Chapter 4

Evaluation of optimized value of Available Transfer Capability using Genetic Algorithm and Statistical Mathematical Modeling

4.1 Introduction

The congestion management in electrical power system has been identified as an integral part of modern energy management systems, but its real time implementation is still a exigent task to power system engineers. The geographical area and the transmission line capability has been fixed for a particular transmission line. The new line set-up is not possible because of large investment involved. Therefore, the Available Transfer capability (ATC) calculation has been recognized as a vital part of modern power system. The higher load demand or Outage of a transmission unit (line or transformer) or a generator may lead to over loading of other healthy lines and cause sudden change in power flow of transmission line results in unstable system. The optimized ATC calculation has a key role for secure power system operation. Different artificial intelligence techniques has been used for computation of ATC for reliable power system.

The Roulette Wheel Selection based Genetic Algorithm (RWSGA) and Tournament Selection Based Genetic Algorithm (TSBGA) has been extended in the present this chapter to compute ATC for secure and stable operation of power system and its effectiveness has been demonstrated on the IEEE 30 bus and 75 UPSEB system. The system consisting of total 41 lines has been evaluated for a given IEEE 30 bus system and 98 lines for 75 bus UPSEB system. The RWSGA and TSBGA methods has been used for selection of individuals to enter in to mating pool for the next generation for the calculation of ATC. The RWSGA method results noise (imperfectness) in output. The Tournament Selection Based Genetic Algorithm (TSBGA) gives improved results as compare to Roulette Wheel Selection Genetic Algorithm for the ATC calculation. The output data of optimized ATC for the specific load has been used for further analysis.

The said data has been analyzed by the statistical tool and derive a statistical model [77]for the specific system. From this statistical data analysis, the most sensitive generator for a specific load has been identified.

4.1.1 Genetic Algorithm

Darwins theory of survival of the fittest [78] has been used in a stochastic technique like GA. The other methods use deterministic rule while GA uses probabilistic evolution, which tends to move the solution towards a global optimum solution. In the case of GA, if initial guesses are weak, it may correct during successive iterations.

GAs are adjustable heuristic search algorithm depending upon the evolutionary thoughts of natural assortment and genetic. It is an intellectual utilization of an arbitrary search used to crack optimization problem. In nature, the rivalry between individual for insufficient resources results in the fitness individual ruling the weaker ones.

4.1.2 Steps for Genetic Algorithm

The following steps are required for the algorithm to perform a specific optimization problem.

1. Initialization of string length, population size m, crossover probability p_c, mutation probability p_m and maximum number of generations i_{max}.

2. Create$N$ random population and assess the fitness of every N strings.

3. Make out the process of reproduction or selection.

4. Make the crossover operation using crossover probability p_c and mutation using mutation probability p_m to generate new N strings.

5. Appraise the fitness of N strings of the new population.

6. If $i \geq i_{max}$, the calculations have been executed and so the process can be stopped. if not, set the generation number as $i = i + 1$ and go to step 3.

4.2 Different Methods to improvements in GA results

Different methods has been used for the improvement of the performance of GA. These methods are explained as under:

4.2.1 Roulette wheel selection based Genetic Algorithm

The stochastically production of one generation to build the basis of the next generation has been identify as the essential component of the assortment process. The weaker individual has lesser chance of survival than fittest ones. Hence the fittest individual will go forward to form a mating pool because of having a better probability of survival.

The roulette wheel selection (RWS), a genetic operator has been used in genetic algorithms for selecting very useful solutions for recombination. The fitness function allocates fitness to the possible solutions or chromosomes in fitness proportionate selection. To relate a probability of selection with each individual chromosome this fitness level has been used.

If the fitness of individual, f_i of individual i, then its probability has been given by Equation: 4.1.

$$Prob_i = f_i \cdot \frac{1}{\sum_{j=1}^{N} f_i} \tag{4.1}$$

Such type of situation has same effect like a Roulette wheel in a casino. Hence this type of selection method has been known as Roulette wheel selection based GA (RWSGA). Normally a share of the wheel has been allotted to each of the likely selections depending upon their fitness value. After that, the arbitrary selection has been made same as the rotation of roulette wheel. The result obtained from the RWSGA contains noise in its output. Hence, the correct value cannot be obtained with RWSGA. To cope-up with this problem, Tournament Selection based GA has been used for the betterment of the results. The specific load at load bus has been served by generator generator bus. The generations at generator bus has been varied to get optimized value of ATC.

4.2.2 Tournament Selection based Genetic Algorithm

In Genetic Algorithm (GA) Tournament selection [79] has been recognized as a very effective and vigorous selection mechanism.

Selection Pressure $P_s \propto$ Size of Tournament (T_s)

Tournament selection has been frequently used in concurrence with imperfectness (noisy) function. After deciding the tournament size and noise level of a noisy fitness function, predict the resulting selection pressure of tournament selection can be predicted. With this method, the understanding of delaying effect of function noise has been easy to compare.

In GA, numbers of selection schemes has been used with different characteristics. The selection pressure has most important factor for fine-tuning of the performance of the objective function. The selection mechanism has been used to choose individuals from the population to insert into the mating pool in GA. These individuals has been used to generate new offspring with the resulting offspring forming the basis of the next generation. Hence, it has been desirable that next mating pool should be filled with the individuals of good health.

Due to selection pressure, the better individual has been preferred. The selection pressure has been identified as the key driver of GA to perk up the population fitness over subsequent generation

Hence Convergence Rate $\propto$ Selection pressure

Genetic Algorithms (GA) are capable of recognizing optimal or near-optimal answers under a wide range of selection pressure [80]. The proper selection pressure is main factor for convergence. Tournament selection gives selection pressure by arranging a tournament among c (Size of the tournament) competitors. The winner (i.e with highest fitness value) of the tournament will enter into the mating pool for next generation. Hence mating pool will be filled with tournament champions has a superior average fitness than the average population fitness.

In tournament selection, all individual, selected randomly, has to play two tournaments with other. The winner of the tournament has highest fitness value. This winner will occupy their place at the mating pool. The crossover and mutation will take place for next generation.

4.2.3 Elitism

Elitist selection is a selection strategy where a limited number of individuals with the best fitness values are chosen to pass to the next generation, avoiding the crossover and mutation operators. Elitism prevents the random destruction by crossover or mutation operators of individuals with good genetics. The number of elite individuals should not be too high, otherwise, the population will tend to degenerate.

Elitism involves copying a small proportion of the fittest candidates, unchanged, into the next generation. This can sometimes have a dramatic impact on performance by ensuring that the EA does not waste time re-discovering previously discarded partial solutions. Candidate solutions that are preserved unchanged through elitism remain eligible for selection as parents when breeding the remainder of the next generation.

4.3 Problem formulation for optimization of Available Transfer capability

This section presents the calculation of optimized ATC with Genetic Algorithm. The accurate optimized ATC has been identified as the prime factor for congestion Management. The optimized ATC of any the system has been calculated for a specific loading condition with objective function. The objective function shown in 4.2 has been framed for the maximization of ATC.

4.3.1 Objective Function

$$Max(f_n(x)) = Max(ATC_n^{i-j}(P, PTCDF)) \tag{4.2}$$

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

4.3.2 Proposed Algorithm

1. Run load flow for the base-case with data file
2. interpret line flows.
3. Create populations for source buyer and supplier bus, through GA.
4. Alteration of bus data by inclusion of new transactions generated through GA.
5. Run a load flow to evaluate the objective function value of ATC (Available Transfer Capability) for all randomly generated population.
6. Convergence condition is verified (Is the transaction accomplished?)
7. Check if the answer to step (6) is no, go to step (3).
8. If the answer to step (6) is yes, print the result pertaining to the optimized value of ATC for a transaction between source and destination bus.

