Biological Based Algorithms For Cost Optimization For Competitive Power System Market: A Review

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Abstract*: The main motivation of this article is to review the problem of cost optimization in power system by managing different parameters such as renewable resources, decision making, storage problems, etc with biological based optimization techniques. To enhance the efficiency of power system optimization, the biological optimization techniques are best suited. As the biological based artificial algorithms not only solve cost problems but also helpful in efficiently and handling productivity of power market efficiently. A comparison of different biological optimization techniques having different characteristics and mathematical parameters which can be applied in hybridization of cost parameters also been discussed. Finally, a framework is purposed for power market to solve the complexity of trading and cost emission problems based upon these biological optimization techniques. The comparison illustrates that biological based techniques are capable of not only solving load dispatch and cost problems but also helpful in controlling and restructuring the power system network

Index Terms*: Biological optimization, economic dispatch, nature inspired algorithms, cost function.

I. INTRODUCTION

In power system operations, generation units in structure of electricity industry are designed to maximize their profit in competitive power market. Restructuring in electricity industry has played vital role in abolition of old and traditional generation system and it also leads to competitive environment in power market [1]. However, changes in market caused some problems such as demand price elasticity, change of generation and distribution structure, change of planning of generation, change of economic dispatch, unit commitment problems.

In power system, all generating units produce heat which cannot be converted into electric power due to loss of heat energy [2]. Therefore, it is necessary to minimize the heat loss effect so that one can boost the efficiency of the fuel which leads to peak production. With the help of optimization process, the production cost can be reduced up-to 30% [3].

In recent years the literature has reported on improving the economic dispatch problems using mathematical equations through the advanced biological based algorithms. In problem of economic optimization there are two important considerations which include heat dispatch problem and fuel cost problem [4]. Optimization play important role in solving the economic dispatch problem because it has artificial intelligence technique that helps to understand monopoly and deregulation environment of system. It further leads to profitability in organizations by solving the investment issues along with the development of hybrid power system [5]. The various issues like distribution and centralization of generation, demand and growth factor of resources, smartening of system and most important controlling of system can be resolved by using various biological optimization techniques [6].

Therefore, optimization of power system is necessary for maximum utilization of resources and minimization of cost function. Earlier there were classical techniques that are mathematical based like iteration method, dynamic programming, etc but they were less accurate and not very much efficient in comparison to bio-based techniques [7-8]. However, with the development of artificial algorithms like Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) the usage of these techniques leads to improvement in power system optimization. It further leads to development of different biological optimization techniques like Krill Herd algorithm (KH), Bacterial Forging optimization (BFO), Intelligent Water Drops (IWD) and they have different characteristics that help to solve the complexity of power system networks. The biological optimization techniques are inspired genetic algorithms which help to solve the different types of problems such as noise filtration, costing factor, tracking problems, etc. The biological algorithms have unique property of introducing the catalyst functions which help to achieve the fast response and accurate results [9-10].

In this article, the different biological based optimization techniques were reviewed by considering various constraints like cost function, damp rate function etc. The paper is arranged as follow. The 2nd Section focused on the objective function formulation i.e. single objective Economic Dispatch problem with operational and system constraints. Next section provides the overview of different biological optimization algorithms to understand its working principle that can be applied to solve ED problem. Section IV is about the suggested or proposed technique for optimization of various cost optimization parameters.

II. PROBLEM FORMULATION

The purpose of solving optimal problem in power market is to maximize the profit with its units. In the following two types of optimization are discussed. They are

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A) Cost Optimization.
B) Voltage Optimization.

A. Cost Optimization

In cost optimization of power markets, the primary objective is to maximize the profit in net cost functions by utilizing the resources to maximum value with minimum losses. For this, a hybrid structure is used in which both renewable and non-renewable resources that are integrated to each other these days [9]. The objective function ED (Economic Dispatch) for cost optimization in power market is given as:

$$MinF_T = \sum_{I=1}^{N} F_I(P_I) = \sum_{I=1}^{N} (a_i + b_i P_I + c_i P_I^2) \quad (1)$$

Where P_i=Power factor, a_i, b_i, c_i are variable factors.
The problem constraints in the ED are:
a) Real Power Balance equation shows the balance between generated power and load demand.

$$\sum_{i=1}^{n} P_{it} = P_d(t) \quad (2)$$

P_{it}=Generated Power, P_d=Distributed load
b) General Limit:

$$P_{I=1}^{Min} \le P_{it} \le P_i^{Max} \quad (3)$$

c) Ramp rate limit constraints:

$$P_{it} - P_{it-1} \le UR_i, \quad P_{it-1} - P_{it} \le DR_I \quad (4)$$

Where UR_i=Ramp Function, DR_i= Damp Function.

