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GA based Fuzzy Logic Solutions for UC & ED Problems

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***Abstract*—The Unit Commitment (UC) problem refers to the process of optimal power generating unitsstart-up and shut-downschedule determination, subject to forecast load demand over a short-term planning horizon (24h). The objective of a generation scheduling optimization problem is to minimize total operating costs, while meeting a large set of system operating constraints. This problem includes two basic decisions--unit commitment decision and economic dispatch decision. The characteristics of this problem are high dimension, non-convex, discrete, nonlinear, and multi-constraints. Many optimization methods have been proposed to solve the UC problem. These methods included Priority List (PL) methods, Dynamic Programming (DP) methods,Lagrangian Relaxation (LR) methods. More recently, meta-heuristic methods have been tested and used, such as Genetic Algorithms (GA),Tabu Search (TS) and Simulated Annealing (SA), along with expert system and neural networks. Genetic Algorithms (GA) have become increasingly popular in recent years in science and engineering disciplines.Some works have been published covering the solution of the UCP and EDP using GA.A single technique like Fuzzy Logic itself is not sure to produce good results, but it can besupplemented with other method like Genetic Algorithm (GA).A new approach is proposed, a hybrid algorithm to solve the UCP and EDP.**

I. INTRODUCTION

The purpose of the Unit Commitment Problem (UCP) lies in providing the system operator with a real, practical and optimum schedule in the next 24 hours for the generating units in the system under study. In the last decades numerous methods have developed to solve the UCP. Most of the previous works deal with data in the UCP as crisp values and the constraints as sharp limits. For the UCP date some of them are forecasted hence they contain some uncertainties.

Consequently need to be treated as FUZZY. On the other hand, some of the constraints are treated in a soft or flexible manner, which enhance the opportunity to get more practical and better solutions.The term economic dispatch has been given to the problem of minimizing the cost of fuel at thermal plants, assuming that hydro generation has been previously defined and that the configuration of the network is known. It is also known which thermal units are on line. The constraints on this problem, as found in the literature, vary widely, generally trading off complexity for solution speed. Many power systems today are operated under economic dispatch with calculations made on-line every few minutes. Under normal circumstances, control signals are sent to generating stations for generating units to adjust their power output in accordance with optimization results.

A new approach is proposed, a hybrid algorithm (GAFL) to solve the UCP and EDP. The FL is used to model the uncertainties and soft limits constraints. The GA is used to solve the combinatorial optimization problem. The GA test allows the acceptance of any solution at the beginning of the search, while only good solutions will have higher probability of acceptance as the number increases.

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II. Methodology

A. Unit Commitment and Economic Dispatch

An efficient unit commitment plays an important role in the economic operation of a power system. The objective of unit commitment is to determine when to start up and shut down units such that the total operating cost can be minimized. The standard unit commitment problem is formulated subject to several constraints that include minimum up-time and minimum down-time, load balances, generating constraints, spinning reserve constraints.

Objective function in the unit commitment problem is to minimize the total production cost which includes fuel cost and start up cost subject to the constraints as given below.Operating constraint is the real power limits on the generator output. The generator output should not exceed the specified limits in the problem i.e.Generation should meet the load demand and the spinning reserve plus transmission losses. In this work transmission losses are neglected.

$$\sum \mathbf{Pi} = \mathbf{P_D} + \mathbf{P_L} + \textbf{spinning Reserve}$$

Where Pi is the real power generation of ith plant and P_D is the total power demand.

Inequality constraints

$$P_{imin} \le Pi \le P_{imax}$$
$$Q_{imin} \le Qi \le Q_{imax}$$
$$V_{min} \le V \le V_{max}$$
$$\delta_{min} \le \delta \le \delta_{max}$$

Where P_{imin} is the lower limit of the real power output of i^{th} unit and P_{imax} the upper limit of the real power output of i^{th} unit.

Minimum up time- Once unit is running it should not be turned off immediately.

Minimum down time- Once unit is recommitted, there is minimum time before it can recommit.

