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UTILIZING OPTIMIZATION TECHNIQUES FOR POWER SYSTEM ECONOMIC SCHEDULING

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Abstract – *The cost associated with generating electrical energy varies among power plants, influenced by the energy source and the emissions produced. Due to these operational cost differences, economic dispatch techniques that consider emissions are commonly employed to optimize power systems, aiming to minimize both operational costs and pollutant emissions. The continual increase in electric power generation, driven by global economic development, has led to a significant rise in greenhouse gas emissions. This surge in electrical generation, primarily fueled by coal (accounting for 42% of global electricity generation), contributes to environmental issues such as global warming, ozone layer depletion, and air pollution. The heavy reliance on fuel for electricity generation results in elevated costs, attributed to expenses incurred by generation companies for emissions fees and fuel procurement. This study addresses these challenges by implementing an advanced approach, utilizing the developed Moth Flame Optimization and Bat hybrid algorithm.*

Keywords – Power system, economic dispatch, optimization methods, scheduling, operational constraints, output allocation.

1. INTRODUCTION

Power system economic dispatch is a crucial problem in the operation and control of power systems. It involves determining the optimal allocation of power output from available generating units to meet the load demand while minimizing the total operating cost. Optimization methods play a vital role in solving economic dispatch problems to achieve efficient and cost-effective power generation.

Optimization Methods

Several optimization methods are applied to solve power system economic dispatch problems. These methods include:

Linear Programming (LP): LP is a widely used optimization technique for economic dispatch. It formulates the economic dispatch problem as an objective function subject to linear constraints. LP provides a computationally efficient method for solving economic dispatch with good accuracy.

Nonlinear Programming (NLP): NLP techniques are employed for economic dispatch problems that involve non-convex cost functions and nonlinear constraints. Methods such as gradient-based

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algorithms, interior-point methods, and genetic algorithms are used to solve NLP formulations of economic dispatch.

Particle Swarm Optimization (PSO): PSO is a metaheuristic optimization technique inspired by social behavior of birds or fish. It has been successfully applied to economic dispatch problems due to its ability to handle non-convex and non-smooth cost functions.

Genetic Algorithms (GA): GA is a population-based stochastic optimization method that mimics the process of natural selection. It is effective in solving economic dispatch problems with non-convex and non-linear characteristics by searching for the global optimal solution.

Mixed-Integer Linear Programming (MILP): MILP techniques are used for economic dispatch problems that involve discrete variables such as binary valve status of generating units. MILP formulations are beneficial for incorporating binary constraints into the economic dispatch model.

Benefits of Optimization Methods

The application of optimization methods for power system economic dispatch offers several benefits:

Cost Reduction: By minimizing the total operating cost, optimization methods help power system operators in reducing the expenses associated with power generation.

Efficient Resource Allocation: Optimization methods enable the optimal allocation of power output from generating units, leading to efficient utilization of available resources.

Environmental Impact: Optimally dispatched power generation can contribute to reducing environmental impact by minimizing fuel consumption and emissions.

Improved System Performance: By achieving the optimal solution, power system economic dispatch through optimization methods enhances the overall performance and stability of the power system.

2. LITERATURE REVIEW

The Across the globe, the electric energy generation sector is facing the challenge of high cost of electric generation due to high fuel cost and emission charges. Emissions charge is normally charged to generation companies based on the amount of emissions generated by the concerned plant, thus the higher the amount of emissions generated the higher the emission charges and vice versa is true [1]. Also, industrial products which are basic needs to human being such as food products, clothes and building materials like cement i.e. are expensive since its' production cost is high due to high price of electricity which is the essential energy for manufacturing industries [2]. Some governments have opted to subsidize the electric generation cost so as to provide some relief to their citizen [3].

As a result of this approach, most of those governments are carrying the huge burden and spending a lot of government funds in subsidization of energy sector instead of being invested into other sectors such as health, water, agriculture i.e. which are still behind especially in developing countries. A number of researches have been done in this area by using different approaches with the aim of reducing the cost of generating electric power and emissions, though the cost of power generation is still high as well as the emissions are still increasing year after year [4], [5]. In this study, Moth Flame Optimization and Bat hybrid algorithm is used to mitigate the high cost of generating electric power facing the energy sector with the consideration of reducing the amount of emissions from thermal power plants

Each generator normally has its own cost function depending on its characteristics. Due to different cost functions among generators, the operating cost tends to differ between the generators. As a result of different operating costs between the generators, the economic dispatch techniques are normally applied so as to minimize the overall cost of generation when operating with more than one power plant of the system [6].

