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Application of Artificial Immune System for Power Generation Optimization

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ABSTRACT

This paper presents application of artificial immune system for economic dispatch problem of thermal plants. Numerical results of various test systems have been presented to demonstrate the performance of the proposed algorithm. In human body the immune system finds virus or bacteria and destroys it. Similarly this technique works. The results achieved from the proposed algorithm are compared with those obtained from differential evolution, particle swarm optimization, PSO Crazy, and GA technique. An artificial immune system is a search technique used in computing to find true or approximate solution to optimization and search problems.

Introduction

The system consisting of generating stations, transmission system and distribution system which provide continuous & reliable electrical energy is called power system. Power generation optimizations provide the information about exact loading of generators having different fixed & variable cost. The study and analysis of power system is a great concern for today's world due to increasing complexities and size of power system all over the world. A power system engineer should always concern in adapting better mathematical models for solving system problem more efficiently and effectively. Optimal operation of the generators on a bus bar is one such problem, which is vital for all power system. Power system optimization in power system generally shows the problem of economics which is the cost of generating real power. The purpose of economic operation of power system is to reduce fuel cost for the operation of the power system. Economic operation is achieved when the generators in a system share load to minimize overall generation cost [1].

When some optimization concept like tournament selection, crossover, mutation and employing with immune system concept then new concept generates that is called AIS Concept [2]. Various mathematical methods and optimization techniques have been employed to solve for ED problems. Among the conventional methods that were previously used include lambda iteration method, base point and participation method and the gradient method [3]. These numerical methods assumed the incremental cost curves of the generating units are monotonically increasing piecewise linear functions. However, this assumption may cause these methods to be infeasible because of the nonlinear characteristics of the actual systems. Dynamic programming (DP) method was implemented for solving the ED problem. Nevertheless, the DP method may cause the dimensions of the ED problem becomes extremely large, hence requires massive computational effort. In the past decade, global optimization techniques such as simulated annealing (SA), genetic algorithms (GAs) and evolutionary programming (EP) have been increasingly used to solve for power system optimization problems [4]. The SA method is an optimization technique that employs probabilistic approach in accepting candidate solutions in the search process so that it can jump out from the local optimal solutions to approach the near global solution [5]. SA based algorithm has slow speed when applied to real power system problems [6].

GAs have long execution time and non-guaranteed in convergence to the global optimal solution contribute the main disadvantages of GAs [7]. Similarly, evolutionary programming optimization technique long execution time posed its main disadvantage [8]. Artificial immune systems can be defined as metaphorical systems grow using facts, theories and components, extracted from the natural immune system [9].

The natural immune system is a very complex system with several mechanisms for defence against pathogenic organisms. The main purpose of the immune system is to recognize all cells within the body and categories those cells as either self or non self. The immune system learns through evolution to distinguish between dangerous foreign antigens and the body's own cells or molecule.

From an information-processing perspective, the immune system is a remarkable parallel and distributed adaptive system. It uses learning, memory and associative retrieval to solve recognition, classification and optimization tasks [10]. A few computational models have been developed based on several principles of the immune system such as immune network model, negative selection algorithm, positive selection algorithm and clonal selection principle [11, 12]. It is an extraordinarily complex system that relies on an elaborate and dynamic communications network that exists among the many different kinds of immune system cells that patrol the body. At the heart of the system is the ability to recognize and respond to substances called antigens whether they are infectious agents or part of the body (self-antigens). In this paper, ELD problem is solved which is based on the clone optimization technique. The developed AIS adopted the Clonal Selection algorithm in determining the optimal active power to be generated by the generating units in a power generation system. The total generation cost is taken to be the affinity measure for the clone optimization-based ED problem. Individual with lower total generation cost is considered to have higher affinity. The aim of the clonal operator is to produce a variation in the population

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around the parents according the affinity [13]. Hence, the searching area is enlarged and therefore the problem can be solved better, avoiding premature convergence. Several loading scenarios on a practical system having 3,6 generating units with a number of inequality and equality constraints were investigated in order to demonstrate the robustness and feasibility of the proposed technique The results obtained from the proposed technique were also compared with those obtained from the GA, PSO, PSO Crazy in order to assess for the solution quality and computational efficiency.

