Optimal Selection and Allocation of Generator For Static ATC Using Differential Evolution Algorithm

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Abstract— In restructured power market, power producers and customers utilize the transmission network and try to maximize their benefits. Hence it is important to improve the static ATC for allowing more transaction in future without any transmission limit violation. This paper suggests the method for establishing bilateral/multilateral transaction based on the optimal generator selection and it's sharing towards load demand. The Differential Evolution Algorithm (DEA) is used as an optimization tool to solve the proposed method. The ATC values are calculated by selecting optimal loading factor. The proposed method is tested on IEEE 24 bus Reliability Test System (RTS) and IEEE 118 bus system.

Keyword- Available Transfer Capability, Bilateral Transaction, Deregulation, Differential Evolution Algorithm.

I. INTRODUCTION

In a Deregulated Environment of Electricity market, number of new profit based electricity trade has been introduced thus making the market more competitive. Bilateral/multilateral is one of the new electricity trades in deregulated environment which gives more profit to the sellers/dealers (GENCO'S) [1]. So all the GENCO'S try to form optimum transactions which give more profit to them. Here transaction refers to transfer of power from one location to another location. A bilateral contract in a deregulated electricity market is an agreement between a willing buyer and a willing seller to exchange electricity. A bilateral transaction between a supplier and a buyer involves the injection of power at one location in the network and the extraction of the same amount of power, at the same time, at another location [2]. Each bilateral transaction should, therefore, be represented by a Source (positive injection) connected to the point of injection and a sink (negative injection) connected to the point of extraction. Mathematically, each bilateral transaction between a seller at bus-*i* and power buyer at bus *j* satisfy the following power balance relationship.

$$P_{gi} - P_{dj} = 0 \qquad (1)$$

Where P_{gi} and P_{dj} are the power injection at seller bus *i* and power taken by the buyer bus *j*.

Multilateral transactions are an extension of bilateral transactions. In a multilateral transaction, there are many generation points (at least more than one), similarly there are many load points (at least more than one). In the case of multilateral transaction, the summation of power injected in different buses i is equal to the summation of load powers taken out at various buses *j*.

$$\sum_i P_{gi}{}^k - \sum_j P_{dj}{}^k = 0 \qquad Where\ \ k = 1,2.....,t_k \qquad (2)$$

Where P_{gi} and P_{dj} are the power injection from the seller bus and power taken by the buyer bus respectively and t_k is the total number of transactions.

The source and the sink are assumed to have the same size (transaction rate in MW). The conceptual model of bilateral structure is that Genco's and Disco's enter into transaction contracts where the quantities traded and the prices are at their own discretion and not a matter for the ISO i.e. a bilateral transaction is made between a Genco and a Disco without third party intervention. These transactions are then submitted to the ISO. In the absence of any congestion on the system, the ISO simply dispatches all the transactions that are requested, making an impartial charge for the service. But it's the responsibility of ISO to ensure that fair use of transmission system, then only all other utilities also efficiently utilize the transmission system.

A number of methods have been proposed for improving ATC using FACTS devices in the literature. An OPF based static ATC enhancement using third generation FACTS devices such as STATCOM, UPFC, and

SSSC is discussed in Ref [3]. In [4] dynamic ATC enhancement using FACTS devices is proposed in which the sensitivity of the structure preserving energy margin with respect to the FACTS controller parameters has been used to obtain the optimal location of the STATCOM and the UPFC. A Particle Swarm Optimization (PSO) approach for optimal location and optimal setting of TCSC, SVC and UPFC for static ATC enhancement is discussed in Ref [5] in which the cost of FACTS devices installation is considered. From literature review most of the author uses FACTS devices to improve the ATC. Placement and setting of FACTS devices in a power system to improve ATC is very challenging issue also the cost of FACTS devices are very high. So to improve the ATC, a new way has to be found by utilizing intact system more effectively. In [6] a new approach of ATC improvement is presented by optimally sharing the two randomly selected generators using genetic algorithm. Along with share ratio if optimal generator is also taken for transaction it may further improve ATC. So improve the ATC to maximum level, the generators also be selected optimally. For that this paper suggests the method of establishing the bilateral transaction based on optimal generator selection and its share to maximize the utilization of the power system. It will help the ISO to maintain reliability of the network without any congestion. The Utility can improve their operating limit and procure surplus power from the established transaction by selecting the optimal IPPs. And also it improves the system Available Transfer Capability (ATC).

ATC is nothing but the ability of a network to reliably transfer electric power between two points in the system under certain network conditions [7].Mathematically, ATC is defined as the Total Transfer Capability (TTC) less the Transmission Reliability Margin (TRM), less the sum of Existing Transmission Commitments (ETC) (which includes retail customer service) and the Capacity Benefit Margin (CBM). Mathematically it is written as,

$$\mathrm{ATC} = \mathrm{TTC} - \mathrm{TRM}(\sum \mathrm{ETC} + \mathrm{CBM}) \tag{3}$$

For the sake of simplicity, TRM and CBM are assumed to be zero. The information of ATC will help market participants to reserve transmission services well in advance for optimal commercial use of transmission network. Determination of ATC considering static limits such as line thermal limit, bus voltage limit and steady state stability limit constraints is termed as static ATC.

