DESIGN OF SSSC CONTROLLER FOR SMALL SIGNAL STABLITY IMPROVEMENT USING TLBO ALGORITHM

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ABSTRACT— In modern power system, stability problem plays an important role. Dynamic stability of the power system is enhanced by simultaneously tune the various damping controller sets with different optimization algorithms. Power system interconnected through tie lines and this resulting into lower frequency oscillations due to variation in load which creates stability problems. To eliminate the stability problems SSSC based damping controller is also used. In this presented work to realize and observe the execution of SSSC based damping controller, SMIB system is developed which based on Modified Phillips Haffron model. Proposed controller is employed using platform provided by MATLAB/ Simulink and result analysis is carried out by compare the results obtained from GA, GSA, PSO and TLBO. Developed system is analyzed for small signal stability improvement in power system with different parameters values. Observations have been tabulated in each case with different fault cases of speed deviation. The system evaluation is done by two method first Eigen value analysis and another time domain simulation. Finally, it is detected that the out of all algorithms TLBO algorithm found more compatible for parameters reduce for settling time and provide superior performance of the power system. Different simulation results are also obtained for various disturbances & operating conditions.

Keywords— Power System Stability, SSSC Controller; Static Synchronous Compensator; TLBO Algorithm; SMIB System;

1. INTRODUCTION

A large interconnected network comprising of generation, transmission and distribution network is termed as power system. Power is generated at generating station and is forwarded via transmission network to the various substations. From there onwards it supplies powers to different users and at last to end consumers via distribution network. It’s a long and complicated mesh of network accomplishing this vital task [1].

To keep all this vital in sequence and proper order without any flaw, it needed to be take care of the conditions affecting its operations. It has to be stable in all conditions or must be capable of returning to stable condition after being disturbed. Mainly, its stability is very important for low load losses with desired output. Therefore, damping has to be proper in power system to eliminate all sorts of disturbances or the situation causing it. But as it is a large interconnected network it is very possible to have frequent disturbances in it. Before knowing how it can be damped or eliminate disturbance causing events it is more essential to know the structure of power system & various stabilities of it [2]. Fig.1 shows the classification of stability as concern with angle and voltage stability.

