ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 4, April 2015

Application of SSSC FACTS Device in Reactive power flow Solution using Biogeography-based optimization

Kirti Joshi[1], Vipul Kumar[2], Divya Mathur[3]

Electrical Department, Rajasthan College of Engineering for woman, India[1,2]

Electrical Department, JECRC University, India[3]

Abstract: This paper describe the reactive power flow solution based BBO to amend the performance of the power system. Biogeography-based optimization is incorporating flexible AC transmission systems (FACTS). Static Synchronous Series Compensator (SSSC) is type of FACTS device used in this paper. In this BBO Store best parent solution and apply mutation and migration process on remaining parents to produce best fitted child sets. This paper define the problem of optimal power flow solution is very severe in modern interconnected transmission system the control of reactive and real power has to be fast to insure that the system remains stable under all condition of operation. The use of thyristor based controllers enable a transmission system to be flexible using SSSC FACTS is a series connected FACTS controller. The proposed BBO method gives better solution quality compared to particle swarm optimization with static synchronous series compensator facts device. The simulation results show that the proposed BBO algorithm is effective, fast and accurate in finding the optimal parameter settings for FACTS devices to solve OPF problems. BBO algorithm is tested on IEEE 14-bus with SSSC FACTS device gives better solution to enhance the system performance.

Keywords: Power system operation, FACTS, Biogeography based optimization, optimal power flow, SSSC Device.

I. INTRODUCTION

The present day power system is a large complex interconnected network that consists of thousands of buses and generators. The network is expanding everyday with the increase in demand and to meet this locality, either new installation of power generating stations and transmission lines is desires or the actual infrastructure operation has to be continued to limits. For contradiction of cost and improved reliability, most of the word's electrical power system continues to be interconnected.

A power system is expected to operate under widely varying condition from no load to overloading to short circuits and it is desired that the quality of supply should be maintained under all conditions .also it is desirable to maintain the three phase currents and voltages as balance as possible so that undue heating of various rotating machine due to unbalancing could be avoided. Good quality power supply also requires exaggeration loss voltage and current waveforms of the system. In the power system compensation is essential to alleviate some of these problems. Here the reactive power flow is controlled by compensating devices at the load end bringing about proper balance between generated and consumed reactive power .Series/Shunt compensation has been in use for past many years to achieve this objective. [1] (FACTS) is a system relaxed of static equipment used for power flow control, load sharing, voltage regulation, and improvement of transient stability and mitigation of system oscillation. This system is a power electronics-based system have introduced Flexible AC Transmission Systems (FACTS) that include Thyristor Controlled Series Compensator (TCSC), Static VAR Compensator (SVC), Static Synchronous Compensator (SSSC), Thyristor Controlled Phase Angle Regulator (TCPAR) etc. [1,][2]. the benefit brought about by FACTS includes improvement of system behaviour and improvement of system reliability. Despite, their essential function is to control power flows. It is meant to enhance controllability and increase power transfer capability of the network.[3] A Static Synchronous Series Compensator (SSSC) is a type of FACTS which is connected in series with a transmission line through the coupling transformer. Optimal Power Flow (OPF) is an important tool for power system operators both in planning and operating stages. The main purpose of an OPF program is to determine the settings of control variables for economic and secure operation of a power system. Amongst a number of different operational objectives that an OPF problem may be formulated for, a widely considered objective is to minimize the fuel cost subject to network and generator operation constraints.

Because of its financial implication, the optimal power flow (OPF) problem has been well rigorously studied over the past few decades. Many optimization techniques have so far been applied to solve this problem.[10]

The optimization techniques have been widely applied to varieties of OPF problems. However, these techniques fail to deal with systems having complex non smooth, non-convex and non-differentiable objective functions and constraints. Because of tremendous improvement in

 DOI 10.17148/IJIREEICE.2015.3401

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 4, April 2015

capability of computers in recent years, evolutionary algorithms, such as genetic algorithm (GA) [11, 12], evolutionary programming (EP) [13, 14], particle swarm optimization (PSO) [15] and differential evolution (DE) are being applied for solving various complex OPF problems to overcome some of the drawbacks of classical techniques.

