Efficient Soft Computing Technique used for Solving Economic Dispatch Problem

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Electrical Power Systems)

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Undertaking for Originality of the Work

I, **Mr. Kathan Shah, Roll No. 18MEEE16**, give undertaking that the Major Project entitled **"Efficient Soft Computing Technique used for Solving Economic Dispatch Problem"** submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology (Electrical Engineering) in the field of Electrical Power Systems of Nirma University, Ahmedabad is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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CERTIFICATE

This is to certify that the Major Project Report (Part-II) entitled "**Efficient Soft Computing Techniques used for Solving Economic Dispatch Problem**" submitted by **Mr. Kathan Shah (18MEEE16)** towards the partial fulfillment of the requirements for Semester-IV of Master of Technology (Electrical Engineering) in the field of Electrical Power Systems of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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ABSTRACT

In power system different problem like Economic Load Dispatch (ELD), Unit commitment, Hydro - thermal scheduling (HTS) and many more are present. For solving mentioned problems different conventional method are present but for getting more accurate and optimal solution soft computing techniques is important tool for it. Here ELD problem is solved using Group leader Optimization Algorithm (GLOA). Economical load dispatch (ELD) is an important aspect in power system domain in power system operations, controls, processes and scheduling are the different part where the necessity and application of ELD are described. Convex and Non-Convex economical load dispatch can be resolved by using classified based techniques and various soft computing techniques.

The Group Leader Optimization algorithm to solve ELD for minimizing the fuel cost of power generation with various constraints like valve point loading. Group leader optimization (GLOA) is comparatively modern technique in optimization. Mathematical models of this algorithm exemplify the efficiency, solution quality and convergence quickness of the method and successful implementation of the algorithm on economical load dispatch problems. Finally, from the simulation results it has been noticed that the proposed way or method has given better results than other existing optimization techniques.

Abbreviations

ELD . . . . . . Economical Load Dispatch

ED . . . . . . Economic Dispatch

EED . . . . . . Economical Emission Dispatch

EELD . . . . . . Economical Emission Load Dispatch

PSO . . . . . . Particle Swarm Optimization

GLOA . . . . . . Group Leader Optimization Algorithm

TLBA . . . . . . Teaching Learning Based Algorithm

CTPSO . . . . . . Constraint Treatment Partical Swarm Optimization

SCA . . . . . . Sine Cosine Alogrothm

GA . . . . . . Genetic Algorihm

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Chapter 1

Introduction

1.1 Economic Load Dispatch

In electric power systems, Economic Load Dispatch (ELD) is used to accommodate customers with excellent, reliable power supply at the lowest possible tariff. The operation of generation facilities can be explained in normal conditions as producing electricity at the most despicable cost to attend consumers efficiently, respecting any operating limits of generation and transmission facilities. This is a key factor in allocating production to units involved in the operation of the electrical system to meet existing constraints and energy requirements. Fuel dynamics for advanced generating systems are significantly nonlinear in finding an intervention approach without restrictions in the form of a fuel cost curve.

1.2 Optimization

It is a performance of performing something (such as a plan, system, or determination) as accurate, functional, or effective as much as achievable specifically we can say that mathematical methods (obtaining the maximum or minimum of a function) involved in this.

1.3 Computation

Computation is any kind of analysis that involves both arithmetic and non-arithmetic steps and applies, for starters, an algorithm, a well-defined framework.

1.3.1 Hard Computing and Soft Computing

Binary-based hard computation, crisp structures, numerical analysis, and crisp applications. Soft computation based on fuzzy logic, neural networks, and inferential statistics, i.e. tolerating imprecision, uncertainty, partial truth, and estimation.

1.4 Stochastic Process

Stochastic alludes to a haphazardly decided process. In computation, stochastic programs work by utilizing probabilistic strategies to unravel issues, as in recreated strengthening, stochastic neural systems, stochastic optimization, hereditary calculations and hereditary programming. An issue itself may be stochastic as well, as in arranging beneath instability.

1.5 Requirement of Nature Based Algorithms

Most traditional or classical algorithms are deterministic. For illustration, the simplex method is deterministic in linear programming. Some deterministic optimization algorithms use gradient information. This is called a gradient-based algorithm. For example, the important Newton-Raphson algorithm is based on gradients because it practices the values of functions and their derivatives and matches itself to smooth one-modal problems. However, if the lens function is disrupted, it will not function properly. In this case, the gradient-free algorithm is preferred. Algorithms with or without gradients do not use derivatives, only function values.

1.6 Group Leader Optimization

Group leader optimization is one of the most essential techniques in computational techniques. This method is developed from the general idea of leaders in the social group and cooperative co-evolutionary algorithm. In this method, group members are influenced by a group leader. The leader represents the nature of the group but becoming the leader should have potential and abilities better than other members. The quality of members of a group might lead to changes like a blight or enhance in new etiquette and peculiarities under the affection of a leader. The formation of a group is based on random selection not based on the similar nature of the member. Different groups are created and each group has its group leader. In the GLOA method, every group strives to attain global solutions following the affection of each group leader which are the nearest members of the group to local or global minima. The fitness value of a leader is greatest among the group after an iteration or some iteration fitness value of other members is better than a leader than that member is the new leader for that group. Some part of the algorithm is creating new members. Hence leader affects the other members of the group and revolution occur at every iteration and group members come closer to each other. From this way solution space will occur between a leader and members and able to find a search area for optimum (Global or Local) solution quickly. After some iteration, it may possible that there is no much difference between the fitness value of leader and members so the transfer of such variable has done between groups randomly to maintain the diversity of the group. This crossover helps a group to come out from the local minima solution and examine for novel solution spaces.

Chapter 2

Literature Review

Introduction to Algorithms and Nature-Inspired Optimization Algorithms[1]

In today's world, optimization is very useful tool in many areas comprises of engineering, industry process and commercial activities driven for economic purpose. Optimization is relied on application i.e. what we want to optimize. It includes reduction of energy utilization, fuel, weight and cost. There are many tools available which plays a vital roal optimization. It may be based on artificial intelligence or genetic algorithm. Main aim of optimization is to achieve desired output and performance with increased efficiency. There is always some algorithm which runs in background for computational method. By aid of input parameters defined for computation, algorithm processes and yields in increased efficiency.

Teaching learning-based optimization algorithm implemented on multi-area economic dispatch[2]

TLBO makes use of a population-based process that aims at a global solution. The population comprises a swarm of students or student class. This method is bifurcated within two sections, the first one is of student and the latter part is of the learning phase. The teacher phase emphasis learning from the teacher and the latter makes use of intellectual process among students.

Solution of Economic Load Dispatch Dierential Particle Swarm Optimization[3]

Swarm particle optimization is a population-based stochastic optimization technology beautiful. In PSO, a potential solution called a particle, bypasses the problem Space follows the current optimal particle. Each particle monitors its coordinates in the assigned problem range quoted among the greatest decision he should make. This value is called pbest. Other "best "values followed by the dredge particle optimizer are the best Values obtained so far from each particle in neighboring particles. This is it cation called lbest. at a particle uses the entire population being topology.

Evolutionary Programming Techniques implemented on Economic Load Dispatch[5]

It is a heuristic search algorithms derived from natural selection of the population and evolutionary process. It typically provides a quick and viable solution. In actual values, it requires the control parameters. In terms of actual values, the population is initialized. There is a shift across all the solutions in the existing population. The next-generation choice is also made between mutated and present solutions.

