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Electric Power Systems Research 56 (2000) 103–110

ELECTRIC POWER SYSTEMS RESEARCH

www.elsevier.com/locate/epsr

The surrogate worth trade-off approach for multiobjective thermal power dispatch problem

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Received 10 August 1999; received in revised form 5 January 2000; accepted 12 January 2000

Abstract

A multiobjective thermal power dispatch problem is solved that has non-commensurable objectives such as operating cost and minimal emissions. Typically, the objectives will conflict in that there is no feasible solution that minimizes them all simultaneously. In such a case, some form of conflict resolution must be adopted to arrive at a solution. In this study, ϵ-constraint method is used to generate non-inferior solutions along with the trade-off function between the conflicting objectives. To access the indifference band, interaction with the decision maker is obtained via surrogate worth trade-off (SWT) method and utility approach. The SWT functions are constructed in the functional space and then are transformed into the decision space. So, SWT functions relate the decision maker's preferences to non-inferior solutions. The validity and effectiveness of the method have been proved by analysing a six-generator system.

Keywords: Economic load dispatch; Multiobjective optimization; Decision making

1. Introduction

In the past, it was normal to formulate optimization models concerning minimizing (or maximizing) a single scalar valued objective function. The optimization models and the analysts' perception of a problem become more realistic if many objectives are considered. The power system can also operate most efficiently when optimized with respect to several objectives or criteria under many constraints [1]. Obviously, trade-offs among these objectives are impossible because of their different natures. So, it is stated that objectives are non-commensurable.

Generally, the multiobjective problems are solved to find non-inferior (pareto-optimal, non-dominated) solutions. Qualitatively, a non-inferior solution of a multiobjective problem is one where any improvement of one objective function can be achieved only at the expense of another. The most widely used methods of generating such non-inferior solutions are the ϵ-constraint and weighted minimax methods [2]. Methodologies for solving multiobjective problem differ in two major ways:

1. the procedure used to generate non-inferior solutions, and
2. the ways used to interact with the decision makers (DMs) and the type of information made available to the DM such as trade-offs.

In almost all decision making problems there are several criteria for judging the possible alternatives. The main concern of the decision maker is to fulfil the conflicting goals while satisfying the constraints of the system. Further, there are two approaches to solve such problems:

1. One assumes that there exists a utility function for the particular problem. Such function is used to obtain the best alternative.
2. The other makes no assumptions regarding the existence of utility function, but provides the DM with a set of simple but effective tools to obtain the best alternative. The SWT method provides the facility to interact with the DM.

Apart from heat, power utilities using fossil fuels as a primary energy source, produce particulates and gaseous pollutants. The particulates and the gaseous

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0378-7796/00/$ - see front matter
PII: S0378-7796(00)00092-4

pollutants such as carbon dioxide (CO_2), oxides of sulphur (SO_x) and oxides of nitrogen (NO_x) cause detrimental effects on human beings. Pollution control agencies restrict the amount of emissions of pollutants depending upon their relative harmfulness to human beings. Therefore, a priority structure can be formed for the multiobjective problem [3,4]. In this paper authors formulate classical economic dispatch as a multiobjective optimization problem. Four objectives are considered for minimization. Namely operating cost and impacts on the environment of NO_x, SO_2 and CO_2 emissions. The formulated multiobjective problem adopts a ϵ-constraint form, which allows explicit trade-offs between objective levels for each non-inferior solution [5]. The SWT method is used to find the best alternative among the non-inferior solutions.

2. Multiobjective problem formulation

In the multiobjective problem formulation, four important non-commensurable objectives in an electrical thermal power system are considered. These are economy and environmental impacts because of NO_x, SO_2 and CO_2.

2.1. Economy objective

The fuel cost of a thermal unit is regarded as an essential criterion for economic feasibility. The fuel cost curve is assumed to be approximated by a quadratic function of generator power output P_i as

$$F_1 = \sum_{i=1}^{N} (a_i P_i^2 + B_i P_i + c_i) \quad \$/\mathrm{h} \tag{1}$$

where a_i, b_i and c_i are cost coefficients and N is the number of generators.

2.2. Environmental objectives

The emission curves can be directly related to the cost curve through the emission rate per Mkcal, which is a constant factor for a given type of fuel. Therefore, the amount of NO_x emission is given as a quadratic function of generator output P_i.

$$F_2 = \sum_{i=1}^{N} (d_{1i} P_i^2 + e_{1i} P_i + f_{1i}) \quad \mathrm{kg/h} \tag{2}$$

where d_{1i}, e_{1i} and f_{1i} are NO_x emission coefficients [6].

Similarly, the amount of SO_2 emission is given as a quadratic function of generator output P_i.

$$F_3 = \sum_{i=1}^{N} (d_{2i} P_i^2 + e_{2i} P_i + f_{2i}) \quad \mathrm{kg/h} \tag{3}$$

where d_{2i}, e_{2i} and f_{2i} are SO_2 emission coefficients [6].

The amount of CO_2 emission is also represented as a quadratic function of generator output P_i.

$$F_4 = \sum_{i=1}^{N} (d_{3i} P_i^2 + e_{3i} P_i + f_{3i}) \quad \mathrm{kg/h} \tag{4}$$

where d_{3i}, e_{3i} and f_{3i} are CO_2 emission coefficients [10].

2.3. Constraints

To ensure a real power balance, an equality constraint is imposed:

$$\sum_{i=1}^{N} P_i - (P_D + P_L) = 0 \tag{5}$$

where P_D is the power demand.

P_L is the transmission losses, which are approximated in terms of B-coefficients as

$$P_L = \sum_{i=1}^{N} \sum_{i=1}^{N} P_i B_{ij} P_j \quad \mathrm{MW} \tag{6}$$

The inequality constraints imposed on generator output are

$$P_i^l \le P_i \le P_i^u; \quad i = 1,\dots, N \tag{7}$$

where P_i^l is the lower limit, and P_i^u is the upper limit of generator output.

Aggregating Eqs. (1)–(7), the multiobjective optimization problem is defined as

$$\text{minimize} \quad [F_1(P), F_2(P), F_3(P), F_4(P)]^T$$

$$\text{subject to} \quad \sum_{i=1}^{N} P_i - (P_D + P_L)$$

$$P_i^l \le P_i \le P_i^u; \qquad i = 1,\dots, N \tag{8}$$

where F_1(P), F_2(P), F_3(P) and F_4(P) are the objective functions to be minimized over the set of admissible decision vector P.

3. The ϵ-constraint method

To generate non-inferior solutions to the multiobjectve problem, the ϵ-constraint method is used [2,7]. For the ϵ-constraint method, one of the objective functions constitutes the primary objective function and all other objectives act as constraints. To be more specific, this procedure is implemented by replacing three objectives in the Eq. (8) with three constraints.

$$\text{minimize} \quad [F_1(P)]$$

$$\text{subject to} \quad F_j(P) \le \epsilon_j; \quad j = 2,\dots 4$$

$$\sum_{i=1}^{N} P_i - (P_D + P_L) = 0$$