



Economic Dispatch Solution for Generating units through Optimization

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Received: 31 August, Revised: 07 September, Accepted: 15 September

Abstract— The complex nature of the modern power system is because of the interconnection of the generating units and day by day increased load demand. The main purpose of the power system is to tantalize the load needs and generate reliable and cheap energy i.e. cost of generation should be optimum i.e. operating every generating unit in such a way to optimize the cost. The cost function of every generating unit is different from other generating unit, so load has to be divided among various generating units to obtain optimum generation. The optimization of power system is done by Economic load dispatch (ELD). ELD is of immense importance in power system operation and planning (PSOP). The primary purpose of ELD is to pacify the load needs at lowest cost while satiating all kind of equality and inequality constraints. Power system has highly non-linear input output characteristics because of different generation constraints. In ELD cost function of each and every generating unit is equated as quadratic function. Numerous methods have been devised to figure out ELD problem incorporating conventional methods like Lambda iteration method and Gradient method, and artificial intelligent method like Particle Swarm Optimization, Generic Algorithms etc.

In this thesis optimization of generating units is done through General Algebraic Modelling System (GAMS). GAMS is a modelling system used for mathematical programming and optimization on a large scale. It helps to develop a mathematical model similar to their corresponding mathematical expression and gives more accurate results.

Keywords— Optimization, ELD, GAMS.

I. INTRODUCTION

The one and only single most extremely important objective of the power system is to dispatch reliable and cheap energy to its consumer. In order to achieve that goal economic load dispatch (ELD) is very critical factor in power system operation and planning. Economic load dispatch is stated as

the practice for the allocation of load to the generating units in order to satisfy the load demand in such a way to minimize the cost of energy generation while all the constraints either equality or inequality constraints are satisfied. In other words, it helps to achieve optimum generation schedule for every generating unit in power system.

In the beginning the economic load dispatch concept was developed to cater different load variations in a given period by running most efficient unit first until it reaches its maximum limits, after that second most efficient unit starts increasing its generation to pacify the load requirements in case of load increasing during peak hours' duration until its maximum range is reached, and so next most efficient unit will start increasing its generation and so on, the drawback of this logic was that the cost of operation increased as during light load hours the units were running at their lower efficiency causing more problems [1]. After that lots of approaches have been developed to figure out economic load dispatch problem. The traditional approach to figure out economic load dispatch problems are lambda iteration method, Newton Raphson method and gradient method, Participation Factor Method and Base Point Method [2]. The problem related to these methods are such that they used only for those generating whose fuel-cost characteristic curve is linear and increases in a monotonic way this leads to extremely high operating cost as because of different constraints the input/output characteristics is non-linear in nature [3]. The effective way to solve the ELD problem in an accurate way is to have the smoothly increasing and continuous nature of the cost curve [4]. Highly intelligent algorithms are used to solve constrained economic load dispatch problem which includes Particle Swarm Optimization, Genetic Algorithms (GA), Evolutionary programming, neural networks, Hopfield neural networks [5]. Some of these methods can result in slow convergence except Particle Swarm Optimization [6].

Different constraints such as transmission losses, load demand balance, quadratic nature of a cost functions, and valve point loading effect made the economic load dispatch

problem a nonlinear optimization problem in a power system operation and planning, conventional methods are not able to solve such a nonlinear problem so for that different techniques have been developed to figure out such complex problem while handling these constraints in order to get real time results [7]. Further development in the solution of Economic load dispatch of thermal power unit have been made by considering the optimum amount of heat release, for that purpose different Heuristics and meta Heuristic techniques have been developed [8]. Optimum emission of flue gases in the air in order to maintain the environment clean and free from the oxides of carbon, sulphur and nitrogen [9]

In this proposed thesis Economic Load Dispatch is done through General Algebraic Modelling System (GAMS). GAMS helps to develop mathematical programming in a same way as that of system mathematical expression and performs the function of the optimization of linear, Non-linear and mixed integrals. GAMS used for a large scale optimization techniques and gives most accurate results.

II. RELATED WORK

Lots of work has been done on Economic load dispatch ranging from small scale to a large scale power system optimization. In this regard some of the work is mentioned here as a literature study.

