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Artificial Bee Colony Algorithm Based Enhancement of Available Transfer Capability By Incorporating FACTS Device In Restructured Power Market

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Abstract

Only a single entity performs both the actions of generation and distribution in a vertically integrated system and it leads to increase in price.This increase in price has to be minimized for the beneficial of customers which is done by Deregulation.This outline changes by introducing open-access market system is known as deregulation. This may help in an abundant increase of power transfer,in the transmission network thereby increasing the effiency of the system. However, this increase of power transfer leads to the demand of Available Transfer Capability (ATC) for the economic transactions. The main aim of this paper is to improve ATC by using FACTS (TCSC and SVC) device in the Combined Economic Emission Dispatch(CEED) condition using the optimized algorithm called Artificial Bee Colony (ABC) algorithm. The proposed approach is testified by making use of IEEE 30 bus test system in MATlab software and the results are obtained.

Keywords: Deregulated power market, Available Transfer Capability, Combined Economic Emission Dispatch, Thyristor Controlled Series Capacitor.

Introduction

Nowadays restructuring of power system is taking place throughout the worldi.e., the electrical utilities are changing their way of trading from vertically integrated into the open market system. The overall objective of deregulation is to increase the competition between utilities and bring new choices for economic benefits [1] & [2] which inturn increase the economic efficiency. This deregulated environment needs an open access market fortransmission. This open access market increase the reliablity, that inturn increase theawareness of the network capability [3].Available Transfer Capability (ATC) is the excessive real power that can be transferred through the physical transmission line, after considering all thephysical limits of the transmission network. The aim of calculatingAvailable Transfer Capability (ATC) is to produce commercially feasible results [4]. Increase in ATC increase free market trading. Increase in the ATC of the physical transmission network helps to overcome the difficulties that of introducing new facilities. In accordance of MW transmitted for each transaction allocation of power flow on each transmission line is done. Loading of transmission line which is optimally selected by using Repeated Power Flow (RPF), can improve the efficiency of the system [7].FACTS device installation can easily increase the ATC of the transmission network. Different stabilities of transmission lines like thermal, voltage and stability constraints can be easily met by implementation of FACTS devices. Different parameters like reactance, voltage magnitude, phase angle can be controlled using the FACTS device[11]. Implementation of ABC algorithm can give optimized values [12] & [13].

This paper implies, Artificial Bee Colony (ABC) algorithm which optimises the results and this is combined with the Combined Economic Emission Dispatch (CEED) formulation to obtain the optimized value of generation for all the generators in IEEE 30 bus system. IEEE 30 bus system is taken as the test system and the ATC calculations by incorporating FACTS device such as TCSC and SVC,are done in MATlab.

Available Transfer Capability

The information of transfer capability is very important for providing efficienttransmission services. The transfer of electrical energy should be within certain operation limits to have a secure and economic power supply, transfering power in bulk quantity becomes necessity, but in practical power system transfer capability is constrained by various operating limits. Hence calculation of ATC by power system engineers is very important for efficient transaction.

Maximum surplus power transaction between two parts of the power system is defined asAvailable Transfer Capability (ATC). ATC is the extensive transfer capability present in the physical transmission system above already existing services thereby providing efficient economical benefits.

ATC = TTC – Existing Transmission Commitments (2.1)

Here, the total amount of power that is transmitted in a network is defined asTotal Transfer Capability (TTC). Existing Transmission Commitments is with in two sensitivity margins as follows,TransmissionReliability Margin (TRM) ensure secure operation of power system after consideration of uncertainties in the system operating condition and Capacity Benefit Margin (CBM) is used for retaining the generation reliability requirements by maintaining the amount of transmission transfer capability which is reserved by Load Serving Entities (LSE).

FACTS Device

FACTS technology makes it possible to utilize the existing transmission facilities by controlling the parameters which governs the operation of transmission system. Active power flow control is possible using FACTS device.

