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USING GREY WOLF OPTIMIZER TO SOLVE ECONOMIC LOAD DISPATCH PROBLEMS WITH REALISTIC CONSTRAINTS

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ABSTRACT

This paper focuses on solving Economic Load Dispatch (ELD) problems in power systems using the Grey Wolf Optimizer (GWO), an advanced optimization algorithm. The objective of the ELD problem is to determine the optimal power generation from multiple power plants while minimizing fuel costs, subject to constraints like generation limits and power balance. The study considers realistic factors such as valve-point effects, which simulate non-linearities in power generation, and ramp rate limits, which restrict the rate of change in power output. The GWO algorithm is applied to handle these constraints and find efficient solutions for various test cases. The results demonstrate the effectiveness of GWO in minimizing the total cost while meeting system demands and respecting operational limits. This approach provides a promising tool for optimizing power system operations, especially in scenarios with complex, non-linear characteristics.

Keywords: Economic Load Dispatch (ELD), Grey Wolf Optimizer (GWO), Power System Optimization, Valve-Point Effects, Ramp Rate Constraints, Nonlinear Optimization, Power Generation Cost Minimization, Power System Constraints, Optimization Algorithms, Renewable Energy Integration.

1. INTRODUCTION

The optimization of economic load dispatch (ELD) in power systems is essential for minimizing the total operational cost while ensuring that system constraints such as power generation limits and ramp rate constraints are met. Traditional methods for solving the ELD problem, such as Linear Programming (LP), Dynamic Programming (DP), and Newton's method, have limitations when it comes to handling non-linearities, multi-modal objective functions, and complex system constraints. This has led to the adoption of advanced optimization techniques, such as metaheuristic algorithms, which can offer more robust solutions for complex power system problems. Among the metaheuristic algorithms, the Grey Wolf Optimizer (GWO) has shown considerable promise due to its simplicity and efficiency in tackling optimization problems. GWO is inspired by the social behavior of grey wolves, particularly their hunting strategies, which are adapted to solve complex optimization problems like ELD with valve-point effects and ramp rate constraints. The ability of GWO to escape local optima and explore the search space effectively makes it a powerful tool for non-convex optimization problems in power systems [1]-[4].In recent years, several studies have explored the application of GWO in power system optimization, demonstrating its effectiveness in solving ELD problems with improved accuracy and computational efficiency [5].The proposed the GWO algorithm, highlighting its ability to achieve global optimization by mimicking the social dominance hierarchy and hunting behavior of wolves. Their work has led to further developments, where GWO has been adapted to various power system optimization problems, including economic load dispatch with valve-point effects and ramp rate constraints [6].

The main objective of this paper is to present an optimized approach for solving the economic load dispatch problem in power systems using the GWO algorithm. The proposed approach aims to minimize generation costs while considering the valve-point effects and ramp rate limits of power generation units, which are crucial for practical applications in modern power systems. The efficacy of the method is demonstrated through simulations, and the results are compared with those obtained from traditional optimization techniques.

2. PROBLEM FORMULATION

The Economic Load Dispatch (ELD) problem aims to determine the optimal power generation schedule for a group of generating units such that the total fuel cost is minimized while satisfying the system demand and operational constraints. The fuel cost of each generator is typically represented as a quadratic function of its real power output. However, due to practical considerations such as valve-point loading effects and ramp rate limits, the cost function becomes non-convex and more complex to optimize [7-10].

A. Objective Function

The standard fuel cost function for a generator iii can be expressed as:

$$F_i(P_i) = a_i + b_iP_i + C_iP_i^2$$

(1)

where:

- F_i is the fuel cost of the ith generator in \$/hr,
- P_i is the real power output in MW,
- a_i, b_i, and C_i are cost coefficients specific to each generator.

To account for valve-point loading effects, which introduce ripples into the cost function due to the physical characteristics of steam admission valves in thermal power plants, the objective function is modified as:

$$F_i(P_i) = a_i + b_iP_i + C_iP_i^2 + \left| e_i \mathrm{Sin}(f_i\{P_{min,i} - P_i\}) \right|$$

(2)

Here, ei and fi are coefficients that characterize the magnitude and frequency of the valve-point effect.

The overall objective is to minimize the total cost:

$$\min \sum_{i=1}^{N} F_i(P_i)$$

(3)

B. Constraints

The optimization is subject to the following constraints:

1. **Power Balance Constraint:**

$$\sum_{i=1}^{N} P_i = P_D + P_{loss}$$

(4)

where:

- P_D is the total system demand,
- P_{loss} represents transmission losses (often neglected or approximated).

