

Review

A review on accuracy issues related to solving the non-convex economic dispatch problem



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ABSTRACT

This paper presents a review on common sources of inaccuracy related to solving the non-convex economic dispatch problem. The inaccuracies originate from using invalidated cost function, inaccurate calculation of transmission losses, violating equality or inequality constraints, comparing the performance of different algorithms based on different modeling equations, and comparing the results with different variants of benchmark systems. Numerous observations of unintended inaccuracies reported in previous published research work are used to illustrate the each argument; however, only few variants of benchmark test systems were sufficient to demonstrate and explain the existence of inaccuracies. The observed inaccuracies presented in this paper are explained, and the corresponding accurate results are presented to be used as standards in the future research.

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Contents

1. Introduction	325
2. Class1: inaccuracy due to using invalidated cost function	326
2.1. Class 1 inaccuracy associated with a 10-unit benchmark system	326
2.2. Class 1 inaccuracy associated with a 40-unit benchmark system	327
3. Class 2: inaccuracy originating from inaccurate calculation of the transmission losses	327
3.1. Class 2 inaccuracy associated with a 6-unit benchmark test system	328
3.2. Class 2 inaccuracy associated with a 15-unit benchmark test system	328
4. Class 3: inaccuracy based on comparing the results obtained from different variants of benchmark systems	329
4.1. 13-unit system	329
4.2. 15-unit system	329
5. Class 4: inaccuracy based on comparing the results obtained from different modeling equations	329
6. Class 5: inaccuracy due to violating equality or inequality constraints	330
7. Recommendations	330
8. Conclusions	331
References	331

1. Introduction

Negative environmental impact of fossil fuel resources and the reduction in the availability of these resources necessitate the best exploitation of them. Accurate and correct solution of the

economic load dispatch (ELD) problem entails the best exploitation of the available fossil fuel resources in power generation. The ELD problem concerns with dividing the total system load among the generating units in the most economic manner while satisfying the system constraints. Definition of the ELD problem and mathematical formulation of the problem can be found in Ref. [1]. Accurate formulation of the ELD problem entails the consideration of practical features such as the valve point effects, prohibited operating zones, ramp rate limits, and multiple fuel options. These practical

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features convert the feasible region in the solution space to be non-convex and non-smooth. Many techniques have been proposed for solving the non-convex ELD problem. Most of these techniques are metaheuristic techniques with stochastic nature, and many of them showed capability of hitting the global optimal solution of some benchmark non-convex economic dispatch problems. Each new research effort in the direction of solving the non-convex ELD problem aims at finding a technique with better capability in hitting the global optimal solution, and each new proposed technique has some advantages related to this capability and some limitations. Judging the efficacy of each technique and choosing one for further development necessitate reporting the results obtained by each proposed technique accurately. The authors observed that there are sources of inaccuracy in the area of solving the non-convex ELD problem which have been spread and repeated in several publications. Therefore, the authors are motivated to present this issue in more details. This paper is the first to review and tackle this important issue.

The aim of this paper is to draw the attention of researchers towards these inaccuracies through reviewing and presenting a sample of them, while explaining the sources of these inaccuracies. This will have a positive impact on enhancing the quality of future research in this field. The count of the published research articles in the field of solving the non-convex economic dispatch problem may exceed the order of several hundreds of articles, so it is not the aim of this paper to provide a complete survey of all the inaccuracies instances in the previous literature. In this situation, a sample of articles that contain unintentional inaccuracies is drawn from the whole population, which consists of all the published articles in this field. This sample is analyzed in order to draw an inferential picture about the causes and types of these inaccuracies. The sample reviewed and analyzed in this paper consists of fifty-two observations of inaccuracy occurrence in the previous literature. Only few variants of some benchmark test systems are considered in this paper. The sample of inaccuracies presented in this paper is divided into five classes according to their sources. These classes are as follows:

- Class 1: inaccuracy due to using invalidated cost function.
- Class 2: inaccuracy originating from inaccurate calculation of the transmission losses.
- Class 3: inaccuracy based on comparing the results obtained from different variants of benchmark systems.
- Class 4: inaccuracy based on comparing the results obtained from different modeling equations.
- Class 5: inaccuracy due to violating equality or inequality constraints.

