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ATC ENHANCEMENT THROUGH OPTIMAL PLACEMENT OF TCSC USING WIPSO TECHNIQUE

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ABSTRACT

Deregulation of electric power industry aims at creating a competitive market and this brings in new challenges in the technical and non technical aspects. One such problem is congestion management which involves relieving the transmission lines off their overloads, which in other words means enhancing the Available Transfer Capacity of the lines (ATC). In this paper the problem of enhancing the transfer capacity of the transmission lines is addressed by installing TCSC'S through the application of one of the variants of the popular Meta heuristic search technique, Particle Swarm Optimization (PSO) namely Weight Improved Particle Swarm Optimization (WIPSO). The problem is solved by taking into account the variations in wheeling transactions across any two selected buses and the algorithm is used for enhancing the ATC under various load conditions in an emission economic dispatch environment and the results are compared against those obtained using PSO.

Keywords: FACTS devices, thyristor controlled series capacitor (TCSC), particle swarm optimization (PSO), weight improved particle swarm optimization, available transfer capacity.

INTRODUCTION

Deregulation of electric power industry aims at creating competitive markets to trade electricity and it generates a host of technical problems that need to be addressed. One of the major requirements of open access environment is the presence of adequate of Available Transfer Capacity in order to maintain economy and ensure secure operation over a wide range of operating conditions. There are several approaches to enhance the ATC; some of the commonly adopted techniques are to adjust the settings of OLTCS and rescheduling generator outputs.

With the capability of flexible power flow control and rapid action, Flexible AC Transmission systems technology host a greater impact over the thermal, voltage and stability constraints of the system. With the increase in system loading ATC values ultimately limited by the heavily loaded circuits or nodes with relatively low voltages. FACTS concept uses circuit reactance, voltage magnitude and phase angles as control variables to redistribute line flow and regulate nodal voltages thereby mitigations the critical situation.

ATC determination based on PTDF'S and FACT devices placement through power flow Sensitivity analysis is reported in [1]. A Mixed Integer Optimization Technique for effectively coordinating the FACTS devices with the conventional generators is discussed in [2].Hybrid mutation particle swarm optimization for enhancing ATC has been proposed in [3].This proposed technique increases the global searching ability of the conventional PSO by applying mutation. Real coded genetic algorithm has been used for the placement of SVC and TCSC with an objective of enhancing ATC under bilateral transfer as well as line outage conditions in [4]. In this paper the device placement (TCSC) has been done for a specific bilateral wheeling transaction power transfer in order to increase the ATC of the system. A GA based technique for the optimal placement of FACTS devices has been discussed in [5]. A PSO based optimization technique which optimizes the generator' active power outputs, generator's bus voltages, TCSC reactance and its location is discussed in [6]. A sensitivity factor based approach for fixing the optimal location and rating of TCSC taking into account the power transaction between the any two selected buses has been discussed in [7]. A hybrid heuristic technique for the optimal placement of TCSC has been suggested in wherein real coded genetic algorithm along with fuzzy sets has been used for optimizing the complex objective comprising of ATC, system voltage profile and device cost [8]. A congestion cost based technique in which TCSC placement is carried out after calculating the congestion rent by running optimal power flow is outlined in [9]. An optimal power flow based FACTS device placement with an objective of maximizing the power flow across a specified interface is discussed in [10]. A sensitivity factor based technique in which the sensitivity factors which describe the line real power flow sensitivity for the line reactance and bus voltage angle differences is explained in [11].The developed sensitivity factors were utilized for the optimal placement of TCSC's and TCPAR's. Two different approaches for the optimal placement of TCSC, one using reactive power loss based sensitivity factor and the other using the sensitivity factor based upon real power flows is suggested in [12]. This proposed technique analyses the device placement both under normal and contingent conditions. A comprehensive approach for optimizing the objective function comprising

