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Implementation of Multiobjective Combined Economic and Emission Dispatch Using Quantum Particle Swarm Optimization

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Abstract – **Now a day's customers have a strong demand for power supply that are both economically efficient and dependable. The increasing power demand and dwindling energy sources need the optimal use of available resources. The allocation of available production resources to fulfil the demand for electricity is a crucial task for a power system administrator in order to fulfil the economic requirements of consumers. Efficient operation is essential for every power system to maximize the returns on the capital investment. The topic of Economic Dispatch (ED) is considered a crucial aspect of the mission of electric power system management.**

The multi-objective generation dispatch in electric power systems considers economic and pollution effect as conflicting objectives, necessitating a balanced compromise between the objectives to provide an optimal solution. The purpose of the Combined Economic and Emission Dispatch (CEED) issue is to optimize the dispatch of electric power, taking into account both economic and environmental factors.

This paper demonstrates the application of quantum particle optimization approach to solve the multiobjective combined economic and emission dispatch issue.

Keywords- Combined Economic and Emission Dispatch, Genetic Algorithm, Quantum Computing, Quantum Particle Swarm Optimization, Swarm Intelligence.

I. Introduction

Across the globe, the electric power business has seen significant transformation to cater to the increasing demands of its customers. Consumers have a strong need for power that is both economically viable and dependable. Power utilities are anticipated to produce electricity at the lowest possible expense. The produced electricity must satisfy both the load demand and account for transmission losses. This indicates that in order to attain the absolute least cost, it is necessary to include the network losses during the dispatch process. The Economic Dispatch (ED) problem is regarded as a crucial component in the functioning of electric power systems. The Economic Dispatch problem is typically expressed as an optimization problem, with the objective of minimising the overall generating 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.

The traditional economic power dispatch is inadequate in meeting environmental protection standards as it just focuses on minimizing the overall fuel cost. The multi-objective generation dispatch in electric power systems considers economic and pollution effect as conflicting objectives, necessitating a balanced compromise between the objectives to provide an optimal solution. The purpose of the Combined Economic and Emission Dispatch (CEED) issue is to optimize the dispatch of electric power, taking into account both economic and environmental factors.

The primary aim of this research is to create an unconventional evolutionary programming method that may be utilised for various power system economic dispatch challenges, while remaining in the background. With the aim of achieving this goal, it is suggested to create a unified evolutionary programming approach to address power dispatch issues. These issues include economic dispatch of generators with restricted operating zones, economic dispatch of generators with multiple fuel choices, combined environmental and economic dispatch with conflicting goals, and multi-area economic dispatch with tie line limitations.

In this study, we employ quantum particle swarm optimization (QPSO) to address the multiobjective combined economic emission dispatch (CEED) issue. The problem is formulated using a cubic criteria function and incorporates a penalty element for the maximum price on a per-unit basis. QPSO is used to a power generating system consisting of 6 units and is then compared to Lagrangian relaxation, particle swarm optimization (PSO), and simulated annealing

II. Literature Review

Over the last fifty years, a multitude of research studies have been documented about this issue of Economic Dispatch (ED). Various goal functions and solution techniques have been explored for the ED problem, depending on the level of complexity. Only a subset of the objectives and solution methods from the relevant literature, which are directly relevant to the current work, are taken into account for this suggested study. The literature survey has been organized and presented according to the following themes.

Several academics have introduced the concept of the multiobjective economic dispatch issue, which involves the consideration of multiple conflicting objectives.

Zhuang and Cai Guo-wei formulated the EED issue as a multi-objective model for power generation dispatch using the ideal point approach in goal programming [1].

Gong et al (2010) and Basu have successfully addressed the severely limited EED issue by formulating it as a multi-objective evolutionary optimisation problem with competing aims [2].

Sivasubramani and Swarup addressed the multiobjective economic emission dispatch (MOEED) problem by considering two conflicting objectives: the quadratic form of the fuel cost function and an emission function with an exponential term [3].

In their 2012 study, Javad and Ghasemi defined the MOEED issue as a nonlinear restricted multiobjective problem with three conflicting objectives: fuel cost, pollution, and systems loss [4].

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 optimisation is applied to both a 6-unit and a 15-unit system.

