Middle-East Journal of Scientific Research 24 (12): 3763-3771, 2016
ISSN 1990-9233
© IDOSI Publications, 2016
DOI: 10.5829/idosi.mejsr.2016.3763.3771

Available Transfer Capability Enhancement with Facts Devices Based on Grey Wolf Optimization Technique

[1]R. Sripriya and [2]R. Neela

[1]Assistant Professor, Department of Electrical Engg,
Annamalai University-608002, Tamil Nadu, India
[2]Professor, Department of Electrical Engg,
Annamalai University-608002, Tamil Nadu, India

Abstract: This paper proposes an application of swarm - inspired new meta-heuristic Grey Wolf Optimization (GWO) technique to enhance the Available Transfer Capability (ATC) of the power system. This optimization technique is based on mathematical approach whose solution convergence inspired by the social hierarchy and hunting mechanism of grey wolves. It explores search space as a multi- level decision mechanism and does not require gradient for the search path**.** Determination and Enhancement of ATC are important issues in deregulated operation of power systems.ATC determination and enhancement for bilateral transaction based on AC Power Transfer Distribution Factor (ACPTDF) with Flexible AC transmission Systems (FACTS) devices is the main objective of this work. Most popular FACTS devices such as SVC, TCSC and UPFC are considered for enhancing the ATC of the interconnected power systems. Optimal location of FACTS devices were determined based on Grey Wolf Optimization (GWO) technique. The problem is solved by taking into account the variations in wheeling transactions across any two selected buses and the algorithm is tested for ATC under various load conditions in a Combined Emission Economic Dispatch (CEED) environment. The proposed technique is implemented on standard IEEE 14, 30 and 57 bus test systems. These systems are loaded starting from base load to 20% of in steps of 5%load increment and the system performance is observed for without and with FACTS devices.

Key words: Available Transfer Capacity (ATC) · Flexible AC transmission system (FACTS) devices · Grey Wolf Optimization (GWO)

INTRODUCTION

Deregulation of the electricity industry throughout the world aims at creating a competitive market to trade electricity, which generates a host of new technical challenges to market participants and power system researchers. Power system restructuring environment policies are adopted in various developed countries and some of the developing countries are in the process of restructuring.

In order to have open access in the restructured power market, a transparent knowledge about the generation capacity and the transmission capability of the system is essential. Since many utilities provide transaction services for wholesale customers, they must have sufficient information about ATC of their transmission networks. Such information will help power marketers, sellers and buyers in reserving transmission services. Various mathematical models have been developed by the researchers to determine the ATC of the transmission system. Flexible AC Transmission Systems (FACTS) have the ability to allow power systems to operate in a more flexible, secure, economic and sophisticated way. FACTS devices can offer an effective and promising alternative to conventional methods for ATC enhancement in the deregulated power systems.

An important concept in the restructuring of the electric power industry to accurately and rapidly quantify the capabilities of the transmission system is described in [1]. Transmission transfer capability is limited by a number

Corresponding Author: R. Sripriya, Assistant Professor, Department of Electrical Engg, Annamalai University-608002, Tamil Nadu, India. Tel: +919786601392.

