ROBUST TUNING PSS FOR MULTIMACHINE POWER SYSTEMS USING MULTIOBJECTIVE HYBRIDATION TECHNIQUE

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ABSTRACT-

Power system stabilizers (PSS) are usually used in power system plants to damp out power system oscillations. In this paper, a simultaneous coordinated tuning procedure of multiple power system stabilizers (PSSs) in multimachine power systems based multiobjective functions Hybridation technique using genetic algorithms (GAs) and the requit simulé (RS). To validate the effectiveness of this tuning approach in enhancing the stability of power systems, modal analysis and nonlinear simulations have been carried out on a multimachine power system.

Keywords:Genetic algorithm, Requit simulé, modal analysis, power system stabilizer, simultaneous tuning, small signal stability.

1. INTRODUCTION

In a power system, the rotor generators angular stability depends on two electromagnetic torque components; the synchronizing torque and the damping torque. A lack of synchronizing or damping torque leads respectively to an aperiodic or an oscillatory instability (Y.L. Abdel-Magid and M.A. Abido, 2003)

The excitation system with its voltage regulator has an important impact on the two torque components, and thus, on the stability. During a disturbance, the increase of the excitation generator voltage has the effect of increasing the internal machine voltage and the synchronization power. So, the use of rapid excitation systems has long been considered as an effective method to increase the synchronizing torque and transient stability limits (Y.L. Abdel-Magid, M.A. Abido, , S. Baiyat and A.H. Mantawy, 1999).

The static excitation systems, where the excitation current is provided by a controlled rectifier, seem to be the appropriate way to achieve both rapid performances and high gain; the limits of the transient stability system will be increased.

Unfortunately, this benefit may be outweighed by the excitation system effect on the damping oscillations by reducing the damping torque (F.P. DeMello and C. Concordia, 1969, A.L.B. Do Bomfim, G.N. Taranto and D.M. Falcao, 2000).

To compensate this effect and improve the damping system, additional signals provided by a Power System Stabilizer (PSS) are generally injected into the excitation system.

The PSS parameters fixed under certain operating conditions are set to the predetermined values. It is important to know that the generator parameters change with the load variation: the machine dynamic behaviour varies with the operating points.

The PSSs must be correctly adjusted and coordinated in such a way that the stability of the global system can be guaranteed for a wide range operating points.

In PSSs tuning, adjustment sequences and location are critical parameters for stabilizing optimal performance. A PSS can be adjusted to improve the damping mode. However, it can produce undesirable effects for other modes. Moreover, the various investments in of PSSs make oscillation behavior different according to the operating points.

In the literature, several approaches using genetic algorithms (GA/RS) have been proposed for coordinated tuning of multiple power system stabilizers (K. Hongesombut & all 2005, M.A. Abido *2000,* K. Hongesombut and Y. Mitani 2004, Y.Y. Hsu and C.L. Chen 1987, P. Kundur, 1994, E.V. Larsen and D.A. Swann, 1981). The main advantage of the AG compared to other optimization techniques is to be a global population optimization method where the solution is independent of the problems complexity.

In many searches, the location of PSSs is chosen before selected tuning methods. The participation factors (PF) method has been extensively used to identify the PSSs possible locations (K. Hongesombut & all 2005, M.A. Abido *2000,*Panda and N. Prasad Padhy, 2007, F. Rashidi and M. Rashidi, 2000).

Generally, when having too much and/or poorly positioned PSSs may cause dysfunctioning of the system. Thus, to reduce these undesirable effects, it is necessary to locate and select an appropriate number of PSSs.

The objective of this work is to ensure an optimum tuning of PSSs with a better location, while reducing their numbers. Hence, we have developed an hybridation method using AG/RS simult anneling program tackling a multi-objective function, based on the real part poles and the damping factor.

The multi-machines power system studied consists of 16 generators and 68 nodes; it represents the New England/New York interconnected network system.