There are several methods and tools available in the literature to calculate static ATC. Christie et. al. [8] proposed a technique based on DC load flow for ATC estimation. This method is easy and computationally fast, but voltage and reactive power is not taken into consideration. Due to the approximations involved in DC power flows, AC Power Transfer Distribution Factor (ACPTDF) [9] method has gained importance. Ajjarapu et. al. [10] proposed Continuation Power Flow (CPF) for ATC computation. This method involves predictor, parameterization, corrector and step-size control as discussed by Chiang et. al. [11]. The CPF, in spite of its popularity has the disadvantage of complex mathematical computations. Repeated Power Flow (RPF), repeatedly solves power flow equations at a succession of points along the specified load generation increment as discussed in reference [12].This method is iterative in nature and so it takes more time to estimate ATC for large systems.

To calculate ATC, traditional deterministic approach is based on the severest case, but the approach has the complexity of procedure. Many optimization methods have been proposed to evaluate ATC, which include several classic optimal algorithms, such as Interior Point method [13], Newton method [14] and Quadratic programming approach [15]. However, dealing with the problem of large-scale nonlinear system, almost all classic optimal algorithms have common defects such as slowly computing speed and unsatisfactory robustness for their single-searching strategy [16]. Recently, evolutionary computation techniques such as Genetic Algorithm [17] and Particle Swarm Optimization (PSO) [18] have been applied to calculate the ATC values. Both Genetic Algorithm and PSO suffer from computational burden and memory. Also, the premature convergences degrade their performance and reduce its search capability. The Available Transfer Capability (ATC) of an interconnected power system is becoming an important concern of both system planners and operators. Due to the advent of open transmission access, the ATC calculations should produce commercially viable results with a reasonable and dependable indication of the transfer capabilities available to the electric power market. This paper proposes a Differential Evolution Algorithm (DEA) for selecting optimal generation and its share to establish the bilateral and multilateral transactions and also to calculate ATC values by selecting optimal loading factor for those transactions. DE [19-20] is an evolutionary algorithm that uses rather greatly selection and less stochastic approach to solve optimization problems than other evolutionary algorithms. The main features of DE are its simple structure, convergence property, quality of solution and robustness. It is used for solving complex constrained non-linear optimization problem. DE uses the difference of randomly sampled pairs of object vectors to guide the mutation process which makes it relatively new when compared to other algorithms. This method is implemented on IEEE RTS 24 Bus system and IEEE118 Bus system.

II. PROBLEM FORMULATION

The optimization problem of this approach is to maximise the ATC value. The objective function is to select optimal generators and its share for establishing the bilateral transaction and find the optimal loading factor for calculating ATC for those transactions.

As discussed in section 1, ATC is defined as the additional power that can be transmitted through a specified interface over and above the already committed transactions. This is stated as maximize,

$$F = Max(ATC) \tag{4}$$

Where

$$ATC = \sum_{i=1}^{n} P_{di}^{old} * \lambda_{opt} - P_{di}^{old}$$

Where n is the total number of load buses taken for the transaction and P_{di}^{old} is the base case load at i^{th} bus. λ_{opt} is the optimal loading factor.

The increased new power in the seller bus is calculated as,

$$P_{gj}^{new} = \sum_{j=1}^{k} \beta_{gk} * \Delta P_{di} + P_{gj}^{old}(opt) \tag{5}$$

Where k is the number of optimum generator buses taken for the transaction, β_{gk} is the optimum generation share ratio for k generators, ΔP_{di} is the change in load demand of i^{th} bus from its base case value and $P_{gj}^{old}(opt)$ is the base case power of j^{th} optimal generator.

Subject to,

Real power balance equation

$$P_i - V_i \sum_{j=1}^{N_B} V_j \left[G_{ij} \cos\theta_{ij} - B_{ij} \sin\theta_{ij} \right] = 0 \quad \text{, Where} \quad i = 1, 2 .... N_{B-1} \tag{6}$$

Reactive power balance equation

$$Q_i - V_i \sum_{j=1}^{N_B} V_j \left[G_{ij} \sin\theta_{ij} - B_{ij} \cos\theta_{ij} \right] = 0 \quad \text{Where} \quad i = 1, 2 .... N_{PQ} , \tag{7}$$

