CUCKOO SEARCH ALGORITHM FOR SOLVING ECONOMIC POWER DISPATCH PROBLEM WITH CONSIDERATION OF FACTS DEVICES

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The essential objective of an Optimal Power Flow (OPF) algorithm is to find steady state operation point which minimizes cost of generators, losses etc. while maintaining an acceptable system performance in terms of limits on generators real and reactive powers and line flow limits. Traditionally, classical optimization methods were used to effectively solve OPF. But more recently due to incorporation of FACTS devices, OPF have become complex and unfortunately these methods are not able to find an efficient solution. Recently, with the development of computer science and technology, evolutionary algorithms are used to solve optimal power flow (OPF) with FACTS devices. In this paper, research work has been carried out with an objective to applied Cuckoo Search (CS) algorithm for both power flow optimal and optimal power flow incorporating FACTS devices. To validate the performance of this algorithm, IEEE 09-bus 3-generators test case system has been used. Several optimization runs have been approved out on different cases of problem complexity with consideration of FACTS Devices (SVC and STATCOM). The results demonstrate that the proposed algorithm is an effective and practical method for the optimal power flow incorporating FACTS controllers.

Keywords: Cuckoo Search algorithm, FACTS Devices, Optimal Power Flow

1. Introduction

In the last years, many efforts have been made to solve the Economic Power Dispatch (EPD) problem, incorporating different kinds of constraints or multiple objectives through various mathematical programming and optimization techniques. The conventional methods include Newton-Raphson method, Lambda Iteration method, Gradient method, Non-Linear Programming (NLP), Quadratic Programming (QP), Newton-based Method, Mixed Integer Programming and Dynamic Programming [1]. All of these mathematical methods are fundamentally

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based on the convexity of objective function to find the global minimum [2]. To solve economic dispatch problem effectively, most algorithms require the incremental cost curves to be of monotonically smooth increasing nature and continuous [3]. Recently, many attempts to overcome the limitations of the mathematical programming approaches have been investigated such as meta-heuristic optimization methods [2]. Some of these algorithms are Particle Swarm Optimization (PSO) Artificial Bee Colony (ABC), Genetic Algorithms, Firefly Algorithm, Bat Algorithm, Artificial Chemical Reaction Optimization Algorithm [4], the Intelligent Water Drops [5], and Modified Bat Algorithm [6].

In this work, CS algorithm is proposed to solve specifically the optimal power flow and the security constraints optimal power flow problem with incorporation of the FACTS devices.

2. Problem Formulation

2.1 Economic load dispatch

The basic economic dispatch problem can described mathematically as a minimization of problem of minimizing the total fuel cost of all committed plants subject to the constraints [1]:

$$Minimize\ C_1\left(P_{gi}\right)=\sum_{i=1}^{N_g} F_i(P_{gi}) \tag{1}$$

$F_i(P_{g_i})$ is the fuel cost equation of the i^{th} plant. It is the variation of fuel cost ($/h) with generated power (MW). Normally it is expressed as:

$$F_i(P_{gi}) = a_i P_{gi}^{\ 2} + b_i P_{gi} + c_i \quad i = 1,2,..., N_g \tag{2}$$

N_g is the number of thermal units, P_{gi} is the active power generation at unit i and a_i, b_i and c_i are the cost coefficients of the i^{th} generator.

