On a Novel Simulation of a Control Technique for Power Oscillation Damping and Applications

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Abstract

This research presents a novel simulation model of adaptive control to make a control process by using MIT rule adjustment mechanism, to power oscillation damping in the SMIB system and to measure its possible effects on the response of the damper by changing its parameters according to an external disturbance using Simulink. The results showed that the use of MRAC technique maintains the response of the damper when changing the transfer function due to external disturbance.

Keywords: Matlab; Control; Simulation; POD

1. Introduction

A control system is defined as a device that dynamically regulates or controls any facility or process. The controller is the most important element in this system, the performance of which depends mainly on adjusting the profit value in accordance with the mathematical model of the controlled system, designed based on specific operating conditions (normal working conditions), but this model changes due to various disturbances and changes in the operating environment, and this necessitates resetting the controller's profit in order to comply with new or emergency operating conditions, so that this controller maintains the desired performance, which expresses the main goal of the control process [1], and to achieve this goal, many techniques were used to achieve examples such as [2]. Although there are many techniques for achieving examples, adaptive control techniques are still required to obtain the full adaptive nature, adaptive control changes the parameters of the control algorithm in real time to compensate for changes in the environment or the system itself, and it also changes the transmission follower of the system depending on the situation. In special cases, an adaptive control system reference model is generally the best application with a digital computer due to the complexity of the controller [3], in this way the response of the system is forced to track the response of the reference model regardless of changes in the parameters of the facility،
The controller parameters are adjusted to achieve the desired closed-loop performance in this way the controller parameters are evaluated to cause the required change in the transmission follower of the facility in order for its performance to become similar to the reference model, in addition to the Mate rule the adaptive control technology reference model (MRACS) is a direct adaptive strategy with some adjustable parameters and an adjustment mechanism for adjusting these parameters. Although research on adaptive control has been going on for a long time, in 1960 it was used to design an autopilot to operate aircraft over a wide range of altitudes and speeds, and therefore the profit scheduling
Depending on some auxiliary measures of wind speed were conditioned [3]. Nowadays adaptive control schemes are replacing traditional control systems that are not able to cope with situations such as:

a. Probability and inertia.
b. The possibility of sudden and unexpected breakdowns.
c. The possibility of frequent and unexpected disruptions.

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As it has been recently used to modify the Pi gain in the FACTS systems controllers to ensure the realization of the limitations of connecting wind turbines to the electrical grid at various disturbances and comparing the MRAC method with the genetic algorithm[4], and to control induction motors [5] and DC motors [6] and tracking the point of greatest potential [7], conventional fixed-profit PID controllers are unable to cope with the above problems, there are many techniques used to design MRACS such as the theory of lebunov and the theory of built-in error, in this research the emphasis was placed on the MIT rule only.

2. The importance of research and its goals

The importance of the research lies in the fact that it touches on one of the most recently used methods for profit examples in traditional organizations, based on tracking the performance of the proposed reference model. The output of the facility must track this performance by entering the output of the conditioning loop as an additional control signal whose task is to force the output of the Controlled facility to track the output of the reference model in all operating conditions and this achieves the goal of the control system to obtain the desired response, especially in systems that contain many parameters of a probabilistic nature, as is the case in electric power systems.

In this research, the focus was on developing a computer model using MATLAB-SIMULINK of an electric power system consisting of a single machine connected to an infinite Assembly Rod containing a POD vibration damper with MRAC technology and studying its potential effect in reducing the demands of speed vibrations, where an adjustment mechanism based on the MIT rule was used.

3. Research methods and materials

The research is based on the development of a computer model of the adaptive control method, a reference model according to the MIT rule for the vibration damper pod, and testing its performance on an electric power system that is a single machine connected to an infinite Assembly Rod. The demonstration of its effect in obtaining damping of rotor speed vibrations in comparison with a conventional pod vibration damper when a disturbance occurs is represented by a change of the transmission dependence of the damper, using MATLAB-SIMULINK.

- **Reference Adaptive Control Model:**

Adaptive control covers the set of technologies that provide an organized method of automatic adjustment of controllers in real time. In the process of achieving or maintaining the desired level of control system performance, when the parameters of the dynamic model of the Controlled facility are unknown or changing with time. There are three main elements of this system, which are as follows: the reference model, the facility model, and the conditioning mechanism as shown in Figure 1.

