

Educational Support Using Graphical User Interfaces to a Robust Stabilizer H₂-PSS Based Genetic Algorithms study

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Abstract: This paper presents the realization and development of a graphical user interface (GUI) for teaching and research in the study of a genetic algorithm (GA) applied to power system stabilizer (PSS) for an advanced robust H₂ controller based on a frequency technique applied on automatic excitation control of powerful synchronous generators, to improve transient stability and its robustness of a single machine-infinite bus system (SMIB). The GA is applied to solve an optimization problem and to achieve control parameters of PSS. The GUI is a useful average to facilitate stability study of power system with the analysis and synthesis of regulators, and resolution of the compromise: results precision / calculation speed. The computer simulation results obtained by the developed graphical user interface (GUI) have proved the efficiency and robustness of the robust H₂ adapted with a genetic algorithm, in comparison with a conventional PSS, showing stable system responses almost insensitive to large parameter variations. This robust control possesses the capability to improve its performance over time by interaction with its environment. The results proved also that good performance and more robustness in face of uncertainties (test of robustness) with the linear robust H₂ controller (optimal LQG controller with Kalman Filter) adapted with a genetic algorithm in comparison with using the classical regulator PID.

Keywords: GUI-MATLAB, Educational Support, powerful synchronous generators, AVR and PSS, LQG control, Kalman filter, stability and robustness, genetic algorithms.

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1. Introduction

Power system stabilizers (PSS) have been used for many years to add damping to electromechanical oscillations. The use of fast acting high gain AVR's and the evolution of large interconnected power systems with transfer of bulk power across weak transmission links have further aggravated the problem of low frequency oscillations. The continuous change in the operating condition and network parameters result in corresponding changes in the system dynamics [1, 2]. This constantly changing nature of power systems makes the design of damping controllers a very difficult task. Power system stabilizers (PSS) were developed to extend stability limits by modulating the generator excitation to provide additional damping to the oscillations of synchronous machine rotors. Recent developments in the field of robust control provide methods for designing fixed parameter controllers for systems subject to model uncertainties.

Conventional PSS based on simple design principles such as PI control and eigenvalue assignment techniques have been widely used in power systems [3, 5]. Such PSS ensure optimal performance only at their nominal operating point and do not guarantee good performance over the entire operating range of the power system. This is due to external disturbances such as changes in loading conditions and fluctuations in the mechanical power. In practical power systems networks, a priori information on these external disturbances is always in the form of certain frequency band in which their energy is concentrated.

The stabilizer of this new generation for the system AVR – PSS, aimed at improving power system stability, was developed using the robust controller H₂ based on LQG.

This has the advantage of maintaining constant terminal voltage and frequency irrespective of conditions variations in the system study. The H₂ control design problem is described and formulated in standard form with emphasis on the selection of the weighting function that reflects robustness and performance goals [14]. The proposed system has the advantages of robustness against model uncertainty and external disturbances (electrical and mechanical), fast response and the ability to reject noise.

The synthesis of robust control H₂ using an advanced frequency technique based on power system stabilizer, the parameter tuning of this later is very important for an adapted robust control H₂ with the variations loading conditions, and configurations as the machine parameters change with operating conditions. The genetic algorithm is a global search technical and an optimization procedure based on natural inspired operators such as crossing, and selection [5,6]. Unlike other optimization methods, the (G.A) operate under several encodings parameters (binary, ternary, real...), to be optimized and not the parameters themselves. In addition, to better guide the AVR-PSS optimal parameters search, the (G.A) use a performance index to approach this solution [6].

GUI (graphical user interface) creates graphical display in one or more windows containing controls, called components that enable a user to perform interactive tasks. The user of the GUI does not have to create a script or type commands at the command line to accomplish the tasks [18, 19]. Unlike coding programs to accomplish tasks, the user of a GUI need not understand the details of how the tasks are

performed. The graphical user interface (GUI) can make the understanding of the effects of stability study of power system with the analysis and synthesis of regulators, and resolution of the compromise: results precision / calculation speed.

Simulation results obtained by developed graphical user interface (GUI) shown the evaluation of the proposed linear control methods based on this advanced frequency techniques optimized by the genetic algorithms applied in the automatic excitation regulator of powerful synchronous generators: the robust H₂ linear stabilizer and conventional PID control optimized by the genetic algorithms schemes against system variation in the SMIB power system, with a test of robustness against parametric uncertainties of the synchronous machines (electric and mechanic), and make a comparative study between these two control techniques for AVR – PSS systems.

2. System Description Studied Under GUI

2.1. Dynamic Power System Model

2.1.1. Power System Description

In this paper the dynamic model of an IEEE - standard of power system, namely, a single machine connected to an infinite bus system (SMIB) was considered [4]. It consists of a single synchronous generator (turbo-Alternator) connected through a parallel transmission line to a very large network approximated by an infinite bus as shown in figure 1.

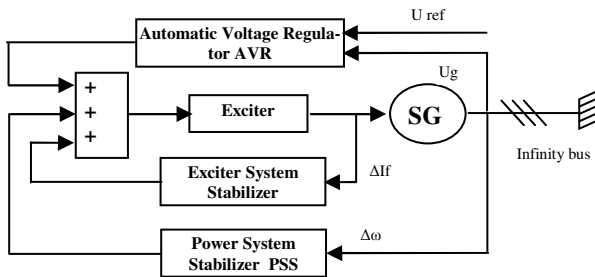


Figure 1 Standard system IEEE type SMIB with excitation control of powerful synchronous generators

2.1.2. The modeling of powerful synchronous generators

This paper is based on the **Park** modeling of powerful synchronous generators. The PSG model is defined by equations (1 to 12) [4, 15]:

$$\frac{d\delta}{dt} = \omega_B (S_m - S_{m0}) \quad (1)$$

$$\frac{d\delta_m}{dt} = \frac{1}{2H} [-D(S_m - S_{m0}) + T_m - T_e] \quad (2)$$

$$\frac{dE'_q}{dt} = \frac{1}{T_{d0}} [-E'_q + (x_d - x'_d)i_d + E_{fd}] \quad (3)$$

$$\frac{dE'_d}{dt} = \frac{1}{T_{q0}} [-E'_d + (x_q - x'_q)i_q] \quad (4)$$

$$\frac{dE_{fd}}{dt} = \frac{1}{T_A} [K_A(V_{ref} - V_t)] - \frac{1}{T_A} E_{fd} \quad (5)$$

The first two equations are obtained from the second order swing equation as

$$M \frac{d^2\delta}{dt^2} + D \frac{d\delta}{dt} = T_m - T_e \quad \text{with} \quad M = \frac{2H}{\omega_B} \quad (6)$$

