Applying genetic algorithm on power system stabilizer for stabilization of power system

[1,3]Arnawan Hasibuan and [2,3]Syafrudin

[1]Engineering Department of Malikussaleh University, Lhokseumawe, Indonesia;[2]Engineering Faculty of Tanjungpura University, Pontianak, Indonesia;[3]School Electrical & Electronic Engineering Universiti Sains Malaysia, Malaysia. Coorresponding author: nawan_hsb@yahoo.co.id, syaf_ee@yahoo.com

Abstract : This paper the genetic algorithm method is used in Power System Stabilizer (PSS) for power system stability is discussed. Parameters of PSS on generator system in a state determined offline using genetic algorithms and the objective function is based on eigen value system was described in detail. PSS parameters and the location is calculated to maximize damping performance in different operating conditions. Genetic algorithm is a kind of random search algorithm based on the mechanism of natural selection and natural genetics. Genetic algorithms are used as search parameters of the PSS technique, which utilizes genetic operators to find the nearest optimal solution. An advantage of the search with the GA is not trapped in an early convergence.

Keyword : power system stabilizer, parameter, genetic algorithm

Introduction

Many attempts have been made in recent years, to improve the performance of damping in an attempt to maintain power system stability with the development of power system stabilizers (PSS). The requirements that must be met in order to increase damping in power systems include high-speed excitation systems, the use of high voltage air channels, and improved cooling of the power system. Use of Genetic Algorithm (GA) has recently attracted the attention of researchers in the field of control. Genetic algorithm (GA) is a powerful optimization technique, independent of the complexity of the problem in which no prior knowledge available. Procedures to be done is to search the PASS parameters via GA.

According to (Abdel-Magid & Dawoud, 1996) the use of high-speed excitation systems has long been recognized as an effective method in improving the stability limits. Static excitation system appears to offer the most practical in high-speed performance so as to provide benefits at the limits of stability. However, this resulted in high-speed damping system is deficient in certain loading conditions. To overcome this effect and increase the system damping, stabilizing signal is introduced in the system through a fixed excitation parameter lead/lag PSS. PSS parameters are usually fixed at certain values under certain operating conditions. It is important to realize that the machine parameter changes due to changes in loading, making the dynamic behavior of the machine are very different at different operating points.

In the daily operation of power systems, changes in operating conditions as a result of load changes. Systems under various loading conditions can be regarded as a limited number of plants. Using genetic algorithm, the parameters of the PSS can be specified in the offline state and the objective function is based on the system eigen-values. Genetic algorithms are used as parameter search techniques, which use genetic operators to find the nearest optimal solution. The advantage of GA technique is independent of the complexity of the performance index is considered. PSS designed in this way will work well under various loading conditions and system stability is guaranteed.

PSS Design and Location

According to (Sebaa & Boudour, 2009) Problem setting and location of PSS parameters that guarantee the performance of damping solved using the GA optimization procedure based eigen-value. For all operating conditions, power system can be modeled by a set of nonlinear differential equations as :

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

Where x is the state variable vector $x = [\delta, \omega, E_q', \Psi_d'', E_d', \Psi_q'']$, and u is the vector of the PSS output signals. The system in equation (1) is then linearized around an equilibrium operating of the power system.
First, Equations (2) and (3) describe a linear model of the power system :

$$\dot{x} = Ax + Bu \tag{2}$$
$$y = Cx + Du \tag{3}$$

In the frequency domain, the transfer function associated with equations (1) and (2) is given by :

$$P(s) = C(sI - A)^{-1}B + D \tag{4}$$

Where the poles of P(s) corresponding to the eigenvalue of matrix A.
The PSS (controllers) is a type of lead-lag and can be described as diagonal matrix K(s) :

$$u(s) = K(s)e(s) \tag{5}$$

Equations (5) can be expressed as :

$$\begin{cases} \dot{x}_k = A_k x_k + B_k e \\ V = C_k x_k + D_k e \end{cases} \tag{6}$$

Where x_k is state vector of controllers.
Combining equations (6) with equations (2) and (3) a closed-loop system is obtained.

$$\dot{x}_{cl} = A_{cl} x_{cl} \tag{7}$$

Where $\dot{x}_{cl} = \begin{bmatrix} x \\ x_{cl} \end{bmatrix}$ is the state vector of closed-loop system.
Let $\lambda j = \sigma_j \pm i\omega_j$ be the j-th eigenvalue (mode) of the closed-loop system in figure 1.
Then, the damping coefficient (ξj) of the j-th eigenvalue is defined with the following equation :

$$\xi_j = \frac{-\sigma_j}{\sqrt{\sigma_j^2 + \omega_j^2}} \tag{8}$$

The goal of the optimization procedure based gas is to reach 5% [11] damping for all modes over all operating conditions being considered, by exploring the search space controller parameters accepted.
Let l be the number of damping controllers in the power system under consideration. If a lead–lag structure with awashout stage is assumed for every controller, the following equation describes the transfer function of the *i*-th controller.

$$K_i(s) = \frac{k_i T_w s}{1 + T_w s} \frac{\left(1 + \left(\frac{\sqrt{a_i}}{\xi_i s}\right)\right)^2}{\left(1 + \left(\frac{1}{\xi_i}\sqrt{a_i s}\right)\right)^2} \tag{9}$$

The time constant T_w in the washout stage is considered constant parameter. The parameters to be determined by the GA procedure are k_i, α_i, and δ_i i = 1, …, l and the PSS location index P_{loc}.