Evolutionary Programming (EP) is a stochastic global search method based on natural biological evolution. In 1995, Q.H. Wu et. al. [12] described the application of evolutionary programming (EP) to optimal reactive power dispatch and voltage control of power systems. Particle swarm optimization (PSO) is a kind of stochastic, population-based optimization algorithm. In 2002, MA Abido et. al. [14] employed particle swarm optimization (PSO) algorithm for optimal settings of control variables in OPF problem. In 2008, Pablo E. et. al. [6] employed the PSO with reconstruction operators (PSO-RO) as the optimization tool to solve security constrained OPF. Differential evolution (DE) developed by Storn and Price has gained attention recently due to its strong ability in searching a global optimal solution. K. P.Wong et. al. [16] developed DE for solving transient stability constrained OPF.

New optimization technique is Biogeography-based optimization technique has been developed by (BBO) (Simon. 2008) based on the theory of biogeography. BBO concept is mainly based on migration and mutation. In the Gas, PSO, BBO has a way of sharing information between solutions. GA solutions "die" at the end of each generation, while PSO and BBO solutions survive forever. PSO solutions are more likely to clump together in similar groups, while GA and BBO solutions do not have any built-in tendency to cluster. Again in BBO poor solutions accept a lot of new features from good solutions. These additions of new features to low quality solutions may improve the quality of those solutions. BBO has already been applied successfully to solve non-convex, large, complex Economic Load Dispatch problems [17]. A biogeography based optimization (BBO) algorithm has been proposed developed and successfully applied to solve optimal power flow (OPF) problem incorporating FACTS devices and valve point discontinuities.

This paper examines the effect of SSSC FACTS device using bbo based OPF solutions for enhance performance of the power system. In this paper solving the optimal power flow problem as minimization cost. The effectiveness of the proposed method examined on IEEE 14-bus tested systems. we compare the performance of bbo technique to pso technique (partial swarm optimization) in application of power system and demonstrate the higher up performance.

II. BIOGEOGRAPHY-BASED OPTIMIZATION TECHNIQUE (BBO)

Biogeography optimization technique is the geographical distribution of biological organisms. In the BBO algorithm, problem solutions is represented as immigration and emigration between the islands**[8].**A BBO which deals with the distribution of species that depend on different factors such as rain fall, diversity of vegetation, diversity of topographic features, land area, temperature, etc. A larger number of species are found in favorable areas compared with that of a less favorable area.

A habitat is defined as an island (area) that is geographically isolated from other islands. Geographical areas that are well suited as residences for biological species are said to have a high habitat suitability index (HSI). The variables that characterize habitability are called suitability index variables (SIVs). SIVs can be considered as the independent variables of the habitat and HSI calculation is carried out using these variables. Habitats with a high HSI tend to have a large number of species, while those with a low HSI have fewer numbers of species. The migration of some species from a habitat to an exterior habitat is known as emigration process and an entry of some species into one habitat from an outside habitat is known as immigration process. Habitats with high HSI have low species immigration rate because they are nearly saturated with species and are more static in their species distribution compared to low HSI habitats. By the same token high HSI habitats have higher emigration rate. The species on high HSI islands have more opportunities to emigrate to neighboring habitats and to share their characteristics with local habitats. Habitats with a low HSI have a high species immigration rate because of their sparse populations.