2. Economic load Dispatch Mathematical Formulation:- The main economic factor in power system operation is the cost of generating real power in any power system this cost has got three components

1. Fixed Cost
2. Semi fixed Cost
3. Running Cost

The economic dispatch problem (EDP) is to determine the optimal combination of power outputs of all generating units to minimize the total fuel cost while satisfying the load demand and operational constraints. It plays an important role in operation planning and control of modern power systems. Under a Recent deregulated electricity engineering, Industry, power utilities try to achieve high operating efficiency to produce economical electricity. Therefore, precise generation costs analysis required [14].Solving the Economic Dispatch optimization problem with an objective to minimize the total cost of generation. The total generation cost to be minimized and therefore The Objective function of the problem is defined as:

$$F_T = \sum_{i=1}^{n} F_i(P_i) \quad (1)$$

$$F_i(P_i) = \alpha_i P_i^2 + \beta_i P_i + \gamma_i \quad (2)$$

$\alpha_i P_i^2$ =Running Cost

$\beta_i P_i$ = Semi Fixed cost

γ_i = Fixed Cost

Where α_i, β_i, γ_i are constraints/ Constants on the input output curve of a generating unit. The input–output curve of a unit can be expressed in million kilowatts per hour or directly in term of Dollar per hour versus output in megawatts. A typical curve is shown in fig1.

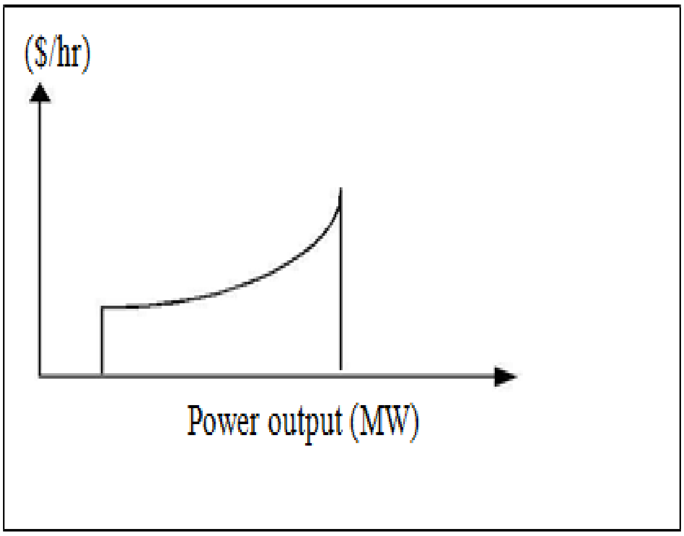

Fig1. Input-output cost curve of generator

Curve between IC (Incremental fuel cost) and Total Power Given at the end of the manuscript in fig 2

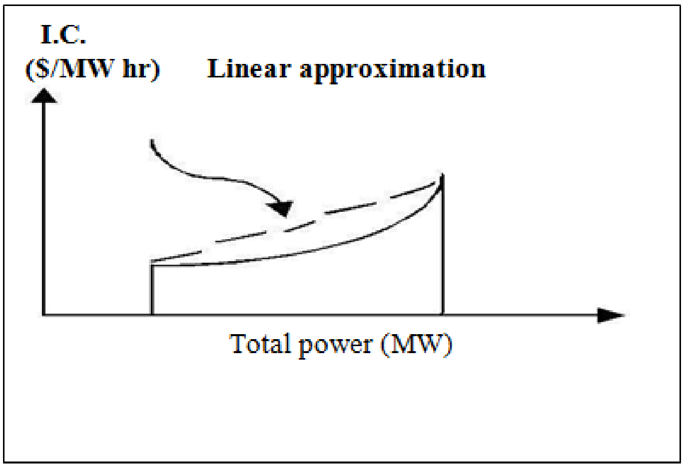

Fig 2. Incremental cost curve

The power balance equation, where the losses are neglected will be as given in equation (3) below, where, P_D is the total load demand [2].

