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Neuro Inspired Genetic Hybrid Algorithm for Active Power Dispatch Planning Problem in Small Scale System

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Abstract

Allocation of optimum active power is a backbone of power system generation planning and its high impact contribution is the need of current electrical utilities and power engineers need to browse this area in short and long term planning scenarios. Power demand requirements mapped to economic feasible solutions matching voltage profile, power demand, minimization of losses, voltage stability and improve the capacity of the system is the need of the hour. Modern techniques based on evolutionary computing, artificial intelligence, search method find their objectives in the area of economic load dispatch planning to reach global optimal solution for this multi-decision, multi-objective combinatorial problem subjected to different constraints. Many algorithms suffer from global convergence problem. To vanish this drawback, neuro inspired genetic hybrid algorithm (NIGHA) has been proposed in this paper to solve economic dispatch problem. Unlike other algorithms, NIGHA utilizes the weights of Neural Network to explore information and knowledge to train GA parameters to search for feasible region where optimal global solution converges. The suggested technique is tested on IEEE 25 bus system. Test results are compared with other techniques presented in literature. Proposed technique has outperformed other methods in terms of cost, computation time.

Keywords: *Neuro Inspired Genetic Hybrid Algorithm(NIGHA) Genetic Algorithm(GA),Economic Dispatch (ED), Neural Network(NN)*

1. Introduction

The economic dispatch (ED) problem is one of the most important areas of today's power system. The purpose of the ED is to find the optimum generation among the existing units, such that the total generation cost is minimized while simultaneously satisfying the power balance equations and various other constraints in the system. Below are the suggested techniques in the literature -

Amudha A. *et al.*, [1] solved unit commitment problem using worst fit algorithm considering the effect of reserve on profit basis. Bavafa M. *et al.*, [2] implemented a hybrid approach based on lagrange algorithm with evolutionary and quadratic programming for short thermal unit commitment considering ramp rate constraint. Catalao J.S. *et al.*, [3] proposed a profit based unit commitment with constraints of emission limitation. A trade off has been done between profit and emission in order to assist decision makers. Chang G.W. *et al.*, [4] proposed a mixed integer linear programming method for unit commitment optimization. This approach is suitable for both traditional and deregulated environment. Christober C. *et al.*, [5] coined an algorithm based on genetic algorithm to minimize the total operating cost.It uses standard reproduction, cross over and mutation operators for the optimization. Christober C. *et al.*,

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[6] proposed a neural network based tabu search for unit commitment optimization which is more efficient than conventional tabu search. Christober C. et al[7] presented approach based on evolutionary programming simulated annealing method considering cooling and banking constraints for cost minimization. Fei L. and Jinghua L.[8] designed algorithm based on local search which combines interior search method for large power system. Ganguly D. et al[9] proposed a new genetic approach based on parallel system to handle impossible solution in an organized fashion for thermal unit commitment. Barquin J.[10] proposed an algorithm for self unit commitment for day ahead market based on simple bids . Iguchi M. and Yamashiro S.[11] implemented an efficient scheduling method for hydro-thermal units considering the account of transmission network. It consists of different stages and constraints are relaxed at every stage and transmission losses are calculated at every stage. Im T.S and Ongsakul W.[12] implemented an Ant colony search algorithm based on new co-operative agent approach for economic dispatch and unit commitment. Jenkins L.[13] implemented four hybrid algorithms based on simulated annealing, local search, tabu search, dynamic programming and genetic algorithms and compared the cost with earlier literature .Klir J. et al[14] presented different fuzzy techniques for optimization. Gonzalez J.G and Kuan E. et al[15] implemented an algorithm for unit commitment optimization considering the complete network modeling and bender method is employed to decompose the problem into integer and continuous variables. Larsen T.J. et al[16] developed a model based on sequential time step. It decomposes the problem at every time step and is solved by free marked model. Liang R.H. and Kang F.C.[17] proposed an extended mean field annealing neural network approach to solve short term unit commitment problem which is tested on Taiwan power system. Liao G.C. and Tsao T.P.[18] introduced hybrid algorithm based on fuzzy logic, tabu search and genetic algorithm to solve short term unit commitment results in reduction in computation time. Liao G.C. and Tsao T.P. [19] implemented an algorithm based on genetic algorithm and Meta Heuristic method for unit commitment problem.It includes genetic algorithm, fuzzy logic and simulated annealing to determine shutdown and startup schedule. Maojun L. and Tiaosheng T. [20] proposed a modified genetic algorithm with three genetic operators called Gene Complementary Genetic Algorithm. Momoh J.A. and Zhang Y.[21] proposed a unit commitment method based on adaptive dynamic programming algorithm. Nagrath and Kothari [22] presented different aspects of power system analysis. Norhamim et al[23] presented a approach for cost minimization based on unit commitment and economic dispatch in large scale power system and comparison has been done with lagrange algorithm. Senjyu Pappala V.S. and Erlich I.[24] proposed a new approach based on adaptive particle swarm optimization. It results in reduction in no. of decision variables . Park J.D. et al[25] proposed an algorithm based on the effect of economic dispatch and consideration of ramp constraints. It reduces the generation level of less efficient units by committing additional units or by economic dispatch. J.D. et al[26] did the stochastic analysis based on uneven load demand on hour basis with the consideration of hit rate of units. Raglend I.J. et al[27] proposed an algorithm including operational, power flow and environmental constraints to plan secure and economic generation schedule. Rampriya B. et al[28] proposed a method in deregulated power system based on lagrangian firefly algorithm for profit based unit commitment. Saber A.Y. et al[29] introduced algorithm based on fuzzy adaptive particle swarm optimization approach. It tracks continuously changing solutions. Sadati N. et al[30] proposed a technique based on particle swarm fusion with simulated annealing for unit commitment optimization. It performs two functions unit schedule and economic dispatch. Seifi H.[31] presented different issues in power system planning. Senjyu T. et al[32] implemented an algorithm based on genetic algorithm for large scale unit commitment with the consideration of new genetic operator and unit integration technique. Senjyu T. et al[33] presented a genetic algorithm based on unit characteristics classification. Numerical results for system of up to 100 units are compared to previously