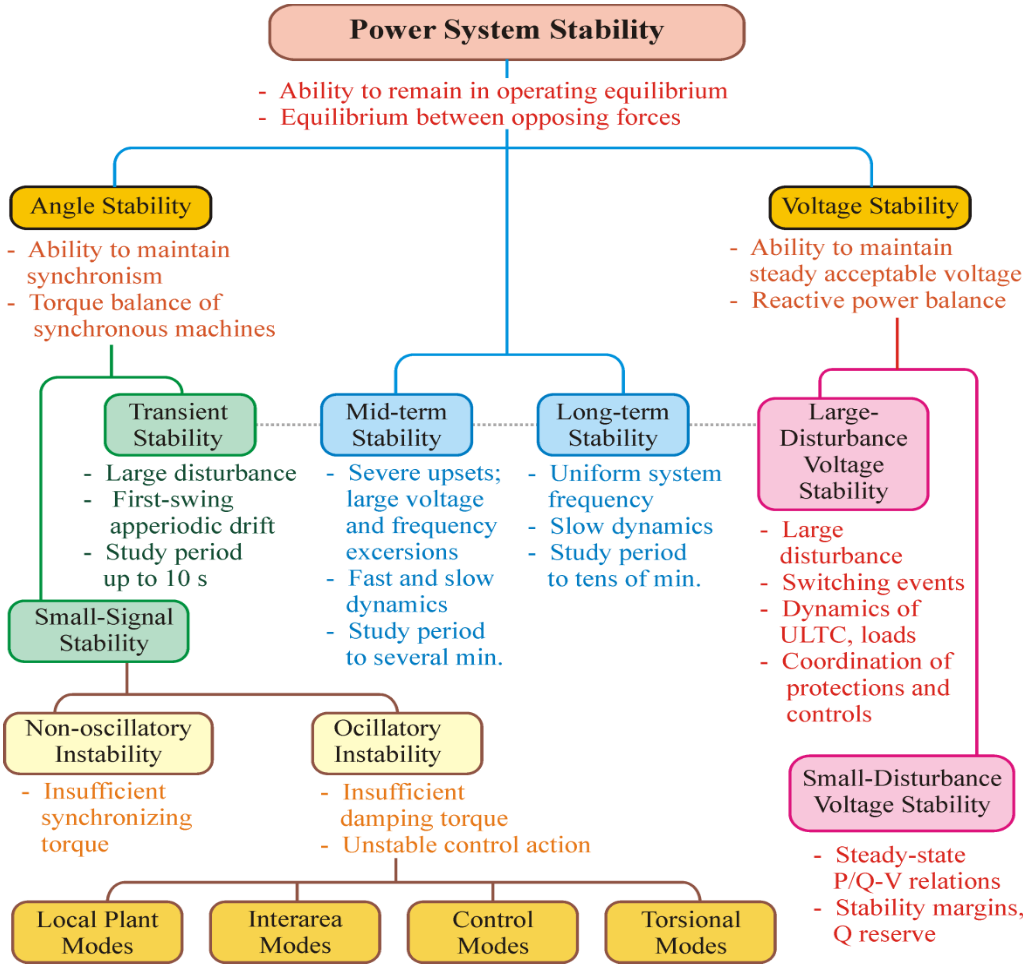

Fig.1 Classification of Stability[3]

Stability is improved by using FACTS controllers. There are two kinds of stability i.e. large and small signal stability. Large signal stability is also known as transient stability. In case of small signal stability when there is no proper damping it occurs[3]. To damp electromechanical oscillations, supplementary controller with FACTS based SSSC device is used to improve the system damping[4]. To produce an electrical torque in phase with speed deviation damping controllers are designed. Power system stability problem can be a concerning issue due to its insufficiency of damping such oscillations. To Controller parameters are optimized using GA, GSA, PSO and TLBO etc.

2. SYSTEM MODEL

2.1 Modeling of SSSC

Fig.2 shows transmission line with SSSC and SSSC connect with coupling transformer and there is controller option with active and reactive power flow as inductive and capacitive mode. [5].

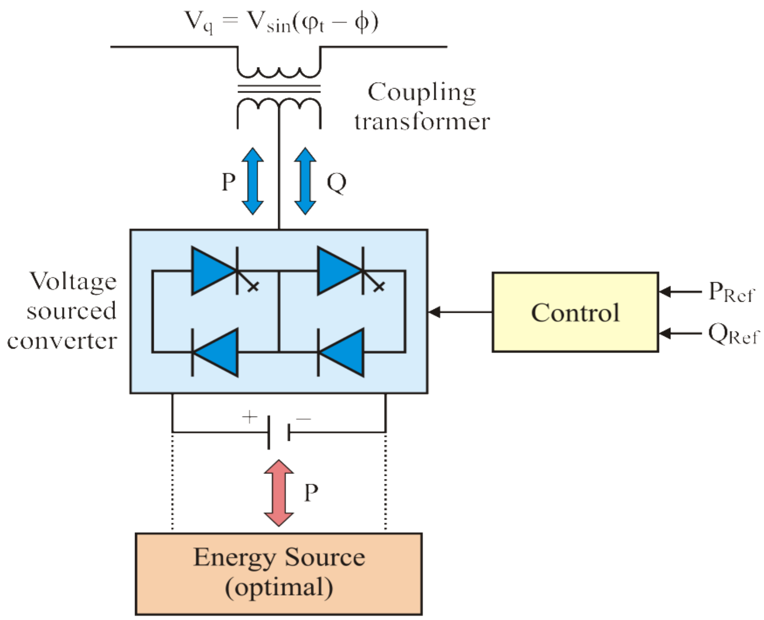

Fig.2: Transmission line with SSSC.

Fig.3 shows the SSSC control system and various parameters as phase lock loop, current measurement, voltage measurement, AC regulator, DC regulator and PWM modulator present. Each block shows different performance maintain stability of the system