Spinning reserve- Spinning is the term used to describe total amount of generation available from all units synchronized on the system minus present load plus losses being supplied. Spinning must be carried so that the loss of one or more units does not cause to far a drop in a system frequency. Spinning is usually in the range of 5% to 7% of system demand.

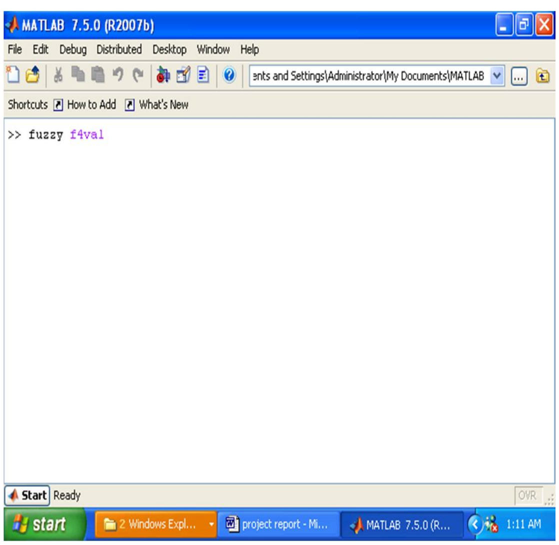
Start up cost- A simplified time dependent start up cost is taken as follows; hot start up cost if down time ≤ cold start hours.

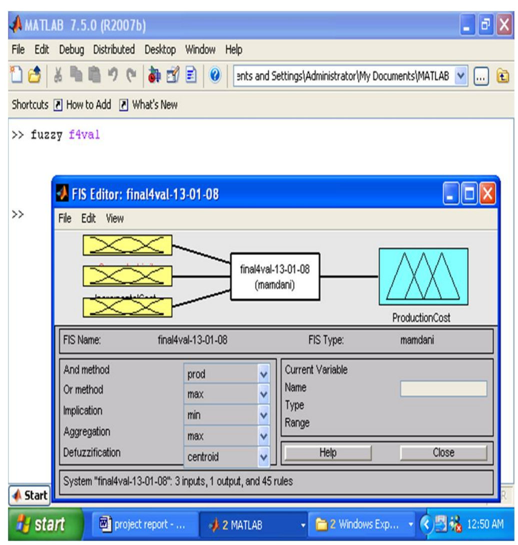
Start up cost = cold start cost, otherwise

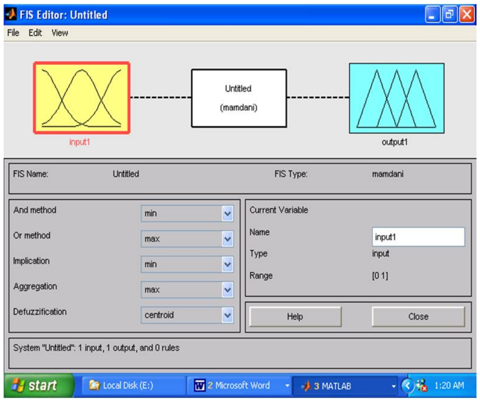
Shut down cost- The shut down cost has been taken equal to zero for every unit.

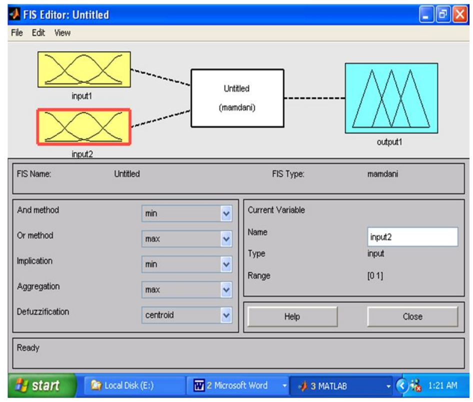
III. Implementation

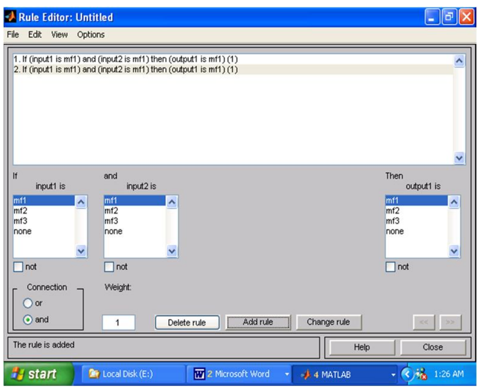
Steps to be followed for solving UCP and EDP using Fuzzy Logic and Genetic Algorithm