Thyristor Controlled Series Capacitor (TCSC)

FACTS devices provide the control for the AC transmission system. The capacity of transmission line is increased by subsiding the impedance connected in series of the line which also increase the network reliability. Reduction of power loss is achieved by TCSC (Thyristor Controlled Series Capacity).It consists of a series compensating capacitor and a two parallel connected Thyristor Controlled Reactor (TCR). The flow of real power in the line is controlled by TCSC, and it enhances the power transfer capability. This control in the real power flow is done by controlling the impedance of TCSC which in turn is controlled by changing the thyristor controlled inductive reactance of inductor. The switching angle of Thyristor 'α' is tunedbetween $90°$ to $180°$,so that the magnitude of inductive reactance is calculated. TCSC working limit ranges between -0.8X_{ij} and 0.2$X_{ij}$where, X_{ij} – TCSC installed transmission line's reactance.

The equivalent reactance Xeqis determined as in equation (3.1.1),

$$X_{eq}(\alpha) = \frac{X_c X_L(\alpha)}{X_L(\alpha)+X_c} \quad (3.1.1)$$

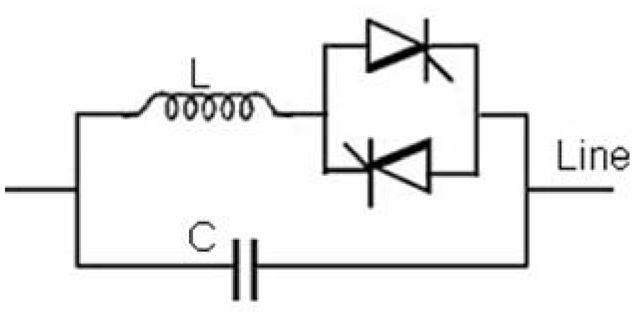

Figure 3.1.1: Equivalent Circuit of TCSC

Static Var Compensator (SVC)

Load is continuously variable in a system, SVC maintains a constant bus voltage and hence SVC is used in this paper.SVC is the most popular FACTs devices in the recent years.The primary purpose is usually for rapid control of voltage at weak points in a network.It offers dynamic control over the voltage profile in the transmission line.It will enhance the active power transfer capability when it is connected to the mid point of the transmission line.It can operate in inductive mode or capacitive mode, where it absorbs or injects reactive power respectively which inturn have a control over voltage profile of the system. The value of reactive power ranges between -100 Mvar and 100 Mvar.

The main advantages of SVC are accuracy in calculation, availability where ever needed, swift response there by improving the performance in steady state. It also regulate a voltage, system power factor, harmonics and stabilizes the system. Compared with synchronous condenser SVC is more advantageous since it don't have moving parts.

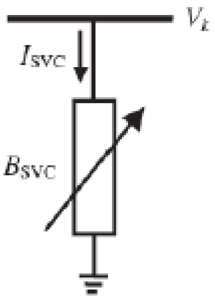

Figure 3.2.1: Equivalent Circuit ForSVC

Mathematical Formulation

Combined Economic Emission Dispatch

With the advent of new technologies, there is also a corresponding increase in environmental pollution rate. Governmental organizations and Non-governmental organizations are constantly expressing their concern over environmental issues. There are many researches being carried out in order to reduce pollution caused due to power generation. One of the method is including emission as one of the constraints in economic dispatch which is called as Combined Emission and Economic Dispatch (CEED). The main objective of CEED is to reduce the fuel cost and emission of the power plant.

The single objective function is gained from the bi-objective CEED problem by applying the Price Penalty Factor$h$ as shown in the equation (4.1.1). This Price Penalty Factor represents by binding the emission function with the fuel cost function.

$$Minimize = (FC + h.EC) \quad (4.1.1)$$

$$h = \frac{(a_k P_{gk}^2 + b_k P_{gk} + c_k)}{(\alpha_k P_{gk}^2 + \beta_k P_{gk} + \gamma_k)} \quad (4.1.2)$$

The fuel cost equation is represented in the quadratic form as,

$$FC = \sum_{k=1}^{Ng} (a_k P_{gk}^2 + b_k P_{gk} + c_k) \quad (4.1.3)$$

Where,

a_k, b_k, and $c_k$are the cost coefficients of the k^{th}generating unit.