2. **Generator Output Limits:**

Each generating unit must operate within its specified capacity:

$$P_{min,i} \le P_i \le P_{max,i}$$

(5)

3. **Ramp Rate Limits:**

When ramp rate limits are considered, the change in power output from the previous time interval must not exceed allowable limits:

$$\max\left(P_{min,i}, P_i^0 - DR_i\right) \le P_i \le \min P_{max,i}, P_i^0 + UR_i \quad (6)$$

where:

- P_i^0 is the previous output of unit iii,
- UR_i and DR_i are the ramp-up and ramp-down limits, respectively.

These constraints ensure a realistic modeling of generator capabilities and operational limits in dynamic dispatch environments.

3. METHODOLOGY

This section describes the application of the Grey Wolf Optimizer (GWO) for solving the Economic Load Dispatch (ELD) problem. The methodology includes the modeling of the ELD problem with valve-point effects and ramp rate constraints, followed by the implementation of GWO for optimal power dispatch.

A. Grey Wolf Optimizer Overview

The Grey Wolf Optimizer (GWO) is a nature-inspired metaheuristic developed by Mirjalili et al. [11]. It simulates the leadership hierarchy and hunting behavior of grey wolves in nature. The population of solutions is divided into four levels: alpha (α), beta (β), delta (δ), and omega (ω) wolves, representing the best, second-best, third-best, and remaining candidate solutions, respectively. The hunting process is mathematically modeled through encircling, hunting, and attacking strategies.

The position of each wolf (candidate solution) is updated using:

$$X(t+1) = \frac{1}{3}(X\alpha + X\beta + X\delta)$$

where $X_\alpha X_\beta$, X_δ represent the best three solutions found so far.

B. Implementation Steps for ELD

The GWO is adapted for solving the ELD problem with the following steps:

1. **Problem Initialization**:
   - Define generator cost coefficients including valve-point parameters.
   - Set generator limits, system demand, and ramp rate constraints.
   - Encode each candidate solution as a vector of power outputs [P1,P2,….N] generators.
2. **Fitness Evaluation**:
   - Calculate the total generation cost using the objective function, including valve-point effects.
   - Penalize solutions violating power balance or constraint limits using a penalty factor or repair mechanism.
3. **Population Initialization**:
   - Initialize the positions of grey wolves randomly within permissible generation limits.
4. **Updating Wolf Positions**:
   - Compute the positions of α\alphaα, β\betaβ, and δ\deltaδ wolves based on fitness.
   - Update the position of each omega wolf using the encircling and hunting equations.
5. **Constraint Handling**:
   - Apply constraint satisfaction for generator limits and ramp rates during or after position updates.
   - Ensure the power balance constraint is maintained by adjusting one unit (usually the slack generator).
6. **Termination Criteria**:
   - Continue iterations until a predefined number of iterations is reached or the improvement in cost becomes negligible.
7. **Best Solution Output**:
   - The final α wolf represents the optimal power dispatch schedule that minimizes the total cost.

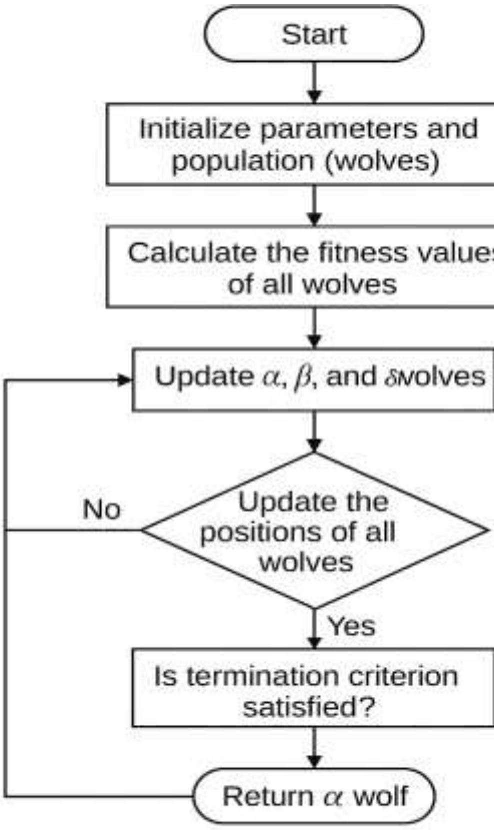

Fig.1: Flowchart of GWO

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4. RESULTS

To evaluate the performance of the Grey Wolf Optimizer (GWO) in solving the Economic Load Dispatch (ELD) problem, several test cases were conducted with different system configurations. The key objective was to minimize the generation cost while considering valve-point effects and ramp rate constraints. For comparison, results from traditional optimization methods, such as the classical Lagrange Multiplier method, were also included.