The stator equations in *dq* & DQ reference frames are given as

$$V_q = E'_q + x'_d i'_d - R_a i'_q \quad (7)$$

$$V_d = E'_d - x'_q i'_q - R_a i'_d \quad (8)$$

$$\text{If} \quad x'_q = x'_d = x' \quad (9)$$

$$V_q + jV_d = (E'_q + jE'_d) - (i_q + ji_d)(R_a + jx') \quad (10)$$

$$V_Q + jV_D = (E'_Q + jE'_D) - (i_Q + ji_D)(R_a + jx') \quad (11)$$

The system equations such as the torque, state variable equations are also presented here in this context. The electrical torque, T_e is expressed in terms of state variables E'_d and E'_q and the non-state variables i_d and i_q and is expressed as

$$T_e = E'_d i'_d + E'_q i'_q + (x'_d - x'_q) i'_d i'_q \quad (12)$$

The direct axis and quadrature axis currents in the synchronous machine, i_d and i_q can be obtained from the following linear equations as

$$\begin{bmatrix} h_1 E_b \cos(\delta) + h_2 E_b \cos(\delta) - E'_q \\ h_2 E_b \cos(\delta) - h_1 E_b \cos(\delta) - E'_d \end{bmatrix} = \begin{bmatrix} (x'_d + z_I) & -(R_a + z_R) \\ -(R_a + z_R) & (x'_d + z_I) \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix}$$

Here, in the above equation, $(z_R + jz_I)$ is the input impedance of the external network viewed from the generator terminals with infinite bus shorted. $(h_1 + jh_2)$ is the voltage gain at the terminals with armature open circuited. The initial conditions for the system equations for P_{t0} , Q_{t0} , V_{t0} and θ_{00} are obtained from the power flow analysis in steady state as

$$I_{a0} \angle \phi_0 = \frac{P - jQ_{t0}}{V_{t0} \angle -\theta_0} \quad (13)$$

$$E_{q0} \angle \delta_0 = V_{t0} \angle \theta_0 + (R_a + jx_q) I_{a0} \angle \phi_0 \quad (14)$$

$$i_{d0} = -I_{a0} \sin(\delta_0 - \phi_0) \quad (15)$$

$$i_{q0} = I_{a0} \cos(\delta_0 - \phi_0) \quad (16)$$

$$v_{d0} = -V_{t0} \sin(\delta_0 - \theta_0) \quad (17)$$

$$v_{q0} = -V_{t0} \cos(\delta_0 - \theta_0) \quad (18)$$

$$E_{fd0} = E_{q0} - (x_d - x_q) i_{d0} \quad (19)$$

$$E_{q0} = E_{fd0} - (x_d - x'_d) i'_{q0} \quad (20)$$

$$d_{q0} = -(x_q - x'_q) i'_{q0} \quad (21)$$

$$T_{e0} = E_{q0} i'_{q0} + E_{d0} i'_{d0} + (x'_d - x'_q) i'_{d0} i'_{q0} = T_{m0} \quad (22)$$

2.1.3. Models of regulators AVR and PSS:

The AVR (Automatic Voltage Regulator), is a controller of the PSG voltage that acts to control this voltage, thought the exciter .Furthermore, the PSS was developed to absorb the generator output voltage oscillations [1].

In our study the synchronous machine is equipped by a voltage regulator model "IEEE" type – 5 [7, 8], as is shown in Figure 4.

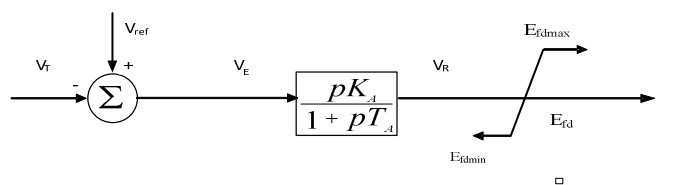


Figure 2 . A simplified" IEEE type-5" AVR

$$V_R = \frac{K_A V_E - V_R}{T_A} \quad , \quad V_E = V_{ref} - V_t \quad (23)$$

In the PSS, considerable's efforts were expended for the development of the system. The main function of a PSS is to modulate the SG excitation to [1, 2, and 4].

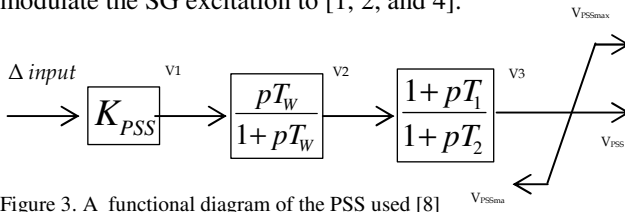


Figure 3. A functional diagram of the PSS used [8]
 In this paper the PSS signal used, is given by: [9]

$$\begin{aligned} \dot{V}_1 &= \frac{V_2 - V_1}{T_1} + \frac{T_2}{T_1} \dot{V}_2 ; \\ \dot{V}_2 &= \frac{V_3 - V_2}{T_2} + \frac{T_3}{T_2} \dot{V}_3 ; \\ \dot{V}_3 &= \frac{V_3}{T_w} \dot{V}_1 ; \dot{V}_1 = K_{PSS} \Delta input \end{aligned} \quad \Delta input = \begin{cases} \Delta P, \int p \\ or \\ \Delta \omega = \omega_{mach} - \omega_0 \\ and \\ \Delta I_f = I_f - I_{f0} \\ and \\ \Delta U_f = U_f - U_{f0} \end{cases} \quad (24)$$

2.2. A Robust H₂-PSS Design Based on LQG Control and Kalman Filter

The control system design method by means of modern FSM algorithms is supposed to have some linear test regulator. It is possible to collect various optimal adjustment of such a regulator in different operating conditions into some database. Linear – Quadratic – Gaussian (LQG) control technique is equivalent to the robust H₂ regulator by minimizing the quadratic norm of the integral of quality [13]. In this work, the robust quadratic H₂ controller (corrector LQG) was used as a test system, which enables to trade off regulation performance and control effort and to take into account process and measurement noise [11,5]. LQG design requires a state-space model of the plant:

$$\begin{cases} \frac{dx}{dt} = Ax + Bu \\ y = Cx + Du \end{cases} \quad (25)$$

Where x, u, y is the vectors of state variables, control inputs and measurements, respectively.

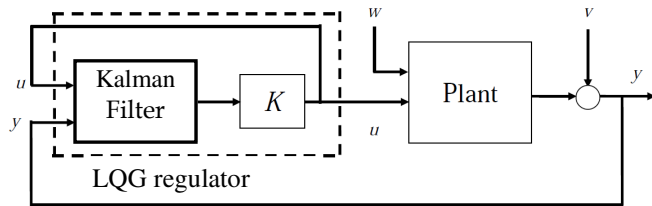


Figure 7. Optimal LQG regulated system with Kalman filter.

