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Harmony search algorithm for SVC controller tuning in voltage support mode

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Abstract

Static Var Compensator (SVC) in one of the most widely used FACTS devices in industry and real world power systems. The problem of finding optimal values of SVC parameters has been studied for years. Many different methods have been carried out to design SVC controllers. But trying to find better controller is still remains. In this scope, Harmony Search (HS) Algorithms method as a meta-heuristic optimization method is considered for tuning the parameters of SVC. A multi machine electric power system is used to test viability of SVC in voltage support under disturbances. Simulation results on a multi machine power system show the ability of SVC in control of voltage as well as stability enhancement. The results are carried out by numerical simulations by using MATLAB software.

Keywords: Static Var Compensator; Voltage Support; Multi-Machine Power System; Harmony Search Algorithms

Nomenclature: ***Symbols:*** δ: Rotor angle;;ω: Rotor speed (pu); P_m: Mechanical input power; P_e: Electrical output power (pu); M: System inertia (Mj/MVA); E'_q: Internal voltage behind x'_d (pu); E_{fd}: Equivalent excitation voltage (pu); T'_{do}: Time constant of excitation circuit (s); K_a: Excitation regulator gain; T_a: Excitation regulator time constant (s); V_{ref}: Reference voltage (pu); V_t: Terminal voltage (pu); Δ: deviation form the nominal value; b_{SVC} : total reactance of SVC; K_r: SVC regulator gain; T_r: SVC regulator time constant (s);

Abbreviations: SVC: Static Var Compensator; FACTS: Flexible AC Transmission Systems; HS: Harmony Search.

Introduction

With the rapid increase of modern industry and load demand, Power grid interconnection, power system is highly stressed and voltage instability poses a primary threat to system stability, in such situations power system voltage stability is of great concern. There are many factors affecting voltage stability of the power system (Hingorani & Gyugyi, 2000): insufficient reactive power, automatic excitation system and its controllers connected with modem generators, voltage dependent loads, load voltage regulating transformers, static Var compensators located in the transmission system to improve voltage, etc. Reactive power compensation is often the most effective method to improve both transmission capability and voltage stability.

Many power system components and controller play a role in voltage instability. The voltage stability can be maintained by Static Var Compensator (Hingorani & Gyugyi, 2000). In analyzing the cause of static and dynamic voltage instability on disturbance occurrence, it is important to determine voltage stability. However, the criteria becomes even more difficult if one attempts to apply the criteria to complex power system. When the SVC controller is used in power system, it must be variable impedance of capacitor (XC) and reactor (Xl) will be taken into bus node equation account to analyze. How to obtain a simple, convenient and practical criterion for static voltage stability is still an important task in researching voltage stability problems. Although there are the other types of shunt compensators, the simple structure of SVC makes it more viable and feasible. The SVC has been widely used for stability enhancement (Rahim *et al.,* 2006; Therattil & Panda, 2010; Bian *et al.,* 2011), voltage support (Ahmed *et al.,* 2004; Shenghu *et al.,* 2009; Chopade *et al.,* 2011) and also reliability improvement of power system (Junget *et al.,* 1991). The benefits of applying SVC in power systems is still of a great concern as it is very interesting for system operators and researchers.

Although many different methods have been carried out to design AVC controllers, but the industries prefer to use PI type controllers. Thus, the attempts are toward finding better methods to tuning the proposed controllers. In this scope, this research deals with tuning SVC controller parameters using a new Meta heuristic optimization method named HS. The proposed optimization method has been reported to be robust and viable.