The equation (4.1.4) represents SO_2 and NO_x emission in a combined quadratic form as shown below,

$$EC = \sum_{k=1}^{Ng} (\alpha_k P_{gk}^2 + \beta_k P_{gk} + \gamma_k) \quad (4.1.4)$$

Where,

α_k, $\beta_k$and $\gamma_k$are emission coefficients of the k^{th} generating unit.

Repeated Power Flow Method For ATC Calculation

To calculate Total Transfer Capability (TTC), here Repeated Power Flow (RPF) method is used. The Repeated Power Flow method frequently solves the power flow equations for an array of points. The transfer power value is constantly improved beyond the base case value before violations.Application of this method is effortless than the other methods. This method takes minimum time for convergence, hence it is more advantage than various methods.

The ATC can be estimated by the following procedure:

- Base case power flow is performed without any violations.
- By including a buyer bus and seller bus, power transfer is being defined.
- Until the limit violation reached the power input is being increased, in the generator and load bus.
- From the buyer bus and seller bus in the transmission network, power delivered is calculated.

RPF method uses the Newton Raphson Power Flow (NR). The complex power will be represented, for the bus k as follows,

$$P_k - jQ_k = V_k * I_k \quad (4.2.1)$$

The above real and reactive power can be serves as,

$$P_k = \sum_{m=1}^{n} |V_k||V_m||Y_{km}|\cos(\theta_{km} - \delta_k + \delta_m) \quad (4.2.2)$$

$$Q_k = \sum_{m=1}^{n} |V_k||V_m||Y_{km}|\sin(\theta_{km} - \delta_k + \delta_m) \quad (4.2.3)$$

Using Taylor's series, the mentioned real and reactive power equations are formed by omitting higher order terms. First bus is acknowledged as slack bus. The changes in real and reactive power $\Delta P_k \& \Delta Q_k$ are provided by Jacobian matrix, which consist of partial derivatives of $P_k \& Q_k$ for voltage angle and voltage magnitude as follows,

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix}$$

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial |V|} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial |V|} \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \quad (4.2.4)$$

The power mismatch can be calculated from the following equations,

$$\Delta P_k = P_k^{(sch)} - P_k \quad (4.2.5)$$

$$\Delta Q_k = Q_k^{(sch)} - Q_k \quad (4.2.6)$$

The mentioned real and reactive power flow equations can be acknowledged as,

$$P_k = P_k^{0}(1 + \lambda J_k) \quad (4.2.7)$$

$$Q_k = Q_k^{0}(1 + \lambda J_k) \quad (4.2.8)$$

The terms in these equations represent,

$P_k^{0} \& Q_k^{0}$ - Real and Reactive power in bus k at present.

J_k- As λ varied, this constant affords the change in load/generation bus.

λ- Parameter serves as an increase in load/generation bus.

TTC level can be evaluated using the following equation,

$$TTC = \sum_{k \in sinJ} P_k(\lambda_{max}) - \sum_{k \in sinJ} P_k \quad (4.2.9)$$

$\sum_{k \in sinJ} P_k(\lambda_{max})$ - Load bus power summation when$\lambda = \lambda_{max}$
$\sum_{k \in sinJ} P_k$ - Load bus power summation when$\lambda = 0$.

The obtained TTC is considered for the assessment of Available Transfer Capability (ATC), by using the equation (2.1).

Artificial Bee Colony (ABC) Algorithm

To find the optimal price of power produced, the ABC optimization methodis usedalong with Combined Economic Emission Dispatch (CEED)and Available Transfer Capability (ATC).ABC algorithm is selected by the nature of food searching activity of a honey bee group. ABC method is advantageous because of its quick convergence property and also it initiates the search with random set of outcomes. Implementaion is easy since ABC algorithm has limited control parameters than other algorithm.

The control parameters are,

- NP -Sum of employed and onlooker bees (Colony size)
- Food Number =NP/2 -Half of the population
- Limit -Employed bee fritter away the food supply, when it can't be good further.
- Max. Cycle -Finishing Criterion

This ABC alogrithm classifies the synthetic bee into three types: the employed bee, onlooker bee, scout bee. This can be described as,

1. *Initialization Phase:*

Initialize the food source. The number of the food source (SN) is to be generated in a random fashion. The i^{th} food source revealed as$z_i = \{z_{i,1}, z_{i,2}, \ldots . z_{i,D}\}$, is given by

$$z_{i,d} = z_d{}^{min} + r\left(z_d{}^{max} - z_d{}^{min}\right) d = 1, \ldots . D \quad (5.1)$$

Here, the standardized random no [0,1] is specified as 'r'.