The goal is to regulate the output y around zero. The plant is driven by the process noise w and the controls u , and the regulator relies on the noisy measurements $y_v = y + v$ to generate these controls. The plant state and measurement equations are of the form:

$$\begin{cases} \dot{x}(t) = A(t)x(t) + B(t)u(t) + v(t) \\ y_v(t) = C(t)x(t) + w(t) \end{cases} \quad (26)$$

Both w and v are modeled as white noise.

In LQG control, the regulation performance is measured by a quadratic performance criterion of the form:

ured by a quadratic performance criterion of the form:

$$J(u) = \int_0^{\infty} (x^T Qx + u^T Ru + 2x^T Nu) dt \quad (27)$$

The weighting matrices Q, N and R are user specified and define the trade-off between regulation performance and control effort.

The LQ-optimal state feedback $u = -kx$ is not implemented without full state measurement. However, a state estimate \hat{x} can be derived such that $u = -k\hat{x}$ remains optimal for the output-feedback problem.

This state estimate is generated by the Kalman filter:

$$\frac{d\hat{x}}{dt} = A\hat{x} + Bu + L(y_v - C\hat{x} - Du) \quad (28)$$

Thus, the LQG regulator consists of an optimal state-feedback gain and a Kalman state estimator (filter), as shown in figure 7.

On the basis of investigation carried out, the main points of fuzzy PSS automated design method were formulated [6]. The nonlinear model of power system can be represented by the set of different linearized model shown in equations (29). For such model, the linear compensator in the form of $u = -Kx$ can be calculated by means of LQG method. The family of test regulators is transformed into united fuzzy knowledge base with the help of hybrid learning procedure (based variable structure sliding mode). In order to solve the main problem of the rule base design, which is called “the curse of dimensionality”, and decrease the rule base size, the scatter partition method [13] is used. In this case, every rule from the knowledge base is associated with some optimal gain set. The advantage of this method is practically unlimited expansion of rule base. It can be probably needed for some new operating conditions, which are not provided during learning process. Finally, the robust H₂ stabilizer was obtained by minimizing the quadratic norm $\|M\|_2^2$ of the integral of quality $J(u)$ in (28), where

$$Z(s) = M(s)x_0 \quad and \quad Z = [x^T Q^{1/2} u^T R^{1/2}]^T, s = j\omega. [6]. (29)$$

2.3. Structure of the power System with Robust H₂ Controller

The basic structure of the control system of a powerful synchronous generator with the robust controller is shown in Figure 8. As command object, we have synchronous generator with regulator AVR-FA (PID with conventional PSS), an excitation system (exciter), an information block and measures (BIM) of output parameters to regulate.

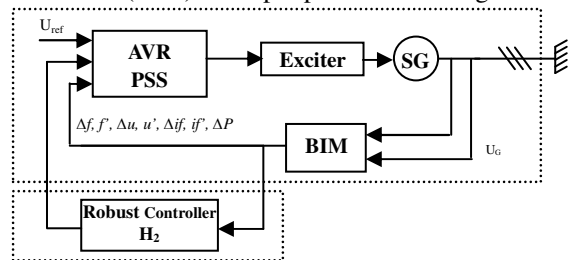


Figure 8. Structure of the power system with robust H₂ controller [3]

2.4. The Genetic Algorithms Theory

2.4.1. Introduction

Overall, a Genetic Algorithm handles the potential solutions of a given problem, to achieve the optimum solution, or a solution considered as satisfactory. The algorithm is organized into several steps and works iteratively. The figure 7 shows the most simple genetic algorithm introduced by Holland [14].

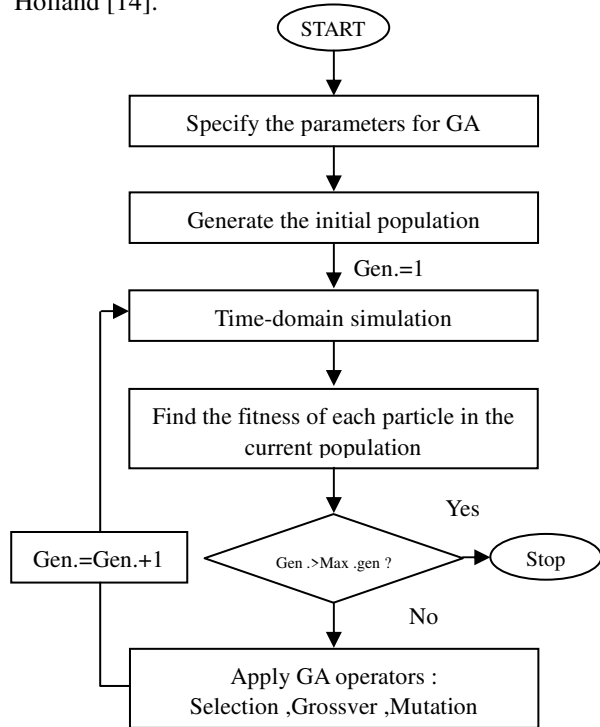


Figure 9. The genetic algorithm organization

2.4.2. The Genetic Algorithm Steps Description [14]

In what follows, we will describe in more detail the various steps of a simple genetic algorithm Figure 9

Coding and initialization: The first step is the problem parameters coding in order to constitute the chromosomes. The most used type of coding is the binary one, but other coding can be also used for example: ternary, integer, real...the passage from the actual representation to the coded one is done through encoding and decoding functions.

Selection: A new set of individuals is former with clone's multiplicity proportional to the respective ratings of the individuals of the previous generation: the higher the rating of a given individual, the more the number of its clones. A popular method is known as roulette wheel, where individuals are selected based on their ratings.

Crossover: Part of the new set is combined randomly in pairs by exchanging random segments of genes.

Mutation: Part of the new set has some of their individuals mutated, that is, random genes of random individuals are changed with a given probability.

Population replacement: The original generation is replaced by the new one, or a new one is created when there is no previous one.

2.3. Application of the Algorithm Genetic to adapt a robust control H₂

The adaptation of the robust control H₂ based on the optimization of the regulation system AVR-PSS this latter considered as control object (figure 8) to synthesize a robust stabilizer PSS-H₂

The synthesis of a robust stabilizing H₂ PSS-adapted by genetic algorithms passes in two steps:

First step: optimization of the control system AVR-PSS by genetic algorithms.

