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Investigation of non–conventional methods for combined economic emission dispatch problem

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Abstract. This paper investigates various non-conventional methods for optimal solution for Combined Economic Emission Dispatch (CEED). CEED can schedule operation of the generators by considering fuel cost, emission level, satisfying load demand and operational constraints so that optimal results are obtained. In this article, the CEED problem is formulated as a multi–objective problem by considering the fuel cost and emission objectives of generating units.

1. Introduction

Fossil-fueled power plants have become a reliable basis for electricity generations in the world. However, with the increasing global awareness of the emission rise in the electricity industry hence researchers proposes to reduce emissions from thermal plants [1]. Furthermore, the price of fossil fuels are increasing and the depleting fossil fuels in nature is very limited [2], Therefore, efficient, low-cost and reliable operation of the electricity generation resources to supply the demand for the system is needed to ensure economic plant dispatching [3]. Some actions are needed to overcome the problem of fuel prices and the increase of emissions from thermal power plants.

Several strategies to reduce emissions have been proposed and studied. Such as replacing obsolete generator components, replacing fossil fuels that have low emissions and installing pollutant filter equipment [4] and installation of small renewable energy based power plants[5,6]. However, these options resulted in several considerations of very large costs, for the long-term option. Furthermore, the settlement only by considering the impact of reducing emission values but not considering fuel costs, only making operational costs larger [7]. Thus the electric power industry has a major problem in the use of fossil fuels such as finding the optimal solution to minimize fuel costs as well as emissions of harmful gases simultaneously. Optimization of fuel costs for each generating unit is called economic dispatch. Nonetheles, the impact of the fossil fuels in each generating unit resulting in the emergence of several particulates to suppress the development of harmful particulates and gases, therefore emission dispatch is needed. Unfortunately, both of these goals are conflicting and difficult to be optimized simultaneously, giving rise to a multi-objective complex solution [8] known as a combined emission economic problem (CEED), where both objectives can be optimized simultaneously.

Conventional and non-conventional methods have been applied in CEED over the past few decades. Conventional methods are based on several complex mathematical formulations such as, Newton - Raphson [9], Lagrange lamda iteration [10], lamda iteration [6,7] and relaxation Lagrange [8,9]. Conventional methods have several advantages and disadvantages such as computationally some methods have proven to have fast convergence [15], proven to be mathematically optimality values [16], while the disadvantages are that some methods cannot be applied into multi-objections. Whereas other methods such as the Artificial Neural Network [17], Particle Swarm Optimization [18], Differential Evolution [19], Ant Colony Optimization [20], Artificial Bee Colony [21], Gravitational Search Algorithm [22], Flower Pollination Algorithm [23], Cuckoo Search Algorithm [24], Moth Search Algorithm [25], Artficial Imune System [26] and Genetic Algorithm [27] are categorized into non-conventional methods. Many non-conventional methods have been developed in recent years because these methods can solve nonlinear, nonconvex and multi-object problems.

The completion of CEED using non-conventional methods based on the nature of the major review of this paper is found in the CEED study. There are aspects of CEED modeling that will be explained in this article, where research will benefit more economical and environmentally to implement the power generation system to be greener. Finally, this study shows that the use of nature-inspired metaheuristic techniques performs better than other heuristic and classical techniques for solving CEED problems.

2. Combined Economic Emission Dispatch

The main objective of CEED is to determine the best electricity procurement schedule issued and generation emissions, depending on demand and operational controls.

2.1. *Minimization of fuel cost*

Minimization of total fuel cost as the sum of a quadratic function. This function is described as follow:

$$F(P_{Gi}) = \sum_{i=1}^{NG} [a_i + b_i P_{Gi} + c_i {P_{Gi}}^2] \tag{1}$$

Where a_i, b_i, c_i are the fossil – fuel cost coefficients of each generator, P_{Gi} is the output of i^{th} generator, NG is the total number of allocated generators in the system.

2.2. *Minimization of emissions*

Minimization of total emissions as the sum of a quadratic function. This function is described as follow:

$$E(P_{Gi}) = \sum_{i=1}^{NG} [\alpha_i + \beta_i P_{Gi} + \gamma_i {P_{Gi}}^2] \tag{2}$$

Where α_i, β_i, γ_i are the fossil – emission coefficients each of generator, P_{Gi} is the output of i^{th} generator, NG is the total number of allocated generators in the system.

2.3. *Constraints*

The minimization process has several challenges, such as equality and inequality. The two constraints must be completed in this process, Equality constraints are usually power balance, the balance between the total powers produced must supply the total power demand plus the total power losses in the network. In addition, the inequality limit is called the generation capacity constraint, where the generating capacity of the generator is limited by its minimum and maximum power limits [28]. The combined economic emission dispatch is subjected to the constraint:

Power balance equality constraint:

$$\sum_{i=1}^{NG} P_{Gi} = P_D + P_L \tag{3}$$

Where P_D represents system load demand and P_L denotes the transmission loss. P_L is obtained using a B – matrix coefficient expressed as:

$$\sum_{i=1}^{N}\sum_{j=1}^{N} P_{Gi}\, B_{ij}\, P_{Gj} \tag{4}$$

Generator capacity contraint:

$$P_{Gi}^{min} < P_{GI} < P_{Gi}^{max} \tag{5}$$

2.4. *CEED Formulations*

Combined Economic Emission Dispatch can be completed by combining both economic dispatch functions and emission dispatch functions using bi-objective. The CEED problem single form objective is formulated as follows:

$$min\, F_{CEED} = F + hE \tag{6}$$

$$\min F_{CEED} = \left[\sum_{i=1}^{NG} F_i\,(P_{Gi}) + h\sum_{i=1}^{NG} E_i(P_{Gi})\right] \tag{7}$$

$$h_i = \frac{F(P_{Gi}^{max})}{E(P_{Gi}^{max})} \tag{8}$$

When h is the penalty factor.