of different mechanisms, including thermal, voltage and stability constraints. The linear ATC computation using DC Power Transfer Distribution Factors (DCPTDF) and its use to allocate real power flows on the transmission lines has been demonstrated in [2]. Development of a simple and non-iterative method to calculate ATC of a transmission system using a new set of distribution factors is presented in [3]. Sets of power transfer distribution factors and voltage distribution factors have been obtained using the sensitivity based approach for the base case as well as contingency cases and utilized to check line flow limits and voltage limits during ATC determination. Hybrid mutation Particle swarm Optimization for enhancing Available transfer Capability has been suggested in [4]. In [5] new approaches are proposed for determining the reactive power flows and then evaluate ATC using Power Transfer Distribution Factors. The insertion of Flexible AC transmission system (FACTS) device in electric power systems seems to be a promising strategy to enhance the ATC values by using Thyristor controlled series compensator (TCSC), static VAR compensator (SVC) and unified power flow controller (UPFC). Particle swarm optimization (PSO) algorithm is employed to obtain the optimal settings of FACTS devices has been discussed in [6]. Multi objective differential evolution has been applied for solving economic environment.tal dispatch problem as explained in [7]. A sensitivity based approach has been used for finding the optimal placement of FACTS devices in a deregulated environment has been developed in [8]. A hybrid immune algorithm for finding the optimal location of UPFCs for obtaining minimum active and reactive power production cost of UPFCs has been presented in [9]. ATC has been determined for bilateral and multi - lateral transactions based on PTDF‘s with FACTs devices using NR load flow approach. The optimal placement of FACTS devices based on power flow sensitivity analysis is reported in [10]. A new set of AC power flow based sensitivity indices have been developed for the optimal placement of UPFC by using Ant colony optimized technique in [11]. The ATC enhancement between the areas is done by using UPFC device. The impact of ATC enhancement on the voltage profile during power imbalances due to generator outages has been studied in [12]. The potential of Grey Wolf Optimization is used for solving Active Power Dispatch problems considering valve point effect has been explained in [13]. The results of the GWO are compared with that of other intelligence optimization algorithms in terms of operating cost of generators and power generation. It gives a robust result, accurate convergence characteristics and optimality of this optimization technique. The Economic Load Dispatch (ELD) problem has been solved by using GWO in [14]. To show the effectiveness of GWO the ELD problem results were compared with other existing techniques. In [15] a newly developed Grey Wolf Optimization algorithm, which is very flexible and quite efficient, has been successfully implemented to solve ELD problems with different constraints. This simulation results proved that the performance of GWO algorithm is better as compared to that of several previously developed optimization techniques. In [16] a Security constrained optimal power flow problem is solved by using GWO technique This proposed algorithm incorporates weighted penalty function for optimal adjustment of voltage and active power injection at generator bus and it uses ratio of tap changing transformer as control parameter to get the minimum total generation cost. In [17] the loss and voltage deviation minimizations are achieved by using Grey wolf Optimizer.

In this proposed work, ATC is calculated using ACPTDF in CEED environment. Then ATC enhancement is carried out by the application of GWO algorithm to optimally place and size the FACTS devices. Three types of FACTS devices are used in this study namely TCSC, SVC and UPFC for enhancing ATC. In order to demonstrate the effectiveness of the proposed method, the standard IEEE 14, 30 and 57 bus test systems were considered and the algorithm has been tested under various load conditions.

Available Transfer Capability: ATC is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above the already committed uses. ATC is the difference between Total Transfer Capability (TTC) and Existing Transmission Commitment (ETC).

$$ATC = TTC - ETC$$

where, TTC is defined as the amount of electric power that can be transmitted over the interconnected transmission network in a reliable manner while meeting all of a specific set of pre and post - contingency conditions. ETC is the power flow over the transmission paths at the desired time at which ATC should be calculated. This is the already committed used power on the transmission path.

In order to calculate TTC, thermal, voltage and security limits are also considered.

ATC at base case between buses m and n using line flow limit criterion is mathematically formulated using

$$ATC_{mn} = \min \{T_{i,mn}\},\ ij \in NL \tag{1}$$

where,
$T_{i,mn}$ is the transfer limit values for each line in the system.

$$T_{ij,mn} = \left\{ \begin{array}{ll} \frac{(P_{ij}^{max} - P_{ij}^{0})}{PTDF_{ij,mn}}; & \text{if } PTDF_{ij,mn} > 0 \\ \infty\ (infinite); & \text{if } PTDF_{ij,mn} = 0 \\ \frac{(-P_{ij}^{max} - P_{ij}^{0})}{PTDF_{ij,mn}}; & \text{if } PTDF_{ij,mn} < 0 \end{array} \right\} \tag{2}$$

Where
P_{ij}^{max} is MW power limit of a line l between buses i and j
P_{ij}^{0} is the base case power flow in line l between buses i and j

$PTDF_{ij,mn}$ is the power transfer distribution factor for the line l between bus i and j when there is a transaction between buses m and n and NL represents the number of lines.