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of reactive power flow overloads on transmission lines, costs of real power generation and load shedding has been discussed in [13] in which reallocation of real power generation is done through PSO technique. A real coded genetic algorithm along with fuzzy sets for the optimal placement of TCSC for enhancing ATC and improving the system voltage profile has been explained in [14]. ATC calculation aided through the determination of Power Transfer Distribution Factors (PTDF's) taking into account the thermal limits has been analysed in [15] An Improved PSO based technique in which there is a constant vigil over the global solution in order to prevent it from getting landed in a local maxima has been suggested in [16] for ATC enhancement. Multi area ATC determination using ACPTDF's and PF's in a CEED environment has been discussed in [17]. An Adaptive Improved PSO technique has been suggested and its application for ATC calculation has been demonstrated in [18]. A sensitivity factor based ATC enhancement technique through optimally placing and sizing TCSC has been illustrated in [19]. A probabilistic modelling based approach for optimally placing TCSC to enhance TTC has been demonstrated in [20]. As FACTS devices enable the line loadings to increase even up to their thermal limits they offer a more promising alternative to conventional methods of ATC enhancement.

Here it is proposed to calculate ATC using ACPTDF (AC Power Transfer Distribution Factor) in a combined Economic emission dispatch environment and an attempt is going to be made to place the TCSC'S and fix their ratings so as to increase the ATC values. The optimal settings and location of TCSC's are obtained from WIPSO algorithm.

AVAILABLE TRANSFER CAPABILITY

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 = TTC- Existing Transmission Commitments

Where TTC is Total Transfer Capability 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.

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

$$ATC_{mn} = \min \{T_{ij,mn}\},\ ij \in NL \quad (1)$$

Where,

$T_{ij,mn}$= Transfer limit values for each line in the system.

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

Where,

P_{ij}^{max} = MW power limit of a line l between buses i and j

P_{ij}^{0} = Base case power flow in line l between buses i and j

$PTDF_{ij,mn}$= Power transfer distribution factor for the line l between bus i and j when there is a transaction between buses m and n

NL = Number of lines

P_{ij}^{max}= MW power limit of a line l between buses i and j

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$PTDF_{ij,mn}$= Power transfer distribution factor for the line l between bus i and j when there is a transaction between buses m and n

NL = number of lines

CEED PROBLEM FORMULATION

The Combined Emission Economic Dispatch problem is formulated using the following equation.

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

Where,

Φ = 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} = Power output of the i^{th} generating unit.

P_d= Total load of the system

P_l = Transmission losses of the system.

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$p_{gi}^{\min}$ and $p_{gi}^{\max}$ are the minimum and maximum values of real power allowed at generator i respectively.

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

ACPTDF FORMULATION

The AC power transfer distribution factor 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_kMW, if the change in transmission line quality $q_l$isΔq_l, PTDF is defined as

$$PTDF_{ij,mn} = \frac{\Delta q_l}{\Delta t_k} \quad (4)$$

Where,

Δt_k= Change in real power transaction among the buyer and seller by Δt_k

Δq_l= Change in transmission line qualityΔq_l. The transmission quality $q_l$can be either real power flow from bus i to j (p_{ij}) or real power flow from bus j to i(P_{ij}). The Jacobian matrix for NR power flow is given by

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

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

$$\left.\begin{aligned} \Delta P_i &= \Delta t_k \\ \Delta P_j &= -\Delta t_k \end{aligned}\right\} \quad (6)$$

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 $\Delta q_l$from the base case.

Once $\Delta q_l$for all the lines corresponding to a change in $\Delta t_k$is known, PTDF'S can be obtained from the formula.

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

ROLE OF FACT DEVICES

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 may be used to improve the system performance by controlling the power flows in the grid.

There are many types of FACTS devices available for power flow control like UPFC, SVC, STATCOM, TCSC and phase angle regulator. Among the FACTS devices Thyristor Controlled Series Capacitor (TCSC) is a versatile device and it is modelled to modify the reactance of the transmission line directly. It may be inductive or capacitive, to decrease or increase the reactance of the transmission line respectively. The TCSC are connected in series with the lines.