Problem formulation and system modeling

In order to test the ability of SVC, application to a real world power system is suitable. Thus, in this paper a multi machine electric power system is used to evaluate the ability of SVC and the proposed, method in voltage support. Fig. 1 shows a nine-bus three machine power system with a SVC installed in one bus 8. Detail of the system data are given in (Sauer & Pai, 1997). In order to

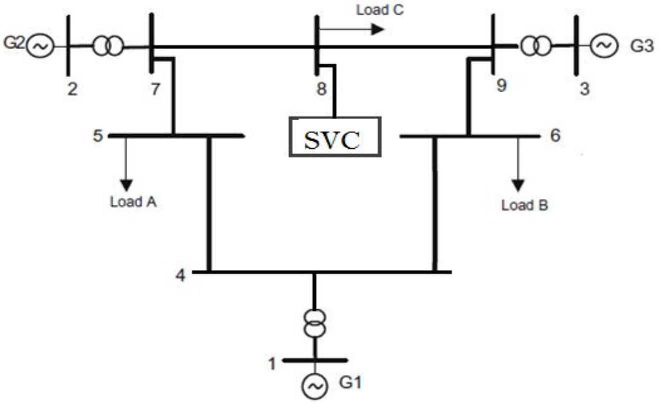


Fig. 1. Multi-machine electric power system installed with SVC at bus 8

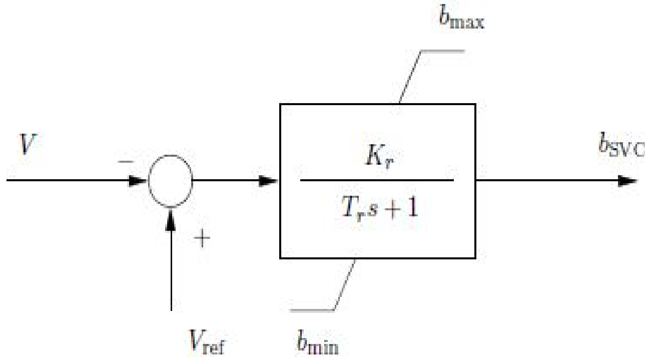


Fig. 2. The SVC model as a time constant regulator

show the ability of SVC under different operating conditions, nominal and heavy operating conditions are considered. The operating conditions are presented in appendix.

SVC model

The SVC is implemented as a time constant regulator to voltage support as depicted in Fig. 2. In this model, a total reactance is assumed equivalent to b_{SVC} . The differential equation of the model is as (1).

$$\dot{b}_{SVC} = (K_r(V_{ref} - V) - b_{SVC})/T_r \tag{1}$$

The model is completed by the algebraic equation which expresses the reactive power injected at the SVC node as (2).

$$Q = -b_{SVC} V^2 \tag{2}$$

The regulator has an anti-windup limiter, thus the reactance b_{SVC} is locked if one of its limits is reached and the first derivative is set to zero (Hingorani & Gyugyi, 2000).

Dynamic model of the system with SVC

By using the SVC model and also the nonlinear model of synchronous generators, the model of power system installed with SVC can obtained. Where, the differential equation of SVC is added to the equations of the power system machines. A complete model of system with SVC is listed in (3). It is clear that by controlling b_{SVC}, the output reactive power of the shunt compensator would be controlled. The main controller of the SVC is shown in Fig. 2. It contains two parameters as regulator gain K_r and regulator time constant T_r. obtaining the optimal and best values of the proposed parameters in one of the most critical pints in the SVC applications. Therefore, this researches deal with application of an optimization method to tuning the SVC parameters. In the next subsection a complete details of HS is presented.

$$\begin{cases} \dot{\omega} = (P_m - P_e - D\omega)/M \\ \dot{\delta} = \omega_0(\omega - 1) \\ \dot{E}'_q = \left(-E_q + E_{fd}\right)/T'_{do} \\ \dot{E}_{fd} = \left(-E_{fd} + K_a\left(V_{ref} - V_t\right)\right)/T_a \\ \dot{b}_{SVC} = (\mathrm{K_r}(\mathrm{V_{ref}} - \mathrm{V}) - \mathrm{b_{SVC}})/\mathrm{T_r} \end{cases} \tag{3}$$

Harmony search algorithm

Harmony search (HS) algorithm is optimization method based on natural musical performance processes that occur when a musician searches for a better state of harmony, such as during jazz improvisation. The engineers seek for a global solution as determined by an objective function, just like the musicians seek to find musically pleasing harmony as determined by an aesthetic (Hong-qi *et al.*, 2008). The HS algorithms is investigated in electric power systems (Shirvani Boroujeni *et al.*, 2011).