reported results. Simopoulos D.N et al[34] implemented an enhanced simulated annealing algorithm for unit commitment problem combined with dynamic economic dispatch. Sriyanyong P. and Song Y.H.[35] proposed a hybrid algorithm based on Particle Swarm Optimization and Lagrange and performed on various 4 and 10 unit systems. Vasan H.P[36] presented hopefield neural network approach for unit commitment and economic dispatch problem. Wang B. et al[37] implemented algorithm for rescheduling of units in fuzzy logic. They proposed a heuristic algorithm called local convergence averse binary particle swarm optimization to solve the unit commitment problem. Wang M. et al[38] proposed a technique considering various constraints for the optimization of unit commitment. It uses the combination of dynamic programming with economic dispatch and comparison with lagrange algorithm has been done.Woods and Woolenberg[39] shared different scenarios of operation and control of power system. Zheng H. and Gou B.[40] designed new algorithm based on ON-OFF unit schedule by using lagrange algorithm which is superior than dynamic programming.Zhu[41] presented different optimization methods of power system. Navpreet Singh Tung et al[42,43,44,45] introduced various unit commitment aspects like pattern search, differential evolution to solve dispatch problem. Hamid Boujeboudja[46] proposed real coded genetic algorithm for unit commitment problem.

2. Problem Formulation

The ED problem[45,46,47] may be expressed by minimizing the fuel cost of generator units under constraints. Depending on load variations, the output of generators has to be changed to meet the balance between loads and generation of a power system. The power system model consists of n generating units already connected to the system.

The ED problem can be expressed as.

2.1**. Fuel Cost Model**

$C(P_{Gi})=\Sigma(a_i*P_{Gi}^2+ b_i*P_{Gi} +c_i)$Rs where i=1…..N

2.2 **Constraints**

- $\Sigma P_{Gi}-P_D-P_L=0$
- $P_{Gi,min}\leq P_{Gi}\leq P_{Gi,max}$ where i=1,2……N