In this paper, the optimal settings of generators were first identified under CEED environment and then AC PTDFs were calculated.

CEED Problem Formulation: The CEED problem is formulated using the following equation.

$$\phi = \min \sum_{i=1}^{Ng} f(FC, EC). \tag{3}$$

where,
Φ is the optimal cost of generation in Rs/hr

FC and EC are the total fuel cost and emission cost of generators.

Ng represents the total no. of generators connected in the network.

The cost is optimized following the standard equality and inequality constraints.

$$\sum_{i=1}^{Ng} p_{gi} = p_d + p_l$$
$$p_{gi}^{\min} \le p_{gi} \le p_{gi}^{\max}$$

where,
P_{gi} Is the power output of the ith generating unit.
P_d Is the Total demand of the system
P_l Is the transmission losses of the system.
$p_{gi}^{\min}$ and $p_{gi}^{\max}$ are the minimum and maximum values of real power generation allowed at generator i.

The bi-objective CEED problem is converted into single optimization problem by introducing price penalty factor h and CEED problem is solved by using evolutionary programming.

ACPTDF Formulation: The AC PTDF is explained below.

A bilateral transaction t_k between a seller bus m and buyer bus n is considered. Line l carries the part of the transacted power and is connected between bus i and j. For a change in real power transaction among the above buyer and seller by Δt_k MW, if the change in transmission line quality q_i is Δq_i, PTDF is defined as

$$PTDF_{ij,mn} = \frac{\Delta q_l}{\Delta t_k} \tag{4}$$

where,
Δt_k = change in real power transaction among the buyer and seller by Δt_k
Δq_l = change in transmission line quality Δq_l .

The transmission quality q_i can be either real power flow from bus i to j (p_{ij}) or real power flow from bus j to i p_{ji}. The Jacobian matrix for NR power flow is given by

$$\begin{pmatrix} \Delta\delta \\ \Delta V \end{pmatrix} = \begin{pmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{pmatrix}^{-1} \begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix} = (J)^{-1} \begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix} \tag{5}$$

If only one of the k^{th} bilateral transactions is changed by Δt_k MW, only the following two entries in mismatch vector on the RHS will be non-zero.

$$\left. \begin{array}{l} \Delta P_i = \Delta t_k \\ \Delta P_j = -\Delta t_k \end{array} \right\} \tag{6}$$

With the above mismatch vector element, the change in voltage angle and magnitude at all buses can be computed from (5) and (6) and hence the new voltage profile can be computed. These can be utilized to compute all the transmission quantities q_l and hence the corresponding changes in these quantities Δq_l from the base case.

Once Δq_l for all the lines corresponding to a change in Δk_t is known, PTDF'S can be obtained from the equation (4).

Problem Formulation: The objective is to maximize the ATC between the sending and receiving end buses.

$$\text{ATC} = \max \sum{}_i^{\max} - P_i^{flow}$$

where,

P_i^{max} is the thermal limit of the line.

P_i^{flow} is the base case flow of the line

In order to maximize ATC, suitable locations have been identified for the FACTS devices and their ratings are fixed by implementing the GWO technique.

FACTS Devices: Flexible AC Transmission systems (FACTS) are used for control of voltage, phase angle and impedance of high voltage transmission lines. The strategic benefits of incorporating FACTS devices are improved reliability, better utilization of existing transmission system, improved availability and increased transient and dynamic stability and also increased the quality of supply. Dynamic nature of load and generation patterns, heavier line flows and higher losses cause security and stability problems. To overcome these problems in the present deregulated environment FACTS devices are essential to improve the system performance by controlling the power flows in the grid, to minimize transmission losses and improve the voltage profile of the systems. When compared to conventional devices these devices can be used an all three states namely steady state, transient state and post - transient state of the power system.

There are many types of FACTS devices available for power flow control. Among them TCSC, SVC and UPFC are considered in this work to enhance the power Transfer capability of the System.

