

# Robust Design of PSS and SVC Using Teaching-Learning Based Optimization Algorithm

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## Abstract

**Power System Stabilizers (PSS)** are very effective controllers in generation of supplementary feedback stabilizing signals. Using of PSS in power systems lonely, not only may not improve voltage stability but also cause great variations in the voltage. In the other hand, Flexible AC Transmission Systems (FACTS) such as Static VAR Compensations (SVC) has been used for dynamic control voltage, increasingly. Incoordination of PSS and SVC parameters can have undesirable effects on generator angle and voltage oscillations. So, simultaneous coordination of PSS and SVC parameters is highly regarded. This paper determines the optimal parameters of PSS and SVC using Teaching-Learning based Optimization (TLBO) algorithm in such a way that the power system withstands against a wide range of contingencies, effectively.

## 1. Introduction

Due to increasing electrical power demand, most power systems are operating near their steady-state stability limits, which may result in critical conditions by slightest disturbance. Dynamic problems of power systems are studied from angle stability and voltage stability point of view [1].

PSSs have been used to increase system oscillation stability, widely. However, installing of PSS in power systems lonely, not only does not improve voltage stability but also causes more variations in the voltage [2].

In recent years, with advantage of power electronics and nonlinear control theory, FACTS devices, such as SVC compensators, have been used to dynamic voltage control, increasingly. Also, in addition to improving voltage oscillations, the SVCs can increase the dynamic and transient stability limits [3]. Incoordination of PSS and SVC parameters can have undesirable effects on generator angle oscillation and voltage oscillation. So, simultaneous coordination of PSS and SVC parameters is highly regarded. Various methods are introduced to design parameters of these devices. Proposed methods are classified into two main groups consist of classical and meta-heuristic algorithms. Superior ability to apply wide range of power systems problems, finding global optimum solutions and convergence are characteristics of meta-heuristic algorithms.

In [4] Bacterial Foraging Optimization Algorithm (BFOA) was presented to simultaneous coordination of PSS and SVC parameters over a wide range of loading. The speed deviation between generators was taken as objective function. Reference [5] illustrated the effectiveness of PSS and SVC in improving transient stability and power oscillation damping of the system under line to ground and three phase fault, separately. Designing

of Coordinated parameters of SVC and PSS using bacterial-foraging oriented by Particle Swarm Optimization (BFPSON) algorithm was proposed in [6]. The objective function was considered Integral of Time multiplied Absolute Error (ITAE) performance index. Reference [7] proposed a method to design a supplementary controller by SVC for damping of the oscillation modes between all the aggregate machines, which in the actual system will correspond to inter-area oscillations. Reference [8] presented a method to obtain a set of optimal PSS parameters under various operating conditions using Gradual Self-tuning Hybrid Differential Evolution (GSTHDE). A function called damping scale is proposed as objective function. Robust solution with SVC to enhancement transient and steady-state performance by introducing class K function was presented in [9]. Also, the uncertainties in the infinite bus voltage and the internal and external reactance's to the generating station were considered, in this study.

Most references and available articles have determined optimal parameters of controllers in the presence of specific disturbance. If the type of contingencies change, there is a risk where controllers' performance is reduce and even the system may become unstable.

This paper determines the optimal parameters of PSS and SVC using the capable algorithm namely TLBO, in such a way that the power system withstands against a wide range of contingency, effectively.

## 2. Problem Formulation

Block diagram of SVC is illustrated in Fig. 1. According to Fig. 1, measured phase voltage is the input signal and output signal is capacitive susceptance for compensation of reactive power.

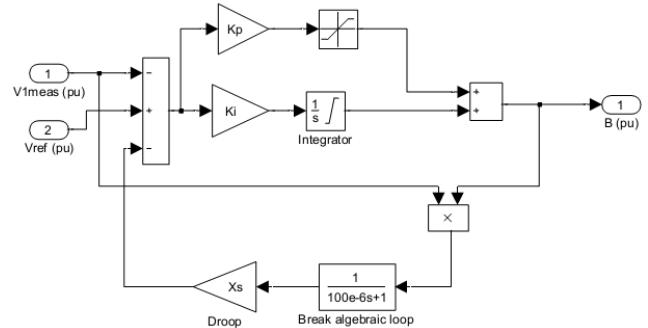
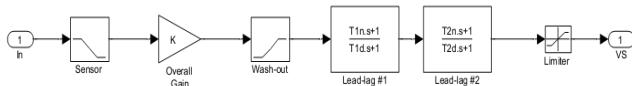


Fig. 1. Block diagram of SVC

Also, Block diagram of PSS is shown in Fig. 2. The input signal is speed generator deviation from nominal value and output is stabilizer signal of excitation voltage.