2. PROBLEM FORMULATION

A widely used conventional lead-lag PSS is considered in this study. Its transfer function, given in (1), consists of an amplification block with a control gain K_{PSS}, a washout block with a time constant T_w and two lead-lag blocks for phase compensation with time constants T_1, T_2, T_3 and T_4.

$$V_{PSS}(s) = K_{PSS} \cdot \frac{sT_w}{1+sT_w} \cdot [\frac{(1+sT_1)}{(1+sT_2)} \cdot \frac{(1+sT_3)}{(1+sT_4)}] \cdot \Delta\omega(s) \qquad (1)$$

Where, the PSS output signal, V_{PSS}, is a voltage added in the system excitation input. The generator speed deviation $\Delta\omega$ is almost used as an input signal of PSS.

In small signal stability studies, the linearized system model around an equilibrium point is usually applied (P. Kundur, 1994).

The analysis of the system eigenvalues, resulting from model linearization, provides important information about the system stability. It indicates the presence of unstable or poorly damped modes and identifies the characteristics of these modes and their origins.

To complete the analysis of system stability and confirm the results obtained from the eigenvalue analysis, nonlinear time domain simulations should be applied on the system (Y.Y. Hsu and C.L. Chen 1987).

The criteria used for examining the results are based on eigenvalues analyses: the real part (σ) of an eigenvalue (λ), given in (2), and the damping factor (ζ), given in (3) (P. Kundur, 1994).In PSS tuning, All system eigenvalues must be placed in the D stability region in the s-plan; this region is determined by the following criteria: $\sigma_{cr} = -1$, $\zeta_{cr} = 10\%$ (Y.L. Abdel-Magid and M.A. Abido, 2003).

$$\lambda = \sigma \pm j\omega \qquad (2)$$

$$\zeta = \frac{-\sigma}{\sqrt{\sigma^2 + \omega^2}} \qquad (3)$$

The multiojective function is formed to optimize a composite set of two eigenvalue-base objective functions, comprising the real part eigenvalue (σ) and the damping factor (ζ) of the dominate electromechanical modes.

We propose in this study a GA program that allows to choose the best PSS location and to reduce their number simultaneously, and we use GA/RS for coordinated tuning of PSS parameters.

In order to evaluate the approach performance and consequently the damping performance, the study will be divided in three applications. In the first one (**Case A**) the PSS locations and their number are predetermined by Participation Factor method and the PSSs are then tuned by GA programme. In second application (**Case B**), we have used the same PSS number as the previous application but we have used the GA for finding PSS locations and tuning their parameters simultaneously. This application can be represented graphically by Figure 1. In the last application (**Case C**), PSS parameters, are optimized simultaneously by GA/RS programme..

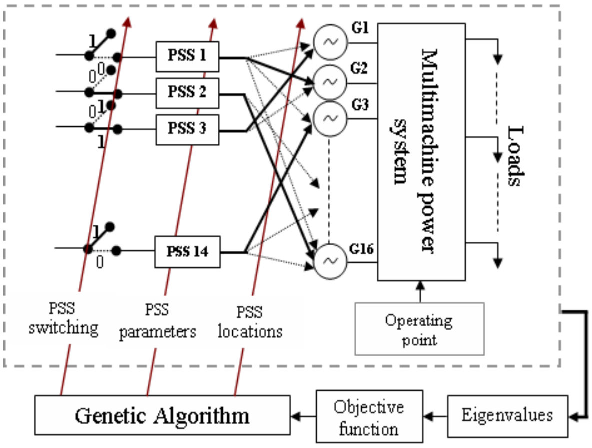

Figure 1. Graphic representation of case C.

Each PSS is connected in series with a switch that can take the values of 0 or 1. The variables representing these switches are added to the other PSS variables of the AG programme. The switch can connect (if its value is 1) or disconnect (if its value is 0) the PSS of the associated generator which can permit finally to reduce the PSS number. During the optimization, when the multiobjective function does not vary significantly because of little influence of some PSSs on the system damping, the AG will not take them into consideration and will eliminate them from the list of PSSs to be installed.

3. APPLICATION RESULTS AND DISCUSSION

The applications were made on New England/New York multimachine power system (16 generators and 68 buses). Details of the system data can be found in (G. Rogers, 2000).

To test the PSS performance tuning, eigenvalues analysis of linear model will be done and nonlinear simulation analysis will be also carried out. The nonlinear time domain simulations were performed for a three phase-fault, with duration of 100 ms on the line 59 # 23. The simulation results represent the speed variations of five generators, the most affected by this defect; they are G.56, G.58, G.59, G.61 and G.68.

