ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 10(33), DOI: 10.17485/ijst/2017/v10i33/104592, September 2017*

Transient Stability Enhancement by Optimal Location and Tuning of STATCOM using Biogeography based Optimization Technique

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Abstract

In this paper, transient stability of a multi machine system is evaluated when the system is experienced a three phase fault and the stability of multi machine system is recovered via optimal placement and tuning of STATCOM. Here, the parameters of the STATCOM are tuned by Biogeography based optimization and the STATCOM is positioned optimally in the system. The performance of the tuned system is compared with various operational conditions like without STATCOM, with STATCOM (untuned) and with two STATCOM (untuned). The time domain simulations and the analysis of the multi machine system are done by PSAT (Power System Analysis Toolbox). When the multi machine system is subjected to a three phase fault, voltage stability of the system is collapsed. The multi machine system with STATCOM (tuned by Biogeography based optimization) regains the stability and gives better voltage profile than the system with STATCOM (untuned), with two STATCOM (untuned) and the system without STATCOM. The results are evaluated with the other operational conditions of the system and it proves that the system has the transient stability when the STATCOM (tuned by Biogeography based optimization) is applied.

Keywords: Biogeography Based Optimization, STATCOM, Transient Stability, WSCC

1. Introduction

FACTS (Flexible AC Transmission Systems) devices are built in these modern years to recuperate the stability of the system. FACTS are the key devices which are used to control the power system operations. STATCOM is one of the FACTS devices which are utilized to regulate the system voltage by taking and giving the reactive power. It consists of a VSI which generates controllable ac voltage supply behind a transformer leakage reactance and an energy storage capacitor. The damping of oscillations using PSS and STATCOM is analyzed in some papers[1,2]. Optimal load flow and reactive power assistance is described in some papers[3,4]. Some research papers are suggested for power system stability enrichment. The optimal placement and tuning of STATCOM has a sig-

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nificant role to improve the stability. This paper gives the detailed investigation of finest location and tuning of STATCOM to advance the transient stability for three phase fault conditions. Time domain simulation of PSAT is used to find out the performance of the controllers.

2. Transient Stability

A power system has to preserve the synchronism condition even though the system is experienced the poorest transient disturbances. A fault, generation divergence or big load divergence might be the reason for the poorest disturbances. The disturbances have consequences on the rotor angles, bus voltages, load flows and many variables of the system. This paper studies the outcome of fault on bus voltages happened in the system.

3. STATCOM

A current addition model of STATCOM has been practiced in PSAT[5]. The reactive power interchange happens between the power system and the controller, because of the current is retained in quadrature to the bus voltage.

The reactive power,

$$Q = i_{sh} V \quad (1)$$

Where i_{sh} = current of the STATCOM which will be injected to system.

K_{r1}= Regulator gain;T_{r1}= Regulator time constant.
A STATCOM can develop the power system performance through the

- Voltage flicker regulation
- Stability when the system is subjected to transients
- Damping of power system oscillations
- Dynamic voltage management
- Reactive power regulation

From this, transient stability of the system is taken to study using STATCOM in this paper. STATCOM takes not as much of space by solid electronic converters. It also

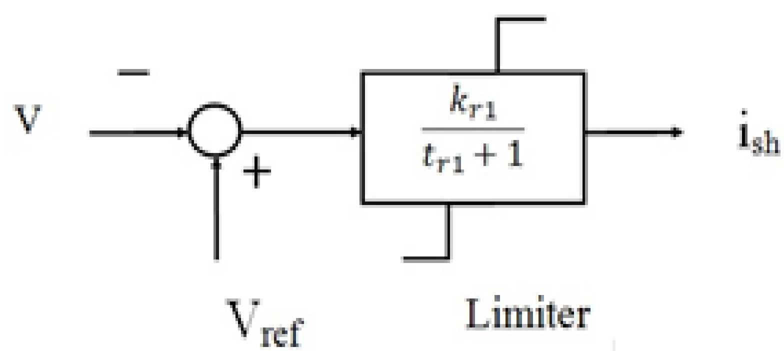

Figure 1. Block diagram model of STATCOM.

diminishes the ecological effect by applying electronic converters.