2.3.1. Objective function

The purpose of the PSS use is to ensure satisfactory oscillations damping, and ensure the overall system stability to different operation points. To meet this goal, we using a function composed of two multi-objective functions [16]. This function must maximize the stability margin by increasing damping factors while minimizing the system real eigenvalues .

$$F_{obj} = -\max(\sigma) + \min(\zeta) \quad (30)$$

The multi-objective function calculating steps are:

- 1-formulate the linear system in an open -loop (without PSS);
- 2-locate the PSS and its parameters initialized by the G.A through an initial population;
- 3- Calculate the closed loop system eigenvalues and take only the dominant modes: $\lambda = \sigma \pm j\omega$
- 4- Find the system eigenvalues real parts (σ) and damping factor ζ ;
- 5- Determine the (ζ) minimum value and the ($-\sigma$) maximum value, which can be formulated respectively as: (minimum (ζ)) and (maximum - (σ));
- 6- Gather both objective functions in a multi-objective function F as follows:

$$F_{obj} = -\max(\sigma) + \min(\zeta)$$

- 7- Return this Multi-objective function value the to the AG program to restart a new generation.

Second step: synthesis of robust controller PSS-H₂ based to AVR-PSS optimized

2. GLOVER - DOYLE Algorithm to Synthesize a Robust Stabilizer PSS- H₂

The standard problem in figure (5) consists in finding a controller K (s) stabilizing internally P (s) and minimizing the norm H_∞ of the transfer matrix in closed loop of w to z.

Problem solving of standard control is proposed as follows [17]:

1. Calculates the Standing regime established (RP);
2. Linearization of the control object (SG+PSS+AVR)
3. The main problem in H₂ control and the definition of the control object increased P(s) in the state space:
 - 3-1. Choice of weighting functions: W_1, W_2, W_3
 - 3-2. The obtaining of the command object increased from weighting functions $W_{1,2,3}$.
4. Verify if all conditions to the ranks of matrices are satisfied, if not we change the structure of the weighting functions;
5. Choosing a value of γ (optimization level);

6. Solving two Riccati equations which defined by the two matrices H and J of HAMILTHON;
7. Reduction of the regulator order if necessary
8. By obtaining optimum values and two solutions of Riccati equations we get the structure of controller H_2 and the roots of the closed loop with the robust controller;
9. We get the parameters of robust controller H_2 in linear form LTI (SS state space, TF transfer function or ZPK zeros - pole - gains)
10. The simulation and realization of the stability study and robustness of power system under different functioning conditions.

Figure 13 shows the proposed in this paper the GA for the PSS parameters optimization for adapt a robust controller

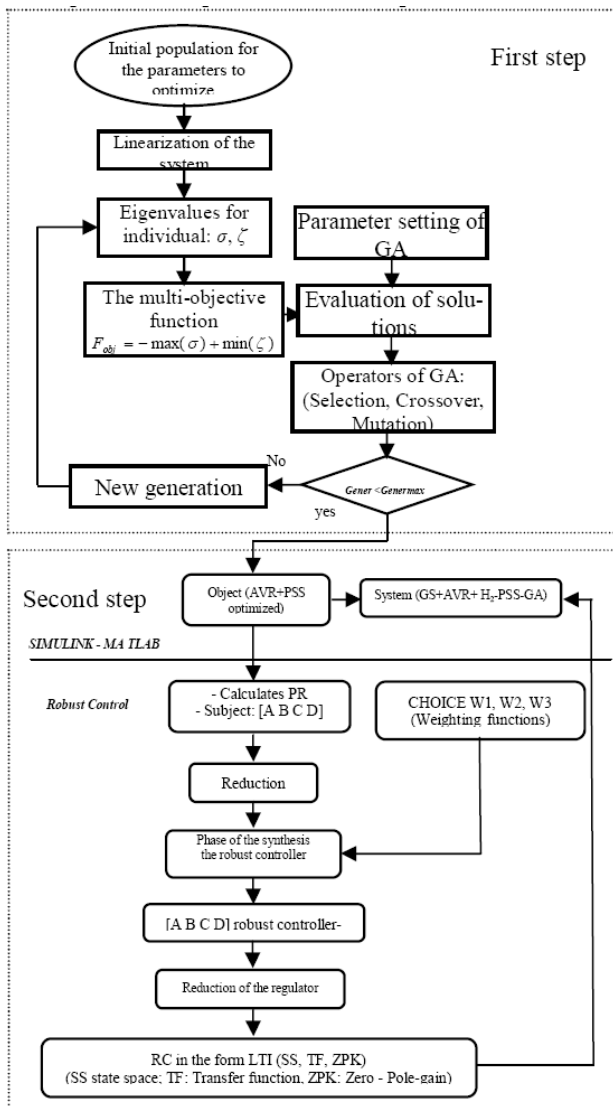


Figure 13. The multi-objective function and GA algorithm for robust optimization of AVR-PSS for adapt a robust controller H_2

3. The Developed GUIs Under MATLAB

3.1. Introduction

GUIDE, the MATLAB graphical user interface devel-

opment environment, provides a set of tools for creating graphical user interfaces (GUIs). These tools greatly simplify the process of designing and building GUIs. You can use the GUIDE tools to perform the following tasks [20]:

1. Lay out the GUI.

Using the GUIDE Layout Editor, you can lay out a GUI easily by clicking and dragging GUI components—such as panels, buttons, text fields, sliders, menus, and so on—into the layout area. GUIDE stores the GUI layout in a FIG-file.

2. Program the GUI.

“GUIDE automatically generates a MATLAB program file that controls how the GUI operates. The code in that file initializes the GUI and includes function templates for the most commonly used callbacks for each component—the commands that execute when a user clicks a GUI component. Using the MATLAB editor, you can add code to the callbacks to perform the functions you want.

3. Starting GUIDE

Start GUIDE by typing guide at the MATLAB command prompt. This command displays the GUIDE Quick Start dialog box, as shown in the following figure 5.

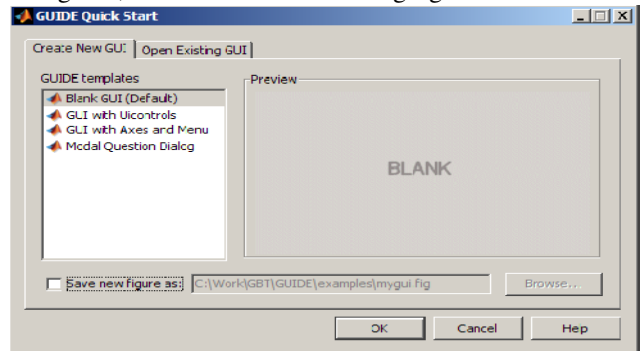


Figure 5. The GUIDE Quick Start dialog box

From the GUIDE Quick Start dialog box, you can perform the following tasks:

- Create a new GUI from one of the GUIDE templates pre-built GUIs that you can modify for your own purposes.
- Open an existing GUI.

