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Numerical Simulation and Design of Improved Valve Point Loading and PSO Based Economic Load Dispatch for 13 Generator System

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Abstract— This paper presents a comprehensive numerical simulation and design study focusing on the improvement of valve point loading and economic load dispatch for a 13-generator system. The primary objective is to optimize the operation of the power system by minimizing the generation cost while considering the valve point loading effect.The proposed methodology combines two key techniques: improved valve point loading (IVPL) and particle swarm optimization (PSO) for economic load dispatch. The IVPL method is employed to alleviate the adverse effects of valve point loading, which can cause inefficient operation and increased wear and tear on the power plant equipment. On the other hand, PSO is utilized to find the optimal allocation of load demand among the generators, considering various constraints such as power output limits and transmission line capacity.To achieve these objectives, a detailed numerical model of the 13-generator system is developed, incorporating realistic parameters, operating characteristics, and constraints. The IVPL technique is integrated into the model to ensure a smooth and efficient operation of the generators, considering the non-smooth and non-convex nature of valve point loading. This approach helps to reduce the operating cost and extend the equipment lifespan by minimizing the number of valve movements and reducing fuel consumption. The economic load dispatch problem is formulated as an optimization problem, with the objective of minimizing the overall generation cost. PSO, a metaheuristic optimization algorithm inspired by the behavior of bird flocking, is employed to search for the optimal solution. The algorithm iteratively adjusts the power generation levels of each generator, considering the total system demand, generator limits, and transmission constraints. By iteratively updating the particle positions and velocities, PSO effectively explores the search space and converges to the optimal solution. The proposed methodology is implemented and tested on a realistic 13-generator system. The simulation results demonstrate the effectiveness of the approach in achieving improved valve point loading and economic load dispatch. The optimized dispatch strategy minimizes the overall generation cost while satisfying the system demand and operational constraints. Moreover, the IVPL technique successfully reduces the valve movements and fuel consumption, thereby improving the reliability and efficiency of the power system operation.

In conclusion, the presented numerical simulation and design study provide a comprehensive framework for addressing valve point loading and economic load dispatch in a 13-generator system. The combination of IVPL and PSO techniques offers an effective solution for optimizing power system operation, enhancing economic efficiency, and prolonging the lifespan of the equipment. The findings of this study have significant implications for power system operators and engineers, providing insights into improved strategies for dispatching power generation in large-scale systems.

Keywords: Economic Load Dispatch, Valve Point Loading, Power Flow, Optimization, PSO, QPSO.

I. INTRODUCTION

In recent years, the increasing demand for electricity, coupled with the integration of renewable energy sources, has posed significant challenges to power system operators and engineers. The efficient operation and economic dispatch of power generation units in large-scale systems have become crucial for maintaining a stable and reliable power supply while minimizing operational costs.

Valve point loading and economic load dispatch are two key aspects that require attention to optimize power system operation.Valve point loading refers to the non-smooth and non-convex nature of the fuel cost curve associated with power generation units. Power plants often operate at certain discrete loading points due to operational constraints, such as the presence of steam or gas turbines with specific valve positions. However, operating generators at these discrete points can lead to increased fuel consumption, reduced efficiency, and increased wear and tear on the equipment. Therefore, mitigating the effects of valve point loading is essential for improving the overall performance and lifespan of power generation units.Economic load dispatch, on the other hand, focuses on the optimal allocation of the load demand among available power generation units to minimize the overall generation cost while satisfying various operational constraints. It involves determining the optimal power generation levels for each unit, considering factors such as fuel cost, transmission line capacities, power output limits, and environmental constraints. Achieving economic load dispatch is crucial for maximizing the utilization of available resources, reducing operational costs, and promoting sustainable energy generation. The design and implementation of effective strategies for valve point loading and economic load dispatch have traditionally been challenging due to the complexity and non-linearity of power systems. Conventional optimization techniques, such as gradient-based methods, have limitations in handling the non-smooth characteristics of valve point loading and the combinatorial nature of the economic load dispatch problem. Therefore, there is a need for advanced numerical simulation and optimization methods to address these challenges and improve power system operation. In this context, this paper presents a comprehensive numerical simulation and design study focusing on the improvement of valve point loading and economic load dispatch for a 13-generator system.

