

A COMPERATIVE ANALYSIS OF COMBINED ECONOMIC AND EMISSION DISPATCH PROBLEM USING CONVENTIONAL AND MODERN ALGORITHMS

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ABSTRACT

An efficient and optimal economic operation of electric power generation has always an important position in the electric power industry. In power system operation, control, management and planning, the dispatch of electric load is the main function that which is further to reduce total production cost of generating units with respect to considered constraints. As the production of electricity from the fossil fuels discharges various pollutants resulted in effective generating units. This leads to the development of combined economic and emission dispatch (CEED) techniques. Economic load dispatch (ELD) and economic emission dispatch (EED) have been applied to obtain optimal fuel cost and optimal emission of generating units respectively. Various techniques have been proposed to solve CEED problem, still convergence is not guaranteed. To overcome those difficulties this paper proposed a genetic algorithm approach. This paper also proposed a lambda based approach for solving CEED problem and finally compared with genetic algorithm methodologies by considering the power limits of the generator, the multi objective CEED problem is converted in to a single objective function usig a modified price penalty factor approach. The simulation results show that the proposed technique for solving CEED problem results in better convergence rate.

Keywords

Combined Economic And Emission Dispatch (CEED), Lambda Iteration, Genetic Algorithm (GA)

I. INTRODUCTION

The economic dispatch difficulty has taken an appropriate twist with highly worried environmental situations. This condition leaded, that absolute minimum cost is not the only condition to be satisfied in the electric power

generation and dispatching difficulties. The production of electricity from the fossil fuel discharges various pollutants like Sulphur Oxides (SO₂), and Oxides of Nitrogen (NO_x) into the atmosphere. These gaseous pollutants results in harmful effects on human beings and also on plants and animals. The Clean Air Act Amendments of 1990 (CAAA) suggest that the electricity using industry must decrease its SO₂ emission by 10 million ton/year and the NO_x by 2 million ton/year from the 1980 level.

On the other hand, considering only the operation of minimum environmental impact is not practical because of the high production cost of the system. Conversely, to operate the generating system with the lesser production cost will result in higher emission. As a result, economic dispatch, emission dispatch or combined economic and emission dispatch is a way selected separately or combined together. To determine the suitable solution to this difficulty, an excellent power management approach is set. Various optimization methods like lambda iteration, linear programming, non-linear programming, quadratic programming, Genetic Algorithm (GA) are used to overcome several economic dispatch difficulties and also the unit commitment difficulties.

The usage of genetic algorithm for economic dispatch difficulties needs a large number of generations if the power generating system has the more number of units. Combined economic and emission dispatch has been emerged in the field of power generation dispatch that concurrently reduce both fuel cost and total emissions. While the emission is reduced the fuel cost may be inappropriately increased or while the fuel cost is reduced the emission may be increased. This difficulty is overcome by creating the objective function and utilizing some optimization methods like GA. But, there are some problems like more time for optimization, operation complexity, etc., exists in using those optimization techniques. To overcome

those difficulties, this paper uses Genetic Algorithm (GA). The remaining sections of this paper will explain the methodology and the result obtained using the proposed technique to solve CEED problem.

II. RELATED WORKS

The main aim of this approach is that cost, emission and loss are combined and moreover the pareto-optimal economic dispatch for emission constrained and loss- restricted case. It's a new recursive technique for recognizing production cost minimization, with an emission constrained and loss reduced condition. Combined Economic and Emission Dispatch (CEED) issue is to schedule the committed generating unit outputs to satisfy the needed load demand at minimum operating cost with minimum emission simultaneously. This multi-objective CEED problem is changed into a single objective function with the help of a price penalty factor.

