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Enhancement of ATC with FACTS Devices in Deregulated Power System Considering Various Contingency and Benefit Margins

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ABSTRACT

The global electric power systems are under stressed condition because of increased per capita power consumption and ever-growing load demand. It is difficult to modify existing infrastructure of transmission systems to meet increasing load demand. The volume of electric power transmitted depends on the real and reactive power supply and the availability of margin in transmission system. Available Transfer Capability is an estimation of additional power transfer capability of the existing transmission system for a further market activity over and above the already committed power transactions. Factors such as weather, line and generator outages must be taken into account when computing the rigorous value of ATC. This paper focuses on enhancing the ATC limit of a system by employing STATCOM and Whale Optimization Algorithm for tuning system variables and to determine optimal size and location. An investigation has been carried out to understand the impacts of ATC by implementing line and generator outages in the test system. Additionally, an investigation has been done to realise the various benefit margins like ETC, TRM and CBM. The competence of the proposed methodology is validated by conducting different case studies on IEEE-30 bus test system using MATLAB for various bilateral and multilateral transactions.

1. Introduction

The Centralized power industries are in the verge of transforming their mode of operation into the pattern of deregulation. In the deregulated electricity market, power producers and buyers are having too many choices in selling and purchasing the power. It is recognized that an innovative competition may reduce the cost of power for retail customers. Consumption of electricity is increased tremendously around the world, which depends upon the economic growth of the state. Commissioning of number of generating stations, transmission and distribution systems may serve the purpose of these commitments. But it may take few years from the planning stage to commissioning of the power plants. Furthermore, the environmental pollution, higher expenditure on installations and operations and availability of the lands nearer to the load centres are some other

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problems. Therefore, it is recommended to improve the existing power systems and networks in order to satisfy the rising demand of power consumption.

Even though the deregulated power system extends numerous advantages, its generation, transmission and distribution sectors suffer from a complex network structure. Excessive power transmission through the transmission system makes it overloading. Generally, the transmission lines are operated nearer to their thermal stability limit in order to meet out the load demand. This excessive power transmission and over loading trigger the phenomena of congestion in the transmission system.

Available Transfer Capability (ATC) is described as evaluation of power transfer capability of transmission systems for additional trading activities beyond the previously committed transactions. The ATC analysis may help the trading communities in understanding the system conditions and constraints. By doing this assignment, the system operators may decide whether any further amount of power could be transacted within its business corridor. So, the Independent System Operator (ISO) must be an expertise about the ATC of the specified network with regard to the reliability and security of the system, whenever dealing with higher transmission capacity of power.

The FACTS devices exhibit exceptional performance in enhancing the thermal stability and loadability limit of high voltage transmission systems. These devices replace the traditional methods in order to have flexible operation, reduced cost with environmental consideration. The installation of FACTS devices like SVC and TCSC may improve the capacity of the power transmission system during regular and contingency conditions [1]. Here, ATC is calculated by using continuous power flow while accounting the thermal limit and voltage profile.

ATC has been estimated for multiple transactions by considering AC power transfer distribution factor (ACPTDF) by installing FACTS devices under normal and line outage conditions [2]. The results are compared with DC power transfer distribution factor (DCPTDF). It is established that ATC has been enhanced for intact as well as line outage cases by employing FACTS devices.

DC power flow model has been used for the calculation of ATC of a system for both single and multiple transactions [3]. Both intact and contingency conditions are considered for the calculation of ATC. Two forms of contingencies like line and generator outages are analysed. This work describes the different pattern of real power flow for variety of transactions under normal and contingency situations.

Continuous power flow-based Thyristor Series Capacitor and static VAR compensator (SVC) approach is explained for enhancing the ATC of a transmission system in [4]. The method is subjected to evaluation both regular and contingency conditions with placement and control parameters of FACTS devices. Real coded genetic algorithm has been employed for identifying the location and control parameters of TCSC and SVC. It has been established that TCSC performs well when compared with SVC while enhancing the ATC under normal and contingency conditions. In [5] a Bee's algorithm is applied for identifying the optimal allotment of FACTS devices for improving the ATC of power transfer among source and sink areas in the case of deregulated environment. Four varieties of FACTS devices like TCSC, SVC, UPFC and TCPST are employed and modelled for steady state studies. The cost involved for the installation are also taken into consideration. The suggested method has been subjected to investigation on IEEE-9 and IEEE-18 bus test systems to reveal the effectiveness of the method.

