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A Hybrid BBO-DE optimization with Eigen value analysis based transient stability improvement by coordinated design of SVC

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Abstract

This paper presents a hybrid BBO-DE with Eigen value analysis based optimization problem. In the power system scenario, the performance study of SVC and PSS are executed in IEEE 39 bus test system for the enhancement of transient stability through power system analysis tool box (PSAT) software. The proposed hybrid algorithm technique is applied to an IEEE test system that consists of 10 generators, 19 loads are considered to study. The objective of test system during three phase fault, the voltage profile and stability are affected. It needs compensation to recover the stability from disturbance. So the hybrid BBO-DE algorithm is used to evaluate the performance of the system. It is considering fault time 2.0 second and clearing time 2.50 seconds in time domain simulation based PSAT software.

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Keywords: SVC,PSS, transient stability, BBO-DE

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1. Introduction

Transient stability i.e Voltage stability is a key issue in recent years .It is a most important concern for the power system network. Voltage instability is one of the causes of the voltage collapse. To develop the stability and control of the system parameters, Flexible AC Transmission Systems (FACTS) are developed in recent years. FACTS

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device is a utilized to improve power system operation and control [1] [2]. The static var compensator (SVC) is shunt device of the flexible AC transmission system (FACTS) family. It can be used to control the power flow and improve transient stability on power grid. So the SVC is one of the FACTS devices which are employed to regulate the system voltage by absorbing and injecting reactive power. When system voltage is low, the SVC generates reactive power similarly the system voltage is high, it absorbs reactive power. The optimal location and tuning of the SVC has a vital role in developing stability of the system [3] [4].

Nomenclature

BBO	Biogeography based optimization
DE	Differential Evolution
CR	Crossover rate
SVC	Static var compensator
PSS	Power system stabilizer
I_{rand}	Random integer
X_j^l	Lower bound of jth vector
X_j^u	Upper bound of jth vector
$X_{i,G}$	ith individual of the gth generation of the vector
X_{r1G}, X_{r2G} & X_{r3G}	Random vectors
r_1, r_2 & r_3	Random variables
$X_{j,i}$	Mutant vector
$U_{j,i}$ & $V_{j,i}$	Trial vector

2. Transient stability with SVC and PSS in 39 bus system

The power system has to maintain synchronism when subjected to severe transient disturbances. Here the disturbances might be a fault, loss of generation or loss of a big load. The disturbances affect the voltage profile, real power, reactive power and stability of the system [5] [6]. This paper investigates the effect of fault on transient stability occurred in the IEEE 39 bus test system. Here, the fault has been initiated through a three phase fault. The performance of the suggested controller is carried out by the time domain simulation in PSAT software. The role of a SVC is to control the voltage at the power system network. Static Var Compensators are shunt connected devices. It generates or absorbs the reactive power .Two types of SVC regulators are used in PSAT.SVC type 1 model is used to study in this paper[7][8][9]. To damp out these oscillations, auxiliary controllers are used. The power system stabilizer (PSS) is one of the auxiliary controllers and its performance has been proved in many circumstances .In this paper, the hybrid BBO-DE algorithms is tuned with SVC.

3. Analysis of Eigen value in 39 bus system

A differential algebraic equation (DAE) set is used for the Eigen value analysis in PSAT software. The form of DAE is

$$\dot{x} = f(x, y) \qquad (1)$$

$$0 = g(x, y) \qquad (2)$$

Where x is the state variable and y is the vector of the algebraic variable. The state matrix is calculated by jacobian matrix. The state matrix is used to calculate the Eigen values. There are two positive Eigen values in the system without SVC shown in figure 1 .This shows the system is in unstable condition.

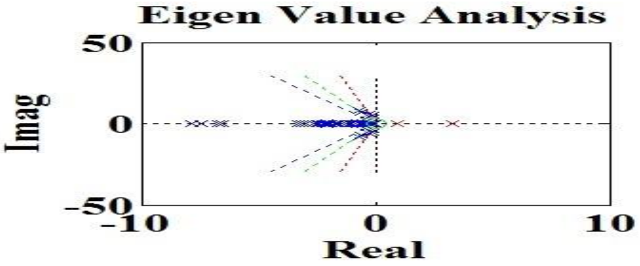

Figure 1 Eigen value analysis without SVC

The table 1 shows that there are 39 buses in the system but positive Eigens value are 2 and negative eigens are 137.