The proposed technique finds the global or near-global optimal solution for the Combined Economic and Emission Dispatch (CEED) problem. Lakhwinder Singh deals with the Economic Emission Dispatch (EED) issue involving real and reactive power scheduling of thermal power generating units. Demirel proposed Economic and minimum emission dispatch with Hopfield Neural Network (HNN) and Lagrange Multiplier (LM) solutions to economic dispatch (ED), NO_x Emission Dispatch (EmD), and Economic- Emission Dispatch (EED) of a sample system which contains six thermal generators are presented. T. Ratniyomchai presents a demonstration of solving combined economic and emission dispatch problems. The main aim of the combined problem can be represented by considering both the fuel cost and total emission with necessary constraints. Genetic algorithm is one of most efficient intelligent search techniques involved in solving economic load dispatch. The two economic and emission dispatch problems are combined and converted into a single objective function with the help of a price penalty factor h.

III. METHODOLOGY

A. Economic Dispatch

The economic dispatch problem is to determine the optimal mixture of power generation in a manner that the entire production cost of the entire system is reduced while satisfying the total power demand and few key power system factors. The fuel cost for all the power generation unit is defined initially. Therefore, the total production cost function of economic dispatch problem is defined as the total sum of the fuel costs of all the generating plant units as mentioned below:

$$F_t = \sum^{N_G} \{a_i p_i^2 + b_i p_i + c_i + |d_i \sin e_i (p_i^{\min} - p_i)|\}$$

where,

N_G is the total number of generating units

F_t is the total production cost

P_i is the minimum output of generating unit i

A_i, b_i, c_i, d_i, e_i are fuel cost coefficients of unit i

This equation helps in determining the total production cost of the generating plant.

B. Emission Dispatch

The solution of economic dispatch problem will provide the quantity of active power to be produced by various units at the minimum production cost for a certain power requirement. On the other hand, the total quantity of pollutant emission is not considered in conventional economic dispatch problem. The quantity of pollutant emission resulted from a fossil-fired thermal generating unit is based on the amount of power generated by every unit. For reducing the complexity, the total emission produced can be modeled as a direct sum of a quadratic function and an exponential term of the active power output of the generating units.

C. Combined Economic and Emission Dispatch

The economic dispatch and emission dispatch are two various problems as discussed previously. Emission dispatch can be included in conventional economic load dispatch problems by merging an emission constraint with the economic load dispatch problem.

D. Problem Constraints

Usually, there are two constraints such as equality and inequality constraints should be considered. For the problem defined in this paper, a power balance equation is set as an equality constraint and the limits of power generation outputs are set as in equality constraints.

IV. CEED USING LAMBDA METHOD

Economic dispatch problem can be solved by using co-ordination, which uses classical optimization techniques namely Lambda iteration method that which cannot be applied directly because of prohibited zones (discontinuities) in the incremental cost curve. So in this work it is assumed that incremental cost curve as continuous and the operation with respect to previous hour loading is avoided (if respective unit's power reaches prohibited zone).

Algorithm for lambda iteration method:

The detailed Algorithm for solving the combined economic and emission dispatch problem using lambda iteration method is given below:

1. Read generator data, emission data, P limits, B-coefficients and power demand.
2. Compute the modified price penalty factor h_m as per steps
3. Choose a trial value of $\lambda_{f,e}$ and assume $P_i = 0$; $i = 1, 2, \dots, n$.
4. Solve P_i 's iteratively and enforce P_i limits.
5. Calculate transmission losses
6. Check for power balance equation

a) If $\left| \sum_{i=1}^n P_i - PD - Ploss \right| < \epsilon$ (a

specified value), the optimal solution is reached.

Print the optimal schedule. **Otherwise**

b) If $\left| \sum_{i=1}^n P_i - PD - Ploss \right| < 0$,

increment $\lambda_{f,e}$ by $\Delta\lambda_{f,e}$ (a suitable step) or

c) If $\left| \sum_{i=1}^n P_i - PD - Ploss \right| > 0$,

decrement $\lambda_{f,e}$ by $\Delta\lambda_{f,e}$ (a suitable step) and go to step 3