The TCSC is modelled as a variable reactance whose value varies from -0.8 X_L to +0.2X_L.

Where, X_L is the reactance of the line.

MODELLING OF TCSC

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

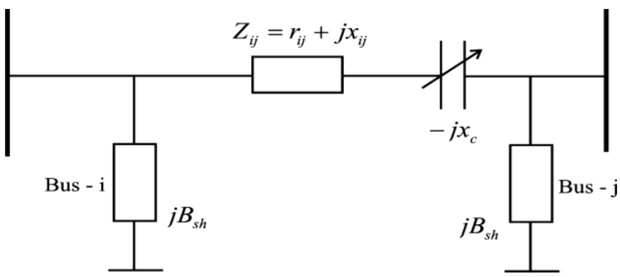

Figure-1. Equivalent circuit of a line with TCSC.

INTRODUCTION OF PSO

PSO was first introduced by Kennedy and Eberhart in 1995.Heuristic optimization technique introduced by the swarm intelligences of animals such as bird flocking, fish schooling. A swarm of particles represents a solution to the optimization problem. Each particle adjusts its position according to its own experience and the experience of its neighbouring particles. The position and velocity of i^{th}particle in the N - dimensional search space is represented as

$$X_i = (x_{i1}, x_{i2}, \ldots\ldots x_{in})$$
$$v_i = (v_{i1}, v_{i2}, \ldots\ldots v_{in})$$

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The best position achieved by a particle is recorded and is denoted by

$P_{besti} = (x_{i1}^{P_{best}} , \; . \; . \; . \; . \; . \; x_{in}^{P_{best}})$

The best particle among all the particles in the population is represented by

$G_{besti} = (x_{i1}^{G_{best}} , \; . \; . \; . \; . \; . \; x_{in}^{G_{best}})$

The updated velocity and position of each particle in $(K + 1)^{th}$ step are calculated as follows

$X_i^{k+1} = X_i^k + V_i^{k+1}$

Where,

$V_i^{k+1} = wV_i^k + C_1 rand_1 \; (x_i P_{besti}^k - x_i^k) + C_2 rand_2 \; (GP_{besti}^k - x_i^k)$

x_i^k = Position of individual i at iteration k

X_i^{k+1} = Position of individual i at iteration k + 1

v_i^k = Velocity of individual i at iteration k

W = Weight parameter

C_1 = Cognitive factor

C_2 = Social factor

P_{besti}^k = Best position of individual i until iteration k

G_{besti}^k = Best position of group until iteration k

$rand_1, rand_2$ = random numbers between 0 and 1.

In this velocity updating process, the acceleration coefficients C_1, C_2 and weight parameter 'w' are predefined and $rand_1$ and $rand_2$ are uniformly generated random numbers in the range of [0, 1].

WEIGHT IMPROVED PARTICLE SWARM OPTIMIZATION

To get a better global solution, the algorithm is improved by adjusting the weight parameter, cognitive and social factors. The velocity of the individual using WIPSO is rewritten as

$$V_i^{k+1} = W_{new} V_i^k + C_1 \, rand_1 (p_{best\,i}^{\;k} - x_i^k) + C_2 \, rand_2 (G_{best\,i}^{\;k} - x_i^k)$$

Where,

$$W = w_{\max} - \left\{ \frac{w_{\max} - w_{\min}}{Iter_{\max}} \right\} x Iter$$

$$W_{new} = (\text{Wmin}) + (\text{W x rand}_3)$$

$$C1 = C_1 \max - \left\{ \frac{C_{1\max} - C_{1\min}}{Iter_{\max}} \right\} x \, Iter$$

$$C2 = C_2 \max - \left\{ \frac{C_{2\max} - C_{2\min}}{Iter_{\max}} \right\} x \, Iter$$

w_{min}, w_{max} = initial and final weights

C_{1min}, C_{1max} = initial ad final cognitive factors

C_{2min}, C_{2max} = initial and final social factors

$Iter_{max}$ = maximum iteration number

Iter = current iteration number

$rand_3$ = random numbers between 0 and 1

ALGORITHM

Choose the population size, the number of generations, w_{min}, W_{max}, C_{1min}, C1max, C2min, C2max, pbest, gbest.

