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Single Area Unit Commitment Optimization Using Pattern Search

Prof. Vikrant Sharma[*], Navpreet Singh Tung[**], Arsh Batish[***] ,Harmandeep Singh[***]

*Associate Professor,**Assistant Professor,***Research Scholars

Department of Electrical and Electronics Engineering

CT Group of Institutions

Jalandhar, India

Abstract: Unit commitment optimization algorithms for the minimization of objective function subjected to various linear and non linear constraints are extensively used in electrical power system planning. The direction of unit commitment algorithm will be economical and robust when the criteria is to evaluate the algorithm in multi-objective and multi-constrained environment in terms of convergence criteria, computation time, memory usage ,avoiding local minima trap and obtain global minima, cost minimization for unit commitment problem satisfying various constraints like load demand, voltages limits, power generations, spinning reserves within defined range and minimize operating cost without effecting the system. An approach for solving unit commitment based on algorithm of Pattern Search has been proposed to generate robust and optimal solution. A Pattern Search based algorithm is developed to establish relationship among various parameters subjected to the satisfaction of different constraints like generation limits and power generation is equal to power demand for the generation of robust solution.

Keywords: Fuzzy logic(FL), Unit-commitment(UC),Economic Dispatch(ED),Load Demand(LD)

NOMENCLATURE

N	Number of units
PD	Power Demand
PGmax	Maximum limit of Unit
PGmin	Minimum Limit of Unit
IC	Incremental Cost
PG	Power Generation
OC	Operating Cost
C	Total Cost

I. LITERATURE BACKGROUND

A. Genetic based Hybrid Algorithms

Christober C. et al[5] coined an algorithm based on genetic algorithm to minimize the total operating cost.It uses standard reproduction, cross over and mutation operators for the optimization . Ganguly D. et al[9] proposed a new genetic approach based on parallel system to handle impossible solution in an organized fashion for thermal unit commitment.Jenkins L.[13] implemented four hybrid algorithms based on simulated annealing, local search, tabu search, dynamic programming and genetic algorithms and compared the cost with earlier literature .Liao G.C. and Tsao T.P.[18] introduced hybrid algorithm based on fuzzy logic, tabu search and genetic algorithm to solve short term unit commitment results in reduction in computation time.Liao G.C. and Tsao T.P.[19] implemented an algorithm based on genetic algorithm and Meta Heuristic method for unit commitment problem.It includes genetic algorithm,fuzzy logic and simulated annealing to determine shutdown and startup schedule. Maojun L. and Tiaosheng T.[20] proposed a modified genetic algorithm with three genetic operators called Gene Complementary Genetic Algorithm. Senjyu T. et al[32] implemented an algorithm based on genetic algorithm for large scale unit commitment with the consideration of new genetic operator and unit integration technique. Senjyu T. et al[33] presented a genetic algorithm based on unit.Characteristics classification. Numerical results for system of up to 100 units are compared to previously reported results.

B. Particle Swarm Optimization based Hybrid Algorithms

Pappala V.S. and Erlich I.[24] proposed a new approach based on adaptive particle swarm optimization.It results in reduction in no. of decision variables .Saber A.Y. et al[29] introduced algorithm based on fuzzy adaptive particle swar optimization approach. It tracks continuously changing solutions. Sadati N. et al[30] proposed a technique based on particle swarm fusion with simulated annealing for unit commitment optimization. It performs two functions unit schedule and economic dispatch. Sriyanyong P. and Song Y.H.[35] proposed a hybrid algorithm based on Particle Swarm Optimization and Lagrange and performed on various 4 and 10 unit systems.Wang B. et al[37] implemented algorithm for rescheduling of units in fuzzy logic.They proposed a heuristic algorithm called local convergence averse binary particle swarm optimization to solve the unit commitment problem.

C. Neural Network based Hybrid Algorithms

Christober C. et al[6] proposed a neural network based tabusearch for unit commitment optimization which is more efficient than conventional tabu search. Im T.S. and Ongsakul W.[12] implemented an Ant colony search algorithm based on new co-operative agent approach for economic dispatch and unit commitment. Liang R.H. and Kang F.C.[17] proposed an extended mean field annealing neural network approach to solve short term unit commitment problem which is tested on Taiwan power system.

