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Improvement of multi-machine power system stability with variable series capacitor using on-line learning neural network

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Abstract

This paper presents an adaptive control technique for the variable series capacitor using a recurrent neural network (RNN). Since, the parameters of the controller are determined by Genetic Algorithm (GA), which is one of the optimization algorithms, they are optimum only for that operating point and it is not possible to obtain good control performance against variations in the operating and fault point. The adaptive controller proposed in this paper consists of an optimum controller using GA and an RNN. As the RNN was on-line training, robust control performance can be achieved for various operating conditions. The effectiveness of this control method is demonstrated by considering simulation of a multi-machine power system.

Keywords: Variable series capacitor; Adaptive control; Recurrent neural network

1. Introduction

Recently, several control schemes using variable series capacitor (VSrC), which is one of the flexible AC transmission system are reported in literature to improve power system stability. It is important to design the suitable controller in order to make a stable system. Generally, power system is highly nonlinear and the operating conditions vary over a wide range. Thus, it is needs a controller with on-line adjustable controller parameters so as to obtain the optimum control performance for each operating condition. To overcome such problems, adaptive controllers such as self-tuning controller, which tunes controller's parameters itself on-line have been proposed [1–3]. However, the adaptive controllers are complex and in real-time identification of the system parameters is a difficult task.

The controller design schemes using Genetic Algorithm (GA), which is one of the optimization algorithms, have been proposed [4]. GA, which is searching scheme based on evolution of creatures in nature, is possible to optimize a large number of parameters at a time. Since parameters of the controller determined by GA are optimum for that operating point, fixed parameter controllers can deteriorate control performance against variations of the operating point and fault point. To solve these mentioned problems the studies using neural network (NN) have been actively reported [5–7]. However, these designs do not guarantee the good control performance for all operating conditions. It is because the NN in these studies is based on off-line learning algorithm.

To overcome problems mentioned above, an adaptive controller, which is a combination of PID controller and an on-line learning recurrent neural network (RNN), is proposed. These parameters are optimized by using GA for a given fault condition in this paper. It is difficult to determine the PID controller parameters by trial and error method. The learning algorithm for the RNN utilizes a backpropagation algorithm to minimize the active power on the generator side. The inputs to the RNN are easily measurable quantities. These are electrical power output deviation and angular velocity deviation on generator side. We demonstrate the proposed method through simulation results on a multi-machine power system.

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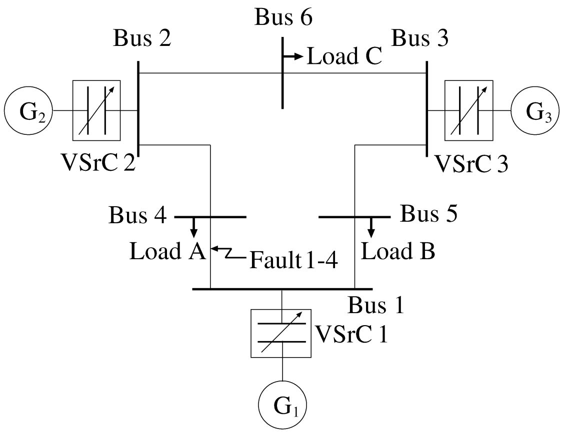

Fig. 1. System configuration.

2. Power system model

Fig. 1 shows the power system model considered in this study. Generated power is transmitted to load distribution center by means of parallel transmission lines. The synchronous generator is equipped with AVR and GOV. The block diagram of VSrC is shown in Fig. 2 and is controlled by the proposed adaptive controller. The PID controller consists of a low-pass filter, high-pass filter, phase compensator as shown in Fig. 3.

3. Design of adaptive controller

3.1. Genetic Algorithm

GAs are search algorithms and optimization procedures, based on the mechanism of natural selection and genetics. It is necessary to establish a fitness function in order to estimate the performance of the population for each generation. The fitness strings of the populations at present are able to survive to new generation. GA consists of three operations: *Selection*, *Crossover*, and *Mutation*. The populations are randomly generated during the initialization process.

Selection is the operation, in that the fitness strings of the populations at the present time are formed in the populations to new generation. The elite selection and the roulette wheel selection are applied for *selection* operation. The elite selection is a procedure that the fitness strings of the populations at the present time are unconditionally survived to new generation. Therefore, this procedure has an advantage that the fitness strings are not weeded out by

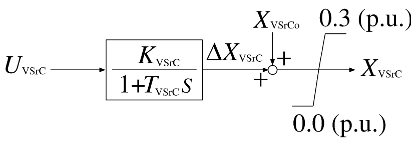

Fig. 2. Block diagram of VSrC.

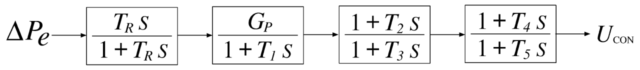

Fig. 3. PID controller.

Crossover and *Mutation* operations. In the roulette wheel selection procedure the string is selected from among the population according to probability which is proportional to the fitness. Therefore, this procedure prevents the fitness strings trapped to a local optimum.

Crossover is a operation in that offsprings are produced by exchanging two strings at a point. Therefore it is possible to generate new string and extend selected space.

Mutation is varied to the value of a point which is randomly selected in a string.

These three operations repeatedly applied until convergence condition is satisfied.

In this paper, the optimum parameters of the controller are searched by GA, since it is difficult to tune suitable parameters for several controllers in the power system. The computational flow chart of the design process of the controller is shown in Fig. 4. All parameters are coded to binary bit-strings. One string is presented by 12 bits, and the size of populations is 20 strings. In order to estimate strings for each generation, the fitness function 'Fit' is defined as follows

$$\mathrm{Fit} = \frac{1}{\mathrm{PI}_{\Delta\omega} + \mathrm{PI}_{\Delta P_e}} \tag{1}$$

$$\mathrm{PI}_{\Delta\omega} = \int_0^T \{(\Delta\omega_1)^2 + (\Delta\omega_2)^2 + (\Delta\omega_3)^2\}\mathrm{d}t \tag{2}$$

$$\mathrm{PI}_{\Delta P_e} = \int_0^T \{(\Delta P_{e1})^2 + (\Delta P_{e2})^2 + (\Delta P_{e3})^2\}\mathrm{d}t \tag{3}$$

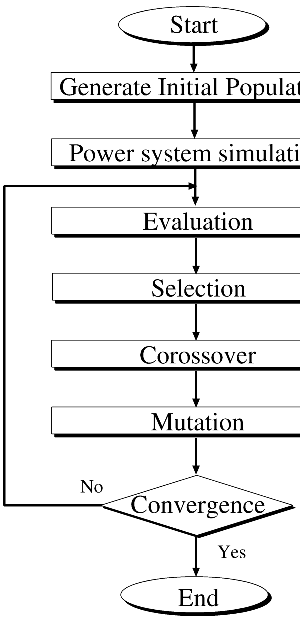

Fig. 4. Flow chart of GA.