The lower bound is designated as $z_d{}^{min}$and anupper bound is designated as $z_d{}^{max}$, with dimension 'd'.

2. *Employed Bee Phase:*

It begins the search of food source and hence it is associated with the result. Employed bee builds a random transform of the new food source and hence it will find its new food source.This new food source can be calculated by,

$$v_{i,d} = z_{i,d} + r'(z_{i,d} - z_{k,d}) \quad (5.2)$$

Here, the dimension 'd' arbitrarily selects from $\{1, \ldots \ldots D\}$

The constant K is arbitrarily selects from$\{1, \ldots \ldots SN\}$,in such a way that $k \neq i$.

The uniform random no [-1,1] is indicated as 'r''
After finding the result ofv_i, it is planned and linked withz_i. If the achieved v_i is superior to the previous solution, the bee will get the most recent solution, if not bee will retain in the previous solution.

3. *Onlooker Bee Phase*:
Once the home food search is accomplished, the employed bee distributes the data concerning the nectar and amount ofeach food source with the assistance of WAGGLE Dance, to the onlooker bee. These will select the necessary food source.

4. *Scout Bee Phase:*
If the attained nectar information for the result is not reasonable, i.e. not better than the preset value, then this food source is ignored and the employed beeconnected to this will turn into scout bee. This scout bee will produce a new food source with the help of equation(5.1).

Results and Discussion

Using MATlab Software, the output ATC values are calculated. These were worked out in the IEEE 30-bus test system which has 6 generators and 41 lines. Both the CEED formulation and ATC calculation were done using this test system. The CEED technique's result is utilized in the ATC calculation.
With the help of the characteristics equation of both the fuel cost and emission, base case load flow is performed using CEED formulation. The below table 6.1 shows the power generated of the six generators.

Table 6.1: Results from CEED Formulation

Generator Bus	Power Generated (MW)	Fuel Cost ($/hr)	Total Emission (lb/hr)	Total Operating Cost ($/hr)
1	176.2632	807.721	417.6650	1.8824e+004
2	48.3829			
5	20.8706			
8	22.7129			
11	12.4534			
13	12.0000			

The table 6.2 and 6.3 provides the results for the ATC formulation before and after incorporating TCSC and SVC respectively. The bilateral transaction is verified for IEEE 30-bus system. The below table provides the resulted ATC values.

Table 6.2: Value of ATC before and after incorporating TCSC

System	Method	Transaction between Buses	ATC values (MW)		Location	Size (p.u)
			Without TCSC	With TCSC		
IEEE 30-bus	Repeated Power Flow	1-3	20.8090	24.7632	1-2	0.2694
		2-12	55.1533	58.1750	4-12	0.4549
		1-6	15.6649	19.1501	2-5	0.6945

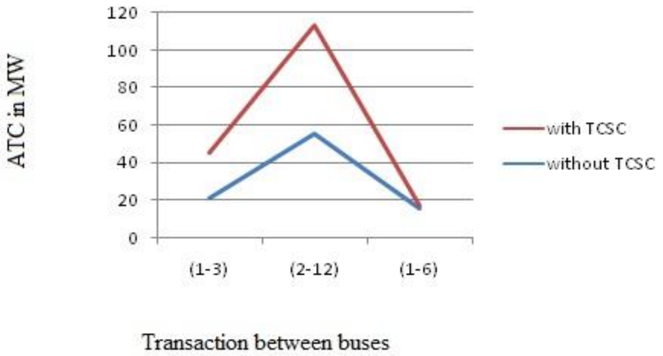

Figure 6.2: ATC result with and without TCSC

Table 6.3: Valueof ATC Before and After Incorporating SVC

System	Method	Transaction between Buses	ATC values (MW)		Location (buses)	Size (Mvar)
			Without SVC	With SVC		
IEEE 30-bus	Repeated Power Flow	1-3	20.8090	25.6145	8	61.1506
		2-12	55.1533	64.2817	24	58.8844
		1-6	15.6649	17.8586	5	23.2406

The figure 6.1 interprets the results of ATC with and without SVC for the bilateral transaction.