Table 1 Time constant values per unit in test system

Eigen value analysis without SVC	
Dynamic order	140
Buses	39
Positive Eigens	2
Negative Eigens	137
Complex pairs	21
Zero Eigens	1

An Eigen value based objective function is used to design the SVC and PSS. Here, damp scale function is used. the complex pair of the eigen value is

$$\lambda=\sigma+j\omega \qquad (3)$$

Where σ is real part of Eigen value and jω is the imaginary part of the Eigen value, σ_0 is damping factor constant i.e (-1). According to this objective function, it relocates the oscillation modes from right side to left side figure 2 of the s- plane within the fan shaped region. Because of that, the optimal values of the objective function are less than zero as shown in figure 2.

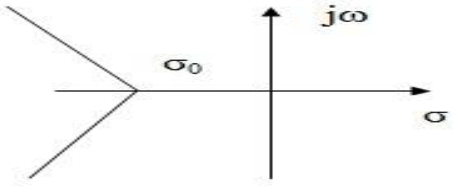

Figure 2 Objective function

4. Benchmark of IEEE 39 bus test system

The time domain simulation works are done by PSAT software. It is used to compute and plot the graphs of the system. The performance of the SVC can be analyzed through 39 test system. An IEEE 39 bus test system with 10 generators and 19 loads is considered to study. The system performance has been studied by applying a three phase fault in PSAT software. Here, assuming fault time is at 2.00 second and the clearing time 2.50 s. The fault has been applied at bus 12 of IEEE 39 bus system. The IEEE 39 bus system is shown in figure 3.The loading Condition of the system in per unit is shown in table 2.