The inequality constraint on real power generation P_{gi} at each PQ bus

$$P_s^{\min} \le P_s \le P_s^{\max} \tag{8}$$

The inequality constraint on reactive power generation Q_{gi} at each PV bus

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max} \tag{9}$$

$$Q_{di}^{new} = Q_{di}^{old} * \lambda_{opt} \tag{10}$$

$$\Delta P_{Di} = \Delta P_{Gk} \tag{11}$$

The inequality constraint on voltage magnitude V of each PQ bus

$$V_{\min} \le V \le V_{\max} \tag{12}$$

The inequality constraint on phase angle $_i$ of voltage at all the buses i

$$\theta_i^{\min} \le \theta_i \le \theta_i^{\max} \tag{13}$$

MVA flow limit on transmission line

$$S_{ij\min} \le S_{ij} \le S_{ij\max} \tag{14}$$

$$\sum_{j=1}^{k} \beta_{gk} = 1 \tag{15}$$

Where

G_{ij}, B_{ij}	Conductance and Susceptance of transmission line Connected between i^{th} and j^{th} bus
P_i, Q_i	Real and Reactive power injection of i^{th} bus
P_s	Real power generation of slack bus
Q_{gi}	Reactive power generation at bus i
N_{PV}	Number of voltage buses
N_B	Total number of buses
N_{PQ}	Number of load buses
N_{B-1}	Total number of buses excluding slack bus
ΔP_{GK}	Change in generation of source bus from its base case value
$V_{min,}$	Minimum voltage limit in all the buses
V_{max}	Maximum voltage limit in all the buses
S_{ij}	MVA limit of all branches

III. OVERVIEW OF DIFFERENTIAL EVOLUTION ALGORITHM

Differential Evolution is a population-based stochastic search algorithm that works in the general framework of evolutionary algorithms. The working of DE is similar to that of Genetic algorithm (GA) except mutation process. In GA, mutation is carried out by changing the genes but in DE, the mutation is carried out on the arithmetic combinations of the randomly generated or best individuals from the whole population. The various operations of DE are initialization, mutation, crossover and selection. The various processes of DE are given below.

A Initialization

The first step of DE optimization process is initialization of population. In initialization process all candidates are randomly generated as a real valued number within its corresponding feasible bounds using the expression

$$X_{ij}^{G} = X_i^{\min} + rand_i[0,1]*(X_i^{\max} - X_i^{\min}),\ i=1\ldots.D \text{ and } j=1\ldots NP \tag{16}$$

Where, NP is number of population and D is number of decision parameter of the problem. x_i^{min} and x_i^{max} are the lower and upper bounds of the i^{th} decision parameter, respectively. $rand_i[0,1]$ represents a uniformly distributed random value in the range [0,1]. Once every vector of the population has been initialised, its corresponding fitness value is calculated and stored for future reference.

B. Mutation

During mutation, three random vectors are selected from current population. The mutation is carried out on randomly selected vector X_{r1}^{G} with the difference of two other randomly selected vectors X_{r2}^{G} and X_{r3}^{G}. The mutation vector is generated using the formula (17)

$$V_i^{G} = X_{r1}^{G} + F*(X_{r2}^{G} - X_{r3}^{G}) \tag{17}$$

Where F is scaling factor, which is typically chosen from within the range [0, 1].

C. *Crossover*

The next step of DE optimization process is crossover. In this step, by applying crossover operation between target vector and mutant vector a trial vector $U_i^{(G)}$ is created according to a selected probability distribution

$$U_i^{(G)} = U_{j,i}^{(G)} = \begin{cases} V_{j,i}^{(G)} & if \quad rand_j(0,1) \le CR \quad or \quad j = s \\ X_{j,i} & otherwise \end{cases} \tag{18}$$

The crossover constant *CR* is a user-defined value (known as the “crossover probability”), which is usually selected from within the range [0, 1]. The crossover constant controls the diversity of the population and aids the algorithm to escape from local optima. $rand_j$ is a uniformly distributed random number within the range (0, 1) generated a new for each value of *j*. *s* is the trial parameter with randomly chosen index {1,…, *D*}, which ensures that the trial vector gets at least one parameter from the mutant vector.

D. Selection

Selection is final operation of DE procedure. This operator compares the fitness of the trial vector and the corresponding target vector and selects the one that provides the better solution. This selected vector is then treated as target vector for next generation.

$$X_i^{(G+1)} = \begin{cases} U_i^{(G)} & if \quad f(U_i^{(G)}) \le f(X_i^{(G)}) \\ X_i^{(G)} & otherwise \end{cases} \tag{19}$$

The feature of DE selection scheme is that a trial vector is compared with only one individual, not all the individuals in the current population.

IV. IMPLEMENTATION OF STATIC ATC USING DE

When applying DE to calculate the ATC, two main issues need to be addressed

- Representation of the decision variables and
- Formation of the Fitness function

A. Variable Representation

Each individual in the genetic population represents a candidate solution. In this paper the loading factor, generator and its corresponding share ratio are taken as the decision variables. The generators are represented by integer points. The remaining variables are represented as floating point numbers in the DE population. The lower and upper bound for generator and its share has not changed for different transactions. It is taken as constant for all types of transactions. But the lower and upper bound for loading factor may vary for different transactions.

