Evaluating Economic Dispatch Problem by Hybrid Particle Swarm Optimization Algorithm for Thermal Generating Units

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Abstract— The modern power system around the world has grown in complexity of interconnection and power demand. The focus has shifted towards the enhanced performance, increased customer focus, low cost, reliable and clean power. In this changed perspective, scarcity of energy resources, increasing power generation cost, environmental concern necessitates optimal economic dispatch. In reality power stations neither are at equal distances from load nor have similar fuel cost functions. Hence for providing cheaper power, load has to be distributed among the various power stations in a way which results in lowest cost of generation. Practical economic dispatch (ED) problems have highly non-linear objective function with equality and inequality constraints. Conventional methods such as lambda iteration method and gradient method have been applied to solve the Economic Load Dispatch (ELD) problem. However, this techniques don't give optimal solution because they require incremental fuel cost curves which are piecewise linear and monotonically increasing to find the global optimal solution. Artificial Intelligent (AI) techniques like Particle Swarm Optimization (PSO) method do give optimal solution. PSO is applied to allocate the active power among the generating stations satisfying the system constraints and minimizing the cost of power generated. In present work, GLSPSA is proposed for solving ELD problems. The efficiency and effectiveness of the proposed technique is benchmarked for test case of three generating units. The results of the GLSPSA compared with that of other intelligence algorithms.

Key words: Economic Dispatch, Thermal Generating units

I. INTRODUCTION

To get better production in power system, this is the requirement to understand the roots of system failure and faults. There are major failure issues like underground cable, tree contact, transformer failure, lightning in electrical system. Any problem occur in power system manifested in current ,voltage or frequency deviations that results in failure of electrical equipment. Some electronic equipment are becoming an integral part of power supply disturbances which make effects with some of the other equipments to produce the distorting harmonics. Most elements of the electric power industry such as power generation, bulk power sales, capital expenditures heavily regulated either at state level or national level. These problems meant new challenges in electric power industry otherwise it may be secure, economical and reliable. Power system optimization is a wide set of interrelated concepts on calculating ,applying and maintaining physical resources for the electricity generation ,transmission and distribution in which the production cost is minimized without sacrificing the quality of product. Power system planning and operation problems have formulated as mathematical optimization problem. Such problems as the economic dispatch , hydrothermal unit commitment and dispatch , maintenance scheduling have formulated The most important plan here is to reduce the production cost while maintaining the varying load demand at any time of the day. Economic Load Dispatch focus upon the coordination of the production cost by proper scheduling of all power plants operating on the system. The power generation must vary according to the load demand, which may vary with season. It is therefore illogical to suppose that the same level of power must be generated at all time. Therefore the economic operation gave the explanation of the load condition at all times. There is a need of method which calculates the total generating cost of all the units which supplying a load. Conventional methods are like linear programming, newton method, gradient method, mixed –integer programming ,quadratic programming , newton flow programming developed to evaluate the ED problems. These methods fails due to their convergence characteristics. So, Intelligence search and non-quantity methods such as neural network, evolutionary algorithms, tabu search, particle swarm optimization, fuzzy set applications , analytic hierarchical process are used to solve ED problems. Many of these methods are inspired by swarm behaviour in nature. Optimization problems requires high-dimensional search space, the conventional optimization algorithms do not give a appropriate solution because the search space increases exponentially as according to the size of problem, therefore solving these problems by using intelligence swarm behaviour. The gravitational search algorithm is a novel heuristic optimization method based on mass interaction and law of gravity. This algorithm has good ability to search the global best solution , but it suffer the slow searching speed in the last iterations. The goal is to find the global best outcome among all the possible inputs. Two main characteristics are required for global best outcome exploration and exploitation. Exploration is the skill of an algorithm to search whole parts of problem space whereas exploitation is the ability to give best solution. So , there is a new hybrid model presents which combines the PSO and GSA algorithms named as PSOGSA. Some standard test functions are used to compare the hybrid algorithm with some other techniques.

II. PROBLEM FORMULATION

The ED problem may be expressed by reducing the fuel cost of generating units subjected to various constraints. Intelligent methods are used iterative techniques that can search local optimal solutions, as well as global optimal solution depending upon the problem domain and the execution time limit. There are various aspiration exploring techniques founded on the principles inspired from the genetic and evolutionary mechanisms which observe natural systems and populations of living beings. These methods retain the advancement of penetrating the answer space more extremely. The main problem is their sensitivity to the selection of parameters with all intelligent methods, neural network is simple and promising. It take less computing instant and memory. It has also normal values for its parameters. As the load demand varies , the power generation has to be adjusted to match the balance between loads and generation of a power system. The ED model consists of n generating units online.