The flowchart for the proposed algorithm has been presented by Fig:4.1

4.4 System Studies and Results

The Roulette Wheel Selection based Genetic Algorithm (RWSGA) and Tournament Selection Based Genetic Algorithm (TSBGA) has been demonstrated on IEEE 30 bus Test system and 75 bus UPSEB system. The basic control parameters shown in Table:4.1

4.4.1 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

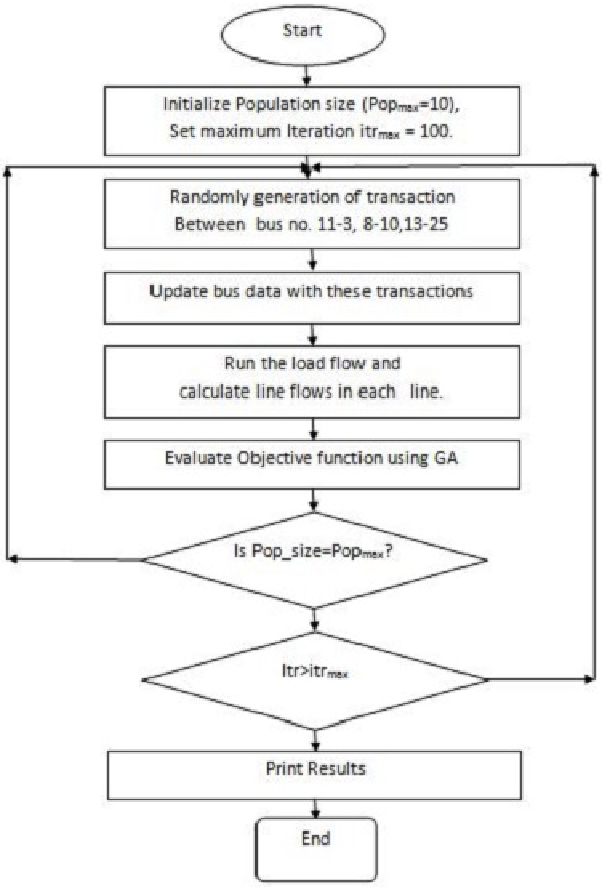

Figure 4.1: Flow chart for GA algorithm

this work, the generation at generator buses has been taken as decision variables for the optimization techniques. The generation at generator bus has been vary for the computation of optimized ATC. Total 41 transmission lines has to be evaluated with the help of the Genetic algorithm.

The Roulette Wheel Selection based Genetic Algorithm (RWSGA) and Tournament Selection Based Genetic algorithm (TSBGA) has been used for computation of optimized ATC with specific loading and generation at different generator taken as decision variable. The algorithm has been run for 100 iteration to evaluate objective function.

4.4.1.1 Roulette Wheel Selection based Genetic Algorithm

The RWSGA has been tested for the IEEE 30 bus system. The comparison between optimized ATC without and with Elitism strategy using RWSGA has been presented by

Table 4.1: Parameters for GA

Sr.no	Parameter	Value
1	Population Size	10
2	Maximum Iterations	100
3	Cross Over Probability	0.8
4	Mutation Probability	0.02
5	Chromosome length	30

Table: 4.2 after 100 iterations. The output without elitism and with elitism has been presented graphically in Fig: 4.4.1.1 and Fig: 4.4.1.1 respectively for a specific load. The Optimized ATC value for the different specific loading at bus number 3,10 and 25 with generation at source bus 2,5,11,8 and 13 of bus number has been determined.

4.4.1.2 Tournament Selection Based Genetic Algorithm

The results obtained from RWSGA contains noise in output results. This problem has been eliminated by Tournament selection based GA (TSBGA) by selecting the best individual to enter in to mating pool for the next generation. The result comparison between with an without elitism policy has been revealed by Table : 4.3. The objective function has been evaluated for 100 iterations and corresponding value ATC has been presented with Fig: 4.4.1.2 and Fig: 4.4.1.2 for with and without elitism policy.

Tournament selection based GA (TSBGA) method has been used to improve final output by selecting of the good population to enter into the mating pool for the next generation. In this policy, the good generations has been allowed to enter in the mating pool for next generation. After applying this method, the result has been improved as shown in Fig: 4.4.1.2 and the same has been recorded as per Table: 4.3. The noise in output has been reduced with TSBGA method as shown in Fig: 4.4.1.1 and Fig: 4.4.1.2. If the elitism strategy applied to TSBGA method, the result has been presented in Table: 4.3 and Fig: 4.4.1.2. There has been very small change in optimized ATC before and after application of elitism strategy as shown in Table: 4.3. Hence, the accurate value has been determined with TSBGA as compare to RWSGA.

Table 4.2: Comparison of Optimized ATC value without and with Elitism using RWSGA 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	86.42154	89.789673
12	19	25	65.096749	71.388545
20	10	21	65.336129	69.137691
5	13	9	40.653891	43.759039
22	46	10	62.095678	62.383257
39	9	19	69.176385	75.297539
12	49	23	97.791088	104.592484
3	10	13	70.602148	79.567558
10	23	49	83.907133	88.525314
30	9	46	65.761128	69.414347

Table 4.3: Comparison of Optimized ATC value without and with Elitism using TSBGA 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	89.88692	91.13095
12	19	25	98.030281	98.030281
20	10	21	68.777434	68.934981
5	13	9	88.497005	88.646535
22	46	10	67.22495	71.314538
39	9	19	80.702521	85.616266
12	49	23	80.206599	82.072934
3	10	13	73.879075	76.054904
10	23	49	70.00502	75.991023
30	9	46	86.519304	96.766622