B. Voltage Optimization

Voltage optimization mainly depends upon the performance of P-V curve. An arc length along P-V curve is used as another state variable so as to remove the unwanted conditions along the main nose point. For voltage optimization, a contingency analysis method based on CP FLOW is used. The voltage deviation (VD) is used to calculate the deviation of bus voltage. The deviation of bus voltages from reference bus voltage is termed as voltage deviation factor.

$$VD = VD^{MB} / VD^{REF}, \quad VD = \frac{\sum_{I=1}^{n} (V - V_I)^2}{V} \quad (5)$$

Where
VD^{MB}=Bus Voltage, VD^{REF}=Reference Voltage
The classical approach involved in voltage optimization techniques help to understand the balancing of load but modern biological optimization techniques help to solve the complexity of networks and their problems. In balancing of bus voltage and reference voltage, the main difference of value calculates the deviation factor of voltage. Biological optimization techniques help to reduce this deviation factor by reducing the noises and filter out uncertain parameters due to which there is improvement in voltage factor [10]. Therefore, it is important part in overall optimization of power systems.

III. OVERVIEW OF DIFFERENT BIOLOGICAL OPTIMIZATION TECHNIQUES

A. Particle Swarm optimization

In 1995 two scientist's Dr. Eberhart and Dr. Kennedy created population based stochastic optimization known as Particle swarm optimization. This technique is unique as it is based on the social behavior of bird flocking and fish schooling. The process starts with the generation of random solution and then optimally finding the best solution. However, it has no evolution operators but has the potential solutions, called particles, which fly through the problem space by following the current optimum particles. The PSO algorithm starts with the generation of random particles which are dispersed in multidimensional space [11]. In this technique the flock of birds/fish advances in multidimensional search space until they found the food. Secondly, swarm particle moves with new local position (p_{best}) and new global position (g_{best}) with comparison to other particle. Updated mode is velocity of particle velocity and position of i^{th} particle for fitness evaluation (t+1) iteration in m-dimensional search space is commutated [12]. The basic building block of PSO algorithm is shown in fig. 1.

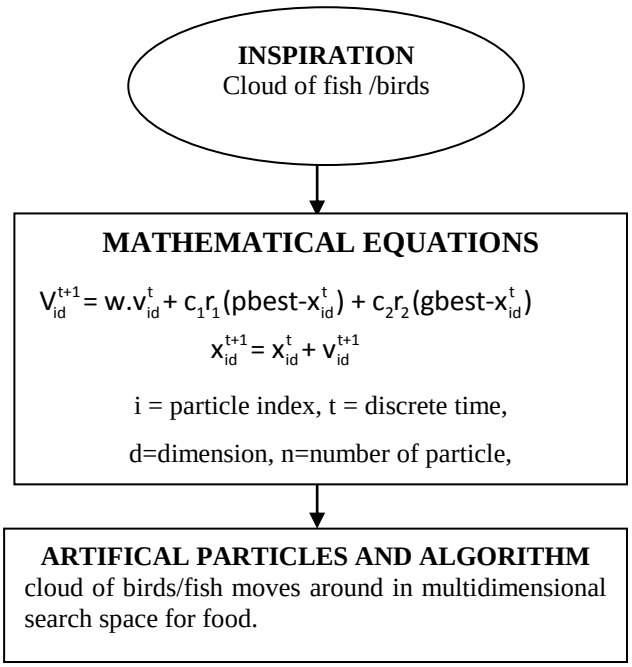

Fig. 1 The basic building block of PSO algorithm.

a.
b.
c.
d.
e.
f.
g.

