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Research Article

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Fuzzy Logic Controller Modelling for Economic Dispatch and Unit Commitment in Electrical Power System

Prof. Vikrant Sharma*, [2]Navpreet Singh Tung, [3]Rashmi Rana, [4]Vivek Guleria
*Associate Professor,[2]Assistant Professor, [3,4]Research Scholars
Department of Electrical and Electronics Engineering
CT Group of Institutions
Jalandhar, India

Abstract:

This paper presents an implementation of fuzzy-logic controller to solve the unit-commitment and economic dispatch problem of thermal generation plant with the main objective of evaluating the total minimum operating cost for each loading condition while subjected to a variety of constraints. The model in this study contains five generation units and the daily load demand is subdivided into 12 intervals. The unit combinations and the corresponding generation scheduling intend to minimize the operating cost. The implementation of fuzzy-logic allows a qualitative description of the behaviour of the system: the system's characteristics and the response without the need for exact mathematical formulations. The numerical values are evaluated by the fuzzy-logic approach. The results have shown that the proposed fuzzy-based approach provides feasible combinations of the generation units and economical cost of operation of these units and have also shown the optimium modelling of the proposed fuzzy-logic approach as compared to other conventional mathematical modelling based approaches.

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.
- IC,LD are considered as input parameters and PG as output parameters.
- Only 3 membership functions are considered which are triangular in nature.

III. FUZZY LOGIC FORMULATION

A. Fuzzy Variables

Input Variables-Load Demand and Incremental Cost

Output Variables- Power Generation(PG1,PG2,PG3,PG$,PG5 of three generating units). In fuzzy set notation this is written as, PG=LDnIC Hence, the membership function of the power generation, µPG is computed as follows.

µPG = µLD nµIC

µPG = min {µLD, µIC}

where µLD and µIC are memberships of load demand and incremental fuel cost respectively.

B. Fuzzy Sets

1) Power Demand : LD
LD(MW)={low(L),normal(N),high(H)}
2) Incremental Cost : IC
IC(Rs/MWhr)={low(L),normal(N),high(H)}
3) Power Generation : PG1
PG1(MW)={low(L),normal(N),high(H)}
4) Power Generation : PG2
PG2(MW)={low(L),normal(N),high(H)}
5) Power Generation : PG3
PG3(MW)={low(L),normal(N),high(H)}
6) Power Generation : PG4
PG4(MW)={low(L),normal(N),high(H)}
7) Power Generation : PG5
PG5(MW)={low(L),normal(N),high(H)}

Here we have input parameters load demand and incremental cost -

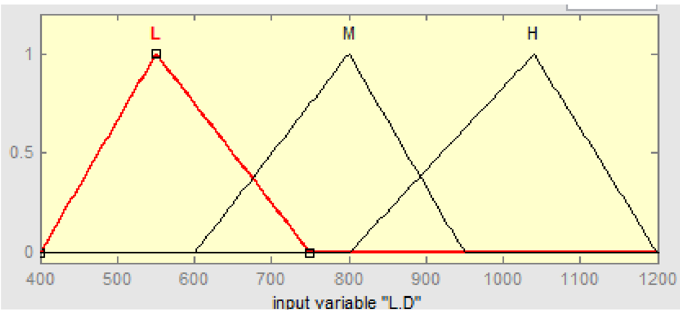

Fig. 1 Membership Function of Load Demand

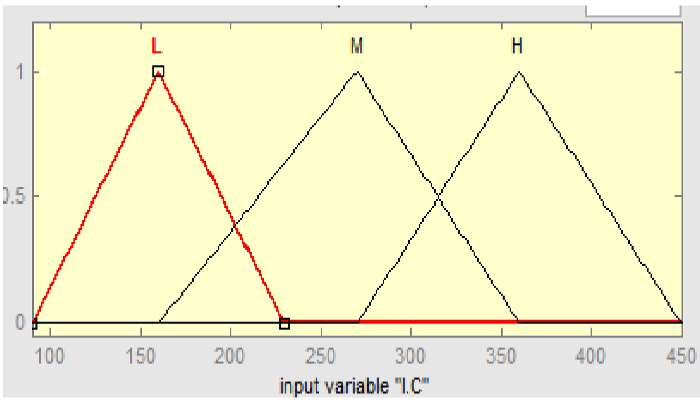

Fig.2 Membership Function of Incremental Cost

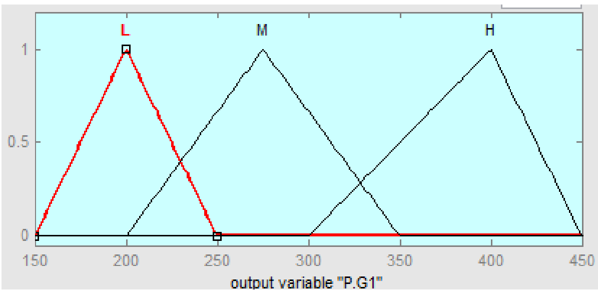

Fig.3 Membership Function of Power Generation(PG1)