4. The Layout Editor

When we open a GUI in GUIDE, it is displayed in the Layout Editor, which is the control panel for all of the GUIDE tools. The following figure shows the Layout Editor with a blank GUI template.

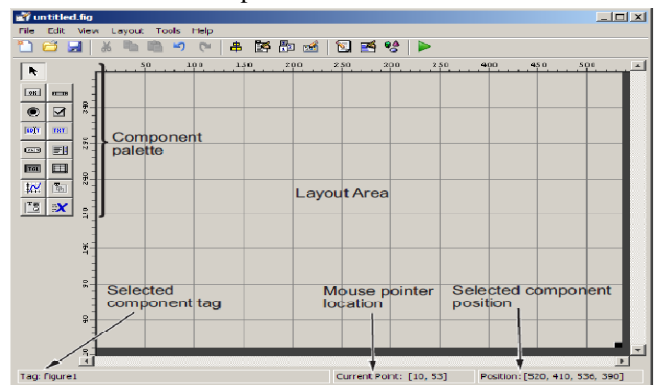


Figure 6. The Layout Editor

3.2. Creation of a GUI to the Genetic Algorithms Theory Study

We consider the simple case of function with tow variables “X1, X2” belonging to the natural numbers set: Minimise

$$F_{obj}(X1, X2) = (1 - X1)^2 \exp(-X1^2 - (X2 + 1)^2) - (X1 - X1^3 - X2^5) \exp(-X1^2 - X2^2)$$

Subject to $3 > X1 \geq -3$
 $3 > X2 \geq -3$

The used parameters:

- A 8 bits binary encoding ;
- The search interval :X1 \in [-3,3], X2 \in [-3,3], ;
- Tournament Method;
- A simple crossing (to one point),with crossing probability Pc=0.7 ;
- A mutation probability Pm=0.3

To run and view the various steps of genetic algorithm, we created and developed a “GUI” (Graphical User Interfaces) in MATLAB software, this latter allows:

- To calculate and display the AG operations (Coding and initialization, Evaluation, Selection, Crossover and mutation);
- To display graphically the problem solution, as is shown in figures 10 and 11.

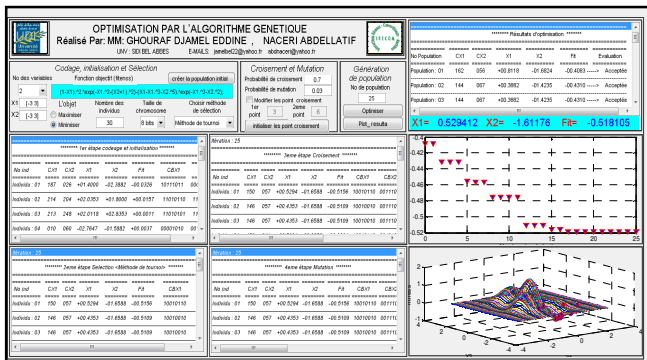


Figure 10. The genetic algorithm optering developed under GUI / MATLAB

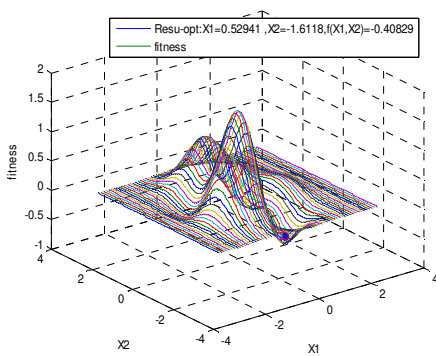


Figure 11. Optimization result by AG

3.3. Creation of a calculating code under MATLAB / SIMULINK

The “SMIB” system used in our study includes:

- A powerful synchronous generator (PSG) ;

- Two voltage regulators: AVR and AVR-PSS connected to;
- A Power Infinite network line

The SMIB mathematical model based on Park model is used for simulation in this paper and is shown in Figure 14. For deferent block detail see Appendix (2, 3 and 4)

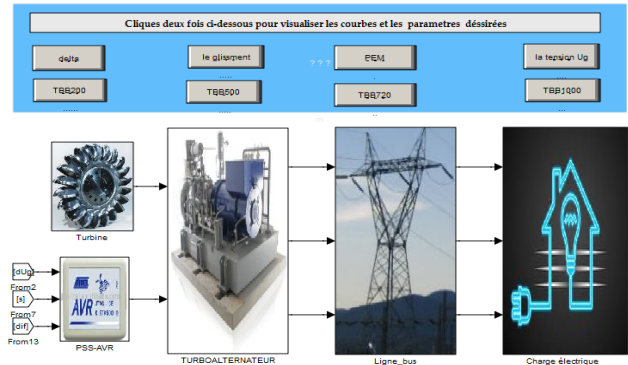


Figure 14. Structure of the synchronous generator (PARK model) with the excitation controller under [10].

3.4. A developed GUI/MATLAB for PSS optimization using GA

The optimized parameters for PSS are: K_{0w} , K_{1w} , T_{1w} , and T_{0w} , and the PSS-AVR model used shows in figure 13 with:

- $0 \leq K_{0w} \leq 10$ Number of Individuals = 100
- $0 \leq K_{1w} \leq 10$ Maximum Generation = 120
- $0.0005 \leq T_1 \leq 0.1$ A crossing probability Pc = 0.7
- $0.0001 \leq T_2 \leq 0.1$ A mutation probability Pm = 0.3

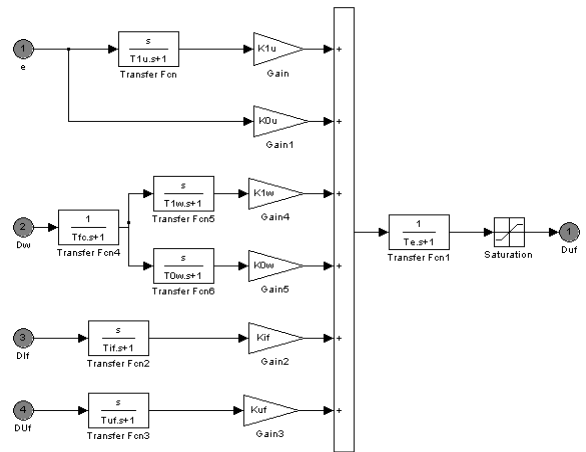


Figure 444 The used model of the AVR-PSS

To analyzed and visualized the different dynamic behaviors we have creating and developing a “GUI” (Graphical User Interfaces) under MATLAB .This GUI allows as to:

- Perform control system from PSS controller;
- To optimized the controller parameters by Genetic Algorithm;
- View the system regulation results and simulation (see GUI-MATLAB in the Appendix 3 created);
- Calculate the system dynamic parameters ;
- Test the system stability and robustness;

- Study the different operating regime (under-excited, rated and over excited regime).