D. Lagrange and Dynamic Programming based Hybrid Algorithms

Bavafa M. et al[2] implemented a hybrid approach based on lagrange algorithm with evolutionary and quadratic programming for short thermal unit commitment consideringramp rate constraint. Momoh J.A. and Zhang Y.[21] proposed a unit commitment method based on adaptive dynamic programming algorithm. Norhamim et al[23] presented a approach for cost minimization based on unit commitment and economic dispatch in large scale power system and comparison has been done with lagrange algorithm. Park J.D. et al[25] proposed an algorithm based on the effect of economic dispatch and consideration of ramp constraints.It reduces the generation level of less efficient units by commiting additional units or by economic dispatch. Rampriya B. et al[28] proposed a method in deregulated power system based on lagrangian firefly algorithm for profit based unit commitment. Dynamic programming is used for optimium search. Wang M. et al[38] proposed a technique considering various constraints for the optimization of unit commitment. It uses the combination of dynamic programming with economic dispatch and comparison with lagrange algorithm has been done. Zheng H. and Gou B.[40] designed new algorithm based on ON-OFF unit schedule by using lagrange algorithm which is superior than dynamic programming.

E. Simulated Annealing based Hybrid Algorithm

Christober C. et al[7] presented approach based on evolutionary programming simulated annealing method considering cooling and banking constraints for cost minimization. Simopoulos D.N et al[34] implemented an enhanced simulated annealing algorithm for unit commitment problem combined with dynamic economic dispatch.

F. Other Algorithms

Amudha A. et al[1] solved unit commitment problem using worst fit algorithm considering the effect of reserve on profit basis.Catalao J.S. et al[3] proposed a profit based unit commitment with constraints of emission limitation. A trade trade off has been done between profit and emission in order to assist decision makers. Chang G.W. et al[4] proposed a mixed integer linear programming method for unit commitment optimization.This approach is suitable for both traditional and deregulated environment. Fei L. and Jinghua L.[8] designed algorithm based on local search which combines interior search method for large power system. Gonzalez J.G and Barquin J.[10] proposed an algorithm for self unit commitment for day ahead market based on simple bids . Iguchi M. and Yamashiro S.[11] implemented an efficient scheduling method for hydro-thermal units considering the account of transmission network. It consists of different stages and constraints are relaxed at every stage and transmission losses are calculated at every stage. Im T.S and Ongsakul W.[12] implemented an Ant colony search algorithm based on new co-operative agent approach for economic dispatch and unit commitment. Kuan E. et al[15] implemented an algorithm for unit commitment optimization considering the complete network modeling and bender method is employed to decompose the problem into integer and continous variables. Larsen T.J. et al[16] developed a model based on sequential time step. It decomposes the problem at every time step and is solved by free marked model. Park J.D. et al[26] did the stochastic analysis based on uneven load demand on hour basis with the consideration of hit rate of units. Raglend I.J. et al[27] proposed an algorithm including operational, power flow and environmental constraints to plan secure and economic generation schedule.

II. PROBLEM FORMULATION

A. Fuel Cost Model

$C(PG_i)=\Sigma(a_i*PG_i^2+ b_i*PG_i +c_i)$Rs where i=1…..N

B. Constraints

- $\Sigma PGi,max \geq PD$
- $PGi,min \leq PGi, \leq PGi,max$ where i=1,2……N

C. Assumptions

- Total losses are neglected .
- Load cycle of 12 hour is taken.
- Some constraints are considered and others are relaxed.

III. PATTERN SEARCH FORMULATION

A. Introduction

The Pattern Search (PS) optimization method is an advanced search based technique that is suitable to solve a variety of optimization problems that lie outside the scope of the standard optimization methods. Generally, PS has the advantage of being very simple in concept, easy to implement and computationally efficient. Unlike other heuristic algorithms, such as genetic algorithms, PS possesses a flexible and well-balanced operator to enhance and adapt the global and fine tune local search. The Pattern Search (PS) algorithm proceeds by computing a sequence of points that may or may not approach the optimal value. The algorithm starts by establishing a set of points called a mesh, around the given point. This current point could be the initial starting point supplied by the user or it could be computed from the previous step of the algorithm. The mesh is formed by adding the current point to a scalar multiple of a set of vectors called a pattern. If a point in the mesh is found to improve the objective function at the current point, the new point becomes the current point at the next iteration.