In their 2016 study, I. Ziane, F. Benhamida, and A. Graa introduced the concept of combined economic and emission power dispatch (CEED) for cases where the fuel cost function may be modelled as a cubic function. The multi-objective function of (CEED) takes into account the max/max price penalty element. The gasoline cost is determined by four parameters: a, c, d, and e. Their strategy for finding the ideal solution is based on the simulated annealing methodology [5].

Fahad Parvez Mahdi and Pandian Vasant employed quantum particle swarm optimization (QPSO) to address the multiobjective combined economic emission dispatch (CEED) issue. The problem was written using a cubic criteria function and incorporated a unidirectional maximum/maximum price penalty component [6].

III. ECONOMIC DISPATCH

The Economic Dispatch (ED) is a crucial optimization problem in power systems that involves determining an economic condition for generation units, taking into account generation and transmission restrictions. An erectile dysfunction (ED) issue exhibits intricate and non-linear properties, involving both equality and inequality restrictions. The goal of an economic dispatch issue in a power system is to find the most efficient combination of power outputs for all generators, in order to minimise the overall fuel cost while meeting specific limitations.

In a conventional economic dispatch (ED) problem, the cost function for each generator is typically approximated by a single quadratic function. This problem is then solved using mathematical programming techniques, such as lambda-iteration, gradient, and dynamic programming methods, as described by Chen & Chen [7]. Nevertheless, simplifying the issue necessitates the use of several mathematical assumptions, like convexity, quadratic, differentiable, or linear goals.

The practical economic dispatch (ED) problem, which includes ramp rate limits, prohibited operating zones, valve-point effects, and multi-fuel options, can be described as a non-smooth or non-convex optimisation problem with both equality and inequality constraints. This complexity makes it challenging to find the global optimum using traditional methods.

ED, or Economic Dispatch, is a crucial function in electric power system operations that allows utilities to maintain a high degree of dependability and efficiency in the power system. The Economic Dispatch (ED) is a mathematical problem that aims to minimise the overall cost of generating electricity from power units, while also ensuring that crucial system restrictions are met. Prior attempts to address erectile dysfunction (ED) issues have included a range of mathematical programming methodologies and optimisation strategies. These approaches rely on the assumption that the incremental fuel cost curves of the units follow a pattern of growing in a stepwise manner.

IV. COMBINED ECONOMIC & EMISSION DISPATCH

In recent years, the economic dispatch problem has seen a significant shift because to growing public awareness for environmental problems. The only consideration of the absolute least cost is no longer the exclusive need in electric power generating and dispatching difficulties. The emissions' limiting levels impose extra operational limitations that must be met while determining the best solution for the economic dispatch problem. The emissions of various contaminants have distinct properties and often demonstrate significant non-linearity. This exacerbates the intricacy and lack of linearity of the emission-constrained economic dispatch dilemma. The economic dispatch and emission dispatch exhibit significant differences. The economic dispatch focuses solely on minimizing the overall fuel cost (running cost) of the system, without taking into account the emission regulations. Conversely, emission dispatch focuses solely on reducing the overall emission of NOx from the system, even if it means disregarding economic considerations. Hence, it is imperative to determine an optimal operating point that achieves a harmonious equilibrium between cost and emission. Based on the information provided, it is confirmed that Combined Economic and Emission Dispatch is a challenge related to optimizing power systems. This problem can be handled utilising intelligent strategies.

The combined economic emission dispatch problem is the amalgamation of the economic load dispatch and emission dispatch problems. The CEED problem is represented in this research using a cubic criteria function instead of a quadratic function. The cubic criteria function has proven to be more efficient in mitigating the nonlinearities of real power generation systems. The economic dispatch problem refers to the task of optimizing the allocation of power generation resources in order to save costs while meeting the electricity demand.

V. RESULTS

Figure 1 illustrates the flowchart of QPSO. During the initial phase, the algorithm parameters are initialised, including the population size, particle diameter, and maximum number of iterations. The second phase involves assessing the fitness value of each particle and storing the personal best (pbest) and global best (gbest) values. Next, the particles are updated using the formula [6] from the QPSO algorithm. The algorithm concludes and provides the most favourable result if it meets the stopping requirements, such as the maximum number of iterations. Alternatively, the algorithm repeats the process starting from the second stage.

