Power System Generation Scheduling and Optimization Using Fuzzy Logic Technique

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ABSTRACT

In this, paper solving the unit commitment problem is usual in a generation scheduling such that the overall generating cost can be at least while satisfying a variety of constraints. The four-generating units are using for the thermal power plant as a case study. The dynamic programming, dynamic graphical programming and fuzzy logic algorithm apply a solution to the unit commitment problem that is logical, possible and with affordable cost of operation which is the main goal of unit commitment. The results procured by the fuzzy logic algorithm are tabular, graphed and compared with that obtained by the dynamic programming and dynamic graphical programming. The result shows that the implementation of fuzzy logic provides a possible solution with significant savings order to obtain preferable unit combinations of particular load demand of at each time period. the commitment is such that the total cost is minimizing. The total cost includes both the production cost and the costs associated with start-up and shutdown of units. Dynamic programming, dynamic graphical programming is an optimization technique which gives the optimal solution.

Keywords: *Generation scheduling, Unit commitment, fuzzy-logic, dynamic programming, dynamic graphical programming and optimization*

I. INTRODUCTION

In the early days the power system consisted of isolated stations and their individual loads. Unit commitment is one of the decision-making levels in the hierarchy of power system operations management. The optimization problem is posed over Time horizons that vary from 24 hours to one week. The objective is to determine the set of generating units, among those owned by a utility that should be connected to the power grid on an hourly basis to supply the demand at minimum operating cost over the scheduling horizon. This optimization problem is constrained by the unit characteristics and other operation limitations. Since the objective of the unit commitment is to determine a cyclic schedule that will meet the system constraints at minimum cost, the economic operation of a power system may be formulated as a dynamic optimization problem [2]. The problem is dynamic in the sense that decisions to startup and/or shutdown units at any stage cannot be made without considering the states of the system at some other stages. The problem of UC is nothing but to determine the units that should operate for a particular load. To ‘commit’ a generating unit is to ‘turn it on’, i.e., to bring it up to speed, synchronize it to the system, and connect it , so that it can deliver power to the time network. The unit commitment is commonly formulated as a non–linear, large scale, mixed integer combination optimization problem.

Review of UCP may be developed. The dynamic Programming (DP) method as in [2] Based on priority list is flexible, but the computational time suffers from dimensionality. As Lagrangian relaxation (LR) for UCP was superior to DP due to its higher solution quality and faster computational time. However, numerical convergence and solution quality of LR are not satisfactory when identical units exist [6]. With the advent of heuristic approaches, genetic algorithm (GA) [7], evolutionary programming (EP) [8], simulated annealing (SA) [6], and tabu search (TS) [8] have been proposed to solve the UC problems. The results obtained by GA, EP, TS and SA require a considerable amount of computational time especially for large system size.

The use of fuzzy logic has received increased attention in recent years because of its worth in dropping the requirement for difficult mathematical models in problem solving. , in comparison fuzzy logic employing linguistic condition, which deal with the practicable relationship between input and output variables. For this cause, fuzzy logic algorithm makes it easier to manipulate and solve several problems, particularly where the mathematical model is not explicitly known, or is hard to solve.

Moreover, fuzzy logic as a new technique approximates reasoning while allowing decisions to be made efficiently. To achieve a good unit commitment planning under fuzzy approach, generation cost and load demand are all specified as a fuzzy set notation. Fuzzy Logic Technique is then applied to yield the desired commitment schedule.[1] In order to demonstrate the superiority of this proposed approach, the power plant of four-thermal generating units is chosen as a test system.

II. THE UNIT COMMITMENT PROBLEM

The unit commitment problem can be mathematically described as given in equation (1).

$$\text{Min } F_i(P_i^t, U_i^t) = \sum t \sum i[(a_i \; P_i^2 \; + b_i \; P_i + c_i)] + SC_i^t(1 - U_i^{t-1})]U_i^t \qquad (1)$$

Where $F_i\,(P_i^t)$is the generator fuel cost function in quadratic form, a_i , b_i and c_i are the coefficients of unit i, and P_i^t is the power generation of unit i at time t.[1]

A. Problem Constrains

The minimization of the objective function is subjected to two kinds of constraints, namely: system and unit Constraints and these can be summarized as follows:

