PSO based Determination of SVC Control Parameters for Power System Transient Stability Improvement

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Abstract: In this paper, particle swarm optimization (PSO) method is used to find the optimal control parameters of FACTS (Flexible AC Transmission Systems) - SVC (Static VAR Compensator) device. SVC is used for voltage and reactive power control in two machine transmission system with PSS (Power System Stabilizer). Simulations are implemented in MATLAB – Simulink. The main purpose of the study is to control the bus voltage deviations after fault. The differences between SVC with unoptimizated control parameters and optimizated control parameters are showed in this paper. Simulation results showed that SVC with optimal parameters is provided the minimum bus voltage deviations after fault.

Key words: Optimization, PSO, FACTS devices, SVC, Transient stability

1. Introduction

In parallel with today's rapid technological developments, the electricity demand is increasing with the same rate nearly. With the continuous load increase, stability limit of power systems have forced the near stability limit and start to decrease stability limits [1]. It is wanted to response fast against the dynamic behavior of electrical loads and disturbance like short circuit. So, FACTS (Flexible AC Transmission Systems) devices begin to take place in power systems by developing the power electronic technologies in order to increase stability limits. Devices, such as a STATCOM, SVC, SSSC, and UPFC, can be connected in series or shunt to achieve voltage regulation, power flow control, and system damping [2]. Transmission control through dynamical control of real and reactive power flow can be provided the FACTS devices [3]. Also, with the FACTS technology, bus voltage, line impedance and phase angle can be set up quickly and flexibly. Therefore, facilitating control of power flow, increase the power transfer capability reduces the cost of the generator, the reliability and stability of the power system may be improved by FACTS devices [4]. In this study, a newly optimization algorithm, namely PSO is applied to SVC controller. This algorithm is based on movements of birds and fish flocks. PSO has been confirmed higher performance in solving various nonlinear functions, compared with some search methods. Recently, Particle Swarm Optimization (PSO) method is developed by Kennedy and Eberhart has appeared for handling the optimization problems [5]. PSO provides shorter calculation time and has more stable convergence characteristics than other stochastic methods [6]. Though, PSO has been employed in several research papers [7-9]. The efficiency of the optimal controller is tested on a two-machine power system under disturbance. Simulation results demonstrate that the proposed method achieves good performance for damping the oscillations in voltage.
The rest of this paper is organized as follows. Section II describes the structure of a simple SVC and two machine power systems with PSS under study. Section III presents the PSO algorithm.

Section IV presents the optimal damping controller design for SVC. Section V presents the simulation results on the performance of the optimal controller using PSO and comparison with optimal and nonoptimal parameters of SVC. Finally, the conclusions are given.

2. Two Machine Power Systems with PSS and SVC

In this paper, two machine transmission systems with PSS (Power System Stabilizer) in [10] is used for the study and is simulated in MATLAB- Simulink. The two machine power system with PSS is shown in Fig. 1. In the system, there are two synchronous generators rated 500 kV/5000 MVA and 13.8kV/1000MVA respectively. All the generators are equipped with identical speed governors and turbines, exciters and Automatic Voltage Regulators (AVRs), and Power System Stabilizers (PSSs). Also, the 5000MW load is connected at bus B3.

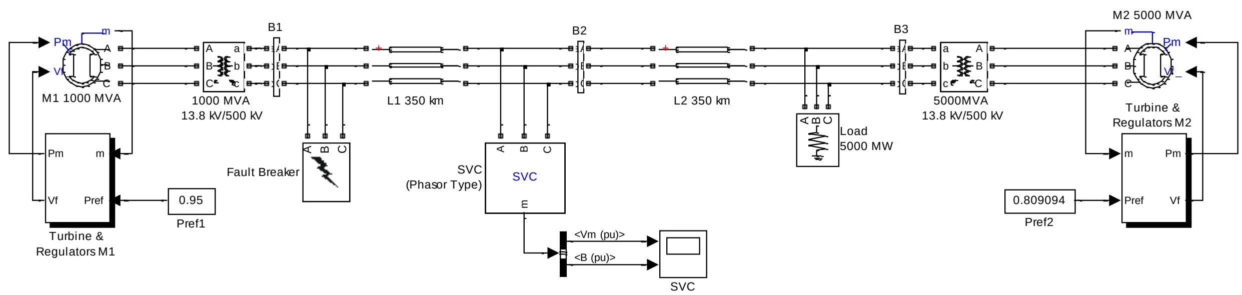

Figure 1. Two machine power system with PSS[10]

A SVC is connected at bus B2. A typical block diagram of a SVC is shown in Fig. 2a. The difference of the actual voltage at bus B2 where SVC is connected and the reference value is given as input to the PI control block. The PI controller consists of gain constant, K_p, and integral constant K_i in voltage regulator. These are the parameters that need to be optimally selected for the SVC to ensure optimal system performance under disturbances.