(Population size 20, no. of generations 50)

Initialize the velocity and position of all particles randomly, ensuring that they are within limits. Here the individuals represent the real power generation of generator buses in the system.

Set the generation counter t=1.

Evaluate the fitness for each particle according to the objective function.

Compare the particle's fitness function with its P_{besti}. If the current value is better than P_{besti}, then set P_{besti} is equal to the current value. Identify the particle in the neighborhood with the best success so far and assign it to Gbest.

Update velocity by using the global best and individual best of the particle.

Update position by using the updated velocities. Each particle will change its position.

If the stopping criteria is not satisfied set t=t+1 and go to step 4.Otherwise stop.

PROBLEM FORMULATION

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

ATC = max $\sum_{i=1}^{NL} P_i^{max} - P_i^{flow}$

Where,

P_i^{max} = Thermal limit of the line.

P_i^{flow} = Base case flow of the line

In order to maximize ATC, suitable locations are to be identified and the placement of TCSC and their ratings are to be fixed.

ALGORITHM FOR ATC ENHANCEMENT

1. Read the system input data.
2. Run the base case load flow in the combined emission economic dispatch setting of generators.
3. Consider the wheeling transaction t_k alone.
4. Compute AC power transfer distribution factor.
5. Taking in to account the line flow limits based upon Stability and thermal limits, determine the value of ATC.
6. Arrange ATC in ascending order.
7. Fix the number of TCSC'S that is to be connected in the system.
8. Run the PSO algorithm to obtain the location and rating of TCSC'S.
9. Calculate ATC after incorporating TCSC'S.
10. Consider the next wheeling transaction t_k and go to step 4.

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SIMULATION AND TEST RESULTS

The proposed TCSC placement algorithm using PSO and WIPSO techniques 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 TCSC are fixed with an objective of improving the ATC for the above mentioned transaction. The ATC values are obtained through ACPTDF calculated for the particular transaction using the NR Jacobian. The number of TCSC's has been limited as 3 taking into consideration the cost of the device. The test results for the ATC enhancement problems are given in tables for 14, 30 and 57 bus systems. The location and rating of the TCSC's has been given in tables.

To study the implementation of TCSC for ATC enhancement, the load on the system were increased in a step by step manner. The improvement in ATC results of the system with and without TCSC can be represented in the Tables 1, 2 and 3 and an equivalent bar chart also represent for all the three systems for various load conditions are represented in Figures 2 to 7. The results have also been obtained by WIPSO technique for comparisons.

Table-1. IEEE 14 Bus Test Systems.

ATC in MW	Without TCSC					With TCSC				
	Base load	5% Over loaded	10% Over loaded	15% Over loaded	20% Over loaded	Base load	5% Over loaded	10% Over loaded	15% Over loaded	20% Over loaded
PSO	16.32	14.69	12.74	18.65	16.47	17.35	16.05	14.13	19.74	17.87
WIPSO	16.85	15.63	14.70	16.25	18.31	18.02	16.72	16.24	17.43	19.48

Table-2. IEEE 30 Bus Test Systems.

ATC in MW	Without TCSC					With TCSC				
	Base load	5% Over loaded	10% Over loaded	15% Over loaded	20% Over loaded	Base load	5% Over loaded	10% Over loaded	15% Over loaded	20% Over loaded
PSO	26.91	27.37	27.87	28.29	28.64	28.58	28.94	29.35	29.65	29.93
WIPSO	26.94	27.43	27.89	28.26	28.57	28.59	29.03	29.38	29.65	29.90

Table-3. IEEE 57 Bus Test Systems.

