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ATC Enhancement in Restructured Power System using Whale Optimization Algorithm

Abstract. *Power industries around the world are moving towards the process of deregulation for the improvement in performance, efficiency and to attract private participants. The primary concerns are cost for transmission, congestion clearance, and Available Transfer Capability. Among these, ATC plays a significant role for secure and reliable operation. FACTS devices are viewed as a dynamic element for the quantity of power to be transferred and for increasing the available power transfer capacity. It overcomes the congestion of the transmission path and provides a chance to increase the electrical power flow on the line. This assignment proposes Wale Optimization Algorithm (WOA) for optimized setting of FACTS devices and for enhancing the ATC. The solution avoids the cost of erecting a new transmission system for power transmission. The validity of the proposed algorithm is confirmed through different test cases on standard IEEE test system.*

Streszczenie. *Energetyka na całym świecie zmierza w kierunku procesu deregulacji w celu poprawy wydajności, wydajności i przyciągnięcia prywatnych uczestników. Głównymi problemami są koszty transmisji, usuwanie zatorów i dostępne możliwości transferu. Wśród nich ATC odgrywa znaczącą rolę w bezpiecznym i niezawodnym działaniu. Urządzenia FACTS są postrzegane jako element dynamiczny dla ilości przesyłanej mocy i zwiększania dostępnej przepustowości. Pokonuje przeciążenia toru transmisyjnego i daje szansę na zwiększenie przepływu energii elektrycznej na linii. W tym zadaniu zaproponowano algorytm optymalizacyjny Wale'a (WOA) w celu zoptymalizowania ustawień urządzeń FACTS i ulepszenia ATC. Rozwiązanie pozwala uniknąć kosztów budowy nowego systemu przesyłowego do przesyłu mocy. Poprawność proponowanego algorytmu została potwierdzona przez różne przypadki testowe na standardowym systemie testowym IEEE.* (***Wzmocnienie ATC w zrestrukturyzowanym systemie elektroenergetycznym przy użyciu algorytmu optymalizacji wielorybów***)

Keywords: Deregulation, Bilateral and Multilateral Transactions, Available Transfer Capability, Total Transfer Capability, Whale Optimization, FACTS Devices.
Słowa kluczowe: urządZnie FACTS, pojemność transferu, optymalizacja waleniua

Introduction

The electric power market has experienced an extensive development during the course of modernisation process. Recently, the power demand has increased tremendously due to the ever-growing power consumption, advanced living condition by the consumers and the industrial growth. With a view of improving the performance, revenues and economy of the power network, a process called deregulation is introduced in the monopoly design of the power system. Deregulation means restructuring and unbundling of the existing system and to allow private participant in the business of electrical energy market. It allows bidding, competition over the players and offer choice to the consumers in choosing their power system and distributions [1].

The initialisation of competition among the electricity market participant provides the way for bidding practice and power transaction through the transmission line between generator and loads. The increased electric power demand has to be encountered with the enough generation and transmission. Establishment of power plants, transmission and distribution system may be the solution to this problem. But it may consume many years for the process of planning, designing, and erecting the system. Further, environmental pollution, initial operational cost and land availability are some other problems. Hence, in order to manage the increasing power demand, modernising the existing electrical power generating stations are the better option and economically feasible. Because of the higher demand of electricity, transmission utilities are compelled to operate nearer to their operating limits which results in the poor performance of transmission components. To mitigate this issue, efficient estimation of the ATC is significant for system planning and operation. Researchers have suggested many techniques and algorithms to deal with these kinds of problems. The subject of ATC receives wider attention among the researchers. Hence formulation of fast and accurate algorithms by including the dynamic nature of the system and its uncertainties is need of the hour [2].