4. Biogeography based Optimization

The base of the Biogeography Based Optimization is the spreading of biological organisms. In 1960, mathematical equation of organisms distribution were discovered and developed. Biogeography's mathematical models explains about the kinds (species) migration from one part of island to another part of island also it explains about the new kinds (species) generation and how they extinct. Here, an island is a habitat and it is isolated from other habitats. A habitat which has high suitability index (HSI) is the well suited pace for the species[6]. The factors like rainfall, diversity of vegetation, land area, temperature decides the suitability index. The BBO algorithm contains two essential parts. One is relocation (migration) and another one is alteration (mutation).

Immigration rate $\mu_k = E*k/n$ (2)

Emigration rate $\lambda_k = I\,(1-k/n)$ (3)

(Where E-Maximum of Emigration rate, I-Maximum of Immigration rate; n-total no. of species)

Mutation rate $m(s) = m_{max}[(1-P_s)/ P_{max}]$ (4)

(Where m_{max}= user defined parameter; P_s=Probability of species; P_{max}= largest of all P_s values)

4.1 Biogeography based Optimization Algorithm

Step 1: Initialize BBO parameters and K_{r1}, T_{r1}.

Step 2:Estimate the HSI to the no. of the species S, the immigration rate λ_k and emigration rate μ_k.

Step 3:Adjust non elite habitats, recompute each HSI and modernize the probability of its species count.

Step 4:Alter each non elite habitat based on the probability and recompute each HSI.

Step 5:If convergence of criterion is reached then display the optimal solution otherwise update the iteration count and go to Step 2.

5. Objective Function

The designing of STATCOM factors has been formulated as an Eigen value based objective function[7]. Here, two objective functions are applied. Real part of the Eigen value (minimization) and damping ratio (maximization) are the two objective functions.

The damping ratio of the iyth critical mode

$$\zeta_{iy} = \frac{-\sigma_{iy}}{\sqrt{\sigma_{iy}^2 + \omega_{iy}{}^2}} \quad (5)$$

Where the eigen value $\lambda_{iy}=\sigma_{iy}\pm j\omega_{iy}$.