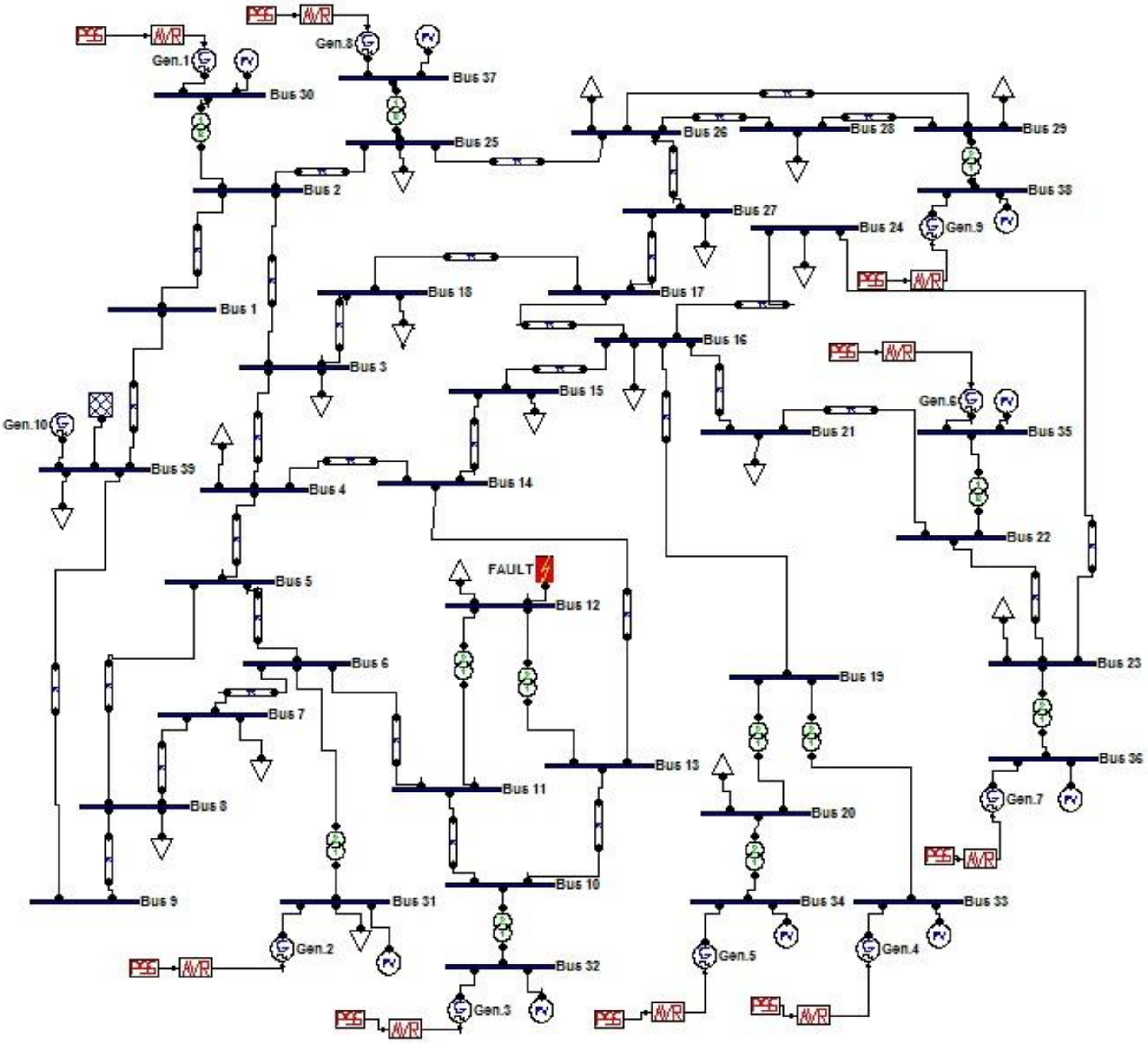

Figure 3 IEEE 39-bus test system

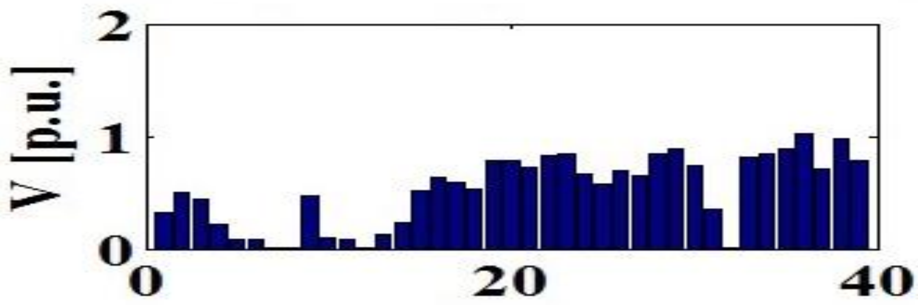

Figure 4 Voltage magnitude profile without SVC in per unit

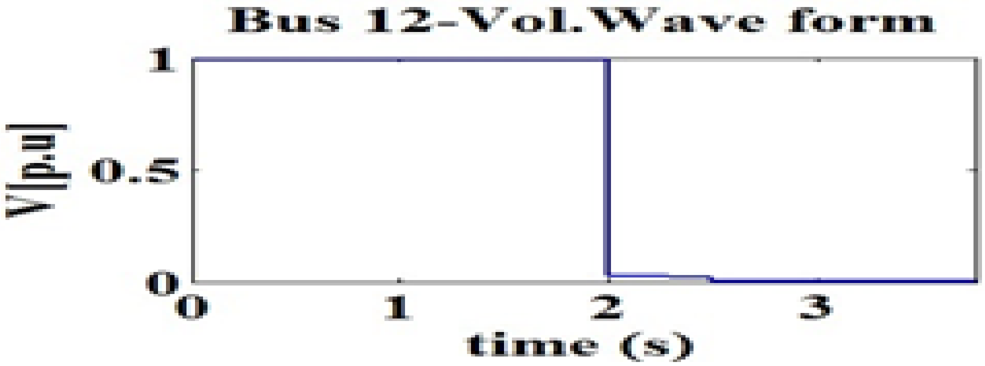

Figure 5 Bus 12 voltage wave form without SVC in per unit

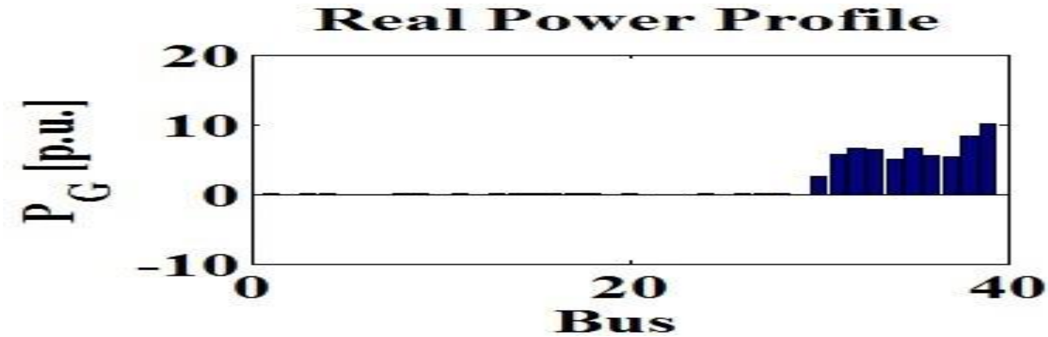

Figure 6 Real power profile without SVC in per unit

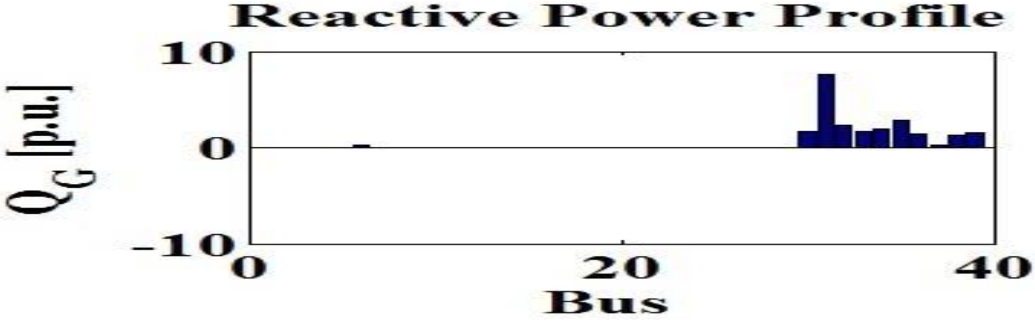

Figure 7 Reactive power profile without SVC in per unit

The voltage profile of figure 3 in the system without SVC is affected severely because of the three phase fault. The system has stopped the time domain simulation within 4 s. The bus 12 of figure 3 has low voltage profile and the stability is affected because of the fault. Here the Bus 12 is selected to apply the SVC. The system parameters without SVC are shown in table2.

4.1 Table

Table 2 test system parameter values without SVC

Bus	Voltage	Phase angle	Real power generation	Reactive power generation
	[p.u.]	[rad]	[p.u.]	[p.u.]
Bus 1	0.32	3.39	0.00	0.00
Bus 2	0.49	12.37	0.00	0.00
Bus 3	0.44	12.24	0.00	0.00
Bus 4	0.22	12.28	0.00	0.00