Mathematically, the concept of emigration and immigration can be represented by a probabilistic model. Let $P_s(t)$ denotes the probability that a habitat contains exactly s species at time t. At time $(t + \Delta t)$ the probability is

$$P_s\,(t + \Delta t) = P_s(t)(1 - \lambda_s \Delta t - \lambda_s \Delta t) + P_{s-1}\,\lambda_{s-1}\,\Delta + P_{s+1}\,\lambda_{s+1}\,\Delta t \qquad (1)$$

where λ_s and μ_s are the immigration and emigration rates when there are s species in the habitat. This equation holds because in order to have s species at time$(t + \Delta t)$, one of the following conditions must hold:

1) there were s species at time t , and no immigration or emigration occurred between t and$(t + \Delta t)$;
2) there were $(s + 1)$ species at time t, and one species immigrated;
3) there were $(s - 1)$ species at time t, and one species emigrated;

If time Δt is small enough so that the probability of more than one immigration or emigration can be ignored, then taking the limit of (1) as $\Delta t \rightarrow 0$ gives the following equation

(2)

$$P_s = \begin{cases} -(\lambda_s + \mu_s)\,P_s + \mu_{s+1}\,P_{s+1} & S = 0 \\ -(\lambda_s + \mu_s)\,P_s + \lambda_{s-1}P_{s-1} + \mu_{s+1}\,P_{s+1} & 1 \le S \le S_{max-1} \\ -(\lambda_s + \mu_s)\,P_s + \lambda_{s-1}\,P_{s-1} & S = S_{max} \end{cases}$$

From the straight-line graph of Fig. 3, the equation for emigration rate μ_k and immigration rate λ_k for k number of species is derived as per the following way

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

IJIREEICE

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 4, April 2015

$\mu_k = \frac{E_k}{n}$ (3)

$\lambda_k = I\left(1 - \frac{k}{n}\right)$ (4)

When $E = I, \lambda_k + \mu_k = E$ (5)

where, E and I are the maximum emigration rate and maximum immigration rate respectively. 'n' is the total number of species in the habitat.

BBO has two mechanisms migration and mutation.

1) Migration

With probability P_{mod} , known as habitat modification probability, each solution can be modified based on other solutions. If a given solution S_i is selected to be modified, then its immigration rate λ_k is used to probabilistically decide whether or not to modify any SIV in that solution. After selecting any SIV of that solution for modification, emigration rates μ_j of other solutions S_j (S_j is the j^{th} solution set other than(S_i , i.e. j =) are used to select which solutions among the population set will migrate randomly to chosen SIVs to the selected solution S_i . Details about the algorithm of migration have been discussed in[17, 18].

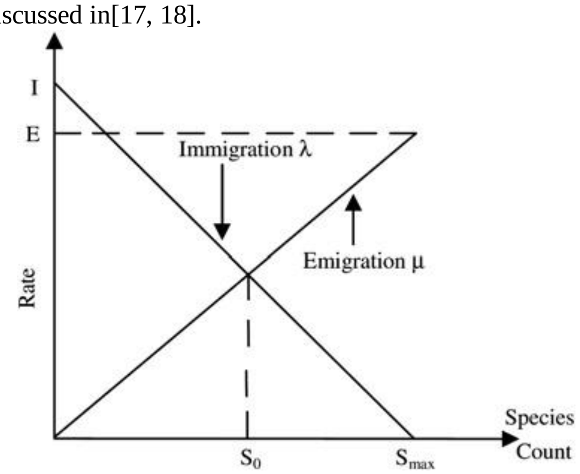

Fig.1. Species model of a single habitat

2) Mutation

In BBO species count contingency, P_s is used to determine mutation rates. The contingency of each species count can be calculated using the differential (18). Each member of habitat has an associated tendency, which indicates the tendency that it exists as a solution for a given problem. If this tendency is lower than that solution is expected to mutate to some other solution. Equivalently, if the tendency of some solution is higher than that solution, then it has very insufficient chance to mutate. Mutation rate of each set of solution can be calculated in terms of species count tendency using the following equation. Mutation rate of each set of solution can be calculated in terms of species count tendency using (Simon., 2008):

$$M_r = m_{max} \left(\frac{1-P_{N_s}}{P_{max}}\right)$$

where M_r = The mutation rate for a habitat that N_s contains species;

m_{max} = the maximum mutation rate;

P_{max} = the maximum tendency.

where is m_{max} a user-defined parameter. Details about the mutation have been discussed in [17, 18].

III. STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC)

Static synchronous series compensator is member of facts consists of a solid state voltage source converter (VSC) which generates a controllable alternating current voltage at fundamental frequency. It can be used to vary the series reactance of line by injecting a voltage into the line. It has also a dc energy source. SSSC can be use to injects a voltage lagging the line current by 90° thus reducing the effective line inductance. The injected voltage can also be made to lead the line by 90° thus damping the power swings. the control is through the firing angle of thyristors. When circuit breaker is off, SSSC is active. When circuit breaker is on, SSSC is switched off. While the primary purpose of a SSSC is to control power flow in steady state, and enhance transient stability of a power system. [5]

Basic operating principle and Equivalent Circuit of SSSC

Fig.1 shows a functional model of the SSSC where the dc capacitor has been replaced by an energy storage device such as a high energy battery installation .This is allow active as well as reactive power. The compensator output voltage magnitude and phase angle can be varied in a controlled manner to influence power flows in a transmission line. [6].The power flow can be calculated by voltages and phase angles at each bus in power system. From these voltages and angles, combined with the known transmission line admittances, the active and reactive power flowing into the network from each bus can be calculated.

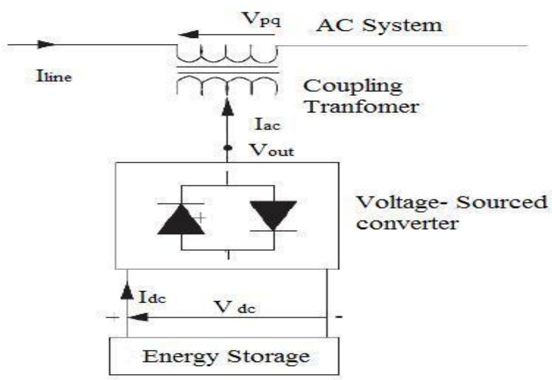

Fig.2. Functional Model of SSSC

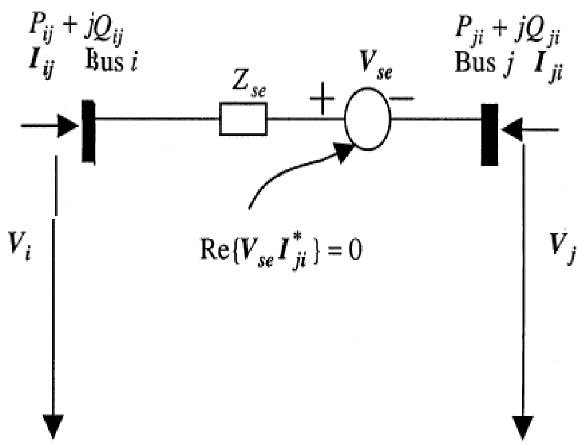

Fig. 3. Equivalent Circuit of SSSC.

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526
INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 4, April 2015

The equivalent circuit of SSSC is as shown in the Figure 2. From the equivalent circuit the power flow constraints of the SSSC can be given as

$$P_{ij} = V_i^2 g_{ii} - V_i V_j (g_{ij} \cos\theta_{ij} + b_{ij} \sin\theta_{ij}) - V_i V_{se}\left(g_{ij} \cos(\theta_i - \theta_{se}) + b_{ij} \sin(\theta_i - \theta_{se})\right) \quad (1)$$

$$Q_{ij} = -V_i^2 b_{ii} - V_i V_j (g_{ij} \sin\theta_{ij} + b_{ij} \cos\theta_{ij}) - V_i V_{se}\left(g_{ij} \sin(\theta_i - \theta_{se}) + b_{ij} \cos(\theta_i - \theta_{se})\right) \quad (2)$$

$$P_{ji} = V_j^2 g_{ji} - V_i V_j (g_{ij} \cos\theta_{ji} + b_{ij} \sin\theta_{ji}) + V_j V_{se}\left(g_{ij} \cos(\theta_j - \theta_{se}) + b_{ij} \sin(\theta_j - \theta_{se})\right) \quad (3)$$

$$Q_{ji} = -V_i^2 b_{jj} - V_i V_j (g_{ij} \sin\theta_{ji} + b_{ij} \cos\theta_{ji}) + V_j V_{se}\left(g_{ij} \sin(\theta_j - \theta_{se}) + b_{ij} \cos(\theta_j - \theta_{se})\right) \quad (4)$$

where

$$g_{ii} + jb_{ij} = 1/Z_{se} \quad , g_{ii} = g_{ij} ,$$
$$b_{ii} = b_{ij} \quad , g_{ii} = g_{ij} , b_{jj} = b_{ij}$$