B**. Poll**
Polling method controls how the pattern search polls the mesh points. It depends on which class of algorithms is used—generalized pattern search algorithms or mesh adaptive direct search algorithms. Poll method specifies which method the poll algorithm uses to create the mesh.

C. **Optimium Search**
Optimium Search specify an optional search that the algorithm can perform at each iteration prior to the polling. If the search returns a point that improves the objective function, the algorithm uses that point at the next iteration and omits the polling.

D. **Search method**
Complete search specifies whether all the points must be searched at each iteration. Search method based on iteration limit is applicable to Genetic Algorithm.

E. **Algorithm Setup**
- Algorithm settings refer to constraint parameters. Initial penalty specifies an initial value to be used by the algorithm. Initial penalty must be greater than or equal to 1.
- Penalty factor increases the penalty parameter when the problem is not solved to required accuracy and constraints are not satisfied. Penalty factor must be greater than 1.
- Bind tolerance specifies the tolerance for the distance from the current point to the boundary of linearly constrained region. This means Bind tolerance specifies when a linear constraint is active.

F. **Stopping Criteria**
Stopping criteria determine what causes the pattern search algorithm to stop.
- Mesh tolerance specifies the minimum limit for mesh size.
- Max iteration specifies the maximum number of iterations the algorithm performs.
- Max function evaluations specifies the maximum number of evaluations of the objective and constraint functions.
- Time limit specifies the maximum time in seconds the pattern search algorithm runs before stopping.
- X tolerance specifies the minimum difference between two consecutive iteration values.
- Function tolerance specifies the termination tolerance for the objective function value.

G. **Graphical Representation**
- Best function value plots the best objective function value at each multiple of interval iterations.
- Mesh size plots the mesh size at each multiple of interval iterations.
- Function count plots the number of function evaluations at each multiple of interval iterations.
- Best point plots the best point at each multiple of interval iterations.
- Max constraint plots the maximum nonlinear constraint violation.

H. **Fitness Function Testing**
Here, objective function is to be evaluated with subjected to constraints like lower generation=power demand and limits of power generation of units. Functions specifies how functions you supply are tested:in serial mode means the objective and constraint functions are evaluated separately at each polling point and vectorized means the objective and constraints during one poll are each evaluated in one function call in parallel means the objective and constraint evaluations are done on a group of processes.

I. Flow Chart of Pattern Search
Pattern search finds a local minimum of an objective function by the following method, called polling. The search starts at an initial point, which is taken as the current point in the first step:

1. Generate a pattern of points, typically plus and minus the coordinate directions, times a mesh size, and center this pattern on the current point.
2. Evaluate the fitness function at every point in the pattern.
3. If the minimum objective in the pattern is lower than the value at the current point, then the poll is successful, and the following happens:
   - The minimum point found becomes the current point.
   - The mesh size is doubled.
   - The algorithm proceeds to Step 1.
4. If the poll is not successful, then the following happens:
   - The mesh size is halved.
   - If the mesh size is below a threshold, the iterations stop.
   - Otherwise, the current point is retained, and the algorithm proceeds at Step 1.

IV. SIMULATION RESULTS

Table 1.Optimium Load Generation using Pattern Search

TIME(hr)	LOAD DEMAND(MW)	U1(MW)	U2(MW)	U3(MW)	U4(MW)
1	250	101.296	108.703	20	20
2	280	128.037	111.963	20	20
3	340	149.895	150.105	20	20
4	380	176.635	163.364	20	20
5	430	193.242	193.242	21.757	21.757
6	520	210	210	52.274	47.725
7	580	210	210	80	80
8	610	210	210	97.684	92.315
9	660	210	210	120.664	119.335
10	720	210	210	148.954	151.045
11	770	210	210	182.068	167.931
12	810	210	210	190.245	199.754

Table 2. Total Operating Cost

TIME(hr)	Total Operating COST(Rs)
1	155977
2	156081
3	156297
4	156449
5	156647
6	157021
7	157292
8	157435
9	157684
10	158000
11	158279
12	158512
TOTAL COST	1885674