The role of FACTS devices in enhancing the stability limit and loadability of high voltage transmission lines are remarkable. These devices provide a dynamic alternative to the conventional methods by means of improved flexibility, cheaper cost with minimum environmental concerns. Series FACTS devices have widely been used to enhance the performance of the transmission lines. Optimised use of FACTS devices and especially TCSC has been utilised to improve the capacity of ATC and to maximise the total transfer capability [3]. Several algorithms were applied to deal with the multi objective optimization problems. PSO method is used for the induction and capacity utilization of FACTS components in high voltage power transmission lines. The benefit of PSO is the ability of agents to interact and exchange the matter among them. The drawback of this algorithm is that the global searching space is reduced because of the multi objective function. A hybrid mutation based PSO method by considering normal PSO and a fresh mutation operator is explained in [4] by overcoming the drawbacks of PSO algorithm.

A multitier FACTS devices have been deployed to enhancement the transmission capability. A Hybrid Particle Swarm Optimization (HPSO) is reported by blending various technique such as Evolutionary Programming (EP), Tabu Search and Simulated Annealing. The objective of this combination is to identify the optimal adjustment of FACTS controllers. The suggested technique is used to identify the areas and parameter settings of FACTS controller like TCSC, TCPS, SVC, and UPFC. Total transfer capability has been enhanced with minimized power losses [5].

Available Transfer Capability assumes significant role in deregulated electricity market. Many power producers and distributors are quartered for dispatching and receiving the power transfer through transmission line. A third generation FACTS devices like UPFCs are employed for enhancing the ATC of the transmission segment. A voltage source modelling of FACTS device is attempted with the help of parameter variation in each and every iteration [6].

It was recorded that ATC can be improved by incorporating FACTS devices and proved that TCSC delivers more ATC than SVC [7]. Here, TCSC and SVC are committed with a view of maximising power transfer through transmission line during regular and contingency periods. ATC has been calculated using continuation power flow method by taking into account thermal limits and voltage profile. Cat Swarm optimization algorithm was recommended for installation of FACTS devices and controlling the parameters of TCSC and SVC.

The security margin of the transmission system can be assessed through its Available transfer capability. The ATC of the systems for the bilateral transactions has formulated by the method of repeated power flow for a standard and line outage conditions. A generation shift factor has been considered for optimising the UPFC, PV bus locations [8].

Biogeography Based Optimization (BPO) and PSO technique has been applied in combined emission economic problem with a view of upgrading the ATC. It can be improved by adding transmission utilities or incorporating FACTS devices. A non-iterative, unique and fast power transfer distribution factor-based sensitivity methods is attempted to identify the places and to improve the ATC [9, 10].

Similarly, A TCSC has undergone testing as a FACTS controller with the help of continuing power flow to improve the efficiency of the transmission utilities [11]. In order to enhance the ATC, a particular strategy has been investigated employing a linear sensitivity-based AC power transfer distribution factor. TCSC has been employed by using the PSO algorithm to get the best value for the TCSC device parameter [12].

A flower pollination algorithm has been adopted for the best distribution of TCSC devices to upgrade the ATC of the transmission system. Estimation of ATC is being carried out by distribution factors for AC power based on the Newton-Raphson power flow method [13, 14]. In order to manage the transmission grid from traffic and to boost the transfer capability, FACTS devices are inducted in to the system. Multi objective optimization problem of ATC maximization with minimum FACTS controllers are developed by a hybrid method of real power flow index with PSO algorithm [15].

In this assignment, ATC of the transmission utilities has been enhanced and losses are minimised with the help of FACTS controllers. The settings of the FACTS devices are optimised by the aid of WOA algorithm.

Available Transfer Capability

Available transfer capability is defined as the computation of power transmission capability of the real transmission utilities for further trading exercise over and above of the previously committed transaction. It is defined as

$$ATC = TTC - \left(ETC + TRM + CBM\right) \tag{1}$$

TTC - Total transfer capability
ETC - Existing transmission commitment
TRM - Transmission reliability margin
CBM - Capacity benefit margin

The ATC assessment may assist the trading participants to learn about the system limitations and conditions. Because of this assessment, the power engineers can come to a decision of whether any excess quantity of power can be transmitted with in its transmission areas. Hence the Independent System Operator (ISO) must have thorough knowledge of the ATC of the concerned network with respect to the security and reliability of the network system, when transmitting bulk quantity of power. Basically, the assessment of ATC is classified as deterministic and probability methods. Deterministic methods are generally used for online applications. In case of on-line computations, the deterministic approach can be used with variety of methods. Out of those, RPF method offer better results over other methods while looking thermal, voltage and stability constraints. This method works well for higher capacity power systems when compared with existing methods.