2.1 Flowcharts of Different Optimizing Techniques

2.1.1 Teaching Learning Based Optimizing techniques

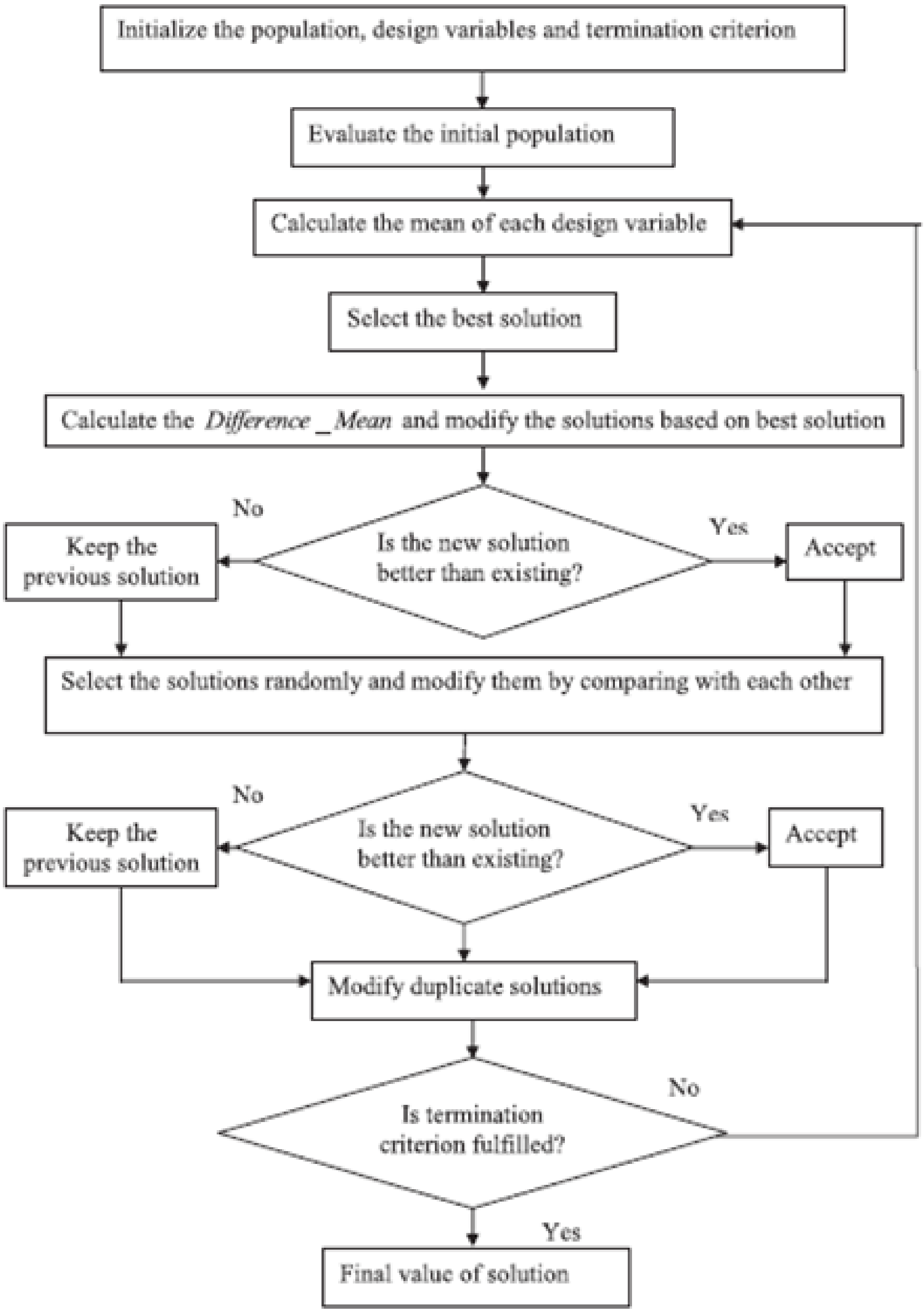

Figure 2.1: Teaching Learning Based Optimization

2.1.2 Differential Particle Swarm Optimization

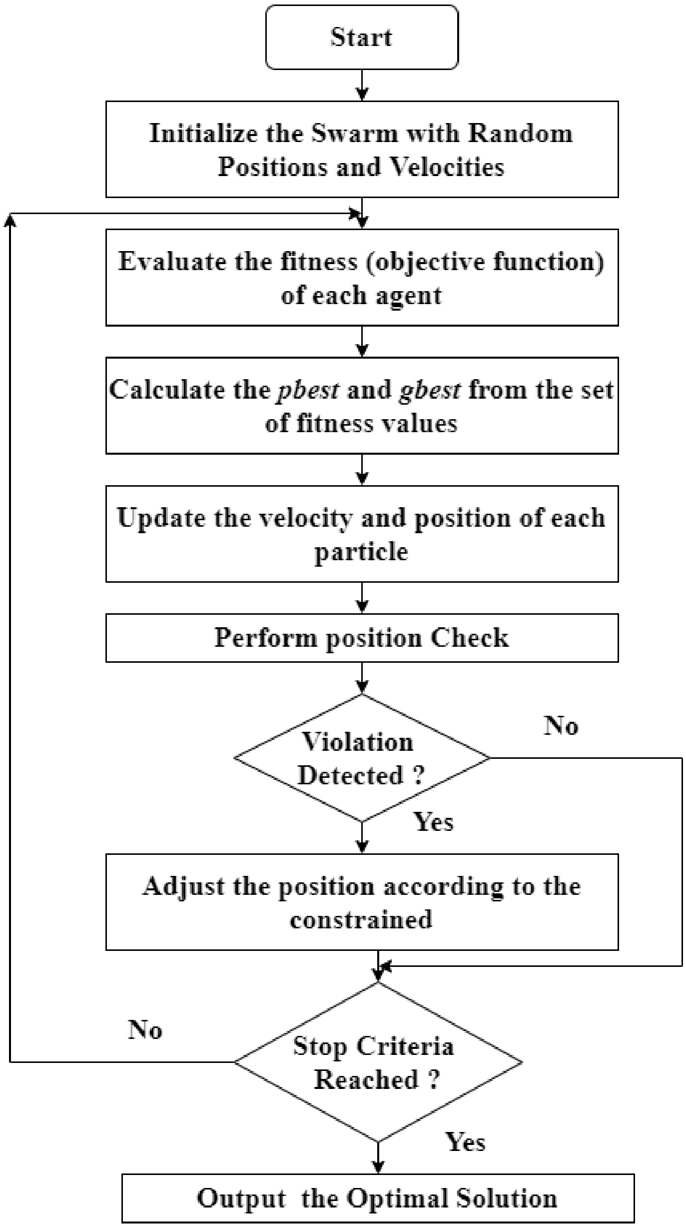

Figure 2.2: Differential Particle Swarm Optimization

2.1.3 Evolutionary Programming technique

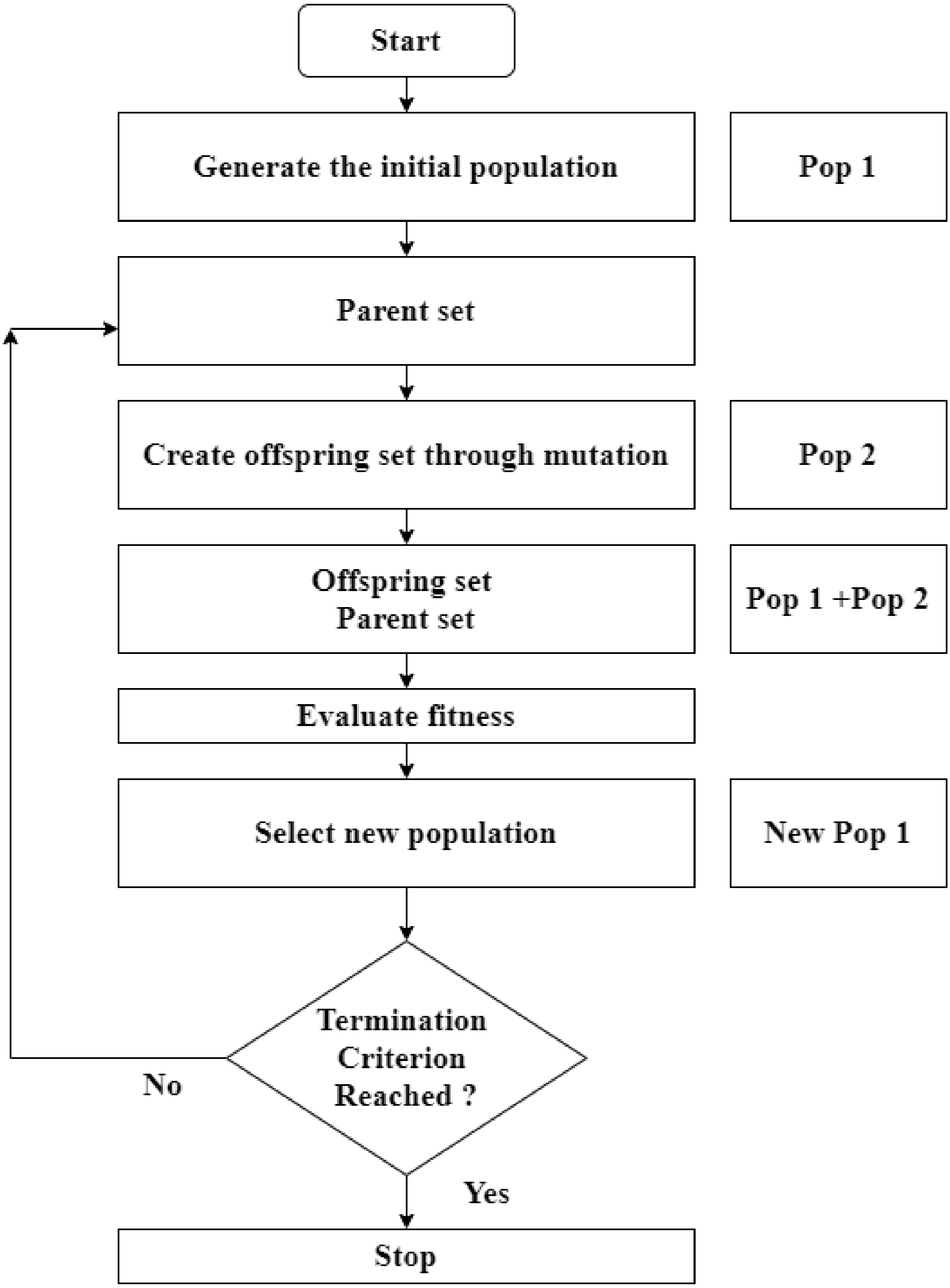

Figure 2.3: Evolutionary Programming Technique

Chapter 3

Group Leader Optimization

This segment contains a unique optimization computation, called the Group Leader Optimization Algorithm (GLOA), which was put forward by Daskin(2011)[5]. When decreeing this calculation for the first time, several groups of people were made from randomization. Each group seeks to determine a global solution that must be considered as the closest leader's fitness value to the near to global. In each group, the leader is some whose fitness is best after repetition in their group, if other parts of the same group consist superiority respect for the group, and at this point, the leader can lose his position. A leader continues to strive to manage all other part's collections so that the modern part can be made from the old part and the pioneering collector. As the number of cycles increases, each group of individuals approaches the leader. It is clear that after a series of evaluations, the collected part can be very comparable to the precurso.

3.1 Mutation and Recombination Process

Create new members, group leaders, and random elements using old members. The equation is:

$NEW = R_1 * old + R_2 * leader + R_3 * ran$

The values of $R1$, $R2$ and $R3$ determine the proportion of old (current) members, leaders, and randomly when they generate a new population. If the new member has a greater fitness score than the old member, substitute the old one with the new one, if not later hold the old one. In this step, the executive concludes whether the new member has a greater fitness score than the old member and substitutes the old member. Otherwise, the old members will be held.

3.2 Crossover Process

This is a single channel crossover method, which means the most crucial part of this algorithm because this method is useful for maintaining group diversity. Here, one can transfer several variables from various groups and select them randomly. This manner is similar to different differential progression vectors, but the main distinction is that transfers occur between members who are