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Economic Load Dispatch with Prohibited operating zone using Traditional Optimization Technique (GAMS)

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Abstract—This paper gives a new Proposed General Algebraic Modeling System (GAMS) economic dispatch problem having non-linear, discontinuous cost function. This new particle swarm optimization technique incorporates time varying acceleration coefficients (NPSOTVAC). The highly non-linear cost function due to ramp rate limit prohibited operating zones effect is considered in the proposed method. The effectiveness of proposed NPSOTVAC algorithm is proved through test on 6 and 15 unit test systems.

Keywords— economic load dispatch, NPSOTVAC, ramp rate limit, General Algebraic Modeling System

I. INTRODUCTION

Economic load dispatch (ELD) is one of the most important problems to be solved for the economic operation of a power system. Economic load dispatch is to define the production level of each plant so that the cost of fuel is reduced for the prescribed schedule of load [1]. The economic load dispatch problem is the problem of varying the generator's real and reactive power generation so as to meet the demands and losses, with the minimum fuel cost, and the generation being under some constrains. The more efficient generator in the system does not guarantee less cost as it may be present in the system where fuel cost is higher. If the plant is located seeing the cost of fuel to be minimum, then the distance to the load centers would increase and losses increase. The typical approach available in the literature is to augment the constraints into objective function by using langrange's multipliers and then solve it. But as the number of the power plants increase, the search space increases to find the optimum generations, the process becomes long and there is a chance for the process to get stuck at local minima. The regular methods for optimization fail when the power plant number increase as this would increase the search space exponentially [2]. Resulting solutions are inaccurate and cause revenue losses. This assumption is not valid for practical generators because the cost functions of generators have discontinuities and higher order non-linearities due to valve point loading [3], prohibited operating zones [4] and ramp rate limits of generators [5].Moreover, evolutionary programming [6-7] and behavioural random search algorithms such as genetic algorithm [8-9], particle swarm optimization [10-11], BBO [12], dynamic programming [13] have been implemented on the ELD problem. GAs does possess some weaknesses leading to larger computation time premature convergence.

In this paper the GAMS is proposed optimization as a methodology for economic load dispatch. It requires less computation time and memory and the results are compared with the new particle swarm optimization technique incorporates time varying acceleration coefficients (NPSOTVAC).

II. PROPOSED NEW GENERAL ALGEBRAIC MODELING SYSTEM

The General Algebraic Modeling System (GAMS) is specifically designed for modeling linear, nonlinear and mixed integer optimization problems. The system is particularly very advantageous with large, complex problems. GAMS module allows the user to concentrate on the modeling problem by making the setup simple. GAMS are especially useful for handling large, complex, one-of-a-kind problems which may require many revisions to establish an accurate model. The data presentation in GAMS can be done in its most elemental form using tables, columns etc. There are standard IF-ELSE, WHILE, LOOP, exception handling logic available which give the inherent flexibility to use GAMS almost like any programming language while retaining the basic advantages. Excellent debugging features exist for quick and effective identification of errors [14][15]. The available solvers provide access to most of the state of the art optimization tools but new solution algorithms for specific applications can be developed using the existing ones and the basic features of GAMS with much lower efforts than needed in a conventional programming language like FORTRAN.