Economic dispatch considering emission as the objective function which harmonizes the conflict of the two objective functions which are economic load dispatch and emissions dispatch [26]. The main focus of the economic dispatch considering emissions is to minimize the cost of fuel while taking into account the emissions being released by the generating stations. In this, the fuel cost optimization is constrained by emission dispatch objective function [7]

In this algorithm, each bat's position represents the solution of the optimization problem and the solution tend to improve as the bat approaches its target/prey. The solution is updated by the factor of velocity as the number of iteration increases. Sometimes the obtained solution is poor as compared to the previously obtained solution. In this case, the previous solution is retained for the next iteration [8].

By using PSO the economic dispatch considering emissions was solved in [9], the IEEE30 bus test system was used as the benchmark. Random Drift Particle Swarm Optimization (RDPSO) which is the novel algorithm derived from PSO and Conventional Lambda technique was used for proposing the better algorithm. In [10], the Improved Artificial Bee Colony (ABC) was used for performing the economic dispatch, but the issue of environmental dispatch was not considered. Also, the ABC method has a weakness of convergence speed.

In [11] a novel Moth Flame Optimization(MFO) algorithm was implemented for solving economic dispatch considering emissions with consideration of valve point effect. The constraint which was considered for the case of equality constraints was power balance constraints and the inequality constraint was generator power output limits. In this study, the IEEE-30 bus test system was used as the benchmark for validation of the results, and three conditions of dispatching considered are economic dispatch, emission dispatch and combined economic and emission dispatch. The concept of hybridization of algorithms was used in [12] whereby PSO and Artificial Neural Network were hybridized for performing the economic dispatch considering emissions. In the developed hybrid algorithm the ANN was used for training the PSO, the 27 hybridized algorithm was implemented in IEEE-30 bus system where developed hybrid was compared with other kinds of algorithms such as classic technique, Quadratic programming, Evolutionary programming and Genetic algorithm. In all cases the developed hybrid results where superior to single algorithm optimization. However, in this study the valve point effect consideration was not accounted.

METHODOLOGY

PROBLEM FORMULATION:

The objective of the economic load dispatch problem is to minimize the total fuel cost.

$$\text{Min } F_T = \sum_{n=1}^{N} Fn$$

$$\text{Subject to } P_D + P_L = \sum_{n=1}^{N} Pn$$

economic load dispatch neglecting losses[3] lagrangian multiplier (lambda-iteration method:

$$F = F_T + \lambda(P_D - \sum_{n=1}^{N} Pn)$$

Where □□is the Lagrangian Multiplier.

Differentiating F with respect to the generation Pn and equating to zero gives the condition for optimal operation of the system

Since FT=F1+ F2………..+FN

Therefore the condition for optimum operation is

dF1/dP1 = dF2/dP2=…………= dFn/dPn

The incremental production cost of a given plant over a limited range is represented by dFn/dPn =FnnPn + fn

Fnn= slope of incremental production cost curve fn= intercept of incremental production cost curve

The active power generation constraints are taken into account while solving the equations which are derived above. If these constraints are violated for any generator it is limited to the corresponding limit and the rest of the load is distributed among the remaining generator units according to the equal incremental cost of production.

3.1ELD WITH LOSS

The optimal load dispatch problem including transmission losses is defined as

Min FT =∑N Fn

Subject to PD + PL - ∑N Pn

Where PL is the total system loss which is assumed to be a function of generation Making use of the Lagrangian multiplier λ, the auxiliary function is given by

F=FT +λ (PD +PL -∑NPn)

The partial differential of this expression when equated to zero gives the condition for optimal Load dispatch, i.e.

$□F/□P_n□□F_T□□□□P_L/□P_n$

$dF/dP_n+□*□P_L/□P_n=□$

Here the term

PL / Pn is known as the incremental transmission loss at plant n and λ is knownas the incremental cost of received power in Rs.per MWhr. The above equation is a set of n equations with (n+1) unknowns ie. 'n' generations are unknown and λ is unknown. These equations are also known as coordination equations because they coordinate the incremental transmission losses with the incremental cost of production.

To solve these equations the loss formula is expressed in terms of generations as

$P_L= □_m□_n P_m B_{mn} P_n$

Where Pm and Pn are the source loadings, Bmn the transmission loss coefficient.