B. System Constraints

(i) Power Balance Constraints: to satisfy the load balance in each stage, the forecasted load demand should be equal to the total power generated for every feasible combination. Equation (2) represents this constraint where P_D^t represents the total power load demand at a certain period [3].

$$\sum_{i=1}^{N} P_i^t \; U_i^t \; - (P_D^t) = 0 \qquad (2)$$

For each time period (T), the spinning reserve requirements R must be met and this can be mathematically Formulated as in equation (3) [3]:

$$\sum_{i=1}^{N} P_i^{max} \, U_i - (P_D) = R \quad t = 1,2,3\ldots\ldots T \qquad (3)$$

C Unit constraints

(i) Generation Limits: Each unit must satisfy its generation range and this certain rated range must not be violated. This can be accomplished through satisfying the formula in equation (4) [3]:

$$P_i^{min} U_i^t \le P_i \;\; \le P_i^{max} U_i^t \quad i = 1,2,3\ldots\ldots\ldots N \qquad (4)$$

Where: P_i^{min} and P_i^{max} are the generation limits of unit i.

(ii) Ramp-Up and Ramp-Down Constraints: To avoid damaging the turbine, the electrical output of a unit cannot be changed by more than a certain amount over a period of time. For each unit, the output is limited by ramp up/down rate at each time period the unit is turned on/off and this can be formulated as in equations (5) and (6)

$$P_i^{t-1} \; - P_i^t \le RD_i \;\; if \; (U_i^t = 1) and \, (U_i^{t-1} = 1) \qquad (5)$$

$$P_i^t - P_i^{t-1} \;\; \le RU_i \;\; if \; (U_i^t \; = 1) and \, (U_i^{t-1} = 1) \qquad (6)$$

Where: RD_i and RU_i is respectively the ramp down and ramp up rate limit of unit i. [3]

III. DYNAMIC PROGRAMMING

Dynamic programming acts as an important optimization technique with broad usage areas. It decomposes a problem for a series of smaller problems, solves them, and develops an optimal solution to the original problem step-by-step. The optimal solution is developed from the sub problem recursively. In its fundamental form, the dynamic programming algorithm for unit commitment problem examines every possible state in every space. Some of these states are found to be in feasible and hence they are rejected immediately. But even, for an average size utility, a large number of feasible states will exist and the requirement of execution time will stretch the capability of even the largest computers. [2] Hence many proposed techniques use only some part of simplification and approximation to the fundamental dynamic programming algorithm. Dynamic programming has many advantages over the enumeration scheme.

The chief advantage being the reduction in the dimensionality of the problem. Suppose we have found units in a system and any combination of them could serve the single load. A maximum of 2^N-1 combinations are available for testing. If:-

[1] No load costs are zero.
[2] 2. Unit input-output characteristics are linear between zero output and full load.
[3] There are no other restrictions.
[4] Start-up costs have a fixed amount.

In the dynamic programming approach that types, it is approved that:

[1] A state consists of an array of units with only specified units operating at a Time and rest off-line.
[2] The start-up cost of a unit is independent of the time it has been off-line (i.e., it is a fixed amount).
[3] There are constant costs for shutting down a unit.
[4] There is a strict priority order, and in each space a specified lower reaches Amount of capacity must be operating.

A thinkable state is one in which of the committed units can be supply the required load and that meets the amount of capacity at each period [2]

IV. FUZZY LOGIC IMPLEMENTATION

Fuzzy logic has sharply become one in every of the foremost among the current technologies for developing advanced control systems. Fuzzy logic addresses applications dead because it resembles human higher cognitive process power. It's the ability to get precise solutions from bound or rough detail. It fills a vital gap in engineering design strategies that was left vacant by the foremost mathematical approaches (e.g. linear control design), and strictly logic-based approaches (e.g. expert systems) in system design. Whereas alternative approaches require accurate equations to model real-world behaviors, fuzzy design will work well with the ambiguities of real-world human language and logic. Fuzzy logic may be a superset of conventional (Boolean) logic that has been extended to handle the construct of partial true values between "completely true" and "completely false". As its name suggests, it's the logic underlying modes of reasoning that are approximate instead of exact. [10] The importance of fuzzy logic comes from the actual fact that almost all modes of human reasoning, wisdom reasoning, are approximate in nature.