3. Metaheuristic Methods

The success of getting the best solution, the speed of convergence and strong computing performance are some of the advantages of the metaheuristic methods. Some metaheuristic methods or commonly called non-conventional methods are explained briefly below.

3.1. *Differential Evolution (DE)*

In 1955, Storn and Prince added Differential Evolution (DE) to an evolutionary algorithm or metaheuristic algorithm [29]. DE does not have derivative functions of objective functions in the classical method and DE is used for multi-dimensional and multi-objective functions. Optimization problems that have objective functions such as stochastic function, are not continuous and change with time can be solved using DE. Agent is a candidate solution in DE. Agents will be moved into the solution room for the placement of existing agents from participation. If the agent's new position is approved as the position of his parents, then the position is accepted and becomes part of the participation and if not then the position is rejected. This process continues to be repeated until the best solution is found. The search space is explored by randomly selecting initial candidate solutions and using mutation operators, crossover and selection.

3.2. *Particle Swarm Optimization (PSO)*

The social behavior of animals and organisms such as fish schooling, herd of elephant and bird flocking were inspirations for PSO which was developed by Kennedy and Eberhart [30]. In this method, each individual is considered a particle and each particle represents a candidate solution. This method is also population based method. A group of individuals (particles) fly through the solution space. The position of the particles is governed by the best position encountered by the particle itself or its neighbour.

PSO algorithm has been developed in recent years. Classical PSO can complete non-linear functions, but it experiences premature convergence. Premature convergence can be handled with various time coefficients to control non-convex economic dispatch and control local and global searches [31]. Other improvement of PSO algorithm was proposed by Abido [32] by developing Multi-Purpose Particle Swarm Optimization (MOPSO).

3.3. *Flower Pollination Algorithm (FPA)*

Inspired by pollination of flowers, the Flower Pollination Algorithm (FPA) was developed in 2012 [33]. Pollination of flowers is the process of transferring flower pollen carried out by insects, birds, and other animals. Indeed, some owers and insects have a very specialized partnership-pollinator, because some flowers can attract species of insects, birds and other animals to carry out effective pollination [34].

There are two types of pollination namely biotic pollination and abiotic pollination. Biotic pollination is a flower that requires pollen delivery by pollinators and 90% of flower plants depend on the biotic pollination process, while abiotic is a flower species that does not require pollination and only 10% of flowering plants depend on the abiotic process [35]. Wind and diffusion can also help flower pollination such flowering plants [36].

3.4. *Gravitational Search Algorithm (GSA)*

Gravitational Search Algorithm (GSA) is a method developed by Esmar Rashedi [37]. This method is a mathematical optimization that has multidimensional functions and included in the heuristic algorithm group. The concept of gravity and mass is the main inspiration of GSA [34,35]. In GSA, gravitational forces cause the movement of all objects towards a sub-optimal solution. This is because search agents are considered as individual objects with specific mass while each object in the system interacts with other objects through gravitational forces. The position of each agent presents a candidate solution to the problem, while the mass of agents is assigned to use objective functions so that a sub-optimal solution is obtained. At the same time, the gravitational force causes the movement of all objects towards the sub-optimal solution. GSA is provoked by the concept of gravity and manifested as the curvature of space-time, which is described by Einstein's general theory of relativity [39].

3.5. *Genetic Algorithm (GA)*

Genetic Algorithm (GA) is a global search method based on natural selection and the GA was developed by John Holland in 1970 [40]. GA is based on the natural selection and genetic factors that survive. GA operates with a set of chromosomes, known as population. It is randomly initialized and then it searches for the filter and filter solution and finally converges to a single best solution. This algorithm uses random techniques and information structures to obtain the results of optimization. The advantage of this algorithm is that it is able to get better results. Many research have proposed GA into CEED problem. Suhu and Swamkar [41] presented a GA based approach that was applied to the economic dispatch problem and compared its results with quadratic programming. The results showed that the GA value is better than the results of quadratic programming. Niched Pareto Genetic Algorithm to compute a CEED was proposed by Horn et al [27] and Abido [42].

4. Conclusions

This paper has provides review on non conventional methods for CEED problem. Any limitations of conventional methods on complex problems such as large computational time, getting trapped into local minima, increasing computational complexity, non satisfactory results can be overcame by applying non conventional methods. In this paper, various advances in the field of evolutionary algorithms for solving combined economic/emission dispatch problem have been discussed. This paper mainly focuses on nature-inspired advanced optimization methods for solving multiobjective CEED problem. Description of some well-known and promising methods have been given along with their working principle.

This study will guide and benefit to implement more economic and environmental friendly real-world power generation system. From this study, it can be concluded that stand-alone nature-inspired metaheuristic techniques are most successful, while GSA are found to be most prospective to optimize CEED problem.

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