Fig. 1 presents a pie chart which shows the percentage of each class occurrence based on all the observations presented in this paper. The paper is organized as follows. Sections 2–6 are utilized to present the five classes of inaccuracy. Each section discusses one class of inaccuracy. Section 7 introduces recommendations for the future research, and finally the conclusion is presented in Section 8.

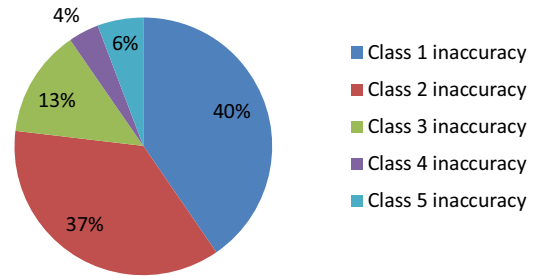


Fig. 1. Percentage of each class occurrence.

2. Class1: inaccuracy due to using invalidated cost function

A validated cost function has to be used in order to evaluate the cost value of a proposed solution. Fine eye inspection of the cost function and the associated data should be accompanied by validating these items using previously reported results in the literature. When a wrong cost function written using certain software is used to evaluate a proposed solution, it may provide much lower cost in a minimization problem than provided by previously proposed techniques, and hence the proposed algorithm will appear to be more efficient compared to previously proposed techniques. In this case, this superiority is not true, since it results from an unintentional inaccuracy in representing the cost function. Several inadvertent inaccuracies in modeling the cost function in software such as MATLAB are observed in previous literature. In the following subsections, examples of these inaccuracies associated with the 10-unit benchmark system and the 40-unit benchmark system are presented. The total number of observations related to this class of inaccuracy is twenty-one; nine related to the 10-unit benchmark system and twelve related to the 40-unit benchmark system.

2.1. Class 1 inaccuracy associated with a 10-unit benchmark system

The data of the 10-unit benchmark system considered in this paper are available in Ref. [1]. To model multiple fuel units with valve point effects, the following equation is used [2–14].

$$C_i(P_i) = \begin{cases} a_{i1} + b_{i1}P_i + c_{i1}P_i^2 + |e_{i1} \times \sin(f_{i1} \times (P_{i1}^{\min} - P_i))| & \text{for fuel type 1, if } P_{i1}^{\min} \leq P_i \leq P_{i1}^{\max} \\ a_{i2} + b_{i2}P_i + c_{i2}P_i^2 + |e_{i2} \times \sin(f_{i2} \times (P_{i2}^{\min} - P_i))| & \text{for fuel type 2, if } P_{i2}^{\min} < P_i \leq P_{i2}^{\max} \\ \vdots \\ a_{ik} + b_{ik}P_i + c_{ik}P_i^2 + |e_{ik} \times \sin(f_{ik} \times (P_{ik}^{\min} - P_i))| & \text{for fuel type } k, \text{ if } P_{ik}^{\min} < P_i \leq P_{ik}^{\max} \end{cases} \quad (1)$$

where $C_i(P_i)$ is the cost function for unit i , P_i is the power output of unit i , k is the total number of fuel types for unit i , a_{ik} , b_{ik} , c_{ik} , e_{ik} , and f_{ik} are the cost coefficients of unit i which uses fuel type k . $P_{ik}^{\min}$ is the minimum output of unit i using fuel k . $P_{ik}^{\max}$ is the maximum output of unit i using fuel k . A MATLAB function has been written which uses Eq. (1) and data presented in Ref. [1] to evaluate the cost value of previously presented solutions in the literature. This cost function written in MATLAB has been validated through evaluating the cost of four solutions presented previously in the literature. The results of this validation process are listed in Table 1, where the reported cost refers to the cost reported in the previous literature. The algorithms in Table 1 are a novel hybrid optimizer (DPD) [2], shuffled differential evolution (SDE) [3], a variant of Colonial Competitive Differential Evolution (CCEDE) [4], and Biogeography-Based Optimization (BBO) [5].

The same validated cost function has been used to correct the inaccuracies listed in Table 2. In Table 2, reported cost refers to the cost reported in the previous literature, and the actual cost refers to the cost calculated by the authors using the validated cost function.

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