2.3**Minimization**

Total Operating Cost=C

2**.4Transmission Losses**

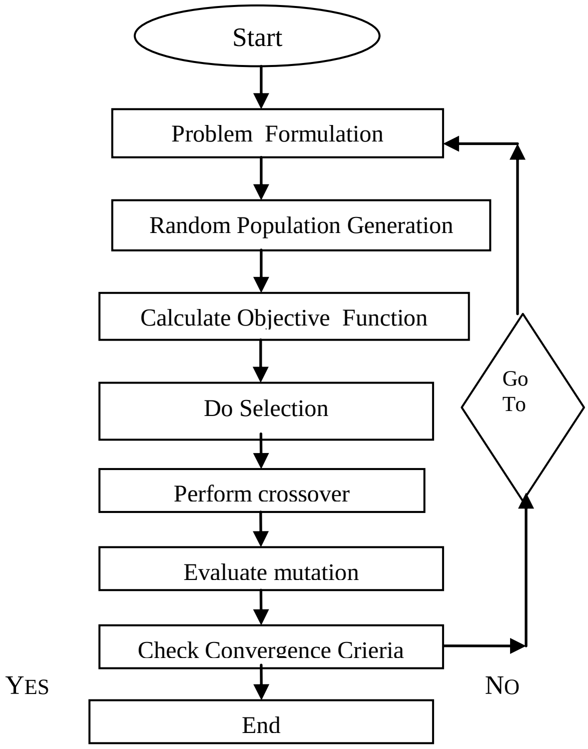
$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N} P_{Gi}B_{ij}P_{Gj} + \sum_{i=1}^{N} B_{0i}P_{Gi} + B_{00}$$

3. Proposed Technique

3.1. Genetic Algorithm

Genetic Algorithm (GA)[48] is a search directed algorithm inspired by survival of the fittest among string structures to form a search algorithm. For reliable solution of optimization problems, GA has been investigated robustly and proved to be effective at exploring a complex space in an adaptive way, directed by the biological evolution mechanisms of reproduction, crossover and mutataion.GA executes the search process in multiple phases: Initialization, Selection, Crossover and Mutation. GA serves as search optimization technique for adaptation of network weights. It is applied to upgrade the performance of ANN i.e. to check the connection weight in the form of binary or real number. It is also applicable for topology selection, training of network, determining the number of nodes in each layer, evolution of connection weights, evolution of learning rule etc. GA does not offer constraint with scaling as back propagation. The reason is that they generally improve the current best candidate monotonically. They perform this by keeping the current best individual as part of their population while they search for better candidates. GA generally does not bothered by local minima. The mutation and crossover operators can step from a peak across a hill to an even lower peak with no more difficulty than jump directly into a peak.

3.2. Flow Chart of GA



3.3. Artificial Neural Network

ANN, [48, 49] often called a artificial neural network, is a mathematical model inspired by biological neural networks. The motivation for the development of neural network technology originated from the zeal to implement an artificial system that could perform intelligent function intersect to those performed by the human brain. It is a powerful data modeling tool that is able to store and show complex input output relationships. In most cases a neural network is an adaptive system, between inputs and outputs, to find patterns in data. Neural network copy the human brain in the following two ways:

1) A neural network acquires its knowledge through learning.

2) A neural network's knowledge is stored within interneuron connection strengths known as synaptic weights. A neural network comprises of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. An ANN is composed [48, 49] of *neurons* that are processing elements in a network. Each neuron gets input data, processes it and gives a single output. The input data can be raw data or output of other processing elements. The output can be the output or it can be an input to another neuron. An ANN is formed by nodes engaged together. Nodes with similar characteristics are arranged into layer. A layer can be seen as a group of nodes which have connections to other layers, or to external environment, but which have no interconnections. There are basically three types of layers. The first layer connecting to the input variables is called input layer. The last layer connecting to the output variables is called the output layer. It is straightforward to extend to multiple nodes. Layers between the input and output layers are called hidden layers. Information is transmitted through the

connections between nodes. This type of network is called feed forward network, or multilayer feed forward network. Layered Feed forward networks have been explored lot. First they have been used to generalize well. Secondly, a training algorithm called back propagation happen which can often find a good set of weights (and biases) in a reasonable amount of tune. Back propagation is a variation on gradient search. It generally exploits a least square criterion.

3.4. NIGHA

NIGHA, a neuro inspired genetic algorithm is proposed for active power dispatch planning problem. The factors influencing NIGHA evolution are genetic operators, fitness function and stopping criteria. The genetic operators namely; two–point crossover and uniform mutation are applied. The fitness function of NIGHA is chosen to be minimization of cost. Convergence of the network is ensured and computation is halted when the objective variation in iterations is within tolerance. Primarily in GA, a set of initial encoded schedules known as chromosomes is randomly created. Each schedule is valuated for "fitness". Then, processes based on natural selection, crossover, and mutation are repeatedly applied on a population of binary strings which represent potential solutions. Over time, the number of above–average individuals increases and better–fit individuals are created, until a good solution to the problem at hand is found [49].