The open-loop electromechanical modes of the system at the studied operating point are shown on Figure 2. The mode repartition shows obviously that the system is strongly unstable.

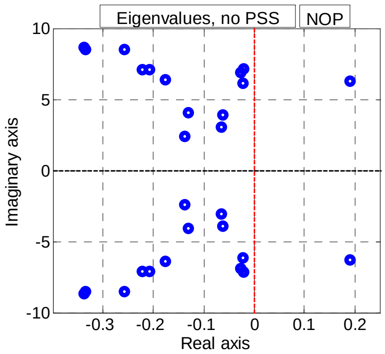

Figure 2. Electromechanical modes of the open-loop system.

3.1 Cases A

Participation factor method is used in this application to find the suitable generators for installing PSSs. 14 generators are found necessary by this method. The coordinated synthesis of parameters for these 14 PSSs is optimized using genetic algorithms. Figure3 demonstrates the electromechanical modes of the closed-loop system using these optimized 14 PSSs. The analyse of system eigenvalues gives a minimum damping factor ζ_{min} = 16.19%and a maximum eigenvalue real part $\sigma_{max} = -0.991$.

Hence, all electromechanical modes were generally shifted in the *D* stability region.

Analyse of generator speed variations, shown on Figure 4, demonstrates clearly that the system becomes stable and the oscillations are damped in less than 10 seconds.

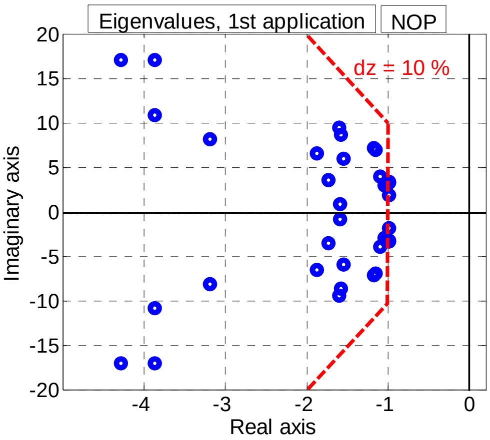

Figure 3. Electromechanical modes, cases A.

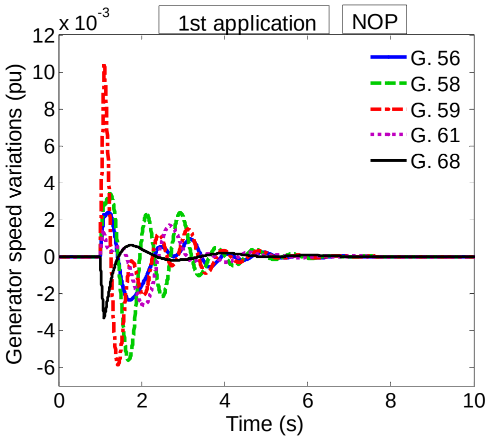

Figure 4. Generator speed variations, cases A.

3.2 Cases B

Considering a fixed number of PSSs equal to 14, these PSS locations are considered as variables to be optimized simultaneously with PSS parameters using a GA programme.

Figure 5 shows the s-plan system mode repartition. The modes are clearly more shifted in the *D* stability region. The minimum damping factor and maximum eigenvalue real part are respectively ζ_{min} = 17.28% and $\sigma_{max} = -1.338$.

Thus well improvements are won on the minimum factor damping (of 6.7%) and on the maximum real part eigenvalue (of 35%) compared to the first application.

Figure 6 demonstrates the non-linear time domain simulation of generator speed variations. The evaluation of system damping performance shows that the settling times of generator speed variation response are improved very well compared to the first application; for example, oscillations of generators (61 and 68) are damped two times faster than their equivalents in the first application.

Thus, the system stability can be improved very well when PSS locations are chosen by GA.

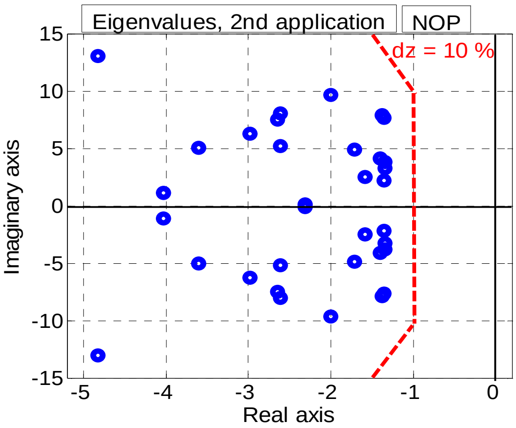

Figure 5. Electromechanical modes, cases B.