B. Ant Colony Optimization (ACO)

This technique is solely dependent upon the behavior of ants and other social insects. This method provides inspiration for the development of biological algorithms for the solution of complex power system optimization

problems. This method was developed by Marco Dorigo [13]. There are basically two techniques that include parallel implementations and applications which lead to contributions of ACO to numerous fields such as traffic congestion, biological structural optimization, and genomics. As real ant use vision because of blindness, they follow trails of pheromone and chemical that left on ground which acts as electronic signals to other ants [14]. This is called "Stigmmergy process. Pheromone builds shorter but faster paths. By comparing with natural process, it is completely based on probability rule that identifies best optimal solution. ACO algorithm involves sequential as well as parallel algorithm processing [15]. Ant colony optimization has wide applications such as bus, machine routing, protein synthesis and folding, advanced network and composition of products. Fig. 2 depicts the Flow Chart of ACO.

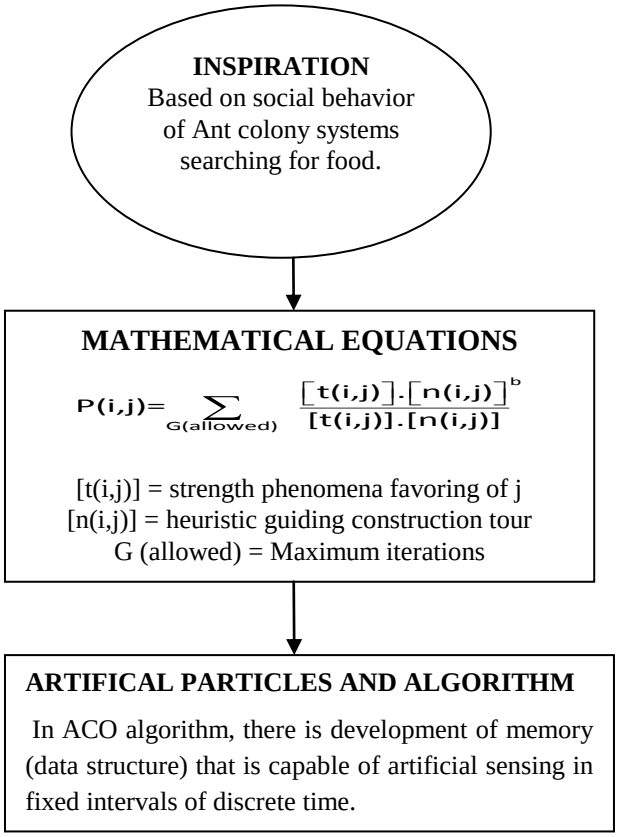

Fig. 2 Flow Chart of ACO.

C. Krill Herd (KH) algorithm

Krill's are biological organisms that found in all oceans around the world. The KH algorithm was based upon the study of Antarctic krill and was developed by Alavi and Grandome in 2012. The objective function for krill movement is to cover the minimum distance from highest density of herd to the food by each krill [16]. The position of krill individual is formulated under these circumstances. These include:

a) Induction of movement by presence of other krill individuals.
b) Foraging activity.
c) Random diffusion.

In this biological operator, mutation and crossover added to algorithm for more precise modeling. In motion induced process, velocity of krill is influenced by neighboring particles due to which sensing distance (SD) parameter is introduced in the system. Secondly, foraging activity involves location identification of particle and particle fitness in the system. Lastly, diffusion process upgrades the new improved position of particle (krill) in the system. KH algorithm plays very important role in voltage deviation problems due to capability of performing in complex and dynamic environment [16]. Fig. 3 shows the building blocks for KH Algorithm.

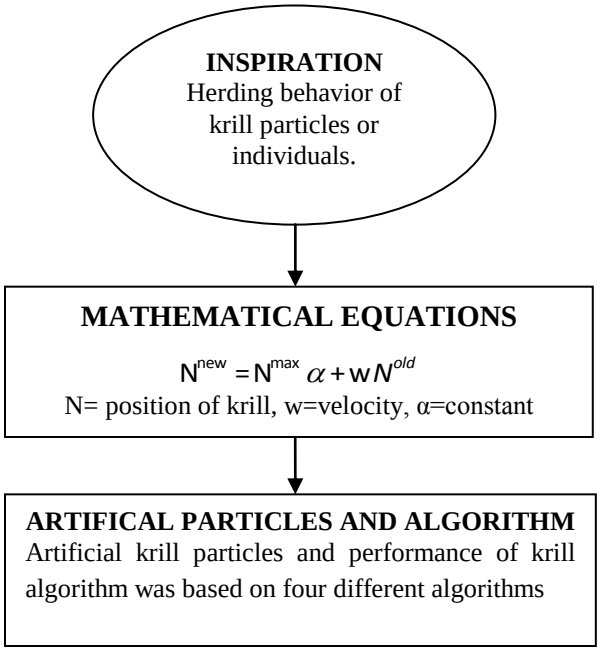

Fig. 3 Building blocks for KH Algorithm.

