Chapter 5

Particle Swarm Optimization for estimation of optimized Available Transfer Capability

5.1 Introduction

The Available Transfer Capability has been recognized as vital part of congestion management in electrical power network. The setup of new transmission corridor has not been possible due to biological and economical reason. Hence, additional power requirement has been managed by the same transmission line. Consequently, the Available Transfer Capability (ATC) calculation has been recognized as a imperative part of modern power system. As the power requirement has been increased due industrial revolutions, the accurate and fast computation of optimized ATC has been taken as challenge for engineers.

Particle Swarm Optimization (PSO) has been identified as speedy, easy and a proficient optimization method based on population proposed by Eberhart and Kennedy [81] in the year 1995. PSO has been recognized as the evolutionary optimization methodology based on population as a Genetic algorithm.

In [82] and [83], the performance of PSO was explored in the area of power quality by improving the process of feeder reconfiguration. Victoire et al.[84] combined PSO, sequential-quadratic-programming, and Tabu-search to form a hybrid technique to tackle the unit commitment problem. Slochanal et al.[85] and Kannan et al. [86] introduced PSO in the area of generation expansion planning. PSO has been used in [85] to maximize the profit of a given generation company subject to certain market condition and various system constraints. In [86], PSO was employed to minimize the investment and operation cost of the generation expansion planning problem. Also in this area, PSO was utilized in solving the expansion planning problem of a transmission line network [83]. Chin et al. [87] have solved the generator maintenance scheduling problem by forming a hybrid technique by means of combining PSO with evolutionary strategies.

The system stability margins has been reduced to transact power from source to destination bus in deregulated environment. To cope up with this situation, the accurate calculation of maximum power transfer capability [88] has been treated as the most important parameter to maintain system security. In paper [88], the computation of maximum power transfer capability with consideration of N-1 contingency by re-dispatching load area generation, using PSO has been discussed.

A self-adaptive improved particle swarm optimization (IPSO) algorithm applied to available transfer capability (ATC) calculation has been discussed in [89]. In this paper, the adjustment inertia-weighted strategy factor to increase acceptability of particle swarm optimization (PSO) and increases convergence speed of PSO, has been projected. By applying penalty function dynamically, the chance to find the global optimum has been augmented and the influence of the initial position of the particles has been decreased. The IEEE 30-bus system has been used for test purpose. A power system has to maintain voltage stability. These values are the highest active power taken by the load buses, voltage amplitude and the angle of the buses. The critical values in electric power systems has been defined with the use of Chaotic Particle Swarm Optimization (CPSO) algorithm [90]. The critical values of voltage stability has been established by simple Particle Swarm Optimization (PSO) and CPSO respectively. The results obtained from CPSO are more effective. The optimum location and size of reactive compensating devices has been found in [91]. The main objective has been set to maintain voltage stability by improving acceptable voltage profile.

To mitigate transmission congestion, generator rescheduling [92] has been recognized as accurate techniques accepted by Independent System Operator (ISO) in a deregulated electricity market. An Optimal Power Flow (OPF) framework has been used to minimize the overall congestion relief cost after rescheduling. Firstly, generators has been chosen based on their generator sensitivity factor (GSF). Secondly, Particle Swarm Optimization has been used for rescheduling those selected generators.

The ATC has been calculated with the help of Roulette wheel selection based Genetic Algorithm (RWSGA) and Tournament Selection based Genetic Algorithm (TSBGA) methods as discussed in chapter-4. This methods will take more time to evaluate objective function. The results obtained from RWSGA and TSBGA is noisy in nature. To overcome this problem, Particle Swarm Optimization (PSO) has been used for determination of optimized ATC in the present chapter for secure and stable operation of power system. The studies have been demonstrated on IEEE 30-bus and a 75-bus Indian systems. The objective of the study is to determine ATC accurately and speedy. The Elitism strategy has been implemented for betterment of result.

5.2 Elementary of Particle Swarm Optimization

It has been encouraged by the behavior of organisms such as fish schooling and birds flock. The time requirement for calculation of the objective function value and storage memory is less than GA. The PSO algorithm has been used with an assumption that birds find food not personally but in flocking. Initially, the population size of the swarm has been selected randomly. Each particle, called potential solution, has been given an arbitrary velocity and it soared through problem space.

Each potential solution, called a particle (agent), has been given a random velocity and soaring through the problem area (n dimensional search space). The previous best value of fitness P_{best} and corresponding fitness value is tracked by each particle. The value which is best among all the P_{best} is called global best (g_{best}). Hence, with this g_{best}, a better and quick solution of the engineering field has been found.