TCSC Modeling: TCSC are connected in series with the transmission line in order to improve the power flow through it. It is modeled to modify the reactance of the transmission line directly. It may be inductive or capacitive, to increase or decrease the reactance of the transmission line. The series capacitor contributes to a better improvement in the voltage profile.

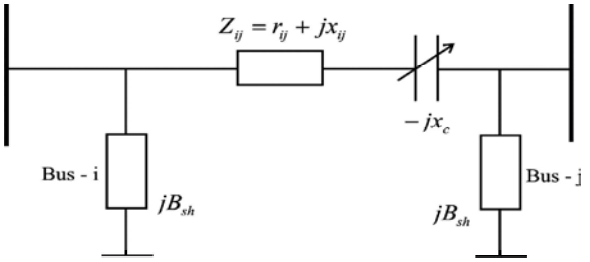

Fig. 1: Thyristor Controlled Series Capacitor

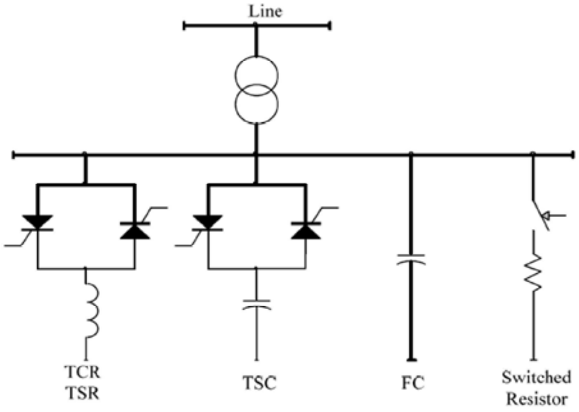

Fig. 2: Static VAR Compensator

The working range of TCSC is as

$$-0.8X_L \leq X_{TCSC} \leq 0.2\,X_L$$

where,

X_{TCSC} is the reactance added to the line by placing TCSC

X_L is the reactance of the line where TCSC is located.

The transmission line model with a TCSC connected between the two buses i and j is shown in Fig. 1.

SVC Modeling: The SVC is a shunt connected FACTS device whose main functionality is to regulate the voltage at a given bus by controlling its equivalent reactance. The SVC may have two characteristics namely, inductive and capacitive. In the inductive mode, it absorbs reactive power and in the capacitive mode, reactive power is injected. It is used for voltage control applications. It helps to maintain a bus voltage at the desired value during load variation. SVC includes two main components namely. Thyristor controlled and Thyristor switched Reactor (TCR and TSR) and Thyristor switched capacitor (TSC). Fig. 3.2 shows the circuit model of SVC.