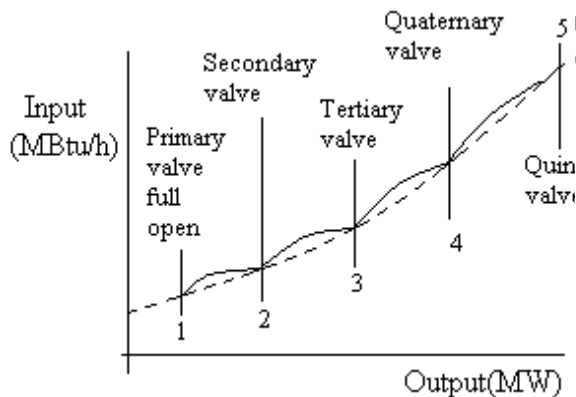


Fig. Thermal unit-input versus output

V. CEED USING GENETIC ALGORITHM

The Genetic Algorithm (GA) is an optimization and stochastic global search technique based on the principles of genetics and natural selection. A GA permits a population composed of several individuals to develop under particular selection rules to a state that reduces the fitness (i.e., minimizes the cost function). The technique was developed by John Holland (1975) over the course of the 1960s and 1970s and finally popularized by one of his student, David Goldberg (1989). Optimization of a problem

in a Genetic Algorithm is realized within the fitness function.

Algorithm for GA method:

The detailed Algorithm for solving the combined economic and emission dispatch problem using Genetic Algorithm method is given below

1. Read generator data, emission data, P limits, B-coefficients, power demand and GA parameters.
2. Compute the modified price penalty factor h_m
3. Generate initial population of chromosome of binary bits using random generation technique.
4. Set the iteration count =1.
5. Set chromosome count =1.
6. Decode the chromosomes of the population and determine normalized system incremental cost, λ_{nm} .
7. Calculate the actual system incremental cost, $\lambda_{f,e}$
8. Calculate the generation output of all the units for each chromosome from its $\lambda_{f,e}$ Value and enforce P_i limits.
9. Calculate transmission losses using B-coefficient equation and compute the error
10. Calculate the fitness value of the chromosome
11. Repeat the procedure from step no. 6 until chromosome count > population size.
12. Sort the chromosomes and all their related data in the descending order of fitness.
13. Check if the error (1) is less than ϵ . if yes, go to 20.
14. Copy the P_e % chromosomes of old population to new population starting from the best ones from the top.
15. Perform crossover on selected parents and generate new child chromosomes, repeat it to get required number of chromosomes.
16. Add all the generated child chromosomes to new population.
17. Perform mutation on all chromosomes.
18. Replace old population with new population.
19. Increment iteration count. If iteration count < max. iteration, go to 5, else print the message "problem not converged in maximum number of iterations".
20. Calculate the total fuel cost, total emission release, emission cost etc. Print the result.

IV. SIMULATION RESULTS

The effectiveness of the proposed method is tested using three generating units system. The two methods used for solving CEED are firstly LAMBDA iteration method and then a binary coded GENETIC algorithm(GA) method. The program is written in MATLAB software package and executed on a P-IV personal computer @ 1.5GHZ.

The three unit system data is in table 1. The generator cost coefficients, emission coefficients and generation limits of three units system are taken from [20]. ELD solution for the three-unit system is solved using conventional technique

(lambda-iteration), evolutionary algorithms such as GA . Three unit system is solved for economic dispatch, emission dispatch and combined economic and emission dispatch (CEED) separately and the results obtained from the three methods are compared.

The parameters used in GA method:

- Number of bits = 12
- Population size = 60
- Number of iterations = 250
- Elitism probability = 0.15
- Cross over probability = 0.7
- Mutation probability = 0.01

The comparison of test results are tabulated individually and elaborately to represent the effectiveness of the proposed method. The comparison results of conventional (LAMBDA) and proposed (GA) method for 3- unit system is shown as in tabular columns:

Table-2: pure economic dispatch -3 unit system(only power limits)

Table-3: pure emission dispatch -3 unit system (only power limits)

Table-4: CEED -3 unit system (only power limits)

Table- 5: overall comparison of total fuel cost and emission release -obtained from above three cases in table 2, 3 & 4

From the results it is observed that compared to conventional method proposed method provides optimal solution with economic cost and less emission of NO_x in to the atmosphere. Hence GENETIC ALGORITHM is more efficient method which gives better solution.