in distinct groups. For this step, the most essential thing is to choose the right transferal rate, because all populations can quickly become similar to pick the wrong transfer rate. The conveyance speed is T times for each group. Wherever, T is an arbitrary number belonging to 1 to 1/2 of the total number of common variables (parameters) plus the variable T. Just individual parameter is conveyed at a moment.

$C_R \leq T \leq (variables/2) + 1$

3.3 Systematic Steps for GLOA

There are five sections in GLOA which are underneath.All the steps below are stated:

- Make (N) the total population in each group randomly within the maximum and minimum range and tend to be their respective responsibilities. The population increase is thus G * P, where G is the number of groups. Individual production is very unintentional. Enter the number of unknown factors and their maximum and minimum reach.
- Evaluate fitness value of all group members.
- Assign leader to each group, member with highest fitness value among the group will be the leader.
- Produce new members using process of mutation and recombination by using old

members.

$$NEW = R_1 * old + R_2 * leader + R_3 * ran \tag{3.1}$$

ran is random number between 0 to 1. Here, $R1, R2$ and $R3$ are the rates determining the parts of old member, leader, and random values of group members while generating the new population. Summation of values of R1, R2, R3 is 1. Proper values of R1, R2, R3 is must require for accurate and optimum solution. Created new member or other member from group have better fitness value than leader than it will replace the leader.

- Now parameters are transferred in the crossover or variable process or members from one group to another. The transferred member is chosen randomly by the group. Here, the transmission speed is H times. One parameter is transferred in each case.

$$1 \leq C_R \leq (var/2) \tag{3.2}$$

'var' is variable and its value is same as population.C_R is random number between 0 to 1.

- Repeat with step 3 to step 5 until number of iteration or accuracy level achieved then terminate the process or go to step 4 for continue process.

3.4 GLOA and ELD

This section defines new techniques for implementing the GLOA algorithm to solve ELD challenges. GLOA is often practiced with different constraints in ELD problems. The foremost purpose of the aforementioned framework is to minimize the cost function. Every systematic step of the GLOA algorithm to determine the solution of ELD as shown below:

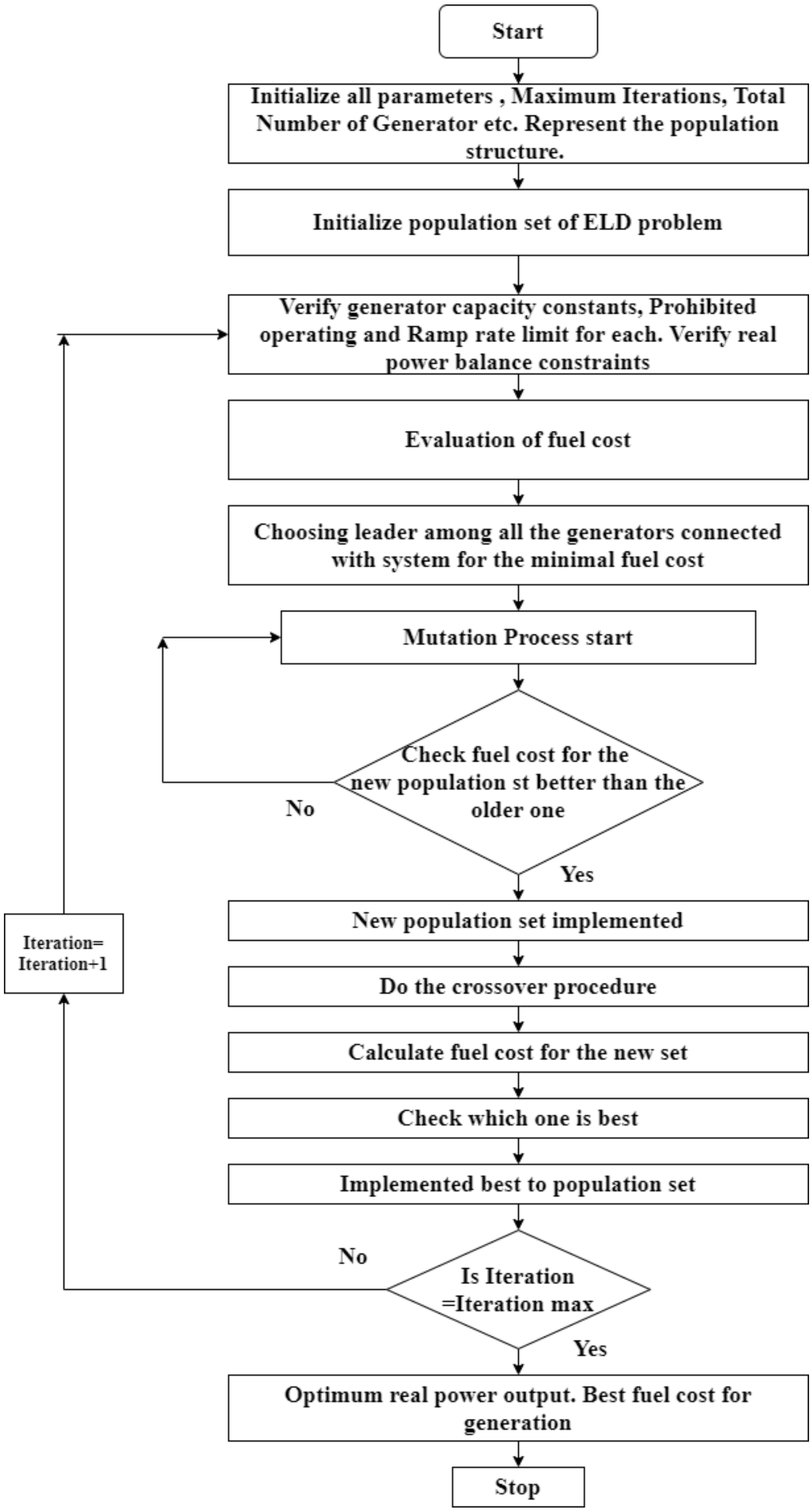

Figure 3.1: GLOA for Economic Load Dispatch

Chapter 4

Formulation of ELD Problem

The conventional composition of ELD challenge is to diminish the fuel cost of individual generator with consideration of power balance with respect to real power and demand power and also subject to limits on generator output. Here, one of the complex types of test system of ELD problem have been composited and solved by GLOA method.

4.1 Quadratic Cost Function and Different Constraints for ELD

The main aim of economic dispatch is to reduce total cost of fuel (C_F) at power plant with consideration of operating constraints of system as shown below:

$$C_F = min[\sum_{i=1}^{n} = nC_F(E_i)] = min(\sum_{i=1}^{n} X_i + Y_iE_i + Z_iP_i^2) \quad (4.1)$$

Ei is power generation unit i and $C_F(E_i)$ is generator cost function and explained as quadratic polynomial.X_i, Y_i, Z_i are cost coefficient of i^{th} generator and n is the number of generators of power plant.

4.1.1 Real Power Balance

$$\sum_{i=1}^{n} E_i - E_d = 0 \quad (4.2)$$

E_d is power demand for lossless transmission consideration.

4.1.2 Generation Capacity

$$E_i^{minimum} \leq E_i \leq E_i^{maximum} \tag{4.3}$$

Here, $E_i^{maximum}$ and $E^{minimum}$ are the maximum and minimum power generation by generator i^{th} unit.

4.2 Power Balance

Once equality constraint is satisfied then power balance is easy to achieve. Summation of total demand and total load should equal to total generation.

$$\sum_{i=1}^{n} E_i = E_d \tag{4.4}$$

4.3 Quadratic Cost Function

This objective function is the same as (4.1). Here, objective cost function C_F is required to be minimized to (4.2), (4.3). losses during transmission is ignored.E_l is zero.

4.4 Valve-Point Effect

$$C_F = min[\sum_{n}^{i=1} C_F(E_i)] = min\left[\sum_{i=1}^{n} X_i + Y_i E_i + Z_i P_i^2 + \left| k_i * sin\{C_i * (E_i^{min} - E_i)\}\right|\right] \tag{4.5}$$

k_i and C_i are cost coefficient

4.5 Equality Constraint With Transmission Losses

$$\sum_{i=1}^{n} E_i - E_d - E_{\text{loss}} = 0 \tag{4.6}$$

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} E_i B_{ij} E_j + \sum_{i=1}^{n} B_{0i} E_i + B_{00} \tag{4.7}$$

4.6 Ramp Rate limit

$$\begin{aligned} & E_i - E_{i0} \leq URL_i \quad \text{(as generation rises)} \\ & E_{i0} - E_i \leq LRL_l \quad \text{(as generation falls)} \\ & \text{and } \max\left(E_i^{\min}, E_{i0} - LRL_i\right) \leq \min\left(E_i^{\max}, E_{i0} + URL_i\right) \end{aligned} \tag{4.8}$$

4.7 Prohibited Operating Zone

Due to faults in machines and components like boilers, feed pumps, steam valve operations and bearing vibration, constraint such as prohibited operating zone (POZ) is taken.

$$\left.\begin{aligned} & E_a^{\min} \leq E_a \leq E_{a,1}^l \\ & E_{a,j-1}^u \leq E_a \leq E_{a,j}^l \\ & E_{a,n}^u \leq E_a \leq E_a^{\max} \end{aligned}\right\} ; j = 1, 2, \ldots, n \tag{4.9}$$

4.8 Calculation of Slack Generator

$$\begin{aligned} & E_d - \sum_{i=1}^{n} E_i = E_n \\ & E_d + E_{loss} - \sum_{i=1}^{n} E_i = E_n \end{aligned} \tag{4.10}$$

Equation (4.9) can be redesign as below:

$$B_{NN}P_N^2 + E_n\left(2\sum_{i=1}^{n-1} B_{ni}E_i + \sum_{i=1}^{n-1} B_{0n} - 1\right) + \left(E_d + \sum_{i=1}^{n-1}\sum_{j=1}^{n-1} E_iB_{ij}E_j + \sum_{i=1}^{n-1} B_{0i}E_i - \sum_{i=1}^{n-1} E_i + B_{00}\right) = 0 \tag{4.11}$$

Chapter 5

Numerical Results

5.1 GLOA Technique for ELD

GLOA has been employed to solve ELD challenges in the test cases and its execution should correspond to certain distinct optimization techniques.

5.1.1 Test Case-1

Here, 40 generator units have taken with assumption of no transmission losses. Data required for input is taken from [6] and same is added in Appendix. 10500 MW is total demand. Here, the output result of EMA[6],QPSO [6] and IPSO [7] are compared with GLOA. In Table 1, minimum fuel cost for 40 generator units is 121412.5354 $/hr. obtained by the GLO algorithm, better than EMA,QPSO and IPSO. The minimum, maximum and average fuel cost obtained from 50 trials are shown in table 2. From table 2, it is seen that GLOA is the fastest as well as it gives most optimum solution. The convergence characteristic of GLOA is displayed in Figure 1. The net power delivered to the system comes out to be 10500 MW. So, the level of the result accuracy is 100 percent with no transmission losses.