Bus 5	0.08	12.75	0.00	0.00
Bus 6	0.08	13.01	0.00	0.31
Bus 7	0.00	12.90	0.00	0.00
Bus 8	0.00	12.62	0.00	0.00
Bus 9	0.47	3.24	0.00	0.00
Bus 10	0.10	12.46	0.00	0.00
Bus 11	0.08	12.63	0.00	0.00
Bus 12	0.00	12.50	0.00	0.00
Bus 13	0.13	12.34	0.00	0.00
Bus 14	0.24	12.22	0.00	0.00
Bus 15	0.51	12.11	0.00	0.00
Bus 16	0.63	12.12	0.00	0.00
Bus 17	0.60	12.14	0.00	0.00
Bus 18	0.54	12.17	0.00	0.00
Bus 19	0.79	12.12	0.00	0.00
Bus 20	0.78	12.07	0.00	0.00
Bus 21	0.72	12.14	0.00	0.00
Bus 22	0.82	12.20	0.00	0.00
Bus 23	0.84	12.18	0.00	0.00
Bus 24	0.67	12.11	0.00	0.00
Bus 25	0.58	12.28	0.00	0.00
Bus 26	0.69	12.17	0.00	0.00
Bus 27	0.64	12.14	0.00	0.00
Bus 28	0.84	12.18	0.00	0.00
Bus 29	0.89	12.21	0.00	0.00
Bus 30	0.73	12.56	2.50	1.74
Bus 31	0.34	13.82	5.69	7.58
Bus 32	0.00	17.93	6.50	2.35
Bus 33	0.81	12.18	6.32	1.71
Bus 34	0.85	12.13	5.08	1.95

Bus 35	0.89	12.26	6.50	2.80
Bus 36	1.02	12.25	5.60	1.39
Bus 37	0.70	12.45	5.40	0.24
Bus 38	0.98	12.29	8.30	1.24
Bus 39	0.79	3.25	10.06	1.59

From above table 2 that bus 12 is reducing to zero value. So hybrid BBO-DE algorithm is applied to the system and to improve the system stability.

