Performance Analysis & Comparison of Optimal Economic Load Dispatch using Soft Computing Techniques

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***Abstract*—Power plants not situated at similar space from center of loads and their fuel prices are dissimilar. In this paper, ELD of actual power generation measured.ELD is preparation of generators to reduce total functioning price of generator units exposed to equality constraint of power balance within minimum and maximum working limits of producing units. In this paper FL, GAs & hybridization of GA-FL is utilized to find optimal solution of ELD systems. ELD resolutions found by resolving conservative load flow equations though at same time reducing fuel prices. Performance of results is analyzed by comparing the data values obtained with the help of soft computing techniques in ELD.**

***Keywords*—ELD; FL; GA; FCGA**

I. Introduction

ED is small term fortitude of optimal output of a lot of electricity generation amenities & to meet system load at nethermost probable cost subject to transmission and working restraints.ELD is resolved by particular computer software which honor operational and system restraints of existing possessions and consistent transmission abilities. In electrical power systems, a incessant equilibrium must be preserved among electrical generation and fluctuating load mandate, though system frequency, voltage stages and security too reserved constant. Besides, it is required that price of such generation be less. In addition, separation of load in producing plant develops a vital operation in addition to an economic matter which resolved at each load change (1%) or each 2-3 minutes. Research methods effectively castoff to resolve optimum load flow difficulties by using direct or non-linear encoding but these algorithms usually restricted to systematic functions. Numerous tasks are multi-modal, intermittent. Stochastic selection approaches used to improve these functions. Although customary resolution methods use features of problem to govern following sampling point, stochastic resolution methods make no such conventions. In its place, subsequent sampled point resolute centered on stochastic sampling or decision rules than a set of deterministic conclusion rules. GAs used to resolve tough difficulties with objective functions that not retain possessions such as continuity, differentiability. These algorithms preserve and operate a set of answers and implement a existence of the fittest approach in their hunt for a improved solution.

The process of generation services to harvest energy at deepest price to constantly assist clients by identifying any working limits of generation and transmission services. Planning and process of power systems under prevailing circumstances, its growth and future growth requires load flow educations, short circuit studies and constancy studies. Though load flow studies are very important for planning, control and processes of prevailing & future growth as acceptable operation of the system be contingent upon knowing belongings of inter connection, new loads, new producing stations or new transmission lines afore they are installed.

II. Literature Survey

G.Sahu et.al (2014) grants the presentation of GA to resolve ELD problem of power system. Planned algorithm verified on two dissimilar test systems seeing transmission damages. The chief cause of cutting total fuel cost and preserve power flows within safety range. **B. Hosamani et.al (2014)** addresses planning and operation of power systems and introduced an approach to provide consumers with reliable and quality power at an economical cost. The main intent of this paper is to develop efficient and fast Fuzzified Particle Swarm Optimization (FPSO) procedure to attain the optimum results of multi-constrained dynamic ED, OPF. This paper focuses on the multi- constrained dynamic economic dispatch problem and introduces the Fuzzified particle swam optimization to solve it. **S. H.Elyas et.al (2014**) introduces a proficient approach for comprehending problem of ELD with effect of valve point by utilizing a novel hybrid procedure for optimization. The fundamental goal for discovery resolution of problem of ELD is to plan the output of committed units of generator so as to fulfill the load of system under numerous operating imperatives. **B.Sahu (2013)** explains GA and quadratic programming ideas in resolving economic load dispatch (ELD) in which entire price of producing power is reduced with a valve point loading outcome though satisfying load request regardless of transmission line losses. **V. Karthikeyan (2013)**