Operating constraint of the SSSC (active power exchange via the DC link) is as

$PE = Re\left(V_{se} I^*_{ji}\right) = 0$ or

$$-V_i V_{se}\left(g_{ij} \cos(\theta_i - \theta_{se}) + b_{ij} \sin(\theta_i - \theta_{se})\right) + V_j V_{se}\left(g_{ij} \cos(\theta_j - \theta_{se}) + b_{ij} \sin(\theta_j - \theta_{se})\right) = 0 \quad (5)$$

The active and reactive power flow constraints is

$$P_{Ji} - P_{ji}^{specifed} = 0 \quad (6)$$

$$Q_{Ji} - Q_{ji}^{specifed} = 0 \quad (7)$$

Where P_{Ji} and $P_{ji}^{specifed}$ are specified active and reactive power flows.

The equivalent voltage injection $V_{se}\theta_{se}$ bound constraints are as

$$V_{se}^{min} \le V_{se} \le V_{se}^{max} \quad (8)$$

$$\theta_{se}^{min} \le \theta_{se} \le \theta_{se}^{max} \quad (9)$$

where , $V_{se} = 0.04\, p.u, V_{se}^{min} = 0.001, V_{se}^{max} = 0.2$

$\theta_{se} = 87.13°$, $\theta_{se}^{min} = 90°$, $\theta_{se}^{max} = 180°$

IV. PROBLEM FORMULATION

Quadratic Fuel Cost Function

The SSSC FACTS device with The BBO technique is utilized to minimize the fuel cost of generation and to improve the system performance by maintaining thermal and voltage constraints. Generally, the fuel cost of a thermal generating unit is considered as a second order polynomial function.

Mathematically, the OPF problem after incorporating SSSC FACTS controller can be formulated as follows [6]-[7] :

$$\text{Minimize } F = \left(\sum_{i=1}^{NG} (a_i\ P_{Gi}^2 + b_i P_{Gi} + c_i\ \right) \quad (10)$$

where A quadratic polynomial a_i , b_i and c_i are the cost coefficients of the i-th generator

$Pi(min)$ =Minimum output of i-th generating unit

$Pi(min)$ = Maximum output of i-th generating unit

NG = number of committed generators;

The minimization problem is subjected to following to equality and inequality constraints.

A. Equality Constraints:

These are the sets of nonlinear power flow equations that govern the power system, i.e,

$$P_{Gi} - P_{Di} - \sum_{j=1}^{n} |V_i||V_j||Y_{iJ}| \cos(\theta_{ij} - \delta_i + \delta_j) = 0 \quad (11)$$

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{n} |V_i||V_j||Y_{iJ}| \sin(\theta_{ij} - \delta_i + \delta_j) = 0 \quad (12)$$

where P_{Gi} and Q_{Gi} are the real and reactive power outputs injected at bus i respectively, the load demand at the same bus is represented by P_{Di} and Q_{Di} , and elements of the bus admittance matrix are represented by $|Y_{iJ}|$ and θ_{ij}.