Objective functions are presented as,

$$J_{3=} \sum_{iy=1}^{n} (\sigma_0-\sigma_{iy})^{2} \quad (6)$$

$$J_4 = \sum_{iy=1}^{n} (\zeta_0 - \zeta_{iy})^2 \text{---------}(7)$$

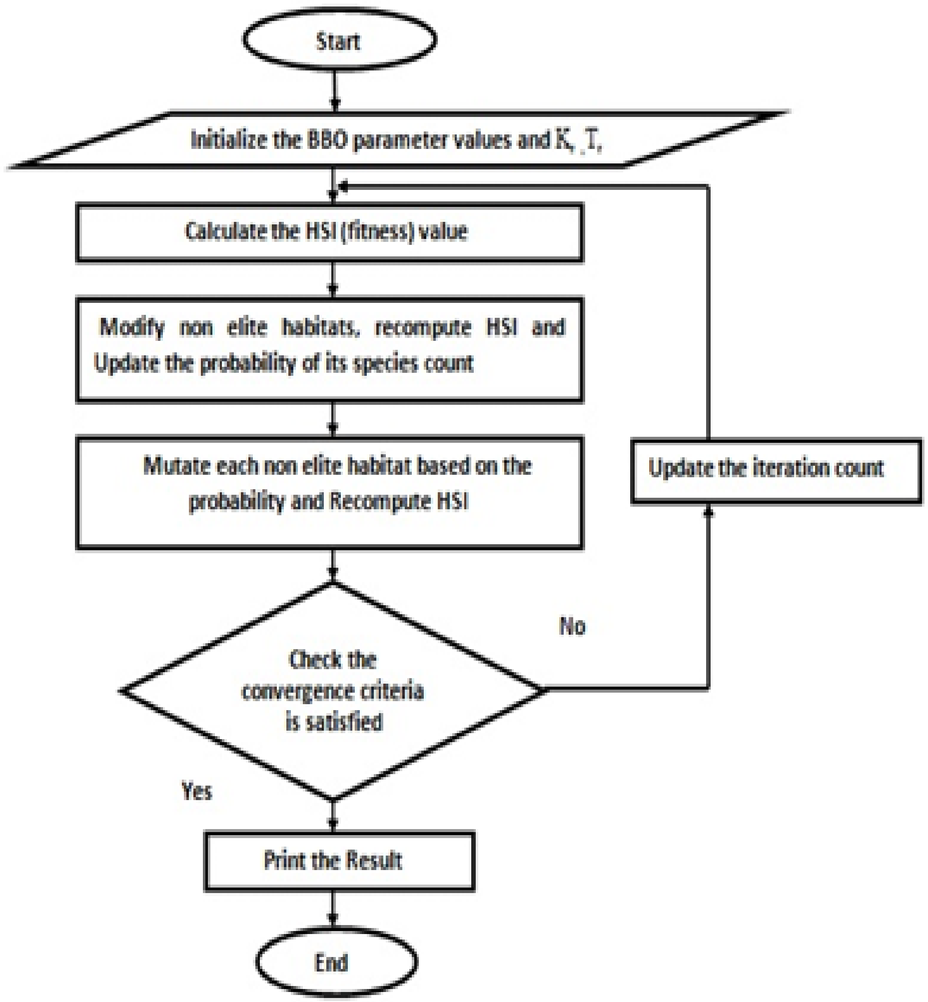

Figure 2. Flow chart for Biogeography Based Optimization.

Where$\sigma_{iy} \leq \sigma_0$, $\zeta iy \geq \zeta_0$ for i = 1, 2 ……, n. The objective function $J=J_3+\alpha J_4$ is employed to have a closed loop Eigen values. The value of α is taken as 7. The fitness function can be modified depends upon the problem. STATCOM parameters K_{r1}, T_{r1} have chosen to adjust as per algorithmic procedure. (Size of the population=100,

K_{r1} lower bound= -50, K_{r1} upper bound = 100, T_{r1} lower bound = -10, T_{r1} upper bound= 10).

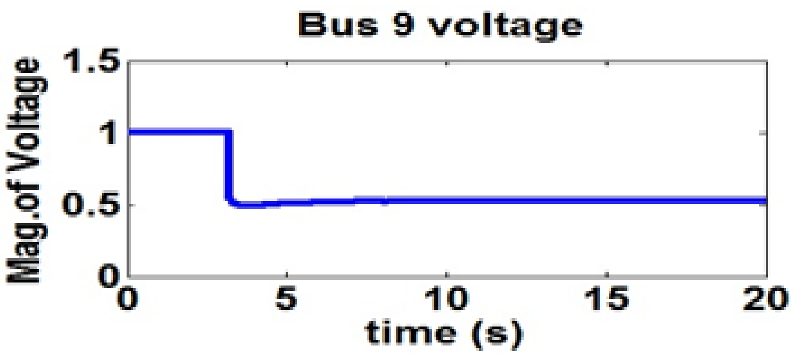

Figure 3. WSCC 9 Bus system.

6. Study of WSCC 9-Bus System

The simulations of time domain are calculated in PSAT software which is employed to evaluate and plot the graphs of the system. The performance of the STATCOM can be evaluated through the system which is selected to exercise and the case studies. A 9 bus system (WSCC) which has 6 transmission tracks, 3 generator constructions, 3 load sites and D (an local load) is considered to analyze.

6.1 Analysis of Bus-6

The act of the system has been assessed by using a 3 phase fault (Fault time at 3.15s and clearing time 3.50s).

The fault has been given at the bus 6 of the system.

Table 1. Loads for the system (per unit)

Load	P	Q
Load A	2.00	0.90
Load B	1.80	0.60
Load C	1.60	0.65
Load D	1.60	0.65

6.2 WSCC 9-Bus System with Fault in Bus-6

After the fault, the voltage profile of the system becomes very low. The bus 6 and bus 9 are identified as weak buses. The voltage waveforms of bus 6 & bus 9 are shown in figure 4 and figure 5.