ATC in MW	Without TCSC					With TCSC				
	Base load	5% Over loaded	10% Over loaded	15% Over loaded	20% Over loaded	Base load	5% Over loaded	10% Over loaded	15% Over loaded	20% Over Loaded
PSO	14.07	16.16	16.51	16.52	18.51	15.05	17.04	17.39	17.21	18.89
WIPSO	16.32	16.15	16.89	17.59	18.37	17.33	17.07	17.74	18.32	18.98

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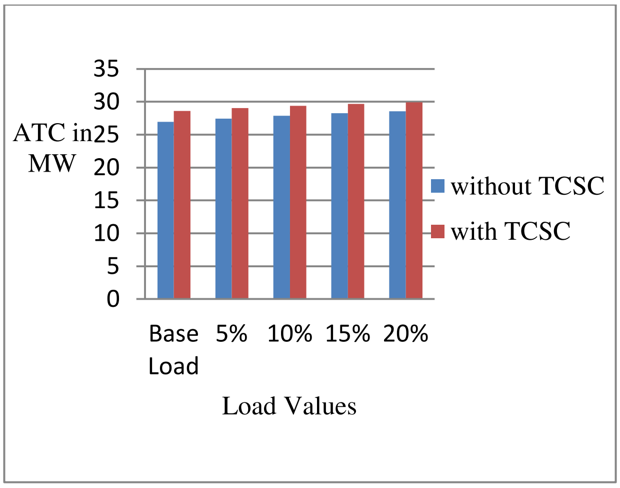

Figure-2. Bar chart for IEEE 14 Bus Test Systems (PSO).

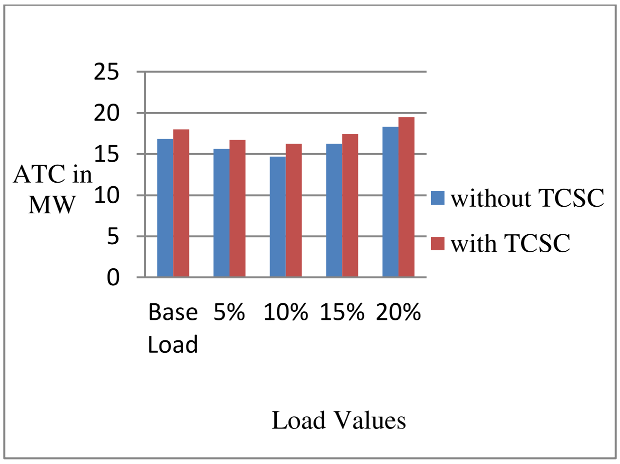

Figure-3. Bar chart for IEEE 14 Bus Test Systems (WIPSO).

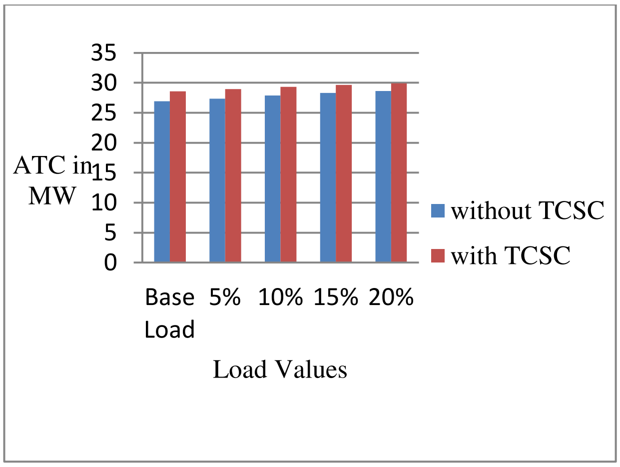

Figure-4. Bar chart for IEEE 30 Bus Test Systems (PSO).