Let Ψ_p be a vector of damping coefficients ξ_j j =1, …, n for the *p*-th operating condition. Where *n* is the total number of modes of the closed loop matrix A_{cl}. Then, the optimization problem to be solved by the GA can be written in the following form:

$$\text{Max F} = \min(\min(\Psi p))\ p = 1, \ldots, m \left(\text{if any } \sqrt{\sigma_j^2 + \omega_j^2} < \varepsilon\ \xi j = 1\right) \quad (10)$$

Subject to :

$k_{i,min} \leq k_i \leq k_{i,max}$

$\alpha_{i,min} \leq \alpha_i \leq \alpha_{i,max}$

$\delta_{i,min} \leq \delta_i \leq \delta_{i,max}$

$1 \leq P_{loc} \leq C_N^l$

where *m* is the total number of operating conditions under consideration, *ki*, ˛*i* and ı*i* are the parameters of *i*-th PSS, *P*loc is the location index, representing the repartition of *l* PSS through the *N* machines, the number of all possibilities is ClN (combinations). And ε is the error in computing the system eigenvalues. This problem is a complex optimization problem with an implicit objective function, depending on the evaluation of eigenvalues of a state matrix and which is very difficult to solve using conventional methods.

Genetic algorithm is an optimization method based on the mechanics of natural selection and natural genetics. The search process is very similar to the natural evolution of biological creature in which successive generations of organisms are given birth and raised until they are able to breed. Only the fittest will survive to reproduce while the weakest will be eliminated.

Individuals in GAs are in the form of character strings that are analogous to the chromosome found in DNA. Each individual represents a possible solution within a search space. A number of individuals in the population are then made to go through a process of evolution, in order to produce a new generation of individuals that is closer to the optimal solution.

Overview Genetic Algorithm

According to (Arnawan, 2001) In genetic algorithm, the set of parameters (an individual) or in biology called a chromosomal for a problem in this case is a function object, created or encoded in binary form. And in every generation, a number of individuals (populations) were evaluated in parallel to match them, as a object function to be optimized. The new populations and enhanced resurrected from the old through the application of genetic operators such as selection, crossover, and mutation.

Selection is a simple service where a long strand which is copied into the mating (ing pool). In accordance with the principle of continuity of matching, matched string higher (meaning having a stronger fitness value) have a greater likelihood for selected follow the operation of other operators.

Crossover randomly selects a pair of parent in the group (pool) and form two offspring through the exchange of corresponding segments of the parent. The population of randomly selected crossover in the string. Crossover exchange in conjunction with genetic material from two parent chromosomes resulting from the two parent genes of different combined into their new descendants.

Mutation is a random change of the position of the string. In presenting a binary string, a simple change mean 0 to 1 and vice versa. Random mutator provides background variation and produce material benefits to the population. Operations were repeated until the specified number of generations is reached. For the structures of genetic algorithms as show in Figure 1.

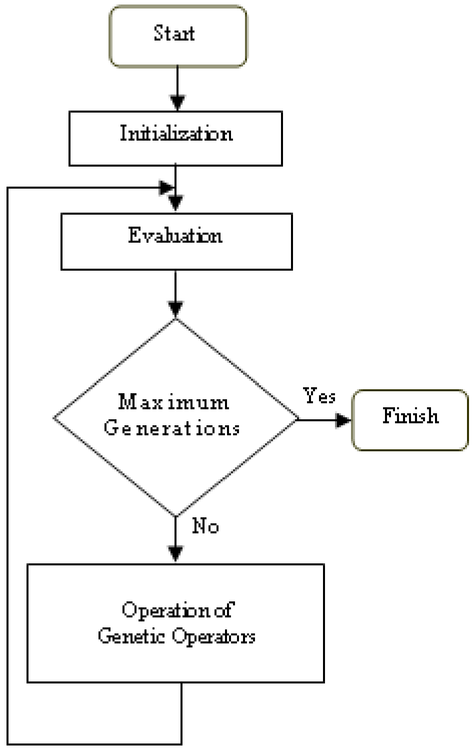

Figure 1. Flow chart of Genetic Algorithm

Step Problem Solving

Before using the methods of tuning the PSS parameters in electric power systems, the first step that must be addressed:

Determine the search equation model of PSS parameters to be optimized. Optimization (minimization / maximization) damping by tuning the value of PSS parameters are known as a linear relationship and expressed as the objective function.

After the previous step is completed, the next step is to work on solving optimization using genetic algorithms, i.e.:

1. Determine the input parameters of the program in accordance with the procedure representation Genetic Algorithm (GA) include: the number of populations and generations, the coefficient of crossover and mutation coefficient.
2. Run the simulation program optimization with genetic program. Evolutionary process the program will report the optimum value, the value of the PSS parameters, the stability of power systems, and report the required computational load.
3. To obtain good results, the coefficient of genetic parameters such as coefficient of crossover, mutation coefficient, population size and number of generations should be varied.

To run the program that created an integrated genetic, in addition to the evaluation function with the solution space is required input coefficient of genetic parameters. The entire genetic parameters obtained by trial and error when performing the test program. This value supports the evolution of a program to produce the optimum value of the function of objects with varying computational load. In the process of evolution of the program genetic parameters required coefficient is the number of population, number of generations, crossover coefficient and the coefficient of mutations. With changed the coefficient of genetic parameters can show results that vary significantly.

Conclusion

Problem of choosing the parameters of the PSS that stabilize the generator set has been converted into a simple optimization problem is solved by GA and eigen-values based on the objective function. A digital simulation model of a power system linearized at some point operations used in genetic algorithm optimization process. PSS parameters are optimized in a position off-line. It is suggested that the parameters of PSS should be updated based on the measurement of real power generation and reactive power. An advantage of the search with the GA is not trapped in an early convergence.

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