According to the knowledge, each particle will shift about the search space. As each particle has accorded some inertia to it and will move to have a component of motion in the direction of its movement. The particle has been well aware of its position in the explore space and will come across with the best solution. The particles have to modify its position towards its g_{best}. To explore optimal solution all the particles in a swarm fly in the direction of g_{best}. The particle has to update its position depending upon its personal best position, global best position among particles and its previous velocity vector as per the following equations:

$$v_i^{k+1} = \omega \times v_i^k + c_1 \times r_1 \times (P_{best_i} - x_i^k) + c_2 \times r_2 \times (g_{best} - x_i^k) \tag{5.1}$$

$$x_i^{k+1} = x_i^k + \chi \times v_i^{K+1} \quad (5.2)$$

Where,

v_i^{K+1} : The velocity of i_{th} particle at $(k+1)^{th}$ iteration

ω : Inertia weight of the particle

v_i^k : The Velocity of i^{th} particle at k^{th} iteration

c_1 : self-confidence range, Positive constant having values between $[0, 2.5]$

c_2 : swarm range, Positive constant having values between $[0, 2.5]$

r_1, r_2 : Randomly generated number between $[0, 1]$

P_{best_i} : the best position of i^{th} particle obtained based on its own knowledge

g_{best_i} : The global best position of the population.

x_i^{k+1} : The position of i^{th} particle at $(k+1)^{th}$ iteration.

x_i^k : The position of i^{th} particle k^{th} iteration.

χ : Constriction Factor

Constriction factor can help ensure convergence. Its lowest value results in speedy convergence and small searching while its higher value results in sluggish convergence and a lot searching.

c_1 and c_2 willl drag the particle in the direction of P_{best} and g_{best} positions.The lowest values of acceleration coefficients let particles to travel distant from the target province, before being pulled back. The highest value results in sudden movement in the direction of the target area.

The term $c_1 \times r_1 \times (P_{best_i} - x_i^k)$ is called particle Memory influence or "Cognition part" which shows the personal view of the particle itself and $c_2 \times r_2 \times (g_{best} - x_i^k)$ is called Swarm influence or the Social part which explains the association among the particles.

The particle velocity has been renowned as prime factor to be considered. If the particle velocity is too high, it may lose good solutions. If the particles having low velocity, it may not travel around sufficiently beyond local solutions. Hence the value of v_{max} has been generally set to 10-20 % of the range of the each variable.

The value selection of ω has also presented a superior equilibrium between global and local investigation according to the following equation.

$$\omega = \omega - \frac{\omega_{max} - \omega_{min}}{iter_{max}} \times iter \quad (5.3)$$

Where,

ω_{max} = inertia weight at the start of iteration.

ω_{min} = inertia weight at the end of the iteration.

$iter$ = Iteration number

$iter_{max}$ = Maximum iterations number.

Fig.5.1 shows the graphical representation of PSO method.

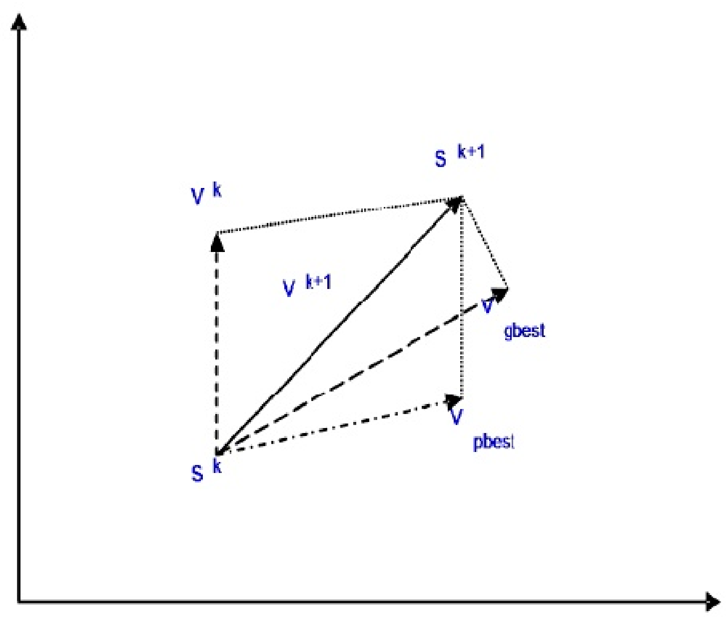

Figure 5.1: Graphical representation of PSO

S^k is the current position of the i^{th} particle in k^{th} iteration. v^k is the velocity of the i^{th} particle in k^{th} iteration. $v^{(k+1)}$ is the velocity of the i^{th} particle in $(k+1)^{th}$ iteration. This velocity is obtained by using information of v^k, P_{best} and g_{best} particles. Finally, new position $S^{(k+1)}$ of the i^k particle in $(k+1)^{th}$ iteration is obtained using S^k and $v^{(k+1)}$.