$□P_L/□P_N□2□B_{mn}P_m$

Also dFn/dPn=FnnPn+fn

∴ The coordination equation can be rewritten as

$F_{mn}P_n□f_n□□□2B_{mn}P_m□□$

SolvingforP$_n$weobtain

P_n =(1-f$_n$/□*□ 2$B_{mn}P_m$) /(F$_n$/□+2B$_{nn}$)

When transmission losses are included and coordinated, the following points must be kept in mind for economic load dispatch solution

1.Whereas incremental transmission cost of production of a plant is always positive, the incremental transmission losses can be both positive and negative.

2.The individual generators will operate at different incremental costs of production.

The generation with highest positive incremental transmission loss will operate at the lowest incremental cost of production

FORMULATION OF PSO:

PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called g-best. After finding the two best values, the particle updates its velocity and positions according to the following equations.

$$V_i^{(u+1)} = w * V_i^{(u)} + C_1 * rand(\ ) * (pbest_i - P_i^{(u)}) + C_2 * rand(\ ) * (gbest_i - P_i^{(u)})$$

$$P_i^{(u+1)} = P_i^{(u)} + V_i^{(u+1)}$$

In the above equation,The term rand ( )*(pbesti - Pi (u)) is called particle memory influence The term rand ( )*(gbesti -Pi (u)) is called swarm influence.

In the above equation, C1 generally has a range (1.5,2) which is called as the self-confidence range and C2 generally has a range (2, 2.5) which is known as the swarm range. Vi (t) which is the velocity of the ith particle at iteration 'i' should lie in the pre-specified range (Vmin,Vmax). The parameter Vmax determines the resolution with which regions are to be searched between the present position and the target position. If Vmax is too high, particles may fly past good solutions. If Vmax is too small particles may not explore sufficiently beyond local solutions. Vmax is often set at 10-20% of the dynamic range on each dimension. The constants C1 and C2 pull each particle towards pbest and gbest positions. Low values allow particles to roam far from the target regions before being tugged back. On the other hand, high values result in abrupt movement towards, or past, target regions. Hence the acceleration constants C1 and C2 are often set to be 2.0 according to past experiences.

The inertia constant can be either implemented as a fixed value or can be dynamically changing. This parameter controls the exploration of the search space. Suitable selection of inertia weight 'ω' provides a balance between global and local explorations, thus requiring less iteration on average to find a sufficiently optimal solution. As originally developed, ω often decreases linearly from about 0.9 to 0.4 during a run. In general, the inertia weight w is set according to the following equation,

$$W = W_{max} - \left[\frac{W_{max} - W_{min}}{ITER_{max}}\right] * ITER$$

Where W -is the inertia weighting factor Wmax - maximum value of weighting factor

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Wmin - minimum value of weighting factor ITER – Current iteration number ITERmax-Maximum iteration number.

4. RESULT

In CASE STUDY- 2: Six Unit System

The fuel cost in Rs./h of three plants of a power system are

□

□

C1 = 756.79886+38.53+0.15240 Rs/h

□

C2 = 451.32513+46.15+0.10587 Rs/h

□□

C3 = 1049.9977+40.39+0.02803 Rs/h

□

C4 = 1243.11+38.30+0.03546 Rs/h

□

C5 = 1658.5596+36.32+0.02111Rs/h

□

C6 = 1356.6592+38.27+0.01799Rs/h

The operating ranges are

10 MW ≤≤ 125 MW

10 MW ≤≤ 150 MW

35 MW ≤≤ 225 MW

35 MW ≤≤ 210 MW

130 MW ≤≤ 325 MW

125 MW ≤≤ 315 MW

Table 5.2

B-Coefficient (in the order of 10^{-4})

□

$$B_{mn} = \begin{bmatrix} 1.40 & 0.17 & 0.15 & 0.19 & 0.26 & 0.22 \\ 0.17 & 0.60 & 0.13 & 0.16 & 0.15 & 0.20 \\ 0.15 & 0.13 & 0.65 & 0.17 & 0.24 & 0.19 \\ 0.19 & 0.16 & 0.17 & 0.71 & 0.30 & 0.25 \\ 0.26 & 0.15 & 0.24 & 0.30 & 0.69 & 0.32 \\ 0.22 & 0.20 & 0.19 & 0.25 & 0.32 & 0.85 \end{bmatrix}$$