B. Inequality Constraints**:**

These are the set of constraints that represent the system operational and security limits like the bounds on the following:

1) Generators Constraints

Real power outputs and reactive power outputs must be restricted within their limits

$$P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max} , i = 1, \ldots, N \quad (13)$$

$$Q_{Gi}^{min} \le Q_{Gi} \le Q_{Gi}^{max} , i = 1, \ldots, N \quad (14)$$

2) Voltage magnitudes Constraints

Voltage magnitudes must be within limits as follows:

$$V_i^{min} \le V_i \le V_i^{max} , i = 1, \ldots, NL \quad (15)$$

3) Transformer tap settings Constraints

Transformer tap settings must be within limits as follows:

$$T_i^{min} \le T_i \le T_i^{max} , i = 1, \ldots, NT \quad (16)$$

4) Reactive power injections Constraints

Reactive power injections due to capacitor banks must be within limits as follows:

$$Q_{Ci}^{min} \le Q_{Ci} \le Q_{Ci}^{max} , i = 1, \ldots, CS \quad (17)$$

5) Transmission lines loading Constraints

$$S_i \le S_i^{max} , i = 1, \ldots, nl \quad (18)$$

6) Voltage stability index Constraints

$$Lj_i \le Lj_i^{max} , i = 1, \ldots, NL \quad (19)$$

V. BBO ALGORITHM APPLIED

The algorithm of the proposed method is as enumerated below.

Step1: Initialize the BBO parameters as follows: Habitat Modification Probability Pmod =1; Mutation Probability = 0.004, maximum immigration rate, I = 1, maximum emigration rate E =1, step size for numerical integration, dt =1, no of iterations = 50, maximum species count, max S, elitism parameter=4, number of SIVs of BBO algorithm= number of Generating units, number of Habitats =50.

Step2: The initial position of SIV of each habitat should be selected randomly while satisfying different equality and inequality constraints of problems. Several numbers of habitats depending upon the population size are being produced. Each habitat represents a possible solution to the given problem.

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 4, April 2015

Step3: Calculate the HSI i.e. value of objective function for each habitat of the population set for given emigration rate, μ, immigration rate, λ, and species, S. In this paper, each habitat is a vector with producing units. Each individual habitat within the total of H habitat represents a candidate solution for solving the fuel cost problem.

Step4: Based on the HSI value elite habitats are identified.

Step5: Each non-elite habitat is modified by performing probabilistically migration operation and HSI of each modified set is recomputed. The verified feasibility problem i.e. each SIV should satisfy equality and inequality constraints of generator as mentioned in the specific problem.

Step6: Species count probability of each habitat is updated using (2). Mutation operation is performed on the non-elite habitat and HSI value of each new habitat is computed.

Step7: Feasibility of a problem solution is verified.

Step8: Go to step (3) for the next iteration.

Step9:Stop iteration after a predefined number of iterations.

VI. BBO ALGORITHM APPLIED

The proposed BBO algorithm to solve optimal power flow problem incorporating SSSC FACTS device is tested on standard IEEE 14-bus and IEEE 30- bus test systems. The proposed algorithm are Implemented using MATLAB 7.8 running on Intel® core™ i3-2120CPU@3.30GHZ,2.91GB of RAM personal computer. The network and load data for this system is taken from [19]. To test the ability of the proposed PSO algorithm for solving optimal power flow problem with and without SSSC FACTS device. One objective function is considered for the minimization using the proposed PSO algorithm. In order to show the affect of power flow control capability of the SSSC FACTS device in proposed PSO OPF algorithm, two sub case studies are carried out on the IEEE 14-bus and IEEE 30-bus test systems.

Case (A): Normal operation (without FACTS device installation),

Case (B): When one SSSC installed. SSSC installed in IEEE 14-bus and IEEE 30-bus test system at line connected between buses 12&13 and 9&10 with line real and reactive power settings of P(minimum)= 0.025125 and P(maximum)= 0.40775. The evolution of objective function during optimization by the proposed method is shown in Figure 4 and in Figure 5 under selected SSSC FACTS device. The optimal settings of control variables and SSSC FACTS device parameters during minimization of objective function are given in Tables 1 and 2 under the selected SSSC FACTS device respectively. From the Tables 2 and 3 it is noted that BBO algorithm is able to enhance the system performance while maintaining all control variables and reactive power outputs within their limits. and all the data of Pgmin and Pgmin are taken in p.u. [20]

The objective function is the total fuel cost and the fuel cost curves of the units are represented by quadratic cost functions. The lower voltage-magnitude limits and the upper limits and transformers with tap ranges have taken. [6]-[7] .