Inequality constraints: Generation power should be within the minimum output P_{gi}^{min} and the maximum output P_{gi}^{max}:

$$P_{gi}^{\ min} \le P_{gi} \le P_{gi}^{\ max}$$

Equality constraints: The total generation should meet the total demand D and transmission losses P_l [7]:

$$\sum_{i=1}^{N_g} P_{gi} = D + P_l \tag{3}$$

2.2 Optimal Power Flow dispatch

The active power-planning problem is considered as a general minimization problem with constraints, and can be written in the following form [8]:

$$\text{Min } f(x,u) \tag{4}$$

S.t: $g(x,u) = 0$ (5)

$h(x,u) \leq 0$ (6)

$x = [\delta \quad V_L]^T$ (7)

$u = [P_{gi} V_G \ P_l \ Q_{SVC} \ldots]^T$ (8)

$f(x,u)$ is the objective function, $g(x,u)$ and $h(x,u)$ are respectively the power flow equations and the limits on physical devices in the power system as well as the limits created to ensure system security. The control variables u are generator active and reactive power outputs, bus voltages, power losses. The state variables are voltage and angle of load buses. For optimal active power dispatch, the objective function F_i is total generation cost as expressed follows [9]:

$$Minimize \sum_{i=1}^{N_g} \left(a_i + b_i P_{gi} + c_i P_{gi}^2 \right) \quad (9)$$

2.3 Optimal Power Flow with STATCOM; Static model and mathematical analysis of STATCOM [10, 11]

The STATCOM is modeled as a controllable voltage source (E_p) in series with an impedance [12]. The real part of this impedance represents the cupper losses of the coupling transformer and converter, while the imaginary part of this impedance represents the leakage reactance of the coupling transformer. STATCOM absorbs requisite amount of reactive power from the grid to keep the bus voltage within reasonable range for all power system loading. Fig. 1 shows the circuit model of a STATCOM connected to the i^{th} bus of a power system. The injected active and reactive power flow equation of the i^{th} bus is given below:

$$P_p = G_p |V_k^2| - |V_k||E_k||Y_p| cos(\delta_k - \delta_p - \theta_p) + \sum_{j=1}^{n} V_i V_j Y_{ij} cos(\delta_i - \delta_j - \theta_{ij}) \quad (10)$$

$$Q_p = -B_p |V_k^2| - |V_k||E_p||Y_p| sin(\delta_k - \delta_p - \theta_p) + \sum_{j=1}^{n} V_i V_j Y_{ij} sin(\delta_i - \delta_j - \theta_{ij}) \quad (11)$$

The implementation of STATCOM in transmission system introduces two state variables ($|E_p|$ and δ_p); however, $|V_k|$ is known for STATCOM connected bus.

It may be assumed that the power consumed by the STATCOM source is zero in steady state.

$$P_{Ep} = Real[E_p I_p^*] = -(G_p)|E_p^2| + |E_p||V_k||Y_p| cos(\delta_p - \delta_k - \theta_p) = 0 \quad (12)$$

Where $|V_k|$ is the voltage at the i^{th} bus; Y_p is the admittance of the STATCOM; G_p , B_p are the conductance and susceptance, respectively, of the

STATCOM; θ_{ij} is the admittance angle of transmission line connected between the i^{th} bus and j^{th} bus, respectively; δ_k is the voltage source angle of the STATCOM; E_k is the voltage sources of STATCOM converters.

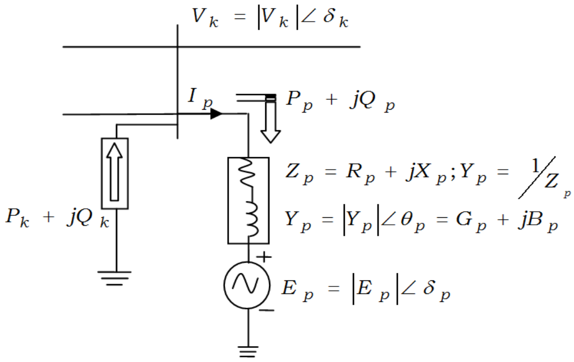

Fig.1. Schematic static model of STATCOM

2.4 Optimal Power Flow with FACTS devices cost (SVC)

The cost function for SVC is developed as follows [14]:

$$C_{SVC} = 127.38 - 0.3051S + 0.0003S^2 \quad (13)$$

Where C_{SVC} is \$/kVar and S is the operating range of the FACTS devices in MVar.