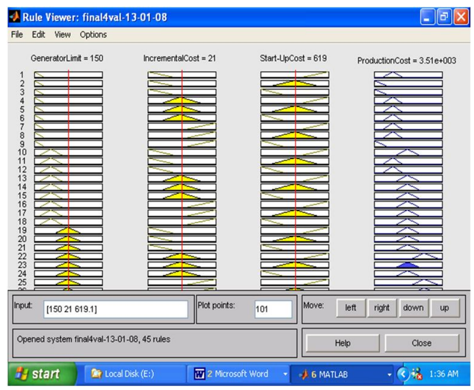


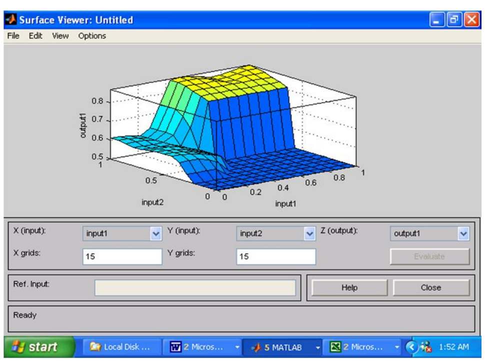


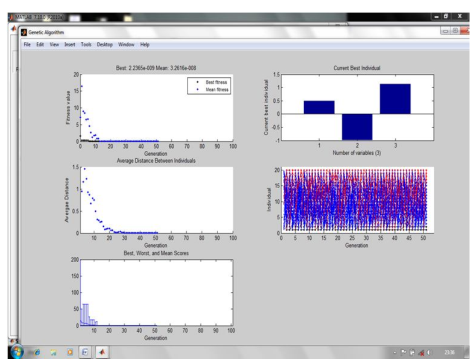












Chapter 4: Case Study and Simulation Results

The aforementioned approach is applied to simple system comprised of 3, 4, 5 and 10 generating units of thermal power plant. Fuzzy logic (FL) and genetic algorithm (GA) simulations are obtained through MATLAB. The result obtained by the FL and GA are compared with solution obtained from LR Method.

Case 1: 3 Unit Systems

TABLE I: GENERATOR DATA [7]

Sl. No	Pmax (MW)	Pmin (MW)	A (Rs/hr)	b (Rs/MWhr)	c (RS/MW^{2}hr)	Incremental Cost (Rs/MW)
1	450	200	500	5.3	0.004	6.10
2	350	150	400	5.5	0.006	6.10
3	225	100	200	5.8	0.009	6.2

TABLE II: LOAD PATTERN [7]

Sl. No	Load(MW)
1	550
2	487
3	495
4	504
5	604
6	630
7	639
8	646
9	832
10	848
11	890
12	931
13	966
14	1025
15	1000
16	950

TABLE III: RANGES SELECTED

Incremental cost		**Start-up cost**	
Least Small Large	4.2-5 4.59-5.79 5.29-6.2	Low Medium High	0-35 15-85 60-100
Load capacity of generators		**Production cost**	
Low Below average Average Above average High	0-67.5 33.75-191.25 135-315 236.25-438.75 360-450	Low Below average Average Above average High	0-945 686.9-1718.9 1375.4-2578.34 2148-3523 3007.28-3695

TABLE IV: RULES DEVELOPED

Sl. No	LCG	SUP	IC	PRC
1	Low	Low	Least	Low
2	Low	Medium	Least	Low
3	Low	High	Least	Low
4	Low	Low	Large	Low
5	Low	Medium	Large	Low
6	Low	High	Large	Low
7	Low	Low	Small	Low
8	Low	Medium	Small	Low
9	Low	High	Small	Low
10	BAV	Low	Least	BAV
11	BAV	Medium	Least	BAV
12	BAV	High	Least	BAV
13	BAV	Low	Large	BAV
14	BAV	Medium	Large	BAV
15	BAV	High	Large	BAV
16	BAV	Low	Small	BAV
17	BAV	Medium	Small	BAV