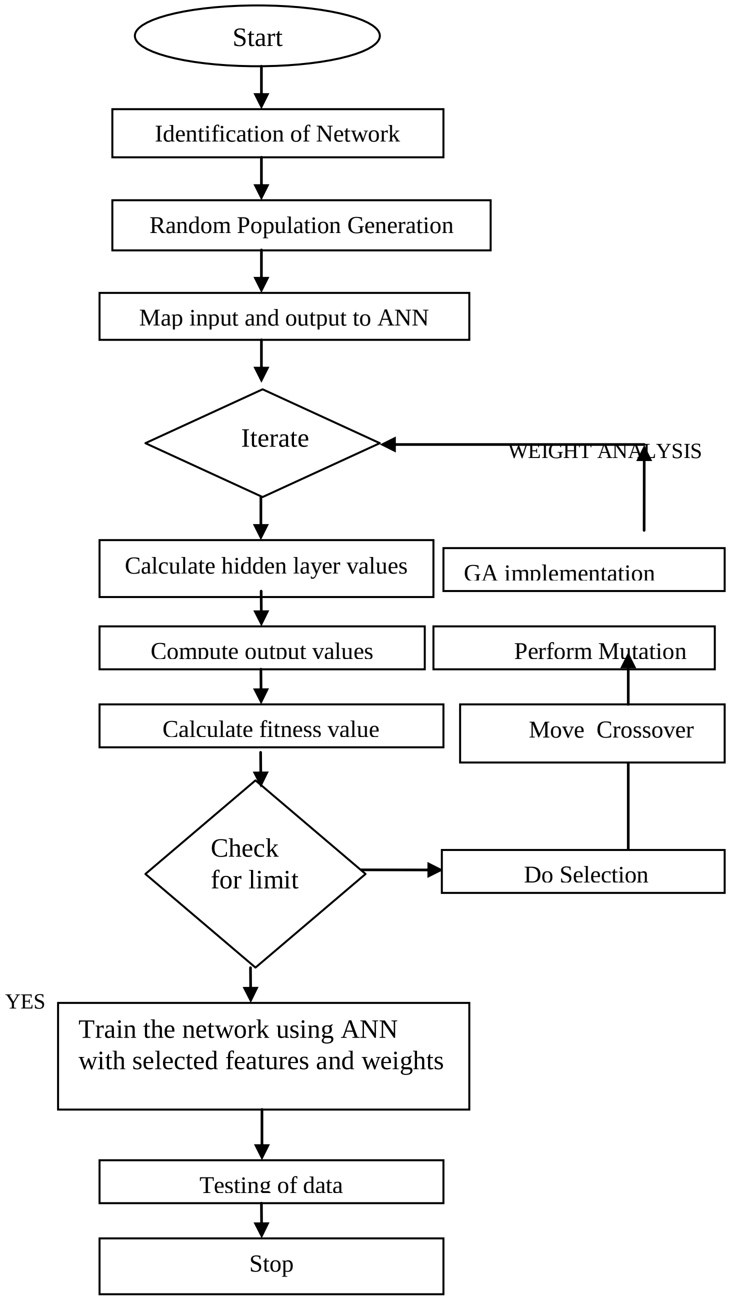
3.4.1. Algorithm

1. Initialize the weights and bias of network
2. Create input and target vectors to suit the network
3. Map chromosomes from the population to the network
4. Run and simulate network
5. Test the fitness function
6. Increase the number of hidden neurons and repeat the process, until minimum objective function value achieved
7. Do three point crossover on the population to exchange information between parents
8. Get the best population, choose parent and mutate
9. Stop if the condition is satisfied

3.4.2 Pseudo code of NIGHA

{
Initialize i ← 0; j ← 0(iteration);
Generate the initial population P_i of the real-coded chromosomes $C_{\mathbf{i}}$;
$W_{\mathbf{j}}$ - representing a weight set for the NIGHA;
While (condition-the current population P_i is not converged)
{
Generate fitness values $F_{\mathbf{i}}$ for each $\mathbf{C_i}$ using the Algorithm NIGHA ( );
Fetch the mating pool ready by terminating worst fit individuals and duplicating high fit individuals;
Using the cross over to reproduce offspring from the parent chromosomes;
i ← i +1;increment counter
Invoke the current population P_i;
Calculate objective function values $F_{\mathbf{i}}$ for each C**i**
}

3.4.3. Flow Chart of NIGHA



4. Active Power Dispatch using NIGHA

- Variables

Power Generation (PG) and cost coefficients (a,b,c) of units with objective function as fuel cost, quadratic in nature. Power Generation variable should be initialized as starting point for initial solution in ant bee colony algorithm.