$$P_1 + P_2 + P_3 + \cdots \ldots \ldots + P_N = P_D \quad (3)$$

$$P_{imin} \le P_i \le P_{imax} \quad (4)$$

$P_{i\,Min}$ = Lower limit of power generated by i[th] unit.

$P_{i\,Max}$ = Upper limit of power generated by i[th] unit.

N=Number of generators in power generation system.

3. What is Immune System? An immune system is a system of biological structures and processes within an organism that protects against disease by identifying and killing pathogens and infected cells. It detects a wide variety of agents, from viruses to bloodsucking worms, and needs to differentiate them from the organism's own healthy cells and tissues in order to function properly. In a simple manner, it recognizes all the body's own cells within the body as the self-cells and the foreign disease causing elements or the antigens as the non-self-cells.

The non-self-cells are further categorized in order to activate the suitable defence mechanism and it is unique with respect to a particular antigen. At the same time, the immune system also developed a memory to enable more efficient responses in case of further infection by the similar antigen. The process taken place in the immune system can be looked as a distributed task force that has the intelligence to take action from a local and global perspective using a network of chemical messengers for communication [12].

Biological Immune system overview

In our atmosphere Viruses, bacteria and other germs are all around us. Most of the time, a healthy immune system keeps us fine.

A. **Virus:-***Viruses* are a simple form of life a few genes wrapped in a protective shell. These genes are the instructions for making new viruses. Outside a cell, a virus can't reproduce itself; but once a virus attacks a living cell, it turns that cell into a virus factory. In time, thousands of new viruses burst out and go on to invade other cells. Clonal selection theory explains how the immune system fights against an antigen. It establishes the idea that only those cells which recognize the antigen, are selected to proliferate. The selected cells are subjected to an affinity maturation process which improves their affinity to the selected antigens.

Lines of Defence:-Mainly three types of line of defence described in fig 3.

(i) First lines of defence are the physical barriers which include the skin, urine, tears, mucosal membrane, etc.

Second lines of defence are the macrophage system, complement, fever, interferon and inflammation.
Third lines of defence are the specific system also known as acquired or adaptive immunity. The specific system Contain T cells and B cells