In [10] a multi objective meta heuristic approach for dynamic ELD problem using multi objective PSO (MOPSO). Emission constrained Economic Load Dispatch problem is solved using differential evolution (DE), [11]. A comparative analysis of Genetic approach based on arithmetic crossover with the enhanced Hopfield Neural Network, Fuzzy logic controlled Genetic Algorithms (FLCGA) and advance Hopfield Neural Network, [12].

A Hybrid technique consisting Genetic Algorithm as an optimizer and SQP used for tuning purpose [13]. Θ -Particle swarm optimization technique is applied for optimization by changing traditional PSO to Θ -PSO by using phase angle vector [14]. Another variant of PSO approach known as Adoptive PSO has been developed and implemented [15]. A Heuristic approach consisting of Iteration PSO associated with variable acceleration coefficient by choosing a proper penalty factor [16]. In [17] above approach is used for combined heat power economic dispatch (CHPED) problem.

Artificial Immune System (AIS) based on evolutionary techniques and colonel selection approach [18]. An Encoding technique based on Genetic Algorithms used for global optimization [19]. A Hybrid Harmony Search (HHS) technique based on Swarm approach meta-heuristic algorithm for the optimization [20]. Other variant of HHS, which is tournament based THS [21].

An iterative PSO developed to get optimum scheduling of power, [22]. In [23] Gravitational Search Algorithm related to law of gravity and mass interaction for the optimization. A

hybrid system consists of PSO and SQP is used for optimization [24].

Hybrid approach consist of PSO, Gaussian probability distribution functions and chaotic sequence for power system optimization [25]. A hybrid system of GA with SQP and IPA (interior point algorithm) with their nine variants are implemented for optimization of thermal generating units [26]. In [27] a hybrid technique called Estimation of Distribution and Differential Evolution developed. Another variant of Differential evolutionary approach is developed which include restoration process in case if the constraints are disobeyed [28]. A self-adaptive DE along with GE is implemented for the solution of dynamic economic load dispatch problem [29]. DE practice is implemented on the optimization of thermal power plant along with the integration of renewable energy resource including wind energy in order to solve the combined economic emission dispatch [30].

A meta-heuristic approach based on the insect's casual nature like Cuckoo and Levy have been developed known as Cuckoo Search Algorithms (CSA), [31]. In [32] and [33] a detailed review of different modifications of Cuckoo algorithms discussed for the purpose of optimization and its significance in the research. to solve this complex nature of ELD a cuckoo algorithm is implemented [34]. A variant of firefly algorithm (MFO) is implemented in [35] for optimization and a comparative analysis is made based on results with different algorithms used in a literature. A multi objective evolutionary technique called chemical reaction optimization has been implemented on DELD, the convergence of presented method is improved by hybridization with differential evolution to get rid of local minima [36].

In [37] different techniques and their hybrid combination based on different has been reviewed and addressed the complexity related to every computational techniques. A review of different hybrid approaches developed for the solution combined economic emission dispatch problem [38]. Another method known as flower pollination Algorithm is used to solve multi objective function of combined economic emission [39]. A quadratic programming approach is presented and compared with different approaches like GAMS, GA, PSO and ED and also with hybrid technique consist of GA, ED and PS [40]. A Moth Flame Optimization (MFO) technique in [41]. A hybrid approach consist of Nelder Mead and pattern search algorithm in which the former performs the function of optimization and the later used to find the best optimum solution [42]. An algorithm based technique known as Social Spider Optimization and its later version (SSSO and ISSO) is implemented in [43]. In [44] SSO is implemented on five models for constrained ELD problem. In [45] a modification of OLC called OLC swarm presented as optimization technique.

