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Study Paper on Multiobjective Combined Economic and Emission Dispatch Using Quantum Particle Swarm Optimization

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Abstract – **Customers nowadays have a high need for power supplies that are both affordable and reliable. The rising power demand and limited energy sources need the most efficient use of existing resources. To meet the economic needs of customers, a power system administrator must allocate available production resources to meet the demand for energy. Every power system requires efficient operation in order to maximize returns on capital investment. Economic Dispatch (ED) is regarded as a critical component of electric power system management.**

The multi-objective generating dispatch in electric power systems considers economic and pollution effects to be competing objectives, needing a reasonable compromise between the two to produce an optimal solution. The Combined Economic and Emission Dispatch (CEED) problem seeks to optimize the dispatch of electric power while taking into consideration both economic and environmental issues. This paper demonstrates the study of quantum particle optimization approach to solve the multiobjective combined economic and emission dispatch issue.

Keywords- Economic Dispatch, Emission Dispatch, Intellligent Methods, Quantum Particle Swarm Optimization.

I. Introduction

Across the globe, the electric power industry has undergone tremendous transition to meet the growing expectations of its consumers. Consumers have a great need for power that is both cost effective and reliable. Power utilities are expected to generate power at the lowest feasible cost. The power generated must meet both load demand and account for transmission losses. This means that in order to achieve the lowest possible cost, network losses must be accounted for throughout the dispatch process. The Economic Dispatch (ED) problem is recognized as a critical component in the operation of electric power networks. The Economic Dispatch problem is usually described as an optimization problem, with the goal of reducing the overall producing cost of the power system, while adhering to the stipulated restrictions. The fundamental Economic Dispatch model takes into account the power balance restriction in addition to the limitations of producing capacity.

Conventional economic power dispatch is ineffective in achieving environmental protection criteria since it only focuses on lowering total fuel costs. The multi-objective generating dispatch in electric power systems considers economic and pollution effects to be competing objectives, needing a reasonable compromise between the two to produce an optimal solution. The Combined Economic and Emission Dispatch (CEED) problem seeks to optimize the dispatch of electric power while taking into consideration both economic and environmental issues.

The problem is formulated using a cubic criteria function and incorporates a penalty element for the maximum price on a per-unit basis.

II. Literature Review

A large number of research papers on the topic of Economic Dispatch (ED) have been conducted during the last fifty years. Various objective functions and solution strategies have been investigated for the ED issue, depending on the amount of complexity. This proposed study considers just a fraction of the relevant literature's aims and solution approaches that are directly relevant to the current effort. The literature survey was organized and presented in accordance with the following themes.

Several scholars have suggested the notion of the multiobjective economic dispatch issue, which requires the evaluation of numerous competing objectives.

Zhuang and Cai Guo-wei used the ideal point technique in goal programming to transform the EED problem into a multi-objective model for power generation dispatch [1]. Gong et al. (2010) and Basu effectively solved the severely constrained EED issue by recasting it as a multi-objective evolutionary optimization problem with conflicting goals [2].
Sivasubramani and Swarup tackled the multiobjective economic emission dispatch (MOEED) problem by taking into account two competing objectives: the quadratic form of the fuel cost function and an emission function with an exponential term [3].

In their 2012 work, Javad and Ghasemi described the MOEED problem as a nonlinear constrained multiobjective problem with three competing objectives: fuel cost, pollution, and system loss.

M. Vijay Karthik and Dr. A. Shrinivasula Reddy have examined the economic dispatch problem while taking into account the constraints of the generators. The genetic algorithm optimization is applied to both a 6-unit and a 15-unit system.

In their 2016 work, I. Ziane, F. Benhamida, and A. Graa established the notion of combined economic and emission power dispatch (CEED) for situations where the fuel cost function may be represented as a cubic function. CEED's multi-objective function takes into consideration the max/max price penalty factor. Four criteria (a, c, d, and e) affect the cost of petrol. Their approach to identifying the optimal solution is based on the simulated annealing process [5].

