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SIMULTANEOUS COORDINATED AND TUNING OF PSS FOR A MULTIMACHINE POWER SYSTEM USING A NEW HYBRIDIZATION (GA-GR) VIA A MULTI-OBJECTIVE FUNCTION

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ABSTRACT

This work presents a new coordinated and robust tuning procedures of power system stabilizer *PSS* using a novel hybridization technique to damp out power system oscillations. This hybridization is based a combination between stochastic Genetic algorithm (GA) methods and deterministic methods (gradient); it is called GA-GR, and even between themselves stochastic methods genetic algorithm and simulated annealing (GA-SA). The proposed approach is used for a multi-objective function based on the real part of eigenvalues and the damping factor, to search for optimal stabilizer parameters. To examine the effectiveness and robustness of this tuning approach in enhancing the stability of power systems, modal analysis and nonlinear simulations have been carried out on New England/New York interconnected network system 68-bus, 16-machine power system.

Keywords: *Genetic Algorithm (GA), Gradient Method, Modal Analysis, Power System Stabilizer, Multimachine Power System, Small Signal Stability.*

1. INTRODUCTION

Due to growth in electric power demand and increasing network structure Dynamic Stability problems, e.g. low frequency oscillation, become important to electric power systems [1]. Low frequency oscillations present limitations on the power-transfer capability. To enhance system damping, the generators are equipped with *PSSs* that provide supplementary feedback stabilizing signals in the excitation system [2]. The power systems stabilizers which are widely used for mitigating the effects of low frequency oscillation modes improve the performance and functions of power systems during normal and abnormal operations. The *PSSs* keep the power system in a secure state and protect it from dangerous phenomena [3]. 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) have been proposed for coordinated and tuning of multiple power system stabilizers [4-10]. In many searches, the location of *PSSs* is chosen before selecting tuning methods. The participation factors (PF) method has been extensively used to identify the *PSSs* possible locations [10-12]. Hybridization is the result of a cross between two species, two kinds or two individuals of related species and is also a crossing of different species. In the case of optimization, the hybridization can be done between deterministic and stochastic methods and even between themselves stochastic methods. The objective of this work is to ensure an optimum coordination and tuning of *PSSs*. Hence, we have developed a hybrid method using GA/Gradient program for a multi-objective function And comparison between the methods of hybridization met-heuristic, based on the real part poles and the damping factor. The multi-machine power system studied consists of 16 generators and 68 nodes; it represents the New England/New York interconnected network system.

2. POWER SYSTEM MODEL

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A power system can be formulated as follows:

$$\dot{X} = f(X, U) \qquad (1)$$

Where X is the vector of the state variables and U is the vector of input variable. The state vector of n generators is given as $[\omega_i, \delta_i, E'_{qi}, E_{fdi}]^T$ and U is the PSS output signal. This model is widely used in the analysis of parameter values settings of PSS [13].

$$\begin{cases} \omega_i = \dfrac{(P_m - P_e - D\omega)}{M} \\ \delta_i = \omega_0(\omega - 1) \\ E'_{qi} = \dfrac{(-E_q + E_{fd})}{T'_{d0}} \\ E_{fdi} = \dfrac{-E_{fd} + K_a(V_{ref} - V_t)}{T_a} \end{cases} \qquad (2)$$

In small perturbations stability studies, linearization model of power system around its operating point is often applied [14]. The state equations of power system can be written as follows:

$$\dot{X} = AX \times BU \qquad (3)$$

Where A is a $4n \times 4n$ matrix and is given by $\partial f / \partial X$, while B is the input matrix with order $4n \times m$ and is given by $\partial f / \partial U$. The A and B are calculated with each operating point. The state vector X is a $4n \times 1$ and the input vector U is a $m \times 1$.

3. POWER SYSTEM STABILIZER

A widely used conventional lead-lag *PSS* is considered in this study. Its transfer function, given in Eq. 1, consists of an amplification block with a controller 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.

$$V_{PSS}(s) = K_{pss} \cdot \frac{sT_w}{1 + sT_w} \cdot [\frac{(1 + sT_1)}{(1 + sT_2)} \cdot \frac{(1 + sT_3)}{(1 + sT_4)}] \cdot \Delta\omega(s) \qquad (4)$$

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*. Small signal stability a study, the linearized system model around an equilibrium point is usually applied [14].