D. Rule Based Bacterial Modeling (RUBAM)

In 2006, Paton, Veachos and Saunders developed this method which is based on interaction of complex environment organisms that occur in natural bacteria structure and ecology. It deals with COSMIC (Computing System of microbial interactions and communication) interaction of characteristics of ecology and evolvable discrete time space patterns. It also generates multiple optimal solutions by sharing the common data. Bacteria act as source of central processing unit which generates information and the mapping of messages is done with the action to be taken against them in the intervals of discrete time. The mapping involved is dynamic in nature and evolvable that enables organisms to change the environment. It leads to increase in life span and process of reproduction in organisms.

Designing of RUBAM algorithm requires balancing of complexity and computational demands that involves interaction of artificial organisms as evolutionary operator with artificial environmental. It is multi model search space system in discrete time that generates multiple optimal solutions [17]. RUBAM algorithm involves basic steps such as development of artificial environment in which we design the fundamental matrix. Secondly, we deal with artificial organisms which operate as detectors which is followed by the development of organism The interaction helps to direct the movement of operators and lastly is the calculation of dissipation of energy. The

building blocks of RUBAM are shown in fig. 4.

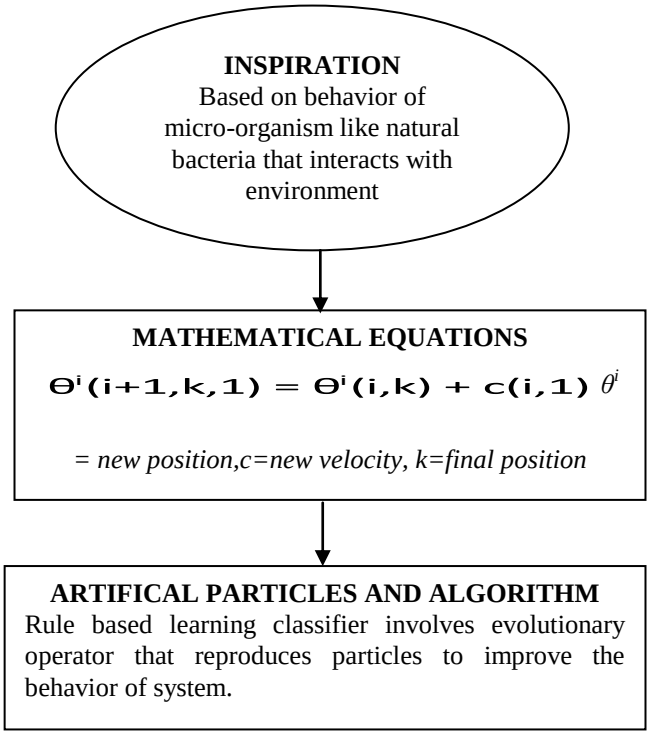

Fig. 4 Building blocks of RUBAM algorithm.

E. Intelligent Water Drops Algorithms (IWD)

IWD was proposed by Hamd-Shah Hasseini which is based on natural river system that contributes the actions and reactions take place between water drops in river flowing in the environment. Based on behavior of water drops, artificial water drop is developed that posses same properties of natural water drop. The important properties of intelligent water drop are:

a) Amount of soil it carries now, SOIL (IWD)

b) Velocity that it is moving now, velocity (IWD).

To implement behavior of path choosing, uniform random distribution is used among the soils, as lower the soil of path, higher is the velocity. IWD Algorithm has basically four stages of development and that are initialization, construction solution, reinforcement and termination. In Initial stage, there is introduction of static variables and dynamic variables. Next stage leads to development of construction graph which is also called the fully connected weighted graph in which addition of components (water drops) is done along with selection and ranking. In reinforcement stage, up gradation of soil global position is done to include best fittest solutions in the system. At last, termination system discards the unwanted constraints and improves its overall performance of result [18]. The building blocks for IWD algorithm is show in fig. 5.