The formulation of the optimal allocation of FACTS devices can be expressed as follows [13, 14]:

$$Min\ C_{Total} = C_1(P_{gi}) + C_2(f) \quad (14)$$

$$E_1(f, g) = 0 \quad (15)$$

$$B_1(f) \succ 0\ ,\ B_2(g) \succ 0 \quad (16)$$

Where:

C_1: Total generation costs.

C_2: Average investment costs of FACTS devices.

C_{Total}: Overall cost of objective function.

E_1 : Equality constraints with respect to active and reactive power flow.

B_1, B_2 : Inequality constrains for FACTS devices and power flow.

f, P_{gi} : are the variables of FACTS devices and real power generated.

The unit for generation cost is US\$/hour and for the investment costs of FACTS devices are US\$. They must be unified into US\$/hour [10, 12]. In this paper, tree years are applied to evaluate the cost function. Therefore, the average value of the investment costs are calculated using the following equation:

$$C_1(f) = \frac{c(f)}{8760 \times 3} \quad (\$/Hour) \tag{17}$$

C(f) is the total investment costs of FACTS devices.

3. Cuckoo Search

Cuckoo search (CS) is one of the latest nature-inspired metaheuristic algorithms, developed in 2009 by Xin-She Yang and Suash Deb . CS is based on the brood parasitism of some cuckoo species. In addition, this algorithm is enhanced by the so-called Lévy flights, rather than by simple isotropic random walks. For simplicity in describing the standard Cuckoo Search, we now use the following three idealized rules [15, 16]:

• Each cuckoo lays one egg at a time, and dumps it in a randomly chosen nest;

• The best nests with high-quality eggs will be carried over to the next generations;

• The number of available host nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability $p_a \in [0, 1]$. In this case, the host bird can either get rid of the egg, or simply abandon the nest and build a completely new nest.

The steps of the CSA are as follows [17]:

1. Select values for CSA parameters, which are the number of nests (eggs) (n), the step size parameter (β), discovering probability (pa), and maximum number of iterations for termination of the cycles.

2. Generate initial population of n host nests $\{x_i\},(i = 1,2,\ldots,n)$ randomly each of which represents a candidate solution to the optimization problem with objective function of $f(x)$ and decision variables

3. Get a cuckoo randomly by Levy flights using $x_i^{\nu+1} = x_i^{\nu} + \beta \oplus Levy(\lambda)$ and evaluate its fitness F_i. Here *Levy(λ)* is a random walk based on Levy flights and the product $\oplus$ means entry-wise multiplications.

4. Choose randomly a nest among n (say j) and evaluate its fitness F_j.

If $F_j < F_i$, replace j by the new solution.

5. Abandon a fraction of worst nests and built new ones. First find out whether each nest keeps its current position (Eq. (18)). R matrix stores 0 and 1 values such that any one of them is assigned to each component of i^{th} nest, in which 0 means that current position is kept and 1 implies that the current position is to be updated:

$$R_i \longleftarrow \begin{cases} 1 & if \quad rand \langle p_a \\ 0 & if \quad rand \geq p_a \end{cases} \tag{18}$$

New nests are conducted by means of Eq. (19):

$$x_i^{t+1} = x_i^t + r \times R_i \times \left(perm\,1_i - perm\,2_i \right) \tag{19}$$

Where r is a random number between 0 and 1. perm1 and perm2 are two row permutations of the corresponding nest. R defines the probability matrix.

6. Rank solutions and find the current best one.

7. Repeat steps 3-6 until termination criterion is satisfied which is usually taken as the maximum number of iterations.

4. Simulation results and discussions

The EPD problem with and without FACTS device is applied to the standard IEEE 09-bus system (Fig. 2) using Cuckoo Search algorithm (CS).