The different operations are performed from GUI realized under MATLAB and shown in figure 12.

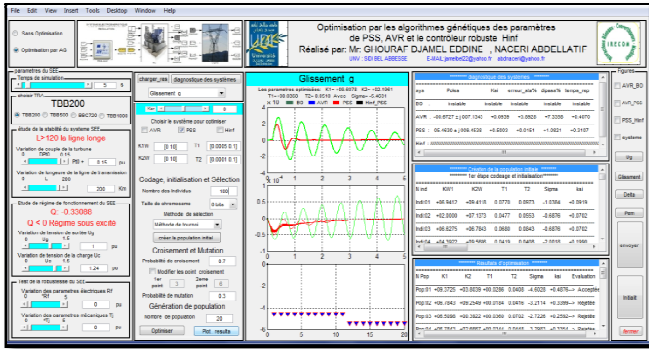


Figure 12 The realised GUI/ MATLAB

We present an example for optimization and tuning the parameters of the GA-PSS using our realized GUI, with:

Number of individuals=10 , Number of population =10

***** Creation of initial population *****
***** 1st step coding and initialization *****

N ind	KOW	KIW	T1	T2	Sigma	ksi
Indi:01	+01.2471	+00.8431	0.0828	0.0828	-0.2217	+0.0225
Indi:02	+01.4824	+00.3765	0.0590	0.0600	-0.5294	+0.0538
Indi:03	+00.5647	+00.2706	0.0145	0.0816	-0.1603	+0.0168
Indi:04	+04.2353	+00.1216	0.0594	0.0953	-0.5294	+0.0538
Indi:05	+05.1294	+00.6902	0.0727	0.0647	-0.5294	+0.0538
Indi:06	+04.7294	+00.5529	0.0430	0.0628	-2.4673	+0.2311
Indi:07	+04.4471	+00.0078	0.0212	0.0643	-2.4172	+0.2425
Indi:08	+00.6118	+00.4157	0.0266	0.0060	-0.2397	+0.0255
Indi:09	+03.1059	+00.4353	0.0992	0.0937	-0.4707	+0.0453
Indi:10	+05.0588	+00.7843	0.0481	0.0898	-1.8467	+0.1662

***** 2nd step selection *****

N ind	KOW	KIW	T1	T2	Sigma	ksi
Indi:01	+01.4824	+00.3765	0.0590	0.0600	-0.5294	+0.0538
Indi:02	+01.4824	+00.3765	0.0590	0.0600	-0.5294	+0.0538
Indi:03	+04.2353	+00.1216	0.0594	0.0953	-0.5294	+0.0538
Indi:04	+04.7294	+00.5529	0.0430	0.0628	-0.24673	+0.2311
Indi:05	+04.7294	+00.5529	0.0430	0.0628	-0.24673	+0.2311
Indi:06	+04.7294	+00.5529	0.0430	0.0628	-0.24673	+0.2311
Indi:07	+04.4471	+00.0078	0.0212	0.0643	-0.24172	+0.2425
Indi:08	+03.1059	+00.4353	0.0992	0.0937	-0.4707	+0.0453
Indi:09	+05.0588	+00.7843	0.0481	0.0898	-0.18467	+0.1662
Indi:10	+04.7294	+00.5529	0.0430	0.0628	-0.24673	+0.2311

***** 3rd step crossover*****

N ind	KOW	KIW	T1	T2	Sigma	ksi	Pc
Indi:01	+01.4824	+00.3765	0.0590	0.0600	-0.5294	+0.0538	0.695
Pc < Pc: There is a crossover 00111111011000001001011010011001							
Indi:02	+01.4824	+00.3765	0.0590	0.0600	-0.5294	+0.0538	0.695
Pc < Pc: There is a crossover 00111111011000001001011010011001							
Indi:03	+03.2000	+00.0588	0.0688	0.0890	-0.5294	+0.0538	0.310
Pc < Pc: There is a crossover 1000100000001111010111111100011							
Indi:04	+05.7647	+00.6157	0.0337	0.0691	-0.5294	+0.0538	0.310
Pc < Pc: There is a crossover 1111010110011101010101010101010000							
Indi:05	+04.7294	+00.5529	0.0430	0.0628	-0.24673	+0.2311	0.344
Pc < Pc: There is a crossover 11001001100011010110110110100000							
Indi:06	+04.7294	+00.5529	0.0430	0.0628	-0.24673	+0.2311	0.344
Pc < Pc: There is a crossover 11001001100011010110110110100000							
Indi:07	+03.1294	+00.1804	0.0243	0.0675	-0.15648	+0.1580	0.076
Pc < Pc: There is a crossover 1000010100101110001111011010100							

Indi:08	+04.4235	+00.2627	0.0961	0.0906	-0.7595	+0.0702	0.076
Pc < Pc: There is a crossover 1011110001000011111101011100011							
Indi:09	+04.7765	+00.8000	0.0434	0.0882	-0.18779	+0.1716	0.520
Pc < Pc: There is a crossover 11001011110011000110011101100001							
Indi:10	+05.0118	+00.5373	0.0477	0.0643	-0.25061	+0.2294	0.520
Pc < Pc: There is a crossover 11010101100010010111100110100100							

***** 4th step Mutation *****

N ind	KOW	KIW	T1	T2	Sigma	ksi	
Indi:01	+02.6118	+00.4235	0.0579	0.0538	-0.1364	+0.1126	
0110111101101001001001100010001							
Indi:02	+01.2941	+00.9412	0.0313	0.0361	-0.06357	+0.0664	
0011011111100000100111101011100							
Indi:03	+00.6118	+00.3059	0.0028	0.0882	-0.01824	+0.0191	
000110100100111000000011011100001							
Indi:04	+02.7529	+00.5843	0.0454	0.0600	-0.12761	+0.1266	
01110101100101010111001110011001							
Indi:05	+05.2471	+00.3882	0.0992	0.0961	-0.07749	+0.0702	
1101111011000111110001111101110101							
Indi:06	+04.7294	+00.5529	0.0938	0.0628	-0.12761	+0.1266	
11001001100011011111011110100000							
Indi:07	+03.1294	+00.6353	0.0489	0.0064	-0.12761	+0.1266	
10000101101000100111110000010000							
Indi:08	+05.2706	+00.2627	0.0727	0.0616	-0.12761	+0.1266	
11100000010000011101110011001101							
Indi:09	+03.6941	+00.8000	0.0426	0.0248	-0.20490	+0.2142	
100110101100110001011010000111111							
Indi:10	+02.0000	+00.5137	0.0481	0.0424	-0.09589	+0.0980	
0101010110000010111101001101100							