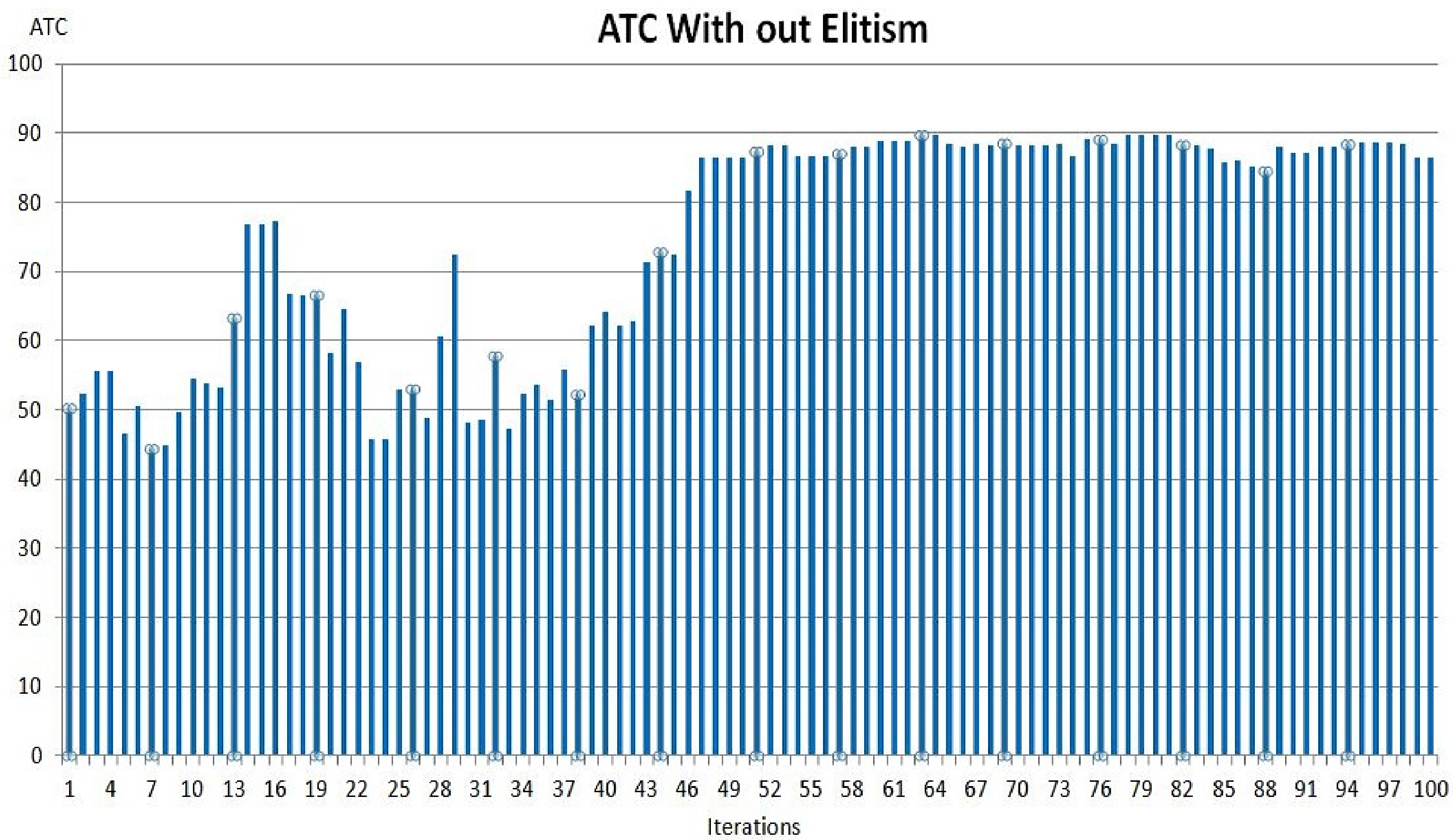

Figure 4.2: Optimized value of ATC using RWSGA without Elitism strategy for IEEE 30 bus test system for 1^{st} loading condition

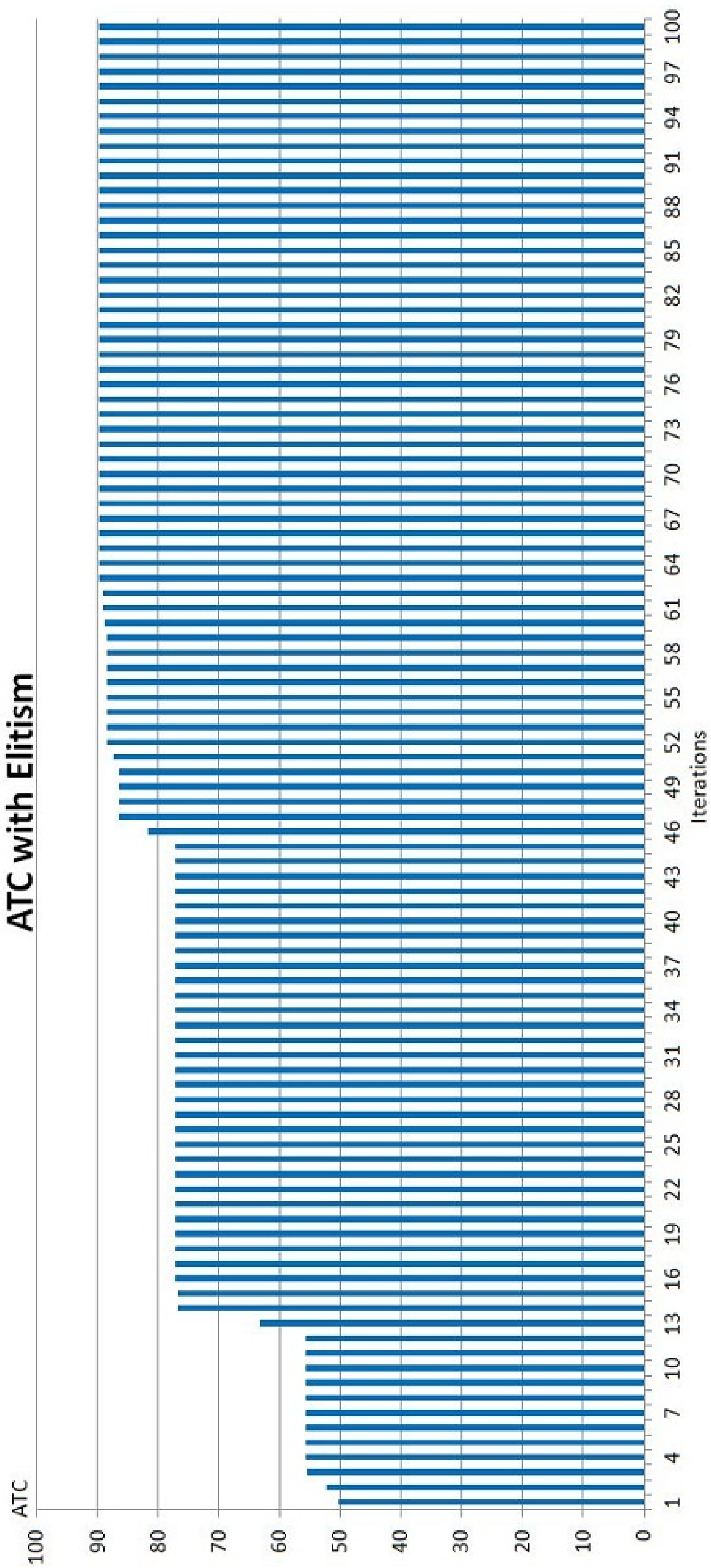

Figure 4.3: Optimized value of ATC using RWSGA with Elitism strategy for IEEE 30 bus test system for 1^{st} loading condition

