# AN EFFICIENT AND IMPROVED GENETIC ALGORITHM APPROACH TO SOLVE ECONOMIC DISPATCH WITH LINEFLOW CONSTRAINTS

K.Nisha
Department of Electrical and Electronics Engineering
ABES Engineering College
Ghaziabad, UttarPradesh, India.
nisha.venktesh@gmail.com

Dr. R.P.Kumudhni Devi
Department of Electrical and Electronics Engineering,
Power System Division
College of Engineering, Guindy, Anna University,
Chennai, Tamil Nadu, India

**Abstract—** ***In this paper an efficient method of ordinary genetic algorithm (OGA) has been proposed to solve economic dispatch (ED) problem with line flow constraints. The proposed method uses the situation where if more number of candidates participate in a competition, the chance of getting a good candidate is better. The set of population directed by evolutionary direction operator, gets directed towards the global optimal solution. The proposed technique is called efficient and improved genetic algorithm (EIGA) and has been tested on IEEE 30 bus system. The new technique is compared with OGA and improved genetic algorithm (IGA). Numerical results imply that the quality of the solution is better and time consumed (in terms of computer cycles ) to get the result is less using the new method as compared with the other two methods.***

***Key words*—Power systems, OGA, IGA, EIGA, EEDO, optimization, ED, evolutionary direction.**

## I. Introduction

Most of electric power made from fossil fuel is produced by thermal power stations. The world's power demands are expected to rise 60% by 2030. With the world wide total of active coal plants over 50,000 and rising, the International Energy Association (IEA) estimates that fossil fuels will account for 85% of energy market by 2030. About 70% of the electricity consumed in India is generated through thermal power plants. The thermal power plant has ED as an important sub problem[6]. Therefore it is essential to have an efficient mathematical technique to find solution for this problem. ED is an important optimization task in power system operation for allocating generation among the committed units. Its objective is to minimize the total generation cost of units, while satisfying the various physical constraints[1].

There are many proposed methods for solving an ED problem. On surveying the literature, OGA is found to be having various advantages such as, ability to scan a vast solution set, bad proposals do not effect the end solution, it does not have to know any rules as it works on its own set of rules. It is very useful for complex and loosely defined problems.

A brief survey of algorithms proposed for the ED problem in the open literature is presented as follows.

The ED problem has many nonlinearities and discontinuities owing to its valve point effect, prohibited operating zones, and ramp rate limits [2-5]. This kind of optimization problem is very hard, if not impossible, to solve using traditional deterministic optimization algorithms.

The Lagrangian multiplier method [6], which is generally used in the ED problem, is no longer directly applicable. To solve a non-smooth/non-convex ED problem, Lee and Breipohi [2] decomposed the non-convex decision space into a number of convex sub-regions and then used the Lagrangian multiplier method to solve the problem. Nevertheless, this may require a large computational burden to obtain an optimal solution when a system has several units with prohibited zones. Fan and McDonald [7] proposed an algorithm based on conventional iterative dispatch to obtain the solution. The reduced gradient method [8] is efficient if the nonlinear problem is provided with small number of inequality constraints. Formulation of the scheduling problem in Newton-Raphson method for solving a set of nonlinear coordination equations leads to a large matrix expression. Problems with Newton's method when applied to ED problems include the computation of the inverse of a large matrix, the ill-conditioning of the Jacobin matrix and the divergence caused by starting values [9].

Successive linearization method is based on successive linearization process and starts with an initial nominal solution, linearizes the objective function around this solution and determines an improved solution in terms of the feasible direction, obtained by solving a minimal cost network flow program [9]. A classical approach to solve the ED problem with valve point modeling is the Dynamic programming (DP). DP works with the unit input-output information directly by enumeration of all possible solutions. DP consists of evaluating the problem in stages (corresponding to each unit), choosing the optimal state (for unit dispatch) for a stage by recursively examining paths from previous stages, then proceeding to the next stage until a complete optimal path is found through all stages[10]. Solution accuracy depends on the state increment value in each stage. To achieve acceptable accuracy, each unit's dispatch must be costed for each fraction if generation is in the unit's operating range. The dimensions of this problem become extremely large (curse of dimensionality) though multiple optimal paths may be obtained, each stage may require excessive evaluations of the recursive relationship [11].