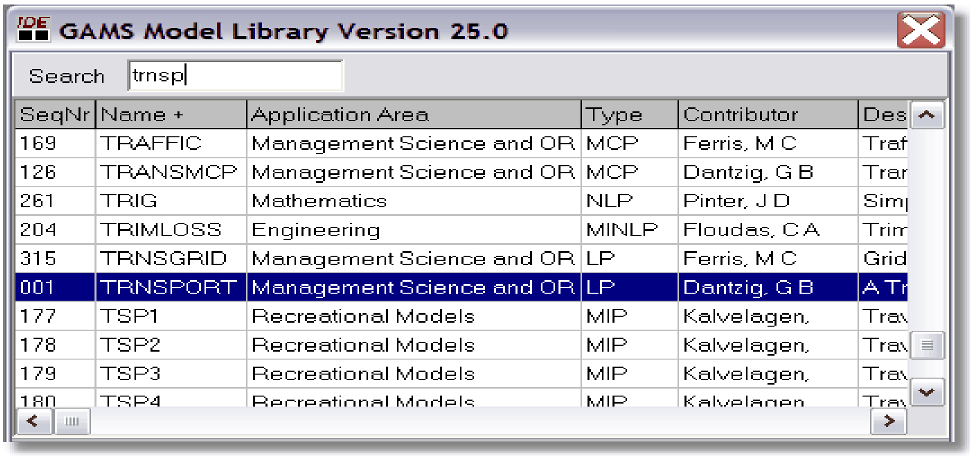

Fig 1 General Algebraic Modeling System

The tool kit in GAMS gives algorithms for each category of problem. GAMS software also has the unique feature of providing a common language that can make use of a variety of solvers. Table-1 gives the list of currently available GAMS solvers. The choice of solver is thus dependent on the understanding of the special structure of the problem and some experimentation. There are five types Model Libraries using in GAMS

1. Model Library
2. The Gams Testlib Library
3. Finlib - Practical Financial Optimization Models
4. The Gams Data Utilities Library

The basic structure of a mathematical model coded in GAMS has the components: sets, data, variable, equation, model and output. The data presentation in GAMS can be done in its most elemental form using Table 1.

Table-1: Solvers In General Algebraic Modeling System

Type of function	**Solver Sub-System**
LP	BDMLP, MINOS5, ZOOM, MPSX, SCICONIC, APEX IV, LAMSP, OSL, XA, CPLEX
NLP	MINOS 5, CONOPT, GRG 2, NPSOL
MILP	ZOOM, MPSX, SCICONIC, APEX IV, XA, OSL, LAMPS
MINLP	DICOPT++

III. METHODOLOGY OF PROPOSED NEW GENERAL ALGEBRAIC MODELING SYSTEM

The GAMS technology is designed to facilitate the work of modelers, who create mathematical models of real processes around us. It relieves modelers of the necessity to design algorithms of models, in addition to the development of models. Thus, the major functional objective of GAMS is to design algorithms for mathematical models. GAMS are the English abbreviation of "General Algebraic Modeling System." However, it does not mean that this system can be used only for mathematical models with algebraic equations. Those, who are acquainted with methods of solving differential equations in partial derivatives, know that the methods are always transformed to a system of algebraic equations. These algebraic equations are solved according to some iteration algorithm. That is, the applicability of GAMS is much wider. GAMS are a modeling system for optimization that provides an interface with a variety of different algorithms. Models are supplied by the user to GAMS in an input file in the form of algebraic equations using a higher level language. GAMS then compile the model and interfaces automatically with a "solver" (i.e., optimization algorithm). The compiled model as well as the solution found by the solver is then reported back to the user through an output file. The simple diagram below illustrates this process show in Fig 2. .

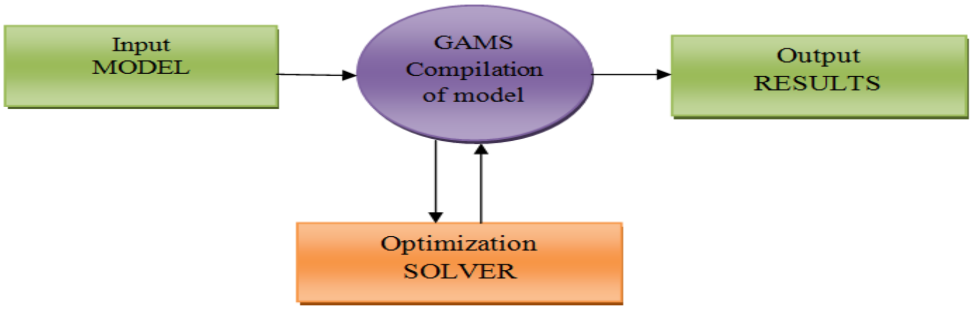

Fig 2 Proposed of General Algebraic Modeling System

The practical static ELD problem with generator nonlinearities such as prohibited operating zones are solved in this paper using General Algebraic Modeling System (GAMS) to find the optimal generation dispatch for different operating conditions. The objective of the economic dispatch problem is to minimize the total fuel cost at thermal power plants subjected to the operating constraints of a power system.