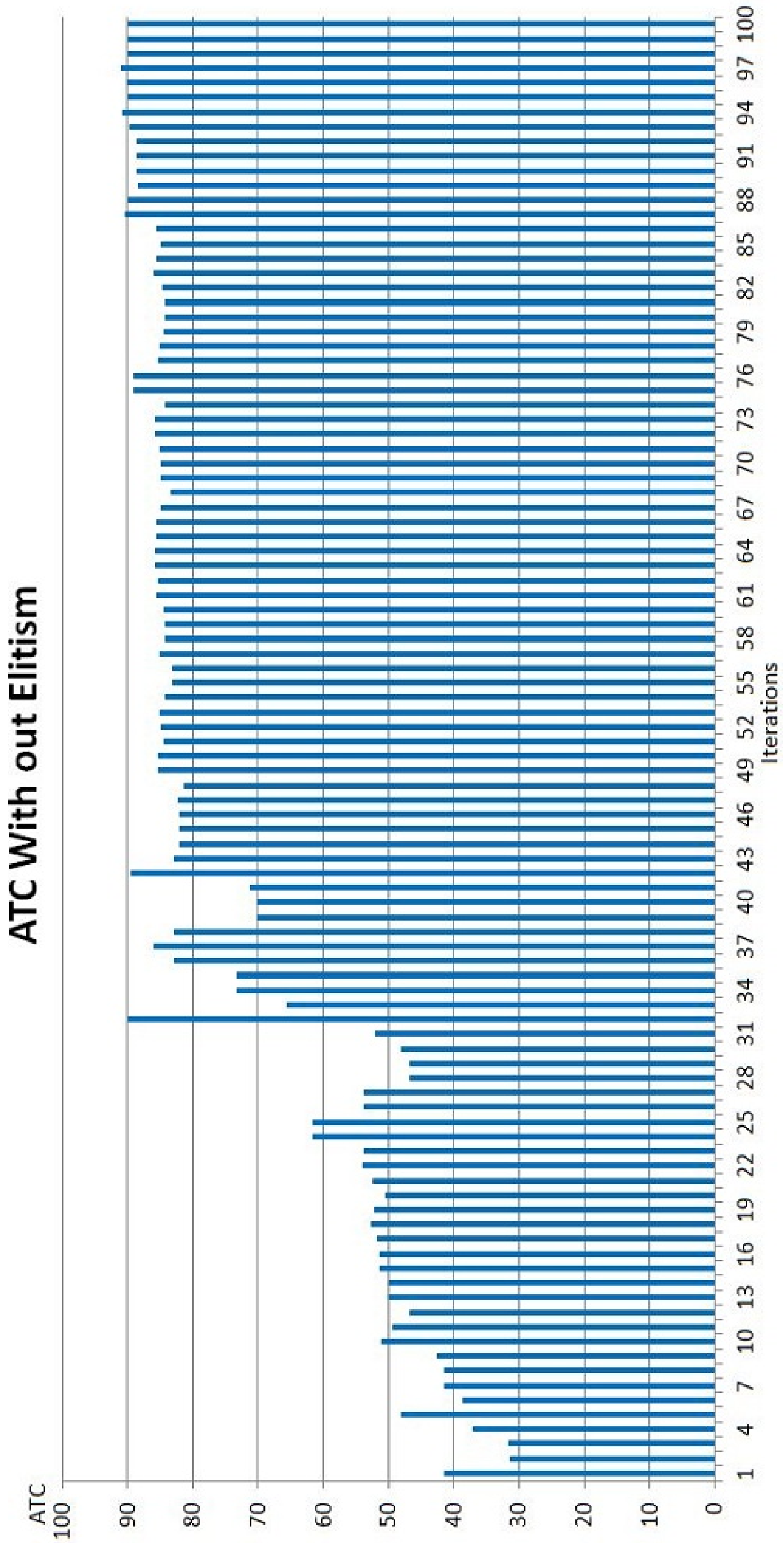

Figure 4.4: Optimized value of ATC using TSBGA without Elitism strategy for IEEE 30 bus test system for 1^{st} loading condition

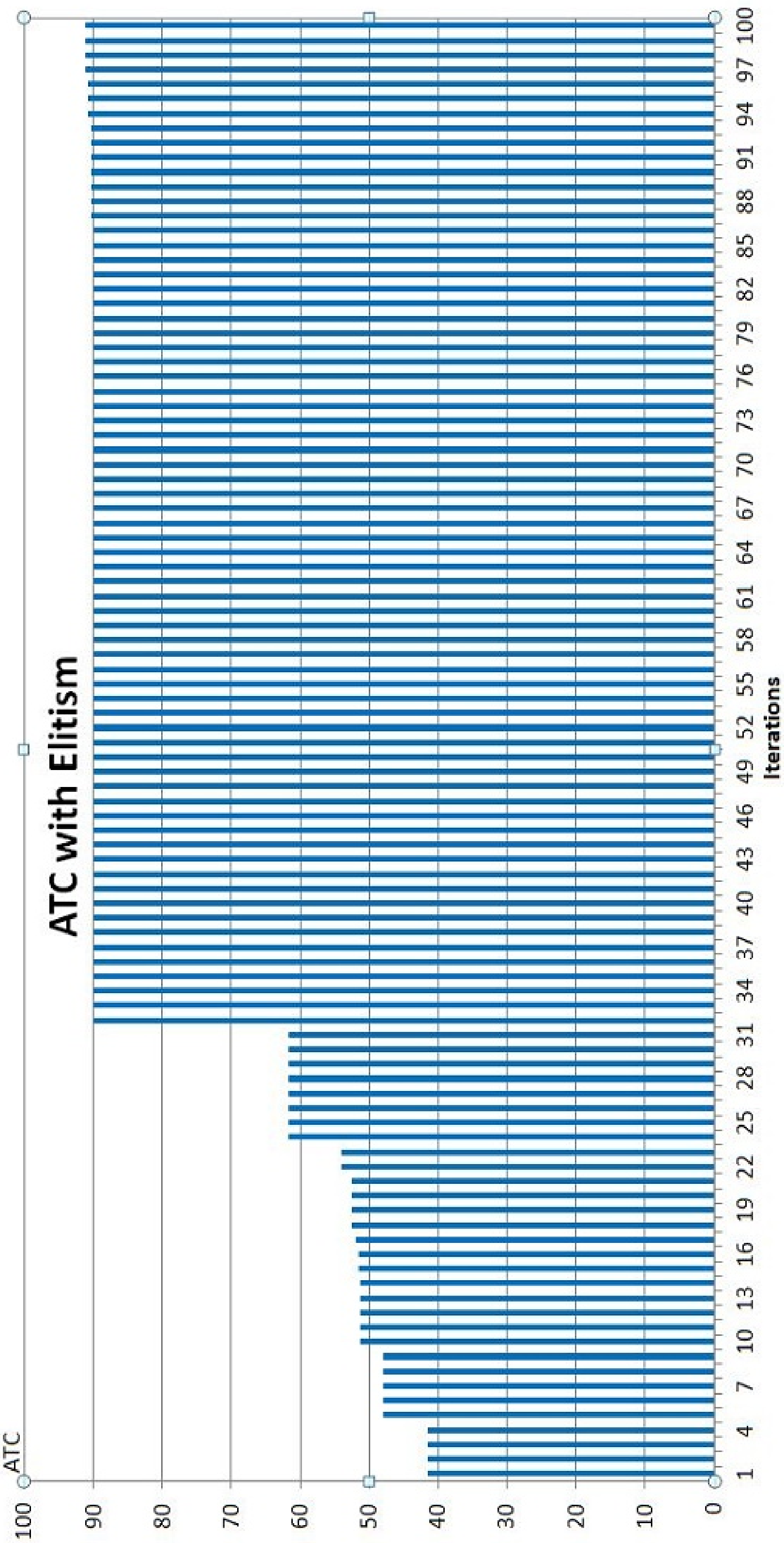

Figure 4.5: Optimized value of ATC using TSBGA with Elitism strategy for IEEE 30 bus test system for 1^{st} loading condition

4.4.2 UPSEB 75 bus system

The maximum capability of each transmission line has been shown in Annexure-B for the 75 bus UPSEB system. The load has been connected to load bus number 17,21 and 26. The load has been governed by 15 generator buses. The generator connected to bus number 2 to 15 has been taken as decision variables for the optimization problem. Hence, there are 14 decision variables are used in this method. The generation at different generator bus has been changed to serve a specific load on load bus to determine optimized ATC . The Objective function has been evaluated for 98 transmission lines. The obtained value of ATC without and with Elitism has been revealed by per Fig. 4.4.2.1 and Fig. 4.4.2.1 respectively. The Roulette Wheel Selection based Genetic algorithm (RWSGA) and Tournament Selection Based Genetic algorithm (TSBGA) has been used for computation of optimized ATC with specific loading and generation at different generator taken as decision variable. The algorithm has been run for 100 iteration to evaluate objective function.