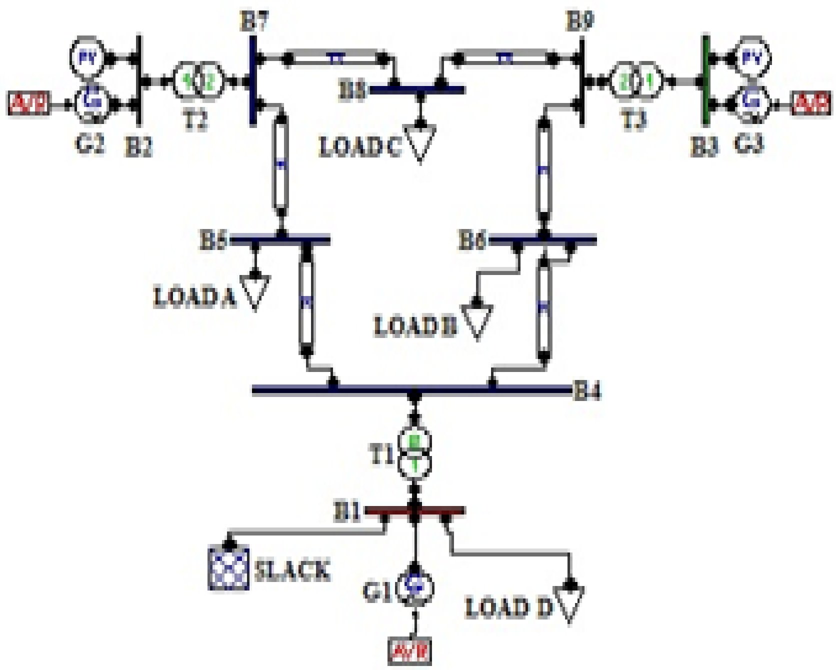

Figure 4. WSCC 9 Bus system with Fault.

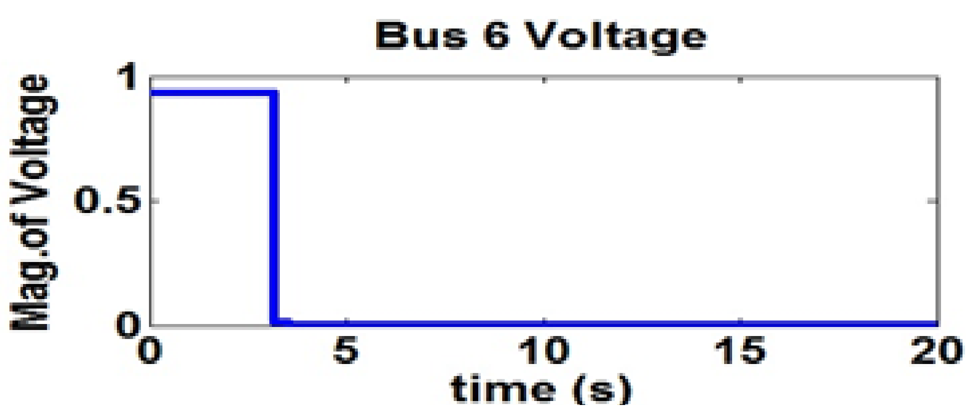

Figure 5. Voltage at bus-6 without STATCOM.