The essential characteristics of fuzzy logic as supported by Zadeh Lotfi as follows:

- In fuzzy logic, precise reasoning is viewed as a limiting case of approximate reasoning.
- In fuzzy logic, matter of degree plays an important role. Any system is fuzzified.
- In fuzzy logic, information is interpreted as a group of elastic or, equivalently, fuzzy constraint on a group of variables
- Inference is viewed as a process of propagation of elastic constraints

V. UNIT COMMITMENT USING FUZZY LOGIC

A. Fuzzy Model for the Unit Commitment Problem

The target of all electrical utility is to control at minimum cost whereas meeting the load demand and spinning reserve needs. Within the gift formulation, the fuzzy variables related to the unit commitment downside are the load capability of generator (LCG), the Incremental fuel cost (IC), the start-up cost (SUC) because the input parameters and also the generation cost (GRC) because the output parameter. These fuzzy variables are given and shortly explained within the following:

- **The load capability of generator** is taken into account to be fuzzy, because it relies upon the load demand at amount of your time.

- **Incremental fuel cost is taken to be fuzzy**; as a result of the cost of fuel could amendment over the amount of your time, and since the cost of fuel for every unit is also completely different.

- **Start–up costs** of the units area unit assumed to be fuzzy, as a result of some units are on-line et al are offline. And it's necessary to say that we tend to embody the beginning costs, closedown costs, maintenance costs and crew expenses of every unit as a set worth that's start-up cost. So, start-up cost of a unit is freelance of the time it's been off line.[1]

- **Generating cost** of the system is treated as a fuzzy variable since it's directly proportional to the hourly load.

B. Fuzzy Sets Associated with Unit Commitment

After characteristic the fuzzy variables related to the unit commitment, the fuzzy sets process these variables area unit hand-picked and normalized between 0 and 1. [1] This normalized cost may be increased by a particular multiplier factor to adjust any desired variable.
The sets process the load capability of generator (LCG) area unit as follows:

LCG (MW) = {Low (Lo), Below Average (BAV), Average (Av), above Average (AAV), High (H)}

The Incremental cost (IC) is declared by the subsequent sets,

IC (Rs) = {low, small, large}

The Startup cost (SUC) is outlined by the subsequent sets

SUP (Rs) = {Zero, Medium, High}

The cost, chosen because the objectives perform is given by,

GRC (Rs) = Low (Lo), Below Average (BAV), Average (Av), above Average (AAV), High (H)

Suitable ranges area unit hand-picked for the fuzzy sets hand-picked from the given problem [1]

C Membership function

Based on the fuzzy sets, the membership functions are chosen for every fuzzy input and output variables. Triangular membership function is chosen for all the fuzzy variables.