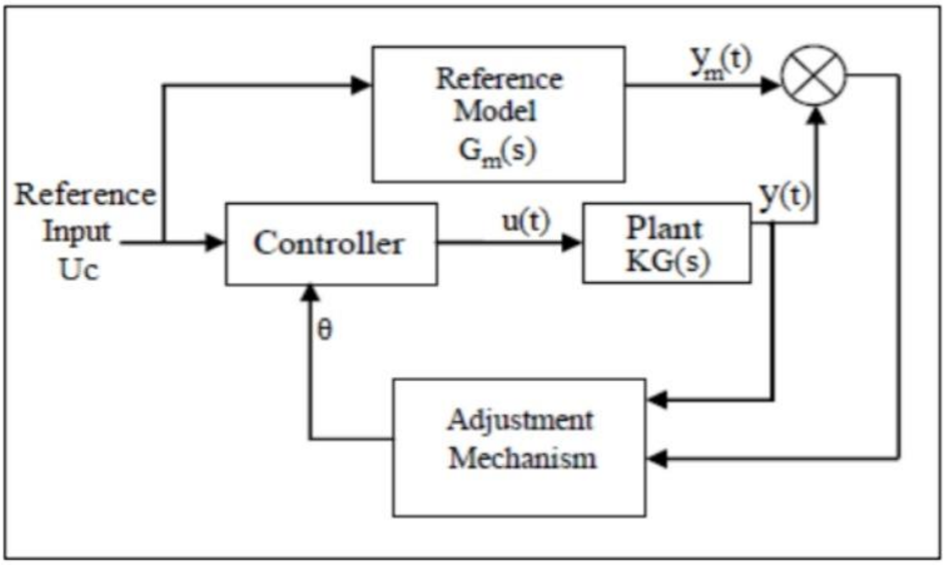

Figure 1. Adaptive control system MRA reference model

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- **Reference model:**

This part of the control system represents the desired performance of the closed loop system, i.e. expresses the performance of the plant based on the given reference income. In this research the reference behavior is modeled as a vibration damper transmission relay in the steady state.

Figure 2. Reference model

The reference model can also be determined from the specifications of the closed loop system as shown in Figure 3, at the desired peak time of 0.413s and the stability time of 0.706s, and the steady-state error of 0.

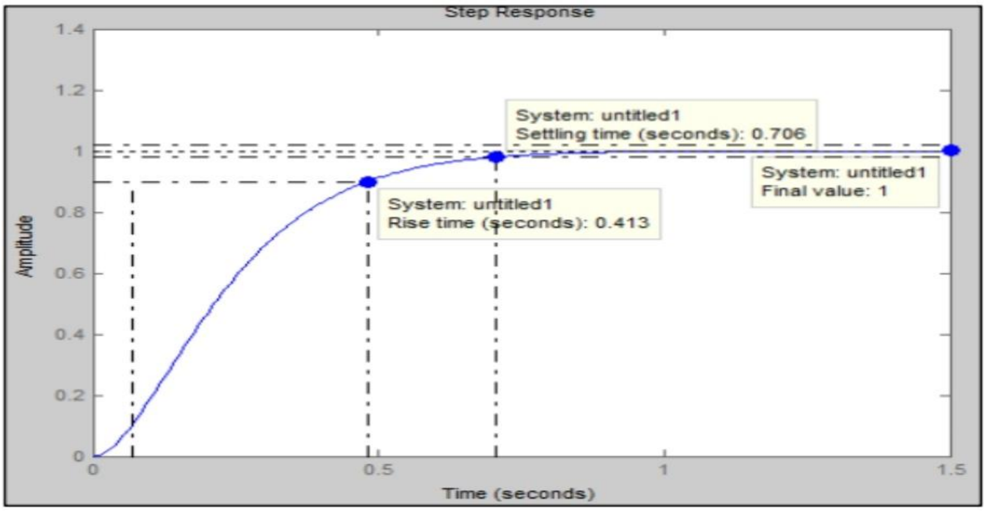

Figure 3. Determination of the reference model from the closed-loop specification

1- **Facility model:** in this research, we used a second-order transmission dependent expressing the desired performance of the damper, which is changed by an external disturbance. The actual output of the controlled process is Yp, so the controller must change / adjust the values of its parameters to achieve the desired performance so that the error is Yp – Ym = error (e) = 0, where Ym represents the output of the reference model and YP represents the output of the controlled process.
2- **Controller:** it is usually described by a set of adjustable parameters.in this research, the transfer follower of the controller is combined with the transfer follower of the system to obtain a transfer follower representing the controlled and controlled system.
3- **Adjustment mechanism:** this component is used to adjust the controller parameters so that the output of the facility
4- The actual output of the tracker is the reference model. The goal of this part of the controller is to change its output (θ) depending on the error (e) between the output of the reference model (Y_m) and the output of the facility (Y_P), how fast the adaptation depends on the parameter called the learning rate or the gain of the adaptation (γ), with high values of (γ) the controller adaptation process is faster for any change in the facility but there are also some side effects where the controller output is calculated by the relationship $U = U_c*\theta$ where U_c represents the reference input and U represents the control signal while (θ) represents the output of the conditioning loop.