Table 5.1: Optimum power output and fuel cost for GLOA and other techniques comparison for 40-unit system

Unit	Power Output			
	GLOA	**EMA[6]**	**QPSO[6]**	**IPSO[7]**
P1	110.7989	110.7998	111.2000	110.8000
P2	110.7989	110.7998	111.7000	110.8000
P3	97.3995	97.3999	97.4000	97.400
P4	179.7333	179.7331	179.7300	179.7330
P5	87.79844	87.7999	90.1400	87.8000
P6	139.9998	140.00	140.00	140.00
P7	259.6014	259.5996	259.6000	259.6000
P8	284.5974	284.5996	284.8000	284.6000
P9	284.6008	284.5996	284.8400	284.6000
P10	130.0001	130.00	130.00	130.00
P11	94.00008	94.00	168.8000	94.0000
P12	94.00170	94.00	168.8000	94.0000
P13	214.7593	214.7598	214.7600	214.7600
P14	394.2783	394.2793	304.5300	394.2790
P15	394.2793	394.2793	394.2800	394.2790
P16	394.2764	394.2793	394.2800	394.2790
P17	489.2794	489.2793	489.2800	489.2790
P18	489.2794	489.2793	489.2800	489.2790
P19	511.2787	511.2793	511.2800	511.2790
P20	511.2784	511.2793	511.2800	511.2790
P21	523.2802	523.2793	523.2800	523.2790
P22	523.2797	523.2793	523.2800	523.2790
P23	523.2785	523.2793	523.2900	523.2790
P24	523.2797	523.2793	523.2800	523.2790
P25	523.2794	523.2793	523.2900	523.2790
P26	523.2806	523.2793	523.2800	523.2790
P27	10.00	10.00	10.0100	10.00
P28	10.00	10.00	10.0100	10.00
P29	10.0008	10.00	10.00	10.00
P30	87.8012	87.7999	88.4700	87.8000
P31	189.999	190.00	190.00	190.00
P32	189.9975	190.00	190.00	190.00
P33	189.9975	190.00	190.00	190.00
P34	164.8005	164.7998	164.9100	164.8000
P35	199.9990	200.00	165.3600	194.4000
P36	194.4057	194.3977	167.1900	199.999
P37	109.9998	110.0000	110.0000	110.0000
P38	110.0000	110.000	107.0100	110.0000
P39	110.0000	110.0000	110.0000	110.0000
P40	511.2802	511.2793	511.3600	511.2790
Fuel Cost($/hr)	**121412.5354**	**121412.5355**	**121448.2100**	**121412.5455**

Table 5.2: Average, Maximum, Minimum Cost Comparison for 40 Generator Units (50 trials)

Methods	Generation Cost ($/hr.)			Time/Iteration(s)	No. of Hits to minimum Solution
	Maximum	Minimum	Average		
GLOA	**121414.2353**	**121412.5355**	**121412.7060**	**0.24**	**45**
EMA[6]	121416.2031	121412.5355	121414.6617	0.29	21
QPSO[6]	121455.9510	121448.2100	121453.628	0.65	15

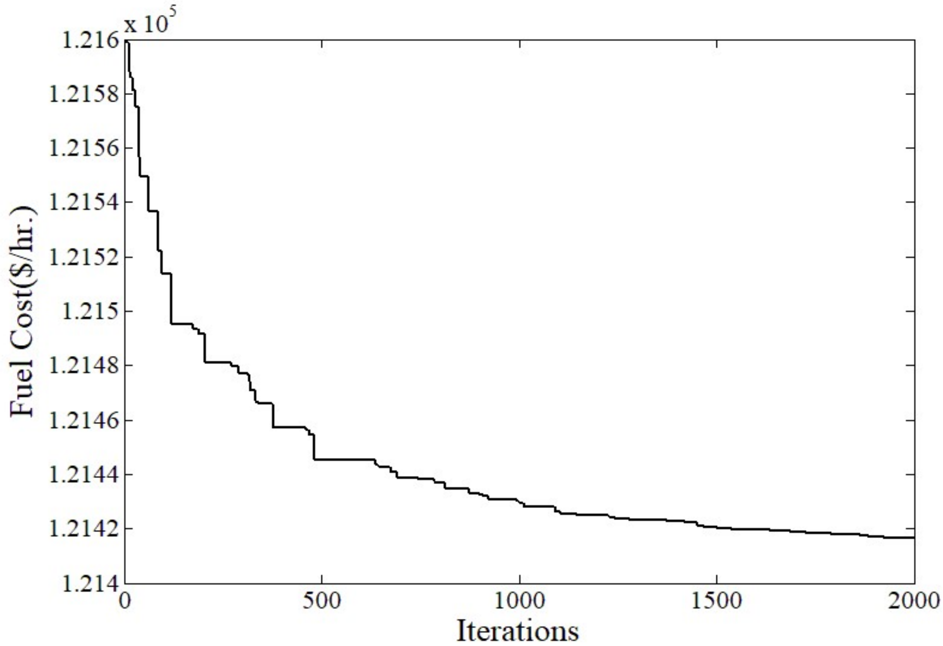

Figure 5.1: Convergence characteristic of GLOA for 40 generator units

5.1.2 Test Case-2

In the Test System-2, Power demand is 2520 MW and 13 generator units have been taken with transmission loss consideration. Require input data is taken from [10] and shown in Appendix. The result obtained by GLOA for Test System-2 is in Table 5.3. The maximum cost, minimum cost, average cost are in Table 5.4. The convergence characteristic is shown in Figure 5.2. The obtained result has been compared with the existing method such as SCA, ORCCRO, SDE.

Table 5.3: Optimum power output and fuel cost for GLOA and other techniques comparison for 13-unit system

Unit	**GLOA**	**SCA [12]**	**SDE [9]**	**ORCCRO [8]**
P1	628.3183	628.3179	628.32	628.32
P2	299.1994	299.1992	299.2	299.2
P3	297.4464	297.4468	299.2	299.2
P4	159.7325	159.7327	159.73	159.73
P5	159.7329	159.7327	159.73	159.73
P6	159.7328	159.7328	159.73	159.73
P7	159.733	159.7331	159.73	159.73
P8	159.7331	159.7325	159.73	159.73
P9	159.7326	159.7328	159.73	159.73
P10	77.3996	77.3995	77.4	77.4
P11	114.7996	114.7993	113.12	112.14
P12	92.3994	92.3997	92.4	92.4
P13	92.3995	92.4	92.4	92.4
Power Generation (MW)	**2560.3591**	2559.8	2560.43	2559.43
Transmission Loss (MW)	**40.35**	39.8	40.43	39.43
Fuel Cost ($/hr.)	**24512.6065**	24512.6085	24514.88	24513.91

Table 5.4: Average, Maximum, Minimum Cost Comparison for 13 Generator Units (50 trials)

Methods	Generation Cost ($/hr)			Time /iteration (s)	No. of hits to minimum solution
	Maximum	Minimum	Average		
GLOA	**24512.59**	**24512.61**	**24512.6**	**0.0355**	**48**
SCA [12]	24512.61	24512.61	24512.61	0.0361	50
ORCCRO [8]	24518.56	24513.91	24515.72	0.0533	27
SDE [9]	24519.74	24514.88	24516.23	NA*	21