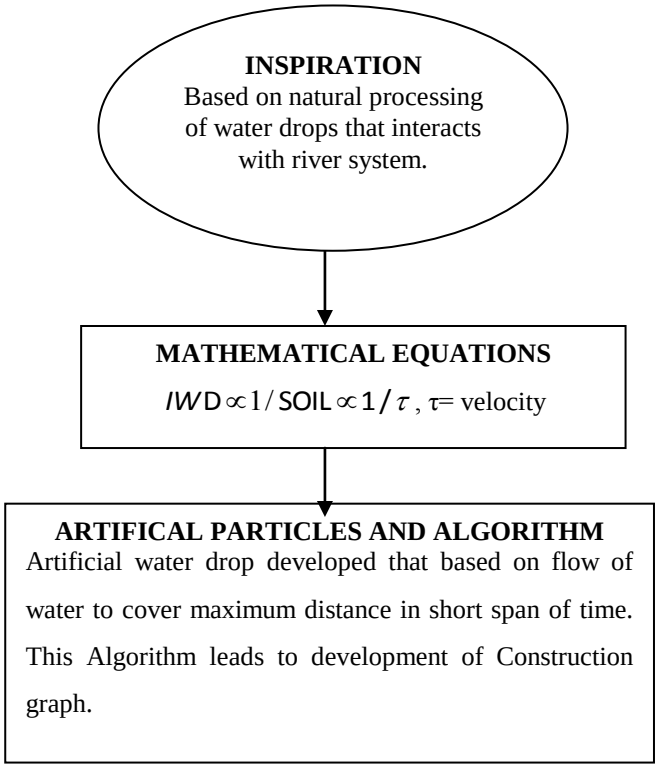

Fig. 5 Building blocks of Intelligent Water Drops Algorithm.

F. Artificial Immune System (AIS)

In artificial immune system, the algorithms are based on immune system of human body. AIS was proposed by Dasgupta in 1999. This algorithm is highly evolved and follows parallel distributed adaptive system. It involves recognition of immune system, immune memory and artificial learning. The main consideration in the AIS is mutation and crossover factors which are based on efficiency of function. There are different types of techniques involved in AIS. They are:

a) Colonel Selection Algorithm.

b) Immune Network Algorithm.

c) Dendrite Cell Algorithm.

d) Self Reacting Cell Algorithm.

AIS introduces the ANSC (Artificial Negative Selection Classifier) which develops the negative algorithm that helps to detect the uncertain data and helps to reduce the noise effect in multi class power system. The AIS algorithm develops in two stages which are generation stage and detection stage. After operating the generation stage and detection stage, cutting method is done in algorithm to improve the performance of overall result [19]. The basic building block of AIS is show in fig. 6.

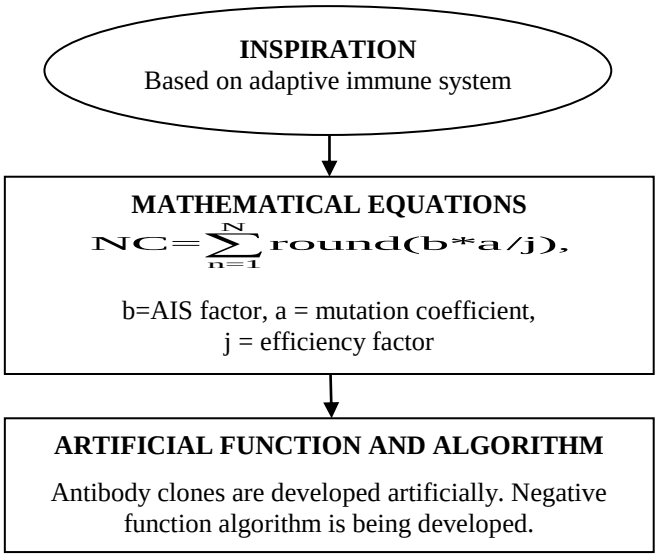

Fig. 6 Building blocks of AIS.

G.Bacterial Foraging Optimization (BFO)

This algorithm is bio inspired algorithm that inherit the characteristic of various bacterial foraging algorithms such as reproduction, cell movement (also called chemo taxis) etc. It was developed by Passino in 2002. In this, there is development of bacterial colony formation instead of individual groups. There are basically three stages of BFO and the stages includes Chemo taxis, reproduction and elimination.