B. *Fitness Function*

Evaluation of the individuals in the population is accomplished by calculating the objective function value for the problem using the parameter set. The result of the objective function calculation is used to calculate the fitness value of the individual. Fitter chromosomes have higher probabilities of being selected for the next generation. The fitness function is given below.

$$ATC = \sum_{i=1}^{n} P_{di}^{\;old} * \lambda_{opt} - P_{di}^{\;old} \tag{20}$$

C. Proposed Algorithm

The proposed DE solution for ATC problem is composed of the following steps

1. Read bus data, generator data, and branch data and specify the load demand (sink) bus for which the transaction has to be established.
2. Read data for DE operations i.e. maximum generation limit, number of population, number of decision Variables, lower and upper limit of decision variables, scaling factor F and Crossover rate.
3. Set generation Gen=0.
4. Generate population randomly according to Eq. (16), with loading factor, generator and its share as the decision variables, where the decision variables are within its feasible bound.
5. For each population of parent vector of generator and its share ratio form bilateral transaction and by using population of loading factor, Compute ATC using Eq. (20).
6. Initialize the iteration iter=1
7. For each iteration do the following steps
    a. Set the parent population with the optimal value of variables which give maximum ATC and is taken as the target vector i
    b. Perform mutation and crossover according to Eq. (17) and (18) and get trail vector.
    c. Selection among the target and trial vector for the survival using Eq. (19).
    d. ATC is computed with the selected best vector value form the transactions, using Eqn. (20)
    e. Check for any operating limit violation.
    f. If any limit is violated increase the iteration iter=iter+1, repeat again from step (b), till the process gets converged. If it does not converge the population has reinitialized automatically, otherwise go to next step.
    g. Best vector selected will be the next parent vectors for the next Population.
8. Increment the generation gen=gen+1

9. Check the maximum generation limit , if yes go to next step, otherwise go to step 4
10. Print the corresponding selected best vectors such as loading factor, the optimum generator and its optimum share ratio for establishing the transaction.
11. Form transaction and Compute ATC using selected best vectors as per Eq. (20).

V. SIMULATION RESULTS

This section presents simulation study carried out on IEEE RTS 24 bus system and IEEE 118 bus system to maximize the static ATC by satisfying all the constraints stated in (3-15). The data for IEEE 24 bus RTS and IEEE 118 bus systems are taken from [20].The ATC is computed in terms of active power transactions. The reactive power at load demand bus is assumed to be increasing as a percentage of real power increase. The simulation studies were carried out by developing Mat lab program and by using Matpower 4.1 software.

A Formation of Bilateral/multilateral transaction to improve ATC in IEEE RTS 24 bus System

The IEEE RTS 24 bus system consists of 11 generator buses, 13 load buses and 38 transmission lines. The idea is to form bilateral/multilateral transactions by selecting optimal generator buses and its share ratio to maximize ATC towards load demand bus using proposed approach. For selecting optimal generator there are 11 possible buses but in this study the 14th bus is not considered for any transactions because it is synchronous condenser bus. The optimal generator share ratio limit is taken in between 0 to 1.

The best result of the DE was obtained with the following control parameters:

No. of Generations : 500
Population size : 100
Crossover Probability: 0.7
Mutation factor : 0.8

In Table1. ATC values for the transactions which formed by randomly chosen generator towards load demand for IEEE RTS 24 bus system is given. In this table the second column shows the frequently changing load buses considered for the transactions. The third column shows the randomly chosen generator buses for the transactions. The first two transactions are bilateral transaction. The second transaction is bilateral, but here the load draws power from the multi nodal point. The remaining transactions are multilateral and multi nodal transaction. That is total sum of power injected in different buses are equal to the total sum of load power taken out at various buses. In fourth column the optimal loading factor (λ) at which thermal limit violation or voltage limit violation occurs is given. The lower and upper bound of voltage limits are taken between 0.95 and 1.05 p.u respectively. The ATC values for all transactions are given in the last column.