5.2.1 Advantages of Particle Swarm Optimization

- For resolving the non-linear problem of power system, Particle Swarm Optimization (PSO) has been identified as dominant optimization technique.
- No derivation is required for optimization.

- PSO coding is easy as compared to other inventive optimization techniques.
- As compared to the other conventional mathematical approaches, PSO is recognized as the best method because of less sensitivity to the nature of the objective function.
- It has only two parameters, namely: inertia weight and two acceleration coefficients as compared to other heuristic methods.
- Less dependent on a set of initial points. Hence the convergence algorithm is vigorous.
- High quality of solution within a short duration.
- Stable convergence characteristics.

5.2.2 Disadvantages of Particle Swarm Optimization

- Poor mathematical foundation for analysis to overcome in the future development of relevant theories.
- Some limitations for real-time Economic dispatch (ED).
- However, it can be applied in the off-line real-world ED problems such as day-ahead electricity markets.
- The PSO-based approach is believed that it has less negative impact on the solutions than other heuristic-based approaches. However, it still has the problems of dependency on initial point and parameters, difficulty in finding their optimal design parameters, and the stochastic characteristic of the final outputs.

5.3 Problem formulation of Available Transfer capability

In this section, the optimized ATC has been evaluated by varying generation at generator bus for a specific loading condition with the help of Particle Swarm Optimization (PSO). The main objective function taken here is to maximize ATC for manifold transactions at three different load bus. The objective function can be defined as under:

5.3.1 Objective Function

$$Max(f_n(x)) = Max(ATC_n^{i-j}(P, PTCDF) \quad (5.4)$$

Subjected to $P_{min} \leq P \leq P_{max}$

Where,

i, j=line index,

n= Number of Transaction,

P= Power Generation at generator bus,

$PTCDF$= Power Transmission Congestion Distribution Factors

5.3.2 Step by step procedure for implementing Particle Swarm Optimization

The optimization through Particle Swarm Optimization (PSO) has been done with the help of the following step:

1. Arbitrarily generate the particles with the consideration of its higher and lower limits.
2. The initial particle values were considered as the P_{best} values
3. Evaluate the objective function of each particle with its P_{best} for all the particles and the best amid the P_{best} is identified as g_{best}.
4. Modify the velocity and position of each particle for the next iteration.
5. Compare the objective function of each particle of the current iteration with that of its P_{best}. If the current value is better than P_{best}, then set P_{best} value equal to the current value and P_{best} location equal to the current location in 'd' dimensional search area.
6. Compare the best current fitness evaluation with the population's g_{best}. If the current value is better than the g_{best}, then reset g_{best} to current best position.
7. Repeat step 4 to 6 until the convergence criterion or maximum no. of iterations are met.

The flow chart for application of PSO in optimization of objective function has been shown by Fig.5.2