V CONCLUSION

When compared with conventional method, the genetic algorithm method, the total cost obtained and the total emission is less and the premature convergence nature of GA method is avoided by introducing elitism and changing probabilities of cross over and mutation. Due to these operators, this modern method is concluded as more efficient method with better solution with reasonable feasible computation time. This can be used further for unit commitment for known priori and also can be used for hydro scheduling.

Table-1 Cost and Emission Coefficients and power limits of 3- Unit System

| Unit | A_i | b_i | c_i | α_i | β_i | Γ_i | P_{min} | P_{max} |
|------|---------|----------|-----------|------------|-----------|------------|-----------|-----------|
| 1 | 0.03546 | 38.30553 | 1243.5311 | 0.00683 | -0.54551 | 40.26690 | 35 | 210 |
| 2 | 0.02111 | 36.32782 | 1658.5696 | 0.00461 | -0.51160 | 42.89553 | 130 | 325 |
| 3 | 0.01799 | 38.27041 | 1356.6592 | 0.00461 | -0.51160 | 42.89553 | 125 | 315 |

Table -2 pure economic dispatch -3 unit system(only power limits)

| Sl No | POWER DEMAND (MW) | METHOD | P1(MW) | P2(MW) | P3(MW) | P_LOSS (MW) | FUEL COST (RS/HR) | EMISSION RELEASE (KG/HR) | EXECUTION TIME (SEC) |
|-------|-------------------|--------------|---------|---------|---------|-------------|-------------------|--------------------------|----------------------|
| 1 | 400 | Conventional | 81.7182 | 174.465 | 149.968 | 7.51626 | 20750.2 | 205.11 | 0.10024 |
| | | GA | 83.412 | 173.965 | 150.128 | 7.5535 | 20810.2 | 205.688 | 0.2469 |
| 2 | 450 | Conventional | 94.2357 | 194.242 | 172.275 | 9.65982 | 23163.2 | 258.549 | 0.10078 |
| | | GA | 95.422 | 192.869 | 171.31 | 9.5971 | 23112.7 | 256.655 | 0.1573 |
| 3 | 500 | Conventional | 105.284 | 211.829 | 192.361 | 11.802 | 25354.7 | 314.99 | 0.08045 |
| | | GA | 107.536 | 211.89 | 192.588 | 11.9005 | 25471 | 317.409 | 0.1951 |
| 4 | 550 | Conventional | 117.484 | 231.115 | 214.199 | 14.3917 | 27794.8 | 386.168 | 0.1002 |
| | | GA | 119.694 | 230.95 | 213.875 | 14.4568 | 27875.7 | 387.806 | 0.3209 |
| 5 | 600 | Conventional | 129.587 | 250.207 | 235.789 | 17.2086 | 30253.1 | 466.329 | 0.12039 |
| | | GA | 132.063 | 250.29 | 235.44 | 17.3054 | 30359.1 | 468.993 | 0.07708 |
| 6 | 650 | Conventional | 141.594 | 269.11 | 257.136 | 20.245 | 32728.7 | 555.189 | 0.08317 |
| | | GA | 144.381 | 269.529 | 256.843 | 20.3896 | 32869.7 | 559.392 | 0.21826 |
| 7 | 700 | Conventional | 154.721 | 289.637 | 280.132 | 23.8146 | 35459.6 | 662.159 | 0.0748 |
| | | GA | 156.737 | 288.774 | 278.223 | 23.728 | 35424.9 | 659.55 | 0.305124 |
| 8 | 750 | Conventional | 166.397 | 308.034 | 300.998 | 27.2744 | 37956.9 | 767.898 | 0.12152 |
| | | GA | 169.261 | 308.242 | 299.812 | 27.363 | 38052.8 | 770.708 | 0.25224 |