TABLE 1.
ATC FOR RANDOM TRANSACTION FOR IEEE RTS 24 BUS SYSTEM

Transaction number	Sink Bus and its share	Source bus and its share	Optimal loading factor (λ)	ATC (MW)
1	3	23	1.65	117.6000
2	5	1,15(0.7,0.3)	3.54	180.5400
3	3,10(0.5,0.5)	7,15(0.5,0.5)	1.53	99.9990
4	4,19(0.5,0.5)	2,23(0.5,0.5)	1.93	119.1000
5	6,9(0.5,0.5)	1,13,23(0.33,0.34,0.33)	2.15	179.4890

The Table 2 shows the established transaction, its **λ** lambda value and corresponding ATC. The second column of Table 2 shows the load demand buses considered for which the transaction has to be established. To establish the transaction the generator buses are selected optimally by using proposed approach. And the optimal share ratio also selected to bring the ATC at higher value. The share ratio sum should be equal to one. That means the load demand is satisfied by the generator by this share ratio. In transaction 1, only one generator bus, so there is no share ratio. The second transaction is bilateral but multi nodal transaction. The 5th load bus demand is satisfied by 2 and 13 generator buses with different share ratio. The sum of this ratio is equal to one. In fourth column optimal loading factor is given. From tables 1 and 2 it is inferred that for the same load buses the randomly selected generator buses give less ATC compared with optimally selected generator buses.

TABLE. 2
ATC FOR ESTABLISHED TRANSACTIONS FOR IEEE RTS 24 BUS SYSTEM

S. No	Sink bus	Optimum Source bus	Optimum Source bus transaction share ratio	Optimal loading factor (λ)	ATC (MW)
1	3	2	1	1.68	123.6020
2	5	2,13	0.336, 0.664	4.20	227.2440
3	3,10(0.5,0.5)	2,7	0.747,0.253	2.26	236.8260
4	4,19 (0.5,0.5)	1,13	0.450,0.550	2.95	249.130
5	6,9(0.5,0.5)	2,7,15	0.392,0.128,0.48	2.74	270.6340

The Table 3 shows the established bilateral and multilateral transaction details for which the improved ATC values are obtained in IEEE RTS 24 bus system. The first two transactions are bilateral and the remaining three are multilateral transactions.The Table 3 shows the randomly selected share ratio for optimally selected generator and its ATC value. For comparisons purpose this values are calculated. From this table it is proved that the optimal share ratio improves the ATC values compared with randomly selected one. For example in 7th transaction if randomly chosen share ratio is taken means the ATC value is 208.7550 MW. Alternatively if the optimal share is taken means it improves the ATC value to 227.2440. The 6th transaction is not taken for comparisons because there is only one generator bus.

TABLE. 3
ATC FOR ESTABLISHED TRANSACTION WITH RANDOM GENERATOR SHARE RATIO FOR RTS 24 BUS SYSTEM

Transaction No	Sink Bus (transaction share)	Optimal Source buses(random transaction share)	Optimal loading factor (λ)	ATC (MW)
2-3	3	2	1.68	123.6020
2,13-5	5	2,13(0.5,0.5)	3.94	208.7550
2,7-10,3	3,10(0.5,0.5)	2,7(0.5,0.5)	2.07	199.9990
4,19-13,1	4,19(0.5,0.5)	1,13(0.5,0.5)	2.90	242.3620
2,7,15-9,6	6,9(0.5,0.5)	2(0.34),7(0.33),15(0.33)	2.17	181.8100

Table. 4 formulated only for comparison purpose. The load demand buses (sink) considered for all types of transactions are same. Based on the generator buses and its share ratio the transactions are changed. The ATC values for randomly chosen transaction are given in second column. The third column shows the ATC values for optimally selected generator towards load demand bus but its share ratio is randomly chosen. The ATC values for optimally selected generator and its optimal share towards load demand bus is given in fourth column. From this table it is observed that the ATC values are higher when the selection of generator and its share ratio towards load is optimum. It is clearly shown in the figure 1. From this figure it is known that the utility can efficiently use their transactions at higher operating condition if it is chosen correctly.

TABLE. 4
COMPARISON BETWEEN RANDOMLY CHOSEN AND ESTABLISHED TRANSACTION: 24 BUS SYSTEM

Sink bus	ATC for randomly chosen transaction with random share(MW)	ATC values considering optimal Source selection and random share ratio(MW)	ATC values considering optimal Source selection and optimum transaction share ratio(MW)
3	117.600	123.6020	123.6020
5	180.5400	208.7550	227.2440
3,10	99.9990	199.9990	236.8260
4,19	119.1000	242.3620	249.1300
6,9	179.4890	181.8100	270.3640

TABLE 5.
OPERATING VALUES OF SINK BUSES FOR DIFFERENT TRANSACTIONS

Sink Bus No.	3	5	3,10	4,19	6,9
Randomly generated transaction	297.6	251.54	139.99,147.49	96.55,150.05	157.75,177.25
Estabilished optimum transaction	303.6	298.24	208.41,215.91	161.56,215.07	203.32,222.82
Estabilished transaction with random generation share ratio	303.6	279.75	189.95,197.45	158.18,211.68	158.90,178.4

Table 5 shows the operating values of sink bus for different types of transactions. At these operating values the transactions attain its maximum ATC values. The transactions are randomly generated transaction,estabilished transaction and estabilished transaction with random generation share ratio. From Fig.1 it is inferred that optimum selection and optimum share based established tranacion's sink buses are capable of higher operating limits compared with randomly remaining two transactions.