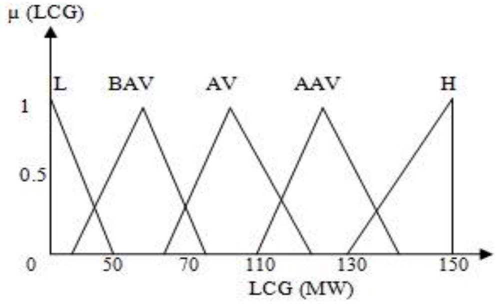

Figure.1 Membership function of load capacity of Generators

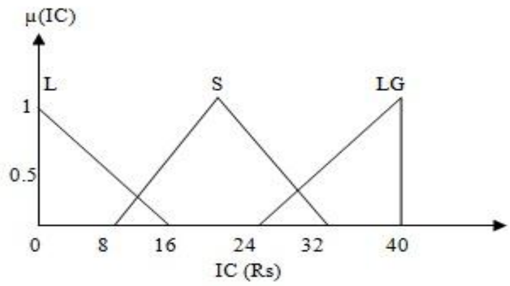

Figure.2 Membership function of Incremental Cost

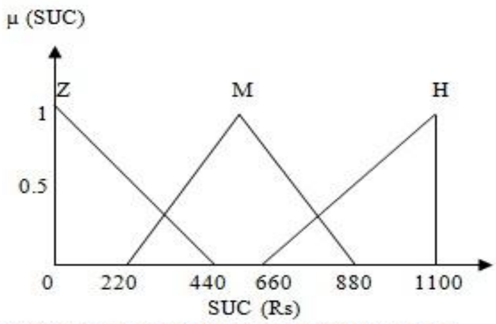

Figure (3): Membership function of Start-up Cost

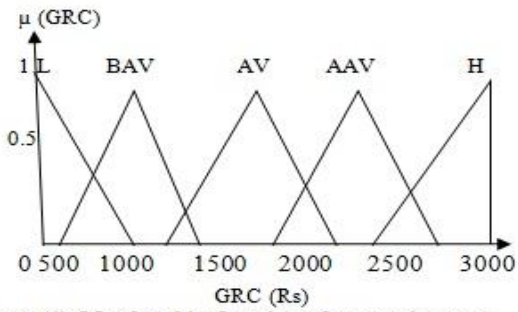

Figure (4): Membership function of generation cost

D Fuzzy If - Then Rules

In a fuzzy-logic-based approach, choices area unit created by forming a series of rules that relate the input variables to the Output variable victimization if-then statements. [1] The If (condition) is an antecedent to the Then (consequence) of each rule. Each decree general can be diagrammatical in the following manner: If (antecedent) then (consequence) Load capacity of generator, marginal cost, and startup cost area unit thought-about as input variables and cost is treated because the output variable. This relation between the input variables and the output variable is given as:

Generation cost = {(Load capacity of Generator) and (Incremental Cost) and (start-up Cost)}

In fuzzy set notation this is often written as

$$GRC = \{\mu LCG \cap \mu IC \cap \mu SUP\} \text{ Or } GRC = \min\{\mu LCG, \mu IC, \mu SUP\} \qquad (7)$$

Using the above notation, fuzzy rules area unit written to associate fuzzy input variables with the fuzzy output variable. primarily based Upon these relationships, and with relation to, a total of forty five rules are often composed (since there are a unit five subsets for Load capability of generator, three subsets for Incremental cost, and three subsets for start-up cost (5×3×3=45).[1] Following If (the load capability of a generator is low, and the incremental fuel cost is massive and the start–up cost is zero),then the production cost is low. other rule area unit show in **table.1** for fuzzification and the fuzzy results should be defuzzified by a definite defuzzification methodology once relating the input variable to the output variable as listed in Table 1. that's referred to as a defuzzification method to realize crisp numerical values.

Table (1): Fuzzy Rules Relating Input/output Fuzzy Variable [1]

RULE	LCG	IC	SUC	GRC	RULE	LCG	IC	SUC	GRC
1	L	L	Z	L	24	AV	S	H	AV
2	L	L	M	L	25	AV	LG	Z	AV
3	L	L	H	L	26	AV	LG	M	AV
4	L	S	Z	L	27	AV	LG	H	AV
5	L	S	M	L	28	AAV	L	Z	AAV
6	L	S	H	L	29	AAV	L	M	AAV
7	L	LG	Z	L	30	AAV	L	H	AAV
8	L	LG	M	L	31	AAV	S	Z	AAV
9	L	LG	H	L	32	AAV	S	M	AAV
10	BAV	L	Z	BAV	33	AAV	S	H	AAV
11	BAV	L	M	BAV	34	AAV	LG	Z	AAV
12	BAV	L	H	BAV	35	AAV	LG	M	AAV
13	BAV	S	Z	BAV	36	AAV	LG	H	AAV
14	BAV	S	M	BAV	37	H	L	Z	H
15	BAV	S	H	BAV	38	H	L	M	H
16	BAV	LG	Z	BAV	39	H	L	H	H
17	BAV	LG	M	BAV	40	H	S	Z	H
18	BAV	LG	H	BAV	41	H	S	M	H
19	AV	L	Z	AV	42	H	S	H	H
20	AV	L	M	AV	43	H	LG	Z	H
21	AV	L	H	AV	44	H	LG	M	H
22	AV	S	Z	AV	45	H	LG	H	H
23	AV	S	M	AV					

E Defuzzification Process

Defuzzification is the transformation of the fuzzy signals back to crisp values. One of the most normally used ways of defuzzification ways Mean of maxima (MOM) methodology. Mistreatment this methodology, the generation cost is obtained as in equation (8):

$$\text{GENERATION COST} = \sum_{i=1}^{N} \frac{\mu GRC_i}{N} \qquad (8)$$

Where: $\mu(GRC)_i$ is the membership value of the maximum clipped output and N is the number of the points corresponding to quantitative value of the output.