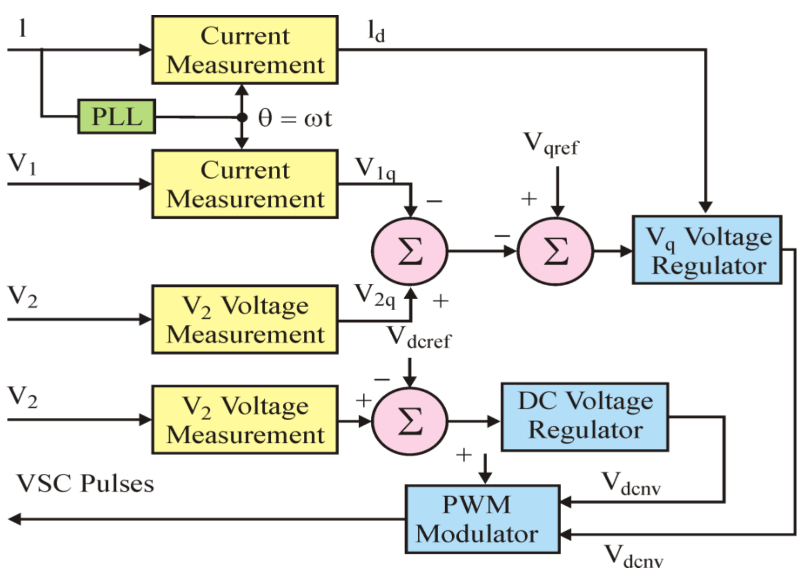

Fig.3. SSSC-Control System [6]

2.2 Linear Dynamic Model of the Power System with SSSC

Fig.4 shows the liner dynamic model of SSSC and that is define by modified Phillips Haffron model of SSSC.

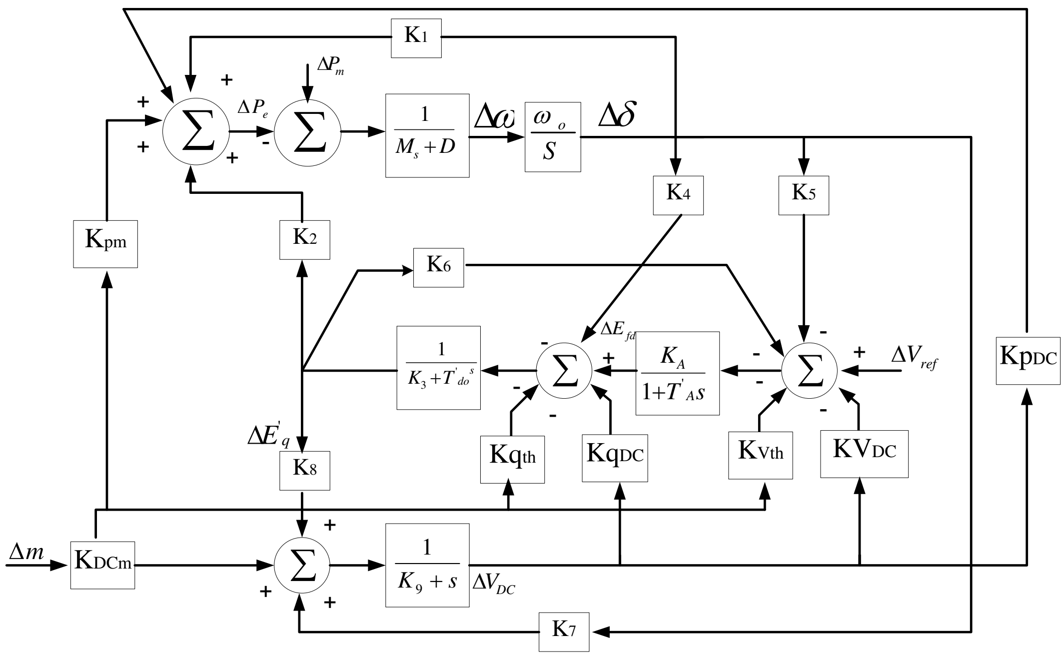

Fig.4 Haffron Model of SMIB with SSSC [7]

2.3Objective Function

Main objective of this thesis is to reduce disturbance causing oscillation with use of SSSC controller. Employment of this increases the stability in form of the settling time via the con trolling of variation in rotor angle and speed. The problem is given as an ITAE of the speed deviations, i.e.

$$J = \int_{0}^{t1} |\Delta\omega| . t . dt \tag{1}$$

In equation (1) Δω is deviation in speed Minimization of J is subjected to,

$$K^{\min} \leq K \leq K^{\max} \tag{2}$$

$$T_1^{\min} \leq T_1 \leq T_1^{\max} \tag{3}$$

$$T_2^{\min} \leq T_2 \leq T_2^{\max} \tag{4}$$

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3. THE TEACHING LEARNING-BASED OPTIMIZATION

TLBO is novel optimized technique and work on two phases as teacher and learner phase. The other algorithm require specific parameters but TLBO required only few parameters. [8]. As there are two distinctive parties its operation also takes place in 2- phases: (a) Teacher (b) Learner.