Table: 1. Cost-curve parameters for IEEE14-bus system

unit	a($MW^{2)}$)	b (MW)	c
1	0.68	22.8	823
2	1.53	25.9	120
3	1.98	29.0	480
4	2.23	30.0	500

Table: 2. Cost-curve parameters for IEEE30-bus system

unit	a($MW^{2)}$)	b (MW)	c
1	0.007	7	240
2	0.0095	10	200
3	0.009	8.5	220
4	0.009	11	200
5	0.008	10.5	220
6	0.0075	12	190

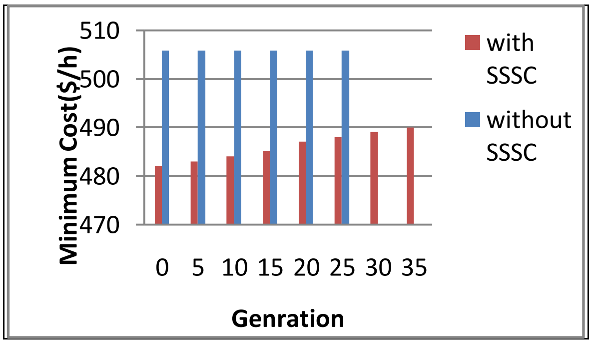

Fig.4. Convergence of cost of generation without and with with SSSC FACTS device for IEEE 14-bus system

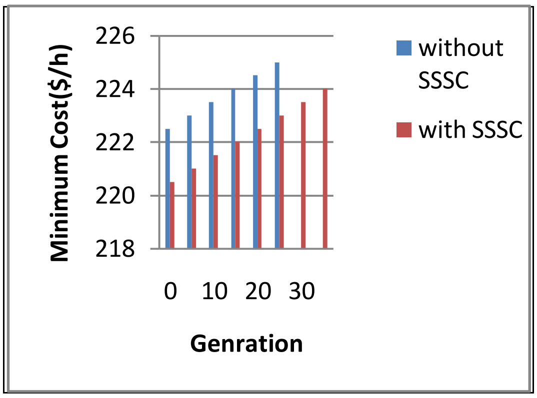

Fig.5. Convergence of cost of generation without and with with SSSC FACTS device for IEEE 30-bus system

Table: 3. Simulation results for IEEE14-bus system

Control Variables	Limits(p.u)		Without SSSC	With SSSC
	max	min		
P_{G1}	3.324	0.0	1	1
P_{G2}	1.400	0.0	0.82751	1.0892
P_{G3}	1.000	0.0	1.5815	2.7922
P_{G4}	1.000	0.0	1.15	1

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 4, April 2015

Table: 4. Simulation results for IEEE 30-bus system

Control Variables	Limits(p.u)		Without SSSC	With SSSC
	max	min		
P_{G1}	2.000	0.50	0.97291	1.7184
P_{G2}	0.800	0.20	0.28282	0.71256
P_{G3}	0.350	0.10	1.2391	1.6821
P_{G4}	0.300	0.10	0.58345	11.3059
P_{G5}	0.500	0.15	0.36275	0.22121
P_{G6}	0.400	0.12	0.85862	1.1138

VII. CONCLUSIONS

In this paper, we purposed an approach for the solution of the reactive power flow problem through the use of a Biogeography based optimization algorithm with SSSC FACTS device. The results obtained from the purposed approach were compared to those reported in the recent literature. It has been observed that the BBO has the capability to converge to a better quality solution and possesses better convergence characteristics and robustness than PSO, GA and other techniques.The results from the two tested systems showed that the integrated OPF with Static Synchronous Series Compensator scheme is very effective compared to other FACTS devices in improving the security of the power system.