explains that price competence is utmost significant problem of power system operations and makes an attempt to catch out the least price by using Particle Swarm Optimization Procedure considering statistics of three generating units. The paper involves the use of damage coefficients with maximum power limit and cost function. PSO and Simulated Annealing smeared to find out the least price for diverse power request. **F. Farheen et.al (2013)** presented operation of PSO for dynamic problem of ELD. The economic operation of the systems which are generating has constantly involved an imperative position in an industry of electric power. **A.Gharegozi et.al (2013)** presents a novel method to solve the issue of best planning using Cuckoo Search Algorithm. The proposed approach provides the most appropriate convergence in the response, high computational speed and high accuracy. **L. Chopra et.al (2012)** shows simple GA and refined GA technique applicable to ELD which books for reduction of price for operational constraints. Lambda iteration technique needs precise alteration of lambda which not provide global optimum resolution. **A.Hasan Zade et.al (2011)** describes ELD problem as a constrained optimization problem and hence efficient method needed to explain this problematic. The paper involves use of a particular variant of Evolutionary Algorithm namely DE to address ELD problem. Fuzzy logic controller designed to control the amplification factor vector of DE dynamically during the process of optimization. **S.C. Swain et.al (2010)** introduces the utilizations of techniques of computational intelligence to problems of ELD. The equation of fuel price of thermal plant is normally communicated a quadratic equation which is continuous. In conditions of real world, the equations of fuel cost occur discontinuous. In perspective of above, both cost equations which are continuous or discontinuous are considered in the present paper.**Bakirtzis. A (1994)** presented two GAs results to ELD. Benefit of GA resulting not enforce any convexity limitations on generator price function. Additional benefit for GAs for efficiently coded to effort on parallel machines. **A.G. Bakirtzis et.al (2002**) introduces an enhanced genetic algorithm for finding the solution of optimal power flow (OPF) with control variables which are both discrete and continuous. **H.Jagabondhu et.al (2009)** grants a relative learning of four diverse evolutionary algorithms i.e. GA bacteria foraging optimization, ant colony optimization and PSO for solving ELD. Concert of every algorithm for resolving ED problem analysed and simulation consequences are shown for precision, consistency and finishing time. **Altun H et.al (2008**) highlighted execution issues of soft computing methods for a effective solicitation to solve ED problem for inhibited optimization problem in power systems. The paper presents review of fundamentals of the methods and includes discussion of the implementation of methods in ED problematic. **A.Kandari et.al (2007)** grants a novel and precise technique for assessing input–output curve limits of power plants. These limits are very imperative for execution economic dispatch values. The greater the precision of projected coefficients, extra precise consequences attained from calculations of economic dispatch. **J. Nanda (2001)** resolves ELD problematic with Line flow limits over operative application of GA since losses of system transmission, power balance equation as equality constraint, active power generations of units and current limits in different lines for inequality constraints.**Palanichamy et.al (1991)** offered a direct and computationally effective technique for ELD. The accustomed B coefficients used for calculation of transmission losses, incremental transmission losses and penalty factors.

III. Economic Load Dispatch

ELD is one of substantial functions in automatic generation control. The Economic Load Dispatch of power production units is an important issue in electric utility industry. Schedule of individual units production which reduces total functioning price of a power system while meeting total load plus transmission losses in generator parameters. This is implication to save energy and tumbling emission.

The problematic goes more compound in great scale system henceforth problematic to find out optimum result due to nonlinear function which comprises number of local optimum. Therefore, importance to resolve this problematic precisely. For financial operation of system total ultimatum must be optimally collective between all generating units reducing total production rate though sustaining operative limits on system.

The fuel rate for all power generation unit explained firstly. Hence total production cost function of ELD problem is distinct as the whole sum of the fuel prices for all generating plant units as stated below:

$$F_T = \sum_{i=1}^{NG} \{a_i P_i^{\,2} + b_i P_i + c_i |d_i\ sine_i(P_i^{\,min} - P_i)|\},$$

Where, NG is total number of producing units

F_T is total generating price

P_i is the power output of producing unit i

P_i^{min} is lowest output of producing unit i

a_i, b_i, c_i, d_i, e_i are fuel rate coefficients of unit i

Above equation calculates total generating rate of producing plant.

A. The Lambda –Iteration Method (LIM)

This is utmost prevalent technique to contract with ELD problematic. Here, variable introduced for solving constraint optimization problem which is said to be as Lagrange multiplier. Lambda explained by unraveling systems of equation. All inequality constraints gratified equations resolved by iterative technique

1) Let a appropriate value λ (0) & this value must be greater than prevalent capture of incremental rate distinctive of the numerous generators.