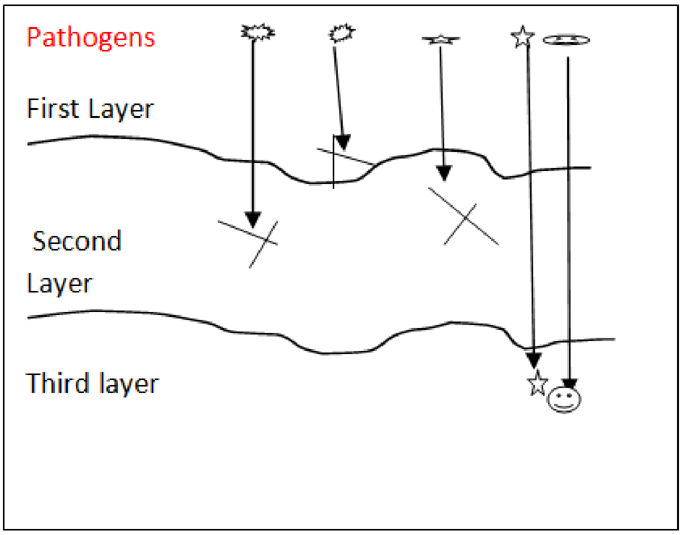

Fig 3. Multilayer defence system

The properties of biological immunes

(i) Ability to produce diversified antibodies. This property can maintain individual variety in evolutionary process of the artificial immunization algorithm, thus develop the global search capability of the algorithm, and avoid falling into local optimum.
(ii) Self-regulation. The balance mechanism in biological immune system can automatically regulate the production of antibodies by inhibition or promotion, so that it can produce necessary and Suitable antibodies. This property corresponds to the inhibition or promotion of antibody concentration in the AIS, which improve the local search capability of the algorithm.
(iii) Immune memory. Some cells that have produced some certain antibodies are preserved as memory cells. If the same antigens relevant to those antibodies are encountered after that, the relevant memory cells shall be rapidly stimulated to produce a great quantity of the same antibodies. With this property of memory and identification of the antigen in the algorithm, searching pace can be facilitate and global search capability can be raised in fig 4 [15].

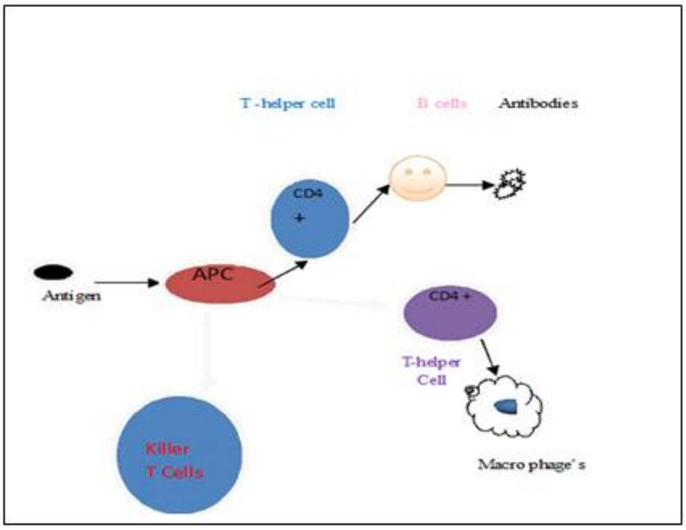

Fig 4. Production of B and T cells

T cells do not secrete antibodies but play a central role in the regulation of the B cell response and are the most excellent in cell mediated immune responses. Lymphocytes, additionally the plasma cells accelerated, can differentiate into long-lived B memory cells.

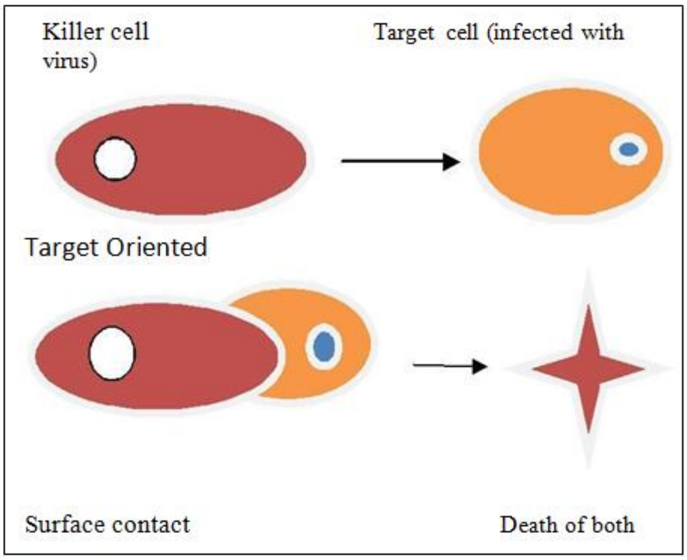

Fig 5. Reaction of Infected cells and Virus

In fig 5 these memory cells circulate through the blood, lymph and tissues, so that when exposed to a second antigenic stimulus, they commence to differentiate into plasma cells capable of producing high affinity antibody, preselected for the particular antigen that had stimulated the primary response [2].