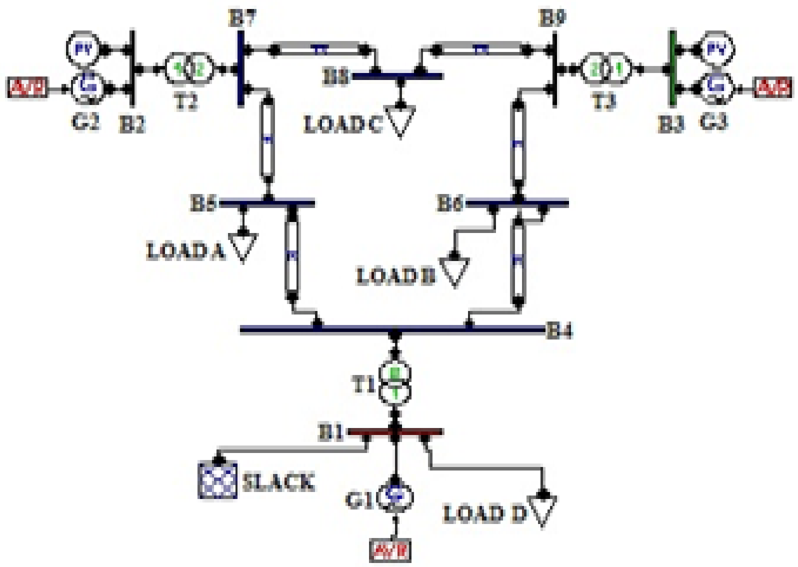

Figure 6. Voltage at bus-9 without STATCOM.

7. WSCC 9-Bus with STATCOM (Untuned)

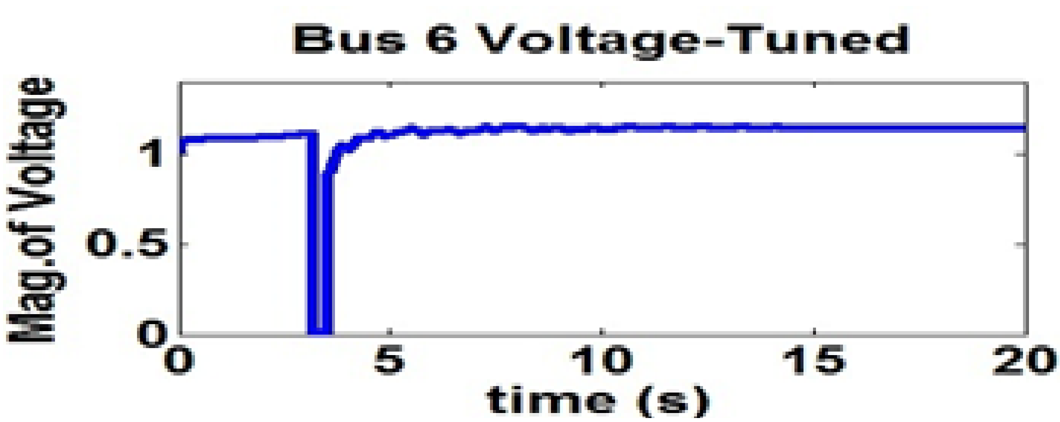

Figure 7. Voltage at bus-6 with STATCOM.

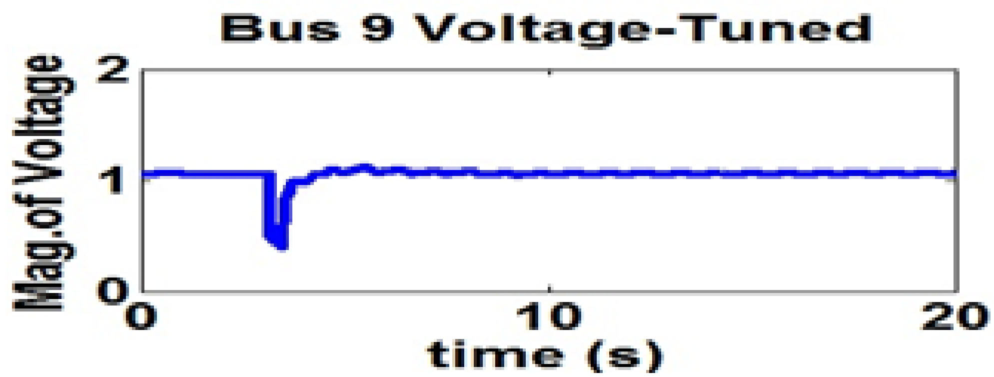

Figure 8. Voltage at bus-9 with STATCOM.

8. WSCC 9-Bus System with STATCOM (Tuned by BBO)

The STATCOM parameters K_{r1} and T_{r1} have been modified by Biogeography Based Optimization. After modification, the voltage waveforms of bus 6 and bus 9 are shown in Figure 8 and Figure 9. Biogeography Based Optimization Tuned parameters: K_{r1}=12.6048, T_{r1}= -7.35477.