In this problem, RPF method has been used to evaluate the TTC value among the pair of sources and sink areas. The RPF method, required to follow the Photo Voltaic curve pattern till the nose point. In RPF method, generation of power and load demand have to be increased at a specified margin. The incremental process of power is continued, till any of the operational constraints of TTC are breached the limit. The changes in the generation of real power and the corresponding load demands are specified by the following equation.

$$P_{Gi} = P_{Gi}^{\circ}\left(1 + \lambda k_{Gi}\right) \tag{2}$$

$$P_{Di} = P_{Di}^{\circ}\left(1 + \lambda k_{Di}\right) \tag{3}$$

Where P_G is the increased active power generation at bus i and P_G° is the actual real power generation at bus i. Similarly, P_D and P_D° refers to increased active power demand and actual load demand at bus i respectively. λ is the scalar parameter and K_{Gi} is the rate of difference in generation as λ varies. K_{Di} is the rate of variation in load as λ changes. The demand of a reactive power (Q_D) is also surged to put the power factor for all loads. Hence, TTC can be computed using the formulation (4). The equation describes the extreme loadability of a network before attaining the voltage collapse along with highest transmission of flows on interfaces. So that, the voltage and thermal limits are checked out of while computing the TTC. The computation of TTC is based on static conditions and may not address for the dynamic stability limitations.

$$TTC = \min\left[\left(\sum_{i\in k} P_{Di}\left(\lambda_{\max}\right) - \sum_{i\in k} P_{Di}^{\circ}\right), \sum_{ij\in TieLines} P_{Maxij}\right] \tag{4}$$

The prevailing transmission commitment is estimated by load flow calculation. The transmission reliability margin is expressed as some of the percent of the TTC. The capacity benefit margin depends upon the market value among power contractors and it is assumed as zero. Finally, ATC can be calculated as

$$ATC = TTC - ETC - TRM = \left(1 - k\right)TTC - ETC \tag{5}$$

Where “k” is the constant and it is some percent of the computed TTC. Voltage profile and line losses are determined by power flow solutions.

Objective Function and Constraints

The basic concept of OPF has been applied while framing the formulation for the calculation of ATC. The stability limits are also taken into account in order to have best possible solution. The prime focus of the problem is to improve the capacity of line flow through the particular transmission system. Hence the intension is to improve the ATC and to enhance the power transfer between the specified pools while satisfying the thermal and voltage stability limits. Hence, the problem may be formulated as

$$\text{Maximize } P_i = \sum_{j\in i} P_{kj} \tag{6}$$

Subjected to

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

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

(9) $$P_g^{\min} \le P_g \le P_g^{\max}$$

(10) $$Q_g^{\min} \le Q_g \le Q_g^{\max}$$

(11) $$S_{ij} \le S_{ij}^{\max}$$

(12) $$V_i^{\min} \le V_i \le V_i^{\max}$$

Design of Static Compensator (STATCOM)

Now days, the power system network systems become more complex and densely loaded. There is a chance of getting erratic and insecure operation like cascaded thermal overloading, frequency and voltage deviations. It may end up with a congestion problem in electricity market operations. The maximum possible limit of security level has to be supported for the secured operation of the system. The advancements in the field of FACTS devices creates a wide avenue for the control of load flows and the efficient utilization of transmission system. The ATC of the dispatch system can be improved by installing static compensator. Equivalent circuit of static compensator has been displayed in Fig. 1.