5.Artificial immune system overview:-

Artificial Immune Systems (AIS) are adaptive systems, motivated by theoretical immunology and observed immune functions, principles and models, which are applied to problem solving.
After all, the field of AIS is not concerned with the investigation of the immune system as a substrate computation, such as DNA computing.
Artificial Immune Systems (AIS) are composed of the following basic elements:

A. A representation for the components of the system
B. A set of mechanisms to evaluate the interaction of individuals with each other and their environment as well. Such an environment is usually simulated through an affinity function, which is based on the objective function in the case of optimization problems.
C. Procedures of adaptation, that indicates the way in which the behaviour of the system changes over time. These procedures of adaptation consist of mutation operators.

Clonal Selection Algorithm

In the Clonal Selection Algorithm, only those cells that recognized the specific antigens would be selected to produce offspring and thus go through the process of affinity maturation. In the selection stage, B cells with high similarity with respect to an antigen i.e. recognized the antigen; are activated and stimulated to proliferate producing a large number of clones. In the maturation process, these clones mutate and turn into plasma cells hitch then that secrete large number of antibodies. Some of the B cells clones maturate into memory cells that have the memory of the antigenic pattern for future infections. The antibodies secreted from the second response would have higher affinity than those of the earlier response. In the computational point of view, this strategy suggests that the process perform a greedy search, where the individual will be locally optimized and the newcomers would yield a broader exploration of the search space. This characteristics makes the clonal selection algorithm is suitable for solving multi-modal optimization problems. In fig 6 clonal selection algorithm is implemented for solving optimization problem, a few adaptations have to be made as follows[12].

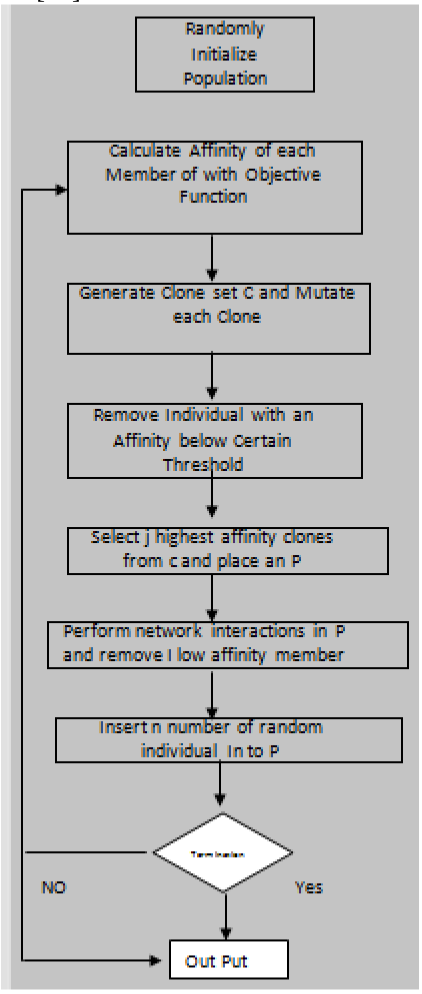

Fig 6. Flow chart of Clonal Selection Algorithms

Implementation of Clone Optimization Technique for Solving Economic Dispatch Problem

The developed clone optimization technique using Clonal Selection algorithm was implemented to solve the economic dispatch problem on a practical system having 3, 6 generating units. Real number was used to represent the attributes of the antibodies. The clonal selection was implemented according to the following procedures [16].

A. Initial population is formed by a set of randomly generated real numbers.

Antibodies AB, i= 1………………… n is Generated. We will set generator counter is set to G=1.

Each antibody was tested for any constraint violation using equations (3) and (4). only antibodies that satisfy the constraint are included in the population set.

B. The similarity (Affinity) value of each antibody in the population set is evaluated using equation (1).

Affinity $A_f = \sqrt{\sum_{i=1}^{L}(AB_i - AG_i)}$

AB = Antibody, AG= Antigen

C. Clone the individuals in the population, giving rise to a temporary population of clones.

The number of clone = [1- f_i /{$\sum_{i=1}^{i=20} f_i$}]*200

f_i = fitness function

$\sum f_i$ = sum of fitness in population

D. The population of clones undergoes maturation process through genetic operation i.e. mutation. The fitness of the mutated clones are evaluated.

