International Journal of Engineering Innovation & Research
Volume 3, Issue 2, ISSN: 2277 – 5668

A Comparitive Study of Optimization Technique for Various Algorithms in Facts Controllers

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***Abstract* – In this paper, we provide the comparison of various algorithms for improving the stability of UPFC power systems which is a FACT device, using Adaptive Input Output Feedback linearization control(AIFLC). This paper compares different algorithms like Genetic Algorithm (GA), Evolution Strategies (ES), Evolutionary Programming (EP), Simulated Annealing(SA), Gaussian Adaptation, Ant Colony Optimization, Particle Swarm Optimization (PSO), Q-Filter Algorithm, Bacteria Foraging (BF), Hill Climbing based on Time, Accuracy, No of Iterations, Complexity of Solution for better stability improvement. This paper provides overview of all the above algorithms.**

***Keywords* – Flexible AC Transmissions (FACTS), Unified Power Flow Controller (UPFC), Adaptive Input Output Feedback Linearization Control (AIFLC), Genetic Algorithm (GA), Evolution Strategies(ES), Evolutionary Programming (EP), Simulated Annealing (SA), Gaussian Adaptation, Ant Colony Optimization, Particle Swarm Optimization (PSO), Q-Filter Algorithm, Bacteria Foraging (BF),Hill Climbing.**

I. Introduction

FACTS technology is a collection of controllers, which can be applied individually or in coordination with others to control one or more of the interrelated system parameters, such as series impedance, shunt impedance, current, voltage and damping of oscillations. It is power electronics based system and it is composed of static equipment used for the AC transmission of electrical energy. The basic idea of FACTS is installing the power electronic devices at the high voltage side of the power grid to make the whole system electronically controllable and provide active and reactive power to the power grid rapidly. The power compensation achieved by FACT devices could adjust the voltage of the whole system and the power flow could be satisfactorily controlled.

Generally, the FACT devices and technology could be divided into three generations, based on switching technology.

A. 1stGENERATION: it includes static var compensator (SVC), Thyristor controlled series compensator (TCSC), and Thyristor controlled phase shifter (TCPS).

B. 2ndGENERATION: it includes Static compensator (STATCOM) and Static synchronous series compensator (SSSC).

C. 3rdGENERATION: it includes Unified power flow controller (UPFC), Interline power flow controller (IPFC), Grid power flow controller(GPFC)

In the FACT device family UPFC is considered as one of the most versatile one, because it has the capability to control power flow in transmission line, improve the transient stability , mitigate system oscillation and provide voltage support

II. Unified Power Flow Controller (UPFC)

UPFC is a combined series-shunt controller; it is providing fast-acting reactive power compensation on high-voltage electricity transmission networks. It uses a pair of three-phase controllable bridges to produce current that is injected into a transmission line using a series transformer. The controller can control active and reactive power flows in a transmission line. The UPFC uses solid state devices, which provide functional flexibility generally not attainable by conventional thyristor controlled system. The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The UPFC concept was described in 1995 by L.Gyugyi of Westinghouse. The UPFC allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system.

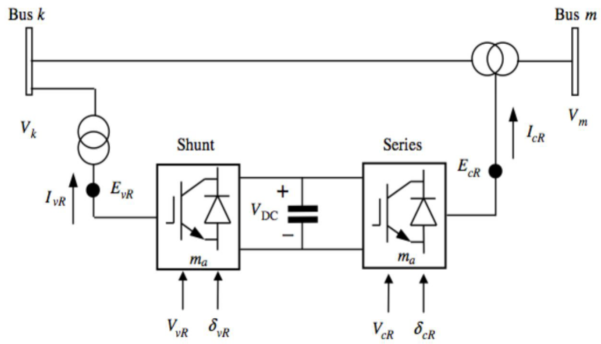

Fig.1. Model of UPFC

We prefer UPFC mainly; because of its efficient coordination control installed in practical networks can result in minimizing operational costs, environmental protection, improved voltage regulation, power factor correction, and power loss reduction [1]. When the UPFC is applied to the interconnected power systems, it can also provide significant damping effect on tie line power oscillation through its supplementary control. The application of the UPFC to the modern power system can there for lead to the more flexible, secure and economic operation [2].

Controlling of specific FACT devices, mainly UPFC is an important problem in power system dynamics. Optimal control approach is one of the examples, but the problem facing in this control is that it uses a linearized system model which is only valid for a particular operating point. This arise the question of robustness. If the chosen point is in the vicinity, control based linearized system is valid. But the stressed power system exhibits a non linear behavior in modern power systems to solve the low frequency oscillation problems which include FACT devices, some authors have tried out this with non linear control method to the systems[3]-[7].For our system Adaptive Input Output Feedback Linearization Control is used to achieve stability estimator.