I-phase is the learning process from the teacher while II-phase is the learning process via interaction of learners among themselves. Concept behind this method is as follows:

I-Phase

In this phase learner learns from teacher and learner how good learn it will depend upon quality of teacher. If teacher is good than students will also have good grades at this instant level knowledge of both teacher and learner is quite similar. Such situation is ideal where student can only learn and improve their knowledge level means outcome up to some point with the help of teacher this means learning also depends upon the learner's ability to learn [9].

Suppose,

M(i)=Mean

T(i)=Teacher

In first iteration, target of T(i) to achieve M(i) as near to the level of its own as possible. After first iteration M(i) is set to new value i.e. M_{new}. Mean difference is given by:

$$MeanDifference(i) = r(i).\{M_{new}.TF \times M(i)\} \quad (5)$$

$$r(i) = randomnumber(0 \le r(i) \le 1)$$

Teacher factor (TF) (0 to 1) decided the new mean value then new solution is,

$$X_{new},(i) = X_{old},(i) + MeanDifference(i) \quad (6)$$

II-phase

In this phase of learning, learners learn via interaction among themselves. Learners learn here by group discussion, formal communication and by presentation also. When one learner is interact with other learner with more knowledge then former learner will increase their own knowledge regarding to that subject.

This is as follows,

For $i = 1:P_n$

Random selection of two learners i.e. X_i, X_j $(i \neq j)$

If

$f(X_i) < f(X_j)$

$$X_{new},(i) = X_{old},(i) + r(i)(X_i - X_j) \tag{7}$$

Else

$$X_{new},(i) = X_{old},(i) + r(i)(X_j - X_i) \tag{8}$$

If function value is better

Than accept X_{new}.

4. RESULT AND DISCUSSIONS

The result analysis of the system is proved by two methods as eign value and time domain simulation. The eign value define complete stability of the system and define the system is more stable when SSSC parameters tuned by TLBO algorithm. The time domain simulation defines various cases and proved robustness of the system.

4.1 SSSC Parameters Optimized by Different Algorithm

Fig.5 shows the graph performance graph of different algorithm. This graph define the TLBO algorithm shows best performance than other. Table 1 shows SSSC parameters optimized by Different technique.

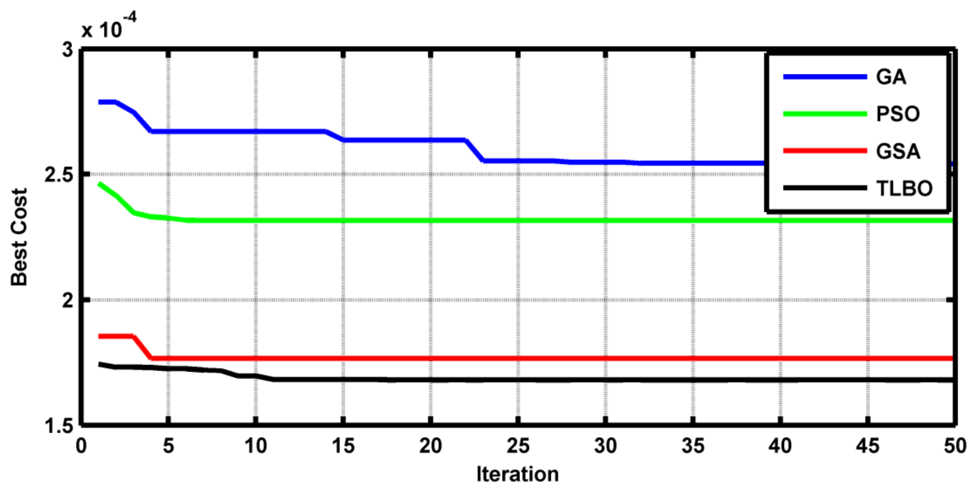

Fig..5 Best Cost V/S Iteration Graph with Different Technique

Table 1: SSSC Parameters Optimized Value

Algorithm	SSSC Parameters		
	K	T_1	T_2
GA	40.87330	0.17090	0.19020
PSO	45.09160	0.37010	0.31040

GSA	65.72090	0.25170	0.27210
TLBO	72.86780	1.00E-04	0.04170

Power system performance was examined 10% step increase in mechanical torque input & 5 % step increase with reference voltage setting also system tested with parameter variation with 25% change in machine inertia constant and open circuit direct axis transient reactance. Table-2 shows we choose various fault consider in SMIB system .