Fahad Parvez Mahdi and Pandian Vasant used quantum particle swarm optimization (QPSO) to solve the multi-objective combined economic emission dispatch (CEED) problem. The issue was designed using a cubic criterion function, which included a unidirectional maximum/maximum price penalty component [6].

III. Economic Dispatch

Economic dispatch (ED) is an important optimization issue in power systems that includes calculating an economic condition for generation units while taking into consideration generation and transmission constraints. An emission dispatch (ED) problem has complex and nonlinear features, requiring both equality and inequality constraints. The purpose of an economic dispatch problem in a power system is to discover the most economical combination of power outputs for all generators, hence lowering total fuel costs while satisfying particular constraints.

In a traditional economic dispatch (ED) issue, the cost function for each generator is usually represented by a single quadratic. This issue is then handled utilizing mathematical programming techniques such as lambda-iteration, gradient, and dynamic programming approaches, as presented by Chen and Chen [7]. Nonetheless, simplifying the problem needs the use of numerous mathematical assumptions, such as convexity, quadratic, differentiable, or linear objectives.

The practical economic dispatch (ED) issue, which incorporates ramp rate restrictions, forbidden operating zones, valve-point effects, and multi-fuel possibilities, is classified as a non-smooth or non-convex optimization problem with equality and inequality constraints. This intricacy makes it difficult to determine the global optimum using existing approaches.

IV. Emission Dispatch

The emission dispatch problem is described as the task of minimizing the release of gaseous emissions from a thermal power plant. The environmental implications of thermal power plants are impacted by the specific methods employed and the unique characteristics of their locations. Coal-fired power facilities have a substantial impact on the surrounding ecosystem. In order to address the issue of high cost, it is advisable to utilize a fuel with a high calorific value. This has the potential to decrease the quantity of greenhouse gas emissions released into the environment. The cost of electricity generation per kilowatt-hour (KWH) will be elevated when the focus is on the Emission Dispatch (EmD).

The power industry is concerned about global warming since it is responsible for emitting greenhouse gases into the environment. As previously mentioned, the revision of the Clear Air Act and the implementation of environmentally friendly regulations have sparked the power sector's interest in reducing greenhouse gas emissions.

In the past, Gent & Lamont [8] suggested a minimal emission dispatch system as a means to decrease emissions released into the environment. The primary aim of their method was to reduce overall Nitrogen Oxide (NOx) emissions rather than total fuel expenses. An inherent drawback of this particular method of distribution is that as the level of emission is reduced, the associated cost may become significantly higher.

V. Combined Economic and Emission Dispatch

The combined economic emission dispatch problem is the sum of the economic load and emission dispatch problems. The CEED problem is represented in this study with a cubic criterion function rather of a quadratic function. The cubic criterion function has shown to be more effective in mitigating the nonlinearities of real power production systems. The economic dispatch problem is the job of optimizing the allocation of power producing resources in order to reduce costs while fulfilling energy demand.

$$F(P) = \sum_{i=1}^{n} a_i P_i^3 + b_i P_i^2 + c_i P_i + d_i$$

where *F(Pi)* is the generation cost (in $/hr) of generating unit *i* when the output power is *Pi*; *ai*, *bi*, *ci* and *di* are the cost coefficients of the generating unit *i*.

Emission dispatch problem can also be defined as a cubic criterion function with four emission coefficients as

$$E(P) = \sum_{i=1}^{n} e_i P_i^3 + f_i P_i^2 + g_i P_i + h_i$$

The emission (in Kg/hr) is denoted by E(Pi), where Pi represents the power generated by unit i. The emission coefficients are represented by e_i, f_i, g_i, and h_i. The goals of reducing the cost of electricity generation and minimizing the release of pollutants can be combined into a single purpose by incorporating a price penalty component. This research considers the maximum penalty factor to address the CEED problem.