**Fig. 2.** Block diagram of PSS

The sample power system is shown in Fig. 3. In this system output of generator has equipped with SVC. Also, PSS is located in the input excitation system.

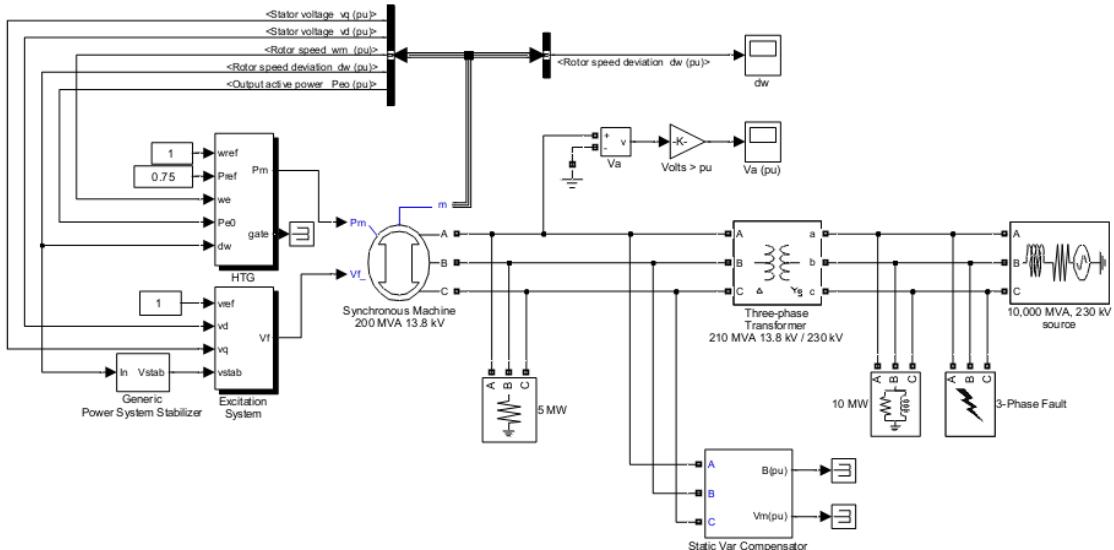
## 2.1. Objective Function

The proposed objective function is expressed as follows:

$$\sum_{faulttype} \alpha_1 \int_0^{t_{stop}} t^{1.2} \cdot |d\omega| dt + \alpha_2 \int_0^{t_{stop}} t^{1.2} \cdot |V_{ph} - V_{ref}| dt$$

Where  $t$  is current time of simulation,  $d\omega$  is speed deviation changes,  $V_{ph}$  is phase voltage,  $V_{ref}$  is reference voltage of SVC,  $t_{stop}$  is final time of simulation and  $faulttype$  is studied fault types. Also,  $\alpha_1$  and  $\alpha_2$  are weight coefficient where are considered the same and equal to 0.5.

In this paper three types of faults consist of line to ground, line to line and three phase are considered. Control variables based on block diagrams in Fig. 1 and Fig. 2 are:



**Fig. 3.** Case study power system in MATLAB environment

## 3. Teaching-Learning based Algorithm

This algorithm is one of the intelligent optimization algorithms which was innovated by inspiration from teaching and learning [10, 11].

This algorithm is a mathematical model considered for teaching and learning which is run in two phases.

$K_{PSS}$  is gain of PSS,

$T_W$  is wash-out time constant,

$T_{1n}$  and  $T_{1d}$  are 1<sup>th</sup> lead-lag time constant,

$T_{2n}$  and  $T_{2d}$  are 2<sup>th</sup> lead-lag time constant,

$K_{P,SVC}$  and  $K_{I,SVC}$  are gain and integrator factor of SVC voltage regulator,

Limits of control variables are given in Table 1.