In [46] a modified HNN method uses two different practices to solve ELD problem in order to minimize the computational time. Differential Evolutionary approach is

implemented and results shown compatibility to those obtained by MHNN and MPSO [47]. The combined heat and power (CHP) day ahead optimization to improvise optimum cost and heat dissipation developed applied on two models which are Electric storage system and thermal storage system [48]. Extension classical Bat Algorithm known as chaotic Bat Algorithm has the issue that operator has to tune the model in order to get the feasible results [49]. An evolutionary approach known as Backtracking Search Algorithms is applies in [50] for optimization purpose. A Meta heuristic approach Grey wolf optimization approach is developed, [51]. In [52] Grey wolf optimization is used for solution of dynamic economic load. Exchange Market Algorithm to achieve globally optimized region [53]. A crisscross optimization approach is developed for optimization on large scale basis of generating units and to achieve better performance [54].

A comparison is made between General Algebraic Modelling System (GAMS) and the quadratic Programming is presented [55] and in [56] optimization is carried out through GAMS, initially ELD was solved using PWL and SOS algorithms which were unable to give optimum schedule for power system. An optimization for the dynamic economic load dispatch is done through GAMS, in results GAMS shown the upper hand over the other available approaches [57].

III. METHODOLOGY

In this paper, Optimization of different generating units is carried out using GAMS as optimization tool on different case studies along with load and generation profiling.

Case 1: this case study includes 26 generating units.

Case 2: Total of 35 generating units are used for optimum scheduling of different generating units.

A. generalAlgebraic Modelling system

General algebraic modelling system commonly known as GAMS is a high level mathematical programming tool used to solve mathematical models according to the mathematical expressions of that model. Used by both commercial areas and academic institutions in different areas of research for optimization purposes varies from production planning to economic modelling. GAMS is developed to solve linear, nonlinear and mixed integral optimization problem. The basic coding structure of the GAMS comprises Sets, Data, Variable, Equations, Model and solve statement, Output. Different constraints and cost functions of generating units are given in the form of table.

TABLE I. UNITS CONSTRAINTS AND COST FUNCTION COEFFICIENTS.

Sr. No	Unit name	P_{max} (MW)	P_{min} (MW)	c_i	b_iP (\$/MW)	a_iP^2 (\$/MW ²)
1	G1	2170	217	2001.32	7.1	0.00277
2	G2	2402	520.5	2202.55	7.97	0.00313

3	G3	1638	350.7	1794.53	6.66	0.00284
4	G4	1370	274	1785.96	6.63	0.00298
5	G5	680	250	1247.83	7.97	0.00313
6	G6	665	222	1249.9	7.95	0.00313
7	G7	1320	264	1755.55	7.69	0.00294
8	G8	1292	274	1801.25	8.01	0.00125
9	G9	2200	450	2855.32	7.93	0.00235
10	G10	1320	374	1798.25	6.75	0.00196
11	G11	1320	375	1815.32	5.12	0.00149
12	G12	1320	256	1915.32	6.64	0.00155
13	G13	1320	275	1720.55	9.60	0.00160
14	G14	1320	200	1650.56	8.66	0.00187
15	G15	1320	295	2390.52	6.12	0.00785
16	G16	600	200	1113.4	8.5	0.00421
17	G17	660	254	1728.3	9.15	0.00708
18	G18	600	180	1285.25	8.25	0.00902
19	G19	450	195	635.5	11.154	0.00515
20	G20	330	99	287.71	8.03	0.00357
21	G21	330	135	455.76	6.6	0.00573
22	G22	330	110	391.93	7.01	0.00492
23	G23	1036	230	1247.15	8.15	0.00333
24	G24	727	250	460.32	7.26	0.00526
25	G25	216	100	107.87	8.95	0.0001
26	G26	175	50	222.21	6.45	0.0016
27	G27	3478	575	3354.96	14.36	0.00014
28	G28	1410	282	1954.96	8.8	0.00378
29	G29	1410	220	1830.85	7.8	0.00222
30	G30	1450	290	1949.72	9.18	0.00122
31	G31	669	134	969.8	7.05	0.00766
32	G32	121	24.2	694.26	4.84	0.00841
33	G33	96	20	278.16	4.18	0.00766

34	G34	500	125	766.32	6.8	0.00345
35	G35	1310	275	1550.32	6.78	0.00245

IV. RESULTS

The research work comprises of total 35 generating units to be economically dispatched in order to get the inexpensive energy from the traditional power system. In this work two case studies have been carried out on with 26 generating units and other with 35 generating units. The results are shown in the form of tables and graphs.