2) Calculate the separate generations

3) Check the equality

$Pd = \sum_{n=1}^{n} Pn)$

B. Langrangian multiplier

Significant and simplest technique of stating economic dispatch load method as a transmission loss of generator power output is B- coefficients. The general formulae of loss formulae as:

$$P_L = \sum_{i=1}^{k} \sum_{j=1}^{k} P_i\ B_{ij} P_j$$

Bij are loss coefficients or B-coefficients, Pi ,PJ are real power injection of ith, jth buses.

Above inhibited optimization problematic changed into unrestricted optimization problem. Langrangian multiplier is a method applied to minimize or maximize in equality constraints form. An augmentes function is as:

L= C_t+ λ (P_D+$P_L - \sum_{i=1}^{k} P_i$)

Ct is total fuel cost for all generating units and λ is said as Langranian multiplier. For minimizing the cost, L with Pi equal to zero.

C. Fuzzy Logic in ELD

The characteristic of fuzzy logic to deal with fuzzy or crisp values without much concern for precise input and continuous operation in case of feedback sensor failure makes it be called as robust and reliable method. Despite of wide variation in the inputs output control is smooth control function. The fuzzy logic controller operates on user-defined rules hence it adapted modify system performance. By the generation of appropriate governing rules the system can be incorporated with new sensors. Fuzzy logic is not limited one or two control outputs, and it is not essential to calculate rate-of-change of limits in order for implementation. The sensor data is sufficient because that provides some signal of system action.

The fuzzy modeling control system starts with deciding input and output variables of fuzzy logic. Mamdani fuzzy inference system used for this. This method used for fuzzy modeling process to acquire information about a data set to calculate the membership function limits which greatest permit the related fuzzy inference system to trail the specified input-output data. This FIS system intended for MISO system. MISO system comprises two inputs and one output.

D. Linguistic variables

These are variables stated in plain language words. These show an significant role in demonstrating crisp information such that it accurately suitable for the problem. Since usage of linguistic variables detected to decrease whole computation complication in many applications & mainly valuable in representing composite non-linear applications.Linguistic variables are fundamental to fuzzy logic operations, however they are frequently flouted in the arguments on the virtues of fuzzy logic. In fuzzy logic applications, non-numeric linguistic variables frequently applied relative to arithmetical values.

IV. RESEARCH METHODOLOGY

A. Algorithm for ELD Using GA

The numerous stages included in solution of GA Algorithm are:

1) Select Population extent, amount of generations, sub-strings length and quantity of trials.

2) Produce primary arbitrarily coded strings as population associates in the first generation.

3) Decipher population to acquire power generation of units in strings.

4) Implement load flow reflecting the unit generation excluding for the slack bus. To assess the system transmission losses, slack bus generation, line flows.

5) Calculate fitness of population members.

6) Execute selection centered on Reproduction executing. Roulette Wheel process with embedded Elitism trailed by crossover with embedded .Mutation to produce the novel population for the subsequent generation.

B. Algorithm for ELD Using GA

Lambda iteration method decent loom to determine ELD due to which generator parameters easily controlled. The penalty factors applied to reflect the impact of losses. Fuzzy with ELD system is applicable to optimization problems. System will obtain optimum resolution to complications with fuzzy constrictions and fuzzy variables. The values of power which is obtained from ELD is then adjusted by fuzzy practical rules and gives more appropriate and approximate results for power of each unit.

- Compute optimal dispatch and entire rate ignoring losses λ.
- Use dispatch and loss formula, compute system losses. It explained by using MATLAB script and function file that use fsolve MATLAB function to resolve system of equations.
- Discover optimal dispatch for a entire generation of PD by coordination equations and loss formula.
- Economic dispatch problematic containing transmission losses computed for effect of transmission losses to represent total transmission loss as a quadratic function of generator power outputs.
- For minimum cost derivative of L (penalty factor) is required with each Pi equal to zero.
- For generating unit outputs P1, P2 and P3are power units of 1, 2 and 3 for better approximation. It can be designed as s flowchart as:

if P3 < P3min P3 = P3min; else

if P3 > P3max P3 = P3max; end end if P2 < P2min P2 = P2min; else if P2 > P2max P2 = P2max; end end if P1 < P1min P1 = P1min; else if P1 > P1max P1 = P1max;

- Units are ranked according to their full load production cost rate and committed accordingly.
- The system obtain optimal solution to problems with fuzzy constraints and fuzzy variables.