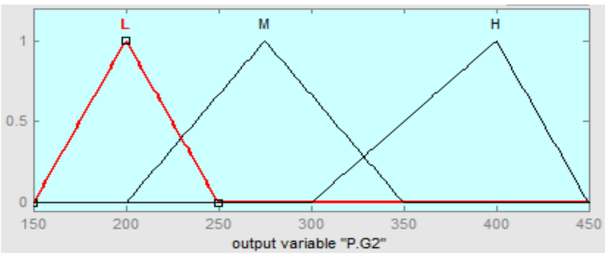

Fig.4 Membership Function of Power Generation(PG2)

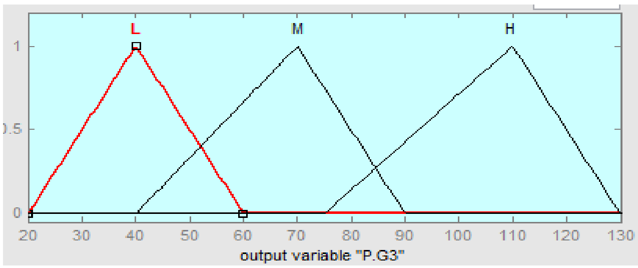

Fig.5 Membership Function of Power Generation(PG3)

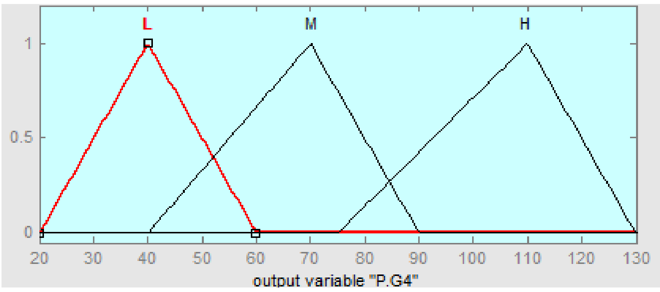

Fig.6 Membership Function of Power Generation(PG4)

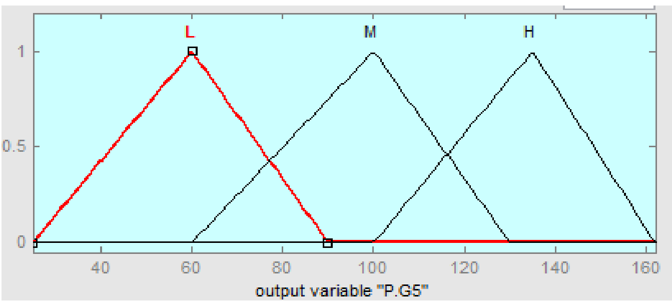

Fig.7 Membership Function of Power Generation(PG5)

Table 1. Unit Schedule(1-ON-0-OFF) and Load Demand

Period(hrs)	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Load
1	1	0	1	0	0	450
2	1	0	1	0	0	500
3	1	0	0	0	1	550
4	1	1	0	0	0	750
5	1	1	0	0	0	780
6	1	1	1	0	0	700
7	1	1	1	0	0	950
8	1	1	0	0	1	800
9	1	1	1	0	1	1000
10	1	1	1	1	1	1050
11	1	0	1	0	0	750
12	1	0	1	1	0	600

Table 2. Cost Coefficient and Power Limits of the Units

S.N	Pmax	Pmin.	a	b	c
1	455	150	1000	16.19	0.00048
2	455	150	970	17.26	0.00031
3	130	20	700	16.6	0.002
4	130	20	680	16.5	0.00211
5	162	25	450	19.7	0.00398

Table 3. Power Generation and Incremental Cost

S.No.	Incremental Cost(Rs/MWhr)	P.G1	P.G2	P.G3	P.G4	P.G5
1	300	327	*	91	*	*
2	360	382	*	108	*	*
3	340	382	*	*	*	132
4	445	382	382	*	*	*
5	445	382	382	*	*	*
6	240	304	304	76.6	*	*
7	360	382	382	108	*	*
8	340	382	382	*	*	132
9	350	382	382	105	*	132
10	360	381	381	105	75	132
11	360	382	382	*	*	*
12	360	382	*	108	108	*

Table 4. Total Operating Cost

S.No.	Total Operating Cost
Total	1,93,560

IV. CONCLUSION

In this paper, the total operating cost using soft computing technique fuzzy logic based hybrid method is implemented.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 fuzzy logic. As the size of units increased and complicated constraints are imposed,it is difficult to address the problem using conventional methods. Fuzzy logic is used to solve this problem as outcome of logical representation of rules are easy to understand and it can apply to n no. of units. After evaluation, total operating cost is optimium which is leading to optimal solution of our fitness function.Hence, fuzzy based approach is more optimized as compared to other traditional algorithms for the modelling of complex system of unit commitment.

FUTURE SCOPE

More hybrid algorithms can be developed for unit commitment optimization 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.

Vivek Guleria is a senior undergraduate research scholar in Department of Electrical and Electronics Engneering, CT Institute of Technology Jalandhar. His area of interest involves Power System, Matlab , Automation & Unit Commitment.

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