In the Hopefield modeling framework to solve ED is an energy function composed of power mismatch, total fuel cost and transmission line losses is defined. Each term of the energy function is multiplied by a weighting factor which represents the relative importance of that term. Selecting of weighting factors closely affects whether the energy function can converge to a minimum, which is decisive in obtaining optimal solutions. In the conventional Hopefield method, the weighting factors are found by trial and error. The computational procedures include a series of adjustments of weighting factors associated with the transmission line losses. After each adjustment of the weighting factor, unit power generations and incremental losses are reevaluated[13].

A genetic based approach was developed by Walters and Sheble, to solve an economic dispatch problem for valve point discontinuities. The algorithm utilizes payoff information of candidate solutions to evaluate their optimality[5].

Improved genetic algorithm, used by Chao-Lung Chiang and Ching-Tzong Su, is equipped with improved evolutionary direction operator to enhance OGA. Fuzzy membership function, phase plane theory and IGA were employed to design fussy phase plane controller to optimally control an induction motor position/speed[15]. The difficulty is that it can handle only least number of population.

J.Nanda and R.Badri Narayanan has used OGA to solve ED problem with line flow constraints. They tested OGA for solving IEEE 14 bus system and IEEE 30 bus system. The economic power dispatched by each generator and the load flow solution was also found using OGA[19].

## II. Problem Formulation

Let NG be the number of generators. The problem is to find the power generated for the given demand $P_D$ and accordingly find the losses using static load flow method for finding losses. The objective is to determine the optimal set of generations $P_{Gi}$(i =1,2,…NG) to minimize the total cost of generation $F_T$ given by:

$$F_T = \sum_{i=1}^{NG} (a_i P_i^2 + b_i P_i + c_i)\$/\text{hr} \qquad (1)$$

subjected to equality constraint,

$$\sum_{i=1}^{NG} (P_i) - P_D - P_L = 0 \qquad (2)$$

and inequality constraints,

$$P_i^{min} \leq P_i \leq P_i^{max} \qquad (3)$$

where $a_i, b_i, c_i$ are the cost coefficients of the $i^{th}$ generating unit, $P_L$ is total system transmission loss, $P_D$ is total demand. $P_i^{max}$ is the maximum generation capability of the $i^{th}$ generator and $P_i^{min}$ is the minimum generation capability of the $i^{th}$ generator.

## III. Solution to the Problem

In this paper, EIGA is proposed and used to solve ED problem with lineflow constraints. The economic power generated by each machine was found using EIGA. The test system taken was IEEE 30 bus system. The loadflow was solved using fast decoupled loadflow (FDLF) method. The system transmission loss, slack bus generation, lineflows, and hence any violation of the slack bus generation and violation of the lineflow limits were found using FDLF method.

The EIGA is different from the IGA, as it is equipped with efficient evolutionary direction operator (EEDO) and it can handle more number of populations as desired using EEDO. The results were compared with those got using OGA and IGA methods.

## IV. Fitness Function Formulation

Implementation of an objective function and constraints in a genetic algorithm are realized within the fitness function. The fitness function acts as a pseudo objective function, since it is a raw measure of the solution value. Inclusion of the constraints in the fitness function requires the introduction of tolerances in satisfying the constraint equations. However, if the fitness function and encoding are well designed, accuracy will not suffer.

