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Optimal Parameter Selection of Automatic Voltage Regulator for a Large Power Plant based on Sensitivity Analysis

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Abstract. The paper describes an optimal parameter selection method of automatic voltage regulator (AVR) for a large power plant in order to improve power system stability. The AVR is generally used to control the output voltage of the generator by regulating the excitation voltage in a generator rotor. In order to improve transient stability in power system, the paper proposes the method to select optimal parameters of the AVR based on exact power system modeling. The performances of the proposed method are carried out by time-domain simulation by applying fault to a power system.

Keywords: Automatic voltage regulator, optimization, parameter selection, sensitivity analysis, transient stability.

1 Introduction

Recently, power systems have become large and complex and then most controllers need faster and more accurate actions [1]-[3]. The automatic voltage regulator (AVR) is an important controller in power generator. The AVR is used for changing DC voltage in a rotor of a power generator. Therefore, it controls a terminal voltage of a generator in order to keep the system voltage constant and also generate reactive power to a power system. It is a kind of high speed controller to achieve its purposes. Therefore, the appropriate selection of parameters of the AVR is very critical issue.

The dynamic behavior of the power system with the AVR is affected by the linear parameters (gain and time constants of phase compensator) and the constrained parameters (saturation output limits) resulting in nonlinear characteristic. The proper selection of linear parameters has been usually achieved based on linear approaches such as eigenvalue analysis with linearized model [4]-[5]. However, the output limit values cannot be tuned with such method. The linear and nonlinear parameters of AVR are optimally tuned based on sensitivity analysis with nonlinear modeling of power system. An exact power system modeling is one of the best approaches in order to accomplish optimization technique with sensitivity analysis.

In this paper, a method to optimize the linear and nonlinear parameters of the AVR with exact power system modeling is proposed and the performances are assessed by case study carried out on a single machine connected with infinite bus system.

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2 Power System Modeling for AVR

As mentioned in the previous section, the behavior of the power system is characterized by the following:

- Continuous and discrete states.
- Continuous dynamics.

In other words, the power system needs to be modeled mathematically by consisting of the interactions between linear and nonlinear behaviors. Therefore, the power system modeling with the differential and algebraic equations can be presented without loss of generalities as follows [6].

$$\dot{\underline{x}} = \underline{f}(\underline{x}, y) \tag{1}$$

$$0 = g(\underline{x}, y) \tag{2}$$

where x represents the continuous dynamic states, for example generator angles, speed, and fluxes; y represents algebraic states, e.g. load bus voltage magnitudes and angles.

With Eqs. (1)~(2), the power system can be modeled as maintaining its nonlinear properties. Also, the trajectory sensitivities which are the first-order derivatives can be computed with those equations. The AVR controller in Fig. 1 is accurately modeled and the power generator is equipped with the AVR. The AVR in Fig. 1 consists of four controllers, which are two low pass filters, phase-lead compensator, and output limits. Generally, the gain (K_{PSS}) is set to 200. Also, it is typical values of 0.04, 200, 12, 1, 1.05, 5, and -5 for T_R, K_A, T_B, T_C, and T_A, respectively [7]-[8].

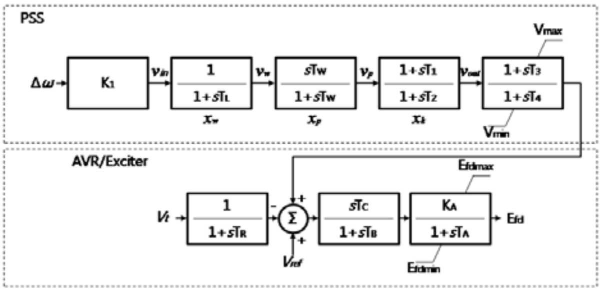

Fig. 1. AVR block representation.

On the other hand, trajectory sensitivities can be obtained if the power system is modeled exactly with nonlinear characteristic because the system is perfectly decomposed and constructed with mathematical model with Eqs. (1)~(2). With the trajectory sensitivities, the optimization process can be applied to select the linear and nonlinear parameters in the AVR. The steepest descent method is one of the simplest numerical optimization algorithms requiring only the first-order gradients. By the steepest descent method, the optimal parameters can be obtained and the values are given in Table I.

Table 1. Optimal parameters of AVR

Values	K_A	T_B	T_C	Efd_{max}	Efd_{min}
AVR	97.95	11.30	2.68	11.97	-5

3 Simulation Results

In order to simulate the proposed optimization method, the paper uses Matlab software to build power system and its controllers including the AVR. To evaluate the performance of the optimized parameters of the AVR, the three-phase short circuit is applied to terminal bus of a generator during 100 ms. Figures 2 and 3 show the performances of the optimized parameters via initial ones. Figures 2 and 3 are the responses of the rotor angle and generator speed deviation, respectively. It is clearly shown that the optimal parameters selected in the paper can dramatically improve the transient stability.

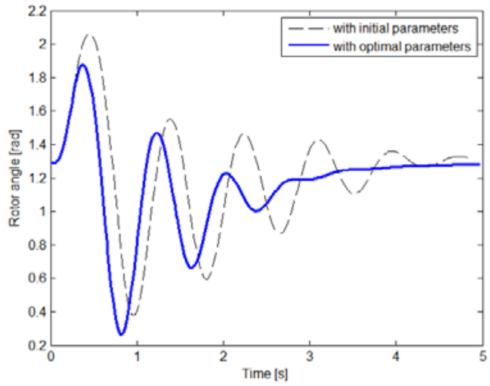

Fig. 2. Generator rotor angle [rad]

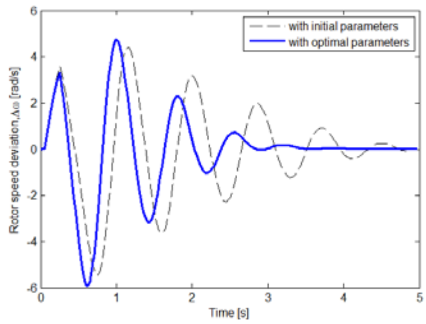

Fig. 3. Generator speed deviation [rad/s]

4 Conclusions

The paper described an optimal parameter selection method of automatic voltage regulator (AVR) for a large power plant in order to improve power system stability. The AVR is generally used to control the output voltage of the generator by regulating the excitation voltage in a generator rotor. In order to improve transient stability in power system, three-phase short circuit was applied to the power system and the responses were investigated. It was clearly shown that the optimal parameters which were obtained with the proposed method in the paper could dramatically improve the transient stability.

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