V. PATTERN SEARCH PARAMETER EVALUATION

- Current Best Point
- Total Function Evaluation
- Iterations
- Mesh Size
- Best Function value

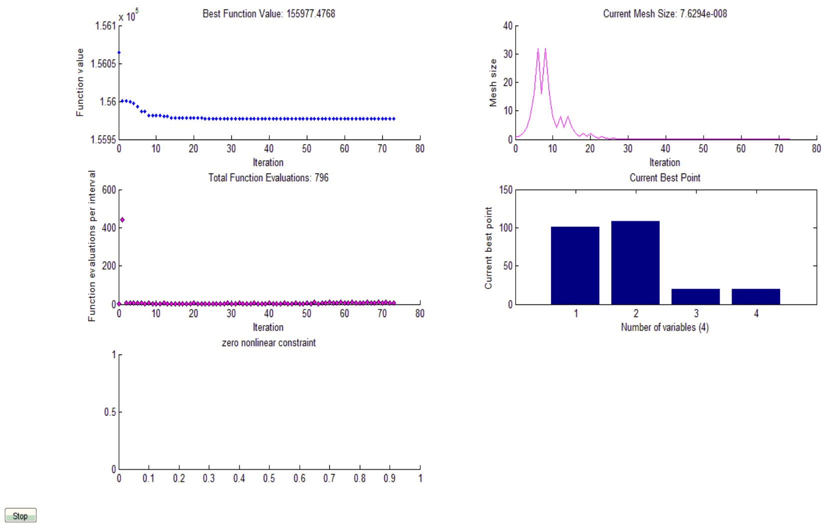

Fig.1 Load 1st hour

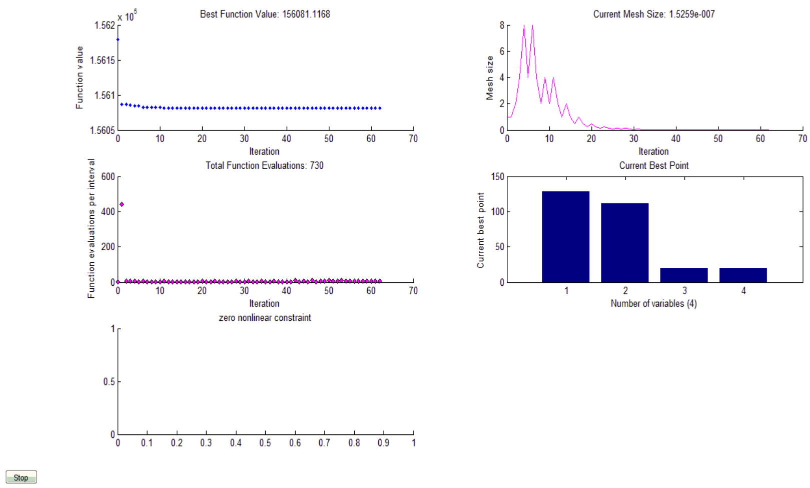

Fig.2 Load 2nd hour

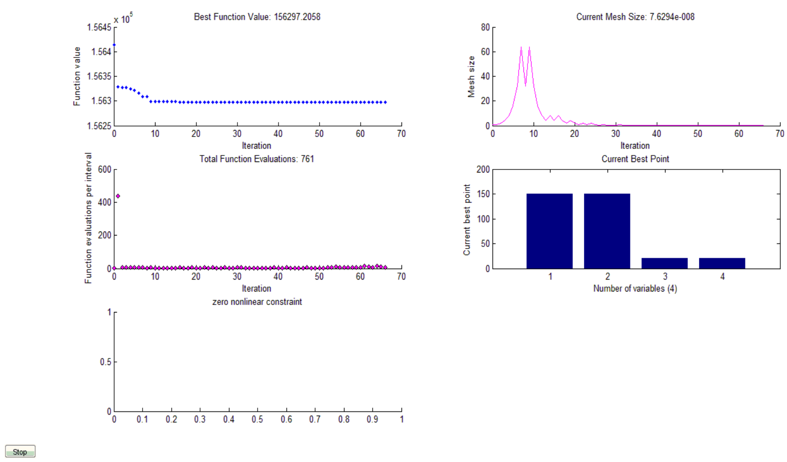

Fig.3 Load 3rd hour

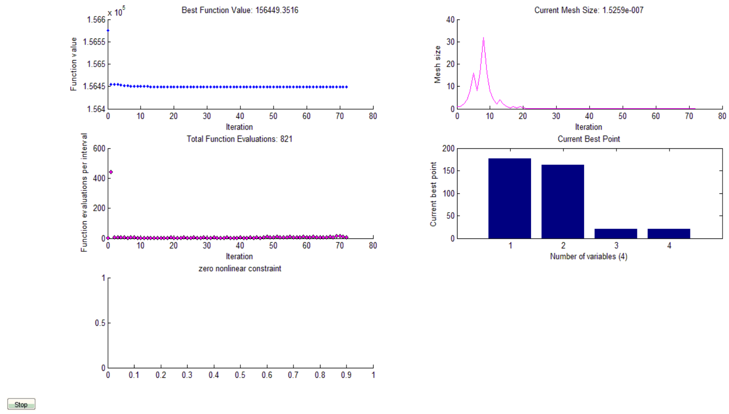

Fig.4 Load 4th hour

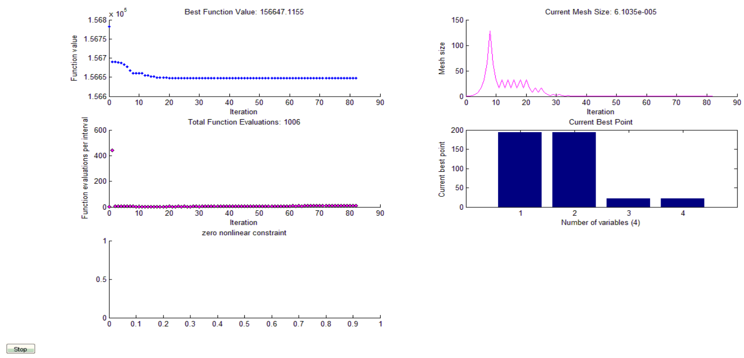

Fig.5 Load 5th hour

VI. CONCLUSION

In this paper, the total operating cost is evaluated using advance search technique pattern search .An effective robust solution for unit commitment problem is necessary for overall optimization as UC problem is complex where ambiguity exists due to no. of constraints and such problem can be addressed easily by using pattern search. As the size of units increased and complicated constraints are imposed,it is difficult to address the problem using conventional methods. Pattern Search is used to solve this problem as outcome of logical representation of parameters are easy to understand and it can apply to n no. of units. It requires no gradients of the objective function. It lends itself to constraints .After evaluation, total operating cost is optimium which is leading to optimal solution of our fitness function. Hence, pattern search based approach is more optimized as compared to other traditional algorithms for the modelling of complex system of unit commitment.

VII. FUTURE SCOPE