- Constraints

Equality Constraints: Power Generation-Power Demand-Power losses=0(P_G-P_d-P_L)

In-Equality Constraints: Power Generation should be between minimum and maximum limit of power generation.
Variables in constraints should be incorporated in pattern search algorithm.

➢ Stopping Criteria

It is maximum generation limit for optimum solution.

5. Simulation Results

This proposed approach is tested on IEEE 25 bus system [44, 45, 46]. Simulation results are achieved and compared with other techniques presented in literature. In table 1 and Table 2, total cost and computational time has been evaluated using NIGHA. Optimal active power generation on IEEE 25 bus system have been presented .Comparison with other techniques like differential evolution, pattern search, real and binary coded genetic algorithm have been carried out. In Table 3, parameter setup used in NIGHA have been stored. Performance evaluation of NIGHA on training, test data has been carried out.

Table 1. Power Generation, Total Cost and Computational Time using NIGHA

PG1 (MW)	PG2 (MW)	PG3 (MW)	PG4 (MW)	PG5 (MW)	Cost ($/hr)	Time (Sec)
268.3668	123.2338	141.4179	27.4627	224.7512	1921.4	1.1

Table 2. Results Comparison with other Techniques [44,45, 46]

Parameters	NIGHA	DE	PS	RCGAs	BCGAs	BFGS
PG1 (MW)	268.3668	212.244 1	212.244	213.68	206.72	211.30
PG2 (MW)	123.2338	122.78 87	122.789	127.46	121.64	126.30
PG3 (MW)	141.4179	140.305 2	140.305	141.93	151.82	151.29
PG4 (MW)	27.4627	27.2958	27.296	29.53	33.21	71.24
PG5 (MW)	224.7512	268.366 2	268.366	258.86	258.05	211.31
Cost ($/hr)	1921.4	2009.3145	2009.312	2010.8	2011.0	2029.3
Time (Sec)	1.1	7	1.2	1.6	4.78	0.0

Table 3. Performance Evaluation on Test and Test Data

Dataset	Training	Test	Val	Actual	Iterations	Population
Performance	1.6357	1.6352	1.6201	1.6333	220	60