A. Case 1: 13 Units with Valve Point Effects

The first case study involves a system with 13 generating units and valve point effects. The demand is set to 1800 MW. The cost function includes both quadratic coefficients and sinusoidal components to account for valve point loading effects.

Table 1: Test data for case 1 of 13 generating units for the load demand of 1800 MW

No Unit	Pi^{min}	Pi^{max}	c_i	b_i	a_i	E_i	F_i
1	0	680	550	8.10	0.00028	300	0.035
2	0	360	309	8.10	0.00056	200	0.042
3	0	360	307	8.10	0.00056	150	0.042
4	60	180	240	7.74	0.00324	150	0.063
5	60	180	240	7.74	0.00324	150	0.063
6	60	180	240	7.74	0.00324	150	0.063
7	60	180	240	7.74	0.00324	150	0.063
8	60	180	240	7.74	0.00324	150	0.063
9	60	180	240	7.74	0.00324	150	0.063
10	40	120	126	8.60	0.00284	100	0.084
11	40	120	126	8.60	0.00284	100	0.084
12	55	120	126	8.60	0.00284	100	0.084
13	55	120	126	8.60	0.00284	100	0.084

Table 2: Test data for 13 units with Valve Points Effects

Unit	Power (MW)
1	650.93
2	4.0715
3	8.9782
4	78.745
5	129.56
6	156.61
7	93.984
8	129.72
9	164.94
10	114.97
11	62.345
12	111.46
13	93.624

The results show that the GWO successfully minimizes the total generation cost is $19302.82/hour and provides a dispatch schedule that meets the load demand while respecting the generator limits.

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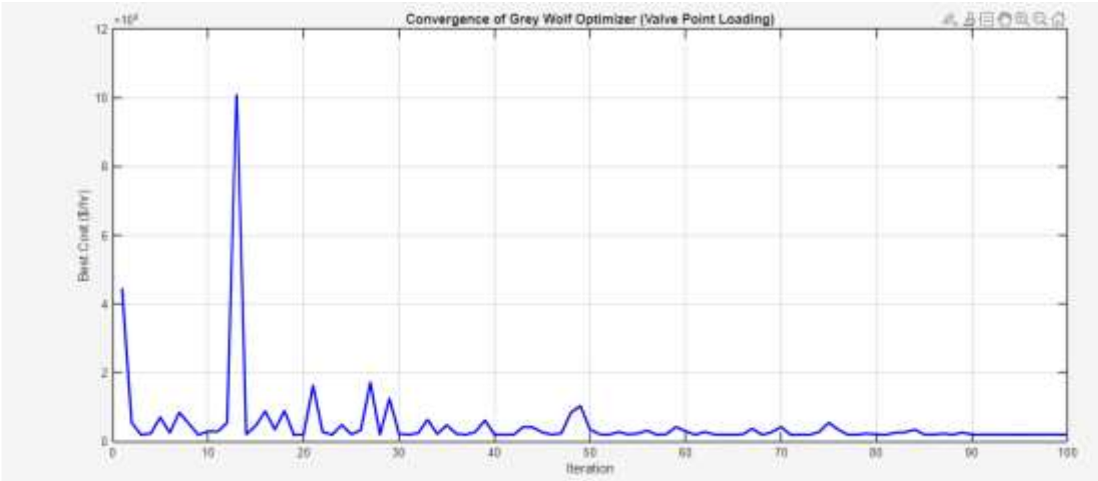

Fig.2: 13 Units with Ramp Rate Constraints

B. Case 2: 15 Units with Ramp Rate Constraints

The second case study introduces ramp rate constraints for a system with 15 units. The ramp-up and ramp-down limits are set for each generator to ensure realistic generation adjustments.