More advanced algorithms can be proposed for unit commitment problem with the incorporation of more constraints to minimize fitness function in this system. Proposed algorithm can be extended to many more units with subjected to more number of constraints as per the requirement of the utility.

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Author's Biography

Prof. Vikrant Sharma is an Associate Professor in CT Group of Institutions, Jalandhar, India. His area of interest involves Optical Communication System, Analog and Digital Communication and Microwave Engineering. He authored and co-authored many research papers in leading international journals and conferences.He involves in teaching and research experience for more than a decade. He is pursuing PHD from PTU.

Navpreet Singh Tung is an Assistant Professor, Department of Electrical and Electronics Engg., CT Group of Institutions, Jalandhar, India.His area of interest involves Power System Optimization, Power System Planning ,Unit Commitment and application of artificial intelligence and MATLAB in Power System. He authored and co-authored many research papers in leading international journals and conferences.

Arsh Batish is a senior undergraduate research scholar in Department of Electrical and Electronics Engineering, CT Institute of Technology Jalandhar. His area of interest involves Power System, Matlab Programming, PLC and Automation & Unit Commitment.

Harman Brar is a senior undergraduate research scholar in Department of Electrical and Electronics Engineering, CT Institute of Technology Jalandhar. His area of interest involves Power System, Matlab Programming, PLC and Automation & Unit Commitment.