In this paper we are studying the basic characteristics of a various algorithms that are suitable for our controller. Further the characteristics are compared. The various algorithms are

A. Genetic Algorithm

A genetic algorithm is a search heuristic that mimics the process of natural selection. This heuristic is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection and cross over. Initially many individual solutions are randomly generated to form an initial population. The population size depends on the nature of the problem, but typically contains several hundreds of thousands of possible solutions. Traditionally, the population is generated randomly, allowing the entire range of possible solutions. Occasionally, the solutions may be seeded in areas where optimal solutions are likely to be found.

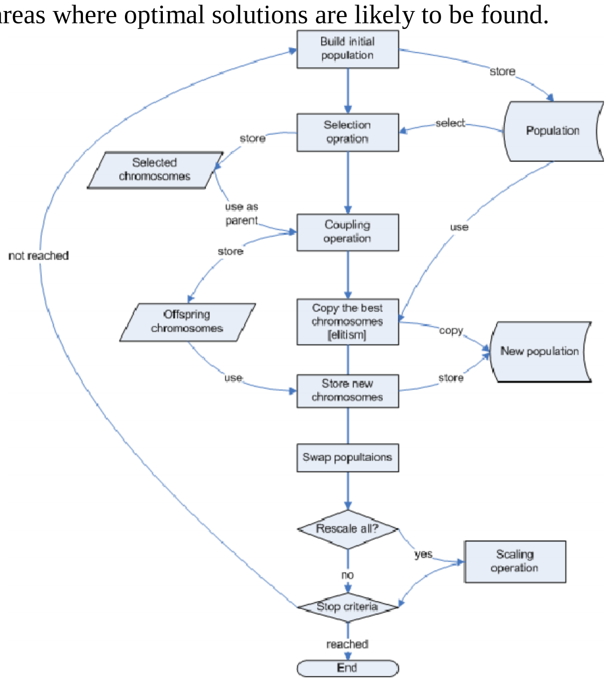

Fig.2. Genetic algorithm flow chart

B. Evolution Strategy

An evolution strategy is an optimization technique based on ideas of adaptation and evolution. It belongs to the general class of evolutionary computation or artificial evolution methodologies. It use natural problem-dependent representations, and primarily mutation and selection, as search operators. In common with evolutionary algorithms, the operators are applied in a loop. An iteration of the loop is called a generation. The sequence of generation is continued until a termination criterion is met. As far as real valued search spaces are concerned, mutation is normally performed by adding a normally distributed random value to each vector component. This step size or mutation strength is often governed by self adaptation. Individual step sizes for each coordinate or correlations between coordinates are either governed by self adaptation or by covariance matrix adaptation.

C. Evolutinary Programming

Evolutionary programming is one of the four major evolutionary algorithm paradigms. It is similar to genetic programming, but the structure of the program to be optimized is fixed, while its numerical parameters are allowed to evolve. Currently evolutionary programming is a wide evolutionary computing dialect with no fixed structure, in contrast with some of the other dialects. It is becoming harder to distinguish from evolutionary strategies. Its main variation operator is mutation; members of the population are viewed as part of a specific species, rather than members of the same species therefore each parent generates an offspring using a survivor selection.

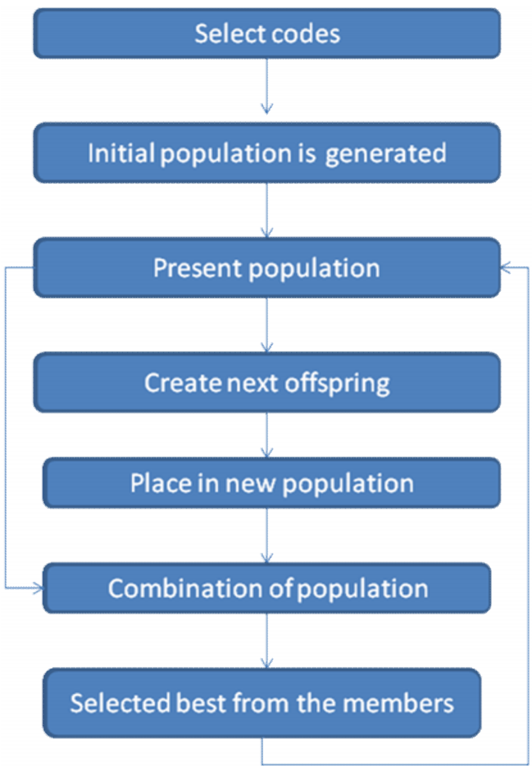

Fig.3. Structure of evolutionary programming algorithm.