The working range of SVC is defined as follows

$$-100\text{MVar} \leq Q_{SVC} \leq 100\text{MVar}$$

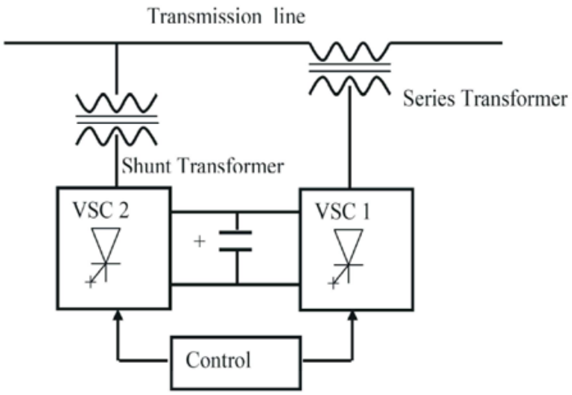

Fig. 3: Unified Power Flow Controller

where
Q_{SVC} is the reactive power injected at the bus by placing SVC

UPFC Modeling: UPFC is one of the most powerful FACTS devices, because it has the ability to control the three parameters of power flow either simultaneously or separately, i.e., transmission angle, terminal voltage and system reactance. It mainly consists of two converters connected by a common DC link, one connected in series with the line through a series injection transformer and another connected in shunt with the line through a shunt coupling transformer. The series controller is used to inject phase voltage with controllable phase angle and magnitudes in series with the line in order to control real and reactive power. The shunt connected controller performs the primary function of delivering the exactly right amount of real power required by the series controller, it also performs its secondary function of generating required reactive power for regulation of the real AC bus voltage. The UPFC offers the unique capability of independently regulating the real and reactive power flows on the transmission lines, while also regulating the local bus voltage. The shunt controller in the UPFC operates exactly as STATCOM for reactive power compensation and voltage stabilization. The series controller operates as SSSC to control the real power flow and UPFC gives better performance as compared to STATCOM, SSSC and TCSC. The UPFC modeled as shown in Fig. 3.

Overview of GWO technique: Grey Wolf Optimizer new population-based method inspired by the behavior of grey wolf was introduced by Mirjalili in 2014.Grey wolves are considered as top level predators and they reside at the top of the food chain. They live in a pack which consists of 5-12 wolves on an average. The social hierarchy of gray wolves is shown in Fig. 1.

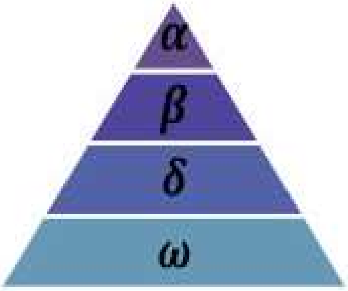

Fig. 4: Social hierarchy of gray wolves

In GWO algorithm, the leadership hierarchy has four groups. They are alpha, beta, delta and omega. The leaders are called alpha. They are called decision maker and dictator of the group. Beta are the subordinate wolves that come on the second level of the hierarchy and they follow the alpha command throughout the pack and gives feedbacks to the alpha. The lowest ranking grey wolf is omega. Omega is not a main member but everyone faces the fighting and problems in the case of losing omega. If a wolf is not an alpha, beta or omega, then it is called as delta. The roles of delta wolves are as scouts, sentinels elder, hunters and caretakers belong to this group. The most common social behavior of grey wolves is group hunting.

The main phases of grey wolf hunting are

- Tracking, chasing and approaching the prey.
- Pursuing, encircling and harassing the prey.
- Attack towards the prey.

Mathematical Model: In the mathematical modeling of the social hierarchy of wolf, alpha (β) is considered as the fittest solution, beta (β) and delta (δ) are the second and third fittest solutions respectively. The rest of the candidate's solutions are considered as omega. The hunting is guided by α, β and δ. The ω wolves follow β, β and δ wolves.

Grey wolves encircle a prey during the hunt maintaining a radial distance. The distance of a wolf from a prey is given by D. Following equations are proposed to mathematically model encircling behavior of grey wolves:

$$D= (C. Xp (t) - X (t))$$

$$X (t+1) =Xp (t) -A.D$$

where, t is the current iteration, A and C are coefficient vectors, Xp(t) represents the position vector of the prey.

The vectors A and C can be calculated as below:

$X=2.a.r1-a$

$C=2.r2$

where, ‘a ‘is linearly decreased from 2 to 0 over the course of iterations and r1 and r2 are random vectors in the range [0,1].

Hunting: In GWO, the first three best solutions (β, β, δ.) obtained are stored so far and push the other search agents (including the omegas) to update their positions due to the position of the best search agents. The following equations are modeled

$D_{\alpha}= (C1.X_{\alpha} (t) - X (t))$

$D_{\beta}= (C2.X_{\beta} (t) - X (t))$

$D_{\delta} = (C3.X_{\delta} (t) - X (t))$

$X1=X_{\alpha} - A1. D_{\alpha}$

$X2=X_{\beta} - A2. D_{\beta}$

$X3=X_{\delta} - A3. D_{\delta}$

$X (t+1) =X1+X2+X3/3;$

The final position would be a random position within a circle which is defined by the positions of alpha, beta and delta in the search space. In other words, alpha, beta and delta estimate the prey position and other wolves update their positions randomly around the prey.