5. Procedure of hybrid BBO-DE algorithm

***Step* 1:** To initialize the parameters of BBO. ***Step* 2:** To Initialize a random set of habitats. (Each habitats have solution to the given problem).

***Step* 3:** For each habitat, calculate the high suitability index (HSI) to the number of the species S, the immigration rate λ and emigration rate μ.

***Step* 4:** To modify non elite habitats and recomputed each HSI.

***Step* 5:** For each habitat, update the probability of its Specie count and mutate each non elite habitat based on the probability.

***Step* 6:** To be recomputed each HSI.

***Step* 7:** If convergence criteria is reached then display the optimal solution otherwise update the iteration count and goto step 3 .

***Step* 8:** Set the boundaries using BBO solution and initialize the DE parameters and the values must be within the feasible bounds of the variable.

$$(X_j^L \leq X_{j,I,1} \leq X_j^U)$$

***Step* 9:** Evaluate the population.

***Step* 10:** Create the off springs and evaluate their fitness.

***Step* 11:** Mutate the population. (For the given parameter $X_{i,G}$ three vectors are Selected randomly ($X_{r1,G}$, $X_{r2,G}$ *and* $X_{r3,G}$).The donor vector $V_{i,G} = X_{r1,G} + F\,(X_{r2,G} - X_{r3,G}$. Where F is a constant.

***Step* 12:** Crossover the population.

$$\text{The trial vector } U_{j,i,G+1} = \begin{cases} V_{j,i,G+1} & \text{if } rand_{j,i} \leq CR \text{ or } j = I_{ran} \\ V_{j,i,G+1} & \text{if } rand_{j,i} \succ CR \text{ or } j \neq I_{ran} \end{cases}$$

$$i = 1,2 \text{ ------ } N\ ;\ j = 1,2 \text{ ------ } D$$

Where CR = crossover rate. I_{rand} = random integer. The trial vector is created by cross over operators. The trial vector is used in selection process

***Step* 13:** Evaluate the fitness and record the best value.

***Step* 14:** Repeat the process from step 9-12 until the convergence criteria met.

***Step* 15**: print the result.

6. Flow chart

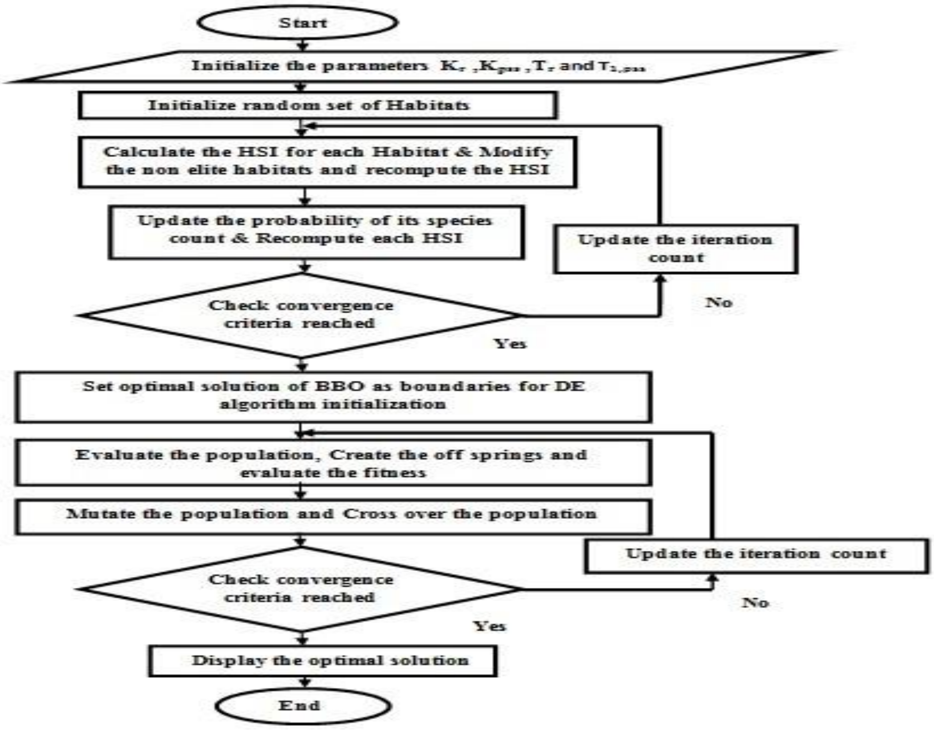

Figure 8 Flowchart based BBO-DE algorithm

The parameter values are analyzed after applying hybrid algorithm in the test system [10] [11]. The parameter values are shown in figures below.