4.4.2.1 Roulette Wheel Selection based Genetic algorithm

The 75 bus UPSEB bus system has been used for for testing of algorithm with and without elitism policy. The result comparison for the determination of optimized ATC without and with Elitism strategy using RWSGA has been presented in Table : 4.4 after 100 iterations. The output with elitism and without elitism has been shown graphically in Fig. 4.4.2.1 and Fig. 4.4.2.1 respectively for a specific load. The Optimized ATC value for the different specific loading at bus number 3,10 and 25 with the variation in generation at source bus 2 to 15 bus number has been determined.

4.4.2.2 Tournament Section Based Genetic Algorithm

The Tournament Selection Based Genetic algorithm (TSBGA) has been tested for 75 bus UPSEB system. The results has been obtained as per Table: 4.5 for with and without elitism strategy. The graphical presentation with and without elitism has been presented by Fig: 4.4.2.2 and Fig.: 4.4.2.2 respectively.

Tournament selection based GA (TSBGA) method has been used to improve final output by selecting of the good population to enter into the mating pool for the next generation. In this policy, the good generations has been allowed to enter in the mating

Table 4.4: Comparison of Optimized ATC value without and with Elitism using RWSGA for 75 bus UPSEB system

MW Loading			Optimized ATC with out Elitism	Optimized ATC with Elitism
L_1	L_2	L_3		
10	15	22	24.62645	26.850161
12	19	25	21.468735	25.134529
20	10	21	20.834415	23.2109
5	13	9	32.719976	44.87963
22	46	10	25.635157	29.334593
39	9	19	30.61402	39.476091
12	49	23	27.675697	38.9193
3	10	13	20.032358	29.110436
10	23	49	24.008925	30.056144
30	9	46	26.671055	27.212129

Table 4.5: Comparison of Optimized ATC value without and with Elitism using TSBGA for 75 UPSEB bus test system

MW Loading			Optimized ATC with out Elitism	Optimized ATC with Elitism
L_1	L_2	L_3		
10	15	22	20.30659	22.718797
12	19	25	22.345652	27.652131
20	10	21	23.557141	24.525382
5	13	9	34.933213	34.933213
22	46	10	27.928962	48.622252
39	9	19	21.162678	28.181166
12	49	23	16.853415	17.130285
3	10	13	33.519357	38.483096
10	23	49	16.496171	17.434039
30	9	46	26.750481	26.750481

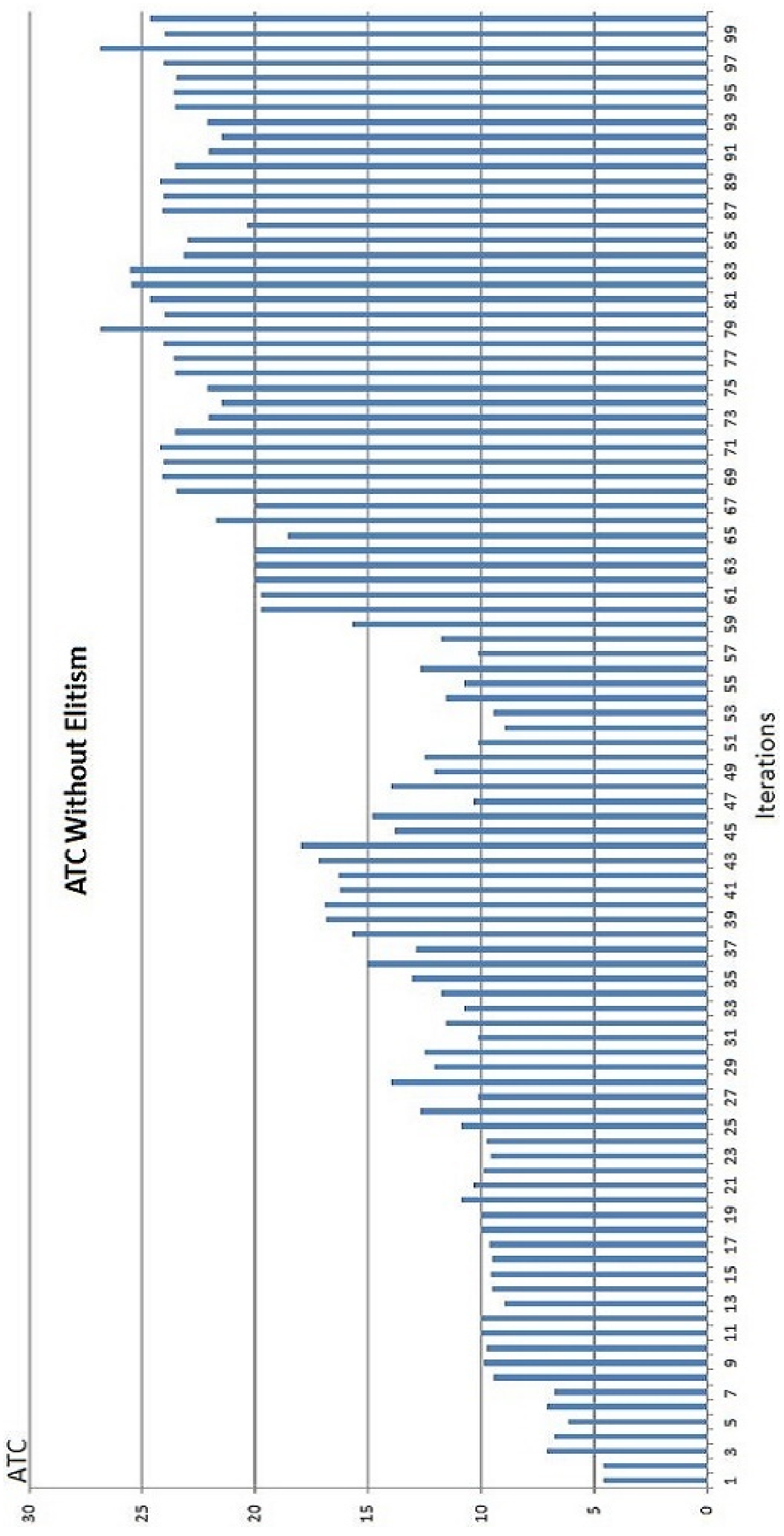

Figure 4.6: Optimized value of ATC using RWSGA without Elitism strategy for UPSEB 75 bus system for 1^{st} loading condition