D. Simulated Annealing

Simulated annealing is a generic probabilistic metaheuristic for the global optimization problem of locating a good approximation to the global optimum of a given function in a large search space. It is often used when the search space is discrete. For certain problems, simulated annealing may be more efficient than exhaustive enumeration provided that the goal is merely to find an acceptably good solution in a fixed amount of time, rather than the best possible solution. In order to apply SA method to a specific problem, one must specify the following parameters: the state space, the energy function, the candidate generator procedure, the acceptance probability function, the annealing schedule and initial temperature. These choices can have a significant impact on the methods effectiveness. Unfortunately, there are no choices of these parameters that will be good for all problems and there is no general way to find the best choices for a given problem.

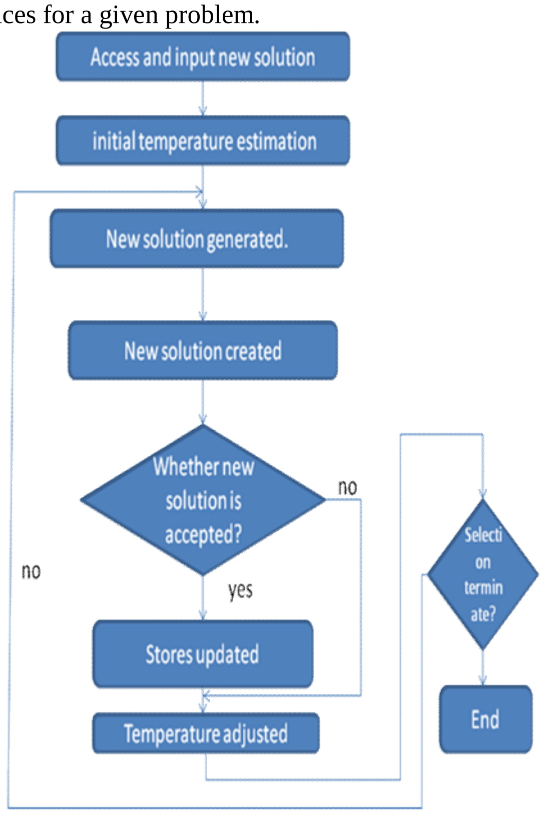

Fig.4. Structure of Simulated Annealing

E. Ant Colony Optimization

Ant colony optimization is introduced by Dorigo in his doctoral dissertation, is a class of optimization algorithms modeled on the actions of an Ant Colony. ACO is a probabilistic technique useful in problems that deal with finding better paths through graphs. Artificial 'ants'-simulation agents-locate optimal solutions by moving through a parameter space representing all possible solutions. Natural ants lay down pheromone directing each other to resources while exploring their environment. The simulated ants similarly record their positions and quality of their solution, so that in later simulation iterations more ants locate better solutions.

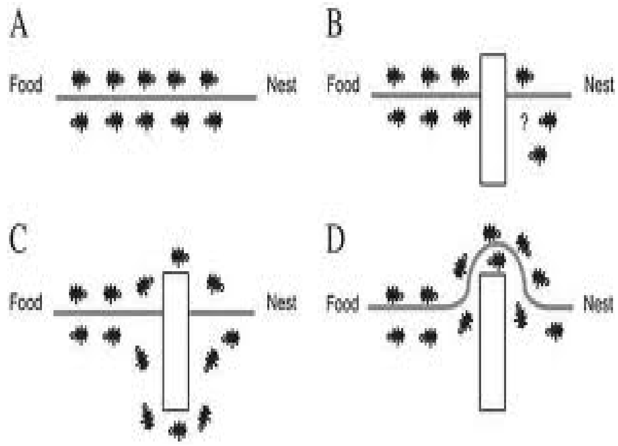

Fig.5. Representation of Ant Colony Algorithm.

F. Particle Swarm Optimization

Particle swarm optimization (PSO) is a global optimization algorithm for dealing with problems in which a best solution can be represented as a point or surface in an n-dimensional space. Hypotheses are plotted in this page and seeded with an initial velocity, as well as a communication channel between the particles. Particles then move through the solution space, and are evaluated according to some fitness criterion after each time step. Over time, particles are accelerated towards those particles within their communication grouping which have better fitness values. The main advantages of such an approach over other global minimization strategies such as simulated annealing is that the large numbers of members that makeup the particle swarm make the technique impressively resilient to the problem of local minima.