Table-3 pure emission dispatch-3 unit system (only power limits)

| Sl No | POWER DEMAND (MW) | METHOD | P1(MW) | P2(MW) | P3(MW) | P_LOSS (MW) | FUEL COST (RS/HR) | EMISSION RELEASE (KG/HR) | EXECUTION TIME (SEC) |
|-------|-------------------|--------------|---------|---------|--------|-------------|-------------------|--------------------------|----------------------|
| 1 | 400 | Conventional | 103.093 | 149.485 | 149.33 | 7.2221 | 20030.2 | 195.871 | 0.12118 |
| | | GA | 104.994 | 151.288 | 150.90 | 7.3925 | 20838.1 | 200.02 | 0.2074 |
| 2 | 450 | Conventional | 117.525 | 169.786 | 169.36 | 9.3059 | 23033.2 | 248.108 | 0.04529 |
| | | GA | 118.245 | 179.703 | 170.26 | 9.4 | 23138 | 250.58 | 0.0499 |
| 3 | 500 | Conventional | 131.238 | 189.881 | 189.57 | 11.628 | 25457.2 | 309.857 | 0.0599 |
| | | GA | 131.43 | 189.99 | 189.42 | 11.633 | 25464.5 | 310.051 | 0.1117 |
| 4 | 550 | Conventional | 144.834 | 209.772 | 209.36 | 14.182 | 27901.1 | 380.826 | 0.07899 |
| | | GA | 145.09 | 209.93 | 209.21 | 14.193 | 27914 | 381.211 | 0.3947 |
| 5 | 600 | Conventional | 158.315 | 229.464 | 228.94 | 16.960 | 30364.2 | 460.733 | 0.0386 |
| | | GA | 158.65 | 229.71 | 228.81 | 16.982 | 30386.2 | 461.467 | 0.18138 |
| 6 | 650 | Conventional | 171.682 | 249.957 | 248.32 | 19.955 | 32845.4 | 549.304 | 0.03923 |
| | | GA | 172.183 | 249.395 | 248.31 | 20.007 | 32890.9 | 550.975 | 0.2652 |
| 7 | 700 | Conventional | 184.937 | 269.257 | 267.48 | 23.160 | 35344.1 | 646.274 | 0.0408 |
| | | GA | 185.066 | 269.109 | 266.83 | 23.112 | 35312.2 | 644.959 | 0.0689 |
| 8 | 750 | Conventional | 198.081 | 289.305 | 286.45 | 26.508 | 37859.2 | 751.385 | 0.0759 |
| | | GA | 199.732 | 289.375 | 287.80 | 26.913 | 38111.0 | 762.291 | 0.20199 |

Table-4 CEED -3 unit system (only power limits)

| SL NO | POWER DEMAND (MW) | METHOD | P1(MW) | P2(MW) | P3(MW) | PLOSS (MW) | FUEL COST (RS/HR) | EMISSION RELEASE (KG/HR) | PRICE PENALTY FACTOR (RS/KG) | TOTAL COST (RS/HR) | EXECUTION TIME (SEC) |
|-------|-------------------|--------------|--------|--------|--------|------------|-------------------|--------------------------|------------------------------|--------------------|----------------------|
| 1 | 400 | Conventional | 102.52 | 153.86 | 151.20 | 7.419 | 20845.9 | 200.38 | 43.55 | 29574.5 | 0.52 |
| | | GA | 101.94 | 152.83 | 150.01 | 7.316 | 20713.4 | 197.91 | 43.55 | 29344.0 | 0.45 |
| 2 | 450 | Conventional | 115.41 | 173.04 | 170.56 | 9.414 | 23126.7 | 250.56 | 43.81 | 34106.1 | 0.45 |
| | | GA | 115.75 | 173.20 | 170.51 | 9.427 | 23142.3 | 250.92 | 43.81 | 34147.6 | 0.72 |
| 3 | 500 | Conventional | 128.82 | 192.66 | 190.34 | 11.70 | 25501.2 | 311.33 | 44.07 | 39224.8 | 0.43 |
| | | GA | 128.91 | 192.56 | 189.98 | 11.68 | 25484.5 | 310.86 | 44.07 | 39187.1 | 0.70 |
| 4 | 550 | Conventional | 142.15 | 212.28 | 210.10 | 14.23 | 27918.6 | 381.68 | 44.33 | 44842 | 0.42 |
| | | GA | 142.33 | 212.26 | 209.78 | 14.22 | 27911.9 | 381.45 | 44.33 | 44825.3 | 0.66 |
| 5 | 600 | Conventional | 155.49 | 231.89 | 229.84 | 17.01 | 30378.4 | 461.58 | 44.59 | 50964.7 | 0.44 |
| | | GA | 155.64 | 231.81 | 229.40 | 16.91 | 30361.8 | 460.99 | 44.59 | 50921.5 | 0.05 |
| 6 | 650 | Conventional | 168.04 | 251.40 | 249.55 | 20.04 | 32879.4 | 550.99 | 44.85 | 57596.1 | 0.43 |
| | | GA | 168.82 | 251.04 | 248.70 | 19.96 | 32819.1 | 548.7 | 44.85 | 57433.2 | 0.73 |
| 7 | 700 | Conventional | 182.48 | 271.45 | 269.61 | 23.38 | 35472.5 | 651.94 | 45.11 | 64887 | 0.36 |
| | | GA | 182.72 | 271.39 | 269.05 | 23.35 | 35455.4 | 651.20 | 45.11 | 64836.3 | 0.22 |
| 8 | 750 | Conventional | 196.11 | 291.38 | 289.61 | 26.96 | 38105.3 | 762.61 | 45.37 | 72710.8 | 0.42 |
| | | GA | 196.45 | 291.4 | 289.06 | 26.94 | 38097.2 | 762.19 | 45.37 | 72683.7 | 0.24 |