Application of HS for parameters adjustment

The proposed optimization method, HS, is applied to tuning the SVC controller. Since, HS is an optimization method, thus, in the first step, an objective function should be considered for the optimization problem. Many different objective functions have been used for such a problems. Here, a most commonly used objective function named Time multiplied Absolute value of the Error (ITAE) is used as performance index. This objective function is showed in (4).

$$\mathrm{ITAE} = \int_0^t t|\Delta\omega_1|dt + \int_0^t t|\Delta\omega_2|dt + \int_0^t t|\Delta\omega_3|dt \tag{4}$$

Since the ITAE shows the error of responses, thus the optimization search tries to minimize the ITAE. Finally, The parameters with lower ITAE are chosen as optimal parameters. A 10 cycle three phase short circuit is assumed in bus 1 and the performance index is minimized using HS. The optimum values of parameters, resulting from minimizing the performance index is presented in Table 1. Where, the limits for parameters are from 0.1 to 100.

Following HS parameters are used:
Number of decision variables (N): 2
Harmony memory size (HMS): 30

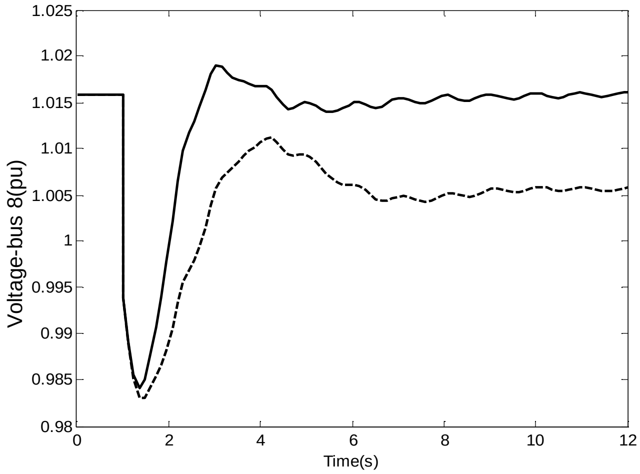


Fig. 3. Voltage of bus number 8 under fault in nominal load condition Solid (with SVC); Dashed (without SVC)

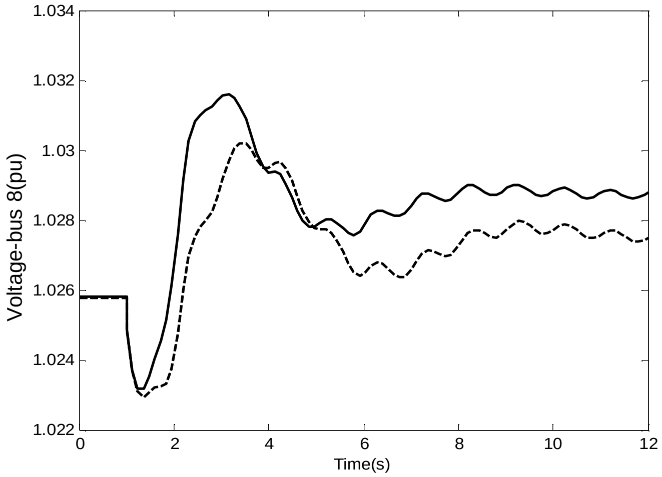


Fig. 4. Voltage of bus number 4 under fault in nominal load condition Solid (with SVC); Dashed (without SVC)