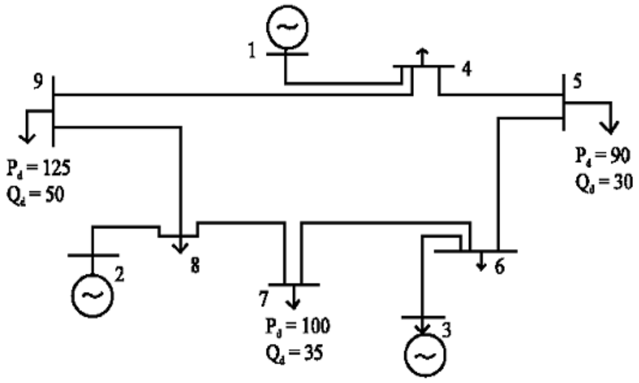

Fig.2. Structure of the IEEE 9 Bus test system

This approach has been developed by the use of Matlab 9. To demonstrate the effectiveness of the proposed approach three cases to be discussed:

4.1. Case 1: Optimal Power Flow with variable losses

In this case, the proposed CS-OPF is applied to standard IEEE 9-bus system (Optimal Power Flow with variable losses), the load demand D=315 MW. The input parameters of CS-algorithm are: nest set to 30 and discovery rate of alien eggs or fraction probability, Pa equals to 0.25 was run for 100 iterations. The obtained results using CS-OPF are given in Tables 1, 2 and compared with those of MATPOWER software [18].

Table 1

Comparison of simulation results obtained of Optimal Power Flow

Variable	P_{G1}(MW)	P_{G2}(MW)	P_{G3}(MW)	$\sum P_G$ (MW)	P_L(MW)	cost in($/h)
CS-OPF	86.596	138.638	93.724	318.959	4.182	5194.92
MATPOWER [18]	89.802	134.345	94.159	318.306	3.306	5296.7

Table 2

Optimal Power Flow with variable losses (CS-OPF)

Bus	V	Angle	Injection		Generation		Load	
No	Pu	Degree	MW	MVar	MW	Mvar	MW	MVar
1	1.04	0.000	86.82	39.636	86.82	39.636	0.000	0.000
2	1	6.8464	138.638	-0.249	138.638	-0.249	0.000	0.000
3	1	4.4125	93.724	-14.782	93.724	-3.882	0.000	10.9
4	1.0192	-2.7042	0.000	0.000	0.000	0.000	0.000	0.000
5	0.9841	-5.0477	-125	-50	0.000	0.000	125	50
6	1.0001	-4.329	-90	-30	0.000	0.000	90	30
7	1.0039	1.895	0.000	0.000	0.000	0.000	0	0.000
8	0.9933	-0.714	-100	-35	0.000	0.000	100	35
9	1.0102	1.2958	0.000	0.000	0.000	0.000	0.000	0.000
Total			4.182	-90.396	319.182	35.504	315	125.9

The results show that CS-OPF algorithm gives much better results than the MATPOWER software. The difference in generation cost between these methods clearly shows the advantage of this method. In addition, it is important to point out that the CS algorithm OPF converge in an acceptable time. For this system was converged to highly optimal solutions set after 30 iterations (Fig. 3).