TABLE IV: RULES DEVELOPED

18	BAV	High	Small	BAV
19	AV	Low	Least	AV
20	AV	Medium	Least	AV
21	AV	High	Least	AV
22	AV	Low	Large	AV
23	AV	Medium	Large	AV
24	AV	High	Large	AV
25	AV	Low	Small	AV
26	AV	Medium	Small	AV
27	AV	High	Small	AV
28	AAV	Low	Least	AAV
29	AAV	Medium	Least	AAV
30	AAV	High	Least	AAV
31	AAV	Low	Large	AAV
32	AAV	Medium	Large	AAV
33	AAV	High	Large	AAV
34	AAV	Low	Small	AAV
35	AAV	Medium	Small	AAV
36	AAV	High	Small	AAV
37	High	Low	Least	H
38	High	Medium	Least	H
39	High	High	Least	H
40	High	Low	Large	H
41	High	Medium	Large	H
42	High	High	Large	H
43	High	Low	Small	H
44	High	Medium	Small	H
45	High	High	Small	H

TABLE V: ECONOMIC DISPATCH OBTAINED FROM LR METHOD

Sl. No	LOAD (MW)	Economic Dispatch			Production Cost in Rs.
		Unit1(MW)	UNIT2(MW)	UNIT3(MW)	
1	550	280	170	100	4856
2	487	237	150	100	4391
3	495	245	150	100	4449
4	504	252.4	151.6	100	4514
5	604	307.2	188.1	108.7	5269
6	630	319.7	196.3	114.2	5472
7	639	323.7	199.2	116.1	5543
8	646	327.1	201.4	117.6	5598
9	832	415.2	260.1	156.7	7137
10	848	422.7	265.2	160.1	7275
11	890	442.6	278.4	169	7643
12	931	450	298.6	182.4	8010
13	966	450	319.1	196.4	8332
14	1025	450	350	225	8896
15	1000	450	340	210	8654
16	950	450	310	190	8184

TABLE VI: COMPARISON BETWEEN PRODUCTION COSTS IN RS OBTAINED FROM FUZZY LOGIC AND GENETIC ALGORITHM WITH LR METHOD

Sl. No	LOAD (MW)	Unit combination	Production Cost		
			LR Method	Fuzzy Method	GA Method
1	487	111	4391	4600	4443
2	495	111	4449	4670	4681
3	504	111	4514	4820	4729
4	550	111	4856	5300	5290
5	604	111	5269	5670	5979
6	630	111	5472	5960	6120

7	639	111	5543	6670	6240
8	646	111	5598	6680	6510
9	832	111	7137	6750	6970
10	848	111	7275	7080	7108
11	890	111	7643	7520	7410
12	931	111	8010	7570	7610
13	950	111	8184	7970	7630
14	966	111	8332	8220	7999
15	1000	111	8654	8220	7999
16	1025	111	8896	8220	7999
TOTAL			**104,223**	**105,920**	**1,04,717**

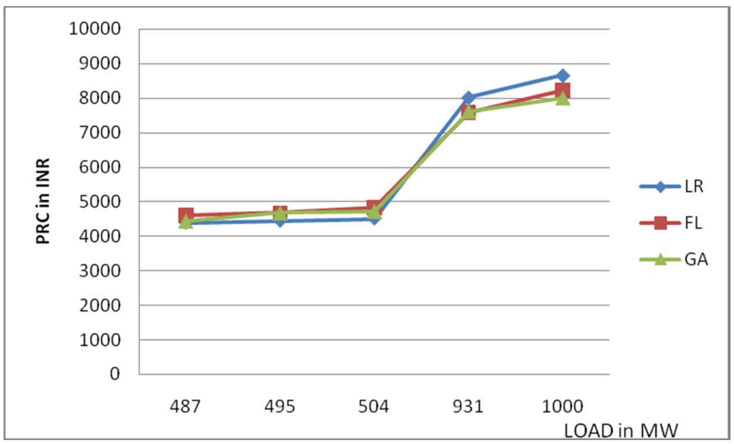


Figure.8: Comparison of Production Cost in Rs obtained from Fuzzy Logic Approach with LR Method for 3 units