In [6], series compensation is used for the enhancement of ATC. A DCPTDF method is adopted for the calculation of ATC for buses under intact and line outage conditions. A repeated power flow method has been applied for normal as well as (n-1) line outage condition for the determination and enhancement of ATC. In [7], ATC has been improved by employing UPFC under both circumstances. Here FACTS devices are used to optimize the locations. Thyristor controlled series capacitor is used to enhance the ATC of the system. The size and location of TCSC is identified by applying firefly algorithm [8].

Different types of approaches have been attempted for the calculation of ATC. Location for the placement of TCSC has been chosen by sensitivity-based PI approach [9]. It is found that there is an improvement in ATC after the installation of TCSC. The ATC of the specified transmission line has been enhanced by ACPTDF approach which is corelated with DCPTDF.

An adaptive moth flame optimization algorithm has been applied to enhance the ATC. It is an adaptive model of the moth flame optimization algorithm [10]. The algorithm is used to identify the optimal location for the placement of FACTS devices. The performance of this method is validated on IEEE24, IEEE30 and IEEE57 test systems.

A hybrid PI-PSO based algorithm was suggested for optimal use of FACTS components with a view of enhancing ATC [11]. The location search space is reduced by applying sensitivity analysis. The introduction of two masking effect reducing techniques takes care of transactions. The proposed method performs better when compared with PSO technique. Thyristor controlled series capacitor is implemented to ease the congestion of the transmission line and to enhance the ATC by reducing power losses [12]. ACPTDF is employed to compute ATC and to identify the location for TCSC. Teaching learning-based optimization algorithm is applied to optimize the TCSC parameters. It is validated on IEEE 30 bus test system and compared with Gray Wolf optimization and PSO techniques.

This work is focused on the enhancement of available transfer capability of a transmission system under contingency conditions using FACTS devices. A technique namely Whales Optimization algorithm has been employed for optimally sizing and placement of FACTS components.

2. Contingency Analysis

Contingency analysis is an important and essential practice in a power system to assess the state of the system in the event of any untoward incident. Contingency analysis is a fundamental subject of the power system to ascertain the ability of the system in meeting the load demand by avoiding voltage violations and loadable limits of connected equipment’s. Usually, it is not possible to establish a power system network which has no failures. Occurrence of fault in the network has to be cleared immediately. Then only the remaining sections of the system provide the supply without any disturbance. Quantity of power flowing through the branches and bus voltages during fault is entirely different from pre-fault situations [13].

Therefore, it is suggested to analyse the steady state behaviour of the system after equipment and line outages. The outages of different equipment may change the power flow pattern and bus voltages. It is impossible to identify which one outage is crucial before doing simulation. Hence it is advised to make simulation studies to know the steady state behaviour of the system, once the various equipment’s are subjected to outages at the same time. This phenomenon is referred as contingency analysis.

It is an analysis used to verify the status of the power system whenever the connected equipment’s are affected by the outages. A variety of operational activities have to be done during the contingency condition such as loss of a transmission line, a transformer, a generator or a load. Prevention of any system outages is impossible, and hence assessing the expected outages to predetermine their impact is important. It helps to model the state variable after any single or multiple outages.

Generally, (N-1) [14] contingency is a standard procedure for evaluating the security of any power system. As for this method is concerned, the specified power system should ride out a particular component outage without violating the constraints of other components while supplying the loads connected with that system. The (N-1) contingency procedure may not support when the system is affected by multiple simultaneous outages simultaneously. Hence (N-K) contingency procedure is adopted for multiple equipment failures. It means that the specified systems should have the ability to withstand the 'K' number of equipment failure at the same time.

2.1 Different Forms of Contingencies

The three primary components of power system are buses, generators, and transmission lines, are treated as the essential elements of the power system. Contingencies may emerge out in different modes among the components. One of the most vulnerable parts of the system is a transmission line due to surging and overloading [15]. A transformer outage is also possible, if the specified voltage is not maintained. The primary source of the power system is a generator. Loss of generation may cause severe problems in the system which may ended up with black out.

Similarly, an electrical bus is a significant component of the power system. Generators, transformers and transmission lines are connected to the remaining part of the system through electrical bus bars. If an outage arises in the bus, it will affect all the equipment's linked with the bus which results in total outage of the system. Hence, an outage of a bus is considered as a crucial factor. Therefore, different kinds of contingencies and their analysis will be useful for proper planning and operation of the network systems.

3. Problem Formulation

3.1 Mathematical Modelling of ATC

Available Transfer Capability is an estimation of transfer capacity available in the existing transmission system for an additional commercial activity beyond the services which has already been committed. The various benefit margins such as TRM and CBM under contingency conditions are addressed in this paper while calculating the value of ATC.