A. Detailed Information Of Three Thermal Units:

The case study incorporates three generating units. The coefficients of fuel cost (objective function) a , b and c of respective thermal units 1 ,2 and 3 and the minimum and maximum limits of the respective generating units in(MW) while satisfying the equality and inequality constraints imposed to the system are shown in table . In this case the load demand expected (Pd) to be determined as 150MW.

The ED problem can be expressed as.

1) Fuel Cost Model:

$C(P_{Gi})=\Sigma(a_i*P_{Gi}^2+ b_i*P_{Gi} +c_i)$Rs where i=1…..N(a,b,c are cost coefficients)

2) Power Balance Constraints:

$\Sigma P_{Gi}-P_D-P_L=0$(Power Generation=Power Demand+ Power Losses)

$P_{Gi,min}\leq P_{Gi}\leq P_{Gi,max}$ where i=1,2……N(Limits of Power Generation)

3) Total Operating Cost Minimization:

Total Operating Cost=C

Unit	a($/MW2)	b($/MW)	c($)	PG_{min}(MW)	PG_{max}(MW)
1	0.008	7	200	10	85
2	0.009	6.3	180	10	80
3	0.007	6.8	140	10	70

Table 4.1: Fuel cost (Rs/h) equations

The purpose of the economic load dispatch problem in electrical power system is to schedule the outputs of committed generating units to meet the consumer load demand at a minimal operating cost, satisfying the equality and inequality constraints imposed to the system.

The economic dispatch for the operation of electrical units is described by a multi-objective mathematical programming problem, which consists of minimizing the function that determines the fuel cost (objective function), finding an optimal generation profile, subject to satisfy the load power and the technical limits of operation of the groups.

III. Gravity Inspired Partiicle Swarm Optimization

The idea for the hybridization of gravity inspired particle swarm optimization is to join the strength of the social thinking factor of particle swarm optimization , combine with the limited search power of gravity based local search algorithm.

This algorithm accepts the agents as objects and the position of ith agent is given by:-

$X_i = (x_i^1 \ldots\ldots x_i^g \ldots\ldots\ldots\ldots x_i^n)$

where i=1…………………………N

Where x_i^g is the location in the gth dimension of the ith agent. The masses are obtainable randomly .

Let the force acting on mass i from the mass j is given as:-

$$F_{ij}^d = G(t) * (M_i(t)*M_j(t))/R_{ij}+\Omega * (X_j^d(t)- X_i^d(t))$$

Where $M_j(t)$ and $M_i(t)$ are the masses of the agents i and j at a time t, G(t) is the gravitational constant at a time t, $R_{ij}(t)$ is distance between i and j objects or the Euclidean space , Ω is a small constant.

The is represented as the given below:

$$R_{ij}(t)=\|X_i(t),X_j(t)\|_2$$

Gravitational constant G (t) is initialized in the arbitrary fashion in the preliminary and is decremented over the period time to organize and outcomes the search precision.

$$G(t)=G_o\, e^{\alpha t/T}$$

where G is gravitational constant which is the function of time "t" and the initial value G_0, where G_0 is the original value of gravitational constant, T is the maximum number of the iterations ,α is the user constant and t is the current iteration.

Supposed the total force acting on agent i in the dimension d is obtainable as :-

$$F_i^t(t) = \sum_{j=1,j\neq 1}^{N} rand_i\, F_{ij}^d(t)$$

where, randj is a random number between the interval [0, 1].

The acceleration of ith agent at iteration t having d dimension is given by the law of motion:-

$$\alpha c_i^d(t)=F_i^d(t)/M_i(t)$$

The velocity of an agent is evaluated as:-

$V_i^d(t+1)=w.v_i^d(t)cj$ x rand x $c_i^d(t)+c_2$ x rand x $(gbest-x_i^d(t))$

Where $v_i^d(t)$ is the velocity of the agent i at iteration t in dimension d, cj´ is a weighting factor, w is a weighting function, rand is a random number between 0 and 1, αc_i^d (t) is the acceleration of ith agent at the iteration t in dimension d and gbest is the best result found till now.

At each, iteration the location of an agent is evaluated as:-

$$x_i^d(t+1)= x_i^d(t) +V_i^d(t+1)$$

Where v_i^d (t+1) is the velocity of next agent and x_i^d is the position of ith agent in dth dimension at iteration t. The value of masses of agents are evaluated by the comparison of fitness:-

$$m_i(t)=currentfitness_i(t)- \quad 0.99*worst(t)/(best(t)-worst(t)$$

$$M_i(t)=m_i(t)*5/\sum_{j=1}^{n} m_j(t)$$

Where the current-fitness $M_i(t)$ is the fitness value of the mass i at any time t and best (t) and worst (t) are the least and the highest fitness value of all the agents. The agents browsing in the search space which are occupied towards the other agents by means of the gravity of force and pushes a run to the agents which are having the heavier mass. The heavier mass expresses a good solution.