E. A new population of the same size as the initial population is selected from the mutated clones based on their affinity.

F. The new population will undergo the same process as stated in steps (i)-(v)

G. The process is repeated until the solution converged to an optimum value.

As other optimization technique, several parameters have to be determined before its implementation such as the population size and number of clones generated by each antibody (for fixed clones' size). Based on the simulation results, the following parameters are found to be suitable: 20 members in a population pool and the number of proliferated clones is 10 for standard cloning. The equation for adaptive cloning process was developed based on the fittest antibody will produce more clones compared to weaker ones.

8. Results of numerical simulation:-The generator operating limits and quadratic cost function coefficients for the 3 and 6 generators in the test system are as in reference [7].

Test System I: Three unit system:- This system is taken from [17]. It has three generating units. The algorithm is applied for total load of 800MW. Transmission Losses are neglected while minimizing a quadratic cost function given by eq. (2) subject to constrains given by (3) and (4). The Table 1 presents the results for different values of load demand. Fig7 shows cost curve and fig 8 shows best fitness curve.

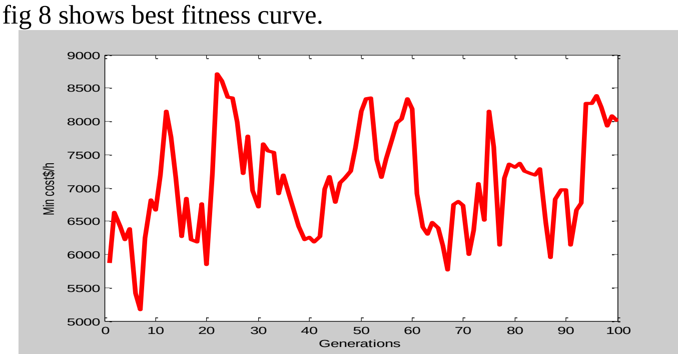

Fig 7 . Cost Curve of 800 MW Demand by Clone Optimization Technique

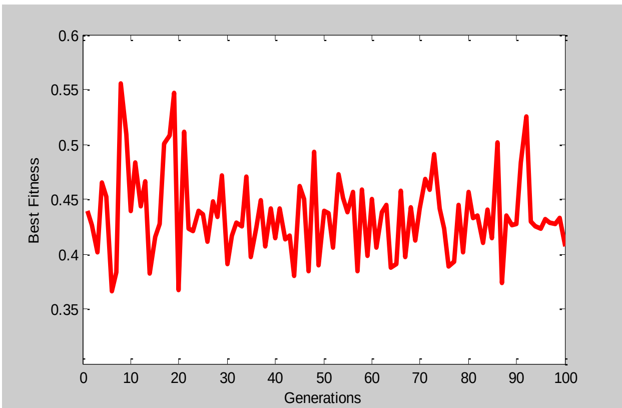

Fig 8. Best fitness curve of 800 MW demand by clone optimization technique

Test System II: Six unit system:- This system is taken from [18]

Its having six generating units. The algorithm is applied for total load of 800MW. Transmission Losses are neglected while minimizing a quadratic cost function given by eq. (2) subject to constrains given by (3) and (4). The Table2 presents the results for different values of load demand.