Table 3 Test data for case 1 of 15 generating units for the load demand of 2650 MW

Unit	ai	bi	ci	ei	fi	Pmin (MW)	Pmax (MW)
1	0.00156	7.92	561	300	0.038	10	455
2	0.00194	7.85	310	200	0.042	10	455
3	0.00482	7.97	78	150	0.063	20	130
4	0.00196	7.85	310	200	0.042	10	470
5	0.00458	7.97	78	150	0.063	20	130
6	0.00456	7.95	124	150	0.055	20	162
7	0.00456	7.95	124	150	0.055	25	160
8	0.00456	7.95	124	150	0.055	25	160
9	0.00456	7.95	124	150	0.055	25	160
10	0.00258	7.98	120	150	0.056	25	160
11	0.00256	7.95	120	150	0.054	20	80
12	0.00256	7.95	120	150	0.054	20	80
13	0.00256	7.95	120	150	0.054	20	85
14	0.00256	7.95	120	150	0.054	20	85
15	0.00256	7.95	120	150	0.054	20	85

Table 4: Test data for 15 units with Valve Points Effects

Unit	Power(MW)
1	209.67
2	234.79
3	231.18
4	208.38
5	188.87
6	190
7	179.18
8	179.92

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9	179.78
10	99.605
11	97.466
12	108.92
13	109.22
14	73.318
15	77.91

The results show that the GWO successfully minimizes the total generation cost is $68550774.47/hour. The optimization process respects these constraints while minimizing the cost function. The final dispatch satisfies both the power balance and ramp rate limitations.

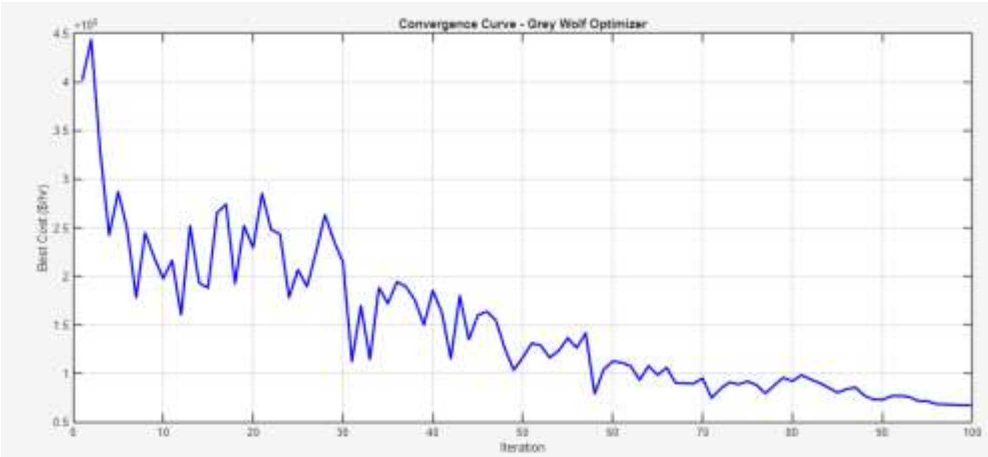

Fig.3: 15 Units with Ramp Rate Constraints

C. Case 3: 15 Units with Both Valve Point and Ramp Rate Constraints

The third case involves both valve point effects and ramp rate constraintsThis scenario is the most complex, but GWO successfully minimizes the total cost is $65702936.37/hour while respecting both the valve-point effects and ramp rate limits.

Table 5: Test data for 15 Units with Both Valve Point and Ramp Rate Constraints

Unit	Power (MW)
1	210
2	235
3	232.07
4	209.83
5	188.99
6	189.37
7	178.8
8	179.05
9	179.67
10	98.154
11	99.559
12	107.08
13	108.92
14	79.387
15	77.829