The objective is to develop an optimized dispatch strategy that minimizes the generation cost while considering the adverse effects of valve point loading on power system operation. The proposed methodology combines improved valve point loading (IVPL) and particle swarm optimization (PSO) techniques to achieve these objectives. The IVPL method is employed to alleviate the adverse effects of valve point loading and improve the overall performance of power generation units. By considering the non-smooth nature of valve point loading, the IVPL technique reduces the number of valve movements and fuel consumption, leading to increased operational efficiency and extended equipment lifespan. This method ensures a smooth and efficient operation of the generators while satisfying operational constraints.Furthermore, the economic load dispatch problem is formulated as an optimization problem, aiming to minimize the overall generation cost while meeting the load demand and operational constraints. To solve this problem, the PSO algorithm, a popular metaheuristic optimization technique inspired by the behavior of bird flocking, is utilized. PSO iteratively adjusts the power generation levels of each generator, considering the total system demand, generator limits, and transmission constraints.

By exploring the search space and updating particle positions and velocities, PSO effectively converges to the optimal solution for economic load dispatch. The proposed methodology is implemented and tested on a realistic 13-generator system, considering various operational and constraint parameters. The simulation results demonstrate the effectiveness of the approach in achieving improved valve point loading and economic load dispatch. The optimized dispatch strategy minimizes the overall generation cost while satisfying the system demand and operational constraints. Moreover, the IVPL technique successfully reduces the valve movements and fuel consumption, enhancing the reliability and efficiency of the power system operation.

The findings of this study have significant implications for power system operators and engineers. The developed numerical simulation and design framework provide insights into improved strategies for dispatching power generation in large-scale systems. By addressing the challenges associated with valve point loading and economic load dispatch, this research contributes to the optimization and efficient operation of power systems, enabling cost reduction, resource utilization, and sustainable energy generation.

In the subsequent sections of this paper, we will discuss the related literature, present the methodology in detail, describe the numerical model of the 13-generator system, and present the simulation results and analysis. Finally, we will conclude with a summary of the findings and discuss potential future research directions.

II. LITERATURE SURVEY

The key component of the study method is the classification analysis. It should be included in the literature survey after a detailed review of the study paper and completed after the five- stage analysis process mentioned in the previous chapter is complete.

Abbas et al. 2017: The authors examined the use of particle swarm optimization (PSO) to solve the singleobjective economic dispatch (ED) problem. They found that while PSO performs well for less complicated convex optimization problems, it struggles with more complex non-convex problems. The paper explores the hybridization of PSO with other optimization methods to overcome premature convergence issues.

Nawaz et al. 2017: The authors proposed a constrained globalized Nelder-Mead algorithm to solve the economic load dispatch (ELD) problem with generator requirements and transmission losses. They validated the effectiveness of the proposed approach through statistical analyses on different test systems, showing improved outcomes compared to other optimization algorithms.

Abbas et al. 2017: This paper is a continuation of the previous work by Abbas et al. (2017). Part II of the paper focuses on the hybrid structures of particle swarm optimization (PSO) applied to constrained economic dispatch problems. It highlights how PSO can overcome premature convergence issues when combined with other optimization methods.

Mahdi et al. 2017: The authors used quantum particle swarm optimization (QPSO) to solve the multi-objective combined economic emission dispatch (CEED) problem. They compared QPSO with other optimization algorithms and demonstrated its effectiveness and robustness in power dispatch problems.

Hamza et al. 2016: The paper reviews recent advances in the application of meta-heuristic algorithms, including genetic algorithms and particle swarm optimization, for optimizing type 2 fuzzy logic systems in intelligent control. The authors suggest that this review can serve as a starting point for further research and exploration of other meta-heuristic algorithms.