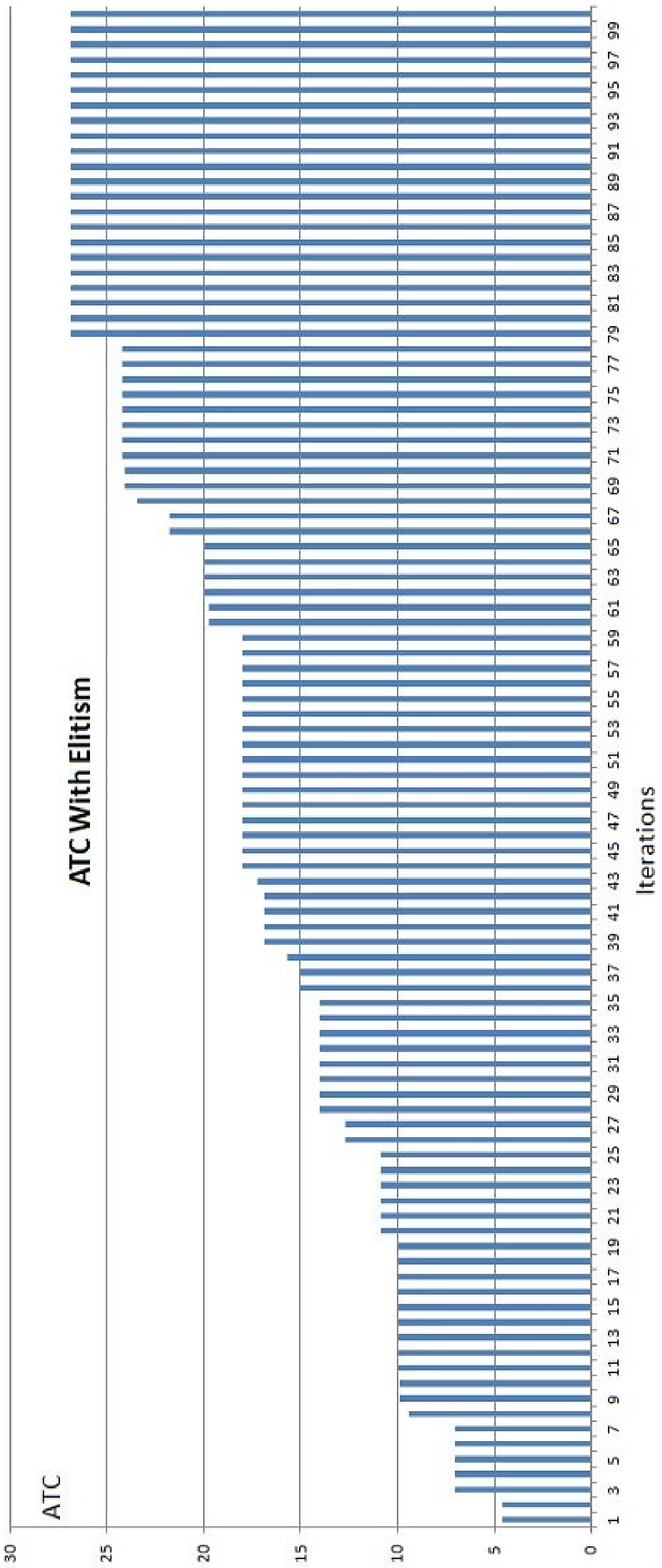

Figure 4.7: Optimized value of ATC using RWSGA with Elitism strategy for UPSEB 75 bus system for 1^{st} loading condition

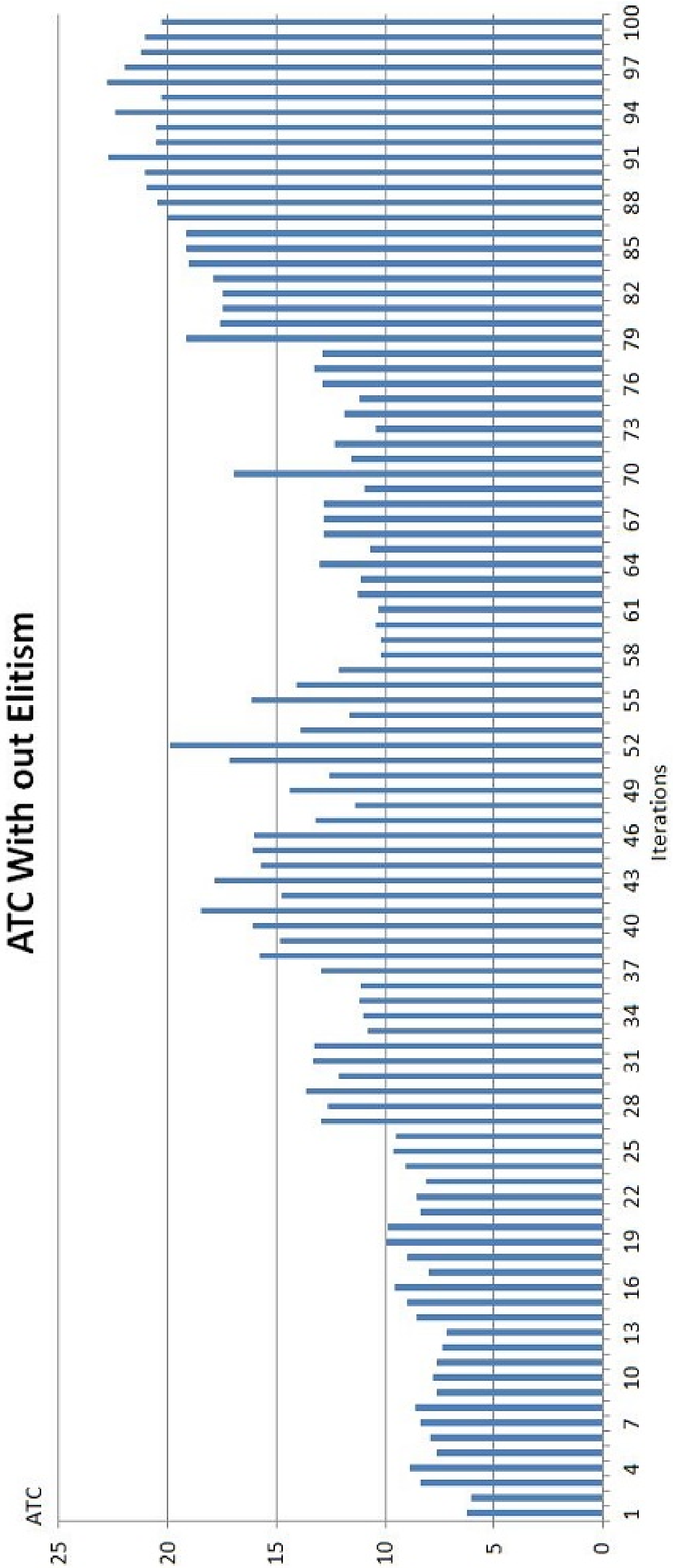

Figure 4.8: Optimized value of ATC using TSBGA without Elitism strategy for 75 bus UPSEB system for 1^{st} loading condition