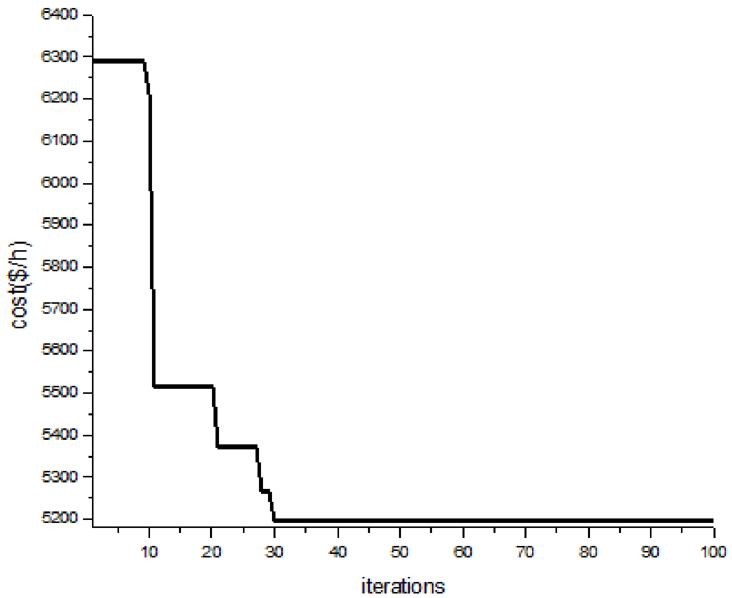

Fig.3. Convergence characteristics of CS algorithms for fuel cost with variable losses

4.2. Case 2: Optimal Power Flow with FACTS devices (STATCOM)

In order to check the feasibility of the proposed method, it is applied to solve OPF-CS with STATCOM of the same test system. We increase the load demand from 315 to 390 MW. The input parameters of CS-algorithm are: nest set to 30 and discovery rate of alien eggs or fraction probability, Pa equals to 0.25 was run for 100 iterations.

From the results of OPF-CS without STATCOM (Table 3), we conclude that increasing load; decrease the voltage of all buses. Here node 5 can be considered as the weakest node (0.933pu) and the drop of voltage is 6.7 %, so to maintain the voltage magnitude at the specified value, the STATCOM is installed at this bus.

Table 3

Optimal Power Flow without FACTS devices

Bus	V	Angle	Injection		Generation		Load	
No	Pu	Degree	MW	MVar	MW	Mvar	MW	MVar
1	1.04	0	107.869	77.229	107.869	77.229	0.000	0.000
2	1	9.6217	173.346	24.921	173.346	24.921	0.000	0.000
3	1	7.1713	117.403	-2.925	117.403	7.975	0.000	10.900
4	0.999	-3.4284	0.000	0.000	0.000	0.000	0.000	0.000
5	0.933	-7.7478	-200.000	-80.000	0.000	0.000	200.000	80.000
6	0.983	-4.1976	90.000	-30.000	0.000	0.000	90.000	30.000
7	0.99	3.3412	0.000	0.000	0.000	0.000	0.000	0.000
8	0.983	0.8917	-100.000	-35.000	0.000	0.000	100.000	35.000
9	1.004	3.2424	0.000	0.000	0.000	0.000	0.000	0.000
Total			8.618	-45.774	398.618	110.126	390.000	155.900

The simulation results of fuel cost power generators, the controlled variables, and its voltage rating obtained by CS are shown in Table 4, 5 and Fig. 4. The simulation results show that the bus voltages have considerably improved: at bus 5 (from 0.933pu to 1.000pu).

Moreover, the results indicate that with the proposed CS algorithm, acceptable fuel cost (7262.5414$/h) compared without STATCOM (7282.3345$/h) is obtained and the power losses has considerably decreased with 9.888%, from 8.618 MW to 7.766 MW. Therefore, the OPF problem with STATCOM using Cuckoo Search algorithm represented a good solution were the cost and the transmission loss are reduced and voltage magnitude are maintained at the specified value.

Table 4

Optimal Power Flow with FACTS devices (STATCOM)

Bus	V	Angle	Injection		Generation		Load	
No	Pu	Degree	MW	MVar	MW	Mvar	MW	MVar
1	1.0400	0.0000	108.621	31.748	108.621	31.748	0.000	0.000
2	1.0000	9.3383	172.997	-1.951	172.997	-1.951	0.000	0.000
3	1.0000	7.0652	116.635	-15.999	116.635	-5.099	0.000	0.000
4	1.0242	-3.3674	0.000	0.000	0.000	0.000	0.000	0.000
5	1.0000	-7.5551	-200.487	-10.201	-0.487	69.799	200.000	80.000
6	1.0026	-4.0988	-90.000	-30.000	0.000	0.000	90.000	30.000
7	1.0070	3.1747	-0.000	0.000	0.000	0.000	0.000	0.000
8	0.9959	0.8349	-100.000	-35.000	0.000	0.000	100.000	35.000
9	1.0117	3.1915	-0.000	0.000	0.000	0.000	0.000	0.000
Total			7.766	-61.402	397.766	94.498	390.000	155.900