The mathematical formulation of ATC determination is described by the Eq. (1) and diagrammatic representation is shown in Figure 1.

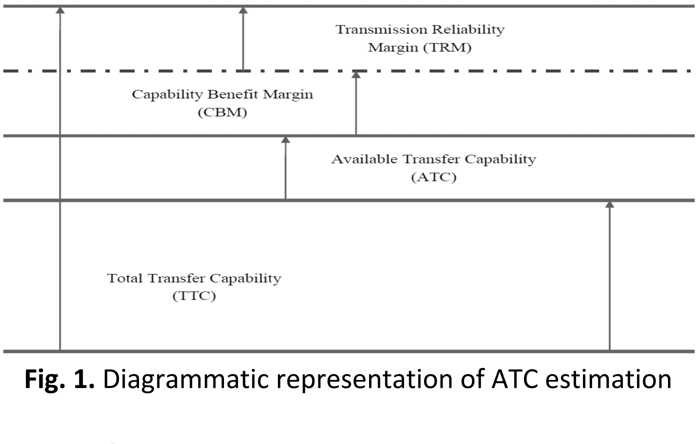


Fig. 1. Diagrammatic representation of ATC estimation

$$ATC = TTC - ETC - TRM - CBM \tag{1}$$

TTC: It reveals the volume of power which can be transmitted through the transmission lines hence the entire stages of stated post contingency and pre contingency states are realised.

TRM: It states the quantity of transmission transfer capability required to guarantee a significant level of security for the associated transmission network.

CBM: It means the amount of transmission transfer capability set aside by the load serving entities to provide access to generation in order to satisfy the generation reliability criteria.

3.2 Objective Function

The target is to enhance the ATC and to improve the power transfer capability in between source and sink areas subject to the various constraints such that there should be no deviations of thermal and voltage stability limits. Available transfer capability problem formulation cans be defined as follows:

Maximize $ATC = \sum_{j\in i} P_{kj}$ (2)

3.3 Constraints

3.3.1 Equality constraints

$$P_i - \sum_{j\in i} V_i V_j Y_{ij} \cos\left(\theta_{ij} + \delta_i - \delta_j\right) = 0 \tag{3}$$

$$Q_i - \sum_{j\in i} V_i V_j Y_{ij} \sin\left(\theta_{ij} + \delta_i - \delta_j\right) = 0 \tag{4}$$

Where P_i and Q_i are real and reactive power flow of the i^th bus.

3.3.2 Inequality constraints

Real power flow limits, $P_g^{min} \leq P_g \leq P_g^{max}$ (5)

Reactive power flow limits, $Q_g^{min} \leq Q_g \leq Q_g^{max}$ (6)

Apparent power flow limits, $S_{ij} \leq S_{ij}^{max}$ (7)

Bus voltage profile limits, $V_i^{min} \leq V_i \leq V_i^{max}$ (8)

3.3.3 STATCOM constraints

$$X_{STATCOM\ I}^{min} \leq X_{STATCOM\ I} \leq X_{STATCOM\ I}^{max} \tag{9}$$

where

$\mathrm{I} = 1,2,3 \ldots\ldots\ldots\ldots \mathrm{n_{STATCOM}}$
$\mathrm{X_{STATCOM\ I}^{min}}$= Min value of X of STATCOM at bus i
$\mathrm{X_{STATCOM\ I}^{max}}$= Max value of X of STATCOM at bus i

4. Whale Optimization Algorithm (WOA)

The swarm intelligence based, nature inspired whale optimization algorithm was invented by S. Mirjalili and A. Lewis in 2016. The characteristic of bubble net surfing for whales with its spiral encircling hunting method makes it a very powerful ability to catch its prey [16]. The objective of complex nonlinear optimization problem is evaluated by humpback whale hunting characteristics. Humpback whales have two predatory techniques throughout their process: one is to lower the surrounding mechanism and the second is to spiral model position updating. This WOA overcomes the drawbacks of slow convergence rate unlike other heuristic algorithms like PSO, ACO and gives global optima.