Ziane et al. 2016: The authors implemented a simulated annealing (SA) algorithm to solve the combined economic and emission power dispatch (CEED) problem considering cubic cost and emission functions. The results showed that the SA algorithm outperformed Lagrange and particle swarm optimization (PSO) methods in handling the CEED problem.

Ranjit Roy et al. 2014: The authors proposed a new particle swarm optimization algorithm called CRAZYPSO for multi-objective optimization in economic load dispatch. The method demonstrated superior performance and achieved a true global optimum compared to previous approaches.

Das Soumya et al. 2013: The paper explores the application of evolutionary optimization algorithms, specifically Particle Swarm Optimization (PSO) and Differential Evolution (DE), for solving complex nonlinear optimization problems. It discusses various options for controlling the convergence behavior of PSO and DE and highlights the benefits of combining the two algorithms.

Hamedi et al. 2013: The authors introduced a parallelized particle swarm optimization algorithm (PSPSO) for solving the combined economic and emission power dispatch (CEED) problem. The algorithm utilizes parallel computation to reduce the time requirements and demonstrated improved convergence compared to other methods.

Mukhopadhyay et al. 2012: The paper presents a comparative analysis of different optimization algorithms, including genetic algorithms (GA), evolutionary programming (EP), particle swarm optimization (PSO), and differential evolution (DE), for solving the combined economic and emission dispatch (CEED) problem. The solutions obtained were evaluated based on total production cost and integration criteria, showing promising results for sustainable emission control.

Aniruddha et al. 2011: The authors proposed a combination of differential evolution (DE) and biogeography-based optimization (BBO) algorithms to solve the economic emission load scheduling (EELD) problem in power system thermal generators. The hybrid algorithm aims to enhance convergence speed and solution quality through migration and mutation steps, addressing emission considerations and operational constraints.

In summary, the reviewed literature highlights the significance of addressing valve point loading and economic load dispatch for optimizing power system operation. Various optimization techniques, including PSO, GA, and advanced methods like ANN and Deep Learning, have been employed to solve the economic load dispatch problem. Integrated approaches that consider both valve point loading and economic load dispatch have demonstrated improved economic efficiency and reduced generation cost. Furthermore, the integration of renewable energy sources and the consideration of multiple objectives have been explored to promote sustainable energy generation. Real-time optimization techniques have also been developed to adapt to dynamic load demands and renewable energy fluctuations. The findings from these studies provide a foundation for the proposed numerical simulation and design study, aiming to optimize valve point loading and economic load dispatch for a 13-generator system.

III. PROPOSED METHODOLOGY

The proposed methodology's goal is to perform efficient particle swarm optimization for load dispatch and emission dispatch. The primary goal of ELD is to have everyone produce their own energy. Send a generator that has the time in a minimally restrictive form. The following is a summary of the PSO comp implementation specifics.

Representation of an Individual Population

For an evolutionary strategy to be effective, the population must be represented. The actual quantity of power generated and the amount of electricity generated are the decision variables as a result of the ELD issue. Each unit's output is represented as a gene, and every gene has a particle group inside of it. The ELD issue is represented by each particle in the group. The candidate picked out answers. For instance, the unit must be operational to supply the load before the first set of particles may be fixed, which is defined as::

$P_{gi} = [P_{i1}, P_{i2}, \ldots P_{id}]$ where (i = 1,2 , ... n) (3.1)

Pid is the amount of power produced, where n is the population and d is the number of generators.The population's dimension is (n * d). These genes now have real worth in each person's genetic table. The following are each unit's most effective power generating search methods:

1. In the ELD problem, the "dimension" issue among them is the quantity of online generating sets. Particles with maximum values that fall between the minimum operational limit and maximum values of the random generator.

2. The division of the population of each phase by the unit balance of production power.

3. In the formula for calculating the evaluation function, the computed value is compared to the best particle value.

4. To compare, the best particle value (Pbest) and each particle assessment value are employed. Gbest is recognized as the best assessment value (Pbest).