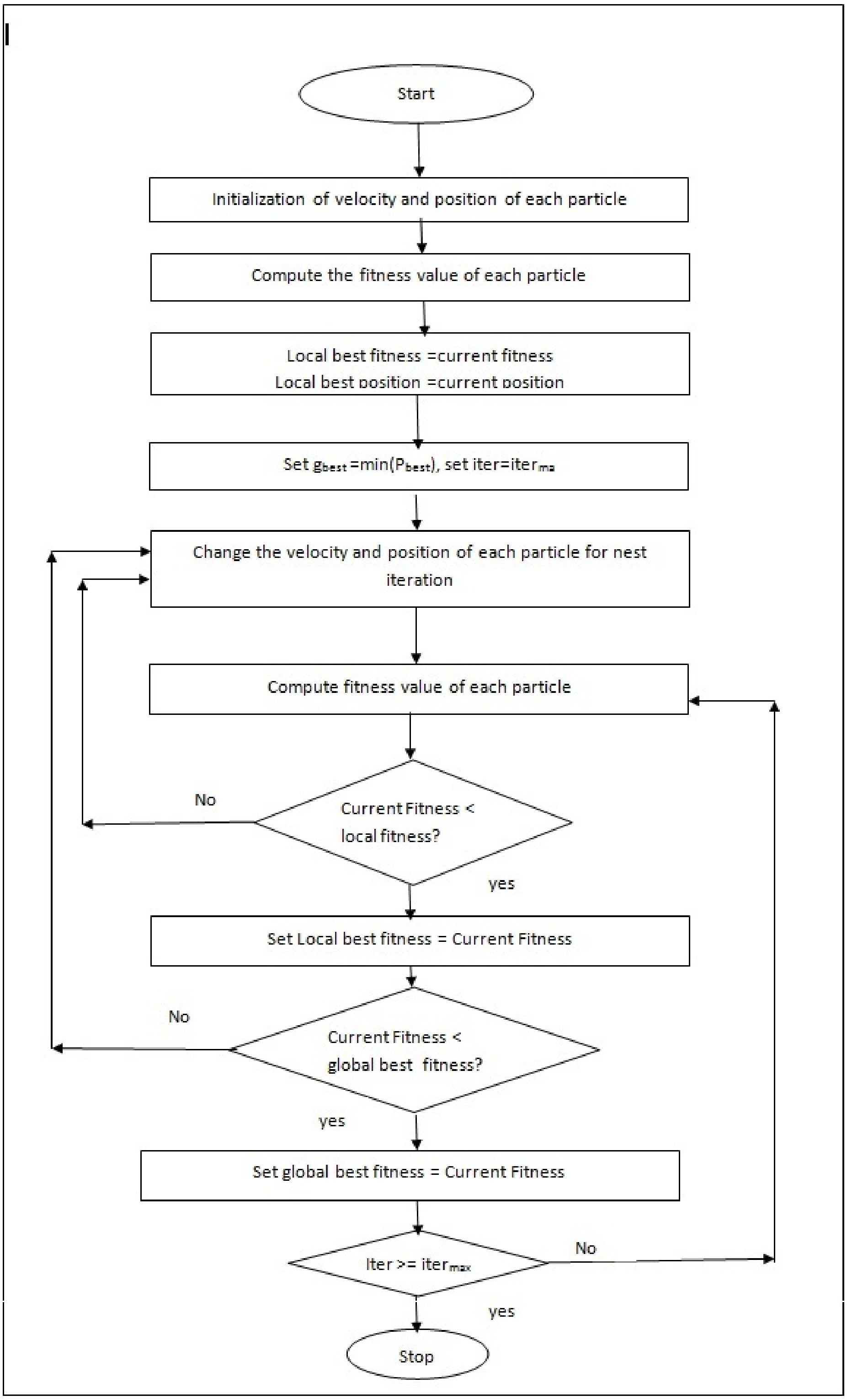

Figure 5.2: Flow chart for PSO algorithm

5.4 System Studies and Results

This work has been demonstrated on IEEE 30 bus test system and 75 bus UPSEB system.

5.4.0.1 IEEE 30 bus system

The maximum capability of each transmission line has been assumed to be 200 MW for the IEEE 30 bus test system. All the five generator at bus 2,5,8,11,and 13 act as source bus. The load has been connected to bus number 3,10 and 25. The load has been served by varying generation at source bus with the optimized value of ATC. In this work, the generation at generator buses has been taken as decision variables for the optimization techniques. The generation at generator bus varies for the computation of optimized ATC. Total 41 transmission lines has to be valuated with the help of the PSO. There are five control parameters used in PSO algorithm. The other parameter has been shown in Table:5.1 for IEEE 30 bus test system.

The comparison between optimized ATC value without and with elitism has been shown by Table : 5.2 for IEEE 30 bus test system. The optimized ATC has been obtained along-with generation at different generator bus for 100 iterations for a specific load with the help of PSO method. The output with elitism and without elitism has been presented graphically in Fig: 5.4.0.1 and Fig: 5.4.0.1 respectively for a specific load.

Table 5.1: Structure of PSO for IEEE 30 bus test system

Sr.no	Parameter	Value
1	Number of Particles	10
2	Number of Variables	05
3	Maximum Iterations	100

5.4.0.2 UPSEB 75 bus system

For UPSEB 75 bus system, maximum capability of each transmission line has been shown different as per Annexure-B .The load has been connected to bus number 17,21 and 26 as shown in Table: 5.4. The load has been governed by 15 generator buses. The generator bus number 2 to 15 has been taken as decision variables for the optimization problem.Hence, there are 14 decision variables has been used PSO algorithm.