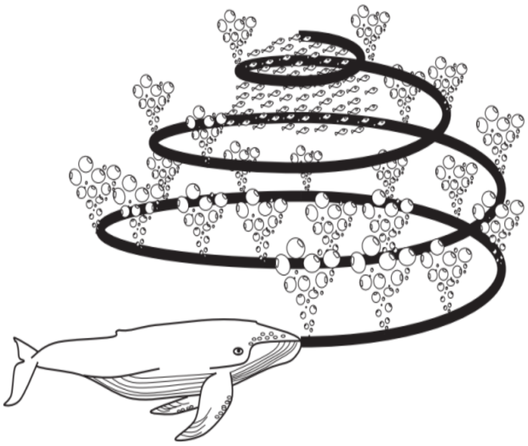


Fig. 2. Whale bubble-net hunting behaviour

The complex mathematical modelling of hunting process is represented by three stages as follows:

4.1 Surrounding Prey

The initial hunting method involves encircling the prey for best candidate solution and the fittest solution is used to update the position. The encircling phenomena of whales around the prey has been portrayed as:

$$X(t+1) = X^{*}(t) - A.D \tag{10}$$

$$D = |C.X^{*}(t) - X(t)| \tag{11}$$

Here, 't' is the current iteration number. A and C are the coefficient vectors. X resembles the position vector and X* signifies the position vector corresponding to the best candidate solution. For each iteration of search operation, X* is updated for better solution. A and C are mathematically represented as:

$$A = 2a.\eta - a \tag{12}$$

$$C = 2.\eta \tag{13}$$

Here, 'a' decrement from 2 to 0 linearly and $\eta \in [0,1]$.

4.2 Bubble-Net Attack Strategy

The humpback whales bubble net strategy is mathematically portrayed with reducing the encircling mechanism and updating spiral position. The encircle decrementing behaviour is obtained by decreasing the value of ‘a’ in Eq. (12). The helix movement of humpback whale is mathematically formulated as:

$$X(t+1) = D'.e^{bl}.cos(2\pi l) + X^*(t) \tag{14}$$

$$D' = |X^*(t) - X(t)| \tag{15}$$

Here D’ is the best optimal distance obtained so far between the whale and prey, l ∈ [-1,1] and ‘b’ defines the spiral shape. The sunchronic behaviour of decrementing encircling mechanism or the position update of whale in the spiral are modelled with same probability.

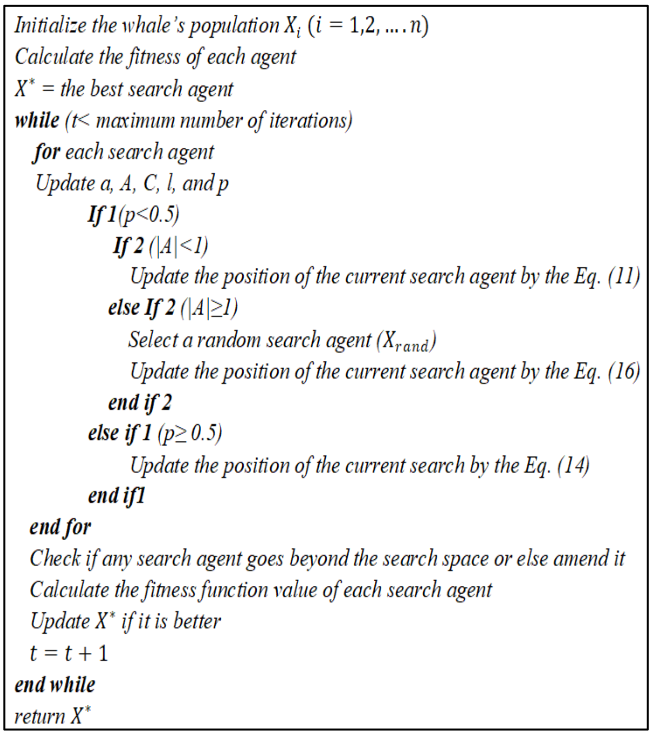
4.3 Hunting Prey Stage

At this stage, ‘A’ vector is employed to hunt the prey. The randomly chosen search agent, X_{rand} with |A|>1 is used to updated the position of whale in contrast with -1<A<1 to perform WOA for global search. The hunting prey stage is mathematically modelled as:

$$X(t+1) = X_{rand}(t) - A.D \tag{16}$$

$$D = |C \cdot X_{rand} - X(t)| \tag{17}$$

The WOA pseudo-code is presented in Figure 3.



```
Initialize the whale's population $X_i$ ($i = 1,2, \ldots .n$)
Calculate the fitness of each agent
$X^*$ = the best search agent
while (t< maximum number of iterations)
  for each search agent
  Update a, A, C, l, and p
      If 1(p<0.5)
        If 2 (|A|<1)
          Update the position of the current search agent by the Eq. (11)
        else If 2 (|A|≥1)
          Select a random search agent ($X_{rand}$)
          Update the position of the current search agent by the Eq. (16)
        end if 2
      else if 1 (p≥ 0.5)
          Update the position of the current search by the Eq. (14)
      end if1
  end for
  Check if any search agent goes beyond the search space or else amend it
  Calculate the fitness function value of each search agent
  Update $X^*$ if it is better
  t = t + 1
end while
return $X^*$
```

Fig. 3. Pseudo-code of WOA

5. Results and Discussion

A case study has been carried out on IEEE 30 bus test system by installing the proposed STATCOM at a specific location as prescribed by the algorithm for enhancing the performance of ATC. A dynamic WOA has been deployed to choose the optimal location and sizing of the STATCOM and to inject the reactive power for improving the voltage profile and ATC of the test system.