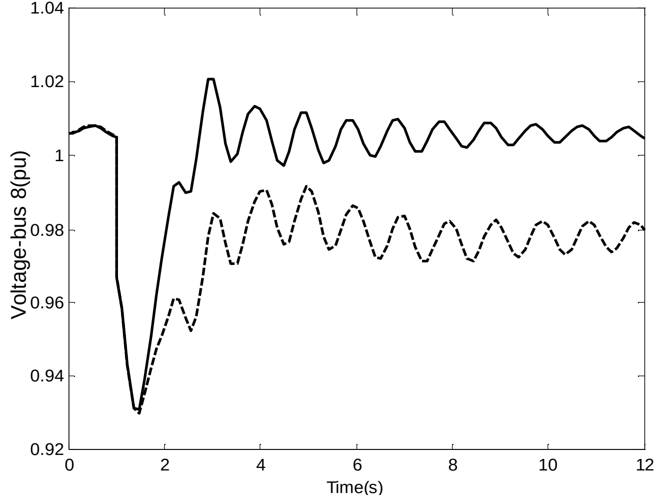


Fig. 5. Voltage of bus number 8 under fault in heavy load condition Solid (with SVC); Dashed (without SVC)

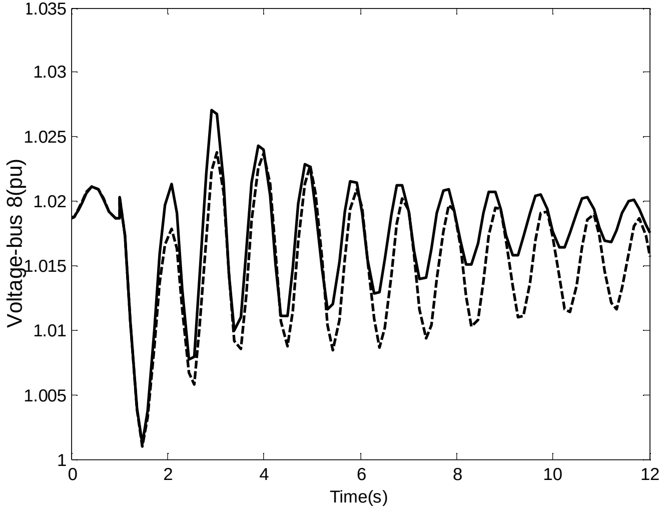


Fig. 6. Voltage of bus number 4 under fault in heavy load condition Solid (with SVC); Dashed (without SVC)

Fig. 7. Voltage of bus number 8 under load change in nominal load condition
Solid (with SVC); Dashed (without SVC)

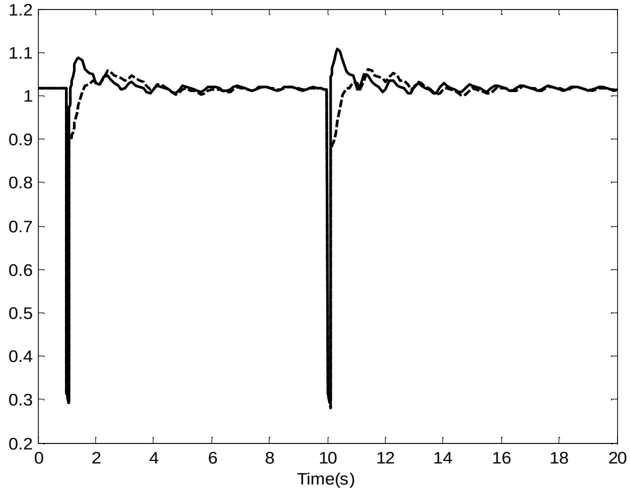


Fig. 8. Voltage of bus number 4 under load change in nominal load condition
Solid (with SVC); Dashed (without SVC)