Here the Gbest assists them in calculating the global optimal result. The optimal solution gets by using the exploitation ability of particle swarm optimization.

IV. Economic Dispatch Formulation Using GLSPSA

A. Variables:

Power generation of the generators and the cost coefficients (a,b,c) of the units with the objective function as the fuel cost , quadratic in nature. Power generation (Pg) , the variable should be initialized as the initial point for the initial result in GLSPSA.

B. System Constraints:

1) Equality Constraints:

Power generation(P_G)= Power demand(P_d) + Power losses (P_l)

$$(P_G-P_d -P_l=0)$$

2) In-Equality Constraints:

Power generation (Pg) should be between the minimum and maximum limit of power generation. Variables in constraints should be integrated in gravity inspired particle swarm algorithm (GIPSA).

C. Stopping Criteria:

It is the highest generation limit for the optimum result. Simulation flow

V. SIMULATION FLOW

A. Step1: Feasible Boundary Position

Agents are arbitrarily initialized and located between the minimum and maximum operating limits of the generators. Each agent should be satisfy with the system constraints.

B. Step 2: Objective Function

This evaluates fitness for each agent while constraints are satisfied. Update G and Gbest for the population.

C. Step 3: Force Evaluation

Total force acting on agent i in different dimensions is evaluated.

D. Step 4: Evaluation of Acceleration and Mass of an Agent

The acceleration of ith agent in d dimension is solved and mass is calculated.

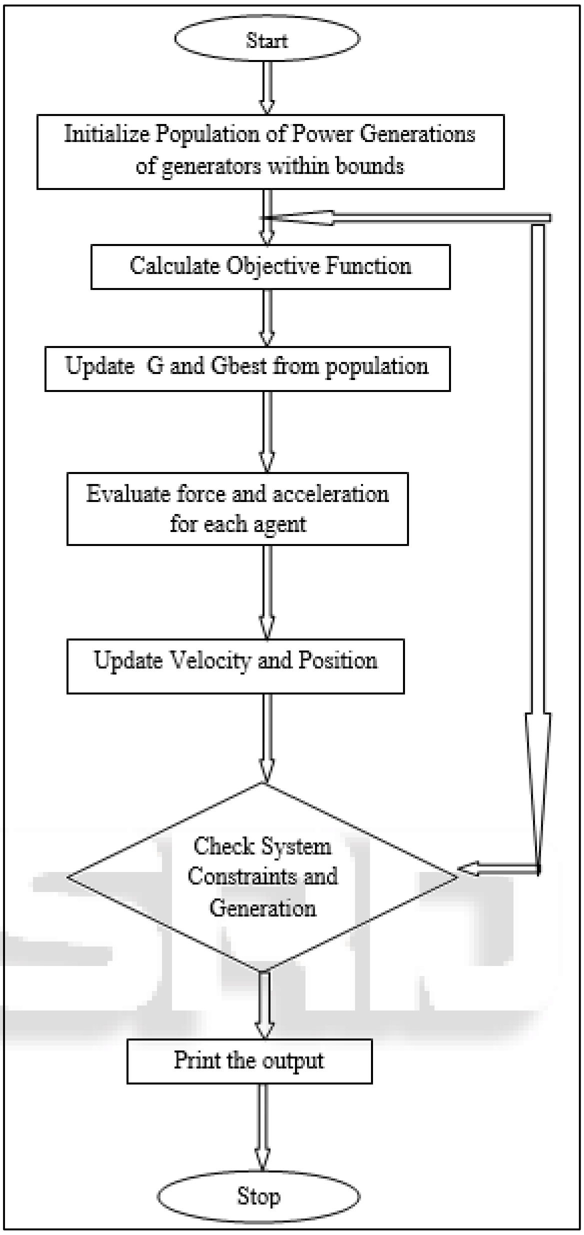
E. Step 5: Update Position and Velocity of Every Agent

The next velocity of agent is calculated and position is updated

F. Step 6: Finishing Criteria

Repeat process 2 to 5 until maximum number of iterations is reached.

VI. DESIGN AND FORMULATION OF GLSPSA



This paper presents a new approach to address practical ED issues. Economic load dispatch in electric power sector is an important task, as it is required to supply the power at minimum cost which aids in profit-making. Power crisis is one of the major issues of concern all over the world today.