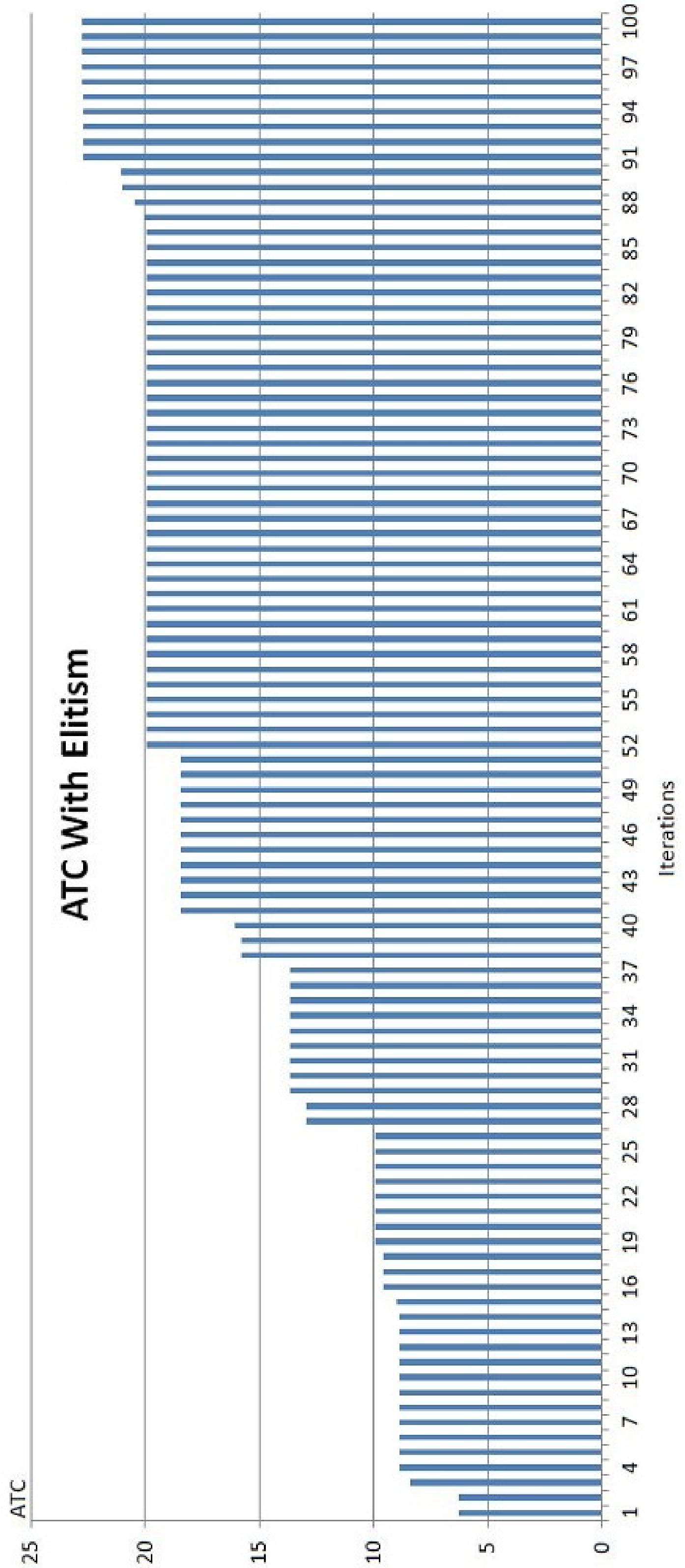

Figure 4.9: Optimized value of ATC using TSBGA with Elitism strategy for 75 bus UPSEB system for 1^{st} loading condition

pool for next generation. The result has been improved as shown in Fig: 4.4.2.2 and the same has been recorded as per Table: 4.5 with the help of this method. There has been very small change in optimized ATC before and after application of elitism strategy as shown in Table: 4.3. Hence, the accurate value has been determined with TSBGA as compare to RWSGA.

4.5 Statistical Model Analysis

In the above-discussed methods, the load flow has to be run for each iteration. The optimized ATC along-with generation at different generator bus for IEEE 30 bus using RWSGA has been used to frame a statistical model for the fast calculation ATC for a specific loading condition. This model will predict ATC from the data collected from TSBGA for IEEE 30 bus system. A generalized equation has been framed for ATC calculation with statistical model analysis. The statistical analysis has been limited with TSBGA algorithm applied to the IEEE 30 bus test system only in this chapter.

4.5.1 Mathematical Modeling using Multiple Regression analysis

Multiple linear regression attempts to model the relationship between two or more explanatory variables and a response variable by fitting a linear equation to observed data. Every value of the independent variable x (Generation at different generator bus) is associated with a value of the dependent variable γ (Available Transfer Capability). Multiple regression is an extension of simple linear regression. It has been used to predict the value of a variable based on the value of two or more other variables. The variable to predict is called the dependent variable (or sometimes, the outcome, target or criterion variable).

More than two independent variables in multiple regression analysis has been discussed in [77]. The main objectives of multiple regression has been list below:

- To obtain general equation for estimation of the dependent variable from values of the independent variables.
- To obtain a measure of error involved in the regression equation as a basis of estimation.

There are five independent variables and one dependent variable used in this work for regression analysis. $\gamma(ATC)$ has been identified as dependent variables and five dependent variables used for analysis. Hence, $\gamma(ATC)$ is the function of independent variables as per Eq. 4.3.

$$\gamma(ATC) = f(P_{11}, P_{22}, P_{33}, P_{44}, P_{55}) \tag{4.3}$$

If there are Five variables $P_{11}, P_{22}, P_{33}, P_{44}$ and P_{55}, the multiple regression has been presented by Eq. 4.4.

$$\gamma = \beta_0 + \beta_1 \cdot P_{11} + \beta_2 \cdot P_{22} + \beta_3 \cdot P_{33} + \beta_4 \cdot P_{44} + \beta_5 \cdot P_{55} \tag{4.4}$$

Where,

γ = Predicted Value of ATC.

$P_{11}, P_{22}, P_{33}, P_{44}$ and P_{55} are the Generation at generating bus for the specific loading condition

β_0 = Intercept.

β_1 = indicates slop of the regression line of P_{11} with $P_{22}P_{33}, P_{44}$ and P_{55} kept constant,

β_2 = indicates slop of the regression line of P_{22} with $P_{11}P_{33}, P_{44}$ and P_{55} kept constant,

β_3 = indicates slop of the regression line of P_{33} with $P_{11}P_{22}, P_{44}$ and P_{55} kept constant,

β_4 = indicates slop of the regression line of P_{44} with $P_{11}P_{22}, P_{33}$ and P_{55} kept constant,

β_5 = indicates slop of the regression line of P_{55} with $P_{11}P_{22}, P_{33}$ and P_{44} kept constant

For the multiple regression, there exists a *least square regression plan* fitting a set of N (number of loading condition) points. The equation for β has been derived from Equations 4.5 and 4.6.

$$\sum_{j=1}^{N} \gamma_j = \sum_{m=0}^{n} B_m \cdot \sum_{j=1}^{N} P_{mj} \tag{4.5}$$

where,

$\sum_{j=i}^{N} P_{0j} = \text{N}$

$n = 1, 2, \cdots 5$(Number of input variables)

$$\sum_{j=1}^{N} \gamma_j \cdot P_{kj} = \sum_{m=0}^{n} B_m \cdot \sum_{j=1}^{N} P_{kj} \cdot P_{mj} \tag{4.6}$$

where,

$P_{0j} = 1$

$k = 1, 2, 3 \cdots n$

From the equation number 4.5 and 4.6 following matrix has been formed.

$$[\gamma_R] = [\beta] \cdot [P] \tag{4.7}$$

where,

$[\gamma_R] = [\sum \gamma \cdot P]$.

$[\beta]$ = Coefficient of P.

$[P]$ = Dependent variable

The coefficients of P i.e $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ and β_5 has been evaluated from equation 4.8

$$[\beta] = [P]^{-1} \cdot [\gamma_R] \tag{4.8}$$

The Final value of β has been found from Eq. 4.9

$$[\beta] = \begin{bmatrix} 152.92 \\ -0.12 \\ -1.52 \\ -1.00 \\ -1.13 \\ 0.41 \end{bmatrix} \tag{4.9}$$

4.5.2 System Studies and Results

The coefficients of $P_{11}, P_{22}, P_{33}, P_{44}$ and P_{55} has been evaluated from the Eq. 4.8,and presented in Eq. 4.9. After evaluating the value of coefficient, the generalized equation has been derived as per Eq. 4.10 for calculation of optimized ATC along with required generation at generator bus for a specific loading condition.

After the regression analysis of the data, the predicted value of ATC has been computed from the Eq. 4.10 by substituting $P_{11}, P_{22}, P_{33}, P_{44}$ and P_{55} and tabulated in Table: 4.6.

$$\gamma(ATC) = 152.92 - 0.12 \cdot P_{11} - 1.52 \cdot P_{22} - 1.00 \cdot P_{33} - 1.13 \cdot P_{44} + 0.41 \cdot P_{55} \quad (4.10)$$

The Mean Absolute Percentage Error has been determined from the Equation 4.11.

$$MAPE = \frac{1}{N}\sum_{i=1}^{N} \cdot \frac{(ATC_{actuali} - ATC_{predicted_i})}{(ATC_{actual_i})} \quad (4.11)$$

Where, N = Number of iterations

The Table 4.6 presents the comparison between ATC calculated by the TSBGA algorithm and predicted by statistical model analysis for specific generation at different generator bus for specific load (10,15,22 MW) at load bus number 3,10 and 25.