C. Algorithm for ELD Using Fuzzy-GA

1) First of all, adjust all limits population size, number of generations,sub-strings length.

2) Initial arbitrary population of individuals produced where the entities coded string of binary numerals.

3) Assessment of fitness population members accomplished on the basis of a fitness function.

4) When optimization benchmark happened, nominated population members more accepted on for diverse processes.

5) The assortment procedure is achieved.

6) Afterward, fuzzy logic originates into play with fuzzy crossover regulator.

7) The random member first associated with the crossover probability value and if benchmark gratified, border achieved.

8) Likewise for mutation, arbitrary member equated beside mutation probability value.

V. Experimental Analysis & Results

A. Results obtained for ELD using Genetic Algorithm

1) Power Generated

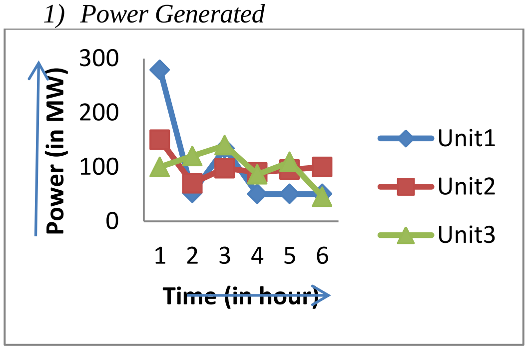

Fig. 1. Power generated

Figure 1 shows power generation for three units which varying according to time/hour.In unit-1 range of powers are 278.912,52.260,134.305,50,50 & 50 for different ranges which shown by blue lines in figure . In unit-2, power ranges are 150, 70, 97.77, 90, 95 & 100 for power ranges shown by red lines .In unit -3, power ranges are 100, 120, 140, 86.23, 109.30 & 45 for different maximum & minimum power ranges & shown by green lines in figure.All power are in MW.

2) Fuel Cost

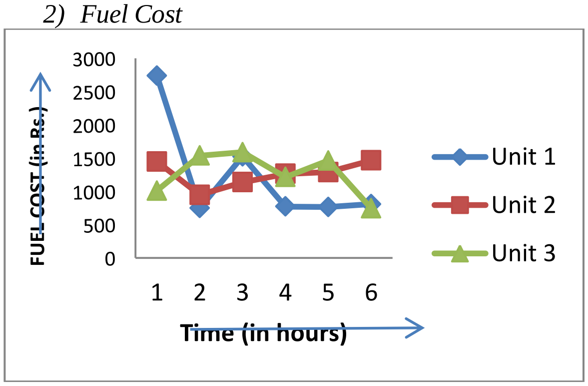

Fig. 2. Fuel Cost

Figure 2 describes fuel cost for three units & cost is according to time per hour.For unit 1 fuel costs are 748.55 to 2736.93 & shown by blue lines.For unit 2,fuel costs are 946.55 to 1465 for power intervals & shown by red lines. For unit 3, fuel costs are 745.18 to 1536.83 for power ranges & shown by green lines.

B. Results obtained for ELD using FL

Figure 5.2.1 shows fuzzy input membership functions. Membership function referred as "gaussmf" used for three linguistic variables low, medium, high for input variables. Figure shows input variable as high with a range of 0 to 150.