The economic dispatch problem can be solved by the genetic algorithm using either the unit input-output or incremental cost curves. The input-output curve solution uses the standard objective function and a penalty term for the conservation of energy constraint[5]. The fitness function is

$$\frac{1}{1 + abs\left[\sum_{i=1}^{NG} F_i(P_i) + pf\left(\sum_{i=1}^{NG}(P_i) - P_L - P_D\right)\right]} \qquad (4)$$

In the above equation (4) *pf* is the penalty factor which can be 1000 or 10,000 so that the difference between the total power generated and the sum of demand and losses is made minimum. This is the fitness function used by K.P.Wong et.al,.[16]. The reproduction operator used is stochastic roulette-wheel selection (SWRS) [17]. The crossover probability and a mutation probability are chosen as prescribed by Kalyanmoy Deb [17].

## V. Improved Genetic Algorithm

OGA algorithms borrow the analogous biological terms for each step. It maintains a population of parameter set solutions and iterate on the complete population. The OGA acts on a set of strings in which each parameter is concatenated after being coded. It uses three main operators, namely reproduction, crossover and mutation to search the optimal solution. Each iteration is called a generation[4].

The IGA is same as OGA except that it has improved evolutionary direction operator (IEDO). The IEDO includes choosing the three best solutions in each generation to perform the evolutionary direction to find a new solution, superior to the previous best solution. The procedure includes initializing the fitness values with OGA and then use IEDO for subsequent generations [12].

## VI. Efficient and Improved Genetic Algorithm (EIGA)

This section elaborates the proposed algorithm. The EIGA is stated first followed by the computational procedure for the proposed (EEDO).

The proposed algorithm utilizes the concept that if more number of best candidates are participating in the competition the better will be the search towards the global optimum. The EEDO can significantly reduce the search effort as it has more number of participating candidates that will become better and better after each and every EEDO operation and generation. This significantly reduces the computational burden in OGA and the suboptimal solutions obtained in IGA.

In this method a convenient number of candidates have been selected (“spop”). Divide spop into three groups as small group, medium group and big group with equal number of individuals.

"*Small* group" chromosome: $z_{sn} = \{C_{sn1},..C_{snk}\}$

"*Medium* group" chromosome: $z_{mn} = \{C_{mn1},..C_{mnk}\}$

"*Big* group" chromosome: $z_{bn} = \{C_{bn1},..C_{bnk}\}$

where s indicates small, m indicates medium and b indicates big, n is the number of individuals in each group, k is the total number of variables in the problem.

## VII. EIGA Algorithm

This section elaborates the proposed algorithm. The EIGA is explained first. The algorithm for EEDO and flow chart thereby follows.

The procedure for EIGA includes initializing the fitness values with OGA. The EEDO loop is the next step. This loop may run for a few times (eg. 4, 5, or 6 times typically) . This improves the fitness of the participating candidates.

The steps those follow the EEDO are reproduction, crossover and mutation are the same as that of OGA.

The solution got by EIGA reaches global optimum mostly, than the solutions got by IGA which often reaches local optimum. The EIGA has also proved to reduce the computer CPU cycles than OGA and IGA. Therefore the results shows that EIGA prompted to improved solution, than the solutions got by OGA and IGA.

## VIII. EEDO Algorithm

The participating candidates are initialized first using OGA. The EEDO is used for subsequent improvement of the participating candidates. The algorithm is as follows.

Step1: Set the number of EEDO loops to be 5. Set the magnitude of the two evolutionary direction operators D1and D2 to be 1, ie D1=1;D2=1

Step2: Choose around 60% (as in this paper) of the participating candidates based on the fitness values. Arrange them under three groups $F_{bn}$, $F_{mn}$ and $F_{sn}$. n = 1,2,….ns.ns=spop/3. spop= 60% of candidates. If ns is a fraction number modify spop or ns accordingly that each group has the same number of candidates for the ease of programming.

Step3: Set Nl = 5 (it may be 4,5, or 6 ). Nl is the maximum number of times the EEDO loop should be executed. Nc = 1 and the loop should be repeated until Nc =Nl. If Nc =Nl goto step 14. If Nc <Nl goto step 5

Step4: Each Nc has to evaluate all the participating candidates of spop.