Attacking Prey: ‘A’ is an arbitrary value in the gap (-2a, 2a), when [*A*]<1, the wolves are forced to attack the prey. Attacking the prey is the Exploration ability. The random value of ‘A’ is utilized to force the search agent to move away from the prey. When [*A*]>1, the grey wolves are enforced to diverge from the prey.

- If [*A*]<1 = Attacking prey → Exploitation
- If [*A*]>1 = Searching for prey → Exploration

Search for Prey: This is the final position of this algorithm. Grey wolf updates their position according to positions of the alpha, beta and delta in the search space. They diverge from each other or explore the search space to search for prey and converge to attack prey.

GWO Algorithm:

1. Read system data and network configurations including line data, bus data and generator data.
2. Initialize population size n, parameter a, coefficient vectors A and C, max. no. of iterations and also initialize β, β and δ positions.
3. Assign the value of first, second and the third best solution $X\beta$, X_{β}, X_{δ} respectively.
4. Evaluate the fitness function of each search agents (β, β and δ.)
5. For each search agent, update the position of current search agent by the equation.

$$X (t+1) = \frac{X1+X2+X3}{3}$$

6. Update a, A and C, calculate the fitness for all search agents.
7. Update $X\beta$, X_{β}, $X_{\delta.}$
8. Check whether the maximum iteration reached or not, if reached display the best positions and variable, otherwise go to step 3.

Algorithm for ATC enhancement:

1. Read the line data, bus data and generator data of the proposed systems.
2. Run the base case optimal power flow (OPF) in the combined emission economic dispatch environment to obtain the base case results.
3. Consider a single wheeling transaction *k*.
4. Compute AC power transfer distribution factor corresponding to the selected t_k.
5. Taking in to account the line flow limits based upon stability and thermal limits, determine the ATC values.
6. Arrange ATC’s in ascending order.
7. Fix the type and number of FACTS devices that are to be connected in the system.
8. Run the GWO algorithm to obtain the location and rating of FACTS devices.
9. Calculate ATC values after incorporating FACTS devices TCSC, SVC and UPFC.
10. Consider the next wheeling transaction t_k and go to step 4.

Simulation and Test Results: The proposed Grey wolf based optimization technique has been tested on standard IEEE 14, 30 and 57 bus test systems. A bilateral transaction has been initiated between buses 12 and 13 in a common emission economic dispatch environment and the ratings and locations of FACTS devices are fixed with an objective of improving the ATC for the above - mentioned transaction. The ATC values are obtained through ACPTDF formula and calculated for the particular transaction using the NR Jacobian. The maximum number of FACTS devices has been limited to 3 taking into consideration the cost of the device. For IEEE 14 bus system FACTS device is limited as one, for IEEE 30 bus system two FACTS devices are considered and for IEEE 57 bus system three FACTS devices are considered. The test results for the ATC enhancement problems are given in tables for IEEE 14, 30 and 57 bus systems.

To study the implementation of FACTS devices for ATC enhancement, the load on the systems were increased in a step by step manner (from the base value to 20% of over base value in steps of 5%) for all the three test systems. For IEEE 14 bus systems the base load demand is considered as 259 MW and for IEEE 30 bus test systems base load demand is considered as 283 MW and for IEEE 57 bus systems base load is considered as 1251 MW.

The ATC values without and with FACTS devices are shown in Tables 6.1, 6.2 and 6.3 and an equivalent bar chart is presented also illustrate the performance of the proposed technique.

Table 6.1: Comparison of ATC values in MW with and without FACTS devices at different load conditions of IEEE 14 bus test system

		ATC values in MW (per line)				
Method	FACTS Devices	Base Load	5% Over Loaded	10% Over Loaded	15% Over Loaded	20% Over Loaded
GWO	W/O FACTS	12.52	11.67	10.72	9.74	8.20
	With TCSC	13.03	11.95	11.07	10.11	8.99
	With SVC	14.48	13.51	12.40	11.33	10.29
	With UPFC	17.67	17.08	16.34	15.82	15.24