VI. CASE STUDY

Plant in Turkey with four generating units has been thought-about as a case study. A daily load demand divided into eight periods (three hours for each) is taken into account. Table two contains this load demand [12] whereas table.3 this demand. The unit commitment drawback are going to be resolved applying the dynamic programming and dynamic graphical programming and fuzzy logic approaches and therefore the results are going to be compared. The parameters of those four generating units as well as the value coefficients, the most and therefore the minimum real power generation, the start-up cost, and therefore the ramp rates of every unit are given in Table 2. As mentioned, the generation cost (GRC) is taken into account because the output variable whereas the load capability of a generator (LCG), the incremental fuel cost(IC) and therefore the start-up cost (SUC) is taken as input variables. It's vital to notice that the ranges of every set are selected once some experiments in an exceedingly subjective manner. As an example, if the loads vary which will be served by the biggest generator is between 0 to 150 MW, Then low LCG can be chosen at intervals the vary of 0–35 MW. [1]This enables a relative and virtual analysis of the linguistic definitions with the numerical values. Similarly, the subsets for different variables are often lingually outlined and it's clear that the vary of LCG and GRC is wider than IC and SUC. Thus 5 zones area unit created for each LCG and GRC fuzzy variables and 3 zones for the slim variables (IC and SUC) .

Table (2): Parameters for the Four-Unit Tuncbilek Thermal Power Plant [12]

Unit No	Generation Limits		Running cost			Start-up cost		Ramp Rates	
	P_{min} (MW)	P_{max} (MW)	a ($/MW^2.h)	b ($/MW.h)	c ($/h)	SC ($)	SD ($)	RU (MW/h)	RD (MW/h)
1	8	32	0.515	10.86	149.9	60	120	6	6
2	17	65	0.227	8.341	284.6	240	480	14	14
3	35	150	0.082	9.9441	495.8	550	1100	30	30
4	30	150	0.074	12.44	388.9	550	1100	30	30

Table (3): Daily Load Demand (MW)

Period hour	Demand(MW)
1-3	168
3-6	150
6-9	260
9-12	275
12-15	313
15-18	347
18-21	308
21-24	231

VII. SIMULATION RESULT

There is fuzzy logic algorithmic rule victimization for the unit commitment drawback of the four-generating units at the Tuncbilek thermal power station in Turkey is developed. A Matlab bug to supply an answer to the matter is additionally developed. The results obtained by the fuzzy logic rule give crisp values of the generation cost in every amount for each given fuzzy input variables. The whole set of results obtained for the four-generating units are summarized in Table 4. The fuzzy logic approach provides a logical and possible answer for each period. For every amount, the ad of the unit commitments equals the load demand. The generation costs obtained by the dynamic programming (DP), dynamic graphical programming (DGP) for victimization to the finding of the start-up cost and therefore the fuzzy logic (FL) comparison result given within the Table 4. There are simulation results of generation cost given in figure 5 is feeding the fuzzy variable knowledge and figure 6 is output of generation cost and figure 7 show the considering with the incremental cost and generation cost with the generating limits of the thought knowledge.