***** Optimization results *****

N Pop	KOW	KIW	T1	T2	Sigma	ksi	Evaluation
Pop:01	+05.8588	+00.5059	+00.0555	0.0075	-2.4821	+0.2719-->	Acceptée
Pop:02	+04.2588	+00.1804	+00.0325	0.0365	-1.8625	+0.2010-->	Rejetée
Pop:03	+04.6824	+00.4510	+00.0372	0.0448	-2.0675	+0.2158-->	Rejetée
Pop:04	+04.4000	+00.1608	+00.0052	0.0534	-1.8033	+0.1992-->	Rejetée
Pop:05	+05.6235	+00.6863	+00.0590	0.0307	-2.4880	+0.2517-->	Acceptée
Pop:06	+06.0000	+00.3216	+00.0516	0.0150	-2.6346	+0.2859-->	Acceptée
Pop:07	+05.9294	+00.3451	+00.0887	0.0115	-2.2553	+0.2275-->	Rejetée
Pop:08	+05.5529	+00.3137	+00.0637	0.0475	-2.1573	+0.2082-->	Rejetée
Pop:09	+05.2706	+00.4392	+00.0263	0.0444	-2.3655	+0.2535-->	Rejetée
Pop:10	+05.3176	+00.4392	+00.0579	0.0444	-2.2063	+0.2176-->	Rejetée

Optimization is finished.....

The obtained optimizing parameters are: KOW= +06.0000 KIW= +00.3216 T1=+00.0516 T2= 0.0150 with Sigma= -2.6346

Table 1 give a simulation result optimized PSS parameters with different SG

TABLE I. THE PSS OPTIMIZED PARAMETERS

parameters	TBB-200	TBB-500	BBC-720	TBB-1000
T ₁	0.0321	0.029	0.0445	0.0234
T ₂	0.054	0.0322	0.0356	0.0214
K _{ow}	4.074	5.011	3.034	5.0142
K _{iw}	5.43	6.45	9.548	1.506

3.5. Implementation of the robust AG-PSS-H2 under the realized GUI/ Matlab

To analyzed and visualized the different dynamic behaviors, we have created and developed a "GUI" (Graphical User Interfaces) under MATLAB. This GUI allows as to:

- Perform controls systems from PSS ,H₂-PSS and H₂-PSS - GA;
- View the system regulation results and simulation;
- Calculate the system dynamic parameters;
- Test the system stability and robustness;

- Study the different operating regime (under-excited, rated and over excited regime).

The different operations are performed from GUI that was realized under MATLAB and shown in Figure 15.

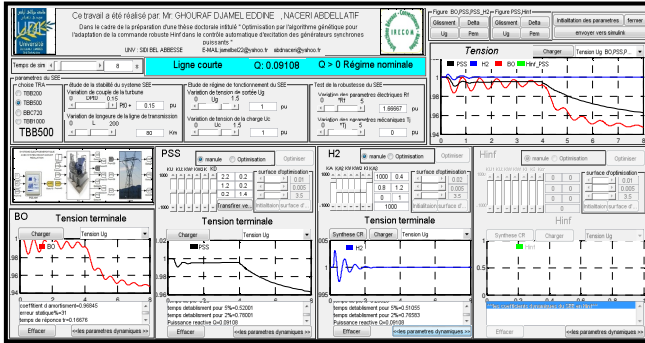


Figure 15. The realised GUI / MATLAB

3.6. Simulation result and discussion

3.6.1. Stability study

For Stability study of SMIB system we have performed perturbations by abrupt variations of turbine torque ΔT_m of 15% at $t = 0.2s$,

The following results (Table 1 and Figure 16) were obtained by studying the “SMIB” static and dynamic performances in the following cases: Closed Loop System with the conventional stabilizer PSS-FA, robust control H_2 -PSS and H_2 -PSS optimized by GA.

We have simulated three operations: the under-excited, the rated and the over-excited.

Our study interested in the synchronous power generators of type: TBB-200, TBB-500 BBC-720, TBB-1000 (parameters in Appendix 1) [10].

Table 1 presents the TBB -500 static and dynamic performances results in (CL) with PSS, H_2 -PSS and H_2 -PSS -GA, for an average line ($X_e = 0.3 pu$), and an active power $P=0.85 pu$, for more details about the calculating parameters see GUI-MATLAB in Appendix 5.

Where: α : Damping coefficient ε %: the static error, d %: the maximum overshoot, t_s : the setting time

Figure 14 show simulation results for:

a: 's' variable speed

b: 'Pe' the electromagnetic power system

c: 'delta' the internal angle

d: 'Ug' the stator terminal voltage

for powerful synchronous generators TBB -500 with $P = 0.85$, $X_e = 0.3$, $Q1 = -0.1372 (pu)$

3.6.2. Robustness tests

In a first step we have performed variations of the electrical parametric at $t = 4s$ (increase 100% of R). Then, we have performed variations of the mechanical parametric at $t = 8s$ (lower bound 50% of inertia J)