1) Fuzzy input (power) membership function

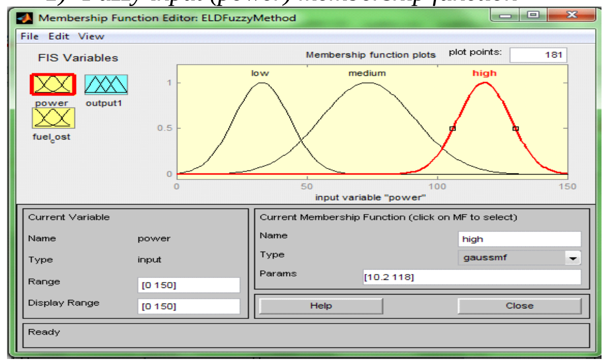

Fig. 3. Fuzzy input (power) membership function

2) Fuzzy output membership function

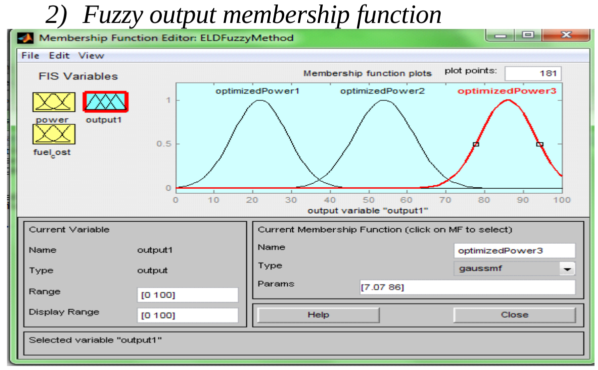

Fig. 4. Fuzzy output membership function

3) Linguistic Variables

TABLE I. Linguistic Levels of Power Input

Input Parameters	Low	Medium	High
P(Power) in MW	0-60	30-130	80-150
Fuel cost (in Rs)	0-50	30-70	60-100

Three membership functions generated for input variable in fuzzy system. The low, medium and high are linguistic levels of power input. For input parameter of power low range is 0 to 60, medium range is 30 to 130 & high range is 80 to 150 . For fuel cost low range is 0 to 50, medium range is 30 to 70 & high range is 60 to 100.

TABLE II. Linguistic Levels of Output Variables

Output Parameters	Optimized Power1	Optimized Power2	Optimized Power3
Optimized Power (in MW)	0-42	30-80	65-100

Table no.2 shows linguistic levels for output variables. Here, Optimizedpower1, optimizedpower2 and optimizedpower3 are linguistic levels. Optimized power1 computed from 0 to 42, optimized power 2 computed is 30 to 80 & optimized power 3 computed as 65 to 100.

4) Surface Viewer

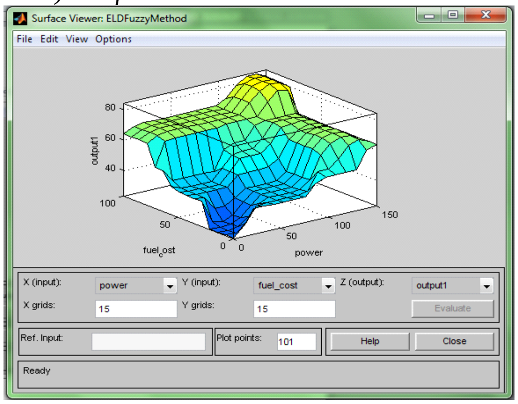

Fig. 5. Surface Viewer

Figure no.5 shows surface viewer is a GUI tool used for examine output surface of a FIS which is stored in a file for any inputs. It selects the two input variables to allot two input axes Y & X, this output value allotted to Z-axis. For a smoother plot creation, Plot point field is used to state number points so that membership functions calculated in input/output sort. Here, 101 is a default value which utilized to observe reliance of outputs for any input.Here, input axis shows as power & fuel cost & output axis as optimized power.

C. Results obtained for ELD using Genetic Algorithm infused with Fuzzy Logic

TABLE III. OPTIMAL RESULT OBTAINED USING GA

Pmin (PW)	Pmax (MW)	Power generated (MW)	Fuel cost (Rs)	Error (%)
50	150	50	772.5	0.1450
75	200	61.932	997.3	0.2131

TABLE IV. OPTIMAL RESULT OBTAINED USING FL

Pmi (MW)	Pmax (MW)	Power generated (MW)	Fuel cost (Rs)	Error (%)
50	150	69.24	779	0.105
75	200	81.321	1009	0.167

TABLE V. OPTIMAL RESULT OBTAINED USING FCGA

Pmin(M)	Pmax(MW)	Power generated (MW)	Fuel cost (Rs)	Error (%)
50	150	93.23	669.5	0.087
75	200	117.324	869.2	0.102