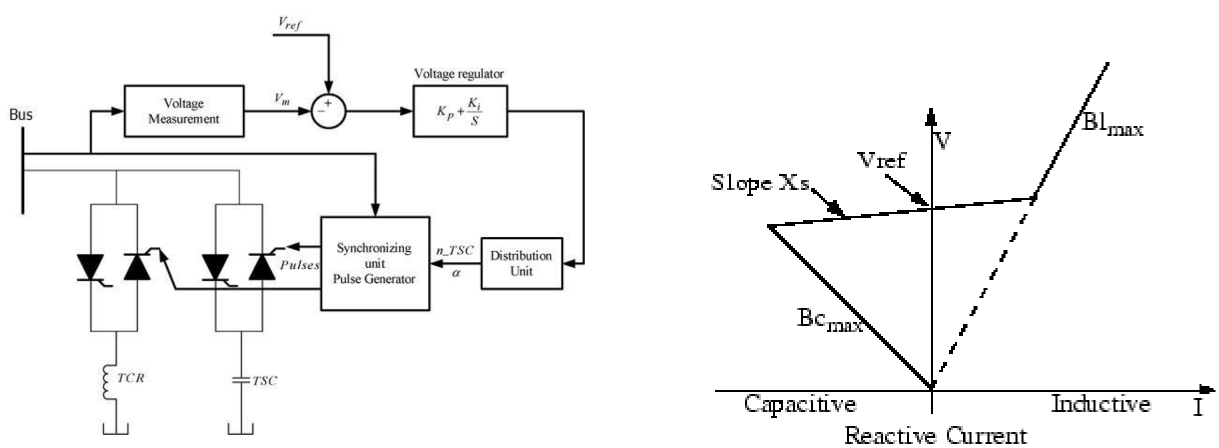

Figure 2. a) Structure of SVC b) SVC V-I characteristic

SVC V-I characteristic is indicated in Fig. 2b which shows the variation of SVC bus voltage with

SVC current or reactive power. SVC V- I characteristic is described by the following equations [matlab help]:

$$V = \begin{cases} V_{ref} + X_s I & \text{If SVC is in regulation range} \\ -I/B_{C\max} & \text{If SVC is fully capacitive} \\ -I/B_{I\max} & \text{If SVC is fully inductive} \end{cases}$$

3. PSO Algorithm

Kennedy and Eberhart proposed particle swarm optimization method which is one of the evolutionary optimization algorithm based on heuristic and probability. This method is inspired by the movements of birds and fish flocks, and used to solve multi-parameter, multi-variable and non-linear numerical problems [5].

The technique is initialized with a population of random particles where each particle is a candidate solution. The particles fly through the problem space by following the current optimum particles. By updating positions of each particle, it tries to find for optimal solution. The PSO algorithm works as follows:

a) Determine the position and speed of the each particle in particle population.
b) Calculate the fitness evaluation depend on position and speed of each particle.
c) Compare every particle's fitness evaluation with its p_{best} value, p_{id}. If current value is better than p_{id}, then set p_{id} value equal to the current value and the p_{id} location equal to the current location in d-dimensional space.
d) Compare the updated p_{best} values with the population's previous g_{best} value and evaluate the best objective function value g_{best}.
e) Update the velocity and positions of particles using below equations,

$$V_{id} = w \times V_{id} + C_1 \times r_1 \times (P_{best} - X_{id}) + C_2 \times r_2 \times (G_{best} - X_{id})$$

$$X_{id} = X_{id} + V_{id}$$

f) Repeat the process between (a) and (e) steps depend on population size and iteration number.

In general the PSO algorithm can be given by the following flowchart, in Fig. 3.