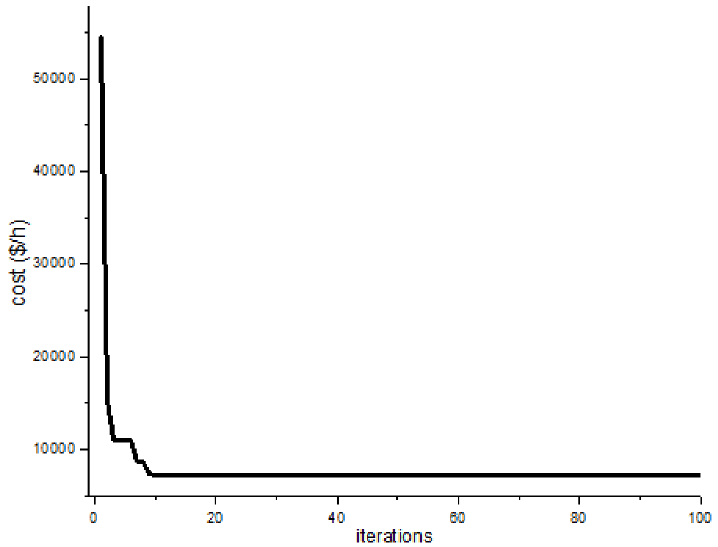

Fig.4. Convergence characteristics of CS algorithms for fuel cost with STATCOM

Table 5

Comparison of simulation results obtained without and with STATCOM.

Variable	P_{G1}(MW)	P_{G2}(MW)	P_{G3}(MW)	$\sum P_G$ (MW)	P_L(MW)	Cost in($/h)
CS with STATCOM	108.1237	172.9974	116.6347	397.7557	7.766	7262.5414
CS without STATCOM	107.6832	173.3462	117.4029	398.4324	8.6182	7282.3345

4.3. Case 3: Optimal Power Flow with FACTS devices cost (SVC).

In this case, we solve the optimal Power Flow with the investment cost of FACTS devices (SVC). We increase the load demand from 315 to 390 MW.

The input parameters of CS-algorithm are: nest set to 30 and discovery rate of alien eggs or fraction probability, P_a equals to 0.25 was run for 500 iterations.

Generally, the FACTS devices are very expensive, and the choice the placement of these flexible devices is essential to insure the efficient operation of electrical power systems and to avoid the improvidence. In our approach, the SVC is installed at critical buses (bus 5). We consider the cost of SVC and the generators to minimize the both total cost.

The solving results show that when using SVC, the security constraints are checked for voltage magnitudes (table 6). As shown in table 7, it is clear that the obtained optimal SVC location brings a considerable reduction of both the total fuel cost and the power losses (6.9460 MW compared to the CS without SVC 8.6182MW).

Table 6

Optimal Power Flow with FACTS devices (SVC)

Bus	V	Angle	Injection		Generation		Load	
No	pu	Degree	MW	MVar	MW	Mvar	MW	MVar
1	1.04	0.000	127.109	30.752	127.109	30.752	0.000	0.000
2	1.05	4.6436	152.614	-14.506	152.614	-14.506	0.000	0.000
3	1.05	3.9063	117.223	-32.374	117.223	-21.474	0.000	10.9
4	1.0254	-3.9368	0.000	0.000	0.000	0.000	0.000	0.000
5	0.982	-8.6375	-200	-80	0.000	0.000	200	80
6	1.0261	-5.2272	-90	-30	0.000	0.000	90	30
7	1.0625	-0.261	0.000	0.000	0.000	0.000	0.000	0.000
8	1.0875	-2.2339	-100	49.353	0.000	0.000	100	-49.353
9	1.0701	0.4012	0.000	0.000	0.000	0.000	0.000	0.000
Total			6.946	-76.774	396.946	-5.227	390.000	71.547