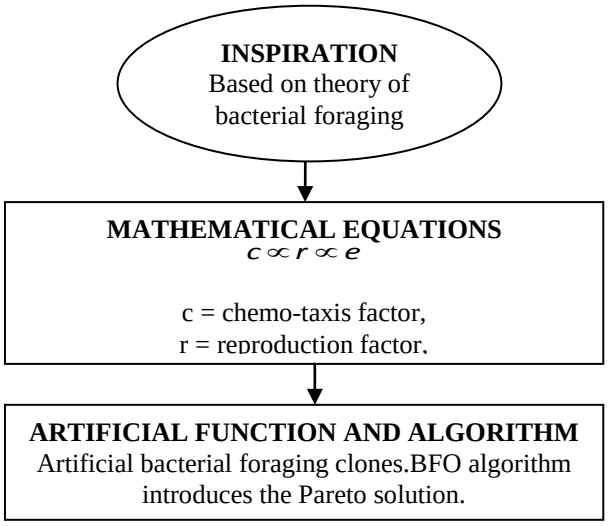

Fig. 7 Basic building block of Bacterial Foraging Optimization

In chemo taxis stage, algorithm is developed for optimal direction which is selection based taken by bacteria in search of food. In this stage, convergence, flipping and advancement of optimal path developed [20-21]. In Reproduction stage, there is introduction of entropy weight decision variables which helps to evaluate the near target values and to reproduce new advance functions. Deviation of Pareto function is evaluated with respect to ideal solution and updated. The last stage of elimination helps to remove the uncertain parameters along with incineration of waste particles to reduce the environmental pollution and saving of energy [22-23]. The building blocks in BFO algorithm is shown in fig. 7. Also, the different comparisons of biological techniques are illustrated in Table 1.

Table 1. Comparison chart of different biological optimization techniques

Algorithm Technique	Biological Parameters	Control Parameters	Applications
PSO	Fish, Food	Chromosomes, Mutation probability, Cross-over probability, Population size	Detection of loses in wireless networks, Data mining, Structural optimization
ACO	Pheromone, Ant , Evaporation rate	Updating of pheromone, Trail evaporation	Data routing problems, Digital Signal Processing.
KH	Krill, Ocean	High Density of herd, Diffusion rate	Evolvable hardware, Robotic designing
RUBAM	Bacteria, Evolutionary operator, Environment	Ecology interaction, Discrete time	Optimal learning, Reactive power dispatch, Drug designing
IWD	Water drops, River	Soil, Velocity	PID Controller
AIS	Immune operators, Cloning, Hyper mutation	Antibody population,	Filter designing, Virus detection.

IV. PROPOSED METHODOLOGY

In optimization problem some parameters are set to predefined limits. As Power market sector uses multiple

parameters, so a Multiple Objective Optimization (MOO) is used generally [24-26]. In Multi objective optimization, the function f(x) is defined as:

$$\min \ F(x)=\{ f_1(x),\ f_1(x),\ f_1(x),.....,\ f_n(x)\} \qquad (6)$$

The flow chart in fig. 8 shows the whole optimization process in cost minimization in power system network.