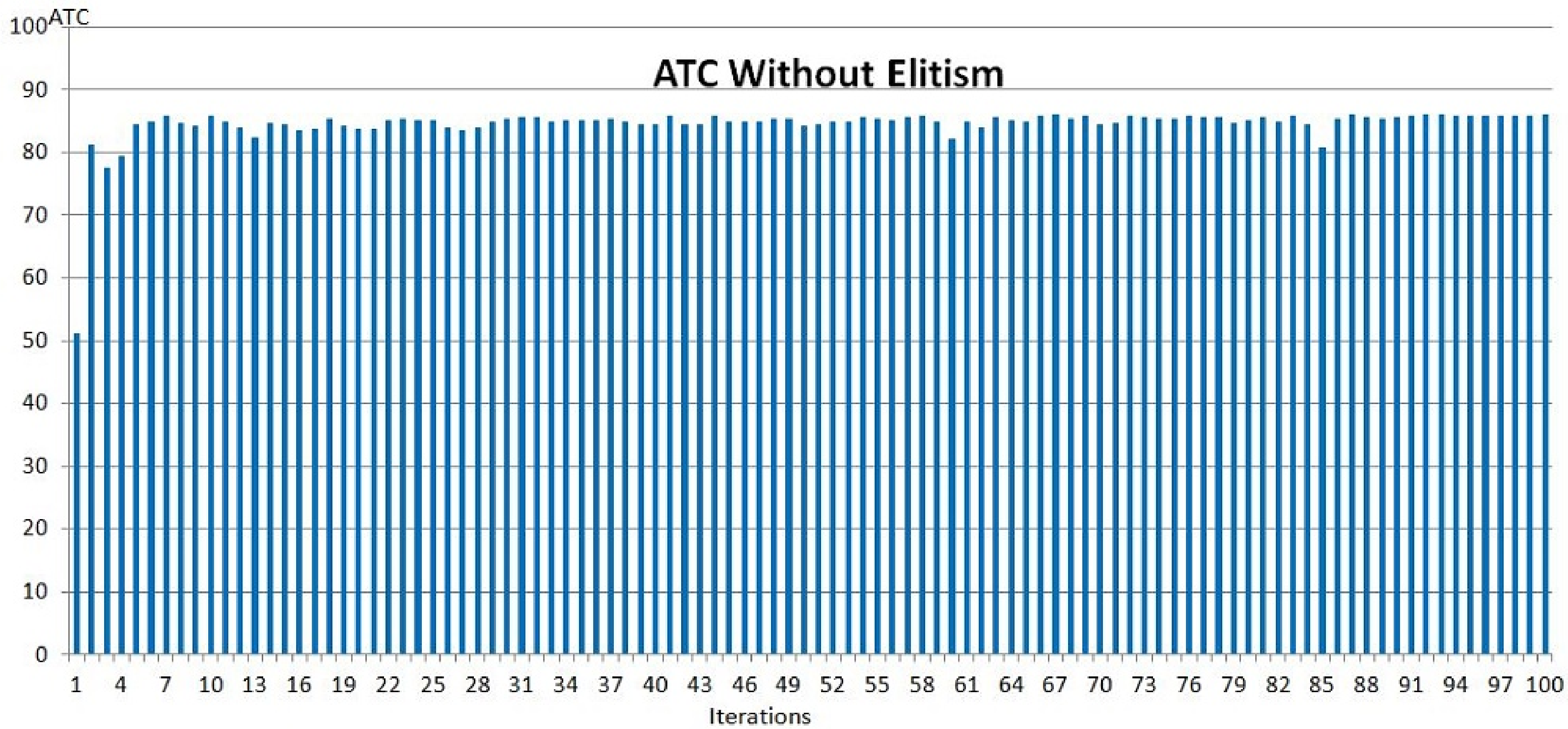

Figure 5.3: Optimized value of ATC using PSO without Elitism strategy for IEEE 30 bus test system for 1^{st} loading condition