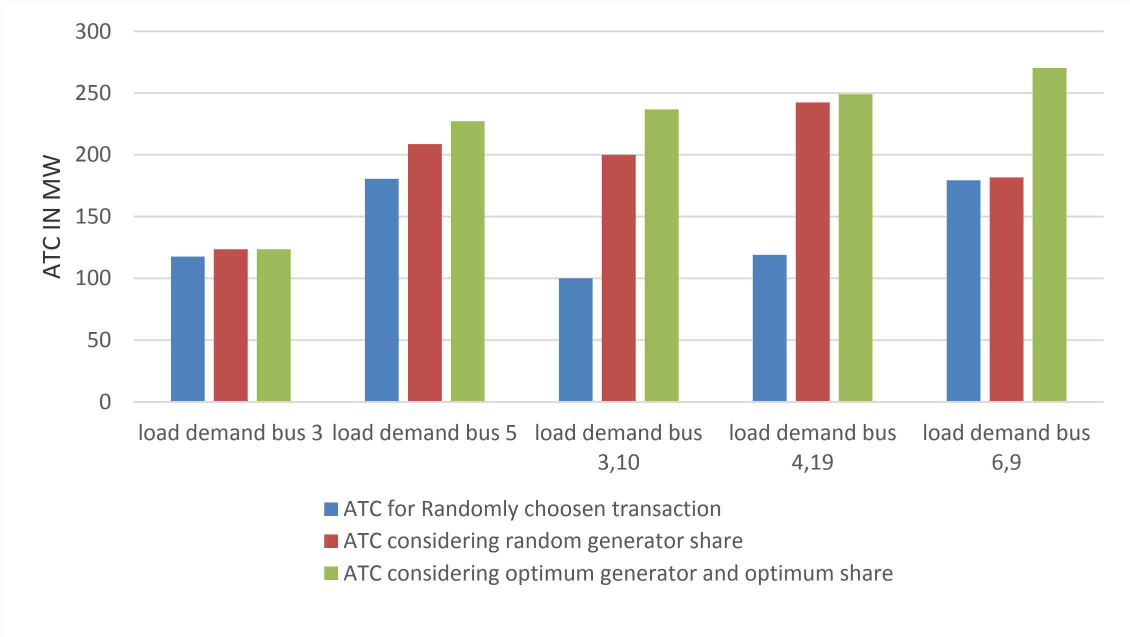

Fig.1 ATC for different transactions in IEEE RTS 24 bus system

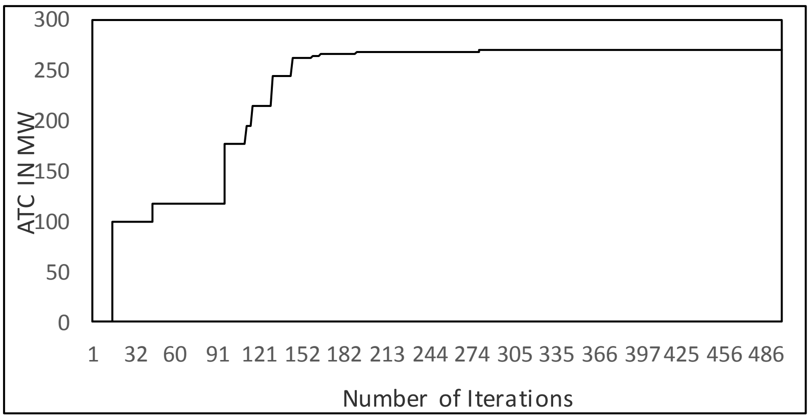

Fig.2 Convergence characteristics of DE for the 5th transaction: IEEE RTS 24 bus system

The Fig 2. graph shows the convergence characteristics of DE for 5th transaction of IEEE RTS 24 bus system. The converged ATC is the maximum ATC value in p.u at the optimal loading factor ,optimal generator bus and its share ratio. It was clearly shown that there is no rapid change in fitness value after 277 iterations. The corresponding ATC value is 270.3640.

B. Formation of Bilateral/Multilateral transaction to improve ATC in IEEE 118 bus system

The IEEE 118 bus system consists of 54 generator buses, 64 load buses and 186 transmission lines. The idea is to form bilateral/multilateral transaction by selecting optimal generator buses and its share to improve ATC towards load demand bus using proposed approach. For selecting optimal generator there are 54 possible buses.

The best result of the DE was obtained with the following control parameters:

No.of Generations : 500
Population size : 100
Crossover Probability : 0.7
Mutation factor : 0.8

In Table. 6 ATC values for the transactions which formed by randomly chosen generator towards load demand for IEEE 118 bus system is given. In this table the second column shows the frequently changing load buses considered for the transactions. The third column shows the randomly chosen generator buses for the transactions. The first two transactions are bilateral transaction. The second transaction is bilateral, but here the load draws power from the multi nodal point. The remaining transactions are multilateral and multi nodal transaction. That is total sum of power injected in different buses are equal to the total sum of load power taken out at various buses. In fourth column the optimal loading factor (λ) at which thermal limit violation or voltage limit violation occurs is given.