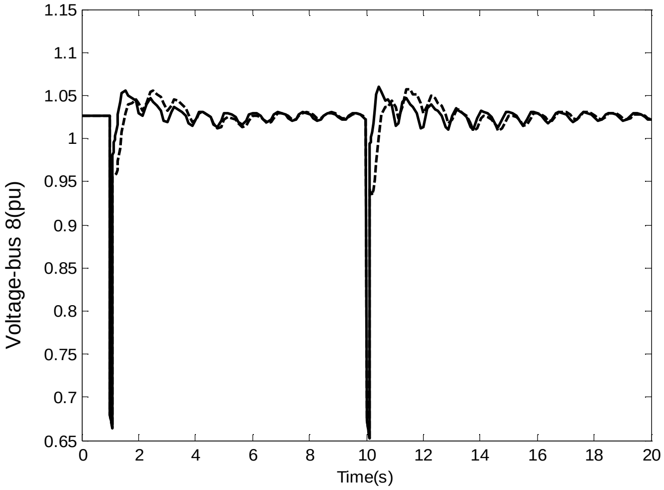


Fig. 9. Voltage of bus number 8 under load change in heavy load condition
Solid (with SVC); Dashed (without SVC)

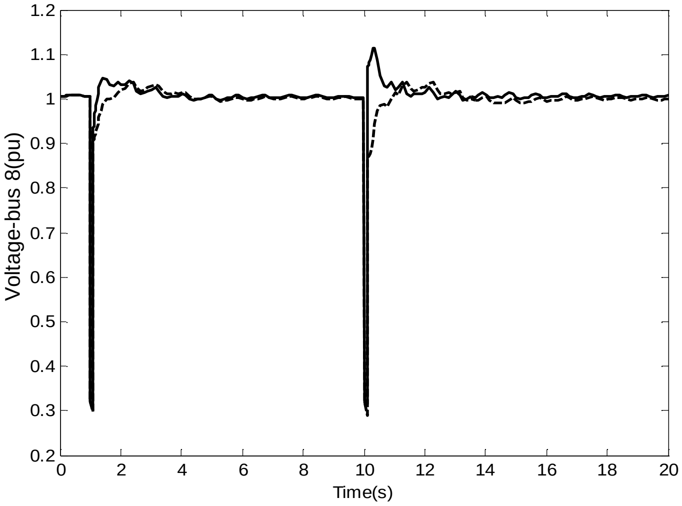
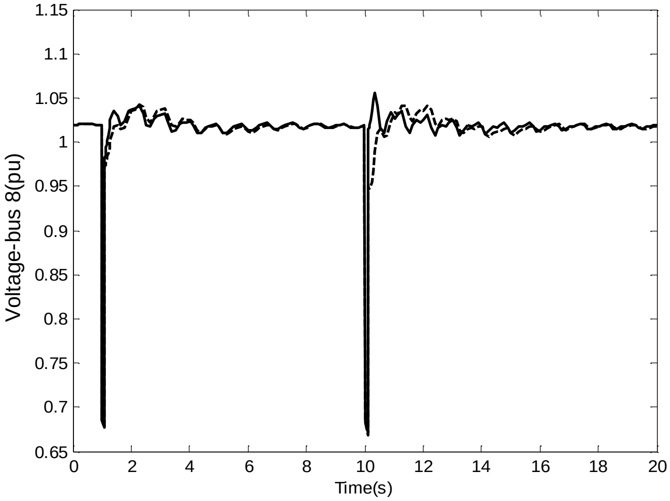


Fig. 10. Voltage of bus number 4 under load change in heavy load condition
Solid (with SVC); Dashed (without SVC)



Number of improvisations (NI): 100
HMCR: 0.9

Table 1. Optimal parameters of SVC using HS

SVC parameters	Optimal value
K_r	111.09
T_r	12.89

Table 2. Considered system loading conditions

Load p.u.)	Nominal		Heavy	
	P	Q	P	Q
A	1.25	0.50	2.00	0.80
B	0.90	0.30	1.80	0.66
C	1.00	0.35	1.56	0.60

Simulation results

The SVC tuned by HS is used to voltage support of bus 8 on the multi machine power system given in section 2. In order to assessment of SVC capability under different disturbances, disconnection of the line between bus 6 and bus 9 by breaker and 10% load change are used as disturbances. Load change is performed as two step changes as increasing and decreasing in different times which are clear in Fig. 7-10. The SVC tuning has been carried out for the nominal operating condition. Simulation results are shown in Fig. 3-10. Where, each figure contains two plots as soli line (responses with SVC installed) and dashed line (responses without SVC).