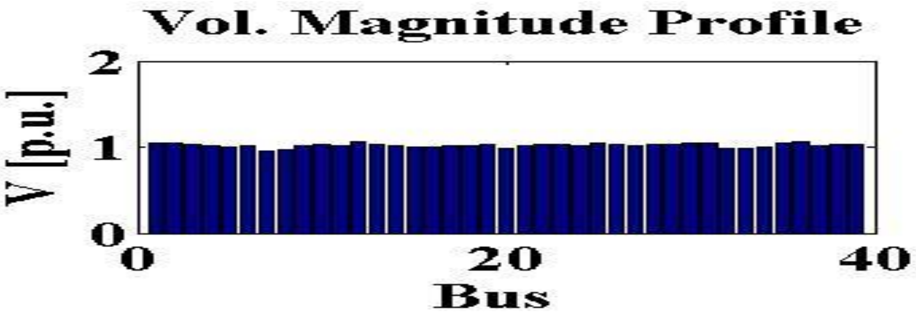

Figure 9 voltage magnitude profile with SVC (BBO-DE)

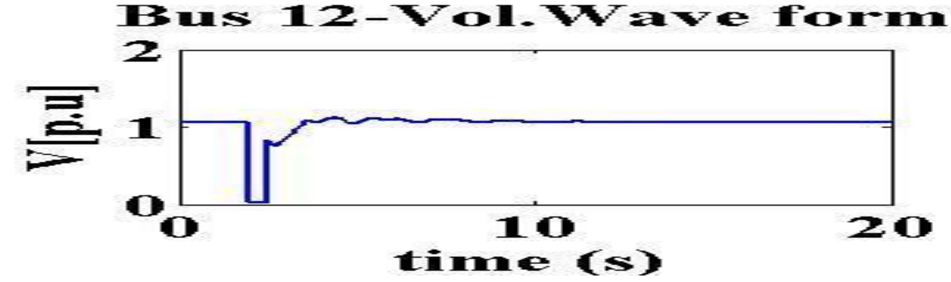

Figure 10 Bus 12 voltage wave form with SVC (BBO-DE)

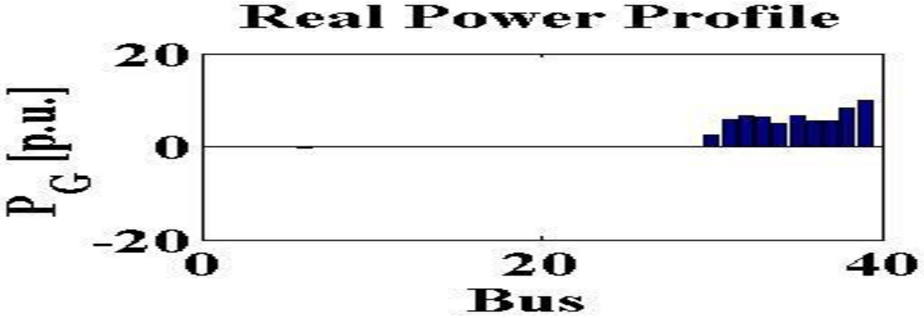

Figure 11 Real power profile with SVC (BBO-DE)

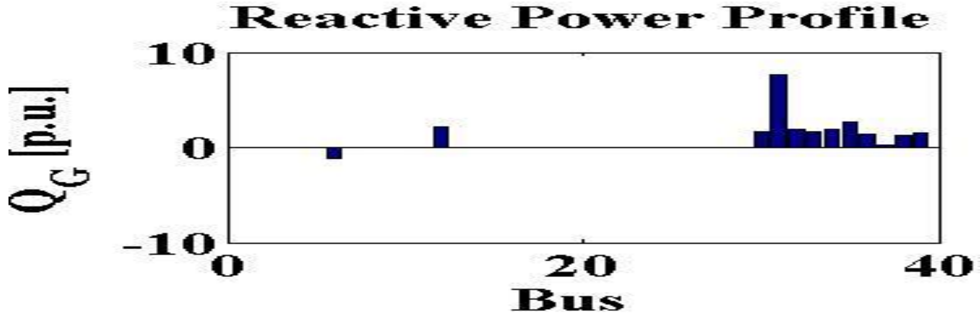

Figure 12 Reactive power profile with SVC (BBO-DE)

After PSAT operation of the system, the positive value of Eigen value is zero and negative value is 140. So the system shows stable condition as shown in figure x. The bus voltage 12 is improved to 1.05 p.u. The parameter values are shown in table 3.