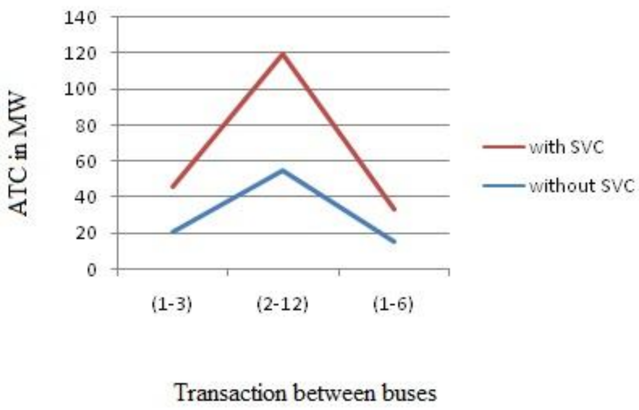

Figure 6.3:ATC Result With and Without SVC

Conclusion

This paperproves, that the involvement of FACTS device will enhance the transfer capability of transmission lines in the system, by improving the Available Transfer Capability in IEEE 30-bus system. Thus a most sufficient transmission to the power system is providedby enhancing the ATC using Artificial Bee Colony algorithm. Among different methods of calculations, Repeated Power Flow (RPF) is used for ATC calculation. It is an iterative procedure and produces an optimized result. The results of the ATC formulation is been attained for the considered bilateral transaction in the test system.

Reference

[1] Kankar Bhattacharya, Math H.J.Bollen, JaapE.Daalder. "Operation of Restructured Power System" , Chalmers University of Technology, Kluwer Academic Publishers, Boston, 2001.

[2] A.R.Abhyankar, Prof.S.A.Khaparde. "Introduction to Deregulation in Power Industry", Indian Institute of Technology Bombay, Mumbai 400076.

[3] Saloni, MeenakshiDhakla. ATC determination for different transaction using ACPTDF: International Journal of Modern Engineering Research, Vol.3, Issue.1, Jan-Feb. 2013 pp-431-435.

[4] "ATC Definitions and Determination, a frame work for Determining Available Transfer Capabilities of the interconnected Transmission Networks for a commercially viable Electricity Market", NERC Report, June 1996.

[5] B.V.Manikandan, S.C.Raja, P.Venkatesh. "Enhancement of Available Transfer Capability with FACTS device in the Competitve Power Market", Scientific Research,Feb, 2010, 337-343.

[6] B.V.Manikandan, S.C.Raja, P.Venkatesh.ATC enhancement with FACTS devices in the Deregulated Electricity Market: Journal of ElectricalEngineering and Technology. 2011, vol.6.

[7] R.Rajathy, R.Gnanadass, K.Manivannan& Harish kumar. Differential Evolution based method for total Transfer Capability Evaluation: International Journal of Engineering Science and Technology, vol.2, No.5, 2010, PP.81-91.

[8] Ugurguvenc. "Combined Economic Emission Dispatch Solution using Genetic algorithm based on Similarity Crossover",Scientific Research and Essays Vol. 5(17), pp. 2451-2456, 4 September, 2010.

[9] RM.SalomenDanaraj, "Solution to Economic Dispatch by Equal Incremental Cost Criterion", EEE Dept, Aurora Technological Research Institute, Hyderabad, India.

[10] N.G.Hingorani, L.Gyugyi. Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems: 1st Indian Edition, IEEE Press, Newyork and standard Publishers Distributors, Delhi, 2000.

[11] R.M.Mathur, R.K.Varma, "Thyristor based FACTS Controllers for Electrical Transmission Systems",1st Edition, John Wiley & Sons Inc., 2002.

[12] D.Karaboga, B.Basturk. On the Performance of Artificial Bee Colony (ABC) Algorithm, Elsevier: Science Direct, 2008, 687-697.

[13] DervisKaraboga, CelalOzturk. A novel clustering approach: Artificial Bee Colony algorithm, Elsevier: Science Direct, 2011, 652-657.