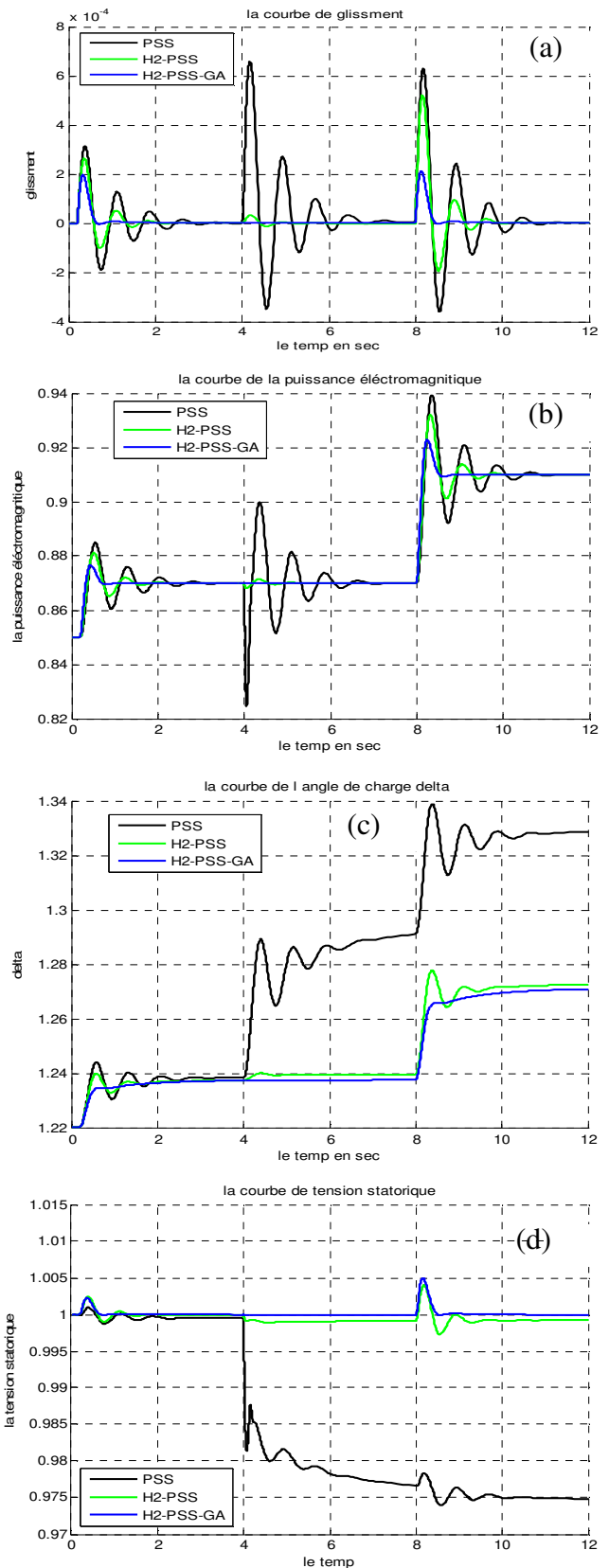


Figure 16 .functioning system in the under-excited regime used of TBB 500 connected to a average line with PSS , H_2 -PSS and H_2 -PSS-GA (Study of the stability and Tests of robustness)

Table 2 :The “SMIB “static and dynamic performances

Damping coefficient α					The static error			
Q	OL	PSS	H ₂ -PSS	H ₂ -PSS-GA	OL	PSS	H ₂ -PSS	H ₂ -PSS-GA
-0.1372	Unstable	-1.761	-2.673	-3.3283	Unstable	1.620	-1.134	negligible
-0.4571	Unstable	-1.731	-2.593	-3.3463	Unstable	1.629	-1.141	negligible
0.1896	-0.0813	-1.855	-2.766	-3.3906	5.138	1.487	-1.167	negligible
0.3908	-0.1271	-1.759	-2.695	-3.3906	5.202	1.235	-1.029	negligible
0.5078	-0.1451	-1.470	-2.116	-2.9582	3.777	0.687	-0.504	negligible
0.6356	-0.1588	-1.442	-2.099	-2.9803	3.597	0.656	-0.467	negligible
The setting time for 5%					The maximum overshoot %			
Q	OL	PSS	H ₂ -PSS	H ₂ -PSS-GA	OL	PSS	H ₂ -PSS	H ₂ -PSS-GA
-0.1372	Unstable	1,704	rapid	Very rapid	9,572	7,892	3,682	1,349
-0.4571	Unstable	1,713	rapid	Very rapid	9,487	7,847	3,482	1,323
0.1896	-	1,617	rapid	Very rapid	10,959	8,314	3,915	1,408
0.3908	-	1,706	rapid	Very rapid	10,564	7,883	3,737	1,630
0.5078	14,320	2,041	rapid	Very rapid	9,402	6,588	2,290	1,877
0.6356	14,423	2,080	rapid	Very rapid	9,335	6,463	2,012	1,801

The electromechanical damping oscillations of parameters of the synchronous power generators under-excited mode in controllable power system, equipped by H₂-PSS-GA (Blue), PSS (Black) and H₂-PSS (green) are given in figure 14. Results of time domain simulations, with a test of robustness (electrical uncertainties and mechanical uncertainties confirm both a high effectiveness of test robust H₂-PSS-GA regulator in comparison with using the classical regulator PID and H₂-PSS . For study of the stability the simulation results, it can be observed that the use of H₂-PSS-GA improves considerably the dynamic performances (static errors negligible so better precision, and very short setting time so very fast system (table 1), and we found that after few oscillations, the system returns to its equilibrium state even in critical situations (specially the under-excited regime) and granted the stability and the robustness of the studied system.

4. Conclusion

Graphical User Interfaces (GUIs) have been proposed over the years as innovative tools to improve teaching at several levels, from primary school to university, in a plethora of subjects and areas of knowledge.

The main factors for successful GUI were addressed, and important tips and hints for building a GUI using the GUIDE tool in MATLAB were addressed. A GUI needs to be visually appealing and easy to use, open source and have a broad range of applicability, rather than just being focused in education

a realized GUI for a robust GA-based on PSS using H₂ controller based an advanced Frequency technique with an optimal LQG controller and Kalman Filter, has been proposed and studied

Note that, our developed GUI was exploited and applied for other study (stability and robustness) using advanced adaptive and robust Controllers. As perspective of this work the implementation of realized GUI in real-time.

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APPENDIX

1. Parameters of power system

Parameters	TBB 200	TBB 500	BBC 720	TBB 1000	Notations
Generators					
power nominal	200	500	720	1000	MW
Factor of power nominal	0.85	0.85	0.85	0.9	p.u.
X_d	2.56	1.869	2.67	2.35	Synchronous longitudinal reactance
X_q	2.56	1.5	2.535	2.24	Synchronous reactance transverse
X'_s	0.222	0.194	0.22	0.32	shunt inductive reactance Statoric
X'_f	2.458	1.79	2.587	2.173	Inductive reactance of the excitation circuit
X'_{fd}	0.12	0.115	0.137	0.143	Shunt inductive reactance of the excitation circuit
X'_{d1}	0.0996	0.063	0.1114	0.148	Shunt inductive reactance of the damping circuit on the direct axis
R_a	0.0055	0.0055	0.0055	0.005	Statoric active resistance
R_f	0.000844	0.00084	0.00176	0.00132	Resistance of the excitation circuit (rotor)
Excitation system AVR					
T_{1u}	0.039	0.039	0.04	0.04	p.u.
T_e	0.04	0.04	0.04	0.04	p.u.
K_{1ua}	7	11	7	10	p.u.
K_{0ua}	50	15	100	15	p.u.
T_{1u}	0.039	0.039	0.04	0.04	p.u.
power system stabilizer PSS					
T_1	0.0321	0.029	0.0445	0.0234	p.u.
T_2	0.054	0.0322	0.0356	0.0214	p.u.
K_{0w}	4.074	5.011	3.034	5.0142	p.u.
K_{1w}	5.43	6.45	9.548	1.506	p.u.

2. Dynamics parameters calculated through GUI-MATLAB