G. Q-Filter Algorithm

The Q-filter algorithm is very simple and fast with a good execution time and rapid attenuation in the periodic disturbance. It is based on internal model which consist of stable poles. But the selective harmonic cancellation is not possible in this algorithm. But the loop gain of the system is altered with high robustness.

H. Bacteria Foraging

When a system has a highly epistatic objective function and number of parameters to be optimized is large then GA has been reported to exhibit high degraded efficiency. To eliminate this problem in GA, a new optimization scheme known as Bacterial Foraging is used for the UPFC controller parameter design. It was found that with the optimized gains the bacteria foraging UPFC shows better damping performance when the system is perturbed. Simultaneous tuning of the UPFC controller parameters with the Bacteria Foraging algorithm gives robust damping performance with variable operation condition and severity of faults.

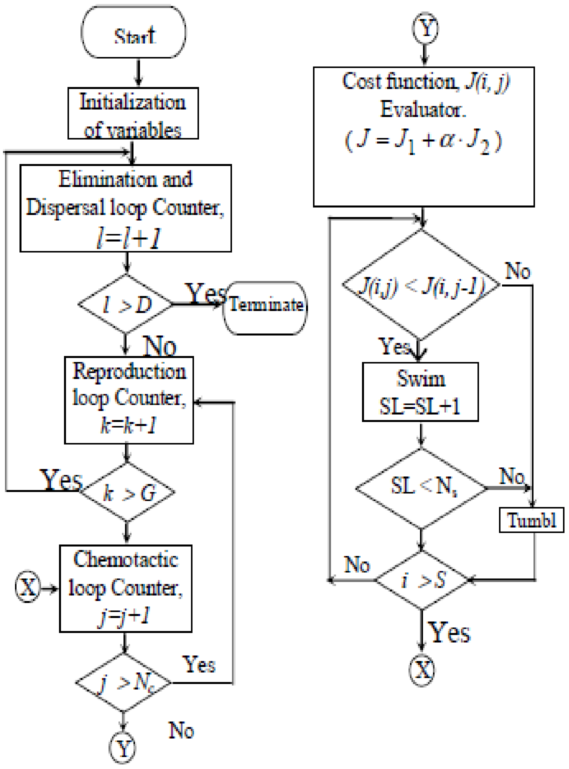

Fig.6. Flow chart for Bacteria Foraging

A comparative study is made between these algorithms according to various constraints such as time, accuracy, number of iterations, and complexity of solutions. The result obtained from this comparison is tabulated below

Table.1 Comparison of Algorithms

Algorithms	Time	Accuracy	No. of Iteration	Complexity Of Solution
1. Genetic Algorithm.	Very High	High Accurate	More	Very Complex
2. Evolution Strategies.	High	Accurate	More	More Complex
3. Evolutionary Programming.	High(Less Than GA)	Good	More	Complex
4. Simulated Annealing.	Less	Less Accurate	Less	Less Complex
5. Gaussian Adaptation.	High	Less Accurate	More	Complex
6. Ant Colony Optimization.	Medium	Accurate	Less	Not Complex
7. Particle Swarm Optimization.	Very High	Accurate	Less	Not Complex
8. Q-Filter Algorithm.	Medium	Less Accuracy	Not Mentioned	Less Complex
9. Bacteria Foraging.	Very Less	Accurate	Less	Less Complex

Based on the above comparison we made a graphical representation to compare each algorithm with each parameter, to identify the suitable algorithm.

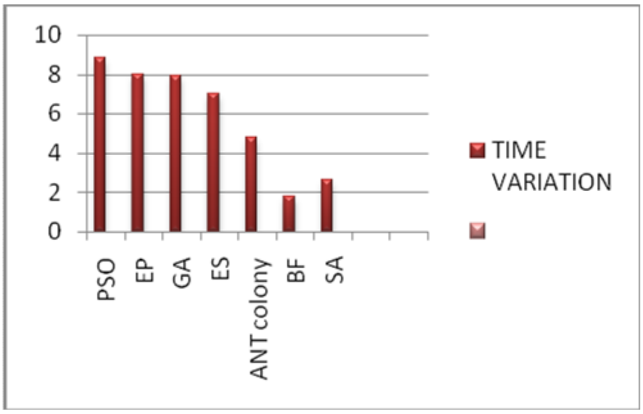

Fig.7. Variation of Time

From the figure.7 we can understand that Particle swarm optimization, genetic algorithm and evolutionary programming takes more time because there is more number of generations to be considered. Where as we can see than compared to all other algorithms bacteria foraging is very fast and also simulated annealing. So based on the above graph we can say that ant colony optimization uses moderate time.