The responses for the nominal operating condition are shown in Fig. 3-6. It is seen that the system with SVC can control the voltage of bus after disturbances. The system responses without SVC show that the voltage cannot drive to the nominal values after disturbance. But the SVC can alter the voltage to the nominal value during post fault. Although SVC is installed to control of bus 8, bus is has a significant suitable performance on the other buses. As shown in Fig. 4, the voltage of bus 4 is also controlled by SVC. With changing the load from the nominal to the heavy, the SVC performance in voltage control is seen with oscillations, but SVC controls the voltage. It is also clearly seen from Fig. 6 that SVC improves the system stability. The system oscillations with SVC are damped faster than the one without SVC.

The results under load changes are shown in Fig. 7-10. It is seen that under this scenario the SVC has a good and robust performance. The voltage is controlled and the system oscillations are damped out successfully.

Conclusions

A mathematical model and an optimization technique for solving the optimization problem of SVC tuning parameters using HS are presented in this paper. The main contribution of this paper is to show a better optimization method to find global optimum values of SVC controller. The results are carried out on a multi machine electric power system with different loading conditions. Application to a multi machine power system opens the door to real world application of the proposed method. Results showed the viability and simplicity of the proposed method for tuning the SVC parameters.

Appendix

The system operating conditions are listed in Table 2. Where, two operating condition as nominal and heavy are considered. The heavy operating condition is obtained by 40-100% changing loads form the nominal values. Table 2

References

1. Ahmed T, Noro O, Hiraki E and Nakaoka M (2004) Terminal voltage regulation characteristics by static var compensator for a three-phase self-excited induction generator. *IEEE Transact. on Industry Appl.* 40(4), 978-988.
2. Bian XY, Tse CT, Zhang JF and Wang KW (2011) Coordinated design of probabilistic PSS and SVC damping controllers. *Intl. J. Electrical Power & Energy Systems*. 33(3), 445-452.
3. Chopade P, Bikdash M, Kateeb I and Kelkar AD (2011) Reactive power management and voltage control of large Transmission System using SVC (Static VAR Compensator). In: *Proc. of IEEE, Southeast Conf.* pp: 85-90.
4. Hingorani NG and Gyugyi L (2000) Understanding FACTS. IEEE Press.
5. Hong-qi L, Tai-hoon K and Shao-long X (2008) An improved PSO-based of harmony search for complicated optimization problems. *Intl. J. Hybrid Information Technol*. 1(1), 57-64.
6. Jung TH and Alvarado FL (1991) Evaluation of a static VAr compensator effect on system reliability using a probabilistic approach. *Third Intl. Conf. on Probabilistic Methods Applied to Electric Power Systems*. London, UK.
7. Rahim AHMA, Nowicki EP and Malik OP (2006) Enhancement of power system dynamic performance through an on-line self-tuning adaptive SVC controller. *Electric Power Systems Res.* 76(9-10), 801-807.
8. Sauer PW and Pai MA (1997) Power system dynamics and stability. *Prentice Hall*, chapter 7. pp: 193-260.
9. Shenghu Li, Ding M, Wang J and Zhang W (2009) Voltage control capability of SVC with var dispatch and slope setting. *Electric Power Systems Res.* 29(5), 818-825.
10. Shirvani Boroujeni SM, Keyvani Boroujeni B, Delafkar H and Safarnezhad Boroujeni A (2011) Harmony Search algorithm for power system stabilizer tuning. *Indian J. Sci. Technol*. 4 (9), 1025-1030.
11. Therattil JP and PC Panda (2010) Dynamic stability enhancement using self-tuning Static Var Compensator, *Annual IEEE India Conf. (INDICON)*. pp: 1-5.