Table-2 Various Cases of SMIB System

Cases	Description
Case-1	Loading Condition
Case-2	25% Change in Machine Inertia
Case-3	25% Change in Direct Axis Time Constant

4.2 Eigen Value Analysis

The eigen value analysis is a very important factor to analysis of stability of the system. The eigen value and damping ratio is presented in this table and when controller parameters tuned with TLBO the damping ratio increased and eigen value shifted more negative half of S plane and stability is improved.Table-3 define eigen value and damping ratio at various cases.

Table 3 Eigen Value

Cases	Without Controller	GASSSC	PSOSSSC	GSASSSC	TLBOSSSC
Case-1	-0.0000±10.93i,0.0001	-2.730 ± 10.56i.,0.25060	-4.540 ± 9.86i,0.41820	-6.08±8.87i,0.56540	-9.23 + 5.45i,0.86110
Case-2	0.0943±6.4270i,0.0150	-1.9602±6.2617i,0.29880	-2.5830 ± 5.5426i,0.4224	-3.2201±5.7501i,0.48860	-5.7794±6.8633i,0.64410
Case-3	0.1463 ± 7.1760i,-0.020	-2.4016 ± 6.9517i,0.32650	-3.2285±6.0021i,0.47370	-3.9803±6.2277i,0.53850	-7.6089 ± 9.5112i,0.6247

4.3 Time Domain Simulation Result

In this section the various speed deviation present at different cases. The system is perform with change in mechanical torque input and reference voltage setting The various graphs presents with different algorithm and define robustness of the system. The (a) and (b) denotes as mechanical torque input and reference voltage setting repectively.

4.3.1 Case-1: Loading Conditions (Pe=0.8 pu,Qe=0.144 pu)

Fig. 6 to 7 shows speed deviation curves at loading condition. The system result presents as without and with PSO, GA, GSA and TLBO algorithm. Both curves presents that when controller parameters optimized by TLBO algorithm shows best result and the oscillation damp out is very fast.

4.3.2 Case-2: Change in Machine inertia Constant

Fig. 8 to 10 shows speed deviation graph when we change parameters of machine inertia. In this condition machine inertia constant increase and decrease at 25%.Every condition the TLBO optimized system shows superior response than other algorithm. The system is settles down very fast and improves stability.