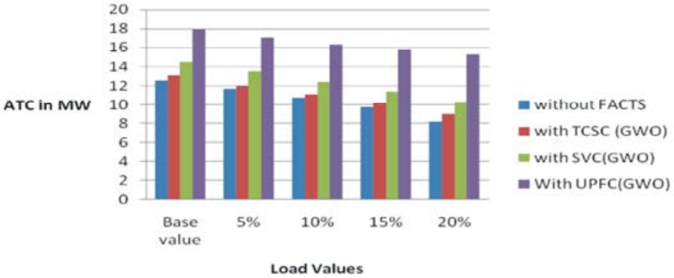

Fig. 6.1: ATC Vs % of Incremental Load for IEEE 14 Bus Test System (With GWO)

Table 6. 2: Comparison of ATC values in MW with and without FACTS devices at different load conditions of IEEE 30 bus test system

		ATC values in MW (per line)				
Method	FACTS Devices	Base Load	5% Over Loaded	10% Over Loaded	15% Over Loaded	20% Over Loaded
GWO	W/O FACTS	26.87	26.22	25.47	24.66	23.78
	With TCSC	27.57	26.80	26.09	25.17	24.49
	With SVC	27.71	26.99	26.24	25.43	24.51
	With UPFC	28.84	28.05	27.28	26.54	25.63

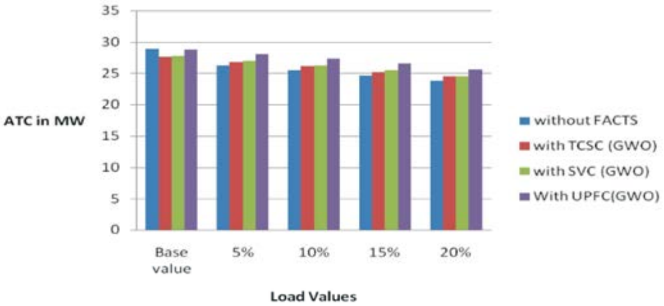

Fig. 6.2: ATC Vs% of Incremental Load for IEEE 30 Bus Test System (With GWO)

Table 6.3: Comparison of ATC values in MW with and without FACTS devices at different load conditions of IEEE 57 bus test system

		ATC values in MW (per line)				
Method	FACTS Devices	Base Load	5% Over Loaded	10% Over Loaded	15% Over Loaded	20% Over Loaded
GWO	W/O FACTS	14.94	13.46	12.69	11.51	10.09
	With TCSC	15.30	14.41	13.21	12.13	10.59
	With SVC	15.99	14.87	13.73	12.58	11.61
	With UPFC	17.26	16.48	15.39	14.73	13.54

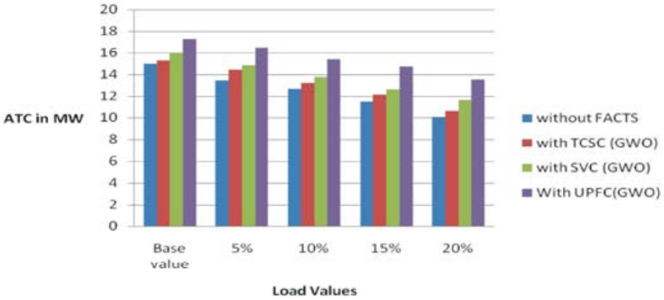

Fig. 6.3: ATC Vs % of Incremental Load for IEEE 57 Bus Test System (With GWO)

CONCLUSION

In this paper, an application of swarm- inspired GWO technique is proposed for ATC enhancement for a bilateral transaction under CEED environment. This optimization technique simultaneously searches the optimum size and location of FACTS devices under normal and varying load conditions. Its performance has been evaluated by implementing it on standard IEEE 14, 30 and 57 bus test systems. The results clearly indicate that there is a considerable increase in the ATC of the lines after placing the FACTS devices for the considered bilateral transaction. The advantage of GWO algorithm is its simplicity, reliability and efficiency. It exhibits a global convergence for many of the practical problems. By applying this technique ATC of the systems can be enhanced for any of the wheeling transactions. This enhancement will improve the open access bidding and also promote competitive markets for electric power trading.

