

# FGP Model for Emission–Economic Power Dispatch

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## INTRODUCTION

Electricity generation is the process of generating electric power from natural energy sources. In early 1830s, the famous British scientist Michael Faraday discovered the fundamental principles of electricity generation.

In most of the cases, electricity is generated from power plants by burning fossil-fuels: coal, oil and natural gas, which produce more pollutions than any other single industry and vastly contribute various impacts to the living environment. However, generation of electric power is increasing in an alarming rate to meet demand in the recent years by ignoring ill effects of pollution to the earth's environment. Therefore, proper planning for economic power generation as well as control of environmental pollution are inevitable ones in the context of generation of electricity from power plants.

The general mathematical programming (MP) model for optimal power generation was introduced by Dommel and Tinney (1968). A Comprehensive Survey on environmental power dispatch models developed from 1960s to 1970s was first surveyed by Happ (1977). Since an emission-economic power dispatch (EPPD) problem is multiobjective in nature, the goal programming (GP) approach (Ignizio, 1976), based on the satisficing philosophy (coined by Noble Laureate H. A. Simon) (Simon, 1945), as a robust tool for multiobjective decision analysis, has been successfully implemented to power generation problems (Nanda, Kothari, &

Lingamurthy, 1988) in the past. The field of chance constrained programming (CCP) (Charnes & Cooper, 1959) has been studied extensively and applied to various real-life problems (Keown & Taylor, 1980) including EPPD problem (Dhillon, Parti, & Kothari, 1993).

However, in most of the practical decision situations, it has been observed that model parameters associated with such problems are often imprecise in nature. The most prominent approach for decision analysis in an uncertain (not precise) environment is fuzzy programming (FP) (Tanaka, Okuda, & Asai, 1974), which is based on the theory of fuzzy sets (Zadeh, 1965).

Again, fuzzy goal programming (FGP) (Pal, Moitra, & Maulik, 2003) as an extension of conventional GP has also appeared as a robust tool to make flexible decision (Pal, Kumar, & Sen, 2009) in fuzzy environment. The FGP approach to EPPD problems has been studied (Pal, Chakraborti, & Biswas, 2011) in the recent past. But, the deep study on the potential use of such an approach is thin and yet to be widely circulated in the literature. Further, in most of the previous studies in this area, only two objectives, minimization of production cost and environmental-emission have been taken into account. But, consideration of other objectives inherent to an EPPD problem is rare in the literature.

In this chapter, minimization of transmission-loss as a prominent one along with the other two objectives stated previously is considered for modeling and solving EPPD problems. In the

model formulation, membership goals of the membership functions associated with fuzzily described objectives of the problem are defined by introducing highest membership value (unity) as aspiration level and introducing under- and over-deviational variables to each of the membership functions. Again, the inherent nonlinear objective functions and constraints are transformed into their linear forms to solve the problem by employing linear FGP methodology.

In the solution process, sensitivity analysis with variations of priority structure of model goals is performed and then the *Euclidean distance function* is used to identify the appropriate priority structure to achieving the most satisfactory decision for power generation in the decision situation.

The effectiveness of the proposed is illustrated by standard IEEE 30-bus 6-generator test system. To expound the potential use of the approach, the model solution is compared with the solutions obtained by using other approaches studied previously.

## BACKGROUND

The constructive optimization model of thermal power plant problem for emission minimization was proposed by Gent and Lament (1971). Thereafter, various emission control models were studied by the active researchers (Sullivan & Hackett, 1973; Cadogan & Eisenberg, 1976) in the past. The EEPD problem in the framework of mathematical programming (MP) was introduced by Zahavi and Eisenberg (1975). Then, different MP approaches to EEPD problems have been studied (Wang & Singh, 2007; Yokoyama, Bae, Morita, & Sasaki, 1988) and others in the past.

Crazy swarm optimized (Cohelo & Mariani, 2007) economic load dispatch for various types of cost functions has been investigated by Roy and Ghosal (2008). A fuzzy satisfaction decision approach was applied to solve the bi-objective EEPD problem regarding minimization of fuel cost and environmental impact of NO<sub>x</sub> emissions (Huang,

Yang, & Husng, 1997). The interactive fuzzy satisfying-based simulated annealing (Laarhoven & Aarts, 1988) technique for EEPD problem has been studied by Basu (2004).

During the last twenty years, emissions control problems were seriously considered and different multiobjective optimization methods for EEPD problems were developed (Abido, 2006; Gong, Zhang, & Qi, 2010; Wang & Singh, 2007) with the consideration of 1990's Clean Air Act Amendment (Congressional Amendment to the Constitution, H.R.3030/S.1490, 1990) and well documented in literature. However extensive study in this area is at an early stage.

Now, the general FGP problem formulation is presented in the following section.

## FGP PROBLEM FORMULATION

The generic form of a multiobjective FP problem can be presented as:

Find  $\mathbf{X}$  so as to:

$$\text{Satisfy: } F_k(\mathbf{X}) \begin{cases} \succ \\ \sim \\ \preceq \end{cases} b_k$$

subject to:

$$A\mathbf{X} \begin{pmatrix} \leq \\ = \\ \geq \end{pmatrix} c,$$

$$\mathbf{X}^{\min} \leq \mathbf{X} \leq \mathbf{X}^{\max},$$

$$\mathbf{X} \geq 0, \quad (1)$$

where  $\mathbf{X}$  is the vector of decision variables,  $A$  is a real matrix,  $c$  is a constant vector,  $b_k$  be the imprecisely defined aspiration level of  $k$ -th objective  $F_k(\mathbf{X})$ ,  $k = 1, 2, \dots, K$ , and  $\succ$  and  $\preceq$  indicate

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