Table 7

Optimal Power Flow results with FACTS devices cost (SVC)

P_{G1} (MW)	P_{G2} (MW)	P_{G3} (MW)	Q_{svc} (MVAr)	Total P_G (MW)
126.95	117.2232	152.6137	84.3534	396.946
Losses (MW)	Total Cost ($/h)	Fuel cost ($/h)	SVC Cost ($/KVAr)	SVC Cost in ($/h)
6.946	7422.8027	7422.5709	105.70161	0.231863

Convergence characteristic of the 3 generators system for total fuel cost is shown in Fig. 5.

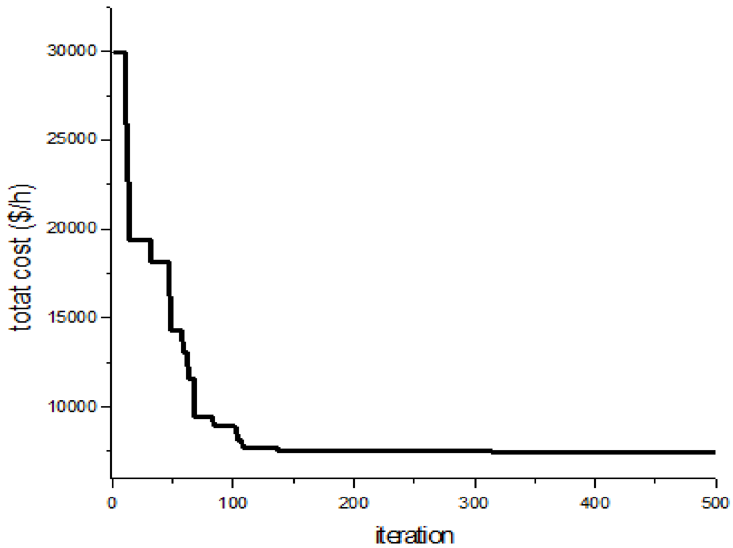

Fig.5. Convergence characteristics of CS algorithms for total cost with SVC

5. Conclusions

In this paper, the CS algorithm has been proposed, and successfully applied to solve both power flow optimal and optimal power flow incorporating FACTS devices. This algorithm which is one of the recent heuristic algorithms for solving optimization problems has several advantages including its few control variables, fast results, easy using process and simple structure.

The proposed algorithm is tested on IEEE 9 bus test power system to demonstrate its effectiveness. The simulation results indicate the robustness of the proposed approach to solve the OPF problem of power systems with and without FACTS. It is observed that the FACTS devices (STATCOM and SVC) can reduce the transmission losses, voltage deviation and the fuel cost. This work can be extended by including other FACTS devices like Unified Power Flow Controller (UPFC) and Thyristor Controlled Series Capacitor (TCSC).

R E F E R E N C E S

[1] *Deepti Gupta, Rupali Parmar* “Optimization of Economic Load Dispatch Thermal Power Plant Using Differential Evolution Technique” International Journal of Engineering Trends and Technology (IJETT) – Volume22 Number 4- April2015

[2] *Mimoun Younes, Fouad Khodja and Riad Lakhdar Kherfane* ‘Multi-objective economic emission dispatch solution using hybrid FFA (fire fly algorithm) and considering wind power penetration’ Energy 67 (2014) 595 -606http://dx.doi.org/10.1016/j.energy.2013.12.043

[3] *Ingrida Radziukyniene* ‘C-Grasp application to the economic dispatch problem’ Thesis the degree of Master of Science University of Florida 2010