TABLE -5 over all comparison of cost and emission in conventional and GA METHODS

| SL.NO | POWER DEMAND (MW) | METHOD | FUEL COST(RS/HR) | | | EMISSION RELEASE(KG/HR) | | |
|-------|-------------------|--------------|------------------|---------------|---------|-------------------------|---------------|---------|
| | | | PURE ECONOMIC | PURE EMISSION | CEED | PURE ECONOMIC | PURE EMISSION | CEED |
| 1 | 400 | Conventional | 20750.2 | 20630.2 | 20845.9 | 205.19 | 195.879 | 200.382 |
| | | GA | 20810.2 | 20838.1 | 20723.4 | 205.688 | 200.03 | 197.915 |
| 2 | 450 | Conventional | 23163.2 | 23033.2 | 23126.7 | 258.549 | 248.108 | 250.561 |
| | | GA | 23112.7 | 23138 | 23142.3 | 256.655 | 250.58 | 250.922 |
| 3 | 500 | Conventional | 25354.7 | 25457.2 | 25501.2 | 314.99 | 309.857 | 311.338 |
| | | GA | 25471 | 25464.5 | 25484.5 | 317.409 | 310.051 | 310.864 |
| 4 | 550 | Conventional | 27794.8 | 27901.1 | 27918.6 | 386.168 | 380.826 | 381.684 |
| | | GA | 27875.7 | 27914 | 27911.9 | 387.806 | 381.211 | 381.457 |
| 5 | 600 | Conventional | 30253.9 | 30364.2 | 30378.4 | 466.329 | 460.733 | 461.589 |
| | | GA | 30359.1 | 30386.2 | 30361.8 | 468.993 | 461.467 | 460.994 |
| 6 | 650 | Conventional | 32728.7 | 32845.4 | 32879.4 | 555.189 | 549.304 | 550.996 |
| | | GA | 32869.7 | 32890.9 | 32819.1 | 559.392 | 550.975 | 548.7 |
| 7 | 700 | Conventional | 35459.6 | 35344.1 | 35472.5 | 662.195 | 646.274 | 651.947 |
| | | GA | 35424.9 | 35312.2 | 35455.4 | 659.55 | 644.959 | 651.203 |
| 8 | 750 | Conventional | 37956.9 | 37859.2 | 38105.3 | 767.898 | 751.385 | 762.612 |
| | | GA | 38052.8 | 38111.6 | 38097.2 | 770.708 | 762.291 | 762.19 |

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