To acquire optimal solution for ELD system, comparison of all results done using minimum & maximum power limits. Here, generated power, cost of fuel & transmission errors compared to achieve optimal solution. For powers of 50 MW to 150 MW, following observations obtained:

1) In GA, generated power is 50 MW for a fuel cost of Rs.772.5 & an error of 0.14501.In FL method, generated power is 69.24 MW with a fuel cost of Rs.779 & an error of 0.10501. In FCGA method, generated power is 93.23 with a fuel cost of 669.5 & an error of 0.00871. By comparing three parameters (as shown in figures nos.6,7 & 8) it is found that FCGA method generates more power with less fuel rates & transmission errors as compared to GA & FL methods.

2) For minimum power of 75 MW & maximum power of 200 MW, by comparing values in figure nos.6,7 & 8, it is again found that FCGA methods generates more power with less cost & transmission errors as compared to GA & FL methods.

D. Comparisons of soft computing methods to obtain optimal solution for ELD system

Comparison of power generation, fuel cost & errors depicted in figures for three methods.

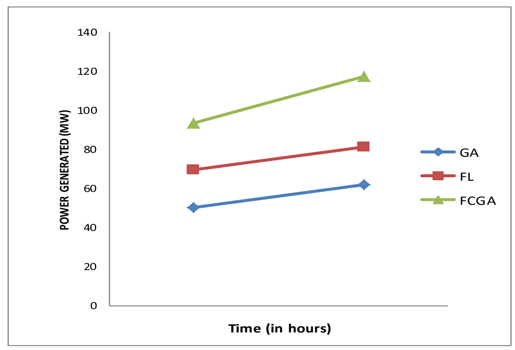

Fig. 6. Comparison of power generation

Figure shows that FCGA produces higher power levels as compared to FL & GA methods.

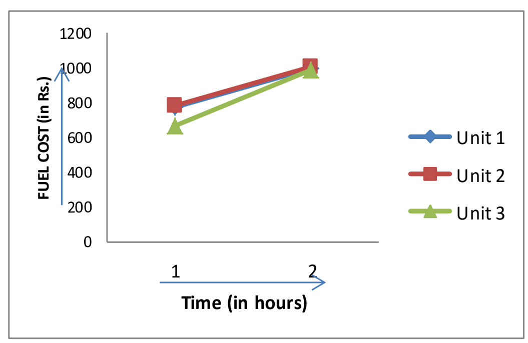

Fig. 7. Comparison of Fuel Costs

Fig.7. shows that FCGA has less fuel cost for power generation as compared to FL & GA methods.

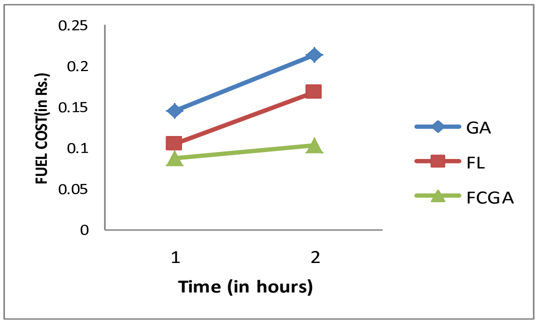

Fig. 8. Comparison of transmission errors

Figure no.8 shows, FCGA has less transmission errors for power generation as compared to FL & GA methods.

VI. CONCLUSION

Simulation results using GA, FL & GA infused fuzzy shows performance improvement between these algorithms. Results shows that GA infused fuzzy shows has better performance as compared to GA & FL techniques since FCGA considers average fitness, change in fitness, optimized crossover probability & optimized mutation probability variables.It observed that performance improvement of ELD increased as required minimum & maximum power ranges increased, resulting cost of power generation reduces with an increase of power generation using soft computing techniques. Transmission errors reduced to -0.0579 which is 39.93% less than GA method & -0.0179 which is 17.04% less as compared to FL method.So, performance improvement of ELD system is able to increase subsequently by reducing transmission error during generation of power. FCGA proved best for optimal solution of power generation with minimum cost & transmission errors as compared to GA & FL methods.

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