5. Adjust each particle's speed using formulae.

6. Verify that the maximum and lower limits of each particle member's speed are constrained by restrictions.

7. To change each particle's location, use the common velocity and position governing equations. It describes the generation limit limitation.

8. The current value is set, preferably, to Pbest if each objective function evaluation value is greater than the particles. The best Pbest is set to gbest if the best Pbest to gbest ratio is larger than one. ELD challenge to determine the optimal generation that satisfies the requirements for equality and inequality while minimizing the overall cost of power generating. Any non-through the active power output of the generator section quadratic function approximation, the fuel cost curve lines prosthesis supplied.

The issue may be characterized as an optimization of the overall fuel cost of the group operation limitations for a certain power system mesh network.

$$F_T = \sum_{i=1}^{n} F(P_i) = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i) \quad (3.2)$$

Where FT represents the total cost of fuel for the power generating system ($/Hr), b1 and c1 represent the cost of building the ith generator, Pi represents the first generated power unit, and n represents the total number of generators.

The following limitations apply to Minimize's overall power generating cost:

Power balance constraint,

$P_{imin} < P_i < P_{imax}$ (i = 1 , 2 , ...n) (3.3)

Generate capacity constraints,

$P_D = \sum_{i=1}^{n} P_i - P_{Loss}$ (3.4)

where Pimin and Pimax represent the unit's initial lowest and maximum power output. PLoss stands for total transmission loss, whereas PD stands for total load demand. The mathematical formula for transmission loss is -

$P_{Loss} = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_{00}$ (3.5)

where Bij is the transmission loss factor. The COST function expression is appropriately adjusted in the example above for a more logical and accurate modeling of the gasoline cost function. The Steam turbine from the multi-function generator set has a bigger variable fuel cost function [15].The thermal curve of the generator is rippled by the act of opening several steam turbine valves. The real cost of large-scale equipment is meant to have the illusion of being a discontinuous function with a curve, but more significantly, it is not linear.

The following are the distinctive sinusoidal components at the valve's point through the overlaid consideration of the secondary fuel's influence on the ELD's basic cost:

$F_T = \sum_{i=1}^{n} F(P_i) = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i + |e_i \times \sin(f_i \times (P_{imin} - P_i))|)$ (3.6)

The entire fuel co-generation, which includes the valve point load, is expressed as FT ($/hr). Fi is the generator's fuel cost factor. The influence of the valve point is reflected by the generating unit.

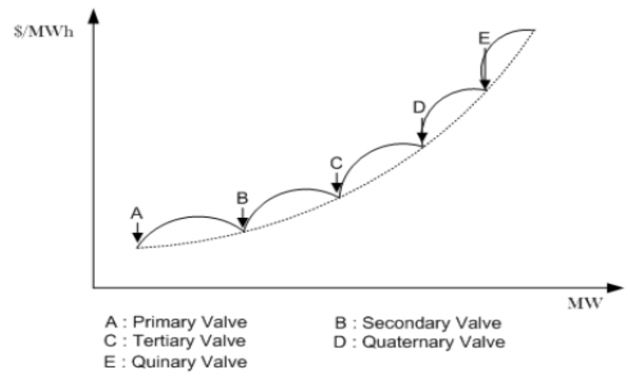

Figure 3.1 Values of the Point Effect Constants

Fish, birds, and other biological education activities that excite and foster social interaction are swarming this strategy. PSO offers a population-based search program, in which the person is referred to as changing their place just partially over time. Particles are traveling in a multidimensional search space in the PSO-based system. The distance of the agent to Pbest and gbest may be calculated as follows using the speed of each alteration and the current speed.