4. OBJECTIVE FUNCTION

The criteria used for examining the results are based on eigenvalue analysis: The real part (σ) of an eigenvalue (λ), given in Eq. 5, and the damping factor (ζ), given in Eq. 6 [14]. In *PSS* tuning, all system eigenvalues must be placed in the *D* stability region in the S-plan as shown in Figure 1; this region is determined by the following criteria: $\sigma_{cr} = -1$, $\xi_{cr} = 10\%$ [4]. In this study, The value of a is considered as 1.

$$\lambda_i = \sigma_i + j\omega_i \qquad (5)$$

$$\xi_i = -\frac{\sigma_i}{\sqrt{\sigma_i^2 + \omega_i^2}} \qquad (6)$$

$$\begin{cases} j_1 = (\sigma_{cr} - \max(\sigma_i)) \\ j_2 = (\xi_{cr} - \min(\xi_i)) \\ j = j_1 + aj_2 \end{cases} \qquad (7)$$

The three parameters to be optimized for each *PSS* (a gain and two time constants) are subject to the following constraints:

$$\begin{cases} 1 \le K_m \le 50 \\ 0.01 \le T_{1m} \le 1 \\ 0.01 \le T_{3m} \le 1 \end{cases} \qquad (8)$$

The other parameters (T_W, T_{2m}, T_{4m}) of *PSS* are considered constants: T_W = 10, T_{2m} = 0.1 and T_{2m} = 0.05.

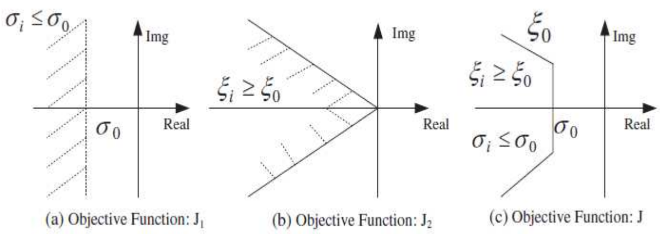

Figure 1: Zone D-shape stability

5. TECHNICAL APPROACH

It can be extremely beneficial to associate a search method whose the characteristics of exploration are very high exploration in a search method whose strong point is exploitation. Hence, the idea of hybrid methods. Where from the idea of hybrid methods. The hybrid methods allow not only to widen the specter of application of certain methods of resolution but also to increase their performance. To apply effective these techniques, we have good visibility with respect to the strong points of each method separately. For example, Genetic algorithms are very efficient when it comes to exploring the search space, but they turn out, then incapable to exploit effectively the zone on which the population converges. It is then more interesting (in terms of duration of execution and quality of solutions) to stop the genetic algorithm to

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use another method. The hybridization can, also, be used to solve simultaneously various aspects of the same problem: This method is often used in the field of the management of production [15] where raise simultaneously various problems such as assignments of machines, Personnel and operations as well as inventory management.

6. TECHNICAL HYBRIDIZATION

Hybridization can take place in one or more components of a research method. She can also consist in assembling several hybridization methods into a single hybrid method. The various techniques of hybridization can be distributed in three main categories [15].

Sequential hybridization consists in executing sequentially various methods of search so that the result of a method serves as an initial solution to the next. This technique of hybridization is the simplest; it does not require modification of the used methods of resolution: It is enough to initialize every method of pre-calculated solutions (hybridization by batch).