Step5: Obtain $P_{bn}$,$P_{mn}$,$P_{sn}$ corresponding to $F_{bn}$,$F_{mn}$ and $F_{sn}$ respectively.( P indicates the corresponding Power Generation and F is the corresponding fitness values.)

Step6: Compute $P_{pn}^{\Phi}$ , $P_{opn}$ and $F_{newn}$ using the following formulae

$$P_{pn}^{\Phi} = P_{bn} + D1(P_{bn}-P_{mn}) + D2(P_{bn}-P_{sn}) \tag{5}$$

$$P_{opn} = \max[\min( P_{pn}^{\Phi} , P_{Gi}^{\max} ), P_{Gi}^{\min} ] \tag{6}$$

Step7: Compute the new fitness of the output candidate by employing equation (4).

Step8: If the value of $F_{newn}$ is greater than $F_{bn}$ or

Step9: If $F_{newn}$ is equal to $F_{bn}$ or $F_{mn}$, then add a random number, Nr, which is uniformly distributed over a certain range, to the non – negative integer $F_{mn}$ or $F_{sn}$, go to step 10. Otherwise goto next step .

Step10: Find $P_{pn}^{\Phi}$ and recompute $F_{newn}$ then goto step 8; otherwise goto next step.

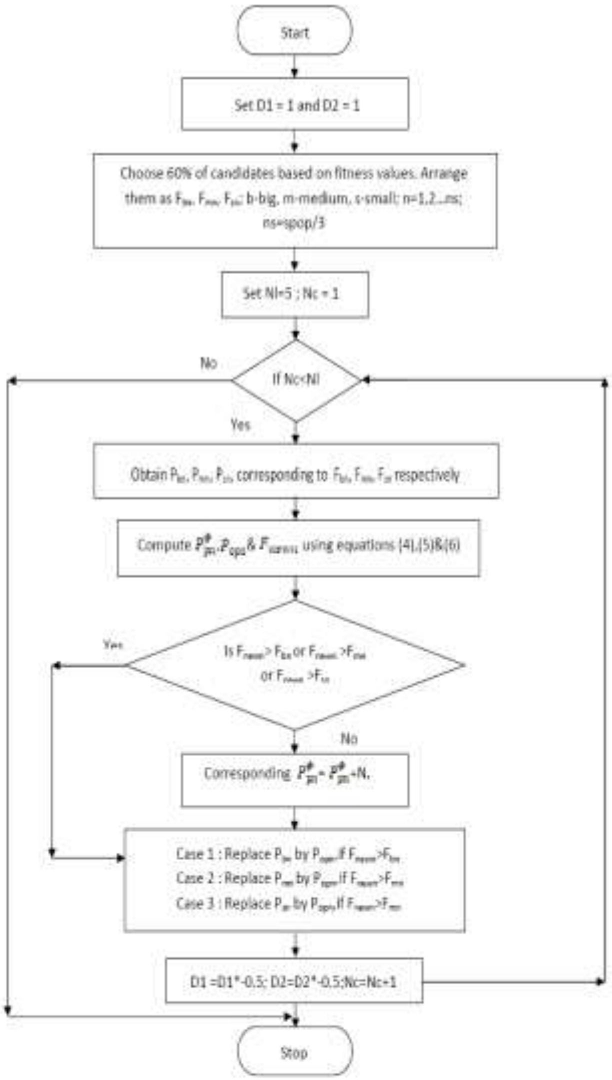
Step11: Case1: Replace $P_{bn}$ by $P_{opn}$ , if $F_{newn}>F_{bn}$
Case2: Replace $P_{mn}$ by $P_{opn}$ if $F_{bn} >F_{newn}>F_{mn}$.
Case3: Replace $P_{sn}$ by $P_{opn}$ if $F_{mn}>F_{newn}>F_{sn}$ .