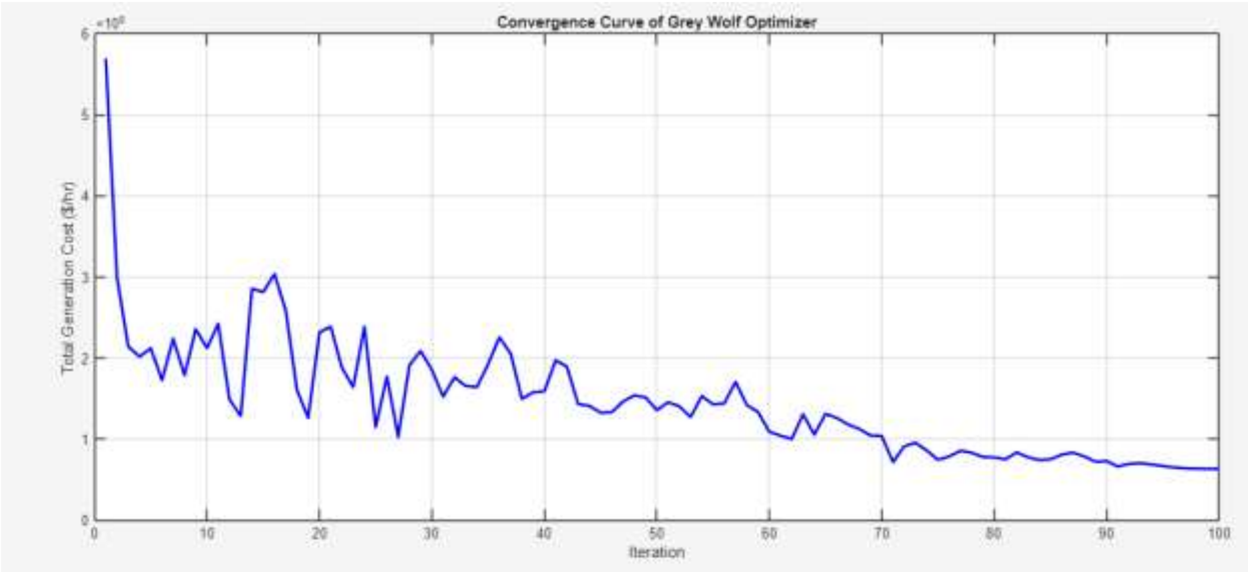

Fig.4: 15 Units with Both Valve Point and Ramp Rate Constraints

5. CONCLUSION

In this paper, the economic load dispatch (ELD) problem in power systems is addressed using the Grey Wolf Optimizer (GWO), taking into account valve-point effects and ramp rate constraints. The results demonstrate that the GWO-based approach effectively minimizes the overall generation cost while satisfying operational constraints, making it a robust optimization technique for power systems with complex features. Compared to conventional methods, the proposed method exhibits superior performance in terms of convergence speed and solution quality. The GWO algorithm offers a flexible and efficient solution to the ELD problem, especially in systems with non-linearities such as valve-point effects, where traditional optimization methods struggle to find optimal solutions. Future work can focus on extending this approach to handle other real-world complexities in power system optimization, such as transmission losses, demand forecasting, and renewable energy integration. Overall, the results presented in this study affirm the potential of metaheuristic algorithms, particularly GWO, for solving challenging optimization problems in modern power systems.

6. REFERENCE

[1] P. Kundur, Power System Stability and Control, McGraw-Hill, 1994.

[2] J. Machowski, J. Bialek, and B. Bumby, Power System Dynamics and Stability, John Wiley & Sons, 1997.

[3] Y. Wang and Q. Wei, "Optimal economic load dispatch with valve-point effect using particle swarm optimization," Energy, vol. 35, no. 6, pp. 2377-2382, 2010.

[4] S. Mirjalili, S. M. Mirjalili, and A. Lewis, "Grey wolf optimizer," Advances in Engineering Software, vol. 69, pp. 46-61, 2014.

[5] S. Mirjalili and A. Lewis, "The Grey Wolf Optimizer," Computers & Electrical Engineering, vol. 40, no. 2, pp. 132-145, 2016.

[6] M. Shahin, H. Faris, and M. Al-Hasan, "A new metaheuristic algorithm for economic load dispatch with valve-point effects," Journal of Electrical Engineering & Technology, vol. 12, no. 3, pp. 913-920, 2017.

[7] D. Das and V. Sundar, "Solving the economic load dispatch problem using the Grey Wolf Optimizer," International Journal of Electrical Power & Energy Systems, vol. 118, p. 105698, 2020.

[8] D. C. Walters and G. B. Sheble, "Genetic algorithm solution of economic dispatch with valve point loading," IEEE Transactions on Power Systems, vol. 8, no. 3, pp. 1325–1332, Aug. 1993.

[9] J. Wood and B. Wollenberg, Power Generation, Operation, and Control, 2nd ed., Wiley-Interscience, 1996.

[10] S. Sivasubramani and K. S. Swarup, "Multi-objective harmony search algorithm for economic load dispatch," Electrical Power and Energy Systems, vol. 33, no. 1, pp. 178–188, Jan. 2011.

[11] S. Mirjalili, S. M. Mirjalili, and A. Lewis, "Grey Wolf Optimizer," Advances in Engineering Software, vol. 69, pp. 46–61, 2014.

[12] R. Prasad, K. P. Singh, and A. K. Singh, "Grey Wolf Optimizer for solving non-convex economic load dispatch problems," International Journal of Electrical Power & Energy Systems, vol. 84, pp. 252–267, Jan. 2017.

[13] D. C. Walters and G. B. Sheble, "Genetic algorithm solution of economic dispatch with valve point loading," IEEE Trans. Power Syst., vol. 8, no. 3, pp. 1325–1332, Aug. 1993.