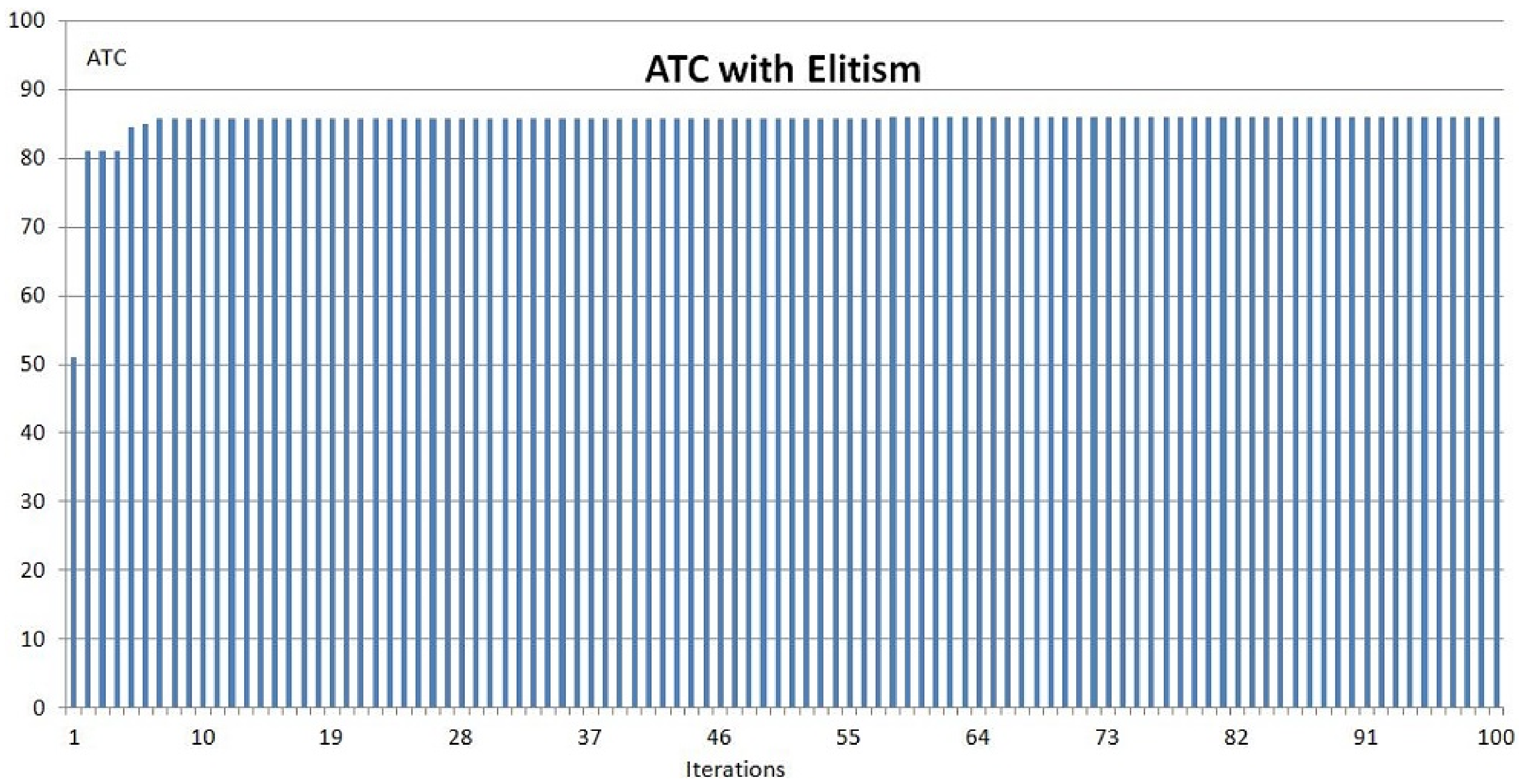

Figure 5.4: Optimized value of ATC using PSO with Elitism strategy for IEEE 30 bus test system for 1^{st} loading condition

Table 5.2: Comparison of Optimized ATC value without and with Elitism using PSO for IEEE 30 bus test system

MW Loading			Optimized ATC with out Elitism	Optimized ATC with Elitism
L_1	L_2	L_3		
10	15	22	85.982636	86.083976
12	19	25	95.313294	98.023415
20	10	21	67.433875	90.467516
5	13	9	61.248428	62.1218
22	46	10	85.456	86.332167
39	9	19	75.277342	75.277342
12	49	23	89.714956	89.714956
3	10	13	77.028916	80.542666
10	23	49	98.357276	103.313709
30	9	46	79.77496	79.77496

The load has been served by the generation at different generator bus for a specific load on load bus to determine optimized ATC. The Objective function has been evaluated for 98 transmission lines. The algorithm will drive the load in such a way that the ATC value should be optimized. The optimized value of ATC has been computed with proposed algorithm. The obtained value of ATC without Elitism has been revealed by per Table:5.4. The parameters used in PSO method has been listed in Table: 5.3.