Result through PSO method

The following PSO parameters are considered

Population size = 100

Inertia weight factorω = 0.9 and = 0.4

Acceleration constant c1= 2 & c2 = 2

 $Vpd^{max} = 2Pd^{max}$, $Vpd^{min\ x} =- 2Pd\text{-}^{max}$

Table1 Result through PSO method

S. No.	Load Demand(MW)	P_1 (MW)	P_2 (MW)	P_3 (MW)	P_4 (MW)	P_5 (MW)	P_6 (MW)	Fuel Cost(Rs/h)
1	600	21.1801	10	82.0887	94.372	205.3665	186.9924	31145.65
2	700	24.9626	10	102.664	110.6361	232.6865	219.0505	36003.17
3	800	28.7452	10	123.2393	126.9002	260	251.1085	40676.02
4	900	32.4969	10.8159	143.6467	143.0316	287.1036	282.9050	45464.15
5	1000	36.0840	15.982	163.159	158.4555	313.0122	313.3070	50362.48

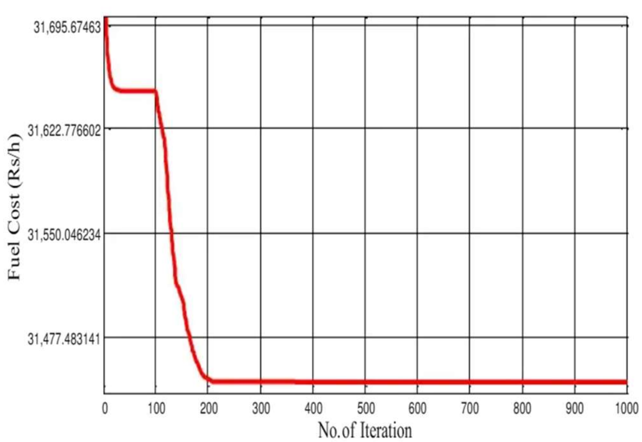

Fig 1 Fuel cost curve without transmission loss for 600 MW load demand

In this figure, fuel cost is converged at 31145.65 Rs/h for 600 MW power demand. Heretransmission losses are neglected. There are 1000 numbers of iteration is taken

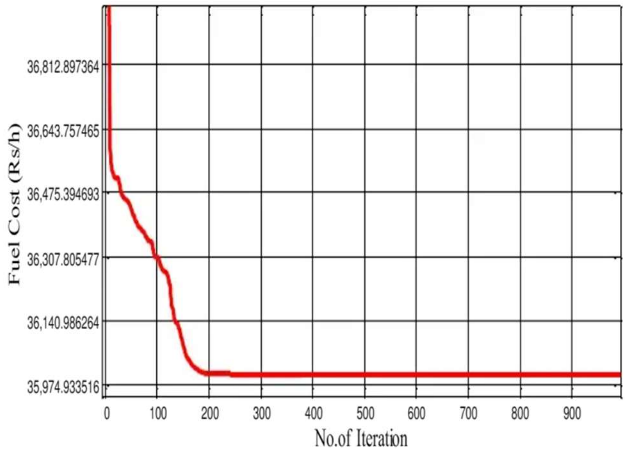

Fig 2 : Fuel cost curve without transmission loss for 700 MW load demand

CONCLUSION

.PSO method was employed to solve the ELD problem for two cases one three unit system and another six unit system. The PSO algorithm showed superior features including high quality solution, stable convergence characteristics. The solution was close to that of the conventional method but tends to give better solution in case of higher order systems. The comparison of results for the test cases of three unit and six unit system clearly shows that the proposed method is indeed capable of obtaining higher quality solution efficiently for higher degree ELD problems. The convergence characteristic of the proposed algorithm for the three unit system and six unit system is plotted. The convergence tends to be improving as the system complexity increases. Thus solution for higher order systems can be obtained in much less time duration than the conventional method. The reliability of the proposed algorithm for different runs of the program is pretty good, which shows that irrespective of the run of the program it is capable of obtaining same result for the problem. Many non-linear characteristics of the generators can be handled efficiently by the method. The PSO technique employed uses a inertia weight factor for faster convergence. The inertia weight is taken as a dynamically decreasing value from Wmax to Wmin at and beyond ITER max. The convergence characteristic of the method for varying ITERmax was analyzed. Values of ITERmax between 1000-2000 give better convergence characteristic, so the value of 1500 is used for optimum results.

PSO algorithm can be combined with other simple optimization techniques to improve their performance when applied to ELD problems and obtain better results Bus Data and Line Data of the system can be taken as input along with the load demand to obtain the minimization function with constraints on voltage and reactive power at various points of the system.

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