The system has the stability when two STATCOMs are applied to the system. But the parameters of STATCOM are untuned. The system with one STATCOM doesn't have the capability to improve the stability of the system. It is shown in figure 7 and figure 8. The proper design in STATCOM parameters using BBO gives stability in systems voltage. It is shown in figure 9 and figure 10.Here one tuned STATCOM gives the desired output.

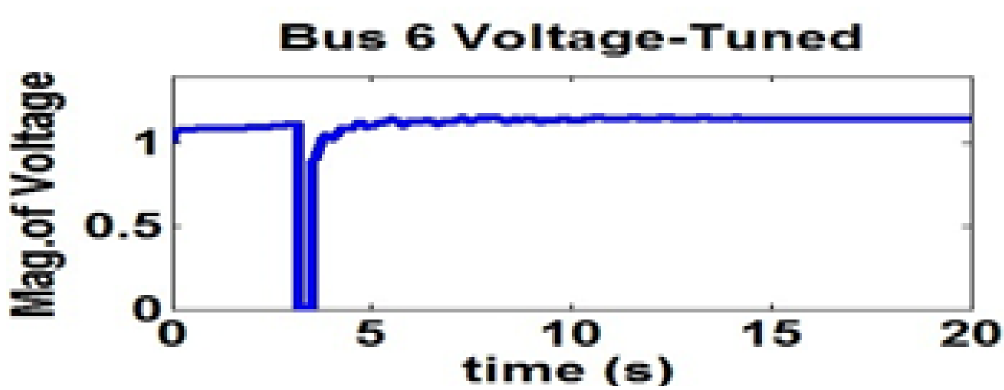

Figure 9. Voltage at bus-6 with STATCOM (Tuned by BBO).

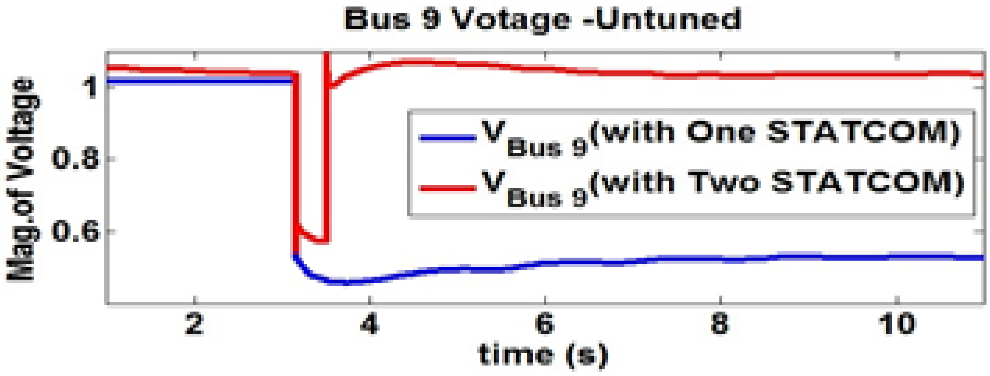

Figure 10. Voltage at bus-9 with STATCOM (Tuned by BBO).

Table 2. Comparison of voltage profile (V in p.u)

Bus	Without STATCOM	With one STATCOM (Untuned)	With two STATCOM (Untuned)	With one STATCOM (Tuned by BBO)
Bus 1	1.00132	0.99862	1.03988	1.04121
Bus 2	0.90340	0.90243	1.02893	1.02573
Bus 3	0.63183	0.63351	1.04454	1.03097
Bus 4	0.62584	0.62543	1.00495	1.01914
Bus 5	0.62645	0.62891	0.94124	0.95012
Bus 6	0	0	1.00367	1.04459
Bus 7	0.76425	0.76490	1.00668	1.00595
Bus 8	0.64599	0.64760	0.98738	0.98568
Bus 9	0.53136	0.53280	1.03792	1.03120

9. Conclusion

The performance of STATCOM has been examined through the time domain and load flow simulations. The optimal positioning and tuning of the STATCOM develops the system's transient stability. The profile of voltage and bus voltage graphs illustrates the advancement in magnitude of voltage and transient stability of the system when STATCOM is applied. The results are evaluated with the BBO tuned parameters for STATCOM and show the effect of the tuned system.

10. References

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