Table 5.3: Structure of PSO for UPSEB 75 bus system

Sr.no	Parameter	Value
1	Number of Particles	10
2	Number of Variables	14
3	Maximum Iterations	100

The comparison has been presented in Table: 5.4 with and without elitism policy. The output with elitism and without elitism has been shown in Fig. 5.4.0.2 and Fig. 5.4.0.2 respectively for a specific load.

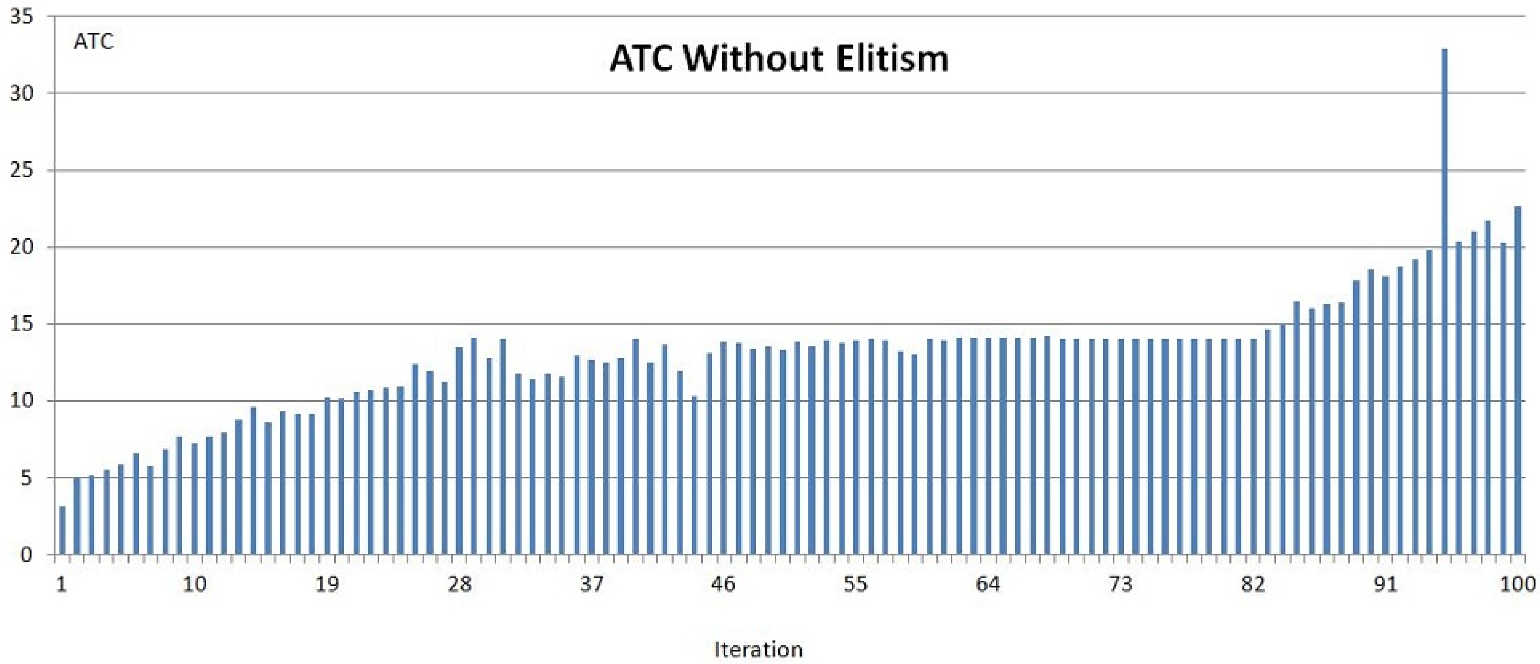

Figure 5.5: Optimized value of ATC using PSO without Elitism strategy for 75 bus UPSEB system for 1^{st} loading condition