TABLE 6.
ATC FOR RANDOMLY CHOSEN TRANSACTION FOR IEEE 118 BUS SYSTEM

Transaction number	Load demand (sink) bus and its share	Source bus and its share	optimal loading factor (λ)	ATC
1	75	116	4.09	145.2520
2	7	2,92	13.95	246.0500
3	29,88	26,89	8.70	279.2770
4	11,96	69,111	7.46	348.7740
5	41,93	10,69,89	9.25	202.1220

The Table 7 shows the established transaction, its lambda value and corresponding ATC. The results presented in the tables show the ability of the proposed model to find the ATC values for a larger test system

TABLE7
ATC FOR ESTABLISHED TRANSACTIONS WITH OPTIMUM GENERATOR SELECTION AND OPTIMUM SHARE FOR IEEE 118 BUS SYSTEM:

S. No	Load Demand bus(transaction share ratio)	Optimum generator bus	Optimum generation bus transaction share ratio	Optimal loading factor (λ)	ATC (MW)
1	75	76	1	4.53	166.2410
2	7	1,6	0.816,0.184	20.94	378.8940
3	29,88(0.5,0.5)	1,116	0.485,0.515	9.47	305.0630
4	11,96(0.5,0.5)	80,116	0.900,0.100	9.35	450.9980
5	41,93(0.5,0.5)	1,6,80	0.111,0.127,0.762	9.49	208.2310

The Table 8 shows the established bilateral and multilateral transaction details for which the improved ATC values are obtained in IEEE 118 bus system. The Table 9 shows the ATC value for optimally selected generator but its share ratio is randomly selected.

TABLE 8.
THE ESTABLISHED TRANSACTIONS DETAILS OF IEEE 118 BUS SYSTEM

Transaction number	6	7	8	9	10
Source bus	76	1,6	1,116	80,116	1,6,80
Sink bus	75	7	29,88	11,96	41,93

TABLE 9.
ATC FOR ESTABLISHED TRANSACTION WITH RANDOM GENERATOR SHARE RATIO FOR IEEE 118 BUS SYSTEM

Transaction No	**Load Demand Bus (transaction share)**	**Optimal generator buses(random transaction share)**	**optimal loading factor (λ)**	**Corresponding ATC value in MW**
6	74	75	4.53	166.2410
7	7	1,116(0.5,0.5)	15.49	275.3490
8	1,116(0.5,0.5)	29,88(0.5,0.5)	9.47	304.9600
9	11,96 (0.5,0.5)	80,116(0.5,0.5)	7.64	358.4570
10	41,93(0.5,0.5)	1,6,80(0.34,0.33,0.33)	9.41	206.1430

The Table 10 formulated only for comparison purpose. The load demand buses (sink) considered for all types of transactions are same. Based on the generator buses and its share ratio the transactions are changed. From this table it is observed that the ATC values are higher when the selection of generator and its share ratio towards load is optimum. It is clearly shown in the figure 3. From this figure it is known that the utility can efficiently use their transactions at higher operating condition if it is chosen correctly.

TABLE 10.
COMPARISON BETWEEN RANDOMLY CHOSEN AND ESTABLISHED TRANSACTION: IEEE 118 BUS SYSTEM

Load demand bus	**ATC for randomly chosen transaction with random share(MW)**	**ATC values considering optimal generator selection and random share ratio(MW)**	**ATC values considering optimal generator selection and optimum transaction share ratio(MW)**
75	145.2520	166.2410	166.2410
7	246.0500	275.3490	378.8940
29,88	279.2770	304.9600	305.0630
11,96	348.7740	358.4570	450.9980
41,93	202.1220	206.1430	208.2310

Table 11 shows the operating values of sink bus for different types of transactions. At these operating values the transactions attain its maximum ATC values.

TABLE 11
. OPERATING VALUES OF SINK BUSES FOR DIFFERENT TRANSACTIONS

Sink Bus No.	75	7	29,88	11,96	41,93
Randomly generated transaction	192.25	265.05	151.635,163.635	209.385,193.385	119.56,107.06
Established optimum transaction	213.21	397.89	164.53,176.53	260.49,244.49	122.615,110.12
Established transaction with random generation share ratio	213.21	294.34	164.48,176.48	214.23,198.23	121.57,109.07