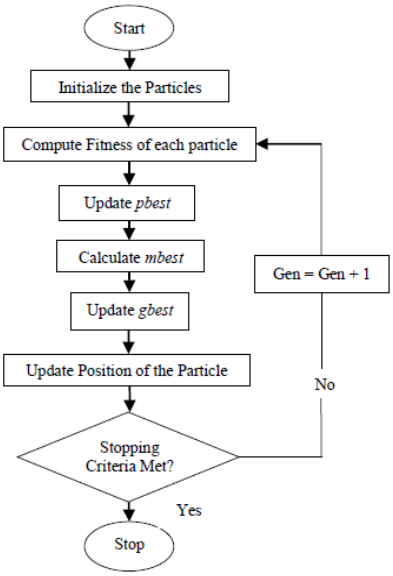

Figure 1: Flowchart of standard quantum particle swarm optimization

CASE I: 6 UNIT SYSTEM

The QPSO algorithm was utilised to solve the CEED issue for a 6-unit power generating system. The cubic criteria function was employed, and the total load demand was set at 150 MW.

Table 1: Parameters setting for QPSO

S.No	Parameters	Values
1	Population Size	1000
2	Maximum Iterations	100
3	Numbers of Run	100
4	Dimension	6

Table 2 minimum and maximum limits of the output powers generated by the 6 units of the power generation system

Generating Units	P_{min} (MW)	P_{max} (MW)
1	50	200
2	20	80
3	15	50
4	10	50
5	10	50
6	12	40

Table 3: Fuel coefficients and emission coefficients for 6-unit power generation system

Economic Dispatch Coefficient				*Emission Dispatch Coefficient*			
a_i	b_i	c_i	d_i	e_i	f_i	g_i	h_i
0.0010	0.0920	14.50	-136	0.0015	0.0920	14.0	-16.0
0.0004	0.0250	22.00	-3.50	0.0014	0.0250	12.5	-93.5
0.0006	0.0750	23.00	-81.00	0.0016	0.0550	13.5	-85.0
0.0002	0.1000	13.50	-14.50	0.0012	0.0100	13.5	-24.5
0.0013	0.1200	11.50	-9.75	0.0023	0.0400	21.0	-59.0
0.0004	0.0840	12.50	75.60	0.0014	0.0800	22.0	-70.0

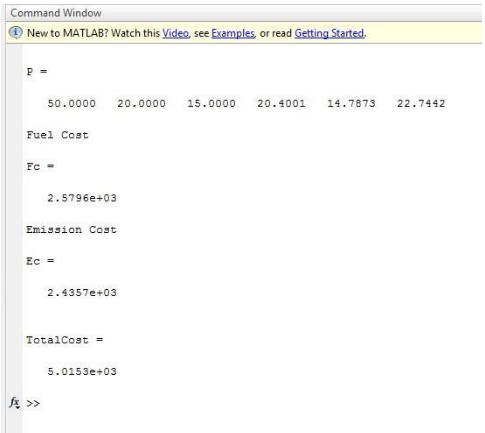

Figure 2: Screenshot of Result

Figure 3: Screenshot of finding Fuel Cost and Emission Cost

Table 4: Comparison of CEED solutions (P_d=150 mw) considering max-max penalty factor

	Langrange	SA [5]	PSO	QPSO [6]	Proposed QPSO
P1	50.65	50	50	50	50.008
P2	21.2	20.09	20	20	20.04
P3	15.46	15.01	15	15	15
P4	22.68	20.61	22.11	22.9	19.76
P5	21.30	22.49	20.6	20.04	17.49
P6	21.11	21.89	22.31	22.03	20.96
Fuel Cost	2734.21	2702.78	2701.796	2701.47	**2583.3**
Emission Cost	2642.702	2607.46	2593.18	2583.64	**2442.6**
Total Cost	5376.912	5310.24	5294.98	5285.12	**5025.9**

CASE II: 5 UNIT SYSTEM:

The QPSO algorithm was utilised to solve the CEED issue for a 5-unit power generating system. The algorithm considered a cubic criteria function and took into account the power loss restriction. The total load demand for the system was 1800 MW.