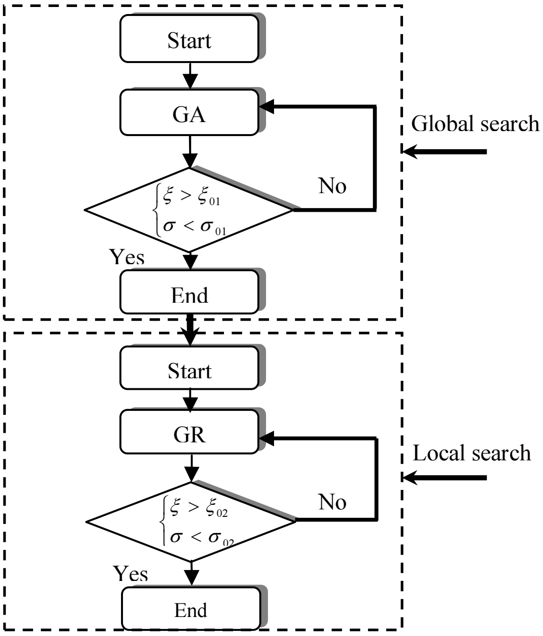

Figure 2: Sequential hybridization or batch (batch model)

Synchronous parallel hybridization is obtained by incorporating a method of resolution into another one. It is a technique finer than the previous one. Indeed, it is necessary to take into account strong interactions between the methods in this type of hybridization (integrative hybridization).

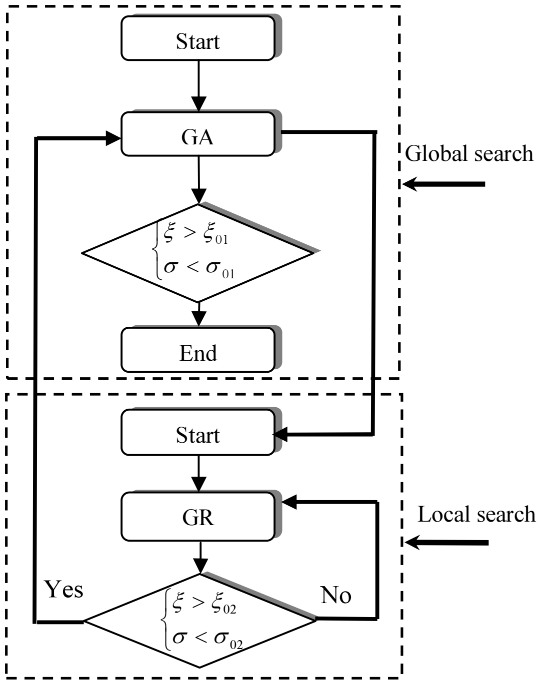

Figure 3: Synchronous parallel hybridization or integrative

Asynchronous parallel hybridization consists in developing parallel various methods of resolution. This co-evolution allows good cooperation solving methods through a coordinator to ensure the transfer of information between the methods of resolution. This technique requires the modification of resolution methods to assure the communication with the coordinator. It is called; Asynchronous parallel hybridization or multiple integrative.

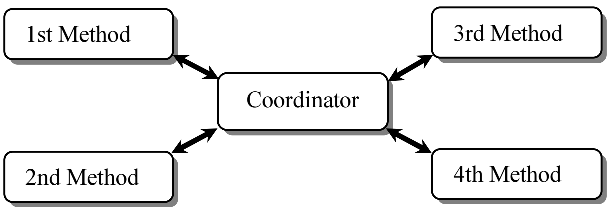

Figure 4: Asynchronous parallel hybridization or multiple integrative

7. APPLICATION RESULTS AND DISCUSSION

In this study, we have selected 14 PSS from 16 using genetic algorithm, the applications were tested on New England/New York multimachine power system (16 generators and 68 buses) as shown in Figure 5, to evaluate the performance of proposed approach based

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stabilizers. Details of the system data can be found in [16].

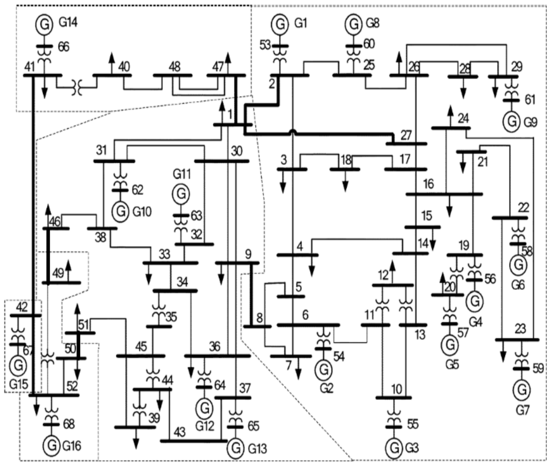

Figure 5: 16-machine and 68-bus power system

Table 1 shows the optimal values of the optimized parameters with the best location of PSS with genetic algorithm. It should be noted that the proposed algorithms are run several times and the best parameters of PSS is chosen.