The issue with the CEED problem involving the maximum/maximum penalty factor can be characterized as follows:

$$OF = F_T = \sum_{i=1}^{n} F(P_i) + \sum_{i=1}^{n} h_{i,\max/\max} E(P_i)$$

The abbreviation OF stands for objective function (CEED), F_T represents total cost, and $h_{i,max/max}$ denotes the maximum penalty factor of generating unit i. The maximum penalty factor can be defined as:

$$h_{i,\max/\max} = \sum_{i=1}^{n} F(P_{i,\max}) / \sum_{i=1}^{n} E(P_{i,\max})$$

$P_{i,max}$ is the upper limit of power generation (in MW) for the producing unit i. The objective of this endeavor is to reduce both the expenses associated with energy production and the release of harmful gases, namely the overall cost, while ensuring compliance with all other limitations. When designing a power production system, it is important to take into account various limitations, both equal and unequal, in order to optimize the system's performance. The two most crucial constraints explored in this study are power balance and generator limit limitations.

VI. Quantum Particle Swarm Optimization

QPSO, introduced and formulated by Sun et al. [9], is an expansion of PSO specifically designed for quantum computing. This article introduces the notion of a quantum bit (qubit) and rotation gate as a means to enhance the features of population diversity. In addition, the utilization of self-adaptive probability selection and chaotic sequences mutation is employed to prevent being stuck in any local optima. Quantum bit and angle are used to describe the state of a particle, rather than its location and velocity as in the fundamental Particle Swarm Optimization (PSO). Therefore, QPSO exhibits enhanced search capability together with rapid and efficient convergence features.

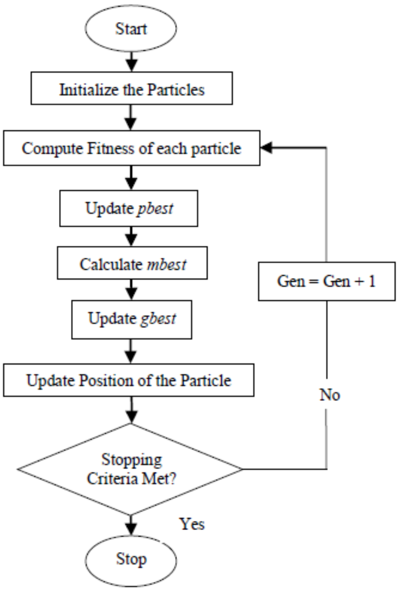

Figure 1: Flowchart of standard quantum particle swarm optimization

VII. Conclusion

This study employs the quantum computing (QC) inspired particle swarm optimization (QPSO) approach to address the economic dispatch (ED) issue. The QPSO technique is known for its robust and dependable search capabilities, as well as its powerful convergence qualities. In this context, the cubic criteria function is employed to model economic dispatch, as opposed to the conventional quadratic function, in order to enhance the system's resilience to the nonlinear characteristics of real power producers. In the upcoming work, we will analyze the outcomes of our study by comparing them to the results obtained from other algorithms such as Particle Swarm Optimization (PSO) and Simulated Annealing algorithm (SA). This comparison will be conducted on a 5-unit power producing system.

In recent years, power systems have significantly increased in size and have gotten more intricate. The issue of determining an optimal method to address the fluctuating energy demand is a significant priority for electricity generating entities. To address the aforementioned obstacle, this research aims to resolve the CEED problem in power systems by the application of intelligent strategies. The primary focus of this research endeavor is to identify an improved method for resolving CEED issues in power systems. Due to the limitations of current optimization strategies, there is a want for a distinct, uncomplicated, efficient, and cost-effective method to get the best solution for power system challenges. The CEED issue has been reformulated as a multi-objective optimization problem, taking into account both fuel cost and pollution targets, while satisfying both equality and inequality constraints.

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