(1)

**Table 1.** Limits of control variables

parameter	high limit	low limit
$K_{PSS}$	25	2.5
$T_W$	15	1.5
$T_{1n}$	2	0.005
$T_{1d}$	1	0.001
$T_{2n}$	10	0.1
$T_{2d}$	15	0.005
$K_{P,SVC}$	100	0
$K_{I,SVC}$	750	0

- Teaching Phase: in this stage, the best member of a society is chosen as a teacher or instructor and attracts average population towards himself. In other words, a good teacher is a person who draws close the knowledge level of class members towards his knowledge level. Obviously, this depends on the class's ability. Mathematical model of

concept difference between teacher's and student's knowledge is as follows:

$$M_{diff} = \text{rand}(0,1) [X_{best} - T_F M_D] \quad (2)$$

Where  $T_F$  is teaching coefficient,

$M_D$  is class mean,

$X_{best}$  is teacher's representative,

$\text{rand}(0,1)$  is a random number between 0 and 1.

Teaching coefficient is a number between 1 or 2 chosen randomly according to (3):

$$T_F = \text{round}[1 + \text{rand}(0,1)] \quad (3)$$

The new population in the next repetitions are made as (4):

$$X_{new} = X + M_{diff} \quad (4)$$

Where,  $X$  is the population member in the last repetition, and  $X_{new}$  is the population member in the new repetition. Replacement and non-replacement of the new member instead of old member is determined by value of objective function.

- Learning phase: in this stage, population members (which are considered as a class) expand their knowledge together. This random process can be expressed as below:

$$\begin{aligned} X_{new} &= X_i + \text{rand}(0,1)(X_i - X_j), \quad \text{if } f(X_i) < f(X_j) \\ \text{Else} \\ X_{new} &= X_i + \text{rand}(0,1)(X_j - X_i) \end{aligned} \quad (5)$$

Population and TLBO algorithm iteration number are assumed 60 and 200, respectively.

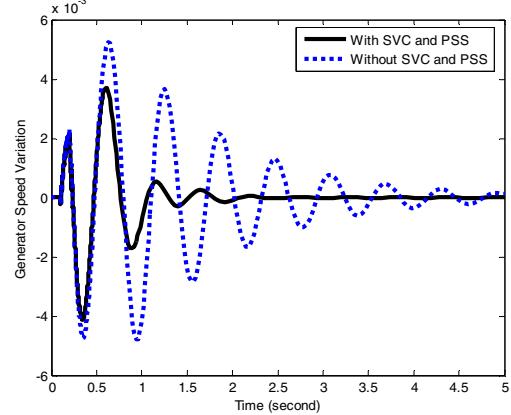
#### 4. Results

In this section, performance of TLBO algorithm are examined to simultaneous reduction of speed and phase voltage deviation for various fault types in power system. Optimal value for control variables using TLBO algorithm are given in table 2.

**Table 2.** Optimal parameters of control variables using TLBO

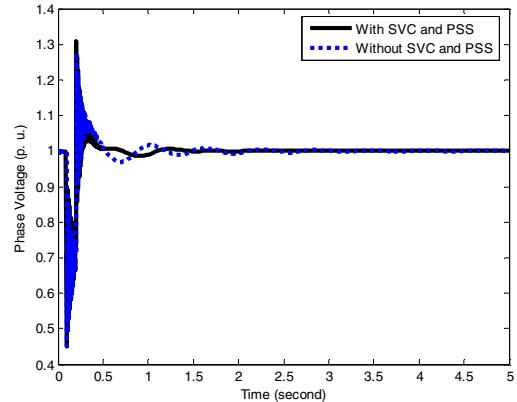
Parameter	Value
$K_{PSS}$	13.190
$T_w$	7.147
$T_{ln}$	1.371
$T_{1d}$	0.012
$T_{2n}$	0.479
$T_{2d}$	10.799
$K_{P,SVC}$	1.189
$K_{I,SVC}$	0.685

Fig. 4 shows the speed deviation of generator for line to grand fault in two conditions, without PSS and SVC and with them by optimal parameters using TLBO.