Table 1. Generator Operating Limits AND Quadratic Cost Function Coefficients

Load (MW)	P1 (MW)	P2 (MW)	P3 (MW)	Cost ($/h)	Power balance violation
800	413.53	180.25	206.21	6746.100	0.0000
	0	61	35		
850	423.76	210.30	215.81	6778.100	0.0083
	93	46	77		
900	444.07	237.71	218.21	8033.900	0.0053
	99	02	52		

S. No.	Load (MW)	P_1 (MW)	P_2 (MW)	P_3 (MW)	P_4 (MW)	P_5 (MW)	P_6 (MW)	Cost ($/h)
1	1200	463.76	164.77	248.13	107.26	113.19	103.54	14570
2	1263	453.94	153.07	284.46	114.08	142.46	115.05	15345
3	1300	485.41	176.52	293.05	112.06	129.09	109.04	15797
4	1350	470.92	181.9	295.45	137.93	75.878	111.55	16466
5	1500		INFEASIBLE					

Unit Output (MW)	PSO [8]	PSO CRAZAY [18]	GA [17]	AIS (Clone Optimization Technique)
P1	447.497	464.5767	474.8066	453.9425
P2	173.322	177.8071	178.6363	153.0732
P3	263.475	265	262.2089	284.4569
P4	139.059	120.9708	134.2826	114.0797
P5	165.476	156.7055	151.9039	142.4574
P6	87.128	90.6358	74.1812	115.0545
Total Generation Cost($/h)	15450	15449.339	15459	15345

Fig 9 shows cost curve and fig 10 shows best fitness curve. From table III gives the comparison of cost of six unit system by using various optimization techniques i.e. PSO [8], PSO-crazy [18] and GA [17]. The minimum cost reported for the six unit system is $15449.3394[18]. It is observed that the best cost of $ 15345.00 has been obtained by clone optimization technique for 1263MW

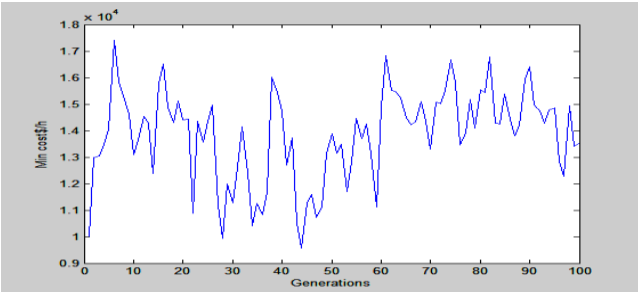

Fig 9. Cost curve of 1263 MW demand by clone optimization technique.

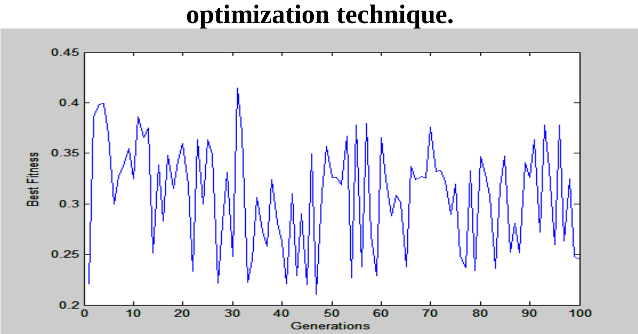

Fig 10 Best fitness curve of 1263 MW demand by Clone optimization technique

The proposed clone optimization technique was much faster than the other techniques. It takes only 3 seconds to provide the optimal solution. The tests were carried out a Intel (R) core (TM) Duo CPU E7500@ 2.93GHz, 2.94GHz personal computer.

Conclusions

A new approach AIS Technique for solving economic Load dispatch problem in power system is presented. The developed optimization technique is capable to determine the power to be generated by each generating unit in power system so that the cost of generation could be minimized while satisfying some operating constraints. Real number representation of the antibody attributes was implemented that represent the optimal output of the generating units. a number of modifications were made on the cloning, mutation and selection schemes of the developed Artificial Immune system technique. The results obtained from various combinations of schemes were compared. It was found that the developed optimization technique gives the best result. A comparative study was carried out between the projected technique, the PSO, PSO CRAZY and also Genetic Algorithm technique. The results have shown that the proposed optimization technique with cloning scheme, mutation and crossover is capable to provide superior results with reduced computation time and cost as well. Hence, the study shows that AIS technique could be a promising technique for solving complicated optimization problems in power system operation.

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