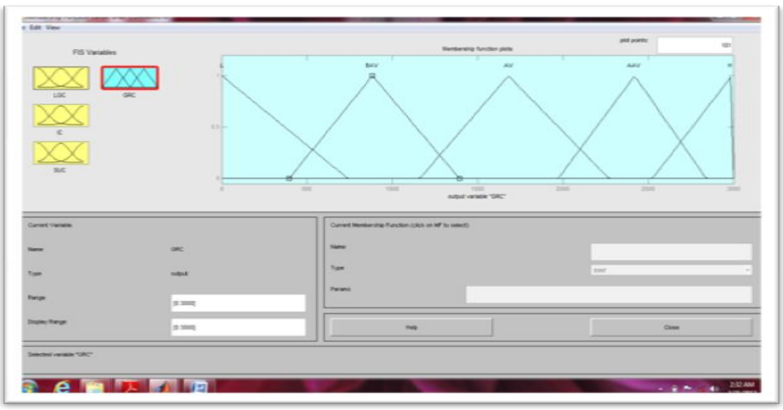

Figure (5): Feeding values to the variables

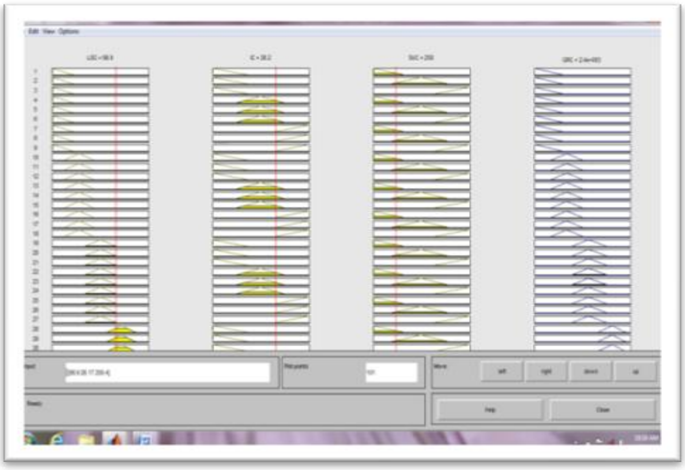

Figure (6): Output of fuzzy in terms of Generation cost

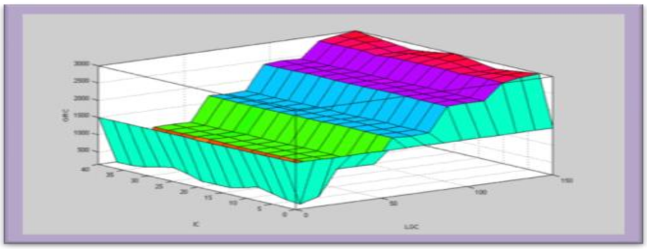

Figure (7): Incremental Cost Vs Generation cost considering Generator limit

Table (4): Comparison between Generation Costs in Rs Obtained From Fuzzy Logic with DP and DGP Method

Period	Load demand(MW)	Unit commitment				IC	Generation cost in Rs		
		Unit 1	Unit 2	Unit 3	Unit 4		DP	DGP	FL
1	168	0	0	87.6920	80.3090	24.32	4413.38	4342.56	3520
2	150	0	0	79.16342	70.83658	22.92	3438.38	3431.38	3460
3	260	0	43.5162	110.7908	105.5932	28.09	6750.17	6734.40	5750
4	275	16.7403	43.1677	110.0306	105.0614	27.98	6849.95	6840.98	6075
5	313	18.9320	48.4999	124.4773	121.0907	30.35	7747.65	7747.65	6130
6	347	20.9916	53.1725	137.3329	135.5031	32.48	8851.98	8851.98	8125
7	308	18.7391	47.8028	122.5849	118.9731	30.04	7596.66	7596.66	6600
8	231	0	39.2739	98.85776	92.66834	26.17	5544.93	5544.93	5420
						TOTAL	**51193.1**	**51090.54**	**45080.00**