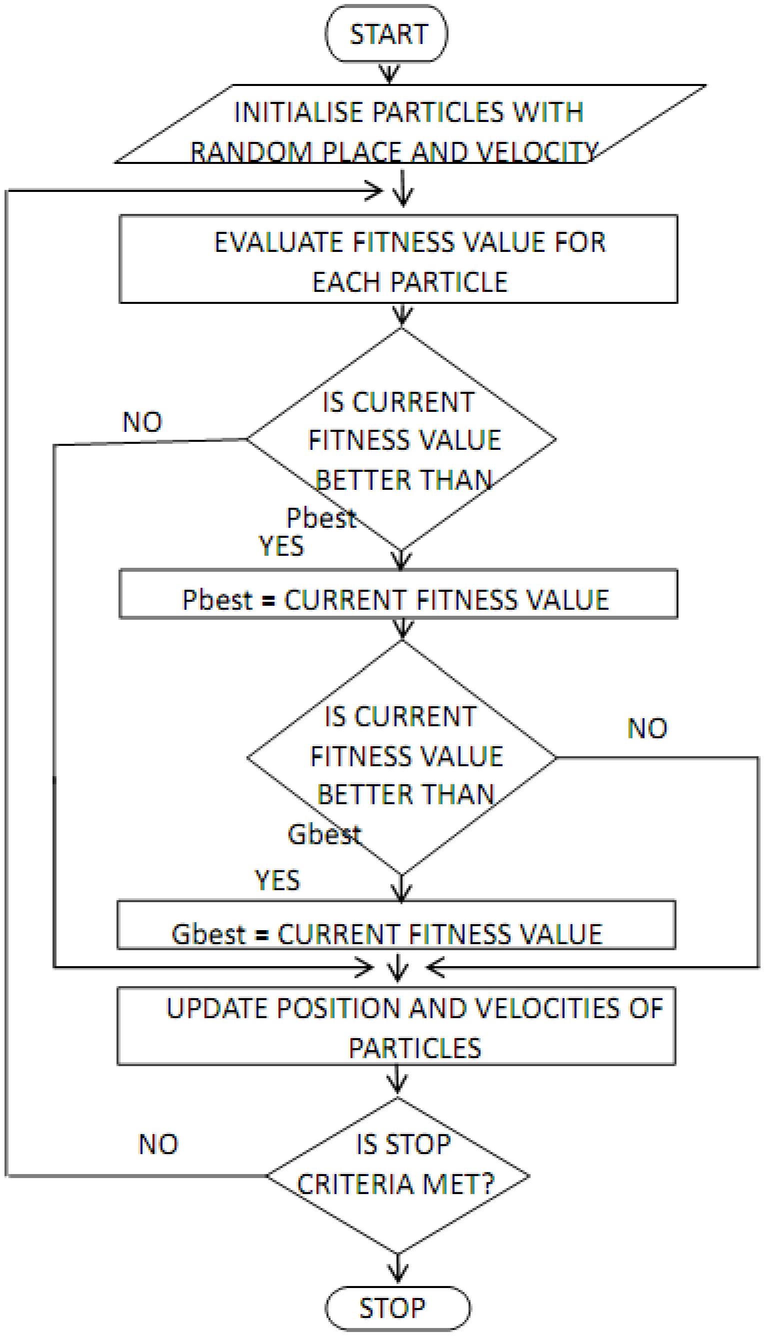

Figure 3. Flowchart of PSO algortihm

4. Optimal Design of A SVC Controller

In the study, the integral time absolute error (ITAE) of the bus voltage deviation was considered as the objective function J:

$$J = \int_{t_0}^{t_{sim}} t.\left|\Delta V_{bus}\right|.dt$$

where ΔV_{bus} is the bus voltage deviation and t_{sim} is the simulation time.
The time-domain simulation of the power system model was performed to minimize the above objective function in order to improve the system response based on voltage deviation. The constraints were SVC controller parameter bounds. The problem can be formulated as the optimization procedure below.

Minimize J

Subject to
$K_p^{min} \leq K_p \leq K_p^{max}$, $K_i^{min} \leq K_i \leq K_i^{max}$

In this paper, the PSO technique is used to solve the above optimization problem. PSO technique use time-domain simulation and optimize the objective function for tuning SVC parameters.

5. Simulation Results

A three-phase fault is considered in the bus B1, at t = 1 s, and then cleared after 0.083 s. Using PSO algorithm whose parameters shown in Table 1, two machine transmission systems with PSS is performed to find the optimal control parameters of SVC under 3-phse fault. Also, the optimal controller parameters that are achieved using PSO optimization technique and unoptimized parameters are presented in Table 2.

Table 1. PSO parameters

Population size	100
Number of iterations	10
Velocity constant,c1	2
Velocity constant,c2	2
Bound for parameters	$0<K_p<30$ $0<K_i<500$

Table 2. SVC control parameters

Parameters	Optimized	Unoptimized
K_p	14.885	1
K_i	486.83	100

Fig. 4 shows the bus voltage responses at the SVC bus B2 and error between reference value and measured value of bus voltage at B2. It is obviously seen from the Fig. 4 that oscillations and overshoot at bus voltage with unoptimized SVC are less than without SVC and also, oscillations and overshoot at bus voltage with optimized SVC are less than with unoptimized SVC.