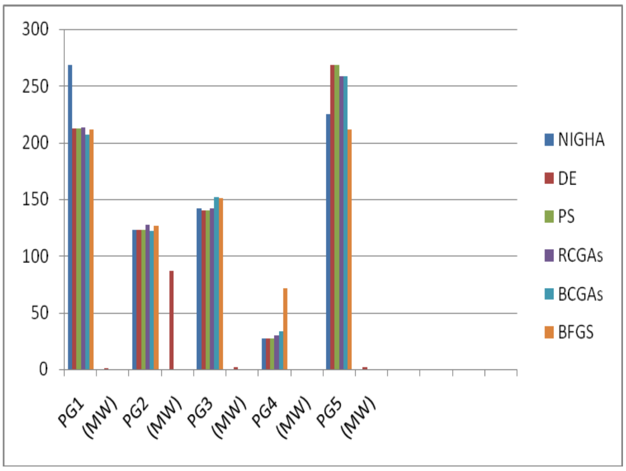


Figure 1. Power Generation Comparison

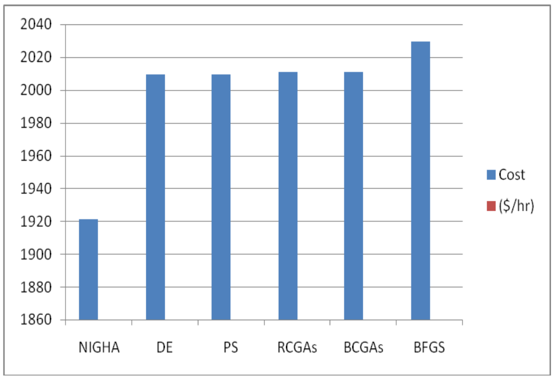


Figure 2. Comparison of Total Operating Cost

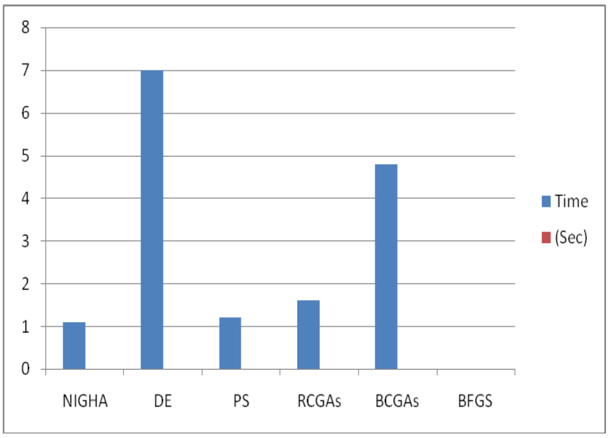


Figure 3. Comparison of CPU Computation Time

In Figure 1, Figure 2 and Figure 3 Variation of operating cost, computation time and power generation using NIGHA and other techniques pattern search, differential evolution, genetic algorithms have been shown.

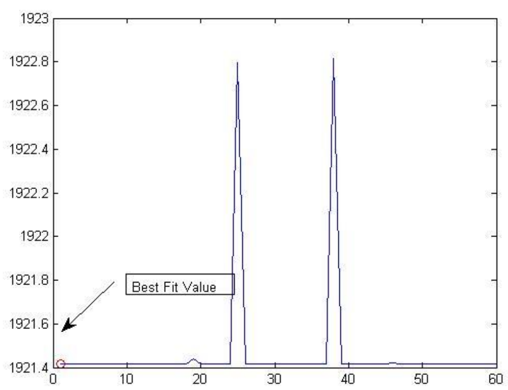


Figure 4. Best fitness Value with Generation

In Figure 4, Search convergence of NIGHA for best solution in feasible region have been presented. Among different global and local values, it achieves its global minima.

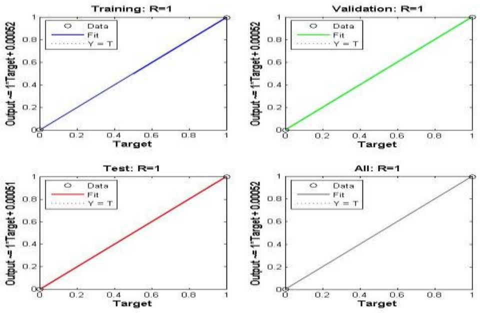


Figure 5. Regression Analysis

In Figure 4 Regression Analysis of training, test and validation phase of data using NIGHA. Fitness level in terms of regression have been linear for curve fit data.

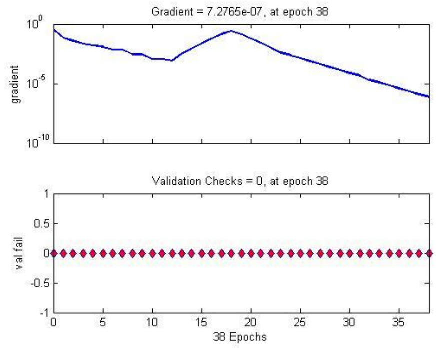


Figure 6. Gradient Analysis

In Figure 6 variation of solution gradients of network with epochs are reflected. Best Gradient at epoch 38 is achieved.

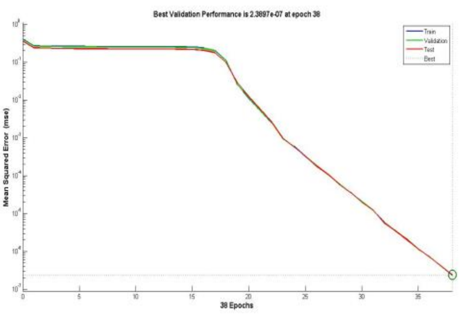


Figure 7. Mean Square Error

In Figure 7.Reduction of error with increasing epoch in NIGHA.MSE converges to minimum value at epoch 18.