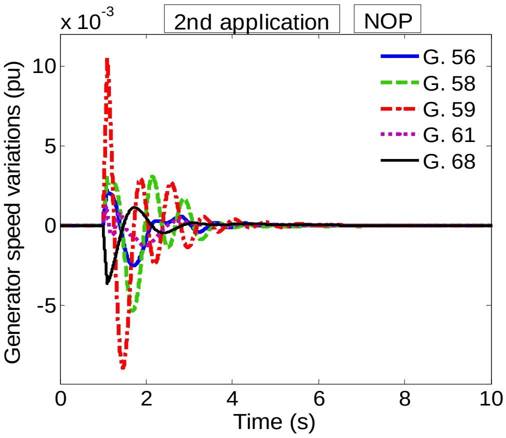

Figure 6. Generator speed variations, cases B.

3.3 Cases C

Considering in this application 12 PSSs number and to be optimized simultaneously with their parameters, we find that are quite sufficient to get a well stable system.

Figure 7 shows the system electromechanical modes, with ζ_{min} = 10.42% and $\sigma_{max} = -0.912$. All the modes are then shifted in the *D* region. We notice that we get almost the same performance as compared with case A, using only 12 PSSs.

Figure 8 gives the simulation results of generator speed variations. The overall stability of the system is thus ensured and the oscillations are damped in less than 10 seconds.

This confirms that it is necessary to choose the PSS optimal locations simultaneously with a coordinated tuning while using only the necessary PSS number.

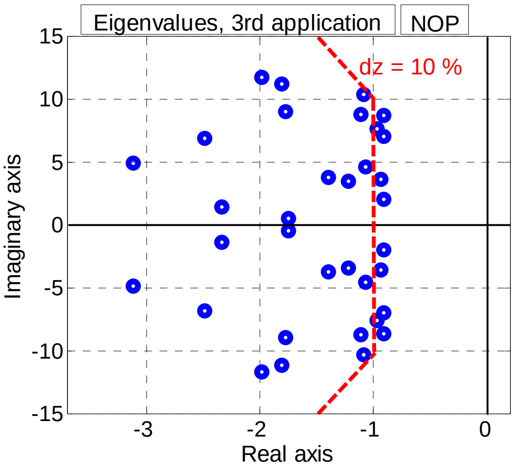

Figure 7. Electromechanical modes, cases C.

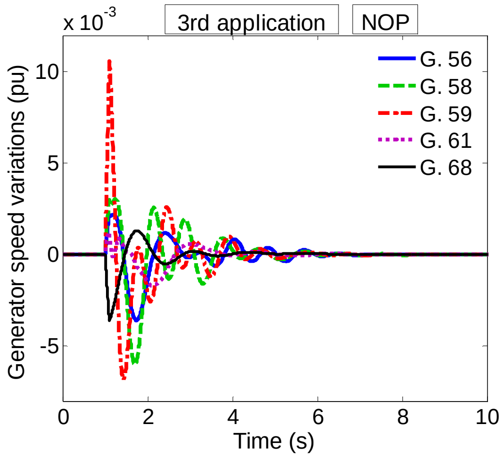

Figure 8. Generator speed variations, cases C.

4. CONCLUSION

In this study, a simultaneously tune multiple power system stabilizers (PSSs) based on multiobjective functions by using genetic algorithms (GA/RS) is presented. Eigenvalues analysis and nonlinear time domain simulations are done to verify the effectiveness of this technique in enhancing the small signal stability of multimachine power systems. The analysis of results showed that the dominant electromechanical modes are well shifted in the D-stability region. To avoid using the participation factor method to find the possible PSS locations, the GA is proposed to search the best PSS locations. The results demonstrate a well improvement of close-loop plant performance. The GA is also proposed to reduce the needed number of PSSs to realise good damping system. Using hybridation method in the nonlinear time domain simulations which are applied for large disturbance and for many operating conditions has also confirmed the obtained results and proved that the power system oscillations are well damped.

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