The line, bus and generator data for the IEEE 30-bus system is taken from reference [17]. This interconnected system has six generators, twenty-one loads along with forty-one transmission lines. Bus-1 is assumed as slack bus and the cumulative power demand is 283.4 MW. FDLF method is applied to obtain the load flows and ACPTDF technique is applied to compute base case values of ATC. The proposed WOA is subjected to simulation in MATLAB platform in a PC with Intel core-i5 processor, 3.10 GHz, 8 GB RAM. The one-line diagram of proposed bus system is divided into three areas such as Area-1, Area-2 and Area-3 with 2 generators in each area shown in Figure 4.

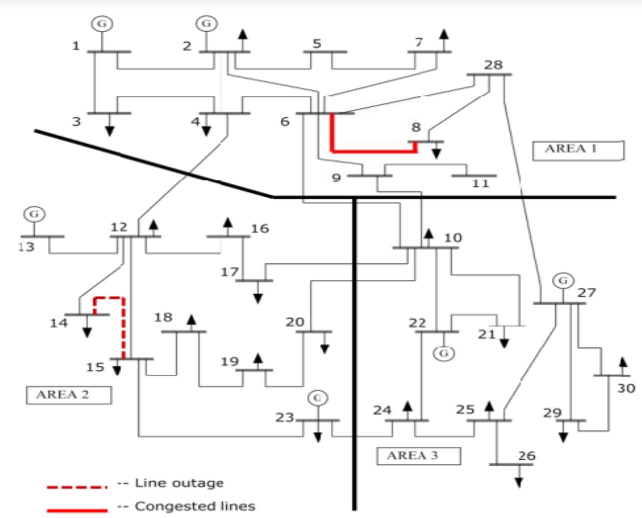


Fig. 4. One-line diagram of IEEE-30 bus system

The experimental simulation analysis has been conducted on the test system under different generator and line outage conditions for various bilateral and multilateral Transactions.

The Bilateral trisections are:

i. Bilateral Transaction 1 (BT1): Seller Bus 2 and Buyer Bus 28
ii. Bilateral Transaction 2 (BT2): Seller Bus 5 and Buyer Bus 30
iii. Bilateral Transaction 3 (BT3): Seller Bus 8 and Buyer Bus 25
iv. Bilateral Transaction 4 (BT4): Seller Bus 11 and Buyer Bus 26

The Multilateral Transitions are:

i. Multilateral Transaction 1 (MT1): Seller Buses 2, 3 and Buyer Buses 4, 7, 8
ii. Multilateral Transaction 2 (MT2): Seller Buses 14, 17, 23 and Buyer Buses 12, 13
iii. Multilateral Transaction 3 (MT3): Seller Buses 24, 27, 29 and Buyer Buses 21, 22

Initially the Fast decoupled load flow is carried out, in order to obtain the values of voltage magnitude, angle, real and reactive power for all the buses. It has been found that the maximum power mismatch is around 0.000910918 and the process takes sixteen number of iterations to provide a best result. Bus voltage, real and reactive power violations are identified from these results. Thereafter, WOA is employed to choose the best locations and sizing of STATCOM.

The proposed WOA adopts two efficient methodologies for reaching the optimal solutions like encircling mechanism and spiral updating position. A trial-and-error approach has been followed to assess the control parameters and is given Table 1.

Table 1
Control parameter of WOA

Control Parameter	Value
Size of population	50
Maximum no of iteration (N)	500
Total number of variable (d)	6
Random number (r)	0 to 1

The parameter space of WOA is graphically reported in Figure 5. It is noted that the optimal location and size of the STATCOM are 5, 21 and 2.35 MVAR, 3.72 MVAR respectively for various contingency conditions.