REFERENCES

[1] HINGORANI N.G., GYUGYI L., UNDERSTANDING FACTS: CONCEPTS AND TECHNOLOGY OF FLEXIBLE AC TRANSMISSION SYSTEMS. IEEE PRESS, PP. 1-29 (2000).
[2] Gotham D.J., Heydt G.T., Power flow control and power flow studies for systems with FACTS devices. IEEE Trans. on Power Syst. 13(1) (1988).
[3] P. Kessel, H. Glavitch, "Estimating the voltage stability of powe system," IEEE Trans. Power
[4] http://www.energy.siemens.com/hq/en/power-transmission/facts/
[5] M. Faridi, H. Maeiiat, M. Karimi, P. Farhadi and H. Moslesh (2011) Power System Stability Enhancement Using Static Synchronous Series Compensator (SSSC)‖ IEEE Transactions on Power System pp. 387- 391.
[6] P. E. O. Yumbla, J. M. Ramirez, C. A. Coello Coello. "Optimal power flow subject to security constraints solved with a particle swarm optimizer," IEEE Transactions on Power Systems, vol. 23, no. 1, Feb., 2008..
[7] Somasundaram P., Kuppuswamy K. & Kumidini Devi R.P., "Evolutionary Programming Based Security Constrained Power Flow", Electric Power SystemsReasearch, Vol. 72, July 2004, pp. 137-145.
[8] Kalyan K. Sen, (1998) ―SSSC- Static Synchronous Serie Compensator (SSSC): Theory, Modeling and Applications‖, IEEE Transactions on Power Delivery, Vol. 13, pp. 241-246.
[9] Rick Rarick, Dan Simon, F. Eugenio Villaseca, Bharat Vyakaranam "Biogeography-Based Optimization and the Solution of the Power Flow Problem", IEEE International Conference on Systems, Man, and Cybernetics San Antonio, TX, USA - October 2009
[10] Bhattacharya A., Chattopadhyay P.K., "Biogeography-Based Optimization forSolution of Optimal Power Flow Problem", IEEE Trans. on Power System.
[11] Q. H. Wu, Y. J. Cao, and J. Y. Wen, "Optimal reactive power dispatch using an adaptive genetic algorithm," Int. J. Elect. Power Energy Syst., vol. 20, no. 8, pp. 563–569, 1998.
[12] Q. H.Wu and J. T. Ma, "Power system optimal reactive dispatch using evolutionary programming," IEEE Trans. Power Syst., vol. 10, no. 3, pp.1243–1249, Jul. 1995.
[13] J. Yuryevich and K.P. Wong, "Evolutionary programming based optimal power flow algorithm", IEEE Trans Pwr Syst, vol. 14, no. 4, pp. 1245–1250, 1999.
[14] M. A. Abido, "Optimal power flow using particle swarm optimization" Proc. Int. J. Elect. Power Energy Syst., vol. 24, no. 7, pp. 563– 571, 2002.
[15] T. S. Chung and Y. Z. Li, "A hybrid GA approach for OPF with consideration of FACTS devices", IEEE Power Engineering Review, vol. 21, no. 2, pp.47-50, Feb. 2001.
[16] H. R. CAI, C. Y. Chung, and K. P. Wong, "Application of Differential Evolution Algorithm for Transient Stability Constrained Optimal Power Flow", IEEE Trans. on Power Systems, vol. 23, no. 2, May 2008.
[17] Bhattacharya A., Chattopadhyay P.K., "Biogeography-Based Optimization for Different Economic Load Dispatch Problems", IEEE Trans. on Power Syst., D.O.I:- 10.1109/TPWRS.2009.2034525.
[18] Simon, S.: 'Biogeography-based optimization', IEEE Trans. Evol. Comput., 2008, 12, (6), pp. 702–713
[19] IEEE 14-bus and IEEE 30-bus system data (1996), (Online) Available at //www.ee.washington.edu
[20] Padma Kottala1, Vaisakh Kanchapogu2" Analysis of Performance of SSSC FACTS Device Using PSOBased Optimal Power Flow Solutions" Majlesi Journal of Electrical EngineeringVol. 6, No. 3, September 2012.