Table 4.6: Comparison between Actual value and Predicted value using statistical analysis using TSBGA algorithm for IEEE 30 bus test system for 1^{st} loading condition

MW Generation					Calculated	Predicted	Absolute percentage
P_1	P_2	P_3	P_4	P_5	Optimized ATC	Optimized ATC	Error
43.01	0.34	40.32	33.28	41.10	85.90	86.01	0.12
43.01	1.91	39.54	32.99	42.62	84.83	85.36	0.63
43.01	1.66	39.98	34.26	41.06	83.09	83.21	0.15
43.01	1.66	39.98	34.26	41.06	83.09	83.21	0.15
42.23	1.86	39.88	32.94	43.50	85.14	85.60	0.55
39.88	1.71	39.49	34.26	40.66	84.38	83.84	0.64
46.38	1.66	39.88	33.48	43.40	84.97	84.76	0.25
46.38	1.66	39.88	33.48	43.40	84.97	84.76	0.25
44.62	1.66	39.98	33.48	43.40	85.22	84.87	0.41
43.26	0.10	39.98	33.48	41.06	85.87	86.45	0.68
40.08	1.66	39.98	33.48	41.06	84.27	84.45	0.21
40.08	1.66	39.98	33.09	41.84	85.10	85.21	0.13
43.21	1.66	40.37	33.48	42.86	84.25	84.43	0.21
40.08	1.66	40.37	31.92	42.86	85.97	86.57	0.70
43.21	1.66	39.98	31.62	43.60	86.81	87.22	0.47
43.21	0.29	40.37	31.48	43.60	89.41	89.08	0.37
43.21	0.15	40.37	31.92	42.82	89.01	88.48	0.59
43.60	0.34	39.98	31.52	42.82	88.43	88.97	0.61
43.70	0.34	39.98	31.92	42.86	89.08	88.54	0.61
40.57	0.34	39.98	32.01	42.86	89.13	88.80	0.37
						MAPE	0.41

For IEEE-30 bus system, the statistical model has been framed using 50 training

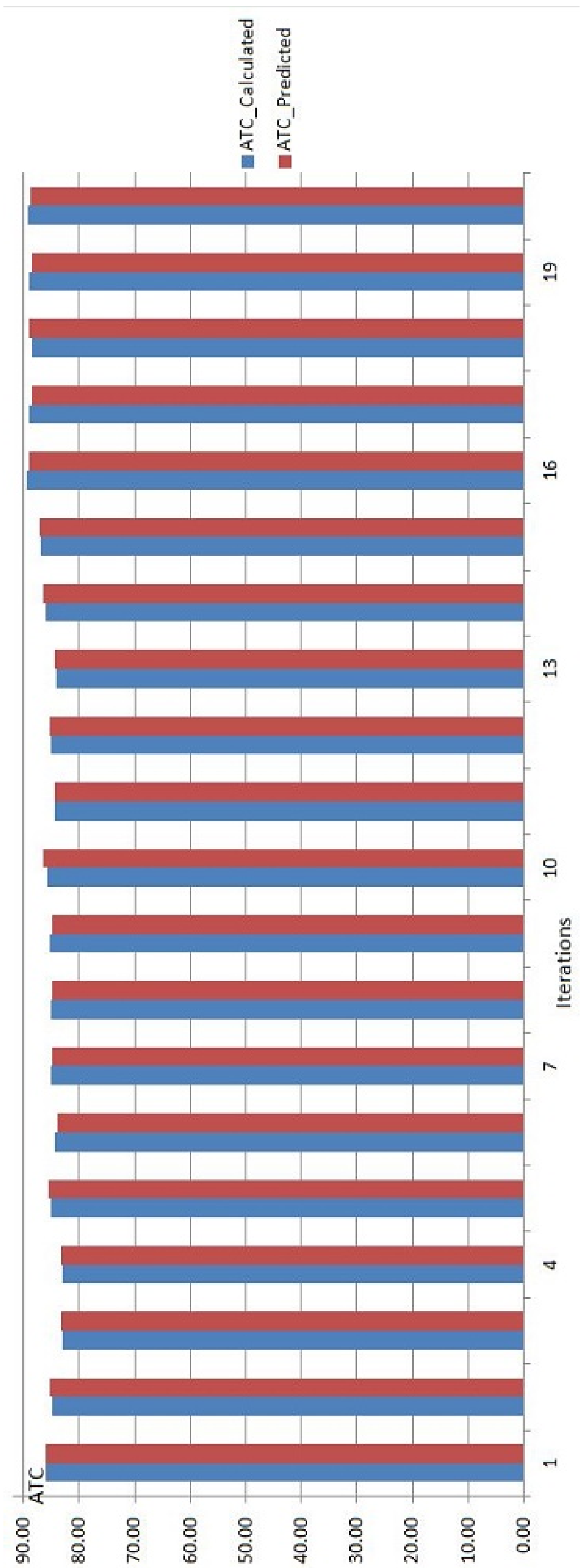

Figure 4.10: Graphical representation of Actual and predicted value of ATC using Statistical model for 1^{st} loading condition

Table 4.7: Error in Prediction of ATC using statistical analysis for IEEE 30 Bus system

Test system	Percentage Error		
	MAPE	Max. Error	Min. Error
IEEE 30 bus test System	0.41	0.70	0.12

patterns corresponding to different generation conditions for a specific load. After mathematical model preparation, the model was tested for 20 novel test patterns. These test patterns were not included in the training patterns. During testing, the absolute average percentage error,the absolute maximum error and absolute minimum error were found to be 0.41 %, 0.70 % and 0.12 % respectively. The Predicted ATC and Calculated ATC with different generations at generator nodes for a specific load 10 MW,15 MW and 22 MW at bus number 3, 10 and 25 respectively has been shown in Table4.6 using statistical model analysis. The comparison between of actual and predicted value obtained from statistical analysis has been publicized by Fig. 4.5.2

4.6 Conclusion

In this chapter, a new method for the computation of Available Transfer Capability (ATC) using RWSGA and TSBGA methods was developed for secure and stable operation of power system. The optimized value of ATC calculated by Roulette wheel selection based Genetic algorithm (RWSGA) results noise (Imperfectness) in the output. As in Genetic Algorithm, the decision variables has been selected randomly, the good results are escaped from the output. For the improvements in output,the elitism strategy has been applied to GA. For the betterment of ATC value computation, the Tournament selection method has been proposed to compute optimized ATC with less noise in output results.

For the real time operation, the calculation of ATC should be as fast as possible. To conquer with this situation, the statistical model has been designed to predict ATC. The data collected from TSBGA i.e the generation value with specific load and corresponding ATC value has been used to frame statistical model. As shown in Table : 4.7 the Mean Absolute Percentage error,maximum percentage error and min percentage error are $0.41\%, 0.70\%$ and 0.12% respectively for IEEE 30 bus system.

The coefficient of $P_{11}, P_{22}, P_{33}, P_{44}$ and P_{55} has been computed from the Eq. 4.10. The coefficient of P_{55} has been identified as more positive as compared to other coefficients. Hence, the generation P_{55} has been more sensitive generation to the specific load. As the load increases, the generation P_{55} increases by 0.41 factor. The optimized ATC value has been evaluated by substituting value of $P_{11}, P_{22}, P_{33}, P_{44}$ and P_{55}in Eq.4.10 for the specific load. The model developed is sufficiently accurate and used for prediction of ATC along-with generation at generator bus for a specific loading condition.