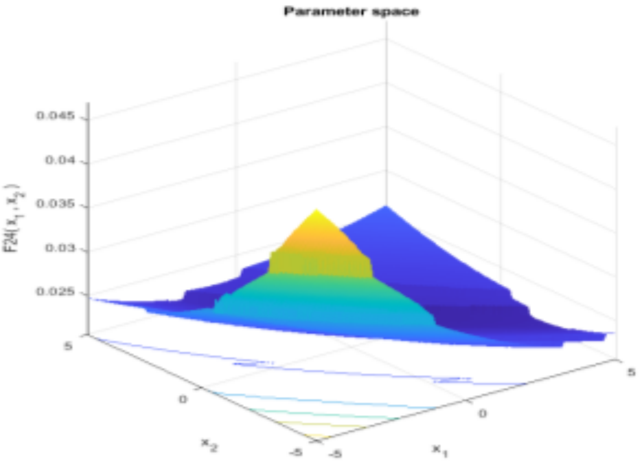


Fig. 5. Parameter space of whale optimization algorithm

The improvement in the voltage profile of the IEEE30 bus system is graphically displayed in Figure 6. From the graph, it is observed that the voltage of each bus is efficiently maximized by the injection of reactive power.

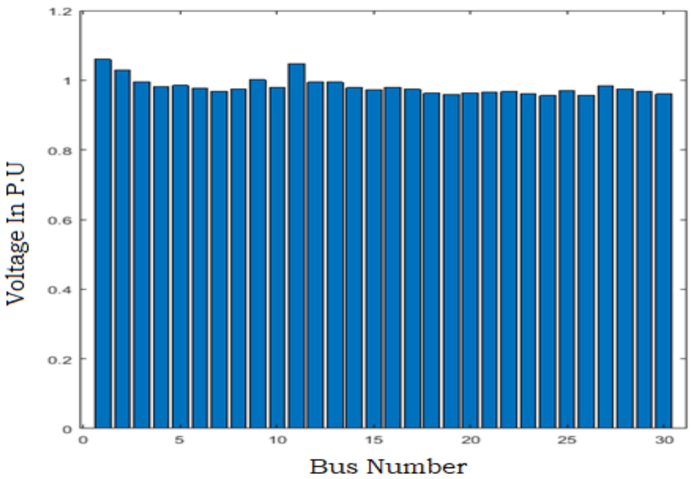


Fig. 6. Voltage profile of IEEE 30 bus system with STATCOM

The objective of the proposed methodology is to assess the status of the ATC under normal network conditions as well as credible contingent conditions. Two different experimental case studies have been carried out on the sample test system.

Case 1 - Various bilateral transactions with the outages of generator and line
Case 2 - Various multilateral transactions with the outage of generator and line

In the first case, four bilateral transactions namely BT1, BT2, BT3 and BT4 are carried out and the results are analysed. In this process, second generator which is connected with 13th bus and the line number 10 which is connected between the buses 6 and 8 is put on outage from the existing network configuration for the purpose of investigation. The impact of the system is analysed by connecting and disconnecting the STATCOM. From this exercise, the competence of ATC is drawn and recorded in Table 2 and Table 3.

Table 2
Simulation results of ATC for various Bilateral Transactions with generator 3 outage at bus-13

Bilateral Transactions	Seller Bus	Buyer Bus	With/Without STATCOM	TTC (MW)	TRM (MW)	CBM (MW)	ATC (MW)
BT1	2	28	Without STATCOM	303	3.0300	2.8700	112.1000
			With STATCOM	410	4.1000	2.8700	218.0300
BT2	5	30	Without STATCOM	288.4	2.8840	2.8840	97.6320
			With STATCOM	296.4	2.9640	2.9440	105.4920
BT3	8	25	Without STATCOM	294.4	2.9440	2.9500	103.5060
			With STATCOM	320.4	3.2040	2.9640	129.2320
BT4	11	26	Without STATCOM	287	2.8700	3.0300	96.1000
			With STATCOM	295	2.9500	3.2040	103.8460

Table 3
Simulation results of ATC for various Bilateral Transactions with line 10 outage (connected between Bus 6 and 8)

Bilateral Transactions	Seller Bus	Buyer Bus	With/Without STATCOM	TTC (MW)	TRM (MW)	CBM (MW)	ATC (MW)
BT1	2	28	Without STATCOM	284	2.8400	2.8400	93.3200
			With STATCOM	292.4	2.9240	2.8400	101.6360
BT2	5	30	Without STATCOM	292.3	2.9240	2.8840	102.1860
			With STATCOM	296.4	2.9640	2.9240	105.5120
BT3	8	25	Without STATCOM	288.4	2.8840	2.9300	97.5860
			With STATCOM	308	3.0800	2.9340	116.9860
BT4	11	26	Without STATCOM	284	2.8400	2.9640	93.1960
			With STATCOM	293.4	2.9340	3.0800	102.3860

From these details, it is perceived that the value of ATC has been improved by applying the proposed approach. The improvement in the voltage contour of IEEE 30 bus system is precisely depicted in Figure 6. In this analysis, TRM value of the test system is considered as 1% of the TTC and CBM has been calculated using Empirical Cumulative Distribution Factor (ECDF) method. Similarly, Total Transfer Capability for Area 1, Area 2, and Area 3 under contingency condition is portrayed in Figure 7.