(13) $$P_i^{STATCOM} = V_i^2 G_{sh} + V_i V_{sh}\left[G_{sh}\cos\left(\delta_i - \delta_{sh}\right) + B_{sh}\sin\left(\delta_i - \delta_{sh}\right)\right]$$

(14) $$Q_i^{STATCOM} = -V_i^2 B_{sh} + V_i V_{sh}\left[G_{sh}\sin\left(\delta_i - \delta_{sh}\right) + B_{sh}\cos\left(\delta_i - \delta_{sh}\right)\right]$$

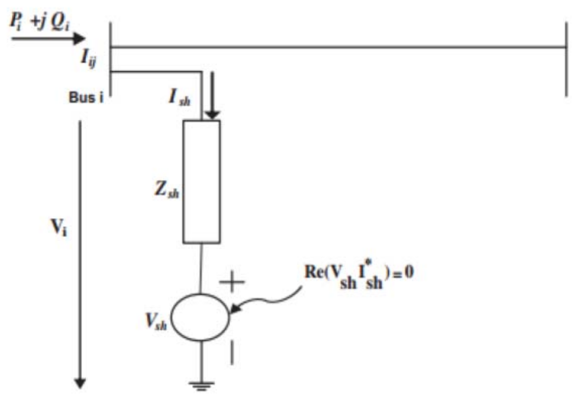

Fig. 1. Diagram of STATCOM

By taking the real power generation as zero, the reactive power supply at bus i can be determined by modelling only the sub-Jacobian matrixes J_3 and J_4 diagonal elements as,

(15) $$\begin{bmatrix} J_1 & J_2 \\ J_3^{STATCOM} & J_4^{STATCOM} \end{bmatrix}$$

Where,

(16) $$J_3^{STATCOM}(i,i) = J_3(i,i) + V_i V_{sh}\left[G_{sh}\cos\left(\delta_i - \delta_{sh}\right) + B_{sh}\sin\left(\delta_i - \delta_{sh}\right)\right]$$

(17) $$J_4^{STATCOM}(i,i) = J_4(i,i) + V_i V_{sh}\left[G_{sh}\sin\left(\delta_i - \delta_{sh}\right) - B_{sh}\cos\left(\delta_i - \delta_{sh}\right)\right]$$

Whale Optimization Algorithm

The whale optimization algorithm was introduced by Mirjalili and Lewis around 2016. This is an advanced swarm intelligence-based optimization algorithm which emulates the hunting character of hump back whales. The prime objective of the technique is to evaluate the complex nonlinear optimization problem by reflecting the whale's preying behaviour. Many researchers have applied the WOA for solving the variety of nonlinear optimization algorithm. There are other heuristic optimization algorithms like ACO, PSO and DE etc. But they are all having the drawback of slow convergence rate and ending with local optima.

The method resembles the whales hunting character. The algorithm resembles the exclusive foraging practice of whales using from it bubble net tactics. The algorithm mimics the distinct bubble-net foraging strategy used by whales [16, 17], as shown in Fig. 2. The Pseudo-Code of Whale Optimization algorithm is given in Fig. 3.

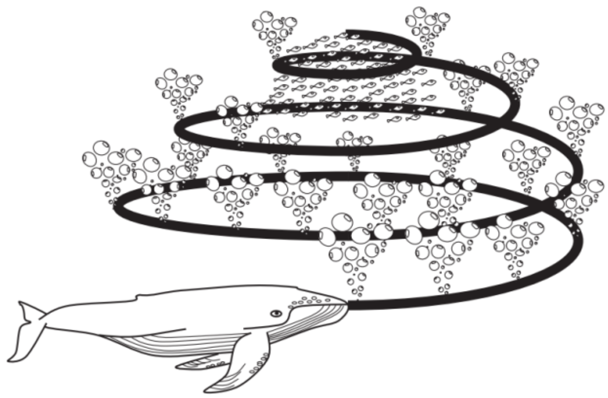

Fig. 2. Diagram of whale bubble-net foraging practice

Once the whale has discovered its victim, it moves upward to begin the preying process and ejects a spiral-shaped bubble net. This predatory character of whales is classified into three categories. They are

- Surrounding Prey
- Bubble Net Attack
- Spiral Update Position
- Hunting Prey Stage

Surrounding Prey

By this algorithm, the whales are initially tries to identify the spot of preying and then besiege it. Actually, the whale does not realize the area of prey in advance. Hence by considering the existing optimal area, the entire group of whales moving towards the advanced place. The encircling of whales, around the prey can be formulated mathematically as,

(18) $$X(t+1) = X^*(t) - A.D, \quad D = \left|C.X^*(t) - X(t)\right|$$

(19) $$A = 2a \cdot rand - a, \quad C = 2 \cdot rand$$

(20) $$a = 2 - \frac{2t}{T_{\max}}$$

Bubble Net Attack

The hump back whales follow the bubble net penetrating method for the purpose of forage. In this process, it changes its direction of movement through the spiral mode to catch the prey in the encircled area. The WOA prescribes two types of predatory behaviour of whales. Shrinking and surrounding mechanism are the spiral update techniques and attained by minimizing the convergence factor 'a' in equation (19) and (20).