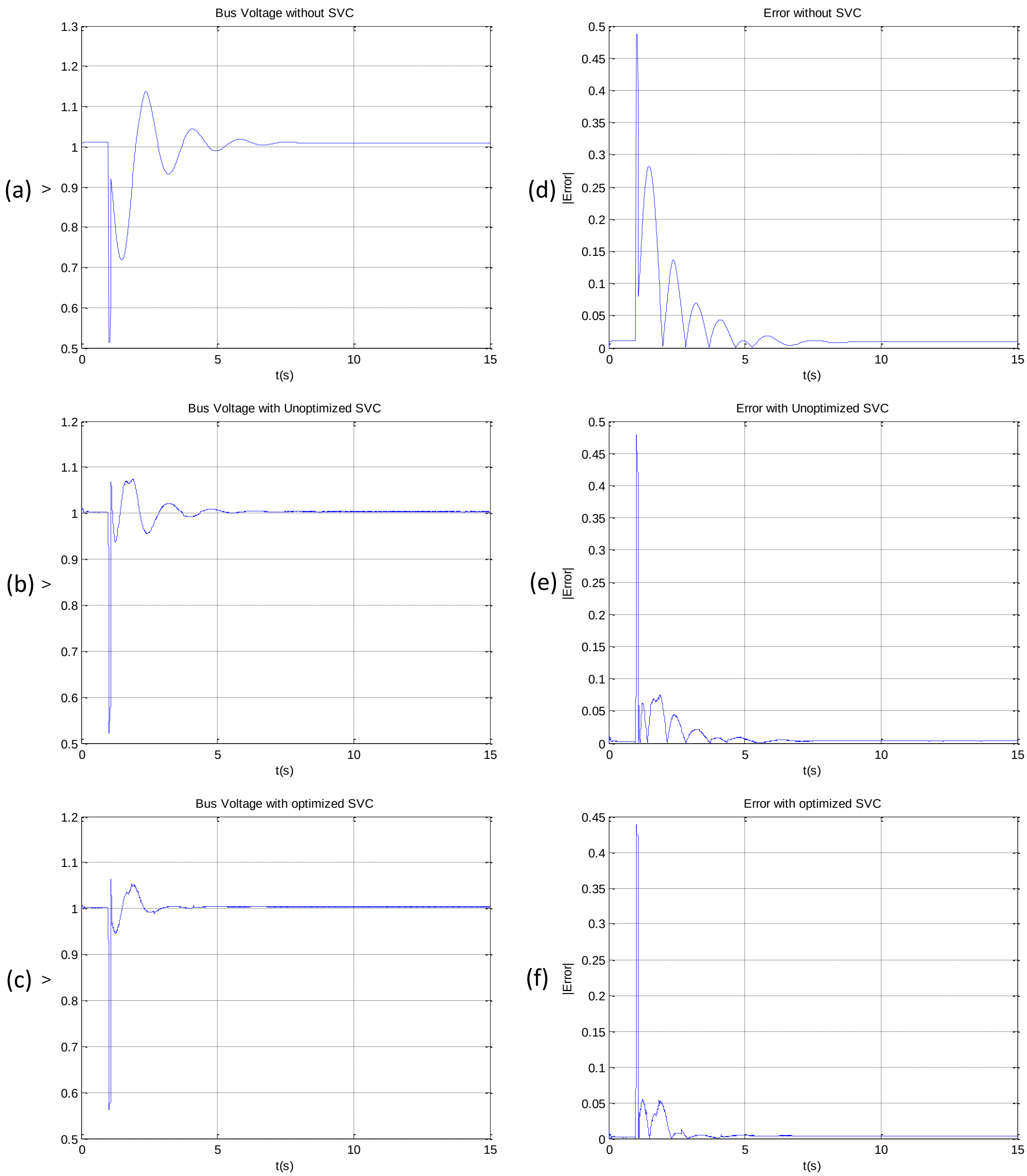

Figure 4. Bus voltage (a)without SVC, (b) with unoptimized SVC, (c) with optimized SVC, Error (d)without SVC, (e) with unoptimized SVC, (f) with optimized SVC

In addition, error between reference value and measured value of bus voltage with unoptimized SVC are less than without SVC and with optimized SVC are less than with unoptimized SVC.

Conclusions

In this paper, PSO has been implemented for optimal parameter setting of the SVC controller in a two machine transmission systems with PSS in order to mitigate the oscillation problem under disturbance. MATLAB - Simulink environment is used for the simulation studies of power system with SVC. In this simulation, value of proportional gain parameter, K_P, integral gain parameter, K_I of PI controller are optimized using PSO algorithm until minimum value of the objective function J with selection of K_P and K_I value. The simulation results indicate that SVC with optimal controller parameters gives better improvement and minimum voltage deviation for the power system transient stability under and after three phase fault.

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