(A).Economic cost function: The primary objective of any ED problem is to reduce the operational cost of system fulfilling the load demand within limit of constraints. Simplified economic dispatch problem can be represented as a quadratic fuel cost objective function as described in Eq. (1)

$$MinF_T = \sum_{i=1}^{N} F_i(P_i)$$

$$F_i(P_i) = (a_i P_i^2 + b_i P_i + c_i) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Where F_T: total generating cost; F_i: cost function of *i*th generating unit; *ai, bi, ci*: cost coefficients of generator *i*; *Pi*: power of generator *i*; N: number of generators.

Equality constraint and Inequality constraints:

(1) System power balance equation*: It is an equality constraint which should be satisfied for power*

$$\sum_{i=1}^{N} P_i - (L_D + P_L) = 0$$

Where *LD* and *PL* are load demand and power losses respectively. To calculate system losses, methods based on penalty factors and constant loss formula coefficients or B-coefficients [16] are in use. The latter is adopted in this paper as per which transmission losses are expressed as

$$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} P_i B_{ij} P_j + \sum_{i=1}^{N} B_{oi} P_i + B_{OO}$$

(2)*Power generation capacity limits:*

$$P_i^{min} \le P_i \le P_i^{max} \qquad i = 1,2,\ldots,N$$

Where and are minimum and maximum power generation capacity limit of *ith* generator

(3) *Prohibited operating zone:*

The generators may have certain range where operation is restricted due to the physical limitation of machine component, steam valve, vibration in shaft bearing etc.The consideration of prohibited operating zone creates discontinuities in cost curve and converts the constraint as below.

$$P_i \in \begin{cases} P_i^{\min} \le P_i \le P_{i1}^{L} \\ P_{ik-1}^{U} \le P_i \le P_{ik}^{L} \\ P_{ik}^{U} \le P_i \le P_i^{\max} \end{cases}$$

Here *k* are the number of prohibited zones in *i*th generator curve, is the lower limit of *k*th prohibited zone, and is the upper limit of *k*th prohibited zone of *i*th generator.

(4) Generator ramp-rate limits

The operating range of on-line generating units is restricted by ramp-rate limits. In practice, the unit output cannot be adjusted instantaneously whenever load changes. Ramp rate limits, i.e. up-rate limit *URi*, down-rate limit *DRi* and previous hour generation restrict the operating region of all the on-line units. When the generator ramp-rate limits are considered, the operating limits of the *ith* generating unit are modified as follows:

$$Mamimum\,(P_i^{min}, P_i^o - DR_i) \le Pi \le Minimum\,(P_i^{max}, P_i^o + UR_i)$$

IV. NUMERICAL RESULTS AND ANALYSIS

***Test system (A)*:** The system consists of 6 generating units, 26 buses and 46 transmission lines [16].The load demand is 1263 MW.The generating capacity and cost coefficients, loss coefficients B, ramp rate limit and prohibited zones for six unit system are given in table 2, 3 and 4 respectively.

Table 2. Data Generating 6- Unit Capacity and Coefficients [16]

Unit name	ai	bi	ci	P_i^{min}	P_i^{max}
Unit-1	240	7.0	0.0070	100	500
Unit-2	200	10.0	0.0095	50	200
Unit-3	220	8.5	0.0090	80	300
Unit-4	200	11.0	0.0090	50	150
Unit-5	220	10.5	0.0080	50	220
Unit-6	190	12.0	0.0075	50	120

Table 3. Loss Coefficients B of the 6-Unit System [16]