Spiral Update Position

Initially, the space between current optimal position and individual whale in the group have to be calculated. Then, activate the whale to catch the prey in spiral. The algebraic equation can be formulated as

$$X(t+1) = D'.e^{bl}.\cos(2\pi l) + X^*(t), \qquad D' = \left|X^*(t) - X(t)\right| \tag{21}$$

Where 'D' gives the space between the i^th whale and the optimal position. 'b' specifies the coefficient of constant used to describe the logarithmic spiral form and 'l' be the random number. During the predatory operation, the whale requires to shrink in the encircled area while spiralling to encircle the forage. Accordingly, in order to attain the same model, spiral encirclement and contraction envelopment are done with the same probability.

```
Initialize the whale's population X_i (i = 1,2, ....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
      If1 (p<0.5)
        If2 (|A|<1)
          Update the position of the current search agent by the Eq. (18)
        else If2 (|A|≥1)
          Select a random search agent (X_rand)
          Update the position of the current search agent by the Eq. (22)
        end if2
      else if1 (p≥ 0.5)
          Update the position of the current search by the Eq. (21)
      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 Whale Optimization algorithm

Hunting Prey Stage

Arbitrarily the whale is changing its existing optimal position, if |A|≥1. This may retain the whale far away against the present reference target and will build up the algorithm's global exploration capabilities. It is necessary to identify a prey which is better than old one. It is mathematically mentioned as,

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

$$D = \left|C \cdot X_{rand} - X(t)\right|,$$

$$r_i = e^t \left(1 \le i \le M\right),$$

$$a_k^i = \{([r_1 * i],[r_2 * i],\ldots,[r_M * i])\}, \quad (i = 1,2,\ldots,M,\ k = 1,2,\ldots,s) \tag{22}$$

Where $\{r_k * i\}$ means considering the decimal part of $r_k * i$.

In order to define the difference between the initial population created by the better point set and the general. Where X_{rand} denotes the random selection of position vector of whale.

Results and Discussion