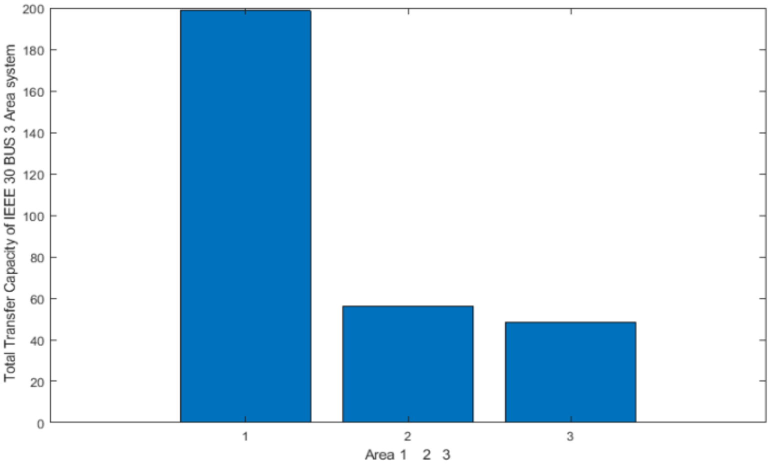


Fig. 7. Total transfer capability for Area1, Area2 and Area3 under contingency condition (Generator 3 outage at bus 13)

The pictorial representation for the determination of CBM using ECDF approach is exhibited in Figure 8.

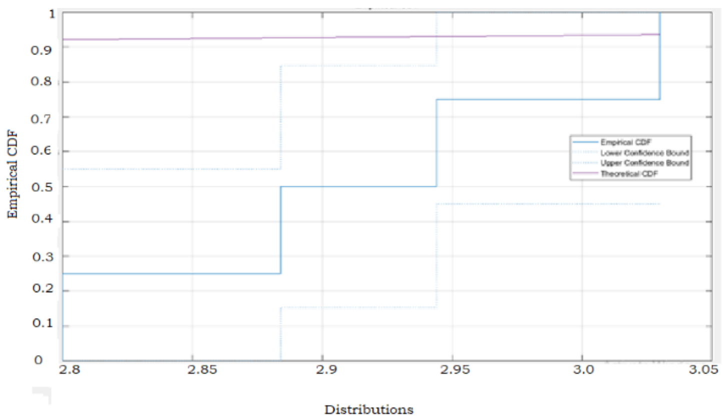


Fig. 8. Determination of CBM using empirical CDF approach

In Figure 9, graphically compares the progress of ATC with / without STATCOM for the entire bilateral transactions under the outage of second generator from the network.

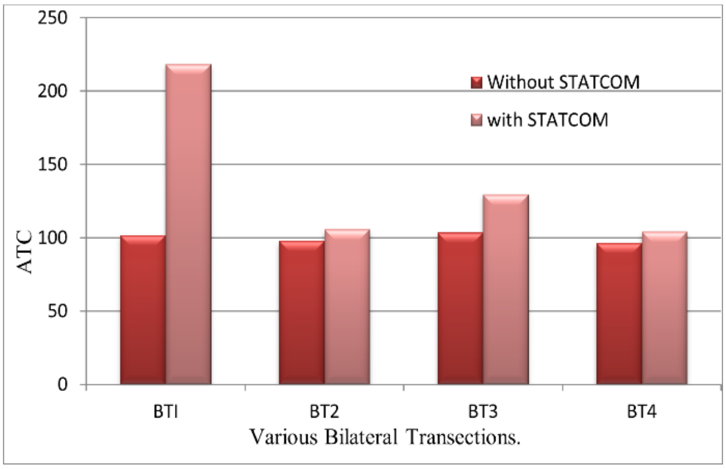


Fig. 9. Comparison of ATC with/without STATCOM for all Bilateral Transactions under generator 3 out of the network

In the second case, three multilateral transactions such MT1, MT2 and MT3 are subjected to examination. Here, the intention is to record the conditions of the ATC by effecting the outage on second generator and line 15 from the existing network. The simulation is executed on the outage system with/without installing the STATCOM device. The outcomes are detailed in Tables 4, 5 and 6. From the findings, it is realised that the performance of ATC has been improved significantly under contingency conditions with the proposed WOA with STATCOM devices.