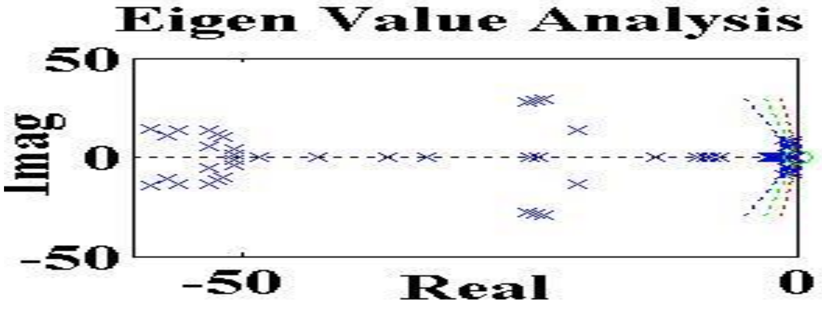

Figure 13 Eigen value graph with SVC(tuned by BBO-DE)

6.1 Table

Table 3: System parameters with SVC (BBO-DE)

Bus	Voltage	Phase angle	Real power generation	Reactive power generation
	[p.u.]	[rad]	[p.u.]	[p.u.]
Bus 1	1.05	18.64	0.00	0.00
Bus 2	1.04	18.68	0.00	0.00
Bus 3	1.02	18.63	0.00	0.00
Bus 4	1.01	18.62	0.00	0.00
Bus 5	1.01	18.64	0.00	0.00
Bus 6	1.01	18.65	-0.14	-1.11
Bus 7	0.95	18.62	0.00	0.00
Bus 8	0.97	18.61	0.00	0.00
Bus 9	1.02	18.61	0.00	0.00
Bus 10	1.02	18.69	0.00	0.00
Bus 11	1.02	18.68	0.00	0.00
Bus 12	1.05	18.68	0.00	2.13
Bus 13	1.02	18.68	0.00	0.00
Bus 14	1.01	18.65	0.00	0.00
Bus 15	1.00	18.65	0.00	0.00
Bus 16	1.01	18.67	0.00	0.00
Bus 17	1.01	18.66	0.00	0.00
Bus 18	1.02	18.64	0.00	0.00
Bus 19	1.03	18.76	0.00	0.00
Bus 20	0.98	18.73	0.00	0.00
Bus 21	1.01	18.72	0.00	0.00
Bus 22	1.04	18.80	0.00	0.00
Bus 23	1.03	18.79	0.00	0.00
Bus 24	1.01	18.68	0.00	0.00
Bus 25	1.05	18.71	0.00	0.00
Bus 26	1.04	18.69	0.00	0.00
Bus 27	1.02	18.65	0.00	0.00
Bus 28	1.03	18.75	0.00	0.00
Bus 29	1.03	18.80	0.00	0.00
Bus 30	1.05	18.73	2.50	1.69
Bus 31	1.04	18.78	5.87	7.60
Bus 32	0.98	18.83	6.50	1.87
Bus 33	0.99	18.85	6.32	1.65
Bus 34	1.00	18.82	5.08	1.92
Bus 35	1.05	18.88	6.50	2.73
Bus 36	1.06	18.93	5.60	1.35
Bus 37	1.02	18.83	5.40	0.20
Bus 38	1.02	18.93	8.30	1.22
Bus 39	1.03	18.62	10.06	1.57

Table 4: Eigen value analysis of system With SVC by BBO-DE algorithm

With SVC by BBO-DE algorithm	
Dynamic order	141
Buses	39
Positive Eigens	0
Negative Eigens	140
Complex pairs	39
Zero Eigens	1

7. Conclusion

The Coordinated design of Static VAR compensator (SVC) has been investigated through the time domain and power flow simulations for the development of transient stability when the system is subjected to a three phase fault. The proposed hybrid method has produced better result. The proposed method has recovered stability after clearing fault in the test system. It improves the voltage profile and minimizes the losses. The Eigen value analysis shows the effectiveness of the proposed method in achieving stability. By proper coordinated tuning of the SVC using hybrid BBO-DE algorithm, transient stability of the system is achieved.

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