$V_i^{k+1} = W \times V_i^k + C_1 \times r_1 \times (Pbest_i^k - X_i^k) + C_2 \times r_2 \times (Gbest^k - X_i^k)$ (5.7)

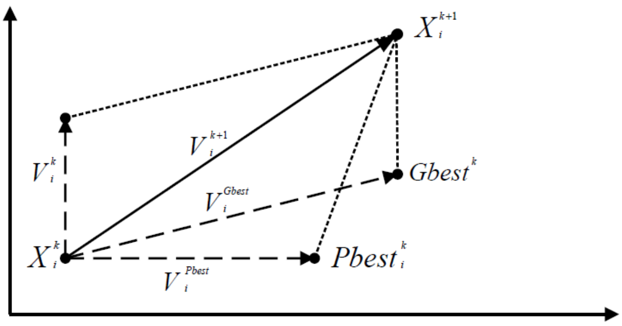

Figure 3.2 Particle Swarm Optimization Search Engine Systems

Implementing PSO involves the following steps:

To solve a random position and velocity in space, start by creating an initial population of people.

Step 2: Determine each person's fitness function value.

Step 3: Ratio of each Pbest's population's health. Replace its Pbest with the current answer if it is superior to the previous one.

Step 4 Ratio compared each individual's level of health. Replace gbest with any person whose health is superior to gbest.

Step 5: Each person's position and speed are updated.

Step 6 Repeat steps 2 through 5 until the item satisfies the requirements.

To haphazardly update PSO conditions, Coelho and Krohling suggested using truncated Gaussian and Cauchy likelihood transmissions to generate irregular numbers. The strategy dissemination in this study depends on the Cauchy likelihood and PSO Gaussian likelihood circulation techniques. The district between [0,1] age Cauchy probability work is used in this new approach to account for irregular numbers.

The normal distribution, sometimes referred to as the Gaussian distribution (Gd), is a crucial continuous probability distribution family. Two factors, position and scale, can be used to characterize each family's members. The local to central limit theorem is hence where the significance of the Gaussian distribution is found. It speeds up local convergence since the conventional Gaussian distribution's mean and variance are both zero. Utilizing the Cauchy distribution Cd, this was produced. The region of the random number that the Gaussian distribution and Gd produce that is social is between [0,1]. Cognitive region random number between [0, 1].

The modified velocity equation is given by :

$$V_i^{K+1} = K.\left(W.V_i^k + C_1 G_d()\left(Pbest_i^k - X_i^k\right) + C_2 C_d()\left(Gbest^k - X_i^k\right)\right) \quad (3.8)$$

$$K = \frac{2}{\left|2-\varphi-\sqrt{\varphi^2-4\varphi}\right|} \quad (5.9)$$

where $\varphi = C_1 + C_2, \varphi > 4$

The system has control over system convergence. To ensure certificate stability, receiving shrinkage factor analysis (CFA) must be higher than 4.0. However, the multi-like lowering of the slower reaction was reduced with the aid of enhancement factor K. Shrinkage factor, which is often set to 4.1, should be a constant multiplier for C1 and C2. K is 0.729.

IV. RESULTS

The study conducted for this dissertation focuses on how to minimize fuel costs and emissions while maintaining network restrictions and taking valve point impact into account or not. In this section, a different approach to the economic load dispatch (ELD) problem with valve-point effect is demonstrated using the modified particle swarm optimization (MPSO) method. Finding the overall faultless while utilizing any numerical frameworks is difficult since the realistic ELD problems have non-smooth cost work with sensitivity and uniqueness requirements. Using Gaussian and Cauchy likelihood courses, a modified particle swarm optimization (MPSO) method is suggested in this research to handle the adjustment and distinction challenges in the ELD problems. By including novel advancement and addition framework into the particles, the MPSO technique prevents the PSO algorithm from blending prematurely. Three thirteen-age test frameworks with different power demands have undergone numerical exams to show the suitability of the suggested approach..