In this research work IEEE-30 bus experimental test is considered to estimate the ability and efficacy of the proposed Whale Optimization algorithm. The line, bus and generator data of the system is taken from reference [18]. The test system includes 6 generators, 21 loads with 41 transmission lines. The overall system demand of 30 bus network system is 293.4 MW. The foremost bus is taken as slack bus in this case. The load flows are estimated using the Fast Decoupled Load Flow method and the base case values of ATC are obtained by the ACPTDF technique in the MATLAB platform. The one-line diagram of IEEE-30 bus system is given in Fig. 4.

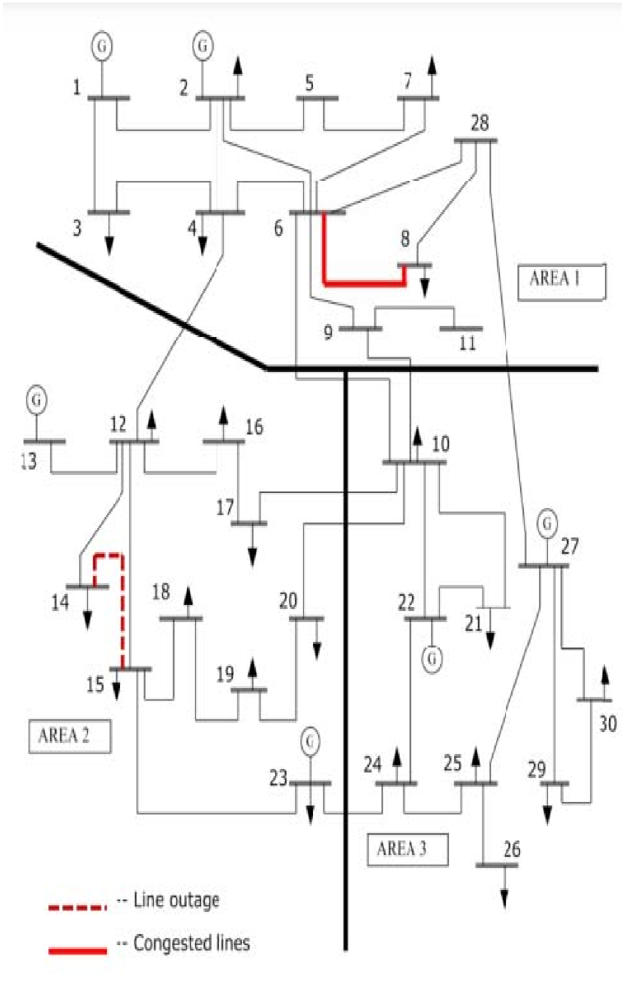

Fig. 4. One-line diagram of IEEE-30 bus system

Table 1. Load flow solution of IEEE 30 bus system

Bus No.	Voltage Mag.	Angle Degree	Load		Generation		Injected
			MW	MVAR	MW	MVAR	MVAR
1	1.060	0.000	0.000	0.000	262.213	-5.268	0.000
2	1.038	-5.458	21.700	12.700	40.000	41.939	0.000
3	1.016	-8.019	2.400	1.200	0.000	0.000	0.000
4	1.006	-9.684	7.600	1.600	0.000	0.000	0.000
5	1.005	-14.456	94.200	19.000	0.000	37.301	0.000
6	1.005	-11.410	0.000	0.000	0.000	0.000	0.000
7	0.997	-13.193	22.800	10.900	0.000	0.000	0.000
8	1.005	-12.198	30.000	30.000	0.000	38.237	0.000
9	1.036	-13.971	0.000	0.000	0.000	0.000	0.000
10	1.018	-15.934	5.800	2.000	0.000	0.000	0.000
11	1.082	-12.908	0.000	0.000	10.000	23.777	0.000
12	1.047	-15.632	11.200	7.500	0.000	0.000	0.000
13	1.071	-15.632	0.000	0.000	17.994	0.000	0.000
14	1.030	-16.551	6.200	1.600	0.000	0.000	0.000
15	1.022	-16.588	8.200	2.500	0.000	0.000	0.000
16	1.028	-16.032	3.500	1.800	0.000	0.000	0.000
17	1.016	-16.177	9.000	5.800	0.000	0.000	0.000
18	1.009	-17.081	3.200	0.900	0.000	0.000	0.000
19	1.004	-17.175	9.500	3.400	0.000	0.000	0.000
20	1.006	-16.923	2.200	0.700	0.000	0.000	0.000
21	1.005	-16.503	17.500	11.200	0.000	0.000	0.000
22	1.005	-16.520	0.000	0.000	0.000	0.000	0.000
23	1.005	-17.055	3.200	1.600	0.000	0.000	0.000
24	0.990	-17.329	8.700	6.700	0.000	0.000	0.000
25	0.983	-18.221	0.000	0.000	0.000	0.000	0.000
26	0.936	-21.052	13.500	2.300	0.000	0.000	0.000
27	1.002	-17.269	0.000	0.000	0.000	0.000	0.000
28	1.001	-12.191	0.000	0.000	0.000	0.000	0.000
29	0.982	-18.554	2.400	0.900	0.000	0.000	0.000
30	0.970	-19.477	10.600	1.900	0.000	0.000	0.000
Total			**293.400**	**126.200**	**312.213**	**153.981**	**0.000**