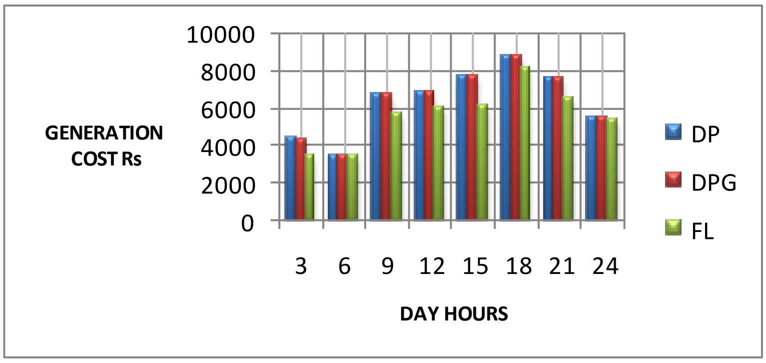

Figure (8): Generation cost of each period

VIII. CONCLUSION

The primary objective has been to demonstrate that if the method of the unit commitment downside will be delineate lingually, then such linguistic descriptions will be translated to resolution an answer that yields a logical and a possible solution to the matter with higher results compared to dynamic programming and dynamic graphical programming. This answer to the unit commitment downside victimization formal logic is with success obtained and also the best set up from a group of fine possible commitment selections has been accomplished. The output Results show that it's doable to urge some enhancements by fuzzy logic approach. Moreover, the results show that the fuzzy logic provides a legitimate and a possible answer to the unit commitment downside whereas satisfying all constraints for every period. For an equivalent unit commitments and also the same incremental fuel cost, the. Within the generation cost obtained by the fuzzy logic area unit less than those obtained by the dynamic programming and dynamic graphical programming. For the eight-time periods, the generation cost is lower once the fuzzy logic approach is used. The savings within the generation cost of the little capability thermal station of Tuncbilek in someday is **6010.54** rupees and monthly**180316** rupees and this makes the annual savings to achieve concerning **2163794.40** rupees. It's powerfully believed that because the capability of the facility plant will increase the savings within the cost conjointly will increase and this justifies the utilization of fuzzy logic to handle the unit commitment downside.

REFERENCES

[1] Assad Abu-Jasser'' Solving the Unit Commitment Problem Using Fuzzy Logic'' International Journal of Computer and Electrical Engineering, Vol. 3, No. 6, December 2011.

[2] Allen J Wood and Bruce F Wallenberg, "power generation, operation and Control", John Wiley and sons, New York.

[3] S. Saleem, "Unit Commitment Solution Methods", Proceedings of World Academy of Science, Engineering and Technology, Vol-26, ISSN 1307-6884, December 2007, pp 600-605.

[4] Ahmed Yusuf Saber, Tomonobu Senjyu, Naomitsu Urasaki "Fuzzy Unit Commitment Scheduling Using Absolutely Stochastic Simulated Annealing" IEEE transactions on power systems, VOL. 21, NO. 2, MAY 2006, pp 953-964.

[5] N. P. Padhy "Unit Commitment – A Bibliographical Survey." IEEE Transactions on Power Systems, vol 9, no 2, pp 1196 – 1205, May 2004.

[6] N. J. Redondo and A. J. Conejo. "Short-term Hydro-thermal Coordination by Lagrangian Relaxation: Solution of the Dual Problem." IEEE Transactions on Power Systems, vol 14, pp 89 –95, February 1999.

[7] S. Dekranjanpetch, G. B. Sheble and A. J. Conejo. "Auction Implementation Problems using Lagrangian Relaxation." IEEE Transactions on Power Systems, vol 14, pp 82–88, February 1999.

[8] S. A. Kazarlis, A. G. Bakirtzis and V. Petridis. "A Genetic Algorithm Solution to the Unit Commitment Problem." IEEE Transactions on Power Systems, vol 11, pp 83–92, February 1996.

[9] K. A. Juste, H. Kita, E. Tanaka and J. Hasegawa. "An Evolutionary Programming Solution to the Unit Commitment Problem." IEEE Transactions on Power Systems, vol 14, pp 1452–1459, November 1999.

[10] S. Rajasekaran, g. A. Vijayalakshmi pai '' neural networks, fuzzy logic and genetic algorithm' prentice-hall of India private limited, new delhi-2013

[11] A. H. Mantawy, Y. L. Abdel–Magid and S Z Selim Shokri. "Integrating Genetic Algorithm, Tabu Search and Simulated Annealing for the Unit Commitment Problem." IEEE Transactions on Power Systems, vol 14, no 3, pp 829–836, August 1999

[12] Ü. B. Filik and M. Kurban, "Solving Unit Commitment Problem Using Modified Sub gradient Method Combined with Simulated Annealing Algorithm," Mathematical Problems in Engineering, Hindawy Publishing Corporation, May 2010, Article ID 295645, 15 pages, Doi: 10.1155/2010/295645