & Senna, 2011) in the past. However, extensive study in the area of modeling BLPPs as well as multilevel programming problems (MLPPs) of EEPGD problems is yet to be widely circulated in the literature. Further, BLP modeling aspect of EEPGD problems in the framework of FGP is yet to appear in the literature.

Now, an EEPGD problem with the objectives of minimizing total fuel-cost and environmental emission is discussed in the following section.

DESCRIPTION OF EEPGD PROBLEM

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Let there be N generators, G_i, ($i= 1,2,\ldots,N$), and P_{gi} be the decision variable of generating power (in per unit [p.u]) from i-th generator, $i= 1, 2, \ldots, N$, in a power generation system. Then, let P_D be the total demand of thermal power (in p.u.) and P_L be the total transmission-loss (in p.u.) associated with the power supply system.

The objective functions and system constraints of the problem are discussed as follows.

Description of Objective Functions

Fuel-Cost Function

The fossil-fuel coal is very scarce and operational cost of a power plant involves huge budget. Therefore, minimization of total fuel-cost is highly desired by DM in a power generation decision situation.

The total fuel-cost ($/hr) function associated with generation of power from all generators of a system can be expressed as

$$Z_1 = \sum_{i=1}^{N} (a_i + b_i P_{gi} + c_i P_{gi}^2), \tag{1}$$

where a_i, b_i and c_i are the estimated cost-coefficients associated with generation of power from i- th generator.

Emission Function

In a thermal power plant operational system, various types of pollutions are discharged to earth's *Environment* due to burning of coal for generation of power.

The total emission (ton/hr) can be expressed as:

$$Z_2 = \sum_{i=1}^{N} 10^{-2}(\alpha_i + \beta_i P_{gi} + \gamma_i P_{gi}^2) + \zeta_i \exp(\lambda_i P_{gi}), \tag{2}$$

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