Initially, the status and conditions of the system has been assessed by conducting load flow studies. Hear a base study by the method of FDLF analysis is carried out on standard IEEE 30 bus system without FACTS devices and is given in Table 1. In this analysis is the maximum power mismatches 0.000910918 and the best solution is obtained at 16th iteration.

The proposed system is subjected to various Bilateral and Multilateral Transactions to calculate the existing real power flow, Total Transfer Capability and Available Transfer Capability. The busses introduced in the bilateral transactions are 2-28, 5-30, 8-25 and 11-26 as BT1, BT2, BT3 and BT4 respectively. The first bus is considered as seller and second bus as buyer. Similarly, three numbers of Multilateral Transactions are carried out among the busses 2, 3, 4, 7, 8; 12, 13, 14, 17, 23 and 21, 22, 24, 27, 29 which is MT1, MT2 and MT3 respectively.

The proposed Whale Optimization algorithm is applied on the system after formulating the bilateral and multilateral transactions at specified busses in order to identify optimal placing and sizing of STATCOM devices. From the experimental study, it is observed that the optimal location and capacities are 5, 18 and 2.19 MVAR, 3.528 MVAR respectively. After installing STATCOM at the bus 5 and 18 the load flow studies are carried out on the test system to calculate actual real power, Total Transfer Capability, and Available Transfer Capability of the system.

Table 2. Simulation Results for various Bilateral Transactions

Bilateral Transactions	Seller Bus	Buyer Bus	Without STATCOM		With STATCOM	
			TTC (MW)	ATC (MW)	TTC (MW)	ATC (MW)
BT1	2	28	356	170.5	425	239.5
BT2	5	30	293	107.5	302.4	116.9
BT3	8	25	311	125.5	321	135.5
BT4	11	26	293.4	107.9	299.4	113.9

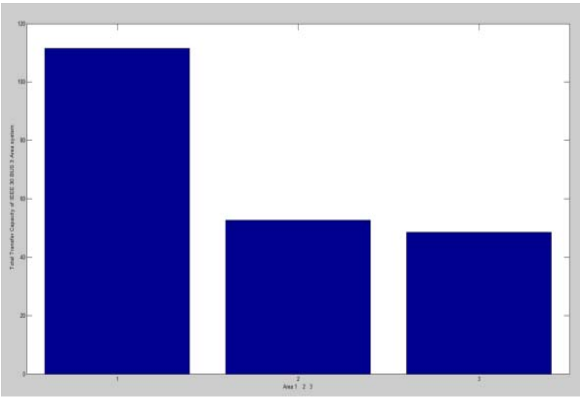

Fig. 5. Total Transfer capability for Area1, Area2 and Area3

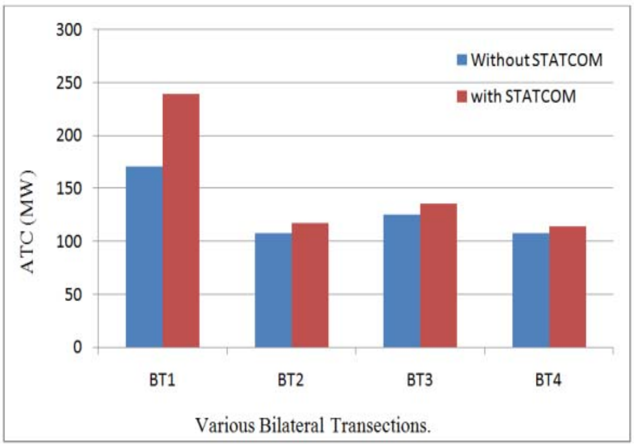

Fig. 6. Comparison of ATC for various Bilateral Transactions

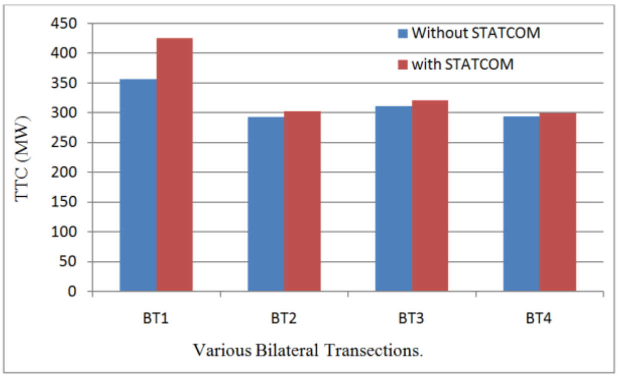

Fig. 7. Comparison of TTC for various Bilateral Transactions

The simulation results of proposed test system with various Bilateral and Multilateral Transactions are clearly recorded in Table 2 and Table 3. This table includes various seller and buyer buses, ATC and TTC for different Bilateral and Multilateral Transactions with and without STATCOM. From the Table 2 and Table 3, values of ATC and TTC are effectively improved after installing the STATCOM in a proper location.