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The basic box diagram of the adaptive control system reference model (MRACS) is shown in Figure (1) as the output of the reference model ym(t) and the output of the actual facility y(t) and the difference between them is called Error (e).

e (t) = y(t) - ym(t) (1)

- **The MIT rule:**

The MIT rule was first developed in 1960 by researchers from the MIT instituteused to design the Autopilot system for aircraft and it is also used to design adaptive controllers with a scheme (MRACS) for any control system according to this rule, the cost follower is defined as follows:

$J(\theta) = e^2/2$ (2)

Where:
e: the error signal between the output of both the actual model and the reference model.
θ: the adjustable parameter that is adjusted so that the value of the cost follower is as low as possible.
For this reason, the change in the value of the parameter θ towards the negative slope of (J) is as follows:

$\frac{d\theta}{dt} = -\gamma \frac{dJ}{d\theta}$ (3)

Where:
$J(\theta)$: represents the cost dependent.
$\frac{d\theta}{dt}$: the output of the conditioning loop has changed relative to time.
$\frac{dJ}{d\theta}$: the cost dependent changes relative to the change of the output of the conditioning mechanism.
γ: adaptive gain for the controller.

From Equation (2)

$\frac{d\theta}{dt} = -\gamma e \frac{de}{d\theta}$ (4)

Where:
Partial derivation $\frac{de}{d\theta}$: called the sensitivity derivation factor of the system, this expression indicates how much the error has changed (θ).

Equation (3) describes the change of the parameter (θ) with respect to time in order to reduce the value of the cost follower J(θ) to zero, here the amount (γ) is a positive quantity, which represents the adjustment profit of the controller. Suppose that the control process is a linear process and has a transport dependent KG(s), where K is an unknown parameter and G (s) is a second-order defined transport dependent, the goal is to design a controller that enables the control process to track the reference model with a transport dependent $G_m(s) = K_0 G(s)$, as shown in Figure (1).

From Equation (1):

$E(s) = KG(s)U(s) - KoG(s)U_c(s)$ (5)

Where:
Ko: the initial value of the parameter affected by the perturbation
K: the new value of the affected parameter after the disturbance occurs.
U: control signal.
U_c: reference income.
Definition of the control law:

$$U(t) = \theta * U_c$$

From Equation (5) and (6) and by making a partial derivation:

$\frac{dE(s)}{d\theta} = KG(s)U_c(s) = \frac{k}{ko} y_m(s)$ (7)

From Equation (4) and equation (7) we can write:

$$\frac{d\theta}{dt} = -\gamma e \frac{k}{ko} y_m = -\gamma' eym$$

Where: γ' represents the gain of conditioning.
Equation (8) will give us the law of parameter adjustment (θ) and the simulation model is shown in Figure (4), as it appears from the simulation results that the response of the facility depends on the air conditioning profit (γ'), in some industrial facilities large values of air conditioning profit (γ') cause system instability and the choice of this value is

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very important.

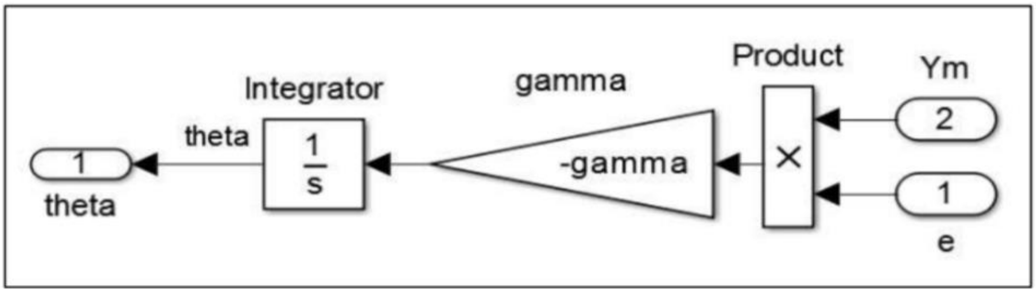

Figure 4. MIT base simulation model

- **Power vibration dampers (POD)**

A vibration damper (POD) is a device that gives an additional control loop to the voltage regulator circuit (AVR) and/ or the turbine system and speed regulator of the generating unit. The use of a vibration damper is one of the most important and most effective ways to improve the stability of the power system. The basic idea of vibration damping in the power system is that in the steady state the speed change should end up to zero or close to it, and the voltage regulator should be driven with a voltage error of only ΔV. The speed of the generator, in the case of transient stability is not constant, and the rotor part is oscillating, and ΔV is subjected to vibrations as a result of the change in the rotor angle. The required task of the vibration damper is to provide an additional signal that compensates for the vibrations of ΔV, and gives a torque vehicle phase-compatible with the speed deviation ΔW, the damper consists of a drain box $\frac{\mathrm{Tw.S}}{\mathrm{Tw.S+1}}$, which reduces the dynamic response to damping When major failures occur with a time constant of (Tw) and the phase supply box $\frac{\mathrm{T1+S}}{\mathrm{T2+S}}$, which is used to compensate for the delay between the output of the damper and the application of electric torque in addition to the gain of the damper Kdd, which determines the amount of damping, shown in Figure 5 the box diagram of the transmission relay of the vibration damper POD connected to the electrical power system.