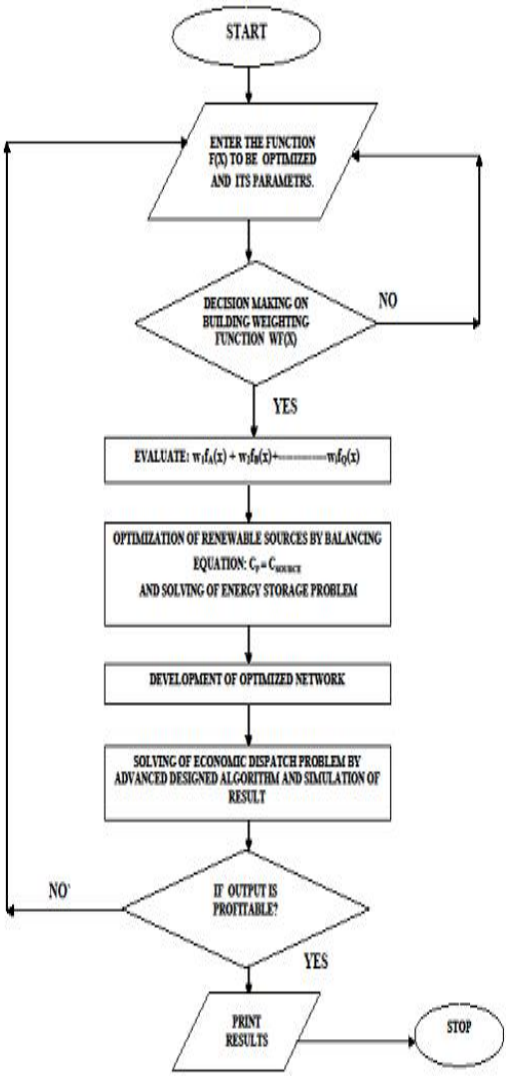

Fig. 8 Flow chart of optimization process in power market

i) Decision Making

Development of weighting methodology gives direction to decision making process of function whether to build or not. It also measures the closeness of market values that applicable to optimal market conditions and it is measured by Heuristic key performance indicators which are based on qualitative functions [27-28]. The general outcome is defined as:

$$w_1 f_A(x), w_2 f_B(x) + ...w_i f_Q(x) \qquad (7)$$

There is a strong dependence of the weighted functions in decision making of optimization process.

ii) Optimization of Renewable Source

In optimization of renewable sources, it deals with continuous power supply units by selecting the minimal cost such as wind, solar, and fuel cell. The time factor also play important role in generation of renewable energy [29]. The objective function is defined as:

$$C_p = C_{Source} \qquad (8)$$

Where C_p = Energy cost during period, C_{Source} = generation cost of i^{th} device.

Optimization of renewable sources lead to development of overall power system by making it less dependent on fossil energy resources that leads to reduction in environmental pollution. Along with, the renewable energy has also other advantages such as inexhaustibility, cleaner, cheap, availability, etc. Optimization of renewable sources can be done by using hybrid renewable systems in which unregulated power is converted into useful load by advance optimized technologies. For example, photovoltaic hybrid systems lead to reduction in emission cost and improve the reliability factor by parallel operation of solar panels [30-31].

V. APPLICATION AREAS

A. Energy Storage Problem

The generation, consumer and trader entities are the main driver entities in power system market. The maximum profit can be incurred if the producers have large storage infrastructure to meet the futuristic demands. The problem lies in when to store, when to sell and whom to sell. Optimization rules help to develop a strategy through which the decisions can be made either to sell or store dependent upon the market constraints [32]. The main parameters are storage capacity, cost of storage and selling price. Further, energy storage devices can be used to deliver the power under natural climatic disasters conditions which reduces the effect of poor quality of electrical power [33].

B. Optimization of Network Structure

The growing interest in smart mechanism of the electrical power systems leads to the integration of renewable sources that includes the adaptive protections on line switches, intelligent meters and on-line measuring devices. But the main problem is integration of these smart devices in existing power system networks. The key objective function in network structure is to minimize the loss of electrical energy [34-35]. Network structure consists of both active and reactive components. Due to there is need of development of hybrid structure with advanced techniques which can handle both series and parallel operations of grid [36]. The optimization in network structure follows the principles of low-cost planning so that it may increase the reliability factor [37-38].

C.Energy Power Trading

The problem is to define relatively cheap low carbon emission credits, securing and sustainability of power plant portfolio with market conditions. The problem is defined for trader's action to gain the profit which is dependent upon energy flows [39-40]. Power market also deals in purchasing and selling of carbon credits which depends upon the performance of organizations to produce clean energy at minimum cost. Therefore, optimization plays very important role in calculating the cost factor of electric market. The intelligent optimization techniques also help to

improve the behavior of power market in best way with eliminating the uncertain parameters.

D. Reduction of Emission Cost

In biological optimization, development of system takes place with emission reduction along with carbon taxes calculation by application of losses equation. These equations are based on probability distribution that helps to evaluate the economic parameters.

VI. CONCLUSION

This paper reviews the different types of biological based algorithms that can be used to improve performance of power market. It also highlights some of the intentions, functions, their mathematical equations and the areas of application as criteria for the analysis. Together, these biological optimization techniques give rise to advancement in the performance of power market. In addition, the comparison of different biological algorithms helps to understand new challenge and uncertainty of the power system. Therefore, there is possibility of further improvement in performance of power market by using hybrid biological optimization techniques which form a part of future work. In addition, these intelligent algorithms help to recognize new opportunities that lead to development of integrated structure of power system that leads to integration of renewable energy sources with non-renewable one.

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