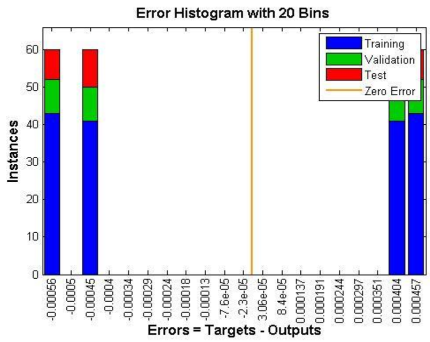


Figure 8. Histogram

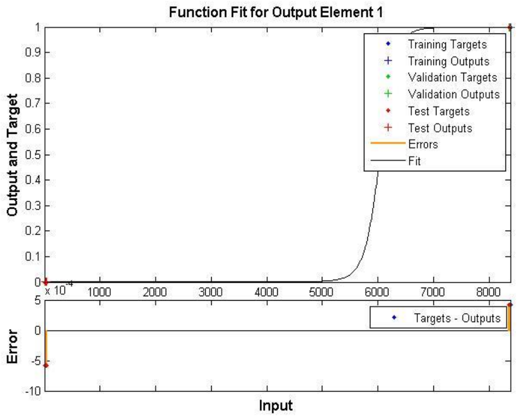


Figure 9. Fitness
Set of error analysis for training, test and validation data.

In Figure 8 and Figure 9, histogram representation of errors(20 bins) and error analysis of training, test and valid data is delivered.

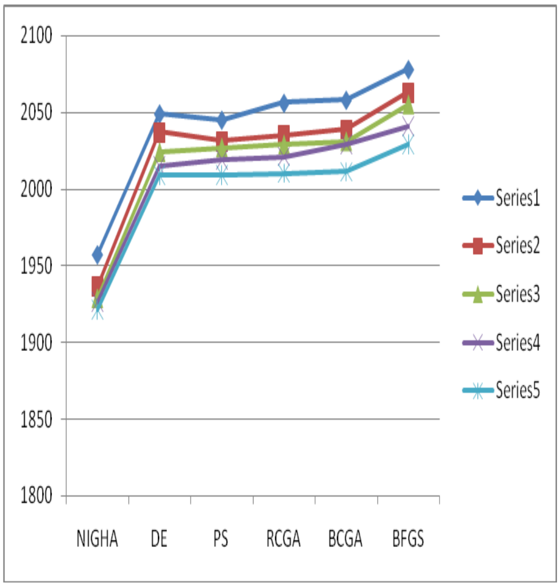


Figure 10. Solution Analysis with Iterations using Different Algorithms

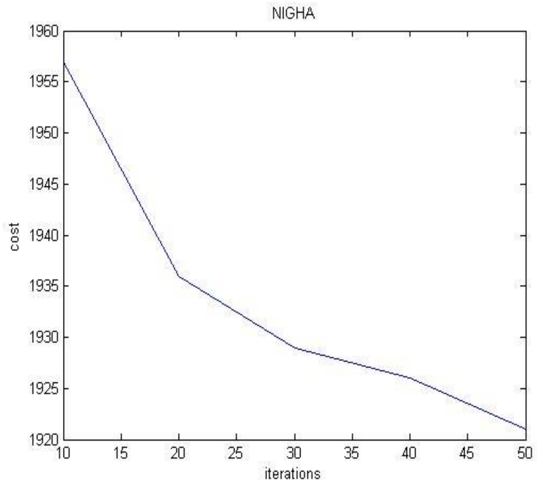


Figure 11.Convergence Solution Analysis with Iterations of NIGHA

In Figure 10 and Figure 11 solution convergences analysis using NIGHA with iteration and comparison with other techniques have been incorporated.

6. Conclusion

An application of soft computing techniques in economic load dispatch planning optimization has been inherently evolving for last few decades. Different evolutionary and intelligent computation methods whether stand alone or hybrid in nature have been developed and successfully applied to economic load dispatch area. In the current research, an application of NIGHA has been applied successfully for economic active power dispatch problem. Proposed technique is tested on IEEE 25 bus system. Test results reveal the minimum operating cost, optimum power generation and high speed convergence of solution. A comparison has been made other techniques presented in literature. It out-performs other techniques presented in literature in terms of computation speed, fuel cost and power generation. Hence, NIGHA algorithm is more robust and lead to optimal solution in economic active power dispatch problem.

7. Future Scope

Upcoming research involves the expansion of NIGHA lead to the formulation and development of hybrid algorithm based on simulated annealing to polish the best solution search capacity of the proposed technique as well as fast convergence for optimal solution with incorporation of practical constraints.

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NOMENCLATURE

N	Number of units
P_D	Power Demand
P_{Gmax}	Maximum limit of Unit
P_{Gmin}	Minimum Limit of Unit
P_G	Power Generation
C	Total Cost
P_L	Power Losses
a,b,c	Cost Coefficients
B	Loss Coefficients

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