A new approach to the solution of ED using particle swarm optimization with gravitational search algorithm has been proposed , the solution time as well as the quality is greatly improved. Hybrid PSO (GLSPSA) method was successfully employed to solve the ELD problem. The generation limits and demand is considered for practical use in the proposed method. The comparison of results fuel cost of three generating units shows that the PSOGSA method was indeed capable of obtaining high quality solution efficiently for ELD problems

GSA (Global search algorithm), FA(firefly algorithm), ABC(artificial bee colony), CS(cuckoo search) and GLSPSA (gravity local search particle swarm algorithm) modern meta –heuristics techniques used for Economic dispatch problems. The results obtained by all these techniques without considering the GLSPSA are quite poor . Total fuel cost in($/hr) and power generation in MW of respective units are obtained . The results fuel cost is compared among the various techniques as given below in table . The fuel cost quite be less then the economic problems will be solved, this can be done by controlling the power generation of respective units.

The results of hybrid PSO (PSOGSA) technique are compared with GSA (Global search algorithm), FA (firefly algorithm), ABC (artificial bee colony), CS (cuckoo search). All the techniques are used to find out the fuel cost or the generating cost and results are obtained among the various techniques and are compared further on three thermal units. In this table three thermal unit like PG1 power generation of unit 1, PG2 power generation of 2 and PG3 power generation of 3 in MW. The generating cost is in $/hr and are compared among the various techniques. As a result, the lowest and required fuel cost is preferred. The fuel cost obtained by GLSPSA is efficient.

Parameters	GLSPSA	CS	ABC	FA	GSA
PG1 (MW)	45.5201	33.490	33.049	32.729	34.51
PG2 (MW)	55.7065	64.116	61.764	63.843	62.74
PG3 (MW)	50.7734	55.126	57.872	56.151	58.92
Cost ($/hr)	1541.1	1600.46	1600.51	1600.47	1600.56

Table 5.1: result of comparison of fuel cost

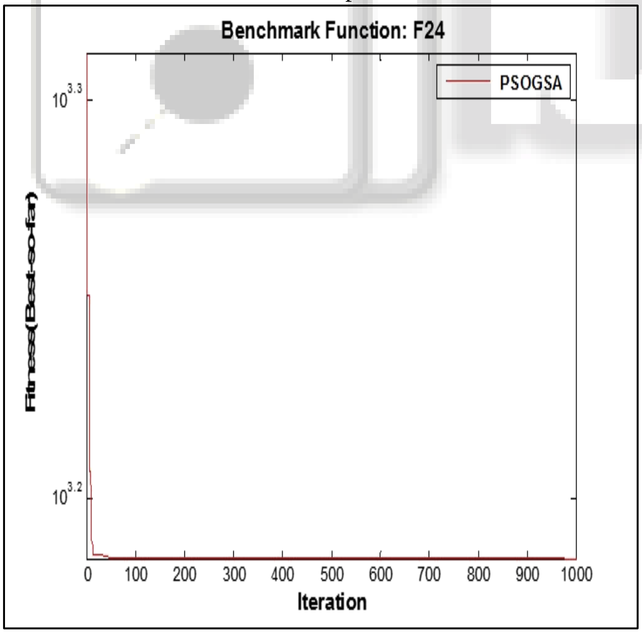


Fig. 5.2: Convergence characteristics of thermal unit system

Benchmark_Function_ID =24
gBestScore = 1.5310e+03
gBest = 17.6364 67.2614 67.1022
GlobalBestCost = 1.0e+03*

Benchmark function is used to test the results with other techniques. In this thesis benchmark id is considered as 24. gBestScore is used for the global best total operating cost . gBest is best power generation of the generator respectively.

VII. CONCLUSION

This presents a new approach to address practical ED issues. Economic load dispatch in electric power sector is an important task, as it is required to supply the power at minimum cost which aids in profit-making. Power crisis is one of the major issues of concern all over the world today. The production is not enough to meet the demands of consumer. Under these circumstances the power system should be efficient in Economic Load Dispatch which minimize the generating cost.

A new approach to the solution of ED using particle swarm optimization with gravitational search algorithm has been proposed, the solution time as well as the quality is greatly improved. Hybrid PSO (GLSPSA) method was successfully employed to solve the ELD problem. The generation limits and demand is considered for practical use in the proposed method. The comparison of results fuel cost of three generating units shows that the PSOGSA method was indeed capable of obtaining high quality solution efficiently for ELD problems.

The convergence is good since the algorithm takes few numbers of iterations to converge hence less computation time. The power loss and fuel cost are observed to vary linearly with load demand The reliability of the algorithm for different runs of the program is highly reliable, implying that irrespective of the runs of the program it is capable of obtaining same result for the problem. PSOGSA is thus an effective method in solving economic load dispatch problem since it works with progressive improvement and it has the advantage of converging to a global point.

The proposed technique has been demonstrated by three unit system and proven to have superior features, including high quality solutions, stable convergence characteristics and good computational efficiency. The convergence to a global point leads to cost savings and hence profits maximization. The algorithm thus, is relatively simple, reliable and efficient hence suitable for practical applications.

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