REFERENCES

1. Sauer and Peter, W., 1997. Technical challenges of computing available transfer capability (ATC) in electric power systems: System Sciences, Proceedings of the Thirtieth Hawaii International Conference on IEEE, pp: 5.
2. Christie, R.D., B.F. Wollenberg and I. Wangensteen, 2000. Transmission Management in the Deregulated Environment: Proceedings of IEEE, 88(2): 170-195.
3. Kumar, A., S.C. Srivatsava and S.N. Singh, 2004. Available Transfer Capability (ATC) Determination in a Competitive Electricity Market Using AC Distribution Factors: International Journal of Electric Power Components and Systems, 32(9): 927-939.
4. Farahmand, H., A. Rashidinejad, A. Gharaveisi and G.A. Shahriary, 2007. Optimal Location of UPFC for ATC Enhancement in Restructured Power Systems: IEEE.
5. Ibrahim and Naresh Kumar Yadav, 2011. Implementation of FACTS Device for Enhancement of ATC using PTDF: International Journal of Computer and Electrical Engineering, 3(3).
6. Manikandan, B.V., S. Charles Raja and P. Venkatesh, 2011. Available transfer capability enhancement with FACTS devices in the deregulated electricity market: Journal of Electrical Engineering & Technology, 6.1: 14-24.
7. Basu, M., 2011. Economic environmental dispatch using multi-objective differential evolution, Applied Soft Computing, 11: 2845-2853.
8. Swapna, G., J. Srinivasa Rao and J. Amarnath, 2012. Sensitivity Approach to improve Transfer Capability through optimal placement of TCSC and SVC. International Journal of Advances in Engineering &Technology, 4(1): 525-536.
9. Seyed Abbas Taher and Muhammad Karim Amooshahi, 2012. New approach for optimal UPFC Placement using hybrid immune algorithm in electric power systems, Electrical Power and Energy Systems, 43: 899-909.

10. Ashwani Kumar and Jitendra Kumar, 2013.ATC determination with FACTS devices using PTDF‘s Approach for multi-transactions in competitive electricity markets, Electrical Power and Energy Systems, 44: 308-317.
11. Prakash G. Burade and Dr. Jagdish B. Helonde, 2012. Optimal Placement of FACTS Device to Maximize the Loadability of Transmission Lines: International Journal of Science and Engineering Investigations, 1(3).
12. Chaitanya, D.V.S.B., N. Bharath Kumar and Mahaboob Shareef Syed, 2014. Impact of Available Transfer Capability Enhancement in a Three Area System Using UPFC: Int. Journal of Engineering Research and Applications, 4, No. 2(1), Feb.
13. Navpreet Singh Tung and Sandeep Chakravorty, 2015. Grey Wolf Optimization for Active Power Dispatch Planning Problem Considering Generator Constraints and Valve Point Effect, International Journal of Hybrid Information Technology, 8(12): 117-134.
14. Sharma, Shivani Mehta and Nitish Chopra, 2015. Economic Load Dispatch Using Grey Wolf Optimization”, International Journal of Engineering Research and Applications, Vol. 5, No. 4, Part -6): 128-132.
15. Sudip Kumar Ghorui, Roshan Ghosh and Subhashis Maity, 2016. Economic Load Dispatch of Power System Using Grey Wolf Optimization with Constriction Factor: International Journal of Scientific & Engineering Research, Vol. 7, No. 4, April.
16. Deep A. Sheth, Hena N. Desai and Hiren D. Mehta, 2016. Security Constrained Optimal Power Flow using Grey Wolf Optimization Technique: international journal of innovative research in electrical, electronics, Instrumentation and Control Engineering, 4(5).
17. Mohd Herwan Sulaiman, Zuriani Mustaffa, Mohd Rusllim Mohamed and Omar Aliman, 2015. Using the gray wolf optimizer for solving optimal reactive power dispatch problem Applied Soft Computing, 32: 286-292.