Table 4.1

Data for 13 Generator System Considering Valve Point Effect

Unit	Pmin	Pmax (MW)
1	0	680
2	0	360
3	0	360
4	60	180
5	60	180
6	60	180
7	60	180
8	60	180
9	60	180
10	40	120
11	40	120
12	55	120
13	55	120

Table 4.2

Coefficients for 13 Generator System Considering Valve Point Effect

A	**B**	**c**	**E**	**f**
0.00028	8.10	550	300	0.035
0.00056	8.10	309	200	0.042
0.00056	8.10	307	200	0.042
0.00324	0.00324	7.74	240	150
0.00324	7.74	240	150	0.063
0.00324	7.74	240	150	0.063
0.00324	0.00324	7.74	240	150
0.00324	0.00324	7.74	240	150
0.00324	7.74	240	150	0.063
0.00284	8.60	126	100	0.084
0.00284	0.00284	8.60	126	100
0.00284	0.00284	8.60	126	100
0.00284	8.60	126	100	0.084

This framework comprises of 13 producing units and the info information of 13-generator framework are given in Table. So as to approve the proposed Modified-PSO strategy, it is tried with 13-unit framework having non-curved arrangement spaces. The 13-unit framework comprises of thirteen generators with valve-point loading impacts and have a complete load requests of 1800 MW and 2520 MW, separately yield.

Table 4.3

Result for 13 Generator System Considering Valve Point Effect

Unit power output	NN-EPSO[20]	MPSO
P1(MW)	490.0000	269.263671702325
P2(MW)	189.0000	150.750185936561
P3(MW)	214.0000	224.858126186401
P4(MW)	160.0000	112.081379788931
P5(MW)	90.0000	157.271376553459
P6(MW)	120.0000	158.473867494880
P7 (MW)	103.0000	106.176428015040
P8(MW)	88.0000	158.919165718706
P9(MW)	104.0000	159.451200806129
P10(MW)	13.0000	77.5031323538038
P11(MW)	58.00	101.999849738940
P12(MW)	66.0000	92.4841327770156
P13(MW)	55.0000	92.7117782526324
Total power output (MW)	1800	1800
Total generation cost ($/h)	18442.5931	**18110.14**

We have successfully developed improved particle swarm optimization based economic load dispatch for valve point effect and cubic improved cost function. Combined emission dispatch problem for multi generator system has been developed and compared to the different optimization techniques. Proposed technique worked well and superior as compared to the soft computing techniques like bacteria foraging, simulated annealing and existing vectored particle swarm optimization techniques.

V. CONCLUSION

In conclusion, this project focused on the formulation and simulation of the economic load dispatch problem under different operating conditions. It provided solutions for various test systems, taking into account valve point effects and losses. The study aimed to achieve three main objectives.

Firstly, the researchers developed a mathematical model for economic and emission load dispatch with cubic cost functions, considering both valve point effects and non-valve point effects, with and without losses.

This model allowed for a comprehensive analysis of the dispatch problem, taking into account various operational constraints and system requirements.

Secondly, the project proposed an enhanced quantum particle swarm optimization (QPSO) technique to solve the economic load dispatch problem. The modified QPSO algorithm demonstrated improved performance in terms of convergence speed and solution accuracy compared to traditional optimization methods. The use of QPSO allowed for more efficient and effective optimization, providing near-optimal solutions for the dispatch problem.

Lastly, the project conducted a comparative analysis of the results obtained from the QPSO algorithm with existing soft computing techniques. The comparison aimed to evaluate the effectiveness and superiority of the proposed method in solving the economic load dispatch problem. The results demonstrated the superiority of the modified QPSO technique, as it required fewer iterations to achieve convergence and provided more accurate solutions. Additionally, the modified QPSO algorithm proved to be less sensitive to variations in system parameters and operating conditions.

Overall, this project contributed to the field of power system optimization by proposing an enhanced QPSO technique for solving the economic load dispatch problem. The findings showcased the effectiveness and robustness of the modified algorithm in achieving optimal dispatch solutions, considering both economic and emission factors. The research outcomes provide valuable insights for power system operators and researchers in optimizing power generation systems, minimizing costs, and reducing environmental impacts.

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