A. Optimization of 26 units at 15000MW load demand.

In this section the optimization of 26 generating units dispatched in order to meet the load of 15000 MW load including losses associated with power system is discussed. Table below shows the results of how much power should be generated from each unit on the basis of the cost function of individual generating unit given in table below.

Negative value of marginal cost shows that the unit is hitting the maximum range so its marginal cost will be less than that of the system marginal cost by an incremental cost of the unit. Zero or EPS shows that the generating unit is operating within the allowable range of generation so its incremental cost will be same as that of system marginal cost, the positive value shows that the generating unit is operating at its minimum allowable range of generation limit, so its marginal cost should be greater than that of system marginal cost by incremental cost of the generating units.

TABLE II. UNIT'S DISPATCHED GENERATION AND INCREMENTAL COSTS

Unit	Generation (MW)	incremental cost \$/MWh
g26	175	-4.21676630288306
g25	216	-2.23974630288306
g11	1320	-2.18366630288306
g22	330	-0.980066302883063
g21	330	-0.855466302883062
g20	330	-0.851066302883062
g12	1320	-0.505266302883063
g13	511.645719650957	0
g1	766.160426459827	EPS
g2	521.927524422215	EPS
g3	805.856743465328	EPS
g4	773.031258872997	EPS
g5	521.927524422215	EPS
g6	525.122412601128	EPS
g7	603.27658212297	EPS
g8	1290.90652115323	EPS
g9	703.673681464482	EPS
g10	1144.7107915518	EPS
g14	689.108637134509	EPS
g15	325.940528846055	EPS
g16	325.091009843594	EPS
g23	463.553498931391	EPS

g24	378.067139057326	EPS
g18	180	0.259933697116937
g17	254	1.50937369711694
g19	195	1.92523369711694

The table below gives the system marginal cost and the total generation cost in order to meet the total load demand.

TABLE III. SYSTEM MARGINAL AND TOTAL GENERATION COST

Load (MW)	System marginal cost	Generation (MW)	Total cost of generation in \$
15000	11.2372663028831	15000	173065.176140111

The graphical representation shows the results from most economical generating unit at left and most expensive unit at right of the graph shown in Fig below.

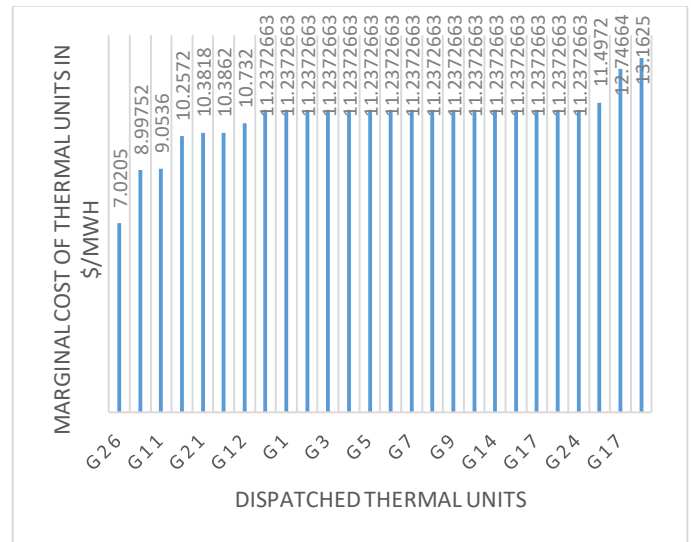


Figure 1. Units marginal cost.

B. Optimization of 35 units at 15000MW load demand.

Total of 35 generating units are used for optimum scheduling of these plants. The load along with losses is taken as the load demand 26359 MW. In below gives the optimum scheduling of the generating unit is illustrated.

The table below gives the optimum scheduling and incremental cost of each generating units.