Table 1: Optimal parameters of PSS

Gen.	K_{PSS}	T_1	T_3
53	26.79	0.624	0.671
54	20.32	0.387	0.793
55	39.31	0.556	0.179
56	29.27	0.222	0.310
57	35.06	0.156	0.587
58	33.31	0.329	0.577
60	7.853	0.921	0.393
61	34.23	0.276	0.139
62	27.23	0.729	0.087
63	21.36	0.332	0.105
64	6.472	0.397	0.801
66	33.45	0.025	0.283
67	38.42	0.470	0.034
68	36.90	0.168	0.248

The Figure 6 represents the evolution of the objective function depending on the number of generations in case batch model optimization between the GA-SA optimization.

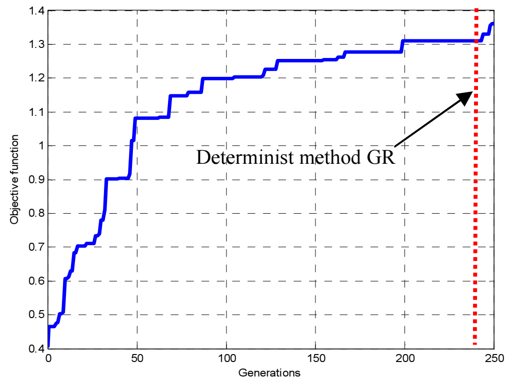

Figure 6: The evolution of objective function using hybridization technique (GA-GR)

To test the *PSS* performance tuning, eigenvalue 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. Figure 7 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 respected.

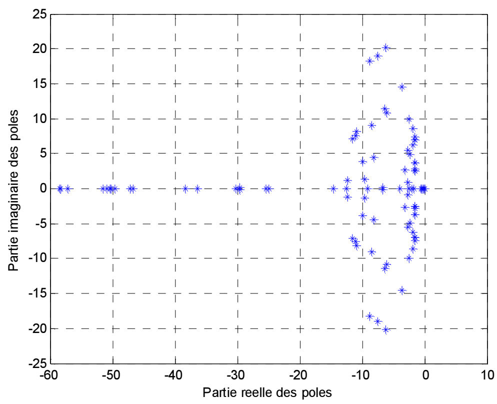

Figure 7: S-plan system mode repartition

The Figure 8 represents the nonlinear time domain simulations of the speed variations of G4 and the Figure 9 represents the comparison of the poles using batch model hybridization GA-RS with the method of GA. Whereas, The Figure 10 represents the comparison of the poles using integrative model hybridization GA-RS with the method of GA and the Figure 11 represents the comparison of the poles using batch model hybridization GA-Gradient method with the GA method.

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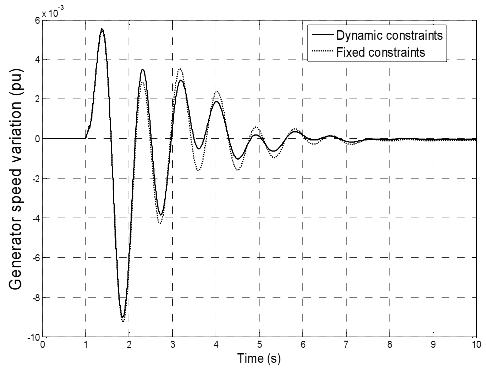

Figure 8: Speed variations of generator 4

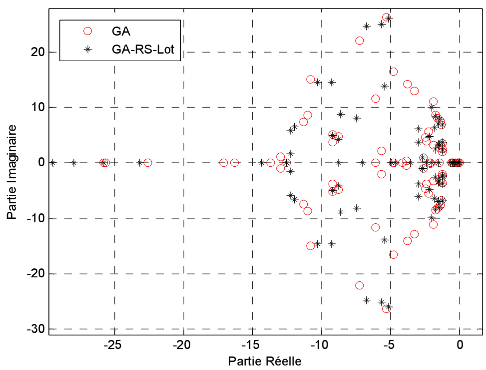

Figure 9: Distribution of eigenvalues of the system in the complex plane.