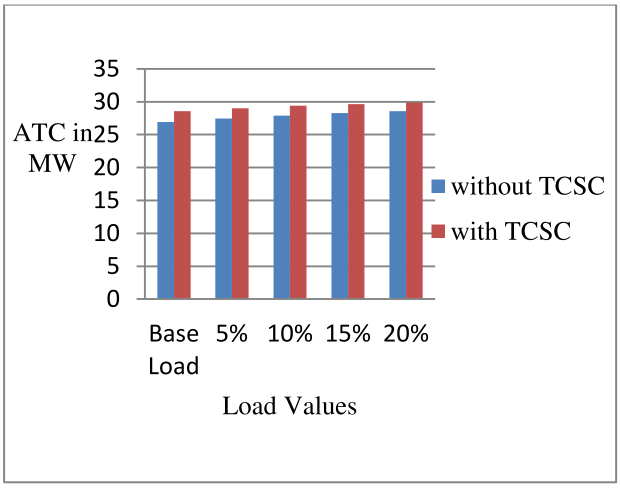

Figure-5. Bar chart for IEEE 30 Bus Test Systems (WIPSO).

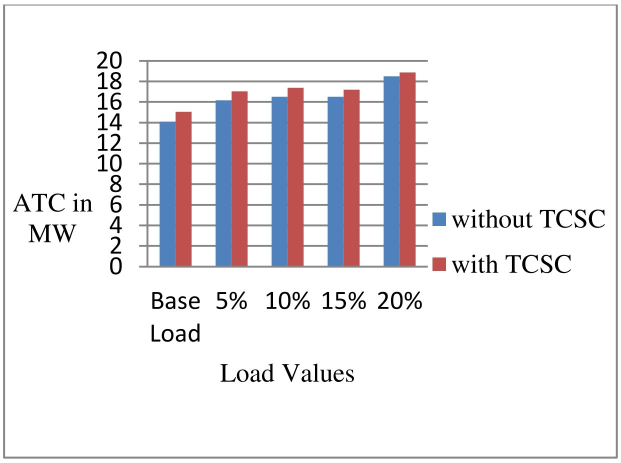

Figure-6. Bar chart for IEEE 57 Bus Test Systems (PSO).

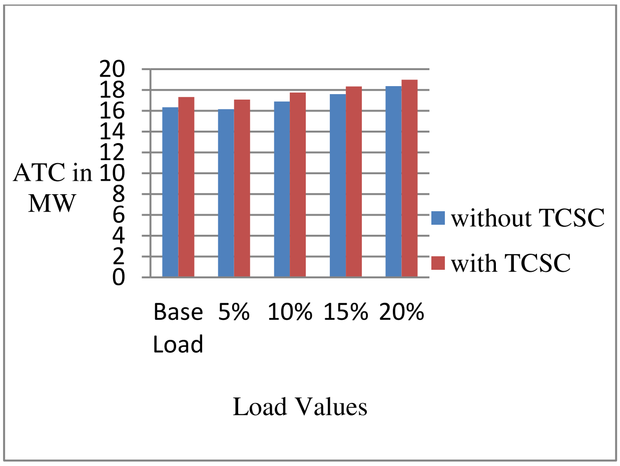

Figure-7. Bar chart for IEEE 57 Bus Test Systems (WIPSO).

CONCLUSIONS

In this paper an ATC enhancement technique for a bilateral transaction under CEED environment has been proposed wherein WIPSO technique has been used for choosing the optimum size and location of TCSC under various loading conditions. The results obtained were compared against those obtained using PSO technique. The results clearly indicate that is a considerable increase in the ATC of the lines after placing the TCSC and due to the fact that the weight parameter, cognitive and social factors are adjusted in WIPSO to obtain a better global convergence; it shows a comparatively better performance than PSO. By applying this technique ATC of the systems can be enhanced for any of the wheeling transactions and a combination of devices may be used for a more flexible enhancement.

REFERENCES

[1] Ashwani Kumar, Jitendra Kumar. 2013.ATC determination with FACTS devices using PTDFs approach for multi-transactions in competitive electricity markets. Electrical Power and Energy Systems 44 (2013) 308-317.