Table 5: Parameters setting for QPSO

S.No	Parameters	Values
1	Population Size	2000
2	Maximum Iterations	200
3	Numbers of Run	100
4	Dimension	5

Table 6: Minimum and maximum limits of the output powers generated by the 5 units of the power generation system

Generating Units	Pmin (MW)	Pmax (MW)
1	320	800
2	300	1200
3	480	1100
4	320	800
5	300	1200

Table 7: Fuel coefficients for 5-unit power generation system

Economic Dispatch Coefficient			
a_i	b_i	c_i	d_i
749.6	6.95	0.000968	12.7*10^-9
1285	7.05	0.0007375	6.453*10^-8
1531	6.531	0.00104	9.98*10^-8
749.6	6.95	0.000968	12.7*10^-9
1285	7.05	0.0007375	6.453*10^-8

Table 8: Loss coefficient of George's formula (Bij) for 5-unit power generation system

0.0212	0.0085	-0.0009	0.0021	0.0007
0.0085	0.0206	-0.0041	0.0037	0.0001
-0.0009	-0.0041	0.0395	-0.0207	-0.0251
0.0021	0.0037	-0.0207	0.0613	-0.0071
0.0007	0.0001	-0.0251	-0.0071	-0.0406

Table 9: Transmission loss constant of generating unit *i* and Kron's transmission loss constant

B_{i0}	-0.0002	0.003	-0.0017	0.0101	-0.0038
B_{00}	0.00085357				

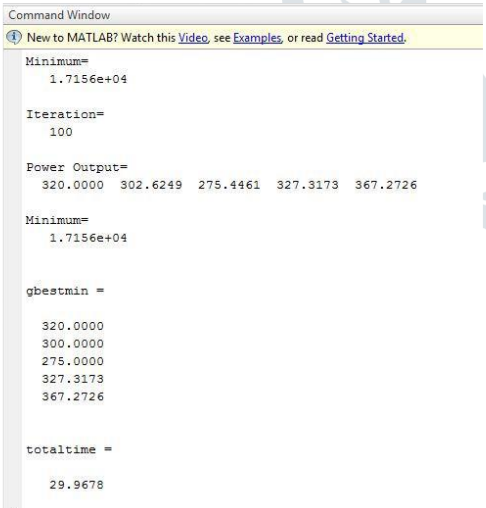

Figure 4: Screenshot of Result

Figure 5: Screenshot of finding Fuel Cost with considering power loss factor

Table 10: Comparison of CEED solutions (Pd=1800 MW) considering power loss factor

	GA [20]	PSO [8]	Proposed QPSO
P1	320	320	**320**
P2	343.74	343.7	**302**
P3	472.6	472.6	**475**
P4	320	320	**320**
P5	343.74	343.7	**367**
Fuel Cost	18611.1	18610.4	**18047.1**

VI. CONCLUSION

In order to analyze and validate the QPSO technique, a comparison is conducted with three other existing methods, namely the Lagrange method, Simulated Annealing (SA), and Particle Swarm Optimization (PSO) [5]. This comparison is carried out for the combined economic emission and dispatch problem.

Table 4 displays the expenses accrued by each of these methods. The results suggest that QPSO surpasses the other three approaches in minimizing the overall cost, indicating its superior performance in addressing the multiobjective CEED issue compared to the others. An issue with PSO, like with other algorithms, is that it can occasionally become stuck in local optima [9]. QPSO has the ability to circumvent local minima in several instances, hence enhancing performance.

The issue at hand is the comparison of Genetic Algorithm and Particle Swarm Optimisation (PSO) in addressing the multiobjective CEED problem, specifically when taking into consideration the power loss component. Table 10 displays the gasoline expenses accrued by this method.

The performance indicators evaluated for assessment are the fuel cost per hour ($/hr), emission cost per hour ($/hr), number of iterations, and computing time in seconds. The obtained results are compared with other well-known methods such as Lagrangian relaxation, Particle Swarm Optimisation (PSO), and Simulated Annealing (SA), demonstrating the evident advantage of Quantum Particle Swarm Optimisation (QPSO) in addressing the CEED problem. This research examined just a small number of generating units since there was insufficient data available for bigger power generation systems.

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