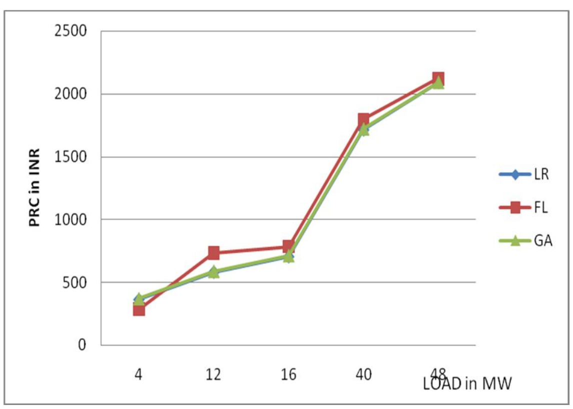


Figure.9: for 4 units

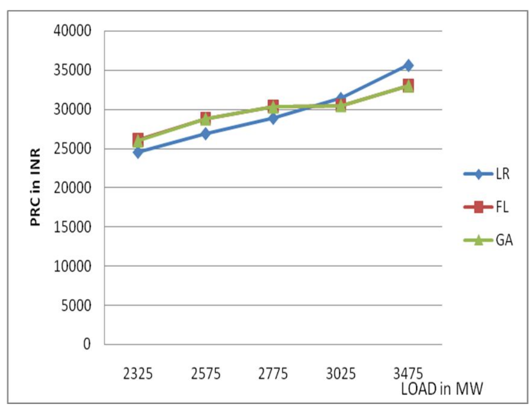


Figure.10: for 5 units

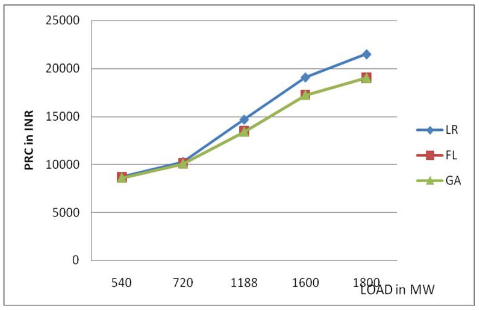


Figure.11: for 6 units

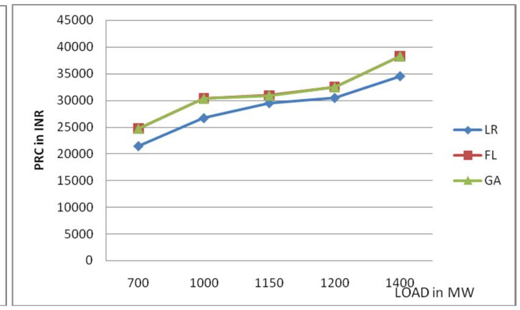


Figure.12: for 10 units

IV. CONCLUSION

A genetic algorithm solution to the unit commitment problem has been presented. The GA is most advantageous for the larger unit systems. Simulation results reveal that optimal tuning of GA parameter to guarantee fast convergence and a highly optimal solution is difficult and depends on the studied unit commitment problem. Additionally, the GA is a random search technique whereby, however, the search is guided by the objective function (e.g. operating cost function).
A basic advantage of the GA solution is the flexibility provides in modeling both time dependent and coupling constants. Another advantage is that GA is can be very easily converted to work on parallel computers. A disadvantage of GA is that, since they are stochastic optimization algorithm, the optimality of the solution they provide can not be guaranteed, however, our results indicate difference between worst and best GA provided solution is very small. Another disadvantage of GAs unit commitment algorithm is the high execution time. However, with the progress in the hardware of parallel computing both disadvantage of the GA unit commitment algorithm will soon be eliminated.

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