[2] A.Yousefi, T.T.Nguyen, H.Zareipour, O.P.Malik. 2012. Congestion management using demand response and FACTS Devices. Electrical Power and Energy Systems. 37: 78-85.

[3] H.Farahmand, M.Rashidinejad, A.Mousavi, A.A.Gharaveisi, M.R.Irving, G.A.Taylor. 2012. Hybrid Mutation Particle Swarm Optimization method for Available Transfer Capability Enhancement. Electrical Power and Energy Systems. 42: 240-249.

[4] T.Nireekshana, G.KesavaRao, S.Siva Naga Raju. 2012. Enhancement of ATC with FACTS devices using Real-Code Genetic Algorithm. Electrical Power and Energy Systems. 43: 1276-1284.

[5] Marouani. I, Guesmi. T, HadjAbdallah. H andOuali. A. 2011. Optimal Location of Multi Type Devices for Multiple Contingencies using Genetic Algorithms. IEEE.

[6] S.K.Joshi, K.S.Pandya. 2010. Influences of TCSC on social welfare and spot price - A comparative study of PSO with Classical method. International Journal of Engineering, Sciences and Technology. 2(3): 69-81.

[7] A.S.Bawankar, V.P.Rajderkar. 2010. Thyristor Controlled Series Compensator to Resolve Congestion Caused Problems. IEEE.

[8] M.Rashidinejad, H.Farahmand, M.Fotuhi- Firuzabad, A.A.Gharaveisi. 2008. ATC Enhancement using TCSC via artificial intelligent techniques. Electric Power Systems Research. 78: 11-20.

[9] NareshAcharya, N.Mithulananthan. 2007. Locating series FACTS devices for congestion management in deregulated electricity markets. Electric Power Systems Research. 77: 352-360.

[10] Ying Xiao, Y.H.Song, Chean-Ching Liu, Y.Z.Sun. 2003. Available Transfer Capability Enhancement using FACTS Devices. IEEE Transaction on power systems. 18(1).

[11] S.N.Singh, A.K.David. 2001. Optimal Location of FACTS Devices for Congestion Management. Electric Power Systems Research. 58: 71-79.

[12] HadiBesharat, Seyed Abbas Taher. 2008. Congestion management by determining optimal location of TCSC in deregulated power systems. Electrical Power and Energy Systems. 30: 563-568.

[13] JagabondhuHazra, Avinash K. Sinha. 2007. Congestion Management Using Multiobjective Particle Swarm Optimization. IEEE Transactions on Power Systems. 22(40).

[14] H.Farahmand, M.Rashidinejad and A.A.Gharaveici, M.Shojaee. 2006. An Application of Hybrid Heuristic Approach for ATC Enhancement. IEEE.

[15] Rong-fu Sun, Yue Fan, Yong-hua Song, Yuan-zhang Sun. 2006. Development and Application of Software for ATC Calculation. International Conferences on Power System Technology.

[16] Chang-hua Zhang, Rong-fu Sun, Chong-xuLiu,Yue Fan, Shuan-baoNiu, Yong-hua Song. 2006. An Improved Practicle Swarm Optimization to Power System Transfer Capability Calculation. International Conferences on Power System Technology.

[17] B.V.Manikandan, S.CharlesRaju and P.Venkatesh. 2008. Multi-Area Available Transfer Capability Determination in the Restructured Electricity Market. IEEE.

[18] Hou-he Chen, Guo-quing Li, Hai-Liang Liao. 2009. A Self-adaptive Improved Particle Swarm Optimization Algorithm and its Application in Available Transfer Capability Calculation. Fifth International Conferences on National Computation.

[19] N.D.Ghawghawe, K.L.Thakre. 2009. Computation of TCSC Reactance and suggesting criterion of its location for ATC improvement. Electrical Power and Energy Systems. 31: 86-93.

[20] M.A.Khaburi,M.R.Habhifam. 2010. A probabilistic modeling based approach for total Transfer Capability enhancement using FACTS devices. Electrical Power and Energy Systems. 32: 12-16.