Hybrid algorithms are probably among the most powerful methods for solving optimization problems. Unfortunately, necessary calculation time can become prohibitive because of the number of individuals manipulated in the population. A way to solve this problem is the parallelization of these algorithms on parallel machines or on distributed systems. The concern of performances and the computing resources limit the possibilities of hybridization. Therefore, we must be careful with respect to the techniques used to obtain good cooperation between the components and hybrid methods.

The use of hybrid algorithms such as the GA/ Gradient approach has shown its effectiveness in relation to the hybridization metaheuristic performance standpoint and the improvement of the objective function. Indeed, we were able to establish;

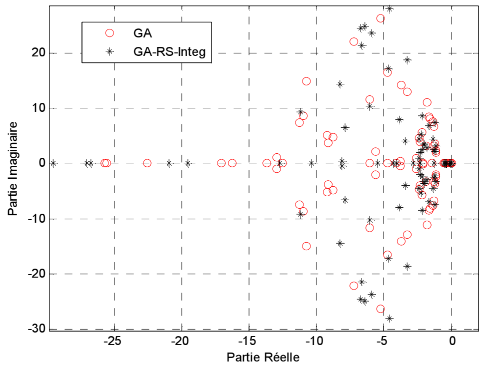

Figure 10: Distribution of eigenvalues of the system in the complex plane

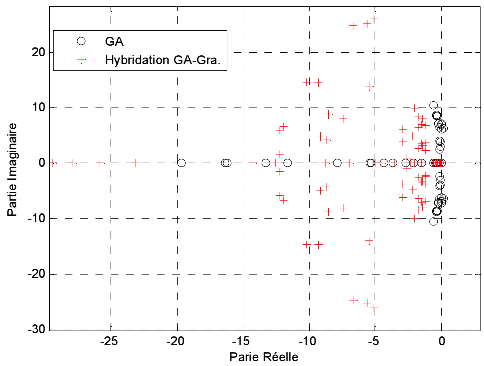

Figure 11: Distribution of eigenvalues of the system in the complex plane.

- An improvement of 29.7% compared to the integrative hybridization using the genetic algorithm and simulated annealing.
- An improvement of 36.9% compared to the hybridization batch using the genetic algorithm and simulated annealing.
- Improvement of 62.7% compared to hybridization GA / gradient using genetic algorithm and gradient method.

Thus, we can say that hybridization using a method of exploration for the metaheuristic population as the genetic algorithm and a method for deterministic operation is very effective in finding a global optimum of the optimized design of *PSS* as well as their coordination.

8. CONCLUSION

In this study, a simultaneously tune multiple power system stabilizers (*PSSs*) based on multi-objective function by using hybridization between genetic algorithm and gradient method (GA/Gradient) is presented. Eigenvalue analysis and nonlinear time domain simulations are done to verify the effectiveness of this technique in

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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. Where, GA is proposed to search the best *PSS* locations.

Combinations of metaheuristics methods are entered they are with deterministic methods for the determination of global optimum, Allowed to open a breach of development of the optimization towards better solutions, for adjustment and coordination of *PSS*, as the methods used separately. Indeed, we were able to find in this study. First of all, satisfactory results using integrative hybridization. Case genetic algorithm and annealed algorithm, compared to the genetic algorithm; Secondly, an important and significant improvement respectively, compared to the GA and compared the integrative hybridization using hybridization batch, and in the finally, a significant improvement compared to previous approaches. The hybridization that involves a method of population for exploring search spaces and deterministic exploration of these space methods, Show to its effectiveness and its liveliness found the global optimum.

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