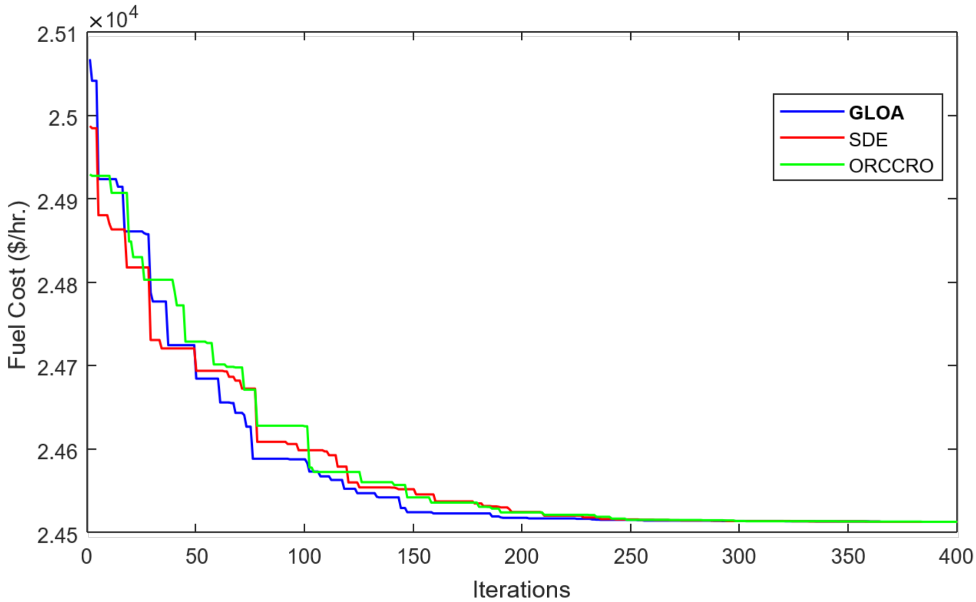

Figure 5.2: Convergence characteristic of GLOA for 13 generator units

5.1.3 Test Case-3

In Test Case-3, the total number of generator units considered are 15 with transmission loss consideration. The total power demand is 2630 MW. Prohibited operating zone and ramp rate limits have been taken as a constraint. Appendix describes the cost coefficients of the generators prohibited operating zones and B-coefficient matrix for transmission loss calculations respectively. The Table 5.5 shows the result obtained by the proposed technique GLOA. The Average, Minimum, Maximum values of generation cost obtained by GLOA are in Table 5.6. A comparison of the obtained result has been done with existing techniques such as CTPSO, PSO, GA. Convergence characteristic is shown in the Figure 5.3.

Table 5.5: Optimum power output and fuel cost for GLOA and other techniques comparison for 15-unit system.

Unit	**Power Output**			
	GLOA	**GA[11]**	**PSO[11]**	**CTPSO[11]**
P1	454.8210	415.3180	439.1162	455.0000
P2	379.6430	359.7206	407.9727	380.0000
P3	129.9661	104.4250	119.6324	130.0000
P4	129.9234	74.9853	129.9925	130.0000
P5	170.0000	380.2844	151.0681	170.0000
P6	459.9770	426.7902	459.9978	460.0000
P7	429.9997	341.3164	425.5601	430.0000
P8	72.1010	124.7867	98.5699	71.7430
P9	69.0948	133.1445	113.4936	58.9186
P10	149.3550	89.2567	101.1142	160.0000
P11	79.8642	60.0572	33.9116	80.0000
P12	25.0936	49.9998	79.9583	80.0000
P13	25.0936	38.7713	25.0042	25.0000
P14	15.0270	41.9425	41.4140	15.0000
P15	15.0554	22.6445	35.6140	15.0000
Total Power (MW)	**2659.921**	2668.4000	2662.4000	2660.6615
Power Loss (MW)	**29.921**	38.2782	32.4306	30.6615
Fuel Cost ($/hr)	**32699.6315**	33113.0000	32858.0000	32704.0000

Table 5.6: Comparison for 15 Generator Units (50 trials)

Methods	Generation cost ($/hr.)			Time (s)	No. of hits to Best solutions
	Maximum	Minimum	Average		
GLOA	**32699.6315**	**32699.6315**	**32699.6315**	**6.0**	**49**
GA[11]	NA	33113.0000	NA	NA	NA
PSO[11]	NA	32858.0000	NA	NA	NA
CTPSO[11]	NA	32704.0000	NA	NA	NA

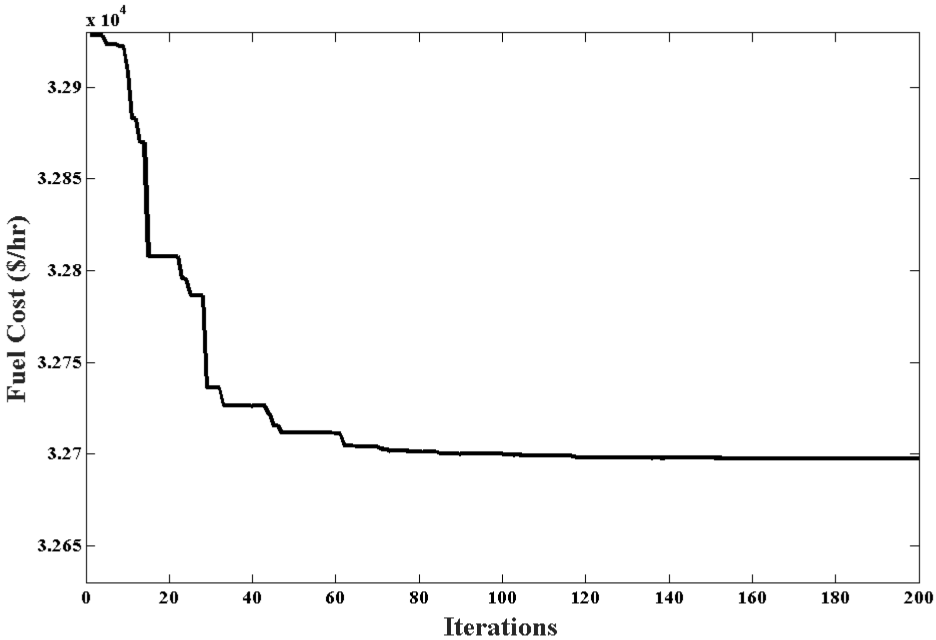

Figure 5.3: Convergence characteristic of GLOA for 15 generator units

5.2 Discussion

5.2.1 Tuning Parameters

It is inevitable to tune parameters for getting the optimal output. For that suitable values of $R1$, $R2$ and $R3$ are inherent. One should take all possible combination of tuning parameter to identify optimized fuel. The compiled obtained result is shown in Table 5.7.

Table 5.7: Tuning Parameters of GLOA for Test System-1

R2	**R3**	**R1**					
		0.5	0.6	0.7	**0.8**	0.9	1.0
0.50	0.45	121412.7082	121412.7075	121412.7074	121412.7071	121412.7069	121412.7073
0.50	0.40	121412.7080	121412.7073	121412.7073	121412.7070	121412.7067	121412.7071
0.45	0.35	121412.7073	121412.7071	121412.7072	121412.7069	121412.7065	121412.7069
0.40	0.30	121412.7073	121412.7069	121412.7069	121412.7068	121412.7064	121412.7066
0.35	0.25	121412.7070	121412.7068	121412.7068	121412.7065	121412.7063	121412.7064
0.30	**0.20**	121412.7068	121412.7067	121412.7065	**121412.7060**	121412.7062	121412.7063
0.25	0.15	121412.7069	121412.7069	121412.7067	121412.7067	121412.7065	121412.7066
0.20	0.10	121412.7069	121412.7071	121412.7069	121412.7068	121412.7067	121412.7068
0.15	0.05	121412.7070	121412.7073	121412.7072	121412.7069	121412.7068	121412.7069
0.1	0.01	121412.7072	121412.7075	121412.7073	121412.7070	121412.7071	121412.7070

5.2.2 Solution Quality

Result obtained from implementation of GLOA for ELD problem on three different test cases proves that GLOA shows best result in terms of fuel cost, number of hits to best solution and simulation time.