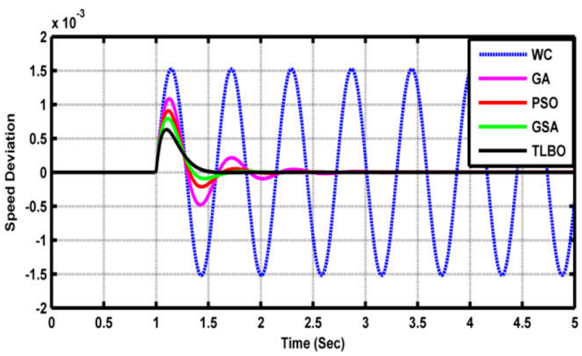

Fig.6 Speed Deviation for (a) condition

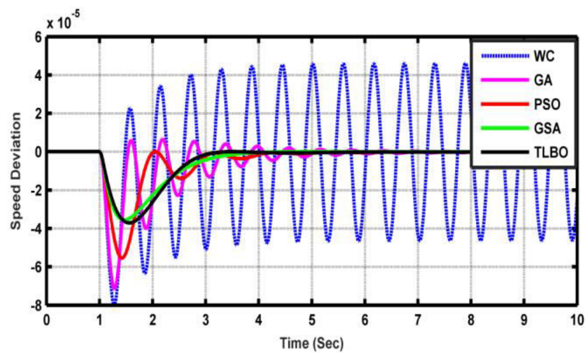

Fig.7 Speed Deviation for (b) condition

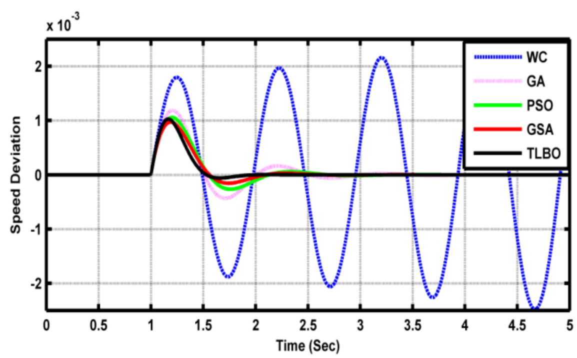

Fig.8 Speed Deviation for 25% Increase in Machine Inertia at (a) condition

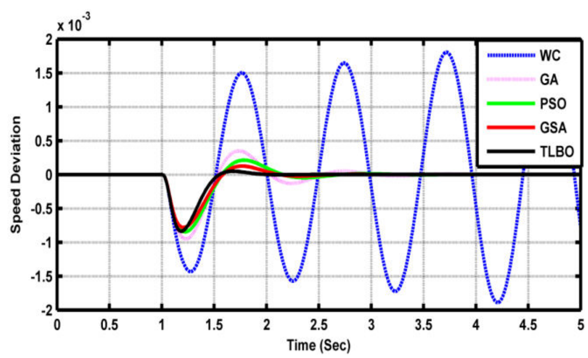

Fig.9 Speed Deviation for 25% Increase in Machine Inertia at (b) condition

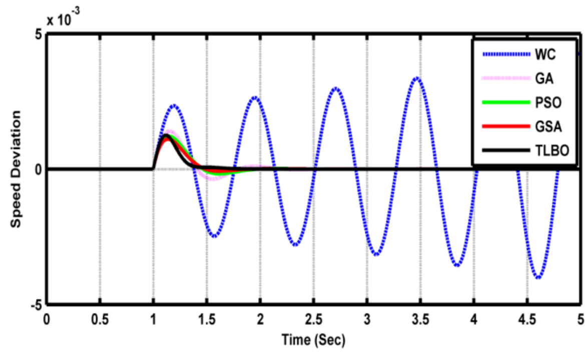

Fig.10 Speed Deviation for 25% Decrease in Machine Inertia at (a) condition

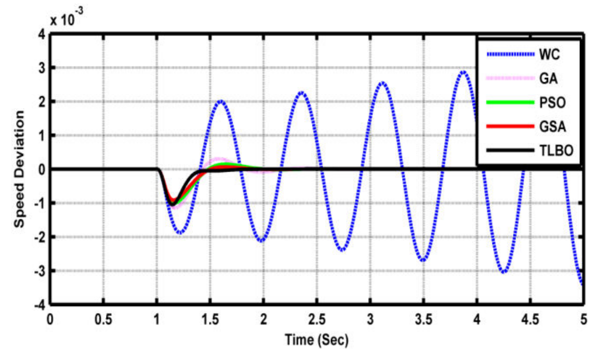

Fig.11 Speed Deviation for 25% Decrease in Machine Inertia at (b) condition

4.3.2 Case-3: Change in Direct Axis Time Constant

Fig. 12 to 15 shows speed deviation graph when we change parameters of direct axis time constant. In this condition direct axis time constant increase and decrease at 25%.The TLBO optimized speed response shows better dynamic response than other. Various settling time present in table 4.

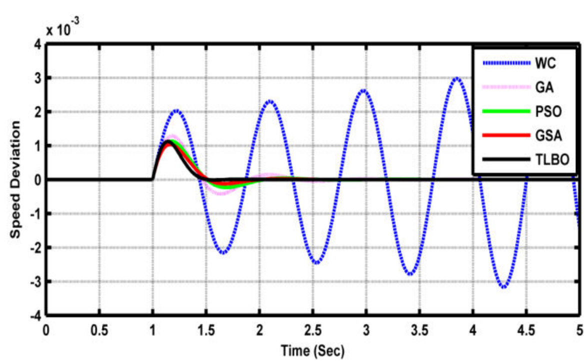

Fig.12 Speed Deviation for 25% Increase in Direct Axis Time Constant at (a) condition

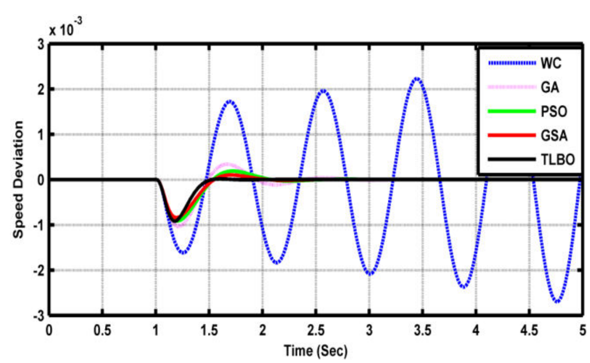

Fig.13 Speed Deviation for 25% Increase in Direct Axis Time Constant at (b) condition