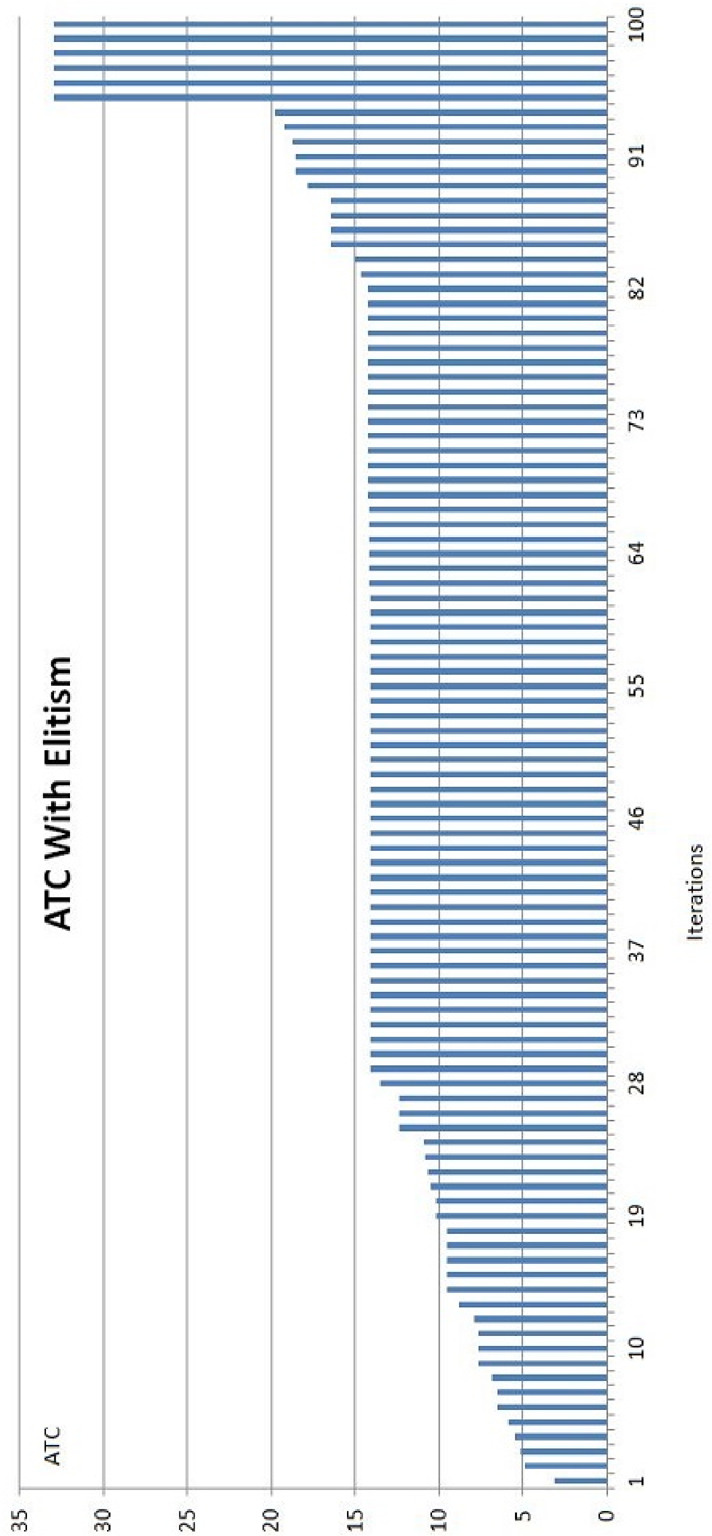

Figure 5.6: Optimized value of ATC using PSO with Elitism strategy for 75 bus UPSEB system for 1^{st} loading condition

Table 5.4: Comparison of Optimized ATC value without and with Elitism using PSO for 75 bus UPSEB system

MW Loading			Optimized ATC	Optimized ATC
L_1	L_2	L_3	with out Elitism	with Elitism
10	15	22	22.67355	32.926282
12	19	25	25.783807	32.242221
20	10	21	30.420965	34.171212
5	13	9	36.444164	40.590236
22	46	10	28.204306	28.204306
39	9	19	42.105862	42.105862
12	49	23	39.761575	47.781647
3	10	13	37.504354	40.578998
10	23	49	29.673329	32.309857
30	9	46	31.058901	31.421785

5.5 Conclusion

In this chapter, a new method for the computation of Available Transfer Capability (ATC) using PSO was developed for secure and stable operation of power system. The speed of PSO is greater than the all possible version of Genetic algorithms demonstrated. The present work has been demonstrated on two different systems namely; IEEE 30 bus test system and 75 bus UPSEB system. It is concluded from above tables and graphs that the PSO gives nearly same optimized ATC with and without elitism strategy.