Table 11 shows the operating values of sink bus for different types of transactions. The transactions are randomly generated transaction, Established transaction and Established transaction with random generation share ratio. From Fig.3 it is inferred that optimum selection and optimum share based established transaction's sink buses are capable of higher operating limits compared with randomly selected remaining two different transactions. Fig. 4 shows the convergence characteristics of DE for 5^{th} transaction of IEEE 118 bus system. The converged ATC is the maximum ATC value in p.u at the optimal loading factor, optimal generator bus and its share ratio. It was clearly shown that there is no rapid change in fitness value after 277 iterations. The corresponding ATC value is 270.3640

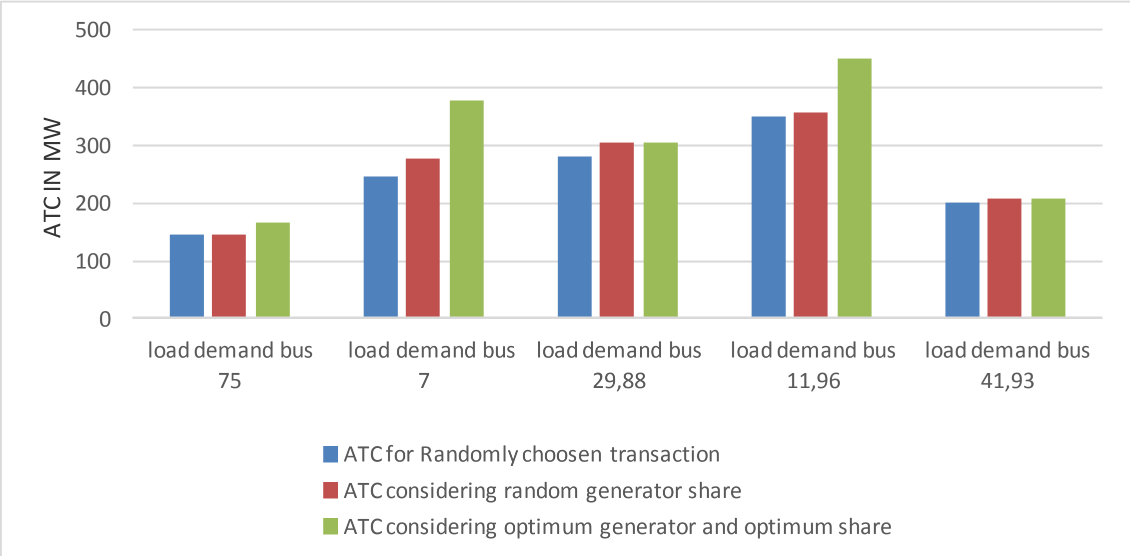

Fig 3 ATC for different transaction for IEEE 118 Bus System

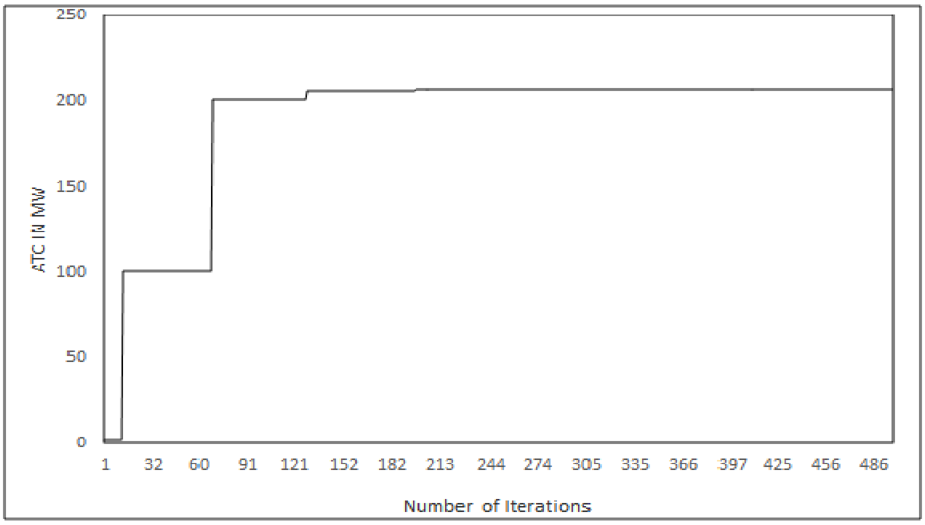

Fig 4 Convergence characteristics of DE for the 5th transaction: IEEE 118 bus system

VI. CONCLUSIONS

In this paper a new method has been suggested to improve the ATC by selecting optimal generation and its share ratio for the load demand. The proposed method was tested with IEEE RTS 24 bus system and IEEE 118 Bus system. The comparison of results with randomly taken transaction also been analysed to observe the improvement of ATC values using DE Algorithm. The test results show that the established transaction improve the ATC values compared with randomly chosen transactions. This study will helpful for ISO to ensure the fair use of system for all the utilities and it encourages more number of future contracts without violating the transmission system constraints. The proposed model also provides efficient incentives to the seller (Genco’s) for reducing the chance of congestion in transmission system.

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