Step12: Check if the last iterative computation of the generation is reached, goto step 3. Otherwise increment EEDO loop and goto step 6(check for the number of candidates in a group).

Step13: Set D1 = D1*-0.5,D2=D2*-0.5.

Step14: Terminate the computation of EEDO.

## IX. EIGA Flowchart

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## X. System Applications

The test system used is the IEEE 30 bus system. The OGA, IGA and EIGA are tested on the system and the results are shown both as the tabular column and performance graphs. Table: 1, gives the result of the IEEE 30 bus system when tested using OGA, IGA, EIGA. The performance graphs are shown in Fig 1 for OGA, IGA and EIGA. The analysis is done using Amd Turion 64 X2 ,1.6 GHz Dual Core processor and during the process it is found that the EIGA works well in terms of CPU cycles (see appendix)than the other two algorithms

TABLE I. RESULTS

| PD=283.4MW | OGA | IGA | EIGA |
|---|---|---|---|
| Pgen[1](MW) | 156.979 | 163.744 | 152.393 |
| Pgen[2] (MW) | 79.8508 | 80 | 79.7427 |
| Pgen[3] (MW) | 18.1232 | 15.6473 | 19.9823 |
| Pgen[4] (MW) | 12.0021 | 12.3714 | 12.9695 |
| Pgen[5] (MW) | 12.232 | 10 | 12.7741 |
| Pgen[6] (MW) | 13.998 | 12 | 14.928 |
| TotPgen(MW) | 293.103 | 293.762 | 292.791 |
| Ploss(MW) | 10.70263 | 10.3619 | 9.39018 |
| Iteration | 50 | 45 | 35 |
| Cost($/hr) | 724.515 | 723.765 | 723.804 |

## XI. Performance Graph

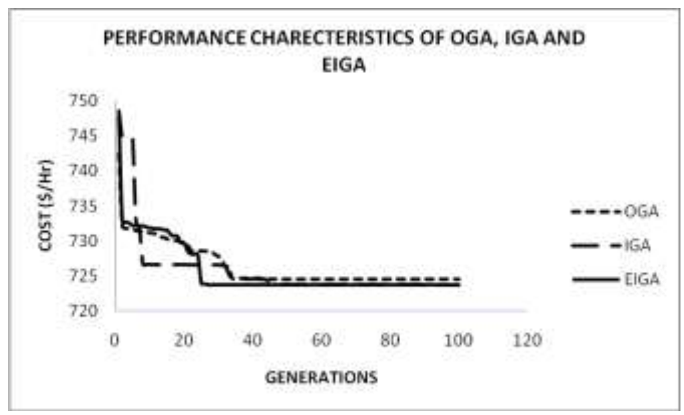


Figure 1. Performance of OGA, IGA and EIGA

## XII. Conclusions

An efficient method for solving the economic dispatch problem has been developed and tested with IEEE 30 bus system. The complication of finding global solution in lesser time for economic dispatch problem was made easier using EIGA. This is proved using numerical results and performance graphs. The difference between IEDO and EEDO is that IEDO has a single loop which gets executed for 4 to 6 times. But EEDO has two loops. A inner loop and an outer loop. The inner loop repeats itself for "spop"(=60) times and the outer loop executes for 5 times( as used in this work). That is the total number of times the EEDO executes itself for 60 X 5 times. But, still the CPU cycles are reduced because, the individuals those participate in the competition are improved by EEDO for every generation of EIGA. Therefore EIGA gives results in less time and converges in lesser number of generations as compared to OGA and IGA. The performance graph of EIGA supports the fact that EIGA is the best of the three algorithms.

EIGA can be used to find solution for any kind of nonlinearities. The computation time in CPU cycles is shown in the appendix.

TABLE II. APPENDIX

| METHODS | CPU CYCLES |
|---|---|
| OGA | 2281 |
| IGA | 1218 |
| EIGA | 953 |

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