B_{ij}	1	2	3	4	5	6
1	0.0017	0.0012	0.0007	-0.0001	-0.0005	-0.0002
2	0.0012	0.0014	0.0009	0.0001	-0.0006	-0.0001
3	0.0007	0.0009	0.0031	0	-0.001	-0.0006
4	-0.0001	0.0001	0	0.0024	-0.0006	-0.0008
5	-0.0005	-0.0006	-0.001	-0.0006	0.0129	-0.0002
6	-0.0002	-0.0001	-0.0006	-0.0008	-0.0002	0.0150
B_{0i}	-0.0004	-0.0001	0.0007	0.0001	0.0002	-0.0007
B_{00}	0.056					

Table 4. Generating 6-Unit Ramp Rate Limits and Prohibited Zones [16]

Unit	P_i^0	UR_i	DR_i	Prohibited Zones
1	440	80	120	[210,240] [350,380]
2	170	50	90	[90,110] [140,160]
3	200	65	100	[150,170] [210,240]
4	150	50	90	[80,90] [110,120]
5	190	50	90	[90,110] [140,150]
6	110	50	90	[75,85] [100,105]

Table 5 provides a comparison of economic load dispatch results obtained by Proposed New General Algebraic Modeling System for a six unit thermal system. In this case power demand 1263 MW, The results are compared with New particle swarm optimization technique incorporates time varying acceleration coefficients (NPSOTVAC) methods. it can be clearly seen from figure 3. The proposed GAMS provide better results as compared to New particle swarm optimization technique incorporates time varying acceleration coefficients (NPSOTVAC) methods.

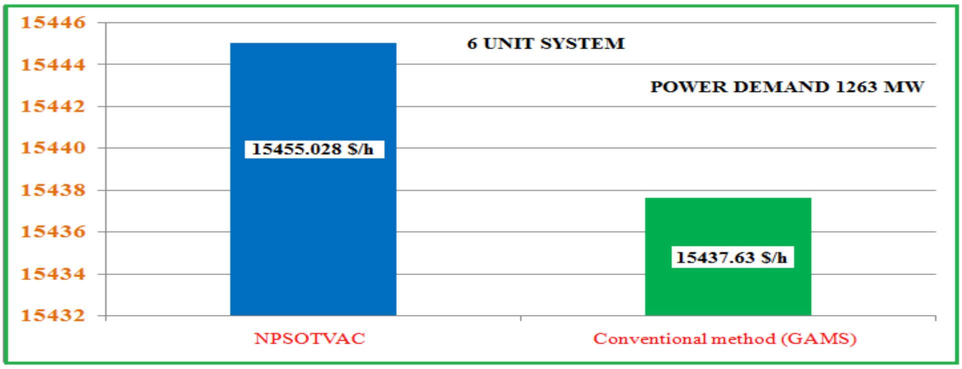

Fig 3 NPSOTVAC and Traditional Optimization Technique (GAMS) result 6 unit

Table 5 comparative table NPSOTVAC and Traditional Optimization Technique (GAMS)

Parameter	**NPSOTVAC [16]**	**Traditional Optimization Technique (GAMS**
P1 MW)	450.01	**446.057**
P2 MW)	171.18	**172.418**
P3 MW)	266.543	**263.123**
P4 MW)	131.916	**142.684**
P5 MW)	165.58	**164.814**
P6 MW)	89.62	**85.858**
Power Load	1263 MW	**1263 MW**
Total power output(MW)	1274.849(MW)	**1274.954 (MW)**
Total loss(MW)	12.44 (MW)	**11.955 (MW)**
Total generation cost($/h)	15445.028($/h)	**15437.612 ($/h)**

***Test system (B)*: This is a system with 15 generating units whose characteristics are given in Table 6 and Table 7 [16]. The load demand of the system is 2630 MW.**

Table 6. Data Generating 15-Unit Capacity and Coefficients [16]