[4] *B. Alatas,* “ACROA: artificial chemical reaction optimization algorithm for global optimization”, Expert Systems with Applications, vol. 38, no. 10, pp. 13170–13180, 2011. [Online]. Available: http://dx.doi.org/10.1016/j.eswa.2011.04.126

[5] *H.Shah-Hosseini*,“An approach to continuous optimization by the Intelligent Water Drops”, Procedia Social and Behavioural Sciences, vol. 32, pp. 224–229, 2012. [Online]. Available: http://dx.doi.org/ 10.1016/j.sbspro.2012.01.033

[6] *S. Yilmaz, E. U. Kucuksille, Y. Cengiz,* “Modified bat algorithm”, Elektronika IR Elektrotechnika, vol.20, no.2, pp.71–78,2014. [Online] Available: http://dx.doi.org/10.5755/j01.eee.20.2.4762

[7] *S.Roshni, C.R.Pradhan, Biswajit Mohapatra,*’ A Comparitive Study of Economic Load Dispatch Problems Using Classical method and Artificial Intelligence Method’ International Journal of Advanced Research in Electrical,Electronics and Instrumentation Engineering, Vol. 4, Issue 3, March 2015

[8] *Belkacem Mahdad, Kamel Srairi, Tarek Bouktir, Mohamed Benbouzid.* Optimal Power Flow for Large-Scale Power System with Shunt FACTS using Efficient Parallel GA. IEEE IECON’08, Nov 2008, Orlando, United States. pp.867-972, 2008

[9] *Mehdi Samimi Rad, Reihaneh Kardehi Moghaddam* ‘A Novel PSOGSA_SQP Algorithm for Solving Optimal Power Flow (OPF) Problem Based on Specific Switching Condition’ American Journal of Research Communication, Rad, et al., 2013: Vol 1(11)

[10] *Dutta Setal.,* Optimal location of STATCOM using chemical reaction optimization for reactive power dispatch problem, Ain Shams Eng J (2015), http://dx.doi.o rg/10.1016/ j.asej. 2015.04.013

[11] *Xiao Y, Song YH.* Power flow studies of a large practical power network with embedded FACTS devices using improved optimal multiplier Newton–Raphson method. Eur Trans Electr Power 2001;11(4):247–56

[12] *Ghadir R, Reshma SR.* Power flow model/calculation for power systems with multiple FACTS controllers. Electr Power Syst Res 2007;77:1521–31

[13] *E. J. Oliveira, J. W. M. Lima, and K. C. Almeida,* “Allocation of FACTS devices in hydrothermal system,” IEEE Trans.power systems, vol. 15, pp. 276-282, February. 2000.

[14] *Lijun Cai and Istvan Erlich Georgios Stamtsis Yicheng Luo* “Optimal Choice and Allocation of FACTS Devices in Deregulated Electricity Market using Genetic Algorithms”

[15] *Xin-She Yang,Zhihua Cui, Renbin Xiao, Amir Hossein Gandomi, Mehmet Karamanoglu* ‘Swarm Intelligence and Bio-Inspired Computation Theory and Applications’ Elsevier-32 Jamestown Road, London NW1 7BY-225 Wyman Street, Waltham, MA 02451, USA First edition 2013

[16] *Yang, X.S., Deb, S.,* 2009. Cuckoo search via Le´vy flights. Proceedings of the World Congress on Nature & Biologically Inspired Computing (NaBic 2009). IEEE Publications, USA, pp. 210-214.

[17] *Yang, X.S., Deb, S.,* 2010. Engineering optimization by cuckoo search. Int. J. Math. Model. Num. Opt. 1 (4), 330343.

[18] *Christopher L. DeMarco* “New System Control Methodologies: Adapting AGC and Other Generator Controls to the Restructured Environment” Power Systems Engineering Research Center- Cornell University 428 Phillips Hall - PSERC Publication 05-64 November 2005