TABLE IV. UNIT'S DISPATCHED GENERATION AND INCRIMENTAL COSTS

Unit name	Generation (MW)	Unit marginal cost
g33	96	-7.60739449154909
g32	121	-6.38289449154909
g26	175	-6.23761449154909
g25	216	-4.26059449154909
g11	1320	-4.20451449154909
g34	500	-3.00811449154909
g22	330	-3.00091449154909
g21	330	-2.87631449154909
g20	330	-2.87191449154909
g31	669	-2.78283449154909
g12	1320	-2.52611449154909
g8	1292	-2.01811449154909
g10	1320	-1.33371449154909
g6	665	-1.14521449154909
g5	680	-1.03131449154909
g30	1450	-0.54011449154909
g35	1310	-0.0591144915490904
g1	1140.39157250909	0
g13	1143.16077860909	EPS
g14	1229.44237741954	EPS
g15	454.656973984018	EPS
g16	565.096732963075	EPS
g17	290.121079911659	EPS
g18	277.611668045959	EPS
g19	204.282960344572	EPS
g2	844.746723889631	EPS
g23	766.984157890254	EPS
g24	570.162974481853	EPS
g28	589.69768406734	EPS
g29	1229.30506566421	EPS
g3	1161.639875272	EPS

	73	
g4	1112.09974690421	EPS
g7	946.95824686209	EPS
g9	1133.64138118066	EPS
g27	575	1.26288550845091

The table below gives the system marginal cost and the total cost of generation.

TABLE V. SYSTEM MARGINAL AND TOTAL GENERAATION COST

Load (MW)	System marginal cost	Generation (MW)	Total generation cost in \$
26359	13.2581144915491	26359	313223.669360519

The graphical representation of each generating unit's marginal cost is give as,

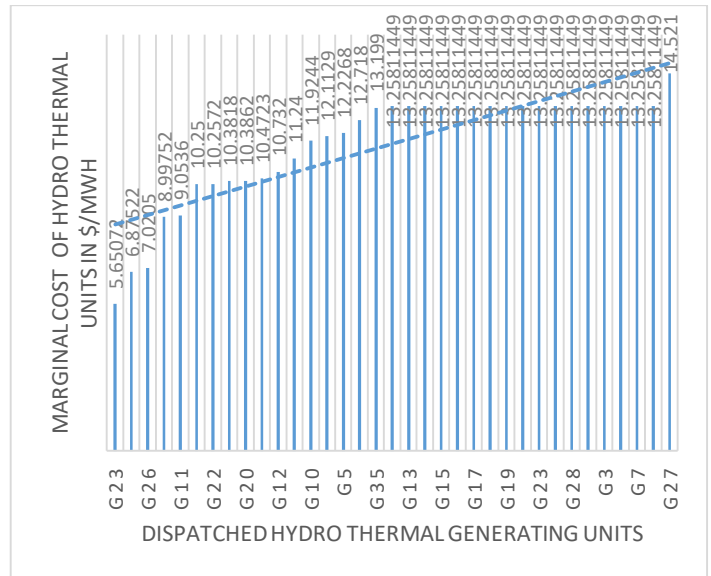


Figure 2. Units marginal cost.

CONCUSLION

One of the main objective of the power system is to provide cheaper and uninterrupted energy to its consumer and to reduce losses in associated with power system by economically dispatching generating units in a power system in order to meet the load requirements which should financially benefit both the generating utility and energy consumers. General Algebraic Modelling System is one of the most efficient and mathematical programming software for the optimization on large scale in which mathematical algorithm is defined based on the mathematical expressions of the system. GAMS used for the optimization purpose on a large

scale system is one of the easy software platform is user friendly, easy handling and takes less time for the execution of program and gives best results. Different scenarios for optimization of Pakistan power system is discussed in this work including optimum dispatching. At the end, results shown the dispatching of hydro-thermal generating units available in the research studies gives the most economical solution for optimization problem.

Future work on this area of study can be done by considering multi-objective function associated with power system. Research can be extended for the optimization of power system along with different constraints associated with unit commitment such as ramp rates etc. further extension can be made to consider the optimal power flow scenario for power system. Due to rapid trend towards renewable sources, Integration of renewable energy sources with the classical power system is one of the complex job. So solution can be developed for the optimum dispatching and integration of renewable energy resources with conventional grids.

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