5.2.3 Robustness

The quality of a certain heuristic algorithm can't be predicted from a single run test. Usually, their success is measured for several numbers of the running of the programs of those algorithms. To get a beneficial result about the execution of the algorithm, several runs with varying initialization of the size of the population should always be made. An algorithm is believed to be stable if consistently performed overall tests. This effectiveness is far superior to numerous distinct algorithms mentioned in the different kinds of literature. Hence, the foregoing findings authenticate the intensified capacity of GLOA to make high-quality computationally effective and robust solutions.

Chapter 6

Conclusion

An efficient GLOA population-based algorithm is employed to tackle ELD problem. It is clear that employed technique is flexible, efficient and comfortable in Global minima and rarely gets trapped in local minima. In this method, no computationally, expensive derivatives are significant so it is quite easy. The numerical results output shows that GLOA is capable to find extraordinary ELD solution as compared to well-regarded optimizer. Obtained output numerical results ensure the excellent capability of GLOA in convergence characteristics, solution quality and heftiness compared to other optimizers. Hence, GLOA technique results revealed that it can tackle complex ELD problems.

Chapter 7

Future Scope

- Implementation of GLOA on Economic load Dispatch for different test case,for various number of generating units and various load demand.
- Some new techniques can also be used to solve ED and EELD for improvising results.
- Extension of a system, which makes use of real world system incorporating renewable energy sources.

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Appendix A

Input Data

A.1 Input Data for Test System-1 (40 generator units)

Table A.1: Fuel Cost Coefficients and Operating Limits of The Generators for Test System-1

Unit	$P_i min(MW)$	$P_i max(MW)$	$ai(\$)$	bi ($/MW)	$ci(\$/MW^2)$	$e_i(\$)$	$f_i(MW^{-1})$
1	36	114	94.705	6.73	0.00690	100	0.084
2	36	114	94.705	6.73	0.00690	100	0.084
3	60	120	309.540	7.07	0.02028	100	0.084
4	80	190	369.030	8.18	0.00942	150	0.063
5	47	97	148.890	5.35	0.01140	120	0.077
6	68	140	222.330	8.05	0.01142	100	0.084
7	110	300	287.710	8.03	0.00357	200	0.042
8	135	300	391.980	6.99	0.00492	200	0.042
9	135	300	455.760	6.60	0.00573	200	0.042
10	130	300	722.820	12.90	0.00605	200	0.042
11	94	375	635.200	12.90	0.00515	200	0.042
12	94	375	654.690	12.80	0.00569	200	0.042

Unit	$P_imin(MW)$	$P_imax(MW)$	a_i (\$)	b_i (\$/MW)	$c_i(\$/MW^2)$	e_i(\$)	fi (MW^{-1})
13	125	500	913.400	12.50	0.00421	300	0.035
14	125	500	1760.400	8.84	0.00752	300	0.035
15	125	500	1728.300	9.15	0.00708	300	0.035
16	125	500	1728.300	9.15	0.00708	300	0.035
17	220	500	647.850	7.97	0.00313	300	0.035
18	220	500	649.690	7.95	0.00313	300	0.035
19	242	550	647.830	7.97	0.00313	300	0.035
20	242	550	647.810	7.97	0.00313	300	0.035
21	254	550	785.960	6.63	0.00298	300	0.035
22	254	550	785.960	6.63	0.00298	300	0.035
23	254	550	794.530	6.66	0.00284	300	0.035
24	254	550	794.530	6.66	0.00284	300	0.035
25	254	550	801.320	7.10	0.00277	300	0.035
26	254	550	801.320	7.10	0.00277	300	0.035
27	10	150	1055.100	3.33	0.52124	120	0.077
28	10	150	1055.100	3.33	0.52124	120	0.077
29	10	150	1055.100	3.33	0.52124	120	0.077
30	47	97	148.890	5.35	0.01140	120	0.077
31	60	190	222.920	6.43	0.00160	150	0.063
32	60	190	222.920	6.43	0.00160	150	0.063
33	60	190	222.920	6.43	0.00160	150	0.063
34	90	200	107.870	8.95	0.00010	200	0.042
35	90	200	116.580	8.62	0.00010	200	0.042
36	90	200	116.580	8.62	0.00010	200	0.042
37	25	110	307.450	5.88	0.01610	80	0.098
38	25	110	307.450	5.88	0.01610	80	0.098
39	25	110	307.450	5.88	0.01610	80	0.098
40	242	550	647.830	7.97	0.00313	300	0.035

A.2 Input Data for Test System-2 (13 generator units)

Table A.2: Fuel Cost Coefficients and Operating Limits of The Generators for Test System-2

Unit	$P_i min(MW)$	$P_i max(MW)$	$a_i(\$)$	$b_i(\$/MW)$	$c_i(\$/MW^2)$	$e_i(\$)$	f_i
1	0	680	0.00028	8.10	550	300	0.035
2	0	360	0.00056	8.10	309	200	0.042
3	0	360	0.00056	8.10	307	150	0.042
4	60	180	0.00324	7.74	240	150	0.063
5	60	180	0.00324	7.74	240	150	0.063
6	60	180	0.00324	7.74	240	150	0.063
7	60	180	0.00324	7.74	240	150	0.063
8	60	180	0.00324	7.74	240	150	0.063
9	60	180	0.00324	7.74	240	150	0.063
10	40	120	0.00284	8.60	126	100	0.084
11	40	120	0.00284	8.60	126	100	0.084
12	55	120	0.00284	8.60	126	100	0.084
13	55	120	0.00284	8.60	126	100	0.084

B-Matrix for Test Case-2

B_{ij}=

$$\begin{bmatrix}
0.0014 & 0.0012 & 0.0007 & -0.0001 & -0.0003 & -0.0001 & -0.0001 & -0.0001 & -0.0003 & -0.0005 & -0.0003 & -0.0002 & 0.0004; \\
0.0012 & 0.0015 & 0.0013 & -0.0000 & -0.0005 & -0.0002 & -0.0000 & 0.0001 & -0.0002 & -0.0004 & -0.0004 & -0.0000 & 0.0004; \\
0.0007 & 0.0013 & 0.0076 & -0.0001 & -0.0013 & -0.0009 & -0.0001 & -0.000 & -0.0008 & -0.0012 & -0.0017 & -0.0000 & -0.0026; \\
-0.0001 & 0.000 & -0.0001 & 0.0034 & -0.0007 & -0.0004 & 0.0011 & 0.0050 & 0.0029 & 0.0032 & -0.0011 & -0.0000 & 0.0001; \\
-0.0003 & -0.0005 & -0.0013 & -0.0007 & 0.009 & 0.0014 & -0.0003 & -0.0012 & -0.0010 & -0.0013 & 0.0007 & -0.0002 & -0.0002; \\
-0.0001 & -0.0002 & -0.0009 & -0.0004 & 0.0014 & 0.0016 & -0.0000 & -0.0006 & -0.0005 & -0.0008 & 0.0011 & -0.0001 & -0.0002; \\
-0.0001 & -0.0000 & -0.0001 & 0.0011 & -0.0003 & -0.0000 & 0.0015 & 0.0017 & 0.0015 & 0.0009 & -0.0005 & 0.0007 & -0.0000; \\
-0.0001 & 0.0001 & -0.0000 & 0.0050 & -0.0012 & -0.0006 & 0.0017 & 0.0168 & 0.0082 & 0.0079 & -0.0023 & -0.0036 & 0.0001\ ; \\
-0.0003 & -0.0002 & -0.0008 & 0.0029 & -0.0010 & -0.0005 & 0.0015 & 0.0082 & 0.0129 & 0.0116 & -0.0021 & -0.0025 & 0.0007; \\
-0.0005 & -0.0004 & -0.0012 & 0.0032 & -0.0013 & -0.0008 & 0.0009 & 0.0079 & 0.0116 & 0.0200 & -0.0027 & -0.0034 & 0.0009; \\
-0.0003 & -0.0004 & -0.0017 & -0.0011 & 0.0007 & 0.0011 & -0.0005 & -0.0023 & -0.0021 & -0.0027 & 0.0140 & 0.0001 & 0.0004; \\
-0.0002 & -0.0000 & -0.0000 & -0.0000 & -0.0002 & -0.0001 & 0.0007 & -0.0036 & -0.0025 & -0.0034 & 0.0001 & 0.0054 & -0.0001; \\
0.0004 & 0.0004 & -0.0026 & 0.0001 & -0.0002 & -0.0002 & -0.0000 & 0.0001 & 0.0007 & 0.0009 & 0.0004 & -0.0001 & 0.0103;
\end{bmatrix} (MW^{-1})$$