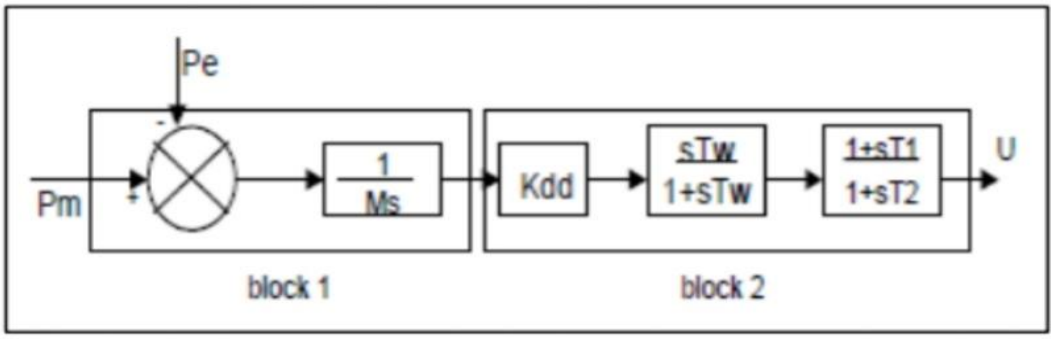

Figure 5. Box diagram of the transmission relay of the vibration damper POD

- **Pod energy vibration dampers with MRAC technology**

Figure 5 shows an mrac simulation model using the MIT rule controls a structure consisting of a vibration damper pod, which expresses its desired performance with a transmission relay representing the response of the damper in the steady state, whose parameter values are selected depending on the specifications of the electrical system, the general formula of the damper is given by the relation:

$$\mathrm{Gp} = \mathrm{K}\frac{\mathrm{Tw.S}}{\mathrm{Tw.S}+1}\cdot\frac{\mathrm{T1}+\mathrm{S}}{\mathrm{T2}+\mathrm{S}}$$

In this research, the appropriate damper parameters were selected for the standard PHILIP-HIFRON system, where the transport continuation represented by it is given by:

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$$Gm = 10.\frac{10.5.S}{10.5.S+1}.\frac{0.9+S}{0.1+S}$$

When a change occurs in the parameters of the damper as a result of a disturbance, the transport dependent represented by it changes in proportion to the new unknown parameters, which give a performance different from the design or reference performance, so that the new transport dependent representing the damper becomes:

$$Gp = 15.\frac{15.S}{15.S+1}.\frac{0.9+S}{0.1+S}$$

The adaptation mechanism based on the MIT rule was chosen with an adaptation profit of (-3), The value of which depends on the type of system used and significantly affects the extent to which the output of the facility follows the output of the desired reference model, but after a specific value of this profit, the system becomes unstable.

4. Results and discussion

Figure 7 shows the simulation model of the tested system expressed by an electric power system single machine connected to an infinite Assembly Rod (SMIB) system constants obtained through the computer program in the appendix. By running the model with the original values of the facility without applying MRACS, we find that the damper does not give the desired performance after a change in the value of the damper parameters from the design value to the actual value as shown in Table (1), from the simulation results shown in Figure (8), it is shown that the value of vibration demands at the 4S profile decreases from the value [0.223-0.447] by a decrease of 0.223 PU by 50%.

Table 1: design value and actual value of the parameters of the pod damper.

The parameter	Design value	Actual value
K	10	5
Tw	10.5	10

5. Conclusion

We found from the results of the simulation carried out in the previous steps that:

The facility model tracks the output of the reference model despite the change of the transmission relay (mathematical model of the controlled process) as a result of a malfunction in the controlled process at the moment 1s. The application of this technique to the deviation of both speed and angle of the SMIB system when a disturbance occurs in the electric torque, which has proven the effectiveness of this technique in reducing the latency of the steady state, which distinguishes this method from other traditional control methods that rely on tracking 1pu reference input, and the output of the controlled process depends on the transmission follower (mathematical model of the controlled process), which can change due to several factors related to disturbances and changes in the operating environment. The effectiveness of the control technique applied in this research, which is consistent with the results achieved in previous relevant research. Improve the responsiveness of systems with unknown and changing parameters over time and ensure that the desired performance is maintained when operating conditions change.

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