Table 3. Simulation Results for various Multilateral Transactions

Multilateral Transactions	Seller and Buyer Buses	Without STATCOM		With STATCOM	
		TTC (MW)	ATC (MW)	TTC (MW)	ATC (MW)
MT1	2,3,4,7,8	212.7	27	220.7	35
MT2	12,13,14, 17,23	205.7	20	251	65.3
MT3	21,22,24, 27,29	200	14.5	211	25.3

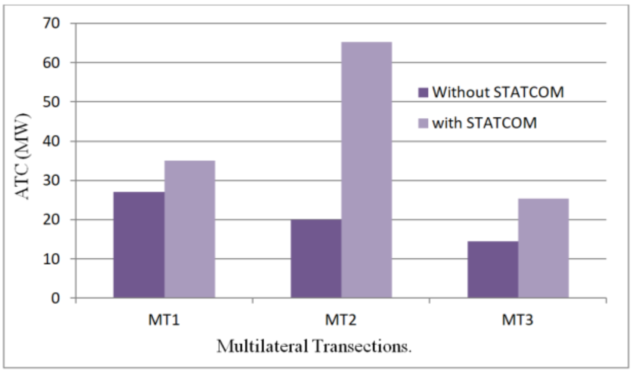

Fig. 8. Comparison of ATC for various Multilateral Transactions

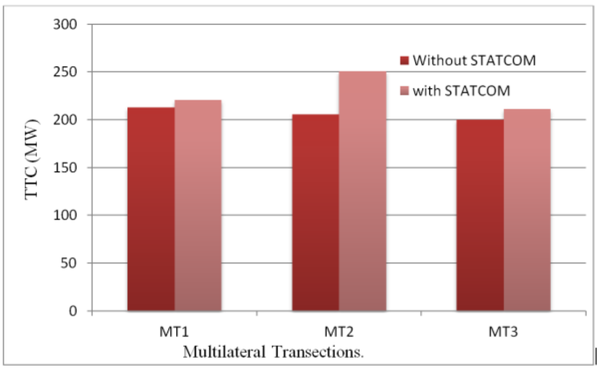

Fig. 9. Comparison of TTC for various Multilateral Transactions

The proposed IEEE 30 bus system are separated into three areas such as Area 1, Area 2 and Area 3 for the purpose of deregulation. The Total Transfer capability of Area 1, Area 2 and Area 3 are graphically reported in Fig. 5. The Comparison of ATC and TTC for various Bilateral Transactions are sharply displayed in Fig. 6 and Fig. 7. Similarly, the comparison of ATC and TTC for various Multilateral Transactions are graphically shown in Fig. 8 and Fig. 9. From the comparison, the proposed STATCOM with Whale optimization algorithm enhanced ATC and TTC with less computational time.

Conclusion

In this paper, enhancement of Total Transfer Capability and Available Transfer Capability of Transmission Companies (TRANSCOs) under competitive open market is proposed. An exceptional FACTS devises of STATCOM is considered and installed at an optimal location of transmission systems. A unique optimization algorithm of Whale Optimization algorithm has been employed for identifying the best location and sizes of the STATCOM. It has been demonstrated that this algorithm has the potential to solve variety of optimization problems by outperform the present algorithms.

The objective of the problem is to enhance the available transfer capability and total transfer capability by minimizing the real power losses of the TRANSCOs. The proposed model is subjected to investigation on various bilateral and multilateral transactions for enhancing the ATC and TTC. The case studies were tested on standard IEEE 30 bus system under deregulated environment. From the outcomes, it has been concluded that a reliable alternative approach of WOA with STATCOM improves the TTC which in turn enhances the ATC by minimizing the transmission losses.

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