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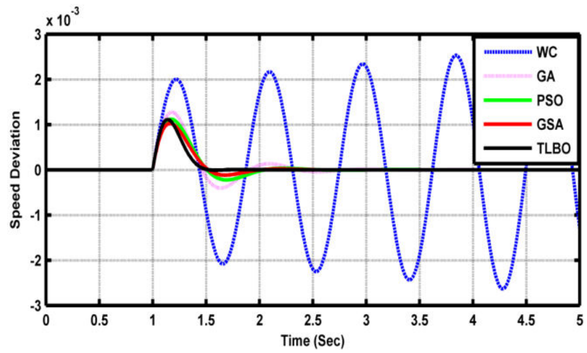

Fig.14 Speed Deviation for 25% Decrease in Direct Axis Time Constant at (a) condition

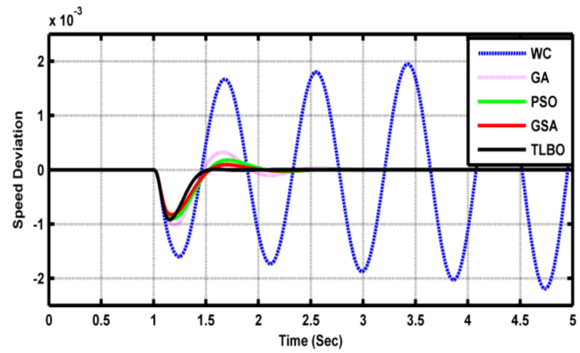

Fig.15 Speed Deviation for 25% Decrease in Direct Axis Time Constant at (b) condition

Table 4: Settling Time for Various Cases

Types of Conditions	With GA SSSC (Settling Time) Seconds		With PSO SSSC (Settling Time) Seconds		With GSA SSSC (Settling Time) Seconds		With TLBO SSSC (Settling Time) Seconds	
	(a)	**(b)**	**(a)**	**(b)**	**(a)**	**(b)**	**(a)**	**(b)**
Case-1	2.4194	5.4990	1.8894	4.0399	1.6564	3.7336	1.4984	3.0963
Case-2	2.91790	2.94410	2.5709	2.5968	2.4274	2.4525	1.8484	1.8719
Case-3	2.69570	2.72890	2.3776	2.4167	1.9412	1.9730	1.4734	1.5000

6. CONCLUSIONS

In this paper define the modified haffron Philips model of SMIB with SSC. The various algorithms is applied in the system. The system adopted ITAE based objective function. The eigen value analysis completely define the stability of system and TLBO optimized system shifted more in negative half of s plane. The speed deviation response at various cases define the TLBO optimized SSSC controller superior response than other algorithm. Finally system damp out oscillations very quickly and stability improve.

7. REFERENCES

[1] Anderson, Paul M., and Aziz A. Fouad. *Power system control and stability, Vol. 1*. 1977.(book)

[2] Wang, H. F. "Static synchronous series compensator to damp power system oscillations." *Electric Power Systems Research* 54.2 (2000): 113-119.

[3] Kundur, Prabha, Neal J. Balu, and Mark G. Lauby. *Power system stability and control*. Vol. 7. New York: McGraw-hill, 1994.

[4] Abido, M. A. "Analysis of power system stability enhancement via excitation and FACTS-based stabilizers." *Electric Power Components and Systems* 32.1 (2004): 75-91.

[5] Wang, H. F. "Static synchronous series compensator to damp power system oscillations." *Electric Power Systems Research* 54.2 (2000): 113-119.

[6] Khadanga, Rajendra Ku, and Jitendriya Ku Satapathy. "Gravitational search algorithm for the static synchronous series compensator based damping controller design." *Proceedings of the 2014 IEEE Students' Technology Symposium*. IEEE, 2014.

[7] Mohapatra, Sangram Keshori, Sidhartha Panda, and Prasant Kumar Satpathy. "Power system stability improvement by static synchronous series compensator-based damping controller employing gravitational search algorithm." *International Journal of Computational Science and Engineering* 11.2 (2015): 143-154.

[8] Rao, R. "Review of applications of TLBO algorithm and a tutorial for beginners to solve the unconstrained and constrained optimization problems." *Decision science letters* 5.1 (2016): 1-30.

[9] Rao, R. Venkata. "Teaching-learning-based optimization algorithm." *Teaching learning based optimization algorithm*. Springer, Cham, 2016. 9-39.