Table 4
Simulation results of ATC for Multilateral Transaction - 1

Multilateral Transactions	Contingency	With/Without STATCOM	TTC (MW)	TRM (MW)	CBM (MW)	ATC (MW)
MT1 Sellers 2, 3 Buyers 4, 7, 8	Without Contingency	Without STATCOM	212.7	2.1270	1.9670	23.6060
		With STATCOM	220.7	2.2070	1.9670	31.5260
	Line 15 outage (Connected between bus 4 & 12)	Without STATCOM	202.7	2.0270	1.9700	13.7030
		With STATCOM	215	2.1500	2.0270	25.8230
	Generator 3 outage (Connected in bus 13)	Without STATCOM	196.7	1.9670	2.1270	7.6060
		With STATCOM	197	1.9700	2.1500	7.8800

Table 5
Simulation results of ATC for Multilateral Transaction - 2

Multilateral Transactions	Contingency	With/Without STATCOM	TTC (MW)	TRM (MW)	CBM (MW)	ATC (MW)
MT2 Sellers 14, 17, 23 Buyers 12, 13	Without Contingency	Without STATCOM	205	2.0500	1.9170	16.0330
		With STATCOM	228	2.2800	1.9170	38.8030
	Line 15 outage (Connected between bus 4 & 12)	Without STATCOM	199.7	1.9970	1.9970	10.7060
		With STATCOM	234	2.3400	2.0500	44.6100
	Generator 3 outage (Connected in bus 13)	Without STATCOM	191.7	1.9170	2.2270	2.5560
		With STATCOM	222.7	2.2270	2.2800	33.1930

Table 6
Simulation Results of ATC for Multilateral Transaction - 3

Multilateral Transactions	Contingency	With/Without STATCOM	TTC (MW)	TRM (MW)	CBM (MW)	ATC (MW)
MT3 Sellers 24, 27, 29 Buyers 21, 22	Without Contingency	Without STATCOM	200.7	2.0070	1.9200	11.7730
		With STATCOM	216.7	2.1670	1.9200	27.6130
	Line 15 outage (Connected between Bus 4 & 12)	Without STATCOM	192	1.9200	1.9270	3.1530
		With STATCOM	213	2.1300	2.0070	23.8630
	Generator 3 outage (Connected in bus 13)	Without STATCOM	192.7	1.9270	2.0570	3.7160
		With STATCOM	205.7	2.0570	2.1300	16.5130

Figure 10 elaborates the comparative analysis of MT1 with a generator and line outage contingency situations.

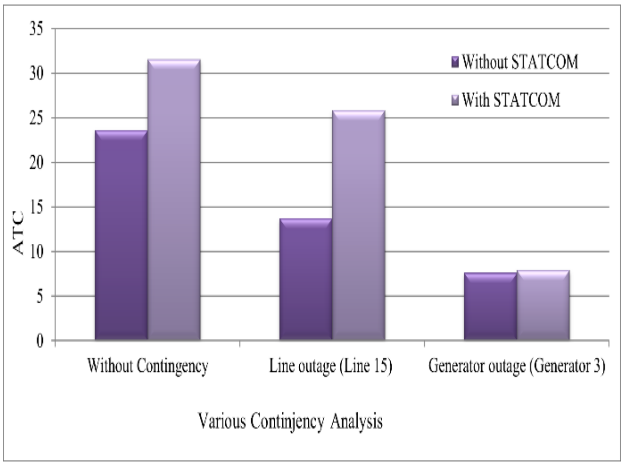


Fig. 10. ATC for Multilateral Transaction-1 with various contingency conditions

6. Conclusion

A conceptual methodology based on whale optimization algorithm has been presented for enhancing the ATC of transmission systems under deregulated environment. The salient feature of STATCOM has been exploited for enhancing the value of ATC. STATCOM is a power electronic voltage source converter which offers shunt reactive power and harmonic suppression. The control parameters of STATCOM are effectively tuned by the WOA for optimizing the size and location of installation. The TRM, TTC and CBM are all most essential information used by the load serving entities for the accurate calculation of ATC. In this work, the impacts of these benefit margins are also analysed and computed while improving the ATC value of test systems. An experiment has also been done to know the influence of ATC enhancement in the event of generator and line outage conditions which may cause severe power imbalances. During the analysis, it is recognised that the proposed technique improves the value of ATC and voltage profile for both bilateral and multilateral transactions. To illustrate the viability and applicability of the proposed approach, it has been subjected to experimental analysis on a standard IEEE 30 bus system. From the outcomes, it can be concluded that an optimal placement of STATCOM enhances the value of ATC under normal and contingency conditions in deregulated power system by avoiding additional generations.

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