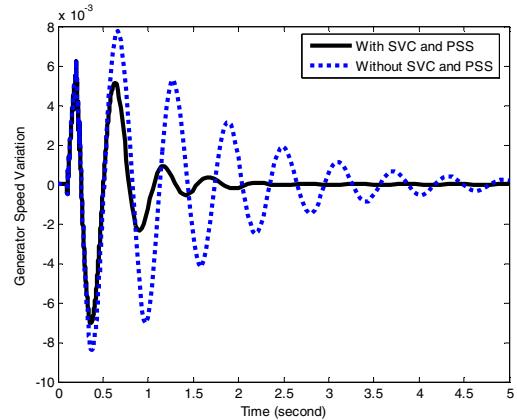
**Fig. 4.** Speed deviation of generator for line to grand fault without/ with PSS and SVC by optimal parameters

Also, phase voltage deviation for line to grand fault in two conditions, without PSS and SVC and with them by optimal parameters using TLBO is shown in Fig. 5.



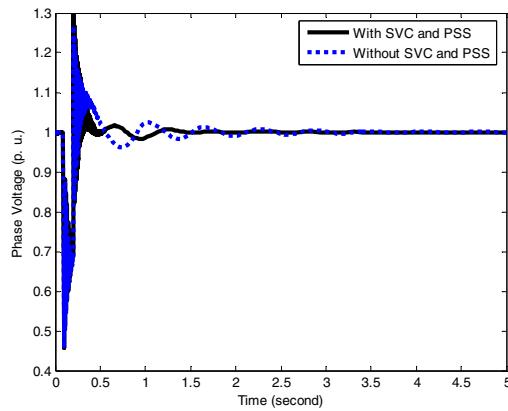
**Fig. 5.** Phase voltage deviation for line to grand fault without/ with PSS and SVC by optimal parameters

Fig. 6 shows the speed deviation of generator for line to line fault in two conditions, without PSS and SVC and with them by optimal parameters using TLBO.



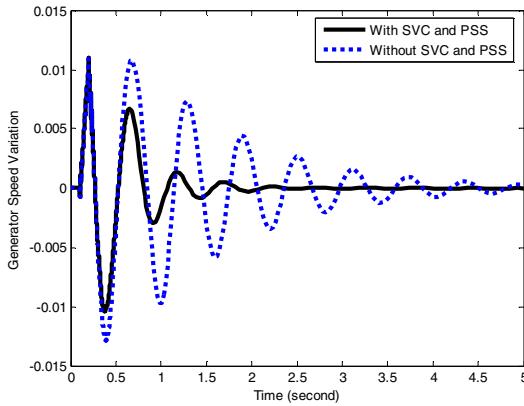
**Fig. 6.** Speed deviation of generator for line to line fault without/ with PSS and SVC by optimal parameters

Also, phase voltage deviation for line to line fault in two conditions, without PSS and SVC and with them by optimal parameters using TLBO is shown in Fig. 7.



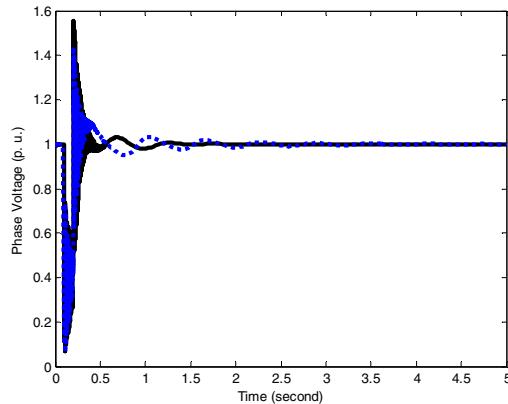
**Fig. 7.** Phase voltage deviation for line to line fault without/ with PSS and SVC by optimal parameters

Fig. 8 shows the speed deviation of generator for three phase fault in two condition, without PSS and SVC and with them by optimal parameters using TLBO.



**Fig. 8.** Speed deviation of generator for three phase fault without/ with PSS and SVC by optimal parameters

Finally, phase voltage deviation for three phase fault in two conditions, without PSS and SVC and with them by optimal parameters using TLBO is shown in Fig. 9.



**Fig. 9.** Phase voltage deviation for three phase fault without/ with PSS and SVC by optimal parameters

## 5. Conclusion

In this paper, simultaneous determination of optimal parameters of PSS and SVC was studied based on minimization of generator speed deviation and phase voltage oscillation. In order to robusting the power system for wide range of contingencies, various type of faults are considered in optimization problem. TLBO algorithm was used to present optimal solution. Simulation results illustrate that proposed method solutions have the least oscillation for various faults type.

## 6. References

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