Next we compared the accuracy of each algorithm.

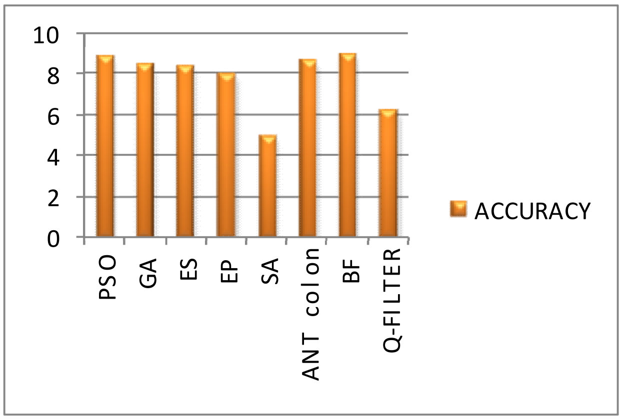

Fig.8. Accuracy

From the figure.8 it is clear that the simulated annealing has lower accuracy while all others have better accuracy. Even then when we consider the ant colony optimization have better accuracy with better time.

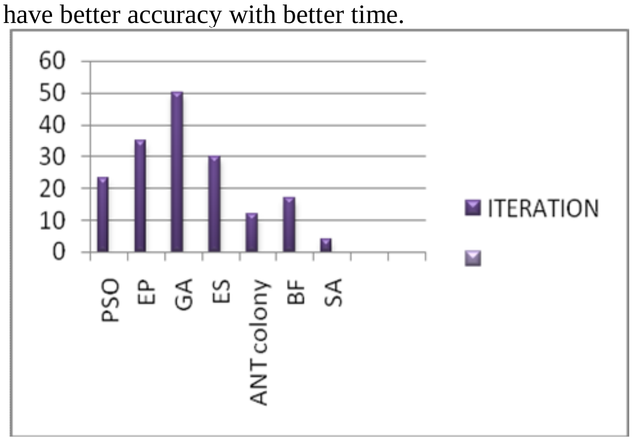

Fig.9. Number of Iteration.

Now we considered the number of iteration that each algorithm needed, based on this figure 9 is plotted and the result was shown.

From the above graph it is well clear that genetic algorithm takes more number of iteration than all above algorithms. Whereas the simulated annealing and ant colony optimization takes less number of iteration. But the simulated annealing brings poor accuracy rate, hence from the graph we can choose ant colony optimization.

From the table 1 we can also analyze that ant colony optimization is less complex. Based on the above graph and its observation we plotted a graph which compares the three algorithms which was selected.

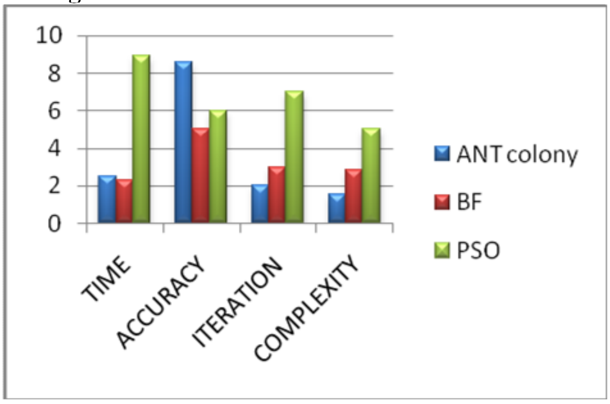

Fig.10. Overall Comparison

In the figure.10 we compared ant colony optimization, bacterial foraging and particle swarm optimization according to time, accuracy, number of iteration and complexity of solution.

From this it is clear that ant colony optimization has better time, accuracy. Number of iteration and has less complexity of solution. So for the improvement of damping oscillation of UPFC we have chose the best algorithm for the optimization.

III. Conclusion

From the above given tabulation and graphs we can identify the best optimization algorithm for FACT controllers, like UPFC. We can also conclude that algorithm such as Ant Colony Optimization, Bacteria Foraging and Particle Swarm Optimization produces better result.

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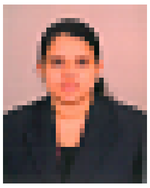

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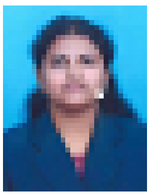

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