B_{i0}=

$$[-0.0001 \ -0.0002 \ 0.0028 \ -0.0001 \ 0.0001 \ -0.0003 \ -0.0002 \ -0.0002 \ 0.0006 \ 0.0039 \ -0.0017 \ -0.0000 \ -0.0032];$$

B_{00}=0.0055(MW);

A.3 Input Data for Test System-3 (15 generator units)

Table A.3: Fuel Cost Coefficients and Operating Limits of The Generators for Test System-3

Unit	a_i ($)	b_i ($/MW)	c_i ($\$/MW^2$)	P_imin (MW)	P_imax (MW)	URi $(MW/hr.)$	LRi $(MW/hr.)$	$Pi0$ (MW)
1	0.000299	10.1	671	150	455	80	120	400
2	0.000183	10.2	574	150	455	80	120	300
3	0.001126	8.8	374	20	130	130	130	105
4	0.001126	8.8	374	20	130	130	130	100
5	0.000205	10.4	461	150	470	80	120	90
6	0.000301	10.1	630	135	460	80	120	400
7	0.000364	9.8	548	135	465	80	120	350
8	0.000338	11.2	227	60	300	65	100	95
9	0.000807	11.2	173	25	162	60	100	105
10	0.001203	10.7	175	25	160	60	100	110
11	0.003586	10.2	186	20	80	80	80	60
12	0.005513	9.9	230	20	80	80	80	40
13	0.000371	13.1	225	25	85	80	80	30
14	0.001929	12.1	309	15	55	55	55	20
15	0.004447	12.4	323	15	55	55	55	20

B-Matrix for Test Case-3

$B_{ij}=$

$$
\begin{bmatrix}
0.0014 & 0.0012 & 0.0007 & -0.0001 & -0.0003 & -0.0001 & -0.0001 & -0.0001 & -0.0003 & 0.0005 & -0.0003 & -0.0002 & 0.0004 & 0.0003 & -0.0001; \\
0.0012 & 0.0015 & 0.0013 & -0.0000 & -0.0005 & -0.0002 & -0.0000 & 0.0001 & -0.0002 & -0.0004 & -0.0004 & -0.0000 & 0.0004 & 0.0010 & -0.0002; \\
0.0007 & 0.0013 & 0.0076 & -0.0001 & -0.0013 & -0.0009 & -0.0001 & -0.0000 & -0.0008 & -0.0012 & -0.0017 & -0.0000 & -0.0026 & 0.0111 & -0.0028; \\
-0.0001 & 0.0000 & -0.0001 & 0.0034 & -0.0007 & -0.0004 & 0.0011 & 0.0050 & 0.0029 & 0.0032 & -0.0011 & -0.0000 & 0.0001 & 0.0001 & -0.0026; \\
-0.0003 & -0.0005 & -0.0013 & -0.0007 & 0.009 & 0.0014 & -0.0003 & -0.0012 & -0.0010 & -0.0013 & 0.0007 & -0.0002 & -0.0002 & -0.0024 & -0.0003; \\
-0.0001 & -0.0002 & -0.0009 & -0.0004 & 0.0014 & 0.0016 & -0.0000 & -0.0006 & -0.0005 & -0.0008 & 0.0011 & -0.0001 & -0.0002 & -0.0017 & 0.0003; \\
-0.0001 & -0.0000 & -0.0001 & 0.0011 & -0.0003 & -0.0000 & 0.0015 & 0.0017 & 0.0015 & 0.0009 & -0.0005 & 0.0007 & -0.0000 & -0.0002 & -0.0008; \\
-0.0001 & 0.0001 & -0.0000 & 0.0050 & -0.0012 & -0.0006 & 0.0017 & 0.0168 & 0.0082 & 0.0079 & -0.0023 & -0.0036 & 0.0001 & 0.0005 & -0.0078; \\
-0.0003 & -0.0002 & -0.0008 & 0.0029 & -0.0010 & -0.0005 & 0.0015 & 0.0082 & 0.0129 & 0.0116 & -0.0021 & -0.0025 & 0.0007 & -0.0012 & -0.0072; \\
-0.0005 & -0.0004 & -0.0012 & 0.0032 & -0.0013 & -0.0008 & 0.0009 & 0.0079 & 0.0116 & 0.0200 & -0.0027 & -0.0034 & 0.0009 & -0.0011 & -0.0088; \\
-0.0003 & -0.0004 & -0.0017 & -0.0011 & 0.0007 & 0.0011 & -0.0005 & -0.0023 & -0.0021 & -0.0027 & 0.0140 & 0.0001 & 0.0004 & -0.0038 & 0.0168; \\
-0.0002 & -0.0000 & -0.0000 & -0.0000 & -0.0002 & -0.0001 & 0.0007 & -0.0036 & -0.0025 & -0.0034 & 0.0001 & 0.0054 & -0.0001 & -0.0004 & 0.0028; \\
0.0004 & 0.0004 & -0.0026 & 0.0001 & -0.0002 & -0.0002 & -0.0000 & 0.0001 & 0.0007 & 0.0009 & 0.0004 & -0.0001 & 0.0103 & -0.0101 & 0.0028; \\
0.0003 & 0.0001 & 0.0111 & 0.0001 & -0.0024 & -0.0017 & -0.0002 & 0.0005 & -0.0012 & -0.0011 & -0.0038 & -0.0004 & -0.0101 & 0.0578 & -0.0094; \\
-0.0001 & -0.0002 & -0.0028 & -0.0026 & -0.0003 & 0.0003 & -0.0008 & -0.0078 & -0.0072 & -0.0088 & 0.0168 & 0.0028 & 0.0028 & -0.0094 & 0.1283
\end{bmatrix} MW^{-1}
$$

$$B_{i0}= \begin{bmatrix} -0.0001 & -0.0002 & 0.0028 & -0.0001 & 0.0001 & -0.0003 & -0.0002 & -0.0002 & 0.0006 & 0.0039 & -0.0017 & -0.0000 & -0.0032 & 0.0067 & -0.0064 \end{bmatrix};$$

B_{00}=0.0055(MW);

Prohibited Operating Zone Data for Test Case-3

Unit	Prohibited Operating Zones (MW)
2	[185 225] [305 335] [420 450]
5	[180 200] [305 335] [390 420]
6	[230 255] [365 395] [430 455]
12	[30 40] [55 65]