Unit	P_i^{min}	P_i^{max}	a_i	b_i	c_i
1	150	455	671	10.1	0.000299
2	150	455	574	10.2	0.000183
3	20	130	374	8.8	0.001126
4	20	130	374	8.8	0.001126
5	150	470	461	10.4	0.000205
6	135	460	630	10.1	0.000301
7	135	465	548	9.8	0.000364
8	60	300	227	11.2	0.000338
9	25	162	173	11.2	0.000807
10	25	160	175	10.7	0.001203
11	20	80	186	10.2	0.003586
12	20	80	230	9.9	0.005513
13	25	85	225	13.1	0.000371
14	15	55	309	12.1	0.001929
15	15	55	323	12.4	0.004447

Table 7. Generating 15-Unit Ramp Rate Limits and Prohibited Zones [16]

Unit	P_i^0	UR_i	DR_i	Prohibited Zones
1	400	80	120	
2	300	80	120	[185,225] [305,335] [420,450]
3	105	130	130	
4	100	130	130	
5	90	80	120	[180,200] [305,335] [390,420]
6	400	80	120	[230,255] [365,395] [430,455]
7	350	80	120	
8	95	65	100	
9	105	60	100	
10	110	60	100	
11	60	80	80	
12	40	80	80	[30,40] [55,65]
13	30	80	80	
14	20	55	55	
15	20	55	55	

Table 8 provides a comparison of economic load dispatch results obtained by Proposed New General Algebraic Modeling System for a 15- unit thermal system. In this case power demand 2630 MW, The results are compared with New particle swarm optimization technique incorporates time varying acceleration coefficients (NPSOTVAC) methods. it can be clearly seen from figure 4. The proposed GAMS provide better results as compared to New particle swarm optimization technique incorporates time varying acceleration coefficients (NPSOTVAC) methods.

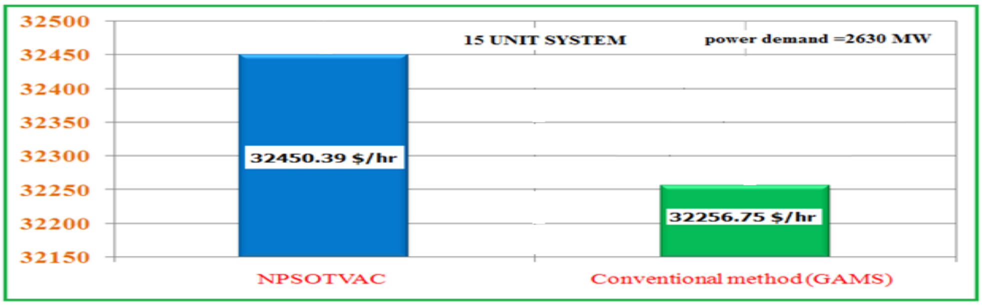

Fig 4 NPSOTVAC and Traditional Optimization Technique (GAMS) result 15 unit

Table 8 comparative table NPSOTVAC and Traditional Optimization Technique (GAMS)

Unit Power Output	NPSOTVAC [16]	Traditional Optimization Technique (GAMS
P1 (MW)	455.00	**455.000**
P2 (MW)	375.00	**455.000**
P3 (MW)	130.00	**130.000**
P4 (MW)	135.28	**130.000**
P5 (MW)	165.77	**271.180**
P6 (MW)	460.00	**460.000**
P7(MW)	424.52	**465.000**
P8(MW)	65.00	**60.000**
P9(MW)	25.00	**25.000**
P10(MW)	157.00	**25.000**
P11(MW)	84.23	**43.389**
P12(MW)	74.68	**55.431**
P13(MW)	25.00	**25.000**
P14(MW)	24.98	**15.000**
P15(MW)	34.00	**15.000**
Power Load	2630	**2630**
Total power output(MW)	2635.46	**2605.00**
Total generation cost($/h)	32450.39	**32256.754**

V. CONCLUSION

Economic Load Dispatch problem being attempted using Proposed Traditional Optimization Technique (GAMS) for 6 generator and 15 generator test system evaluates the performance of the proposed approach. The solution results are high accuracy and fast computational time. Therefore, this results shows that Proposed New General Algebraic Modeling System optimization is a promising technique for solving complicated problems in power system.

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